2025 Forest and Land Management Plan – The Arboretum at Flagstaff

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Updated Management Plan for the Arboretum at Flagstaff – Prologue

Introduction

The Arboretum at Flagstaff, formally known as the Transition Zone Horticultural Institute, boasts an extensive history in the Flagstaff area, where it has provided valuable services to both locals and tourists alike. The Arboretum at Flagstaff (hereafter referred to as The Arboretum) was originally home to philanthropist Frances McAllister, who provided substantial support to local science education programs and advocacy groups, which includes Lowell Observatory, Northern Arizona University, and the Grand Canyon Trust, amongst many others. Her commitment to environmental education was considerable as well, with McAllister eventually donating the property and land that encompasses the current extent of the Arboretum. While the property has undergone notable changes in both structure and ownership, its foremost objectives have remained in line with McAllister's original vision. As such, the longstanding objectives of the Arboretum are to be a space that increases the understanding and appreciation of native plants that occupy the Colorado Plateau, thus better facilitating their conservation in the process. These are achieved through numerous educational and recreational offerings, all of which are enhanced by the unique features of the property itself. Preserving the quality of these features is also of great importance, requiring proactive management and stewardship to uphold the Arboretum's reputation and legacy.

Need for New Management Plan

The current management plan for the Arboretum, which states objectives for the property and the necessary actions to reach them, was written in 1999 and has not received any substantial updates since the time of its writing. As the document has aged, the relevancy of its management suggestions has waned considerably as it fails to account for several internal and external changes. This includes shifting climate conditions, changes in structures and personnel, and the presence of a newer body of research and management prescriptions, amongst others. Of greater note is the fact that the current management plan is primarily concerned with the forested portions of the property, despite the Arboretum hosting extensive meadow habitat alongside some notable washes and wetland habitats. As such, this plan more closely reflects that of a forest management plan, rather than one better suited for a more diverse property that includes a number of habitat types and developed gardens.

The narrower scope of the 1999 management plan for the Arboretum, while more appropriate for the time it was written, makes it clear that a new, more comprehensive plan needs to be developed. A primary concern of the 1999 plan is establishing a means with which to procure funding for a variety of fuel treatments. Since its writing, several fuels treatments in and around the property have been carried out, though the plan's ability to guide the Arboretum in continual procurement of funds will dampen over time with a lack of revision.

When developing management plans, it is common for updates or revisions to be implemented every five to ten years, generally to ensure the use of modern practices informed by the best available science and to account for any disturbance-related changes that have occurred on the ground. The interval of these revisions makes the

datedness of the current management plan for the Arboretum more evident, prompting a more immediate need for updating to occur. Not only would an updated plan ensure management of the property be guided by modern principles, but it would also allow room for novel perspectives from the Arboretum staff and board members, the majority of whom were not involved with the Arboretum in 1999, to be more clearly showcased. While many of the objectives and guiding principles of the Arboretum remain, a new plan would aid in documenting new visions for the property, allowing it to better serve communities in the long term. Along with these benefits, a new management plan would also be able to better showcase and utilize some of the Arboretum's innate qualities, many of which went uncovered in the current plan. These primary reasons, amongst many others, establish the need for substantial management plan revisions that will better serve the Arboretum in the near and distant future.

New Plan Items

A new management plan must include a considerable amount of revised content to become an improved and more comprehensive guiding document. Some of the most pertinent information to include involves strategies to alleviate financial burdens, namely securing proper fire insurance, applying for Arizona Department of Forestry and Fire Management (DFFM) grants, and diversifying income sources through a variety of means. Ensuring financial stability of the Arboretum is essential in allowing it to continue its mission as a non-profit outlet of environmental education and community service. Additionally, the new plan would benefit greatly from updated management strategies that more clearly recognize the ecological diversity present on the property. This would manifest through unique styles of management for the property's forests, meadows and wetlands along with the facilities and garden spaces.

Alongside the revision of existing content in the current management plan, a new management plan would benefit extensively from the incorporation of novel ideas and elements. A valuable addition would involve future considerations primarily regarding changes in climate and adjacent land development that could impact operations at the Arboretum. This also extends to the considerations of staff and board members, in which documenting their visions for the property could more easily allow them to be reflected in the property's management. Similarly, the inclusion of various figures and imagery would allow for some of the innate qualities of the Arboretum to be better communicated to any readers of the document. These visual aids can better depict the features of the property, all while detailing any future management actions with greater clarity.

Significance of Implementing a New Plan

The benefits of drafting and implementing a new management plan would enhance the internal operations of the Arboretum, thus allowing it to better serve the Flagstaff community and beyond. With updated management priorities, the new plan would more closely align with current staff and board visions, ensuring that future desires are more cohesive and have a clearly documented backing. Having a physical resource with which to communicate these plans can also aid the Arboretum in procuring grants that make these management actions more fiscally achievable. These

updated forms of management would also improve the safety and resilience of the property to a variety of disturbances. This improved safety would be of mutual benefit to surrounding communities while strengthening the possibility of the Arboretum procuring much needed fire insurance as well. More refined and diversified management strategies would also be beneficial to the distinct ecosystem types present upon the Arboretum property, thus ensuring the maintenance of intact ecosystems which form the foundation of their educational and recreational programming. The implications of a new management plan would be profound for the property, allowing it to be more closely managed in the image of a true arboretum with considerable offerings and features that speak to its distinctive characteristics.

Management Science

The ponderosa pine ecosystem in which the Arboretum is situated has been subject to historical mismanagement that has resulted in unstable landscape conditions. With the spatial structure of these forests being considerably altered due to fire suppression activities and general mismanagement, these landscapes have undergone shifts in productivity and community composition (Reynolds et al., 2013.). These changes increase the risk of Ponderosa pine ecosystems to high severity fire, insect outbreak, and the spread of disease and parasites (Reynolds et al., 2013). This long-term mismanagement has increased the need for restorative management at a landscape scale, and a return to historic, pre-settlement conditions. With proper restorative treatments, ecological function and resiliency can return to these systems and ensure additional safety to nearby communities.

Modern professional guidelines informed by current research and findings in ecology, primarily those pertaining to Ponderosa pine ecosystems in the Southwest, form the basis of the new plan's management components. Rather than utilizing forest management principles concerned primarily with timber production, this plan adheres to current understandings of disturbance regimes, historic stand conditions, and ecosystem dynamics to promote continued vitality of the ecosystem types present in the Arboretum. Restoration of diverse age structures that are more in line with historic forest conditions through a reduction of density has been found to support biodiversity and enhance the functioning of Ponderosa pine forest ecosystems (Kolb et al. 2007). The health benefits associated with treatments that reduce density facilitate improved stand responses to a variety of natural disturbances, including the outbreak of fire and insect infestation (Wallin et al. 2008). Treatments that reduce density can also have a secondary effect on the forest understory, enhancing its health and productivity through increased exposure to light and a release of overstory competition (Griffis et al. 2001). Prescribed fire has also been utilized to improve resiliency in Ponderosa pine forests and ecosystems that were once regularly exposed to fire, reducing fuel loads that contribute to the risk of high severity burns with significant effects on local ecology (Young et al. 2022). Management that prioritizes complexity in forest spatial patterns is also significant, with these fine-scale differences providing benefits for both wildlife and

surrounding vegetation (Tuten et al. 2015). Effective interpretation of these findings in management of the Arboretum grounds this new plan in the best available science, leaving room to accommodate new findings where possible.

Professional Ethics

The site analysis and management recommendations included in this new plan are grounded in the Society of American Foresters (SAF) Code of Ethics (SAF, n.d.), a pragmatic yet philosophical guide for professional conduct in forestry and natural resource related work. These ethical principles were developed to emphasize land stewardship across generations with respect to current scientific knowledge and findings, societal values, all while productively engaging with professionals, landowners, and professionals. Upholding and improving standards of practice is the cornerstone of sound management, allowing forests and the resources they contain to be better protected over time.

The SAF Code of Ethics encompasses six core principles and pledges:

1. Foresters have a responsibility to manage land for both current and future generations. We pledge to practice and advocate management that will maintain the long-term capacity of the land to provide the variety of materials, uses, and values desired by landowners and society.
2. Society must respect forest landowners' rights and correspondingly, landowners have a land stewardship responsibility to society. We pledge to practice and advocate forest management in accordance with landowner objectives and professional standards, and to advise landowners of the consequences of deviating from such standards.
3. Sound science is the foundation of the forestry profession. We pledge to strive for continuous improvement of our methods and our personal knowledge and skills; to perform only those services for which we are qualified; and in the biological, physical, and social sciences to use the most appropriate data, methods, and technology.
4. Public policy related to forests must be based on both scientific principles and societal values. We pledge to use our knowledge and skills to help formulate sound forest policies and laws; to challenge and correct untrue statements about forestry; and to foster dialogue among foresters, other professionals, landowners, and the public regarding forest policies.
5. Honest and open communication, coupled with respect for information given in confidence, is essential to good service. We pledge to always present, to the best of our ability, accurate and complete information; to indicate on whose behalf any public statements are made; to fully disclose and resolve any existing

or potential conflicts of interest; and to keep proprietary information confidential unless the appropriate person authorizes its disclosure.

6. Professional and civic behavior must be based on honesty, fairness, good will, and respect for the law. We pledge to conduct ourselves in a civil and dignified manner; to respect the needs, contributions, and viewpoints of others; and to give due credit to others for their methods, ideas, or assistance.

To align with these ethical principles and pledges, the priorities of the new Arboretum management plan are concerned with the preservation and enhancement of ecological integrity within the property. Doing so would ensure the space can be utilized and interpreted to its fullest extent for the foreseeable future and serve generations of human, wildlife, and vegetative communities. The proposed management actions in the new plan seek to enhance the health and resilience of the Arboretum's forest on a broad scale, which can mitigate risks of wildfire and related ecological disturbances when done in tandem with treatments on adjacent lands. Should these treatments be conducted efficiently and in a coordinated effort, the resilience of local communities in the face of these disturbances would be bolstered as a result. Management of lands on the property will also be conducted in a manner that facilitates educational opportunities, with spaces of forest and meadow that have undergone different treatment types and display distinctive characteristics. These natural displays have the potential to inform the management of surrounding areas to better suit their priorities, while also demonstrating a structural mosaic to visitors of all professional and educational backgrounds. Through the utilization of the professional standards and ecological principles in the SAF Code of Ethics, this work better reflects the practices needed for sustainable, long-term management and restoration of ecosystems that have been subject to a history of degradation.

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Forest and Land Management Plan

The Arboretum at Flagstaff

Wildflowers from the Arboretum at Flagstaff
Image Source – *Arboretum Photo Gallery*

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Mission Statement

The Arboretum at Flagstaff, formally known as the Transition Zone Horticultural Institute, has evolved to provide many services to the greater Flagstaff community and beyond, though its core objectives have remained congruent with those upon which it was founded. Since its establishment, efforts in native plant conservation, educational programming and research, along with community engagement have been its foremost priorities. Through these efforts, the Arboretum continues to connect local communities and visiting patrons to the unique characteristics that define the ecology of Flagstaff and the wider Colorado Plateau.

