Grazing Feasibility Study for the Mt. Tamalpais Watershed, Marin Municipal Water District, California

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1. Executive Summary and Key Findings

For many years, the Marin Municipal Water District (MMWD) has used various types of manual labor and heavy equipment—and until 2005, herbicide application—to manage invasive weed species that degrade plant and wildlife habitats and interfere with staff access and public recreation. These same tools have also been used to reduce fire fuel loads, especially in designated fuelbreak areas. Although MMWD has only experimented with domestic livestock grazing a couple of times in the past, this practice has been increasingly used by both public and private lands management agencies to achieve some of the same vegetation management outcomes as mechanical and chemical methods.

In February 2017, MMWD released a request for proposals for a feasibility study to determine whether livestock grazing can be successfully used to augment its existing vegetation management program. LD Ford, Rangeland Conservation Science, a consulting firm based in Felton, California, was selected based on their extensive expertise in grazing and other rangeland management practices.

Dr. Lawrence Ford assembled a team of leading qualified experts who spent the spring and summer of 2017 interviewing livestock operators and MMWD staff, as well as reviewing relevant published and unpublished documents, maps, and aerial photographs of MMWD's Mount Tamalpais Watershed lands (MTW Lands).

Scientific literature provided the theoretical basis for recommendations about grazing and its expected effects on targeted MTW resources such as rare plants and priority weed species. A telephone survey of 13 contract graziers[1] and livestock ranchers (Section 6) offered a more practical understanding of how vegetation management could be accomplished with grazing and browsing animals. Results of these interviews and known physical site constraints reveal limitations that temper the promise offered by academic studies and theoretical research. These results are briefly summarized here and then described in full in the body of this report.

Weed Management

Phone surveys revealed that site constraints, complex grazing objectives, and lack of permanent infrastructure make MTW Lands unappealing to ranchers who make their living by producing animal products (Section 6). Therefore, contract graziers who charge a fee to provide grazing/browsing services would be required. However, contract grazing/browsing is likely unrealistic as an overall weed management tool on MTW Lands because of high per-acre costs, probable need for repeated grazing/browsing treatments each year, and questionable success of grazing/browsing for management of many of MMWD's target weed species (Section 7).

While using livestock to manage some weed species has been successful in controlled experimental settings, transferring experimental techniques to MTW Lands where there are complex and in some cases competing objectives is not practical. For example, there are many sites where the goal is to both protect rare plants and manage weeds and/or where there are multiple weed species that would require different grazing timing or frequency. Furthermore, some grazing animals either cannot tolerate certain weeds or graze so broadly that they consume desirable species as well (Section 5). The idea of

[1] A person who raises livestock on grazing land, used here to those who raise animals on browsing land where woody plants are the predominant feed. This term is used to refer to people who own livestock for contract vegetation management, rather than being traditional ranchers who raise livestock to produce animal products.

training livestock to consume unfamiliar weed species has been popularized in recent years, but data regarding actual control of many species are lacking.

Livestock will undoubtedly consume *some portion* of most of the high-priority weed species on MTW Lands, but grazing or browsing is unlikely to provide the full desired level of control. Although it may not completely remove targeted weeds, grazing can be managed to help reduce weed mass and seed production—if timed effectively and repeated frequently. If not managed properly though, browsing or grazing may cause branching of flowering heads and production of additional seeds, which could actually lead to weed expansion.

Fuelbreak Maintenance

Section 5 describes grazing and browsing habits of domestic livestock. Browsing by sheep and goats may be useful for control of fire fuels in the high priority fuelbreak areas, which are shown in the MMWD *Draft Biodiversity, Fire, and Fuels Integrated Plan* (Panorama Environmental, Inc. 2016: Figures 3-11 to 3-14). However, woody plant removal by equipment and hand crews is more effective to remove larger stems and is more selective, allowing better protection of non-target plants. The combination of browsing and mechanical/manual treatments, applied repeatedly in rotation through priority areas, would be more effective and efficient than either treatment alone.

Rare Plant Species

Carefully planned and executed grazing would likely be useful for enhancing habitats for native grassland species, including the priority rare species (Section 3 and Appendix 1), on some of the 16 Potential Grazing Areas identified by MMWD staff (Section 4 and Appendix 2).

Cost Considerations

Cost effectiveness of grazing and browsing methods for vegetation management in comparison to mechanical and manual methods[2] indicates a cost advantage for grazing for the following actions (Section 6, Table 2):

- Existing fuelbreak retreatment (only where plants are palatable and wood diameter is small)
- Roadside mowing (especially for herbaceous vegetation)
- Dam maintenance
- Accumulated fuels and brush reductions (only where wood is small diameter)
- Yellow starthistle management (only if timed correctly and for large areas combined into one project)
- General grassland and thatch management for selected special-status plants (very effective with proper timing, but no costs of mechanical methods to compare to)

Combined Weed Management and Cost Effectiveness Analysis

The study team evaluated the expected effectiveness of targeted grazing to meet MMWD's conservation objectives at each of the Potential Grazing Areas identified in Section 7. Using this, plus cost effectiveness analyses, Table 3 ranks the priority of Potential Grazing Areas for MMWD to consider if they decide to proceed with grazing.

In summary, only one of the 16 Potential Grazing Areas appears to have no feasibility for grazing, and thus should not be considered further:

- Grassy Knoll

[2] Actions and Projected Costs from Panorama Environmental, Inc. 2016, Table 7-2. p. 7-5.

Only one ranked *high* in expected management effectiveness and cost-effectiveness:

- Poison Spring Grasslands

Seven others ranked *medium* in expected effectiveness:

- Sky Oaks
- Pumpkin Pine-Fish-Lag Meadows
- Azalea Hill
- Pine Mountain South Gate
- Bathtub Gap-Carson Ridge (medium+)
- Cascade Creek
- Midpoint Meadows (medium+)

Priority grazing areas that include the target species should be evaluated individually and grazing plans and monitoring protocols should be developed before grazing is initiated. If MMWD is interested in pursuing grazing, the study team recommends they start with testing at one or more of the most promising grazing areas.

2. Project Background

The MMWD Grazing Feasibility Study team included Dr. Lawrence Ford, Principal and Senior Natural Resource Scientist (California Certified Rangeland Manager license #M70); Lisa Bush, Agriculture and Range Management Specialist (California Certified Rangeland Manager license #M18); Pete Van Hoorn, Rangeland Ecologist (California Certified Rangeland Manager license #M101), all of LD Ford Rangeland Conservation Science; and Justin Davilla, Special Resource Ecologist and Botanist, of EcoSystems West Consulting Group. They were supervised by and collaborated with Andrea Williams, MMWD Plant Ecologist, and Janet Klein, MMWD Natural Resources Program Manager.

An initial meeting between A. Williams, J. Klein, L. Ford, and L. Bush helped to identify highest priority objectives for a potential grazing program. These included fuelbreak maintenance, meadow restoration (thatch reduction and management of exotic perennial grasses) and enhancement, weed suppression and eradication, and possible management of tanoak resprouts in Sudden Oak Death-affected areas. Ms. Williams subsequently identified priority rare plants and weeds to potentially target with grazing through telephone conversations and in the memo titled "Grazing Species Selection Final" (Appendix 1).

Due to budget constraints, the only on-site reconnaissance was one half-day visit by L. Bush with A. Williams in March 2017. A follow-up meeting in June 2017 between MMWD staff, L. Ford, and L. Bush refined the scope of work. Several subsequent teleconferences also occurred. MMWD staff provided detailed information about MTW Lands, including a memo about priority species to target and maps of potential grazing areas, which are referenced and appended to this report.

MMWD asked specifically for analysis of "the feasibility of using limited scale, limited duration grazing to reduce brush and weeds in designated fuel load reduction zones as well as to improve grassland health in an economically and environmentally sustainable fashion" in their February 2017 request for proposals. Grazing is being considered as a potential vegetation management action (notably as an alternative to herbicides) in the *MMWD Draft Biodiversity, Fire, and Fuels Integrated Plan* (Panorama Environmental, Inc. 2016). In addition to the vegetation management goals noted above, MMWD recognizes the particular importance of maintaining water quality and minimizing conflicts with scenic open space and recreational opportunities associated with grazing.

Generally, this analysis focuses on the potential use of grazing and browsing for targeted beneficial management of specific plants or types of vegetation. It should be noted though that livestock grazing can also be used to achieve broader ecosystem goals such as improving habitat for native grassland birds, amphibians, rodents, and invertebrates by reducing cover and obstruction of non-native grassland plants, increasing grassland structural heterogeneity, and reducing thatch. Grazing can also be managed to target zones of higher risk fire fuels, avoid areas of special habitat use during sensitive times, and avoid or minimize potential impacts to water quality and recreational opportunities.

3. Grazing Management to Benefit Selected Rare Plants and Control Selected Weeds

3.1 Management Considerations, Recommendations, and Feasible Grazing Management for Rare Plants, Special-Status Habitats/Natural Communities, and Weeds

Selected rare plants include Mount Tamalpais thistle (*Cirsium hydrophilum* var. *vaseyi*), Marin western flax (*Hesperolinon congestum*), harlequin lotus (*Hosackia gracilis*), and marsh zigadenus (*Toxicoscordion fontanum*). Weed species selected for consideration include barbed goatgrass (*Aegilops truincialis*), yellow starthistle (*Centaurea solstitialis*), poison hemlock (*Conium maculatum*), eggleaf spurge (*Euphorbia oblongata*), reed fescue (*Festuca arundinacea*), French broom (*Genista monspessulana*), common velvet grass (*Holcus lanatus*), and Harding grass (*Phalaris aquatica*). Ms. Williams' full memo is attached as Appendix 1. The memo also lists plants that were *not* selected.