The current mission of the Arboretum is as follows:

The Arboretum at Flagstaff's mission is to increase the understanding, appreciation, and conservation of plants and plant communities native to the Colorado Plateau.

For such a mission to be achieved, the Arboretum must ensure that its daily operations reflect this commitment. These include plant propagation and conservation, habitat restoration and construction, alongside sustainable gardening and landscaping practices amongst others. Through the intermarriage of research, educational outreach, and community involvement, the Arboretum has come to play a pivotal role in both showcasing and preserving the biodiversity of the region.

Arizona Department of Forestry and Fire Management Stewardship Plan

To better achieve the management objectives identified within this plan, the Arboretum intends to expand its connections and partnerships with land management agencies capable of providing grant funds and other assistance. This is most apparent with the Arizona Department of Forestry and Fire Management (DFFM), which owns land adjacent to the Arboretum and provides various forms of aid to landowners through their Forest Stewardship Program. Through meaningful collaboration with DFFM and the effective implementation of their program, the Arboretum will enable itself to more readily procure grant funds for future operations.

The DFFM Forest Stewardship Plan states the following regarding landowners:

The Forest Stewardship program offers forest landowner assistance with management plans, provides forest resource stewardship through strategic implementation of forest health policies, and cooperative forestry assistance programs.

The Arboretum prides itself upon the ownership and maintenance of intact ecosystems through modern stewardship practices and preservation techniques. Working with partners capable of supporting more intensive management is essential for these practices to continue in earnest. As such, the Arboretum intends to continue its

efforts to develop and grow partnerships with local agencies and organizations dedicated to the preservation of natural resources.

1. Introduction to the Arboretum

1.1. Location & Access Points

The Arboretum at Flagstaff's physical address is 4001 South Woody Mountain Road, located in Coconino County, Arizona, in T21N, R6E, Sec 35. The property is situated at 7150 feet of elevation. The property can be accessed through its main gate which is open to visitors from the public and Arboretum staff. See Maps 1 and 3 to view the location of the Arboretum in relation to adjacent properties and landowners.

1.2. Acreage Summary

The Arboretum at Flagstaff encompasses 200 acres of land. Most of this landholding is comprised of Ponderosa pine forest, which accounts for roughly 110 acres. Cultivated gardens make up around 10 acres spread throughout the extent of the property. The remaining acres are comprised of open meadow along with several structures including the visitor center, horticulture center, greenhouse, residences, and other features.

1.3. Patterns of Ownership

Established in 1981, the Arboretum at Flagstaff has operated as a private non-profit botanical garden. In 1937, some decades before it became a public garden, the property was owned by John and Frances McAllister. The McAllister's had purchased the property from the Sinclair family, after whom the Sinclair Wash which runs through the property was named. In 1967, Frances McAllister constructed a residence on the property where she resided until 1983. After that point, the house served as a visitor center for the Arboretum.

Lands adjacent to the Arboretum are generally placed in state trust or are owned by the United States Forest Service (USFS). These state trust lands occupy sections north and west of the Arboretum, some of which have been utilized by Northern Arizona University's School of Forestry as a research forest. Lands to the south and east of the Arboretum belong to the Coconino National Forest. The neighboring national forest lands in Section 35 are part of the "Woody" grazing allotment leased to the Manterola Sheep Company, which predates the 1999 management plan and remained since then. Between 100-150 sheep graze in the area directly to the northwest of the Arboretum during the summer months.

In the years during and following the writing of the 1999 management plan, the lands adjacent to the property have undergone considerable development. Some private and state trust lands in the area have changed hands during this period as well, with the Flagstaff Ranch Golf Club, Woody Mountain Estates, Timberline Place,

Equestrian Estates, Mountain Dell, and several active housing projects being the more notable developments in the area. W.L Gore and Associates has also constructed manufacturing facilities that border the golf club. The “Dry Lake” area, an area dominated by an old volcanic crater, has been subject to housing development and landscaping due to Flagstaff Ranch Golf Club owning a portion of the land it occupies.

1.4. Property History

In 1937, John and Frances McAllister purchased the 200-acre property from the Sinclair family, who were previously homesteading on the land. Several buildings were constructed on the property during the years in which Frances McAllister lived there. Little in the way of timber harvesting or grazing was conducted, generally being limited to hand thinning and one to four cows roaming the property grounds.

The Transition Zone Horticultural Institute, which would eventually come to be more widely known as the Arboretum at Flagstaff, was established in the year of 1981 through the vision of its benefactor, Mrs. Frances McAllister. Her interest in botany and horticulture led her to visit botanic gardens across the globe and played significant influence in the founding and development of this property. Having lived in Flagstaff since 1936, she held a particular interest in the species of the Colorado Plateau, a geographic area which spans roughly 170,000 square miles across four states and an elevation range between 2,000 and 11,000 feet. McAllister’s personal experiences with the difficulties of gardening in the pine-dominated ecosystem that surrounds Flagstaff, along with the recognition of the sparse horticultural research being conducted in high altitude environments further motivated her founding of the Arboretum. This was achieved through the generous gifts of the 200-acre McAllister Ranch and an operating endowment, which aided the foundation of the property and its early years of operation. While the endowment has been drawn down considerably from its original amount, ongoing efforts to restore it have been taking place through the proposed sale of a conservation easement.

Currently, the Arboretum at Flagstaff operates as a formal research and educational institution. Roughly 2,319 different plant species have been displayed and interpreted to date, all in efforts to accomplish its mission. The property also boasts a rare plants collection, consisting of 30 different plant species, representing a third of federally listed and candidate species across the states of Arizona, New Mexico and Utah. Of these plants, 12 have been listed as endangered, with four threatened and 14 sensitive species accompanying them.

1.5. Landscape Setting

1.5.1. Topography

The property itself has a flat to slightly undulating topography which differs considerably from its immediate surroundings. A portion of the Sinclair Wash runs through the Arboretum property, which flows off to the east before running through the city of Flagstaff and the Northern Arizona University campus. A second unnamed drainage that comes from along Woody Mountain Road also runs through the property. The elevation gradient of the surrounding landscape is notable, with rising elevations in all directions when exiting the property. The Naval Observatory to the north of the property sits atop a 7,560-foot ridge, with landscapes to the west and east approaching 7,500 feet in elevation as well. The elevational gradient to the south is less severe in comparison but remains situated well above the highest points of the property.

With the Arboretum situated at a low point relative to its immediate surroundings, it experiences unique site conditions that are not often reflected in adjacent areas. Cold air, subsurface groundwater, and seasonal flow from washes have thus been observed to collect on the property due to these topographic conditions. This causes the Arboretum to often be a very cold and occasionally wet site relative to its surroundings.

There exist some additional features of interest in areas adjacent to the Arboretum. A clearly visible cinder pit east of the property and the nearby Dry Lake speaks to the geologic history of the area. The City of Flagstaff's well field to the southwest of the property also merits mentioning.

1.5.2. Soils

Digital soil survey data of the Arboretum and adjacent property extents are not readily available. However, the Natural Resource Conservation Service (NRCS) does maintain data on nearby soils within the city of Flagstaff and Coconino National Forest. The similarity of these nearby soils to the Arboretum makes them useful for describing property soil conditions, though not ideal for informing future management actions. This missing data indicates a need to establish contact with NRCS for future surveys to be conducted. Until then, the Arboretum must rely on soil survey data from nearby areas alongside soil surveys from decades past.

The past soil data available to the Arboretum comes from a 1983 survey conducted by the Soil Conservation Service. Due to the poor weather conditions during their time on the property, the resulting soils map was somewhat lacking in detail. The general nature of the survey results hinders its ability to inform garden design or research but provides a necessary basis of information that may inform future soil surveys.

The meadow soil was observed by the past SCS surveyors to be rather deep and well drained, with the soil surface spanning between 0-20 inches in depth. The soil

maintained a noteworthy water holding capacity with moderately slow permeability. The surface layers are rich in organic matter and associated plant nutrients.

The forest soil was observed to be moderately deep, spanning between 20-40 inches in depth. Much like the meadow soils, they maintain a considerable water holding capacity with similarly slow permeability. While much of the soil surface consists of basalt cobbles, stones or fractured bedrock, it also contains high quantities of organic matter and associated plant nutrients. These coarse fragments along the surface and within the clay-like sub-stratum make the soil somewhat difficult to work with for gardening or manual planting. That said, the soil has been conducive to the germination and regeneration of Ponderosa pine saplings.

The pH values, along with salt content and sodium absorption ratios of both the forest and meadow soils have made them well-suited for vegetative growth. As per the 1983 Soil Conservation Service survey, the hazard of soil by water has been deemed *moderate*. With the presence of two drainages within the extent of the Arboretum, alongside its topographic features, soil erosion by water is a natural consideration in the property's management.

While no modern soil survey data exists for the Arboretum online, inferences can be made regarding their texture and series through available data from adjacent areas. Soils belonging predominantly to the Pluto and Purpleheart series were the most common in nearby meadows. In terms of soil orders, these adjacent areas were observed to mostly contain mollisols which are commonly associated with meadow and grassland ecosystems. Some alfisols were also present in the surrounding area, which are more commonly associated with a variety of forest types. The meadow soils in the Arboretum reveal a dark soil horizon rich in organic matter, which is characteristic of most mollisols. The clay-like sub-stratum in the forest soils is also typical for most alfisols, though more observation would be required before determining them to be true alfisol soils.

1.5.3. Vegetation

A variety of plant communities exist within the confines of the Arboretum property, including forests, meadows and riparian areas. Each of these ecosystems boasts considerable richness in vegetative plant species that speak to their overall health and intactness. The description of the plant species within these ecosystems was formed from the combined information of staff members, grounds surveys, bloom lists, prior research, and the results of past site analyses.

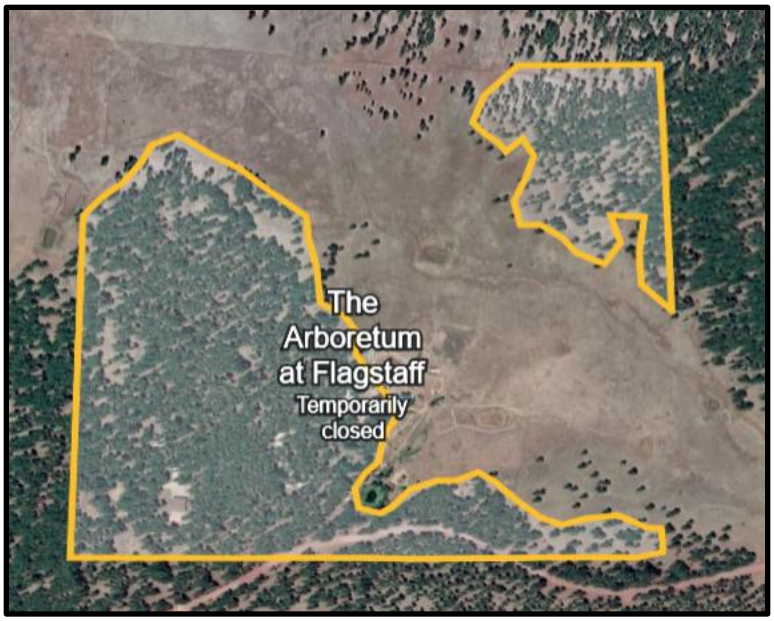


Figure 1 - Extent of Arboretum forests in 2022 (87.59ac and 20.83ac)

The most extensive ecosystem type on the Arboretum is that of ponderosa pine forest, which was said to occupy roughly 115 acres of the property. This acreage estimate was included in the 1999 management plan, though the forest has undergone a series of treatments since that time. Spatial analysis of 2022 satellite imagery indicated that around 110 acres of the property are forested, a number which may also not be precise since the Arboretum has received additional treatments after this image was captured.