To summarize, the following text is excerpted:

> "MMWD stewards over 20,000 acres of watershed lands, supporting over 1,000 plant species, water for 190,000 residents, and recreation for millions of visitors. State or federal government or the California Native Plant Society consider more than 50 of these plants to be rare; over 100 are listed as invasive by the California Invasive Plant Council. In order to limit the scope of the contract, a maximum of 12 plant species are to be considered in potential grazing scenarios.
>
> I made selections of priority species based on how prevalent the species was on watershed lands potentially subject to grazing; whether the species may serve as a representative for other similar species; and whether the population may be influenced by grazing. MMWD staff also decided to remove Nicasio and Soulajule lands from consideration, which further reduced potential species selection. These lands—Nicasio in particular—may be evaluated for grazing at a future date. Additionally, if grazing is shown to be feasible and beneficial on watershed lands, grazing plans will provide an additional opportunity to examine potential effects on species not currently included in this study.
>
> *Rare Plants Selected (Table 1 [in Appendix 1])*:
> Mt. Tamalpais thistle is a biennial plant that grows in wet, serpentine-influenced sites. Approximately 12 sites are extant in the county, nine of which are on watershed lands. This species is declining for several reasons: changes in hydrology, shading at forest edge sites, and lack of bare ground in wet meadow sites. Well-meaning but ignorant individuals may be killing plants, but other than a planted site we have no direct evidence of this. Mt. Tam thistle was chosen as a broadly distributed but rare and declining species, endemic and emblematic of the watershed, which may benefit from well-managed grazing.
>
> Marin western flax is our only extant federally listed species within the area of focus. It can be found in three sites on watershed lands in serpentine grassland and edges of chaparral. Thought to be on the decline due to competition from other plants, it may also benefit from well-managed grazing.
>
> Harlequin lotus grows in wet meadows on seven sites across the watershed. A low-growing, short-lived perennial, this species overlaps at one site with Mt. Tam thistle but otherwise is

found in non-serpentine wet meadows on the watershed. It may be declining from a combination of hydrologic changes and competition from invasive plants (particularly perennial grasses).

Marsh zigadenus is another wet-meadow species, but it can be found in chaparral as well, and has an affinity to serpentine soils. So far it has been mapped at 18 locations across the watershed. A geophyte, and poisonous, it is unknown how the species will respond to grazing.

Rare Plants Not Selected (Table 2 [in Appendix 1]):
Most of the rare taxa were excluded from consideration because they were too uncommon, or grew in habitats unlikely to be grazed.

Weed Species Selected (Table 3 [in Appendix 1]):
Weedy plants were difficult to narrow down, but species chosen were those on which we currently spend the most time and/or money on, and those which are affecting the most high-quality habitat.

Weed Species Not Selected (Tables 4 and 5 [in Appendix 1]):
With over 100 weeds included on the Cal-IPC of Invasive Plant Inventory, giving a rationale for each would be time-consuming. Species that were uncommon or rare (Table 5) were not selected based on their low abundance; Table 4 contains rationales for more common species. Several of these were excluded simply due to lack of space on the priority list.

Native Species:
Not included are native woody species tanoak (*Notholithocarpus densiflorus*), coyote brush (*Baccharis pilularis*), and chaparral pea (*Pickeringia montana*), which also make up a large portion of our fuel reduction work. If there is time, some or all of these may be added to the list of species considered."

With guidance from the study team, Ms. Williams also prepared maps of the 16 most suitable potential grazing areas (Appendix 2), which are described in Section 4. These areas either include target plants that may benefit from grazing (rare plants) or that may be negatively affected by grazing (weeds) or that are priority fuelbreak areas.

The remainder of this section describes various aspects of the rare plants and weeds selected by A. Williams for potential targeting with grazing (Appendix 1). It also includes information on special-status habitats and natural communities identified by J. Davilla. It is primarily based on review of published scientific literature, but also relies on some unpublished professional papers as well as personal observations by members of the study team.

3.1.1 Rare Plants

Mt. Tamalpais thistle (*Cirsium hydrophilum* var. *vaseyi*)

Ranking and status	**Federal[3]/ State[4]/ CNPS[5]:** None/None/1B.2 **MTW Lands**: Common. Endemic to Marin County and the Mt. Tamalpais watershed with only 12 recorded occurrences, nine of which were found on MTW Lands. Presently six extant, small occurrences, many of which are in decline and several additional occurrences have been extirpated since 1990 (Panorama Environmental, Inc. 2016).
Habitat requirements—General[5,6] and on MTW Lands[7]	**General:** Meadows and seeps with serpentine soils. Considered "obligate" wetland species occupying areas with prolonged soil saturation and/or inundation although not typically found in areas with deep standing water (i.e., stockponds). 240-620 meters elevation. **MTW Lands:** Limited to serpentine seeps and meadows in broadleaf upland forest and chaparral. Mapped occurrences generally less than five acres with fewer than 250 individuals. Typically associated with native obligate wetland species, with seep margins dominated by woody vegetation including coast live oak (*Quercus agrifolia*), coyote brush, coffeeberry (*Frangula californica*), Douglas-fir (*Pseudotsuga menziesii*), chaparral pea, and California blackberry (*Rubus ursinus*).
Vulnerabilities for protection and management—Foliage growth and flowering periods[6], regeneration/ re-sprouting after defoliation, seedbank	Biennial (occasionally short-lived perennial) herb. May–August (September) flowering period. No direct studies of Mt. Tamalpais thistle response to grazing but presumed to respond similarly to Mt. Hamilton thistle (*Cirsium fontinale* var. *campylon*; CNPS 1B.1); a rare biennial serpentine endemic occurring in seeps and meadows in southern Santa Clara County. Mt. Hamilton thistle is somewhat tolerant of grazing but is susceptible to trampling (HT Harvey et al. 2008).

[3] U.S. Fish and Wildlife Service (2017) FT = Threatened: Threatened of becoming endangered within the foreseeable future throughout all, or a significant portion of its range.
[4] CDFW (2017) ST = Threatened: A native species or subspecies that, although not presently threatened with extinction, is likely to become an endangered species in the foreseeable future in the absence of special protection and management efforts.
[5] Tibor (2001); California Native Plant Society (2017); CNPS Lists: List 1A: Presumed extinct in California. List 1B: Rare, Threatened, or Endangered in California and elsewhere. List 2: Rare, Threatened, or Endangered in California, more common elsewhere. List 3: Plants about which more information is needed. List 4: Plants of limited distribution: a watch list. Threat Code extensions: 1: Seriously endangered in California. 2: Fairly endangered in California. 3: Not very endangered in California.
[6] California Natural Diversity Database (2017).
[7] Memo prepared by A. Williams (Appendix 1) and GIS site analysis and resultant maps prepared by A. Williams (Appendix 2).

Forage considerations—Quality, palatability, quantity	Spiny, fibrous perennial forb with poor palatability to grazers. Spiny flowers likely to be avoided by sheep and cattle, but goats likely to consume Mt. Tamalpais thistle, especially if other woody browse is lacking.
Grazing effects—General and on MTW Lands	**MTW Lands:** None of these populations are known to have been grazed by domestic livestock for many years, if ever. **General:** Response to grazing is unknown but presumed to be similar to other native thistles endemic to serpentine seeps and meadows. The closest likely analog is the Mt. Hamilton thistle (see above), several populations of which have been actively grazed for habitat enhancement. HT Harvey and Associates (2008) reported that spring grazing impacts were minimal as cattle consume other more desirable green forage, and trampling was also reported to have minimal long-term effects. Nevertheless, grazing directly in serpentine seeps supporting Mt. Tamalpais thistle is likely to be detrimental to this species as excessive trampling in mucky soils may injure or uproot existing plants prior to seed set and facilitate infestations of undesirable invasive plants (J. Davilla, co-author, personal observation).
Grazing management considerations and recommendations (exclusion, timing, intensity, repetition, trade-offs)	**Timing/Exclusion**. Early season, moderate intensity cattle grazing has had positive benefits to native species richness and cover in studies conducted in southern Santa Clara County (Coyote Valley/Kirby Canyon) by decreasing competition from exotic annual grasses (Weiss 1999, Weiss et al. 2007). Grazing may also mediate the effects of nitrification from automobiles and industry and climate change. However, it is likely that trampling and alteration to the hydrologic regime may adversely affect Mt. Tamalpais thistle. Its spiny, fibrous morphology means that it is likely to be mostly avoided by cattle and sheep, especially when flowering. However, goats are likely to browse flowering plants, limiting seed production. Exclusion from grazing or short duration, early-season grazing is recommended.

Marin western flax (*Hesperolinon congestum*)

Ranking and status	**Federal**[3]**/ State**[4]**/ CNPS**[5] FT/ST/1B.1 **MTW Lands:** Rare. Two extant occurrences on MTW Lands in serpentine grassland and chaparral.

Habitat requirements—General[5,6] and on MTW Lands[7]

General: Grasslands and chaparral (ecotone/openings) on serpentine soils. Often found along ridgetops and on well drained, south or east facing aspects. 5–370 meters elevation.

MTW Lands: Mostly occurring in serpentine chaparral with several populations co-occurring with Mt. Tamalpais manzanita (*Arctostaphylos montana* ssp. *montana*; CNPS List 1B.3).

Vulnerabilities for protection and management—Foliage growth and flowering periods[6], regeneration/ re-sprouting after defoliation, seedbank

Annual herb. April–July flowering period. No existing studies on regeneration after defoliation but species is low-growing and likely to be avoided/unaffected by early season grazing. Marin western flax likely co-evolved with grazing herbivores, including tule elk (*Cervus canadensis nannodes*), pronghorn antelope (*Antilocapra americana*), and mule deer (*Odocoileus hemionus*). Therefore, compatibility with appropriately managed grazing regimes is expected. There are no demographic studies evaluating soil seedbank and reproductive habits (e.g., mating, pollination).