The dominant tree in the system is ponderosa pine (*Pinus ponderosa var. scopulorum*). While occurring rather infrequently, Fendler's ceanothus (*Ceanothus fendlerii*) is the most common shrub within the property limits. The understory is generally occupied by a variety of native grasses, with Arizona fescue (*Festuca arizonica),* squirreltail (*Elymus elymoides*), and mountain muhly (*Muhlenbergia montana*) being the most common. Less common but notable grass species on the property include pine dropseed (*Blepharoneuron tricholepsis*), blue grama (*Bouteloua gracilis*), deer grass (*Muhelbergia rigens*), and little bluestem (*Schizachyrium scoparium*). The forested land on the property also includes several herbaceous species such as vetch (*Vicia americana*), deervetch (*Lotus wrightii*), wheeler thistle (*Cirsium wheeleri*), cinquefoil (*Potentilla sp*.), goldenrod (*Solidago sparsiflora*), and sedge (*Carex occidentalis*). The distribution of these species is generally incumbent upon the structure and health of these forested acres, which varies greatly within the property.

Examples of closed canopy forest can be readily found in the southwestern section of the property. The 1985 site analysis of the area claims it having a higher

density of trees that reduce productivity in the understory, information that was substantiated in the 1999 management plan which identified 63 acres as closed canopy. Notable treatments to reduce the cover of this forest type have been conducted since then, though subsequent regeneration within treated areas has occurred as well. The age structure and density of these areas is somewhat variable, however, with small groves of yellowbellies indicating the presence of older trees, but also areas that have become dense dog-hair thickets over time. A small patch of Gambel oak (*Quercus gambellii*) can also be found here.

A fuel break was established in 1985 along 7 acres adjacent to the elk fence, creating an area with evenly spaced trees. Maintenance of the fuel break has yet to occur since its establishment, with regeneration of pines and other vegetative species present. As a result, the fuelbreak has become virtually indistinguishable from its immediate surroundings. The initial disturbance from the fuel break also contributed to an increase in weedy species such as squirreltail, horseweed (*Conyza canadensis*), willoweed (*Epilobium paniculatum*), dalmatian toadflax (*Linaria dalmatica*), and nettle-lead goosefoot (*Chenopodium murale*).

The northeast corner of the property hosts an additional twelve acre stand of forest which was logged roughly a century ago. Prior site analysis indicated a relatively even-aged forest structure, consistent with the logging and regeneration timeline. The structure of the forest is dominated by a patchwork of dense clusters separated by larger openings in the forest canopy. The diversity of tree species in this area is notable with the presence of juniper species (*Juniperus sp*.) that are often relegated to warmer parts of Flagstaff with dry, often volcanic slopes. Similarly, this area hosts a unique variety of grasses and forbs such as three-awn grass (*Aristida sp.*), spring beauty (Claytonia lanceolata), false boneset (*Kuhnia eupatoria*), New Mexico Vervain (*Verbena macdougallii*), showy goldeneye (*Viguiera multiflora*) and Richardson's goldflower (*Hymenoxys richardsonii*).

Additional acres of the property demonstrate a woodland to meadow ecotone, with widely scattered trees and a lack of crown closure that are an important resource for maintaining various wildlife species. These woodlands are seen bordered against more heavily forested areas alongside more open meadow habitats. The common herbaceous plants in this area include pussytoes (*Antennaria parvifolia*), sandwort (*Arenaria fendleri*), Indian paintbrush (*Castilleha integra*), buckwheat (*Erigonum alatum*), blue flax (*Linum lewisii*), and mountain parsley (*Psuedocymopterus montanus*).

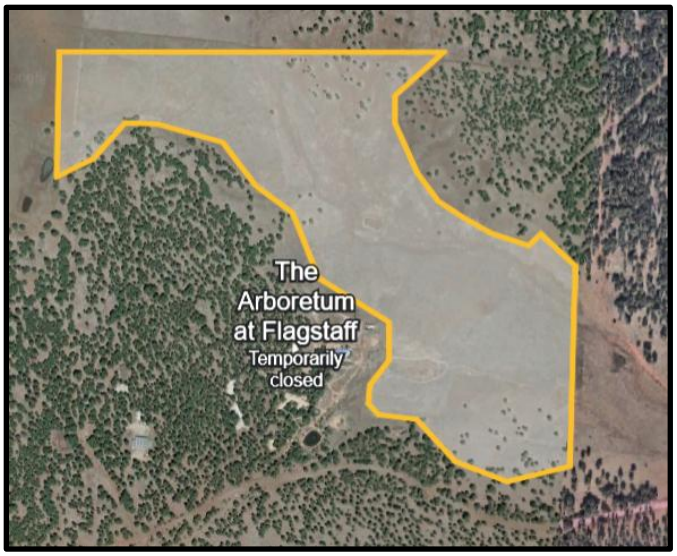


Figure 2 - Extent of meadow on the Arboretum in 2022 – Source: Google Earth

Approximately 80 acres of the Arboretum property are occupied by meadow or pastureland. Estimates of the meadow acreage, particularly in the southeastern corner, have varied somewhat over the years as moderate tree encroachment and subsequent treatments have altered its spatial structure. As seen in the above figure, tree encroachment into the meadow space is a common occurrence that requires routine management to prevent further type change. This can be divided into four distinct plant communities that host a range of native and introduced species. The meadow itself possesses a mixture of perennial grasses and forbs, alongside several common herbs.

The native grass meadow is an important natural feature of the Arboretum, being one of the few intact and easily accessible meadow ecosystems in the southwestern region of the United States. Arizona fescue and mountain muhly are the dominant grasses within this portion of the meadow, though other grass species such as blue grama, pine dropseed, deergrass, spike muhly, minute muhly, and squirreltail have had a documented presence as well. Herbaceous plants such as common yarrow (*Achillea millefolium*), sandwort (Arenaria spp.), pussytoes (*Antennaria rosulata*), wormwood sage (*Artemisia carruthii*), wand penstemon (*Penstemon virgatus*) and cinquefoil have also been identified in this area.

The cultivated wheatgrass pasture occupies the eastern section of the meadow and came to be through artificial seeding from the McAllister Ranch in 1960. This was done in attempts to improve the available forage to cattle that occupied the land for a time. The exotic grasses that were used in the seeding include intermediate wheatgrass (*Elymus intermedium*), crested wheatgrass (*Agropyron cristatum*), tall wheatgrass (*Agroopyron elongatum*), along with the native western wheatgrass (*Elymus smithii*). Before seeding the eastern section, it was previously dominated by crested wheatgrass

exclusively, though the added wheatgrasses have been known to proliferate in wetter years. Other grasses in this section include minute muhly and squireltail, while herbaceous plants such as common yarrow, milkvetch (*Atragalus humistratus*), King's lupine (*Lupinus kingii*), and cinquefoil are also known to occur here.

Tall wheatgrass has been known to dominate the northwest section of the meadow, with patches of mountain muhly and related annual grasses accompanying them. Common yarrow, wormwood sage, and poison milkweed (Asclepias subverticillata) are some other common plants that occur in this area, along with Richardson's goldflower, toadflax and rabbitbrush.

Smooth brome (Bromus inermis) dominated pastures occur inside the elk fence, though the species can be seen in many portions of the meadow. This species has a history of use in both pastures and roadsides and is generally utilized for grazing purposes. Common yarrow, wormwood sage, toadflax, King's lupine and wand penstemon can often be found amongst these smooth brome pastures.

The different vegetative communities in the meadow are valuable from an educational and research perspective. In 1979, monitoring of the cultivated wheatgrass pasture and native meadow had begun. According to the 1999 management plan for the Arboretum, the last survey of the pasture and meadow was conducted in 1994. While there exists a somewhat extensive gap between the last survey and the present day, these different grasslands remain important for the study of vegetative and insect communities, while also presenting extensive opportunities to research practices of meadow restoration. While the retention of native meadow is of great importance, particularly in the southwestern region, the educational value of the non-native grassland communities within the meadow benefits the Arboretum in the meantime.

Figure 3 - Some former cattle tanks that occupy portions of meadow space

The riparian areas of the Arboretum are rather small in extent and dependent on seasonal flow and precipitation and thus are not seen to support much in the way of riparian vegetation. This is likely due to the nature of these riparian areas, which are comprised of constructed ponds, repurposed cattle tanks and retention basins. Two drainages run through the property, one being the Sinclair Wash which flows into the meadow of the Arboretum. The second drainage flows into the property's pond and further out into the riparian interpretive area during periods of sustained flow. The seasonality of their flow leaves most of these areas without permanent pooling of water, however. Along the Willow Pond, a variety of willows (*Salix spp*.) and narrow-leafed cottonwood (*Populus angustifolia*) have been planted which mirror the riparian conditions that can be found in local ecosystems. These areas, while exuding more artificial characteristics, remain important for a variety of wildlife species in an otherwise arid environment.

1.5.4. Climate

The temperatures recorded at the Arboretum are generally 10-15 (°F) colder than weather recording sites in and around the city of Flagstaff. One of the coldest recorded temperatures was -37 on February 1st, 1985. There have been few occasions where the Arboretum has experienced temperatures of -20 or below, conditions which are even less common in the greater Flagstaff area. While the average growing season in Flagstaff ranges from 73 to 164 days (120-day average), the Arboretum is typically only frost free for 60 to 93 days. As such, the property has been known to receive snowfall into the month of June, with the earliest snowfalls beginning in September.

The United States Department of Agriculture has identified the city of Flagstaff of having hardiness zones between 5b to 7a. While longer term weather observations would need to be made to determine the hardiness zone of the Arboretum, it would likely be lower than the city and surrounding areas. With the minimum temperatures recorded on the property being lower than that of greater Flagstaff, the hardiness of the Arboretum is more likely between 5a to 5b.

See tables 8 and 9 in section 12 of the plan for NOAA data pertaining to weather conditions and precipitation accumulation for the greater Flagstaff area.

1.5.5. History & Archaeology

The United States Forest Service has classified the area surrounding the Arboretum as a region of low site density for the potential of historic of prehistoric sites. Two historic sites exist within the boundaries of the Arboretum – the old St. Clair homestead which is located near the Horticultural Center and a United States military Cavalry camp which existed around the property's north tank in the 19th century.

In 1985, Dr. Don Weaver of the Museum of Northern Arizona conducted a site search in the general area of the Arboretum. This search was intended to identify any significant archaeological sites that may exist around these parcels of land. At the end of this search, Dr. Weaver found no sites and was unable to identify the need to conduct any further archaeological research at the Arboretum.

2. Property Structures & Features

2.1. Greenhouse & Retail Nursery

The Arboretum utilizes a greenhouse structure to more reliably propagate plants native to the Colorado Plateau. Doing so ensures a satisfactory level of quantity and genetic variety in these plants, which can prove beneficial in planting and restoration projects. Many of them are also moved to the retail nursery where they become available for purchase by visitors. Traditional nurseries and retailers tend to include many ornamental species in their inventory, many of which are introduced species with variable impacts on local biodiversity. As such, the greenhouse and nursery in the Arboretum are primarily concerned with distributing native plants and communicating their importance in preserving the ecology of the region.

2.2. Fire Ecology Kiosk

Situated near the property's most visited structures is the informational FireWise Kiosk. Within and around this feature are a variety of informational and interpretive signage related to the history and effects of natural fire in the southwestern region of the United States. This property feature speaks more directly to the Arboretum's identity as a research and educational institute.

2.3. Horticultural Center

The Arboretum's Horticultural Center, in which the main greenhouse can be found, contains a variety of storage and office spaces utilized by the property's staff. Materials and tools for the property's gardens can be found here, along with more general item storage.

2.4. Gardens

Approximately 10 acres of the Arboretum are utilized for garden spaces and installations. These spaces contribute extensively to the character of the property, where a variety of native flowering species are grown alongside additional pollinator and medicinal species. Ornamental shrubs and trees have also been planted in these spaces, contributing to the diversity of foliage that can be seen on the property grounds.

3. Forest Ecosystem Description & Assessment

3.1. Aesthetics

The forests within the Arboretum property bounds are generally single-species Ponderosa pine stands, which are the dominant native forest type in Flagstaff. These forests are characterized by single-species dominance, with other tree types being only sparsely distributed within these ranges. The unique morphology of the Ponderosa pine, along with permanently green needles, contributes to a lively aesthetic regardless of the season. These trees are also recognized for their abstract, puzzle-piece shaped bark, which emits a vanilla-like scent in warm weather. As Ponderosa pine approaches an old-growth stage of life, this bark transitions from a brownish black to a more orange coloration. The more mature and widely spaced forests on the property receive enough light for seasonal blooms to occur after experiencing some rainfall.

The aesthetic profile of Ponderosa pine forests, in the Arboretum and beyond, possesses unique seasonal distinctions. Summers are punctuated by deep green needles and a lively understory of various grasses and forbs. The autumn season is known for pine needles carpeting the ground and the yellowing of understory vegetation. Snowy winters bring snowcapped Ponderosa pine trees, with the white backdrop providing considerable contrast to their bark color. The spring, meanwhile, is mostly associated with damp conditions punctuated by early returning greenery, preparing for more intense summer blooms.

3.2. Forest Health

The forested acres of the Arboretum demonstrate considerable variability in terms of their health, generally credited to its range of stand density. This has long been beneficial for environmental education purposes, allowing Arboretum staff to demonstrate the direct effects of tree density on the health of forests in the arid climate of the Colorado Plateau. Over time though, the growing density of some forested plots has contributed to significant declines in health and productivity, outweighing the educational benefits derived from diverse forest structure.

While some portions of the Arboretum's forest appear to be excessively dense and not in ideal health, the property also maintains plots of forest that excel in both health and productivity. Of the estimated 110 acres of forest on the property, there exist three distinct parcels: closed crown forest, thinned areas including the treated fuel break, and the woodland ecotone. The 1999 forest management plan states that 75 acres of the forest were closed crown, though the location and extent of these closed crown stands have changed since the time of its writing. Comparatively, 33 acres of the forest were said to reflect the woodland ecotone, though this has also likely changed with additional treatments and the proliferation of ponderosa pine regeneration. The fuel break has also

been disturbed through this regeneration which holds implications for the resilience of the entire forest under a natural disturbance.

Figure 4 - Clumps of doghair thicket amongst larger dominant trees

The 1999 management plan divides the more densely forested area into two distinct stands, one occupying 12 acres in the northeast corner of the property, and the other spanning 63 acres in the southwestern portion of the property. Some logging occurred in the northeast corner 85 years ago, though regeneration in this area has produced standing trees now anywhere between 70-80 years old. The stand was said to be even aged and unevenly stocked in the 1999 management plan, with some gaps between dense tree clusters, but with a complete lack of understory growth within these clusters. Much of the same is true for the 63 acres in the southwestern corner, but the lack of spacing between clusters and dog-hair thickets reduces understory productivity even further. Stands like this, which demonstrate uninterrupted and excessive density, suppress tree growth rates and are more likely to suffer disease outbreak and insect infestations. Some trees in this stand have a diameter (or dbh) greater than 11.6” though, qualifying them as higher diameter sawtimber. There is also some notable species diversity in this stand, as it is home to a small grove of Gambel oak.

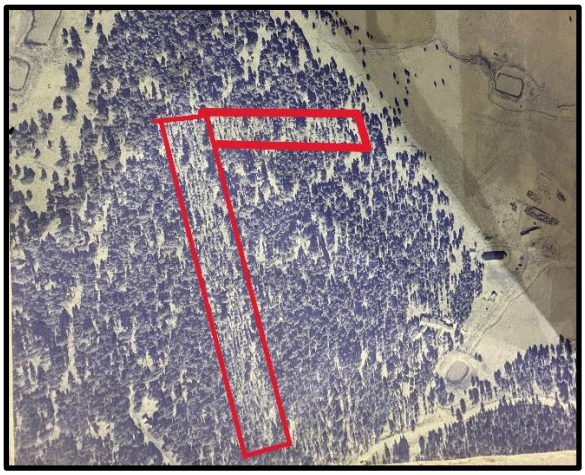


Figure 5 - Imagery of the Arboretum fuel break in the 1980s (left) - Source: Arboretum staff Colin Kubarych

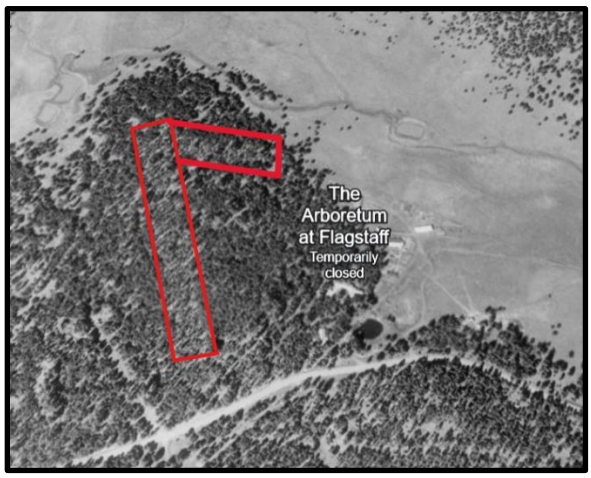


Figure 6 - Imagery of the Arboretum fuel break in the 1980s in 1997 when it was last visible (right) - Source: Google Earth satellite imagery

The 1985 fuel break was created and thinned to a 12’ x 12’ spacing in effort to mitigate the effects of higher severity fire, along with promoting healthier forest structure with appropriate spacing. Past satellite imagery indicates that the fuel break, established on the western section of the property, extends to the north before turning to the east where it nearly borders the meadow. All trees of a 12” DBH (diameter at breast height) or higher were left standing, whereas most trees under this requirement were thinned. This prescription was intended to create a stand structure of scattered groves of predominantly larger trees. The 1999 management plan notes that since the time of this thinning, growth rates of the trees in the treated areas began to occlude the fuel break. Since then, it has almost disappeared entirely and requires additional thinning to be properly restored.

Figure 7 - Post treatment stand with well-spaced tree groups

The woodland ecotone contains trees that, in contrast to the denser stands, have been subject to little or no competition for vertical or horizontal space. The trunks of these trees tend to be highly tapered due to these favorable conditions, with their crowns able to grow considerably wide. The unique morphology of these trees extends beyond their trunks and canopies, with some possessing branches that extend very low to the ground, as opposed to the natural pruning of lower branches in a more competitive setting. While this would typically be interpreted as a fire risk due to these branches acting as potential ladder fuels, the spacing of trees within this stand reduces the risk of immediate and severe fire impacts. Currently this stand demonstrates a higher quality of forest health within the Arboretum and would require less intensive management in future years.

3.3. Timber

The Arboretum is located in Section 35, which was one of the alternate sections granted to the Santa Fe (formerly the Atlantic and Pacific) railroad. Earlier maps of the area designate the property as “A.L.T. timber rights”, indicating that the surface rights to the area, once held by the Arizona Lumber and Timber Company of Flagstaff, were at some point sold or returned to the United States government. Records exist of early timber harvesting in the 20th century, though these sources are contradictory in the exact timing of these harvests. According to the 1999 management plan, there exist Coconino National Forest records that claim timber was cut and harvested from the area in 1904, though a similar paper from the United States Geological Survey identifies Section 35 as harvested in 1902. While the exact year of these harvests remain unclear, the claimed harvest dates are close enough to reliably inform landowners on the area and its management history.

The yearly cuts that took place during this period were often intensive, with all trees that were accessible and commercially viable being harvested. Slash from these cuts were generally broadcast burned. Adjacent lands managed by the USFS underwent further cutting in 1934, along with some pulpwood cuts in 1980. While routine thinning treatments were conducted on the Arboretum property during the years Frances McAllister resided there, little timber was harvested. The Arboretum has since conducted multiple forest thinning treatments to protect property infrastructure.

State trust lands in sections 26 and 34 were originally harvested between the years 1919-1920, in which approximately 80% of their merchantable volume was removed. These sections were once again harvested in 1957 via light sanitation cuts of 300-800 board feet per acre.

3.4. Fire

Figure 8 - Old slash pile from previous forest stand treatments

The Arboretum is surrounded on the north and west sides by state trust lands which received several fuel reduction treatments throughout the 2000s. The lands south and east of the Arboretum are managed under the jurisdiction of the United States Forest Service. Both agencies that manage these lands, due to their agreements and obligations to fire suppression on their lands, would assist the Arboretum in the event of fire on the property. Treatments on these properties generally comprise of mechanical thinning and controlled burns, many of which have been conducted along Woody Mountain Road and other areas adjacent to the Arboretum. These treatments and agreements of mutual aid provide the Arboretum with some protection against the effects of fire should one occur in its general vicinity.

The City of Flagstaff also responds to fire alarms and provides protection for subscribers; the Arboretum is a subscriber to this program from the city.