Forage considerations—Quality, palatability, quantity

Marin western flax is considered palatable to livestock as it does not contain toxic compounds or other vegetative features (e.g., spines) that grazing animals would avoid. Although low-growing, its abundant flowers per individual may attract livestock during periods where grasses have been grazed low and forage is otherwise limited (USFWS 2011). Marin western flax tends to grow in dense patches, although overall patch size is usually small (less than 0.5 acres).

Grazing effects—General and on MTW Lands

Near to MTW Lands: There are six occurrences of Marin dwarf flax on nearby Golden Gate National Recreation Area (GGNRA) grazing lands. Point Reyes National Seashore staff, who are responsible for special-status plant monitoring on GGNRA lands concluded that "Marin dwarf flax may benefit from a moderate level of cattle grazing through the reduction of taller competing vegetation as the flax is subject to shading by competing grasses or may be suppressed by buildup of thatch from previous year's herbage if left ungrazed." (USNPS 2001).

General: Studies in Santa Clara Valley show moderate cattle grazing will reduce competition for resources from invasive, non-native grasses and may benefit native annual forbs (Weiss 1999, Weiss et al. 2007). Increased nitrification due to automobile exhaust and industry (smog) favors many of these exotic grasses leading to unfavorable conditions for native species, in particular annual forbs, but cattle grazing has been shown to mediate this response (Weiss 1999).

There are no published studies evaluating the effects of goats, sheep or other domestic livestock on serpentine endemics. Due to forage preference for woody browse and grasses, goats are unlikely to adversely affect Marin western flax; however, sheep preference for forbs would likely lead to detrimental impacts to the species.

Grazing management considerations and recommendations (exclusion, timing, intensity, repetition, trade-offs)	**Timing/Intensity**. Early season grazing prior to the April–July flowering period would most likely avoid damaging this plant. Moderate intensity cattle grazing may benefit existing populations by decreasing competition from exotic grasses including Italian ryegrass (*Lolium multiflorum*), brome grasses, and wild oats. Grazing intensity should be sufficient to remove standing biomass of exotic grasses but also maintain desirable levels of RDM[8] to support native annual forbs and minimize impacts to established native perennial bunchgrasses. Grazing effects on Marin western flax have not been studied in detail and so any grazing on MTW Lands should be undertaken carefully with annual monitoring and implementation of adaptive management strategies. Sheep grazing is not recommended due to their preference for forbs.

Harlequin lotus (*Hosackia gracilis*)

Ranking and status	**Federal[3]/ State[4]/ CNPS[5]:** None/None/4.2 **MTW Lands:** Common. Six extant occurrences; one occurrence overlaps with Mt. Tamalpais thistle but otherwise occurs in non-serpentine areas.
Habitat requirements—General[5,6] and on MTW Lands[7]	**General:** Wetlands and roadsides; broad-leafed upland forest, coastal bluff scrub, closed-cone coniferous forest, cismontane woodland, coastal prairie, coastal scrub, meadows and seeps, marshes and swamps, North Coast coniferous forest, valley and foothill grassland. 0–700 meters elevation. **MTW Lands:** Mostly occurring in mesic, well developed grasslands/meadows bordering trails and roadsides. Largest occurrence is in Potrero Meadow near Laurel Dell Road.
Vulnerabilities for protection and management—Foliage growth and flowering periods[6], regeneration/ re-sprouting after defoliation, seedbank	Perennial rhizomatous herb. March–July flowering period. Short-lived perennial only reproducing from seed, but new seedlings are relatively uncommon. Requires cross pollination to produce viable seeds. Underground stems are not true rhizomes as plant is unable to reproduce vegetatively. Seeds exhibit relatively low viability with only 7–30% germination in one greenhouse study. Other field studies have shown germination in the field ranges from 0–6.5%. Seeds disperse explosively from ruptured seed pods and may be transported by grazing ungulates. However, the majority of viable seed remains within several meters of the parent plant. Plants are expected to regrow after defoliation where underground shoots remain intact (COSEWIC 2010).

[8] Residual Dry Matter (RDM). RDM refers to the dry mass (and height) of plant matter left on the ground from previous growth before the start of the next winter growing season (September/October). The amount and species of forage that is produced in a growing season is largely dependent on the environment of soil and RDM during the previous late autumn. This affects seed germination and seedling growth, and will be optimized under the indicated range of herbaceous mass and height. The RDM standards are based on Bartolome et al. (2006).

Forage considerations—Quality, palatability, quantity	No evidence that harlequin lotus in unpalatable, and other species in the same genera are palatable to livestock. As a showy, flowering herb, it may be targeted by sheep but is unlikely to be excessively grazed by cattle or goats, particularly if more desirable forage is present. Individual plants are prostrate/spreading with low overall density.
Grazing effects—General and on MTW Lands	**General:** Unlikely to be impacted by low to moderate grazing intensity and may benefit from decreased competition from exotic annual grasses and woody plant encroachment. Low growing species with extensive root network unlikely to be excessively damaged by trampling. Moderate levels of grazing by cattle will likely target taller species leaving more prostrate harlequin lotus unaffected. However, grazing by sheep may adversely impact harlequin lotus due to their preference for forbs.
Grazing management considerations and recommendations (exclusion, timing, intensity, repetition, trade-offs)	**Intensity.** Because most extant occurrences of harlequin lotus within MTW Lands are in grassland and meadows with well developed (loamy) soils, moderate intensity spring grazing by cattle may reduce competition from exotic annual grasses and prevent further encroachment of woody shrubs and trees (i.e., coyote brush, French broom, Douglas-fir). Sheep are not recommended due to their preference for forbs. Goats may be useful for vegetation management in meadows supporting harlequin lotus where woody plant encroachment is problematic.

Marsh zigadenus (*Toxicoscordion fontanum*)

Ranking and status	**Federal[3]/ State[4]/ CNPS[5]:** None/None/4.2 **MTW Lands:** Common. 10 extant occurrences on MTW Lands. Additional mapped occurrences beyond MTW Lands in areas not evaluated here for grazing feasibility.
Habitat requirements—General[5,6] and on MTW Lands[7]	**General:** Vernally wet areas. Meadows and seeps, usually in serpentine chaparral. 15–1000 meters elevation. **MTW Lands:** Widely distributed throughout MTW Lands, limited entirely to vernally wet areas, usually serpentinite, including seeps and small meadows within or immediately adjacent to serpentine grassland and/or chaparral. Most mapped occurrences in close proximity to roads and trails, although some are in fairly remote areas. Largest occurrences are in Potrero Meadow and north of Pine Mountain Road.

Vulnerabilities for protection and management—Foliage growth and flowering periods[6], regeneration/ re-sprouting after defoliation, seedbank	Perennial bulbiferous herb (geophyte). April–July blooming period. Limited entirely to vernally wet areas, usually serpentinite. Grows to nearly one meter in height and produces many large flowers. Ability to resprout after grazing or cutting if meristematic tissues are undamaged and sufficient soil moisture. Annual seed production and seedbank viability is currently unknown.
Forage considerations—Quality, palatability, quantity	Species of the genera *Toxicoscordion* are generally considered unpalatable to domestic livestock due to the presence of zygacine, a neurotoxic steroidal alkaloid. Plants may grow in dense patches, particularly where competing vegetation is limited (Panter et al. 1989).
Grazing effects—General and on MTW Lands	**General:** Grazing exclusion is recommended for all kinds and classes of livestock in areas supporting marsh zigadenus, particularly early in the growing season when more palatable forage is lacking. In wet meadows and seeps supporting marsh zigadenus with infestations of French broom or other invasive weeds, hand removal and offsite disposal of weeds is recommended.
Grazing management considerations and recommendations (exclusion, timing, intensity, repetition, trade-offs)	**Exclusion.** Marsh zigandenus is highly toxic to livestock at all phenological life stages. Exclusion may be accomplished using temporary and/or permanent wildlife-friendly fencing or by timing grazing to occur outside of the bolting or flowering period (March–July) for sparser populations. Livestock are most likely to consume marsh zigadenus when confined to areas with dense patches or where other more palatable forage is unavailable.

3.1.2 Special-Status Habitats/Natural Communities

Upland Serpentine Grassland	
Ranking and status	**Special-status[9] (State/Local):** California Department of Fish and Wildlife (CDFW) high priority habitat for certain plant alliances and associations. **MTW Lands**: Rare. Approximately 101 acres mapped within MTW Lands (Evens and Kentner 2006).
Habitat requirements—General[10] and on MTW Lands[7]	**General:** Low fertility grasslands on ultramafic soils, often on south facing aspects. Typically found on hillslopes and ridgetops.

[9] CDFW List of Vegetation Alliances and Associations (2010).

MTW Lands: Serpentine soils occur along a series of northwest to southeast trending ridgelines in the central portion of MTW Lands. Serpentine grasslands are found in a mosaic of habitat types and are often bordered by shrub-dominated serpentine chaparral. Most patches of serpentine grassland are less than one acre, with the largest patch mapped at 10.6 acres immediately north of Alpine Lake (Evens and Kentner 2006).

Vulnerabilities for protection and management[11]—Foliage growth period, regeneration/ re-sprouting after defoliation

Low productivity grassland with high native forb composition. Serpentine grasslands have high rates of endemic plants, many of which are considered rare or endangered. Productivity is generally low due to decreased nutrient availability and high rates of soil infiltration and drainage.

RDM[8] levels are typically recommended at 500 lbs/acre (Brownsey et al. 2016). In general, desirable native species will recover from low- to moderate-intensity grazing but may be adversely affected by high-intensity grazing as low levels of RDM and bare/open areas may promote the establishment of exotic annual grasses (i.e., barbed goatgrass) and other invasive species. Excessive grazing, particularly during the flowering period for endemic forbs, is likely to reduce seed production and germination and decrease native species richness and cover.

Forage considerations—Quality, palatability, quantity

High quality and palatability. Low overall productivity and forage compared to non-serpentine grasslands. Typically higher percentage of forbs, many of which are endemic native species.

Grazing effects—General and on MTW Lands

General: Grazing may be beneficial to serpentine grasslands under well-managed regimes. Studies have shown grazing may mediate the effects of climate change and anthropogenic nitrogen deposition (smog) by reducing the abundance of exotic annual grasses, thereby favoring native perennial grasses and endemic forbs (Weiss 1999). Short duration, moderate intensity late winter/early spring (February–April) cattle grazing has increased richness and abundance of desirable native perennial grasses and annual forbs in coastal grasslands (D'Antonio et al. 2001, Hayes and Holl 2003, Stahlheber and D'Antonio 2013).

Grazing management considerations and recommendations (exclusion, timing, intensity, repetition, trade-offs)

Timing/Intensity. Must carefully consider suitable RDM[8] levels and avoid grazing during flowering periods of special-status forbs. Short duration, moderate intensity cattle grazing would reduce cover and abundance of exotic annual grasses. Horses may cause increased erosion and substrate damage. Sheep are likely to overgraze desirable native forbs. Goat grazing in serpentine grasslands is understudied and may result in uneven grazing or overgrazing of desirable forbs and native subshrubs.

[10] Barbour et al. (2007).
[11] Sawyer et al. (2009).

Serpentine Chaparral

Ranking and status	**Special-status[9] (State/Local):** CDFW high priority habitat for certain plant alliances and associations. **MTW Lands:** Rare. Approximately 326 acres mapped within MTW Lands (Evens and Kentner 2006).
Habitat requirements—General[10] and on MTW Lands[7]	**General:** Occurring on ultramafic (serpentine) on south facing slopes, typically in a mosaic with serpentine grassland. Often occurring on moderate to steep slopes with rocky outcrops. **MTW Lands:** Serpentine chaparral is situated in a mosaic with serpentine grassland throughout much of the north-central portion of MTW Lands. Dominated by sclerophyllous, woody shrubs including manzanitas, ceanothus, and chamise (*Adenostoma fasciculatum*). The largest contiguous patches of serpentine chaparral are located northwest of Bon Tempe Lake and Alpine Lake.
Vulnerabilities for protection and management[11]—Foliage growth period, regeneration/ re-sprouting after defoliation	Serpentine chaparral is a shrub-dominated community occurring in low-fertility, ultramafic substrates with high rates of endemism. The herbaceous understory is sparse with widely scattered subshrubs, grasses, and forbs. This community supports several species considered rare and endangered including Marin western flax, marsh zigadenus, and Mt. Tamalpais manzanita. Serpentine chaparral is vulnerable to browsing as many of the shrubs lack burls and will only regenerate from seed. Moreover, seed productivity and germination rates in serpentine substrates are low, limiting recovery from defoliation and trampling.
Forage considerations—Quality, palatability, quantity	Limited herbaceous forage available for grazers. Generally restricted to woody browse, although dominated by native, often endemic species.
Grazing effects—General and on MTW Lands	**General:** Grazing adjacent serpentine and non-serpentine grasslands will inhibit woody shrub establishment and prevent expansion of serpentine chaparral. **MTW Lands:** Native shrubs, several of which are rare endemics, dominate serpentine chaparral within MTW Lands. Cattle grazing in adjacent grassland is not expected to impact serpentine chaparral other than to prevent encroachment of shrubs into grassland. The dense assortment of nearly impenetrable shrubs is generally unpalatable or not preferable to livestock. The presence of large rocks presents a tripping hazard, serving as a further deterrent.

Grazing management considerations and recommendations (exclusion, timing, intensity, repetition, trade-offs)	**Exclusion (Timing/Intensity).** Grazing is not recommended. In the absence of grazing adjacent serpentine grasslands, chaparral may be expanding due to succession on MTW Lands. Goats should not be used to manage French broom and other invasive weeds in serpentine chaparral unless the infestation is monospecific as they are non-selective browsers and will harm the desirable native vegetation, and may also promote the establishment of invasive weeds.

Wetlands, Meadows, and Seeps (Non-Serpentine)

Ranking and status	**Special-status[9](State/Local):** CDFW high priority habitat for certain plant alliances and associations. Wetlands are protected under various federal, state, and local laws and designated for resource protection under the Marin Countywide Plan (County of Marin 2007). **MTW Lands:** Very rare. Approximately 15 acres mapped within MTW Lands (Evens and Kentner 2006).
Habitat requirements—Genera[10] and on MTW Lands[7]	**General:** Occurring where surface or groundwater is perched or saturated within the upper 12 inches of the soil profile. Typically found in topographic depressions or channels where water accumulates for several weeks or more and supports a preponderance of hydrophytic vegetation. **MTW Lands:** Most wetland features are flat to gently sloped meadows or seeps situated on hillslopes where groundwater intercepts the surface. Meadows and seeps are rare but widespread throughout MTW Lands. Sky Oaks meadow north of Bon Tempe Lake is the largest wetland complex in MTW Lands and supports a large population of harlequin lotus.
Vulnerabilities for protection and management[11]—Foliage growth period, regeneration/ re-sprouting after defoliation	Wet meadows and seeps in well-developed soils typically support an array of hydrophytic perennial grasses and forbs, with a high percentage of non-native grasses in areas with seasonal hydrology. Grazing in wet meadows may reduce competition from these non-native annual grasses and increase species richness although trampling and excessive grazing may degrade water quality. Trampling may also adversely affect perennial species.
Forage considerations—Quality, palatability, quantity	High forage quality and palatability. Low available quantity. High percentage of native and endemic species, many of which are considered rare.
Grazing effects—General and on MTW Lands	**General:** Grazing can either benefit or impact wetlands depending on the type of wetland (i.e., seasonal, vernal pool, emergent), plant species composition, and timing/intensity of grazing activities. Seasonal wetlands generally respond favorably to spring grazing regimes by reducing cover of

	hydrophytic exotic grasses and forbs (e.g., common velvet grass, Harding grass, bird's foot trefoil [*Lotus corniculatus*], bristly oxtongue [*Picris echioides*]) and promoting increased native species richness and cover (Marty 2005). However, areas with prolonged inundation are generally dominated by perennial species that are susceptible to tramping and excessive grazing pressure.
Grazing management considerations and recommendations (exclusion, timing, intensity, repetition, trade-offs)	**Exclusion (Timing/Intensity)**. Grazing should only occur in seasonal wetlands with high percentage cover of exotic annual grasses and forbs. Cattle grazing in seasonal wetlands has decreased abundance of exotic annual species and increased richness and abundance of native wetland forbs (Marty 2005). Moderate intensity grazing could occur in mid–late spring when seasonal wetlands are mostly dry and when annual grasses are in flower are likely to be targeted by grazing animals.

Wet Meadows and Seeps (Serpentine)

Ranking and status	**Special-status[9](State/Local):** CDFW high priority habitat type. Wetlands are protected under various federal state and local laws, and are designated for resource protection under the Marin Countywide Plan (County of Marin 2007). **MTW Lands:** Very rare. Limited to just seven serpentine wet meadows and seeps totaling 1.5 acres within MTW Lands (Evens et al. 2006).
Habitat requirements—General[10] and on MTW Lands[7]	**General:** Shallow depressions, swales, and channels where surface water is at or near the ground surface for several weeks or more. Seeps typically occur where subsurface groundwater daylights on or near the toe of hillslopes. Serpentine seeps occur in areas with ultramafic soils often within serpentine grassland or chaparral. **MTW Lands:** Most serpentine meadows and seeps within MTW Lands as small (< 0.6 acres) and occur in a mosaic of serpentine grassland, chaparral, and Sargent cypress (*Hesperocyparis sargentii*) woodland.
Vulnerabilities for protection and management[11]—Foliage growth period, regeneration/ re-sprouting after defoliation	Wetlands in serpentine soils support a unique array of plant species, several of which are rare endemics including Mt. Tamalpais thistle and marsh zigadenus. In general, species are intolerant of trampling and excessive grazing pressure.
Forage considerations, Grazing effects, and Grazing management considerations	Same management considerations and recommendations for grazing as noted above for non-serpentine wet meadows and seeps. Unlikely to be grazed due to very rare occurrence.

Oak Woodlands

Ranking and status	**Special-status[9](State/Local):** CDFW high priority for certain dominant plant species alliances and associations, and also covered under the 2004 California Oak Woodlands Protection Act. **MTW Lands:** Common. Approximately 2,496 acres of oak woodlands within MTW Lands (Evens and Kentner 2006).
Habitat requirements—General[10] and on MTW Lands[7]	**General:** Widespread throughout California, composed of many dominant species of oak. In Marin County, coast live oak is the dominant species in oak woodlands and commonly associated with California bay laurel (*Umbellularia californica*), madrone (*Arbutus menzeisii*), tanoak, buckeye (*Aesculus californica*), and Douglas-fir. Often occurring on north and west facing aspects. **MTW Lands:** Widespread throughout MTW Lands. The majority of oak woodlands are associated with other dominant trees including California bay laurel, madrone, and tanoak. The canopy is partly open to mostly closed and typically occurs on moderate to steep slopes in well developed, non-serpentine soils. Many contiguous patches are relatively large (>10 acres), with the largest mapped at 122 acres (Evens and Kentner 2006).
Vulnerabilities for protection and management[11]—Foliage growth period, regeneration/ re-sprouting after defoliation	Oak woodlands have varying amounts of herbaceous understory species richness and cover depending on canopy cover, slope, aspect, and hydrology. Oak regeneration is a primary concern related to grazing in oak woodlands. Seedlings are sensitive to trampling and excessive grazing, particularly outside of the spring growing season when other more desirable forage is lacking.
Forage considerations—Quality, palatability, quantity	High forage quality and palatability. Variable understory productivity depending on substrate, slope, canopy cover (light availability), and precipitation. Quantity restricted by abundance and composition of available understory herbaceous species.
Grazing effects—General and on MTW Lands	**General:** Grazing is feasible in areas where desirable grassy forage is sufficient. However, in more closed-canopy systems (40–60% cover), understory productivity decreases and unpalatable non-native thistles (Italian thistle [*Carduus pycnocephalus*], milk thistle [*Silybum marianum*]) are common (J. Davilla, co-author, personal observation). Selective avoidance of thistles may degrade the understory and trampling may increase erosion and prevent the establishment of oak seedlings.