Fire can pose a significant threat to the property, facilities and purposes of the Arboretum, staff have taken steps to prepare for and respond to fire in emergency situations. The preparations the Arboretum has taken to address fire are as follows:

- A three-inch water line from the Pump House to the Equipment Complex provides water for the fire hydrants located at the Pump House, Administration Building, Horticultural Complex and Equipment Complex. 400 feet of 2.5" fire hose and two nozzles are available for this system, which is backed up by 35,000 gallons of water stored in cisterns east of the Pump House. Two water pumps and one-horse pump located in the Pump House, along with a 7.5 horsepower submersible pump in the cistern, can charge the three-inch line to 60psi. The submersible pump is used for day-to-day operations, with a 1 horsepower pump is held in reserve should it ever fail. An emergency generator is available to provide power to both pumps at any time.
- Fire extinguishers are located in each structure and in all Arboretum vehicles. The property's extinguishers are checked on a yearly basis.
- Smoke alarms have been placed in the Administration Building, Visitor Center, Public Restrooms, Horticulture Center, and the Walter Reichardt house.
- Forests in and surrounding the property receive fuel reduction treatments via mechanical thinning, fuel break establishment, and prescribed burns.
- Yearly fire prevention inspections are conducted on the property.

3.5. Current Concerns

In terms of fire preparedness, the Arboretum has identified areas of concern in which future treatments and management action can be beneficial.

- Some forest stands, many near property complexes, have closed canopies
- Several instances of doghair thickets occurring within the forest
- The 1985 fuel break has remained overgrown and requires thinning
- Dense stands face increased risk of fire damage or insect outbreaks
- Wood harvested from thinning may need to be managed internally given the small market for wood products
- Some adjacent areas (i.e. Woody Ridge) pose considerable fire risk

3.6. Actions Taken

While the need for additional treatments remains, the Arboretum has engaged in extensive management action to mitigate its overall fire risk.

- Thinning treatments near buildings (1998)
- Trees near gardens and parking lots have had many dead branches up to 8' removed, reducing ladder fuels
- Additional thinning to reduce basal area and establish group spacing (2003)
- Prescribed burns conducted along the interior loop of the Arboretum (2005)

- AZDFFM funded thinning treatments (2006, 2018, 2023)
- Flagstaff Fire Department thinning and prescribed burns (2002, 2004, 2005)

4. Meadow Ecosystem Description & Assessment

4.1. Aesthetics

The open expanse of meadow within the Arboretum possesses unique and varied aesthetic values. Its positioning in the property makes it a particularly effective foreground for viewing distant hills and forested areas, along with the more distant San Francisco Peaks. The spaciousness and sunlit nature of the meadow exists in stark contrast to these surrounding landscapes, most of which boast varying degrees of canopy closure and subsequent shading. The variety of species present in this meadow extent gives the land a rich texture and color composition, with many native and introduced plants creating a mosaic with distinct seasonal characteristics. The late spring and early summer seasons are best known for their display of various colors brought about by wildflower blooms and the sprouting of various annual and perennial species. The fall and winter seasons, by contrast, shift to a golden hue as these species enter states of dormancy. Beyond the vegetation that forms this meadow, its open and spacious character allows visitors to witness wildlife species browsing the land or moving across it to various locations.

4.2. Meadow Health

Figure 9 - Evidence of Smooth Brome presence in meadow spaces

One of the defining characteristics of the Arboretum's meadow habitat is its intactness, which has become increasingly rare in the southwestern United States due to prolific livestock grazing. However, the meadow extent is not entirely immune from the impacts of vegetative type conversion and grazing, as evidenced by the species

compositions noted in section 1.5.3. While there remain notable stretches of healthy, intact meadow occupied by native grasses and forbs, other portions of the meadow are dominated by introduced grasses that have historically been utilized as livestock feed. Encroachment of these introduced grasses into native meadow ranges generally appears to be nonaggressive, though their presence alone warrants some degree of concern. Additional monitoring will be necessary in determining the meadow's health with greater nuance.

The health of the meadow has also faced threats from the encroachment of adjacent forests. This generally involves the establishment of saplings and trees in what has historically been the extent of the meadow. This is most evident in buffer areas where the forest and meadow meet, though some trees have become established deeper into the meadow via wind dispersion or wildlife. Should this encroachment remain unchecked, the meadow would likely undergo considerable change in its vegetative species composition, with grasses and forbs being replaced by trees and shrubs. Monitoring and appropriately responding to these forms of encroachment are necessary to keep this area from undergoing such a change.

5. Watershed Description & Riparian Area Assessment

5.1. Rio de Flag & Sinclair Wash

The Rio de Flag is a tributary of the Little Colorado River, which eventually joins the greater Colorado River in the Grand Canyon. This system is supported by the Sinclair Wash, which drains into the Rio de Flag. While these systems are often dry and without any significant flow for most of the year, this trend can change drastically during monsoon seasons or periods of continuous snowmelt. Flooding within the Sinclair Wash watershed been known to occur in years with considerable precipitation, particularly within communities such as Mountain Dell which were constructed partially on a historic floodplain. These flood risks have been effectively mitigated through the Mountain Dell Drainage Improvement Project, but mismanagement of the upper Sinclair watershed can still exacerbate the severity of flooding in nearby communities and partially offset this flood mitigation work. While their flow is incredibly variable, these watercourses are prized for their value to wildlife as water sources and movement corridors, all while contributing to groundwater recharge and related municipal benefits.

The USGS StreamStats website reveals that considerable amounts of water move along the nearby Woody Mountain. Water moving from the north and northeastern sides of the mountain drains into and through the Arboretum. Given that these sides of the mountain are heavily forested, there is considerable flood risk from this area in the event of wildfire.

5.2. Wetlands

Figure 10 - Ducks in the Willow Pond near the Arboretum entrance – Source: Arboretum Photo Archives

The Arboretum has utilized the natural and topographic features of the landscape to create artificial wetlands fed by the drainage along Woody Mountain Road. This method of habitat construction reduces the need for municipal water inputs, instead allowing for seasonal flows to keep these areas replenished. The Willow Pond that neighbors the property's visitor center more closely resembles the characteristics of a natural wetland than the other tanks and drainages whose primary purpose has generally been that of water retention. Many wildlife species have been witnessed in and around the Willow Pond, which is also known to attract waterfowl. The ability of this pond to serve as a habitable space for wildlife species speaks to the potential of the property's old cattle tanks being used in future habitat conversion projects.

5.3. Erosion

Figure 11 - Soil erosion along the transition zone between forest and meadow

As previously mentioned in the soils portion of the management plan, certain areas within the Arboretum are somewhat prone to erosion from water. With the Sinclair Wash (and a second, unnamed wash) running through the property, there is reasonable concern for soil erosion during periods of extensive snowmelt and monsoon-related precipitation. While the washes that run through the Arboretum rarely experience much significant flow, the potential for sedimentation and vegetation loss remains. The space between the forested stands and meadow of the property demonstrates the most visually evident effects of erosion, with the flow of water effectively removing portions of topsoil and vegetation. There is also evidence of erosion occurring deeper into the meadow, suggesting that erosion on the property could be more widespread than previously assumed. Though current evidence of erosion on the property is somewhat minimal, it merits consideration for proactive management that mitigates long-term impacts.

6. Wildlife

While the Arboretum was founded with a primary focus on plants of the Colorado Plateau, the characteristics of the property have made it a hotspot for viewing various wildlife species. The washes that run through the property also serve as a movement corridor and water source for wildlife, facilitating unique encounters and viewing experiences for visitors. See tables 2,3,4 and 5 for non-exhaustive lists of birds, mammals, reptiles/amphibians, and arthropods that can be found in and around the Arboretum.

Figure 12 - Coyote spotted on property grounds – Source: Arboretum Photo Archives

6.1. Rare, Threatened & Endangered Species

Areas adjacent to the Arboretum property have been identified as essential habitat for the Mexican Spotted Owl, which are referred to as a “protected activity center”

(PAC). The forested acres of the Arboretum have not been identified as a PAC for the Mexican Spotted Owl, which exempts the property from thinning restrictions which would otherwise jeopardize its habitat quality. Controlled burns in the area, however, must occur outside the owl's breeding season, which occurs between March 1 and August 31.

The Willow Pond on the Arboretum property once maintained a small population of Little Colorado Spinedace (*Lepidomeda vittata*), a federally threatened fish species. As the name suggests, the species is endemic to the Little Colorado River, of which the Rio de Flag is a local tributary. Its populations have fluctuated considerably due to periods of drought and shifting water levels. Presently, there is no confirmation of Little Colorado Spinedace populations remaining present in the pond.

7. Institutional & Property Objectives

The objectives for the Arboretum on a property and institutional level are informed by both the 1999 management plan and the determined priorities of both staff and board members.

- Enhance offerings as a research and educational institute
- Procure various funding sources to complete high priority management
- Mitigate all detectable fire risks present within the property
- Develop partnerships with adjacent landholders to address risk factors

8. Desired Future Conditions

Through continued maintenance and future treatments, the Arboretum intends to enhance the ecological integrity and educational value of the lands within its property boundaries.

- The Arboretum forests will be more resilient in the face of high severity fire, insect outbreak, and related disturbances.
- The health of forest understories will be enhanced through a series of treatments, facilitating the expansion of native plant diversity and distribution.
- Forest management will prioritize diverse age structures, maintenance of view screens from roads or fences, and enhancement of wildlife habitats.
- A small section of untreated forest along the nature trail will be preserved for the purposes of educational interpretation.
- Exotic weeds will be controlled within the forest and effectively addressed when conducting thinning treatments.
- The meadow will be continually treated to mitigate tree encroachment and vegetation type conversion.

- Some non-native grass meadow will be preserved for educational purposes, while other areas will undergo restoration efforts.
- The riparian areas of the property will be continually monitored and maintained to continue servicing the surrounding wildlife.

9. Management Recommendations

9.1. Forest Management

The primary management concerns for the forests on the Arboretum relate to general stand improvement though actions such as strategic thinning, fuel reduction, and cooperative management with adjacent landholders. Planning and implementing these forms of management are necessary to reduce the property's risk to high-severity fire and related disturbances, while also enhancing the ecological integrity of the forest itself. In developing plans for more proactive forest treatments, both the forest and the property in its entirety can become more resilient to natural disturbances and can reflect the efficacy of modern land stewardship and ecological restoration in practice.

Forest structures in the Southwestern United States have been altered significantly through a history of fire suppression policies, which is evident within and immediately outside the boundaries of the Arboretum. The absence of frequent lower-intensity fire, of which the landscape has been historically accustomed to, stand densities have been allowed to increase to unhealthy extents and facilitate the buildup of surface and ladder fuels. Shifting trends in regional climate only serve to compound the threat of high-severity fire to occur, which has the potential to damage both structures and ecology. Several treatment methods exist to address these conditions and restore the integrity of forests within and surrounding the property. While many have notable effects when applied individually, an integrated approach that utilizes multiple treatment types would be ideal to mitigate disturbance risk for both the Arboretum and surrounding landowners.

Thinning is an often-prescribed treatment to reduce stand density and promote a forest structure that is more resilient to disturbance and change. The density of stands within the Arboretum were excessive in the 1999 plan and have not received enough subsequent thinning for this to have changed substantially. Should more acres of forest undergo more intensive mechanical thinning, risks of fire and related disturbances will be reduced with the increase in tree group spacing. Similarly, thinning will result in a release from competition for the trees that remain standing, allowing more widely spaced Ponderosa pines and the patches of Gambel oak on the property to thrive and grow more resilient. Thinning treatments are not entirely without risk, though, with the possibility for invasive weeds to spread along disturbed soil being very potent. This can be mitigated with the strategic spreading of slash piles accrued from thinning, though

the risk remains to be worth acknowledgement. While not without its risks and considerations, a variety of thinning procedures have the potential to enhance the quality of forest stands in and around the property, especially when paired with complementary management actions.