Grazing management considerations and recommendations (exclusion, timing, intensity, repetition, trade-offs)	**Timing.** Grazing is recommended in oak woodlands with suitable herbaceous understory productivity and composition to support livestock without significant potential for erosion, invasive weed infestation, or oak seedling mortality. RDM[8] standards to achieve the desired conditions should be carefully followed based on soil type and slope (Bartolome et al. 2006).

Willow Riparian

Ranking and status	**Special-status[9](State/Local):** CDFW high priority habitat, and designated for resource protection under the Marin Countywide Plan (County of Marin 2007). **MTW Lands:** Very rare. Approximately 2.1 acres of willow riparian habitat within MTW Lands (Evens et al. 2006).
Habitat requirements—General[10] and on MTW Lands[7]	**General:** Embankments of ephemeral to perennial drainages and creeks in full sun to partial shade. **MTW Lands:** Within MTW Lands, willow riparian habitat is widely dispersed and patches are small (< 0.5 acres) (Evens and Kentner 2006). Willow riparian generally occurs on ephemeral or intermittent drainages with flat to gentle slopes in full sun.
Vulnerabilities for protection and management[11]—Foliage growth period, regeneration/ re-sprouting after defoliation	Willow riparian habitat is susceptible to grazing impacts from trampling. Cattle and sheep will not consume willows but may congregate in riparian habitat for watering and shade. Willow riparian scrub is generally impenetrable with few herbaceous understory species.
Forage considerations—Quality, palatability, quantity	Limited herbaceous forage available for grazers. Generally restricted to woody browse. Willows are usually the sole dominant species, particularly in areas classified as willow scrub.
Grazing effects—General and on MTW Lands	**General:** Grazing livestock can affect riparian habitats through trampling, herbivory, nutrient loading, and direct and indirect impacts to water quality. During the winter and spring, animals in adjacent grasslands will generally graze preferred green herbaceous forage in uplands. In the summer and fall, as plants dry out, grazing animals may be attracted to the persistent green vegetation in riparian areas and may use woody cover for shading. This leads to increased erosion and degradation of the vegetation due to herbivory and trampling.

Grazing management considerations and recommendations (exclusion, timing, intensity, repetition, trade-offs)	**Exclusion.** Grazing and browsing should be excluded from willow riparian areas to the extent feasible using temporary fencing or by orienting grazing pastures in a manner that does not include this habitat type. The drawbacks to grazing exclusion include increased fire hazards and potential infestations of non-native invasive plants.

Coastal Prairie/Native Perennial Grassland

Ranking and status	**Special-status[9](State/Local):** CDFW includes most native grass alliances and associations as high priority habitat. **MTW Lands:** Rare. Approximately 61.5 acres of native perennial grassland within MTW Lands (Evens and Kentner 2006).
Habitat requirements—General[10] and on MTW Lands[7]	**General:** Coastal prairie and native grasslands in well-developed soils occur in close proximity to the coast where there is direct influence from fog and annual precipitation averaging 30 inches or more. These grasslands are typically dominated by native bunchgrasses including purple needlegrass (*Nassella pulchra*), red fescue (*Festuca rubra*), California oatgrass (*Danthonia californica*), meadow barley (*Hordeum brachyantherum*), and pine bluegrass (*Poa secunda*). **MTW Lands:** The majority of grasslands in well-developed soils are dominated by non-native annual grasses. Coastal prairie and native perennial grassland are minor components of MTW Lands with most contiguous patches less than one acre. The largest patch is approximately 19 acres on a west facing aspect immediately east of Kent Lake (Evens and Kentner 2006).
Vulnerabilities for protection and management[11]—Foliage growth period, regeneration/ re-sprouting after defoliation	Coastal prairie and native perennial grasslands in well-developed soil generally respond favorably to moderate intensity spring grazing. Cattle grazing has been shown to reduce exotic annual grasses while increasing native species richness and abundance (D'Antonio et al. 2001, Hayes and Holl 2003, Stahlheber and D'Antonio 2013). Common perennial grasses including purple needle grass, California oatgrass, and red fescue have later flowering periods and are largely undamaged by spring grazing. Increased light and water availability due to reduced cover of annual grasses also favors germination of native forbs.
Forage considerations—Quality, palatability, quantity	High-quality and quantity of herbaceous forage. With the exception of certain weeds (e.g., thistles, aromatics), the majority of vegetation is palatable to all kinds and classes of livestock.

Grazing effects—General and on MTW Lands

General: Cattle grazing at moderate intensity in late winter and early spring may increase native species richness and cover while reducing non-native annual grasses. The benefits of grazing native perennial grasslands are maximized when non-native annuals are flowering, prior to seed set (D'Antonio 2001, Stahlheber and D'Antonio 2013, Skaer et al. 2014). Reduced competition from annual grasses allows for native perennial grasses to compete for available light and soil moisture, and openings promote the establishment of native annual forbs. Moderate intensity winter and spring grazing generally does not negatively impact established perennial bunchgrasses (Hatch et al. 1999, Hayes and Holl 2003, Bartolome et al. 2004).

Grazing management considerations and recommendations (exclusion, timing, intensity, repetition, trade-offs)

Timing/Intensity. Continuous moderate intensity late winter to spring grazing is beneficial for reducing non-native annual grass density while increasing native species richness and cover (Hatch 2004, D'Antonio et al. 2001, Hayes and Holl 2003, Bartolome et al. 2004, Stahlheber and D'Antonio 2013, Skaer et al. 2014). RDM[8] standards to achieve the desired conditions should be carefully followed based on soil type and slope (Bartolome et al. 1980, 2006).

3.1.3 Weed Management

Barbed goatgrass (*Aegilops triuncialis*)	
Pest rating (Cal-IPC[12] CDFA[13])	**Cal-IPC:** High; A, A, B **CDFA:** List B
Habitat requirements—General[12] and on MTW Lands[7]	**General:** Grasslands and disturbed areas, often serpentinite. **MTW Lands:** Not widespread but limited to serpentine and adjacent grasslands. Existing populations are relatively large (>3 acres). Potential for existing populations to expand in the absence of management or due to improper grassland management.
Vulnerabilities for control and management[12]—Foliage growth and flowering periods, regeneration/ re-sprouting after defoliation, seedbank	Annual grass. Early winter germination with mid-spring bolting (boot) period and May–June flowering. Produces two types of seeds, with jointed seeds remaining viable for two years. Only susceptible to grazing during two- to three-week bolting phase (Brownsey et al. 2016). Requires high-intensity, targeted grazing as low to moderate stocking rates or grazing during the unpalatable flowering period is likely to exacerbate infestation due to selective avoidance by livestock. Increased soil nitrification due to grazing may further promote establishment of barbed goatgrass.

[12] Cal-IPC: California Invasive Plant Council Inventory (2006).

High	Severe ecological impacts on physical processes, plant and animal communities and vegetation structure
Moderate	Substantial and apparent, but generally not severe, ecological impacts on physical processes, plant and animal communities, and vegetation structure
Limited	Ecological impacts are minor on a statewide level or there was not enough information to justify a higher score
Alert	Species with the potential to rapidly invade unexploited ecosystems

Cal-IPC assessment of ecological impact levels- Impact, Invasiveness, Distribution:

A	Severe, possibly irreversible, alteration or disruption of an ecosystem process
B	Moderate alteration of an ecosystem process
C	Minor alteration of an ecosystem process
D	Negligible perceived impact on an ecosystem process
U	Unknown

[13] CDFA: California Department of Food and Agriculture (2017)-

A	Action required
B	Action required at discretion of Agriculture Commissioner
C	Action only when found in a nursery at discretion of Agriculture Commissioner

Forage considerations—Quality, palatability, quantity	Poor to low forage quality. Only palatable to cattle during the early growth, vegetative period prior to flowering. Often forms nearly monospecific stands if unmanaged (DiTomaso et al. 2013). Goats will likely consume goatgrass when in flower when other more palatable vegetation is lacking.
Grazing effects—General and on MTW Lands	**General:** Very difficult to control without herbicide application. May be controlled using properly timed, repeated prescribed fire, or by short-duration, high-intensity cattle grazing. Grazing exclusion is necessary during flowering periods when plants are unpalatable to livestock to avoid seed spread. Selective avoidance by grazing livestock will lead to rapid expansion and may result in dense, monospecific stands within several growing seasons.
Grazing management considerations and recommendations (exclusion, timing, intensity, repetition, trade-offs)	**Timing/Intensity**. If possible, areas with heavy infestations of barbed goatgrass should be temporarily fenced and grazed by cattle at a rate of two cows per acre continuously for two to three weeks (Brownsey et al. 2006). Because goatgrass produces seeds that are viable for two years, grazing must occur annually to achieve effective control. Grazing in only one season is likely to exacerbate an infestation. RDM[8] levels should not exceed 500 lbs/acre following grazing treatment. Goatgrass often occurs in serpentine soils that support rare and endangered plant species. Management objectives for these species may conflict with the required short duration, high-intensity grazing regime required for barbed goatgrass control.