The goals of thinning treatments on the property are centered upon the reduction of risk to wildfire and the restoration of ecosystem structure. Management of these stands is not intended to precisely mirror the type of forest structure witnessed prior to the interruption of the landscape's fire regime, though some treated acres could come to closely resemble this. The following management objectives identify the preferred spatial characteristics for the forest in the Arboretum:

- Residual basal area average between 60-80ft^2 BA/A across the stand
- Maintain tree clumps of varying basal area
- Retain some higher density tree clumps that are desired for wildlife cover
- Reduce overall canopy cover to approximately 55%, primarily as tree groups
- Increase diversity of size classes and distribution; permit establishment of regeneration in openings to promote structural heterogeneity in long-term

Prescribed fire is another beneficial treatment that reduces fuels in the understory and contributes to a healthier stand structure. The southwestern United States is home to various fire adapted ecosystems which have deteriorated in health, resulting from historic post-settlement fire suppression. This holds true for stands in the Arboretum and adjacent parcels of land as well. Reintroducing low intensity burns to the area could be effective in reducing the buildup of fuels that increase the intensity of fire. This can promote understory growth as layers of litter are removed, while also inducing mortality amongst intermittent and suppressed trees, leaving healthier dominant and codominant species to grow. Prescribed burn treatments also carry a degree of risk and thus are often carried out under specific weather conditions. When combined with thinning treatments, prescribed burns have the potential to reintroduce natural fire to an ecosystem while reducing the risk to surrounding properties.

The restoration and maintenance of strategic fuel breaks remains a high priority in the Arboretum's strategy to mitigate fire risk. Well established and maintained fuel breaks have the potential to significantly slow the progression of fire and provide firefighters with safer space to operate. While a fuel break was established in the Arboretum in 1985, it has not received an appropriate level of maintenance and requires more substantial treatments to be restored. Restoration of this fuel break will improve its resilience to high-severity fire and have some restorative effects to adjacent standing trees. Additional buildings have been constructed on the west side of the property since 1999 (i.e. Facilities, Merriam-Powell), which indicates the need for a fuel break on the property to extend beyond its prior boundaries. Utilizing the road to the west of the

facilities building and potentially extending the fuel break to the northwest corner of the property could more effectively protect both its new and more longstanding buildings.

The efficacy of fuel breaks is largely dependent upon how well they are implemented across a larger landscape, indicating the possibility of fire risk from outside the property's boundaries. Higher risk areas such as the nearby Woody Ridge could have residual effects on the Arboretum if they burn, with the potential to carry over embers via high-speed winds facilitated by high-severity fire. While restoring the fuel break on the property remains highly beneficial, more substantive risk mitigation would necessitate cooperative and coordinated efforts.

Though much in the way of management can be completed within the property boundaries of the Arboretum, more comprehensive risk mitigation will require collaborative action with adjacent landholders remains critical for it to be successful. There exists a diversity of land ownership in the parcels surrounding the Arboretum, with Forest Service and State Trust lands, Northern Arizona University's Centennial Forest, private landowners such as the neighboring Manterola Sheep Company, and lands connected to the Department of Defense such as Camp Navajo and the nearby Naval Observatory. The types of risk that the Arboretum faces are shared by these landowners, and their management objectives are largely the same as it pertains to risk mitigation. These shared objectives may facilitate the development and coordination of treatments across property boundaries and spur the development of long-term partnerships and cost sharing. The mutual benefits derived from these partnerships make the prospect of coordinated, cross-boundary treatments all the more viable in future years as stand and climate conditions become more unruly.

Collaborating with these various partners also comes with the likelihood of management efforts being funded through grants sponsored by state and federal agencies. Procuring grant funds for these treatments will ultimately reduce the financial burden associated with them, while allowing for these treatment projects to be more expansive in their scope. Having open communication with these surrounding landholders, while identifying the need for grant funded management, can result in treatments that protect all parties without any notable financial burden.

While not an exhaustive list, some of these grant funds may be applicable to sponsoring treatments in and around the Arboretum:

- NRCS EQIP Fund
- Good Neighbor Authority
- AZDFFM Grants
- USFS Grants and Cooperative Agreements

Figure 13 - Mature trees occupying garden space close to property structures

Managing the space between the forest and the property grounds is of particular concern to the Arboretum. While maintaining healthy older trees wherever possible remains a management priority, concern remains over the long-term risk of trees growing within the gardens and near property structures. The potential for windthrown trees damaging these structures or landscaped areas cannot be ignored. Similarly, garden spaces have been subject to excessive shading from nearby tree canopies, reducing their aesthetic value and making them more difficult to maintain. This can be mitigated via strategic pruning of tree limbs, and even removal of certain trees when deemed necessary. Careful consideration of essential viewscreens on the property that preserve its visual appeal should be taken when developing and conducting any management of the grounds. The result of these actions should more clearly delineate the boundary between the cultivated gardens and forested areas of the Arboretum.

As a research and educational institute, the Arboretum intends for management actions within its boundaries to showcase a range of forest structures and treatment types. Having a landscape that reflects various methods of management remains an important resource to the public on applied forest restoration principles. With that, there will remain some extent of doghair thicket and closed-canopy forest, while much of the space between them will be treated to reduce stand density and buildup of fuels. This diversity in stand structure can allow observers a side-by-side view of forest health under different forms of management. Observers may also witness the habitat preferences of terrestrial wildlife, birds, and understory plants which highlight the benefit of holistic forest management practices.

9.2. Meadow Management

Figure 14 - Controlled burns on the meadow of the Arboretum to reduce tree encroachment

Source: Markit! Forestry

Given the rarity of intact meadow ecosystems in the Southwestern region of the United States, effective meadow preservation and enhancement is a high priority for the Arboretum. Continual encroachment upon the meadow by Ponderosa pine trees has been identified as the most visually evident threat to this ecosystem which requires consistent treatment to effectively address it. Past controlled burns in the meadow were the primary method of suppressing trees and other woody species in the meadow, which have been generally effective. These treatments could also be utilized alongside hand or mechanical thinning to expand the meadow beyond its current range, reclaiming boundary areas that have been overtaken by forest. The presence of non-native grasses within the meadow is also a concern and can be addressed via professional treatment methods, or experimental approaches where appropriate. Some erosion from nearby washes have been identified in the boundary area between the meadow and forest, which can be readily addressed through minimalistic treatments such as small check dams. Maintaining the characteristics of a native meadow is essential to the Arboretum's mission as an educational institute which showcases healthy and intact ecosystems within the Colorado Plateau.

9.3. Riparian Management

The wetlands and seasonal drainages on the property, while not yet presenting any need for immediate or intensive management, still warrant continued maintenance to support their ecological function and habitat value whenever appropriate. These areas are critical in their potential to conserve biodiversity of species that are largely reliant on moist environments in a landscape that has grown increasingly arid and unpredictable. Management of these areas should prioritize the reduction of sedimentation and erosion, while enhancing habitat conditions wherever possible.

With the severity of erosion on the property remaining low for the time, there exist many inexpensive and non-invasive procedures to mitigate its effects. The “plug and spread” method of erosion treatment involves the placing of small berms or barriers in an existing channel to regulate flow. This facilitates the spread of water across a wider area, discouraging erosive flow and increasing surrounding soil moisture. Check dams are somewhat similar to the “plug and spread” treatment, with the placement of solid structures in a channel to encourage the buildup of sediments. As sediments collect around these check dams, it facilitates the recolonization of vegetation which in turn stabilizes the streambank. This treatment would be more appropriate in the event a channel has been deeply incised, though most of the erosion observed on the property has been relatively shallow.

9.4. Additional Considerations

Figure 15 - Ornamental trees planted within naturally occurring forest

To more closely resemble a true arboretum, some ornamental trees that do not naturally occur in the native Ponderosa pine forest type have been planted on the property. As the property receives a satisfactory level of treatments that restore the health and resilience of its forests, the opportunity to plant a greater variety of trees may arise. Doing so would require careful consideration of trees appropriate for the ecology and climate of the region and would be more achievable with the leveraging of volunteers to oversee their establishment. Due to the more immediate need for fuel reduction treatments on the property, little in the way of tree planting has occurred outside of the garden spaces. Future planting could potentially take place in treated areas of the forest with open canopy, or even in less natural spaces of the meadow. While not a feasible form of management at present, the planting of various tree species would provide immense educational value for the Arboretum.

More comprehensive management of the Arboretum requires data and measurements that have been unavailable to the organization for some time. Little in the way of soil data is available for the property and surrounding parcels, which could be utilized to better inform management of the meadow and forest alike. Working with land management partners to conduct a soil survey on the property would thus be of considerable benefit. Maintaining a master log of treatments conducted on the property would also allow staff to better determine which areas would benefit most from future treatments. Some space within the facilities can be utilized to store this type of data, alongside digital storage methods to ensure it is readily accessible to staff. Climate data specific to the Arboretum property itself would also be of interest considering how distinguishable it is from the typical climate of Flagstaff. This data could potentially be obtained from the Southwest Experimental Garden Array (SEGA) or other groups that hold extensive climate records. Other noteworthy data to compile includes the 1985 Arboretum site analysis, which was utilized substantially in the drafting of the property's 1999 forest management plan. Identifying gaps in data and knowledge can facilitate future activities and practices amongst the staff and board that seek to address them.

10. Glossary

Doghair thicket – A dense stand of generally same-age trees, often resulting from fire suppression or lack of forest treatment, that receives little light or understory growth.

Yellow barked tree – Used to refer to Ponderosa pine trees of a more mature age class, given their transition from darker colors to a brighter yellow and orange over time.

Snag – A dead, standing tree which provides critical wildlife to birds, insects and other forms of wildlife.

Fuel break – A designated strip of land in which vegetation is completely removed or significantly reduced to mitigate the spread of fire and minimize its impacts.

Ladder Fuels – Vegetation that facilitates the spread of a fire from understory brush to the above tree canopy.