Yellow starthistle (*Centaurea solstitialis*)

Pest rating (Cal-IPC[12] CDFA[13])	**Cal-IPC:** High; A, B, A **CDFA:** List C
Habitat requirements—General[12] and on MTW Lands[7]	**General:** Open annual grassland and disturbed areas (e.g., roadcuts, fallow agriculture land). **MTW Lands:** Widespread throughout MTW Lands and typically found in disturbed grassland with well-developed soils, as well as ruderal areas in close proximity to roads and other development. Largest infestations within and immediately east of Ridgecrest-Rock Spring-Potrero, which is a potential grazing area in open grassland.

Vulnerabilities for control and management[12]—Foliage growth and flowering periods, regeneration/ re-sprouting after defoliation, seedbank

Annual herb (occasionally biennial). May–October flowering period. Winter germination most prevalent in nutrient rich, deep, well drained soils. Not usually in areas with serpentine soils. Deep taproots (≥1m) form early below a leafy basal rosette. Stiff, branched stems emerge in early–mid spring.

Ray flowers produce two types of seeds, one with pappus and one without, both requiring insect pollination. Barbed pappus bristles easily attach to clothing, fur, and hair and are spread by humans and animals. Wind distribution is limited to several feet from parent plant. Will resprout or produce stems and flowers after grazing if soil moisture is available. Grazing will limit flowering if continued just prior to, or beyond bolting and flowering. Only goats will continue to consume yellow starthistle after flower buds have produced spines (DiTomaso et al. 2006).

Forage considerations—Quality, palatability, quantity

Low to moderate forage quality. Toxic to sheep and horses. Cattle will only consume yellow starthistle during the vegetative period prior to production of thorny flower heads. Goats will readily consume yellow starthistle during all phenological stages (DiTomaso 2001, DiTomaso et al. 2006).

Grazing effects—General and on MTW Lands

General: Early season short-duration, high-intensity cattle grazing just prior to flowering has been shown to limit the number of flowering individuals and decrease overall seed production (DiTomaso 2001, DiTomaso et al. 2006). Cattle will not consume yellow starthistle in flower due to the presence of stiff spines surrounding the flowering heads. Cattle should be excluded from grazing once plants are in flower as selective avoidance will increase the density of yellow starthistle and may spread seed to unoccupied areas.

Prolonged high-intensity grazing is likely to impact desirable native vegetation. Short duration, high-intensity goat grazing can be very effective in controlling flowering yellow starthistle, as goats will consume spines (DiTomaso et al. 2006). Moreover, yellow starthistle flowers after most desirable grassland species have set seed. Repeated goat grazing treatments are often required to control yellow starthistle infestations to target resprouting and later blooming individuals.

Grazing management considerations and recommendations (exclusion, timing, intensity, repetition, trade-offs)

Timing/Intensity/Frequency. Short-duration, high-intensity goat grazing may be used where feasible to control infestations of yellow starthistle. Goats should be allowed to forage once yellow starthistle have bolted and begin to produce flowers prior to seed set. Goats should be removed once the majority of yellow starthistle flowers have been consumed and before RDM[8] levels are too low. Goats can be returned to the pasture to control later flowering individuals as necessary. Cattle grazing is not recommended as high-intensity grazing is likely to impact native vegetation and trampling may increase seed germination and spread. Moreover, yellow starthistle will readily occupy bare areas created by heavy cattle grazing.

Poison hemlock (*Conium maculatum*)

PEST RATING (CAL-IPC[12] CDFA[13])	**Cal-IPC:** Moderate; B, B, B **CDFA:** None
HABITAT REQUIREMENTS—GENERAL[12] AND ON MTW LANDS[7]	**General:** Ruderal. Disturbed areas in mesic grasslands or wet meadows. **MTW Lands:** Not well mapped. Generally widespread along roadsides, and disturbed areas in wet meadows and non-serpentine grasslands.
VULNERABILITIES FOR CONTROL AND MANAGEMENT[12]—FOLIAGE GROWTH AND FLOWERING PERIODS, REGENERATION/ RE-SPROUTING AFTER DEFOLIATION, SEEDBANK	Biennial (occasionally perennial) herb. April–September flowering period. Occupies mesic, often disturbed areas including ruderal areas, roadsides, and annual grassland. Prolific seed production with one plant capable of producing up to 39,000 seeds, about which 80% are viable. Seeds do not have dormancy restrictions and may germinate in the first year of production. Cattle or other livestock will not graze poison hemlock unless no other is forage available. This species is highly toxic and consumption will cause severe injury or death. Pitcher (1989), DiTomaso (1999), and Pokorny and Sheley (2012) concluded that excessive grazing in areas with poison hemlock may result in the increased rate of establishment and spread into unoccupied areas due to selective avoidance and trampling. However, L. Bush (co-author) has observed for many years and in many locations in Marin County, that poison hemlock does not generally occur in areas that are regularly grazed.
FORAGE CONSIDERATIONS—QUALITY, PALATABILITY, QUANTITY	Toxic/poisonous to all kinds and classes of livestock. There is anecdotal evidence that it is tolerable to goats (Davison et al. 2007).
GRAZING EFFECTS—GENERAL AND ON MTW LANDS	**General:** Toxic to grazing livestock due to alkaloid compounds. Grazing should be avoided in areas with dense poison hemlock infestations. Some anecdotal reports that goats may safely consume poison hemlock but this is largely discouraged in current scientific literature (Pitcher 1989, Davison 2007). High-intensity grazing in close proximity to hemlock populations may exacerbate the spread of this species and increase the size of infestations due to selective avoidance, decreased competition, trampling, and soil nitrification.

Grazing management considerations and recommendations (exclusion, timing, intensity, repetition, trade-offs)	**Exclusion.** Published scientific literature supports the idea of grazing exclusion in areas supporting dense occurrences of poison hemlock because poison hemlock is not only toxic to all kinds and classes of livestock, but selective avoidance may increase the size of existing infestations (Pokorny and Sheley 2012, DiTomaso et al. 2013). However, L. Bush (co-author) has observed for many years and in many locations in Marin County, that poison hemlock does not generally occur in areas that are regularly grazed.

Eggleaf spurge (*Euphorbia oblongata*)

Pest rating (Cal-IPC[12] CDFA[13])	**Cal-IPC:** Limited; C, C, B **CDFA:** None
Habitat requirements—General[12] and on MTW Lands[7]	**General:** Ruderal/disturbed areas including waste places, roadsides, and pastures although may establish and persist in relatively undisturbed areas if introduced. **MTW Lands:** Disturbed areas in many different habitat types but typically in close proximity to roads and trails with full sun or partial shade.
Vulnerabilities for control and management[12]—Foliage growth and flowering periods, regeneration/ re-sprouting after defoliation, seedbank	Perennial herb. May–August flowering period. May form dense, monospecific stands. Evidence that allelopathic, dense roots prevent germination and persistence of native species. Can reproduce by seed or by plant division where crown buds develop at the base of stems and can produce new shoots or roots. Seed typically falls directly beneath or near parent plant with little other forms of dispersal. Dormancy and long-term viability of the seedbank is currently unstudied. Eggleaf spurge will readily resprout following cutting, burning, or grazing.
Forage considerations—Quality, palatability, quantity	The milky sap of eggleaf spurge is a mildly toxic irritant and generally avoided by cattle and horses. Goats and sheep have been shown to prefer the related species leafy spurge (*Euphorbia esula*), and have been used to control it elsewhere (Johnston and Peake 1960, DiTomaso et al. 2013).
Grazing effects—General and on MTW Lands	**General:** Because eggleaf spurge often forms dense, monospecific patches, targeted high-intensity goat or sheep grazing during the flowering period may control and reduce populations of this species. However, in areas where spurge is not dominant, goats and sheep may consume other more desirable vegetation including native shrubs and forbs.

Grazing management considerations and recommendations (exclusion, timing, intensity, repetition, trade-offs)	**Timing/Intensity/Frequency**. Current recommendations are to stock goats at a rate of approximately 12–16 animals/acre and sheep at approximately three to six animals/acre during the flowering period (DiTomaso et al. 2013). Grazing will not eradicate perennial spurge but will significantly reduce the seedbank, limiting spread and allowing for the establishment of other desirable native species. Grazing animals should be returned to the infested area periodically as plants are flowering to prevent seed production and dispersal.

Tall fescue (*Festuca arundinacea*)

Pest rating (Cal-IPC[12] CDFA[13])	**Cal-IPC:** Moderate; C, B, A **CDFA:** None
Habitat requirements—General[12] and on MTW Lands[7]	**General:** Grasslands, wet meadows, savannah, ruderal/disturbed areas. **MTW Lands:** Widespread throughout well-developed grasslands, meadows, and ruderal areas within MTW Lands. Most occurrences are patchy and relatively small although several support dense monospecific stands of tall fescue. An occurrence of tall fescue is currently expanding within Potrero Meadow which supports important rare plants like Mt. Tamalpais thistle, harlequin lotus, and marsh zigadenus.
Vulnerabilities for control and management[12]—Foliage growth and flowering periods, regeneration/ re-sprouting after defoliation, seedbank	Perennial grass. May–June flowering period. Tufted, cool season, sod grass often planted for pasture, turf, hay, and/or erosion control. Easily escapes into natural areas although newer cultivar varieties may not be as invasive. Deep, fibrous root system extends to 0.6 meters and tufts enlarge around the perimeter by rhizomes and tillers. Can reproduce from seed or vegetatively from rhizome fragments remaining after cutting or grazing. New plants do not produce viable seeds in the first year. Once present, seeds germinate in the first year after production and may be viable under certain conditions for up to 19 years. Tall fescue is often infected by an endophytic fungus which is toxic to livestock, although it is not usually fatal (Walsh 1995, Henson 2001).
Forage considerations—Quality, palatability, quantity	High-quality forage palatable to all kinds and classes of livestock. Most preferred by cows and horses. However, stands infected with endophytic fungus render tall fescue poisonous to livestock (Henson 2001, Batcher 2004, DiTomaso and Healy 2007).