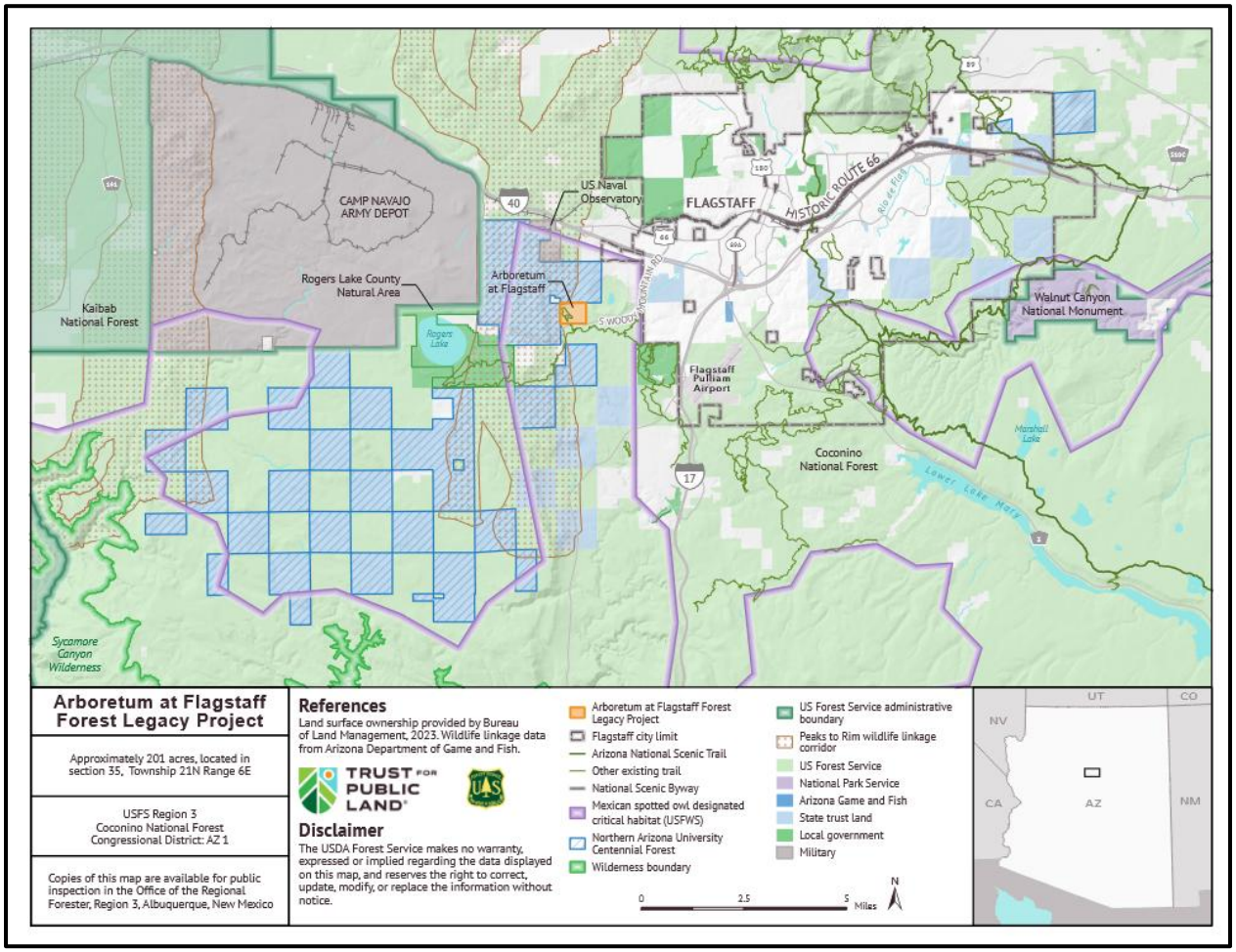
Stand Density – A measure of the number and size of trees in a given area; associated with measurements of Trees per Acre (TPA) or Basal Area (BA).

Canopy Closure – The proportion of the forest floor covered by the shading of tree crowns, affecting light availability and general understory conditions.

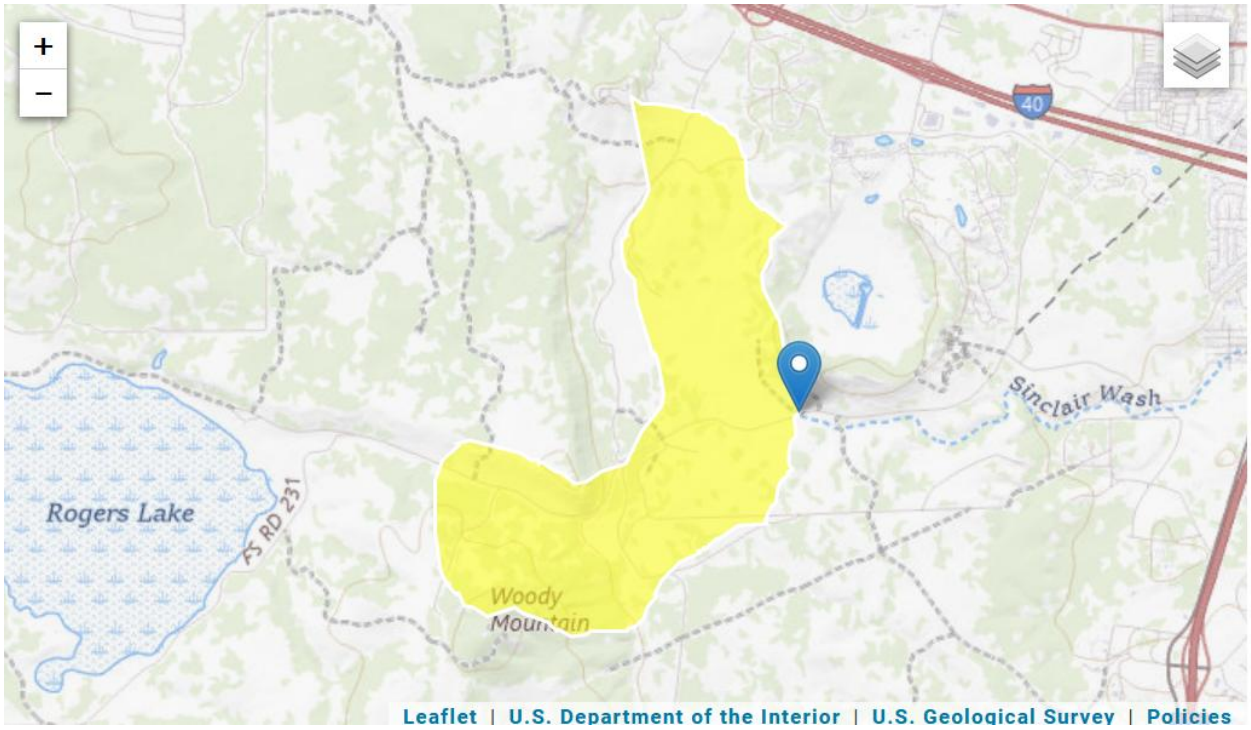
Closed Crown Forest – A forest in which tree crowns often touch and overlap, significantly reducing the level of light that can reach the understory.

Vegetation Type Conversion – The replacement of a distinct vegetative community (i.e. native grass meadow) by another (i.e. forest), often due to natural disturbance or invasive management procedures.

11. Maps

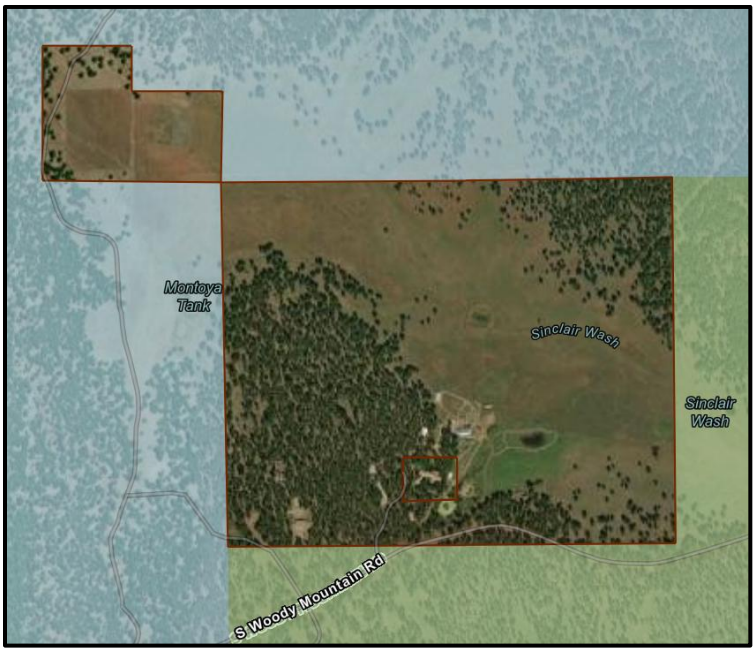


Map 1 - Land ownership patterns in and around the Arboretum – Source: Trust for Public Land



Map 2 - Map of the upper portion of the Sinclair watershed, to approximately where it leaves the Arboretum

Source: USGS StreamStats



Map 3 - Satellite imagery of the Arboretum property and diverse land ownership. Clear extent notes private land (Arboretum property + Manterola Sheep Company), green extent is USFS land, and blue extent is state trust land

Source: Coconino County Parcel Viewer

12. Appendix: Miscellaneous Figures & Tables

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
ELEV	Mean Basin Elevation	7262.566	feet
ELEVMAX	Maximum basin elevation	8029.92	feet
JANAVPRE	Mean January Precipitation	2.45	inches
JULAVPRE	Mean July Precipitation	2.4	inches
PRECIP	Mean Annual Precipitation	23.8	inches
RELIEF	Maximum - minimum elevation	921.17	feet
TEMP	Mean Annual Temperature	45.36	degrees F

Table 1 - Basin characteristics and climate data around Sinclair Wash – Source: USGS StreamStats

Bird Group	Species
Water Birds	Mallard, Ruddy Duck, Pied-billed Grebe, American Coot, Great Blue Heron
Diurnal Birds of Prey	Turkey Vulture, Osprey, Northern Harrier, Sharp-shinned Hawk, Cooper's Hawk, Northern Goshawk, Swainson's Hawk, Red-tailed Hawk, American Kestrel, Peregrine Falcon
Grouse and Quail	Gambel's Quail, Dusky Grouse
Pigeons and Doves	Rock Pigeon, Eurasian Collared-Dove, Mourning Dove
Owls	Great Horned Owl, Northern Pygmy-Owl, Northern Saw-whet Owl
Goatsuckers	Common Nighthawk, Common Poorwill
Swifts	White-throated Swift
Hummingbirds	Broad-tailed Hummingbird, Rufous Hummingbird
Woodpeckers	Lewis's Woodpecker, Red-naped Sapsucker, Downy Woodpecker, Hairy Woodpecker, American Three-toed Woodpecker, Northern Flicker
Flycatchers	Olive-sided Flycatcher, Western Wood-Pewee, Willow Flycatcher, Hammond's Flycatcher, Dusky Flycatcher, Cordilleran Flycatcher, Say's Phoebe, Ash-throated Flycatcher, Cassin's Kingbird, Western Kingbird
Vireos	Plumbeous Vireo, Warbling Vireo
Jays and Crows	Woodhouse's Scrub-Jay, Steller's Jay, Pinyon Jay, Clark's Nutcracker, American Crow, Common Raven
Larks	Horned Lark
Swallows	Tree Swallow, Violet-green Swallow, Northern Rough-winged Swallow, Cliff Swallow, Barn Swallow
Chickadees	Mountain Chickadee
Nuthatches	Red-breasted Nuthatch, White-breasted Nuthatch, Pygmy Nuthatch
Creepers	Brown Creeper
Wrens	House Wren, Bewick's Wren, Marsh Wren
Kinglets	Ruby-crowned Kinglet
Gnatcatchers	Blue-gray Gnatcatcher
Thrushes	Western Bluebird, Mountain Bluebird, Townsend's Solitaire, Swainson's Thrush,