Grazing effects—General and on MTW Lands	**General:** Studies have shown nearly 75% of tall fescue stands are infected with an endophytic fungus that may cause sickness to grazing livestock (Henson 2001). In general, grazing animals will avoid tall fescue when other, more desirable forage is available. This is likely to exacerbate the infestation, and over time could result in monospecific patches of tall fescue that are nearly impossible to control. Dense patches may be targeted by high-intensity grazing during the summer flowering period which may inhibit the spread of an existing infestation. However, in the absence of a native seedbank in the vicinity, this is unlikely to improve species richness and cover of more desirable vegetation.
Grazing management considerations and recommendations (exclusion, timing, intensity, repetition, trade-offs)	**Exclusion (Timing/Intensity).** For areas with dense, contiguous patches of tall fescue (>2 acres), targeted high-intensity grazing during the flowering period may prevent development and germination of seed thereby reducing the rate of spread. However, full eradication will require planning and implementation of control measures in addition to grazing.

French broom (*Genista monspessulana*)

Pest rating (Cal-IPC[12] CDFA[13])	**Cal-IPC:** High; A, A, B **CDFA:** C
Habitat requirements—General[12] and on MTW Lands[7]	**General:** Woodlands, grassland, scrub, chaparral; disturbed areas, often along road cuts, trails, and riverbanks. **MTW Lands:** Most widespread and problematic weed species on MTW Lands. Over 1,400 acres infested, several occurrences are larger than 20 contiguous acres. French broom is most prevalent in the eastern portion of MTW Lands north and east of Bon Tempe Lake, Phoenix Lake, and Lake Lagunitas and along the MTW Lands' urban interface.
Vulnerabilities for control and management[12]—Foliage growth and flowering periods, regeneration/ re-sprouting after defoliation, seedbank	Perennial shrub. March–May flowering period. Individuals can live up to 20 years and reach a maximum height of 10 feet. Forms dense, nearly impenetrable monospecific stands. Disturbance dependent and can occupy a wide range of soil types and plant communities. French broom typically occupies the ecotone of two adjacent dissimilar plant communities (i.e., woodland and grassland) and in disturbed areas along roads and trails. It is deeply rooted and readily resprouts from cut or browsed stems. It produces prolific amounts of seed that are dispersed explosively from ruptured seed pods. A medium sized plant can produce up to 8,000 seeds that may remain viable in the seedbank for 50 years or more. Seedling densities often exceed 100 per square foot and plants may flower and produce seeds within two years when they reach a height of approximately two feet. Soil disturbance and fire

	stimulates germination, and seeds may pass through the digestive track of sheep undamaged (Hoshovsky 1986).
Forage considerations—Quality, palatability, quantity	Goats will readily consume French broom, particularly when immature. Sheep will consume flowers and seedpods but seeds pass through digestive tract undamaged. Cattle will not graze woody broom but may consume new seedlings. French broom is mildly toxic to cattle, sheep and horses but does not seem to affect goats (Hoshovsky 1986, Bossard et al. 2000, DiTomaso and Healy 2007, DiTomaso et al. 2013).
Grazing effects—General and on MTW Lands	**General:** Cattle, sheep and horses will not graze or browse mature French broom; however, trampling may inhibit the establishment and long-term success of seedlings in areas adjacent to an infestation. Goats will browse French broom and are most effective for control prior to plants reaching maturity (Hoshovsky 1986, Bossard et al. 2000, DiTomaso et al. 2013), as effective management requires them to consume flowering individuals prior to the development of viable seeds. Goat browsing on younger broom is likely an effective method for preventing spread and decreasing overall infestation density. However, goats are not effective in clearing dense, mature stands of broom. Goat browsing is unlikely to cause mortality to mature French broom as it will resprout from cut stems, even when browsed almost to ground height.
Grazing management considerations and recommendations (exclusion, timing, intensity, repetition, trade-offs)	**Timing/Intensity.** Where feasible, targeted high-intensity goat browsing throughout the spring flowering period prior to seed production may be effective. Goats are non-selective and will browse native vegetation, including rare species such as Mt. Tamalpais manzanita. Therefore, using goats for broom control should be limited to monospecific stands where goats can easily be corralled and managed using temporary fencing or other shepherding techniques. These techniques may be infeasible for many areas supporting French broom.

Common velvet grass (*Holcus lanatus*)

Pest rating (Cal-IPC[12] CDFA[13])	**Cal-IPC:** Moderate; B, B, A **CDFA:** None
Habitat requirements—General[12] and on MTW Lands[7]	**General:** Mesic grasslands; escaped cultivar, wetland-riparian. **MTW Lands:** Currently not widespread but early infestations observed in valuable wet meadow habitat. Largest mapped occurrence in Lagunitas Meadow which is also supports extant harlequin lotus and marsh zigadenus.

Vulnerabilities for control and management[12]—Foliage growth and flowering periods, regeneration/ re-sprouting after defoliation, seedbank	Perennial grass. June–August flowering period. Introduced cultivar planted as forage crop and occasionally as turf grass. Although not rhizomatous, common velvet grass can reproduce from decumbent tillers. It is a prolific seed producer and seeds may remain viable in the seedbank for several years. However, the majority of seeds germinate in the first year with an 87% germination rate for seeds on the soil surface but just 5% germination of seeds two centimeters deep or more (Pitcher and Russo 1988, Gucker 2008). Common velvet grass will readily resprout after grazing defoliation as low as two centimeters above the ground if meristems are undamaged and soil moisture is available (Pitcher and Russo 1988).
Forage considerations—Quality, palatability, quantity	Theoretically high-quality forage palatable to all kinds and classes of livestock; however, L. Ford and L. Bush (co-authors) have made conflicting observations about its palatability.
Grazing effects—General and on MTW Lands	**General:** Common velvet grass will readily spread into surrounding areas without ongoing management and control. It may be controlled by higher intensity grazing for longer durations (Gucker 2008, DiTomaso et al. 2013) but eradication of the species is unlikely using grazing due the perennial nature of plant and the ability to regenerate from decumbent tillers (Pitcher and Russo 1988). Common velvet grass is a "low fertility species" and increased nitrogen from cattle may reduce abundance (Pitcher and Russo 1988, DiTomaso et al. 2013).
Grazing management considerations and recommendations (exclusion, timing, intensity, repetition, trade-offs)	**Timing/Intensity.** High-intensity cattle or sheep grazing during the flowering period may prevent further spread and establishment of common velvet grass (Gucker 2008). However, high-intensity grazing is non-specific and so grazing in mesic coastal prairie grasslands with a significant native bunchgrass component could be detrimental as these species typically flower at the same time as common velvet grass. Grazing for common velvet grass control should only be implemented where large infestations are nearly monospecific and grazing can be targeted directly to that patch.

Harding grass (*Phalaris aquatica*)

Pest rating (Cal-IPC[12] CDFA[13])	**Cal-IPC:** Moderate; B, B, B **CDFA:** None
Habitat requirements—General[12] and on MTW Lands[7]	**General:** Annual grassland and coastal prairie, mesic areas. **MTW Lands:** Although not well-mapped within the MTW Lands, existing populations are extensive with the largest occurrences in the Sky Oaks Region adjacent to Bullfrog Road and in open grassland in Bathtub Gap.

Vulnerabilities for control and management[12]—Foliage growth and flowering periods, regeneration/ re-sprouting after defoliation, seedbank	Perennial grass. February–March flowering period. Forms large clumps with rhizomes around the base. Prolific seed production but seedlings compete poorly with well-established vegetation. Seeds require a dormancy period of up to 127 days before germination. Primarily expands from rhizomes and tillering. Harding grass will resprout after grazing if meristematic tissue and rhizomes are undamaged. Vegetative parts remain green well past the flowering period making it desirable forage for later season grazing. May be toxic to livestock in large quantities and produces alkaloids that are particularly poisonous to sheep (Bourke et al. 1990, DiTomaso and Healy 2003.).
Forage considerations—Quality, palatability, quantity	High-quality forage palatable to all kinds and classes of livestock except sheep. Most preferred by cows and horses.
Grazing effects—General and on MTW Lands	**General:** Introduced as forage for livestock, this species is palatable and nutritious and high-intensity grazing later into the growing season may reduce its vigor and fecundity. However, grazing alone, especially at low intensity is not expected to control this species due to abundant tillering, and may exacerbate infestations due to seeds distributed by the livestock (Peterson 1988).
Grazing management considerations and recommendations (exclusion, timing, intensity, repetition, trade-offs)	**Timing.** Early season cattle grazing during the flowering period is the most effective method for Harding grass control as defoliation during this period reduces tillering (Peterson 1988). It is very unlikely Harding grass will be eradicated by grazing alone.

4. Suitable Potential Grazing Areas/Potential Grazing Scenarios

4.1 Area Selection

The study team identified 16 potential grazing areas through discussions with A. Williams and her GIS site analysis. Ms. Williams then prepared maps of the grazing areas (Appendix 2). Suitable grazing areas are those that provide adequate livestock forage to sustain animal health; are physically accessible to graziers, for delivering livestock with their vehicles and for their staging and grazing equipment; are reasonably close to water sources that could be adapted for livestock watering; and do not include very steep canyons and cliffs or dense forest. These areas either include target plants that may benefit from grazing (rare plants) or that may be negatively affected by grazing (weeds) or that are priority fuelbreak areas.

Should MMWD determine that grazing is an appropriate vegetation management tool for their MTW Lands, final grazing area selection should be based on additional site review, including evaluation by contract graziers to determine if unknown site constraints exist and if proposed areas can be grazed/browsed without damaging non-target vegetation or causing other undesired effects.