	Hermit Thrush, American Robin
Mockingbirds and Thrashers	Northern Mockingbird, Sage Thrasher
Starlings	European Starling
Waxwings	Cedar Waxwing
Warblers	Orange-crowned Warbler, Virginia's Warbler, Yellow Warbler, Yellow-rumped Warbler, Grace's Warbler, Black-throated Gray Warbler, Townsend's Warbler, Hermit Warbler, Wilson's Warbler
Tanagers and Allies	Western Tanager, Black-headed Grosbeak
Sparrows and Juncos	Green-tailed Towhee, Spotted Towhee, Chipping Sparrow, Brewer's Sparrow, Vesper Sparrow, Lark Sparrow, Black-throated Sparrow, Lark Bunting, Dark-eyed Junco, White-crowned Sparrow
Blackbirds and Orioles	Yellow-headed Blackbird, Western Meadowlark, Brewer's Blackbird, Brown-headed Cowbird, Bullock's Oriole
Finches	House Finch, Cassin's Finch, Red Crossbill, Pine Siskin, Lesser Goldfinch, American Goldfinch
Old World Sparrows	House Sparrow

Table 2 - Table of Birds documented to appear in the Arboretum – Source: Arboretum Birds Checklist

Common Name	Scientific Name
Gopher Snake	*Pituophis catenifer*
Arizona Black Rattlesnake	*Crotalus cerberus*
Western Fence Lizard	*Sceloporus occidentalis*
Arizona Treefrog	*Hyla wrightorum*
Red-spotted Toad	*Anaxyrus punctatus*
Tiger Salamander	*Ambystoma mavortium*

Table 3 - Table of local repitles & amphibians that can be seen in the Arbroetum

Functional Group	Common Names
Detritivores	Darkling beetles, fungus beetles, rove beetles, tree bugs, bristletails, springtails, lice

Herbivores	Click beetles, leaf beetles, flower beetles, scarabs, weevils
Predators	Ground beetles, clown beetles, pseudoscorpions, square-headed wasps, velvet ants, spiders
Omnivorous Ants	Red wood ants, black formic ants, citronella ants, big headed ants, timid ants, thief ants, Myrmica ants

Table 4 - Table of arthropods found in the Arboretum's forest & meadow – Source: Arthropods of the Arboretum (Dr. Derek Uhey, 2024)

Common Name	Scientific Name
Elk	*Cervus canadensis*
Mule Deer	*Odocoileus hemionus*
Antelope	*Antilocapra americana*
Coyote	*Canis latrans*
Gray Fox	*Urocyon cinereoargenteus*
Abert's Squirrel	*Sciurus aberti*
Cliff Chipmunk	*Tamias dorsalis*
Striped Skunk	*Mephitis mephitis*
Porcupine	*Erethizon dorsatum*
Cottontail	*Sylvilagus floridanus*
Jackrabbit	*Lepus californicus*

Table 5 - Table of Flagstaff mammals that can be found in and around the Arboretum

Peak-Flow Statistics Parameters [Peak Region 2 Colorado Plateau 2014 5211]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
CONTDA	Contributing Drainage Area	1.24	square miles	0.103	16017
ELEV	Mean Basin Elevation	7349.213	feet		

Peak-Flow Statistics Flow Report [Peak Region 2 Colorado Plateau 2014 5211]

PIL: Lower 90% Prediction Interval, PIU: Upper 90% Prediction Interval, ASEp: Average Standard Error of Prediction, SE: Standard Error, PC: Percent Correct, RMSE: Root Mean Squared Error, PseudoR^2: Pseudo R Squared (other -- see report)

Statistic	Value	Unit	PIL	PIU	ASEp
50-percent AEP flood	59.3	ft^3/s	12	292	122
20-percent AEP flood	157	ft^3/s	44.7	551	87.2
10-percent AEP flood	261	ft^3/s	84.8	804	75.7
4-percent AEP flood	446	ft^3/s	158	1260	68.6
2-percent AEP flood	629	ft^3/s	226	1750	66.6
1-percent AEP flood	852	ft^3/s	306	2370	67.3
0.5-percent AEP flood	1120	ft^3/s	394	3180	68.8
0.2-percent AEP flood	1560	ft^3/s	522	4660	72.9

Table 6 - Sinclair Wash Peak Flow Estimates – Source: USGS StreamStats

▲ Map Unit Composition	***Purpleheart-Pluto complex, 0 to 4 percent slopes (4001)***
65% - ***Pluto*** Geomorphic Position: *lava plains*	▲ **Map Unit Composition**
20% - ***Procky*** Geomorphic Position: *lava plains*	50% - ***Purpleheart*** Geomorphic Position: *lava plains*
10% - ***Grandwash*** Horizon data n/a	40% - ***Pluto*** Geomorphic Position: *plateaus*
5% - ***Purpleheart*** Horizon data n/a	10% - ***Pinespring*** Horizon data n/a | View Similar Data
▲ **Map Unit Data**	▲ **Map Unit Data**
Map Unit Key: *3441506* *[Graphical Summary]*	**Map Unit Key:** *3441501* *[Graphical Summary]*
National Map Unit Symbol: *315lm*	**National Map Unit Symbol:** *30sh8*
Order of Mapping: *Order 4* ?	**Order of Mapping:** *Order 4* ?
Map Unit Type: *Complex* ?	**Map Unit Type:** *Complex* ?
Farmland Class: *Not prime farmland*	**Farmland Class:** *Not prime farmland*
Available Water Storage (0-100cm): *9.74 cm*	**Available Water Storage (0-100cm):** *10.9 cm*
Flood Frequency (Dominant Condition): *None*	**Flood Frequency (Dominant Condition):** *None*
Flood Frequency (Maximum): *None*	**Flood Frequency (Maximum):** *None*
Ponding Frequency: *0*	**Ponding Frequency:** *0*
Drainage Class (Dominant Condition): *Well drained* ?	**Drainage Class (Dominant Condition):** *Well drained* ?
	Drainage Class (Wettest Component): *Well drained* ?

Table 7 - Soil data from adjacent forest and meadow landscapes – Source: UC Davis WebSoil

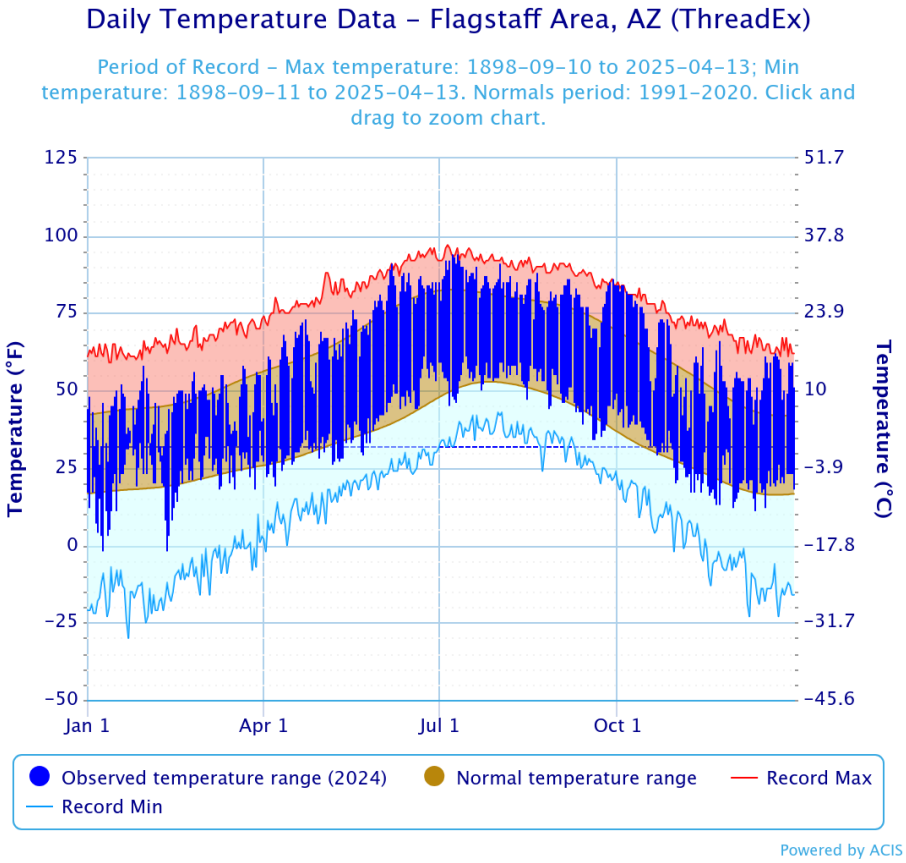


Table 8 - Flagstaff Area Temperature Data – Source: NOAA

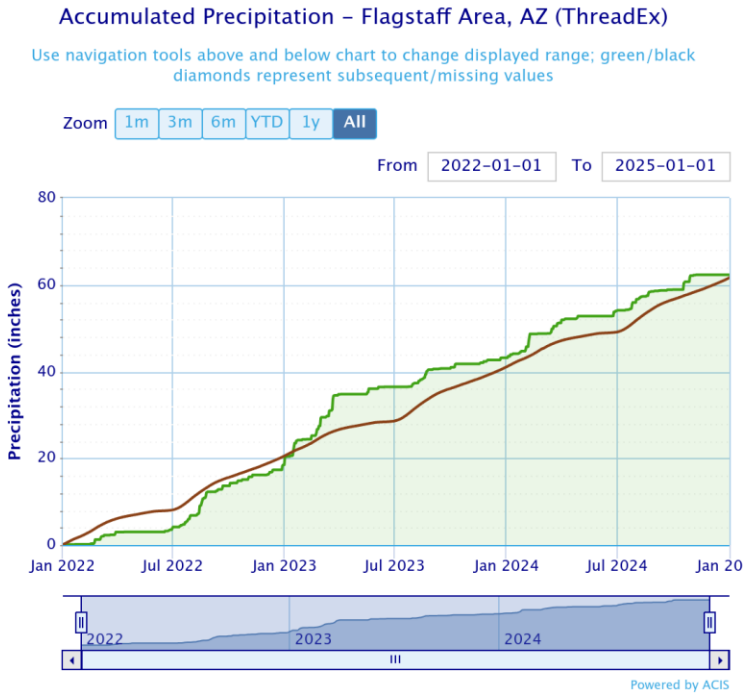


Table 9 - Precipitation Accumulation Graph (2022-2025) – Source: NOAA

13. Resources

The Arboretum at Flagstaff. N.D. *Checklist of the Birds*

AZGFD. N.D. *Arizona's Wildlife*

J. Maschinski, R. Libengood, M. Wagner. 1999. *Forest Management Plan – The Arboretum at Flagstaff*

Arizona State Forestry Wildland Fire Hazardous Fuels (WFHF) Grant Program. 2015. *Marking Guidelines*

Uhey, D. 2024. *Arthropods of the Arboretum*

*Note – This section is still under development as additional (often historic) resources utilized in this plan remain uncovered.