4.1.1 Potential Grazing Areas and Management Objectives

1. Sky Oaks. This 282-acre potential grazing area includes significant infestations of French broom with low-density and pioneer occurrences west of Bon Tempe Road, and denser more substantial populations to the east ranging from 11 to 90% cover. This area includes numerous other smaller weedy infestations of broom species, common velvet grass, Harding grass, yellow starthistle, tall fescue, barbed goat grass, and eggleaf spurge. One extant occurrence of harlequin lotus is situated in the Sky Oaks meadow immediately north of Old Bull Frog Road. Fewer than 100 plants were observed in 2012 although the population is spread over approximately 10 acres with most individuals immediately adjacent to trails.

Primary objectives are to control and reduce infestations of French broom with particular emphasis on sparse/pioneer occurrences. Grazing management in Sky Oaks meadow should place emphasis on timing and intensity of grazing to control existing weeds and exotic annual grasses without significant impacts to harlequin lotus and other native plants. Appropriate grazing management should benefit harlequin lotus and native species richness/cover by reducing competition from invasive weeds and exotic annual grasses.

2. Porteous-Ross Reservoir-Worn Spring Middle. This 115-acre potential grazing area includes significant infestations of broom with many areas occupied by more than 50% cover, particularly in the south near Phoenix Lake. One small patch of leafy spurge occurs in open grassland near terminus of Worn Spring Road. No priority rare plant populations occur in this grazing area. Grassland and oak woodlands suitable for grazing livestock dominate this area.

Primary objectives are to control and reduce infestations of French broom and eggleaf spurge while managing grasslands and oak woodland understory to reduce the abundance of weeds and exotic annual grasses and increase native species richness and cover. This would likely be achieved by targeted goat browsing in areas with significant broom infestations and moderate intensity, continuous late winter-spring cattle grazing in grasslands and oak woodlands. If hand removal is infeasible, targeted late spring to summer goat browsing using a temporary enclosure should be used to control eggleaf spurge. Goats should be restricted from native chaparral to the maximum extent feasible.

3. Pilot Knob. This 59-acre potential grazing area is densely forested with native perennial grassland in the southern portion along Pilot Knob Road and Lakeview Road. No rare plants or invasive weeds are currently mapped in this area.

Management objectives include preventing future incursions of invasive plants and exotic annual grasses and enhancing the native species composition in existing grasslands. French broom is limited to two small patches along the northern border of the grazing area. These infestations are best managed using manual removal techniques. Moderate intensity spring grazing prior to seed production by native perennial grasses may enhance existing native grasslands. However, grazing should be carefully monitored in this area to ensure native perennial bunchgrasses are not adversely affected.

4. Ridgecrest-Rock Spring-Potrero. This 191-acre potential grazing area is mostly forested with chaparral in the center of the area and non-native annual grassland along the western border. Harding grass and tall fescue are present with several small populations of yellow starthistle occurring just beyond the area boundary. Mt. Tamalpais thistle, harlequin lotus, and marsh zigadenus co-occur in several wet meadows and in serpentine seeps in the northeast portion of the area. Small patches of serpentine grassland are isolated and grazing in these areas is likely infeasible.

Grazing management in contiguous non-native annual grassland and oak woodland in should occur from late winter to spring to reduce the abundance of exotic annual grasses while promoting increased native species richness and cover. Grazing should also be considered in contiguous grassland west of this area to improve habitat and prevent establishment and/or spread of invasive species, including yellow starthistle. If possible, hand removal of tall fescue should occur prior to introduction of grazing livestock to prevent expansion of the existing infestation due to selective avoidance. Broom is not problematic in this area.

5. Pumpkin-Pine-Fish-Lag Meadows. This 179-acre potential grazing area has moderate to dense infestations of broom, particularly along the northeast and southern boundaries. Common velvet grass and Harding grass also prevalent in mesic grassland and oak savannah immediately bordering Sky Oaks Road. This meadow complex also supports extant, patchy occurrences of harlequin lotus and marsh zigadenus.

Grazing should be timed to reduce the cover and abundance of exotic annual grasses and invasive weeds while carefully minimizing impacts to harlequin lotus. Grazing should not occur in areas supporting marsh zigadenus to avoid poisoning livestock. French broom should be managed with targeted summer goat browsing where feasible, particularly while broom is in flower prior to seed set. Goat browsing will likely require temporary exclusion fencing to avoid impacts to adjacent native woody plant communities (e.g., chaparral, woodland).

6. Deer Park-Worn Spring North. The majority of this 138-acre potential grazing area is invaded by broom species, with the densest infestations along the west and east perimeters. No other targeted invasive weeds or rare plants are currently identified in this area, although there is the potential for future Harding grass, common velvet grass, and yellow starthistle invasions in grassland and oak savannah based on proximity to nearby occurrences of these species.

Grazing management should target invasive broom where possible using targeted spring goat grazing to prevent existing plants from flowering and producing seed. Goat grazing will likely require temporary exclusion fencing to avoid impacts to adjacent native woody plant communities (e.g., chaparral,

woodland). Continuous late-winter to mid-spring cattle grazing in open grassland and oak savannah (or oak woodland with well-developed herbaceous understory) may reduce cover of exotic annual grasses and increase native species diversity. However, cattle grazing may also promote the establishment and spread of invasive thistle species, especially in oak woodlands, and should be carefully monitored.

7. Bill Williams-Indian Crown. This is a narrow and steep 18-acre potential grazing area directly abutting an urban interface to the east has low to medium broom cover throughout the majority of area. At least one population of eggleaf spurge is also identified in grassland in the central portion of the area immediately west of Indian Road. No other targeted invasive weeds or rare plants are identified in this area.

Very limited grazable (herbaceous) acreage is available and therefore cattle and sheep grazing is likely infeasible in this area. Targeted spring goat browsing should be implemented to control significant infestations of dense French broom occurring mostly along the eastern half of this area at the urban interface. Goat grazing will likely require temporary exclusion fencing to avoid impacts to adjacent native woody plant communities and to avoid conflicts with neighboring residents.

8. Fawn Ridge-Deer Park. The entirety of this 57-acre potential grazing area is invaded by broom species, with medium- to high-density cover in the north central portion of the area north of Deer Park Road. Harding grass is mapped in disturbed grassland in the northwest portion of the potential grazing area along Concrete Pipe Road. Eggleaf spurge is also present adjacent to Deer Park Elementary School. No other targeted invasive weeds or rare plants are present in this area. This area is heavily forested with limited herbaceous acreage available for cattle and sheep grazing. Grassland patches are largely disjunct and adjacent woodland has nearly entire canopy cover and offers limited available forage.

Targeted spring goat browsing could be used to control invasive broom while late spring and summer grazing could be effective for controlling eggleaf spurge. Due to the widespread distribution of broom, management is best achieved in small, temporary enclosures to focus browsing behavior on broom while avoiding impacts to woody communities and native plants.

9. Azalea Hill. Low-density French broom covers the north and east portions of this 231-acre potential grazing area. This area consists of a mixed mosaic of grassland, chaparral, and woodland with a significant area of serpentine soil. A northwest to southeast trending ridgeline supports an extant population of Marin western flax in serpentine grassland and chaparral. Barbed goatgrass has begun to establish in this area and may threaten Marin western flax if allowed to persist and expand at this location. Several serpentine seeps in the southwest portion of the area north of Alpine Road and east of Fairfax-Bolinas Road contain Mt. Tamalpais thistle. Common velvet grass is also present in mesic grasslands throughout the center of the area and may be spreading at these locations.

Several factors, including the localized occurrences of rare plants and invasive weeds and varying RDM[8] requirements for serpentine and annual grassland communities, complicate grazing management in this area. In general, late-winter to spring moderate-intensity cattle grazing should be implemented to reduce abundance of exotic annual grasses while promoting increased native species richness and cover. The area supporting Marin western flax should be grazed prior to flowering when taller exotic grasses are the dominant available forage. This area should be carefully monitored to ensure impacts to this population are minimized. Areas supporting barbed goatgrass should only be grazed for a two- to three-week period after plants have bolted but prior to production of unpalatable flower heads (Brownsey et al. 2016). Serpentine seeps should be excluded from grazing using temporary fencing or other suitable

management techniques. Targeted spring goat browsing should be implemented to control significant infestations of dense French broom occurring mostly along the eastern half of this area at the urban interface. Goat browsing will likely require temporary exclusion fencing to avoid impacts to adjacent native plant communities and to avoid conflicts with Meadow Club golf course immediately west of these occurrences.

10. Pine Mountain South Gate. This 58-acre potential grazing area includes a northwest to southeast trending ridgeline dominated by serpentine grassland and chaparral that contains an extant occurrence of Marin western flax. These occurrences are generally in decline with no individuals seen in the northernmost occurrence for the past several years. Barbed goatgrass is currently invading most of these locations and can be considered a direct threat to Marin western flax and other native vegetation. Low-density broom is also present along the western perimeter of this area adjacent to Fairfax-Bolinas Road.

If feasible, moderate-intensity spring cattle grazing could be used in serpentine grassland to control exotic annual grasses and promote increased richness and cover of native species. Marin western flax occurrences should be grazed prior to flowering when taller exotic grasses are the dominant available forage. These areas should be carefully monitored to ensure impacts to these populations are minimized. Areas supporting barbed goatgrass should only be grazed for a two- to three-week period after plants have bolted but prior to production of unpalatable flower heads (Brownsey et al. 2016). Broom is not problematic in this area although there is potential for occurrences immediately to the west to spread into this area if uncontrolled.

11. Bathtub Gap-Carson Ridge. This 207-acre potential grazing area includes a north to south trending ridgeline dominated by serpentine grassland and chaparral that supports several seeps containing marsh zigadenus and Mt. Tamalpais thistle. These species co-occur in one seep complex in the central portion of this area. In the northern portions of MTW Lands, serpentine chaparral supports an occurrence of Marin western flax and an adjacent serpentine seep is occupied by a small population of marsh zigadenus. The serpentine seep containing marsh zigadenus and Mt. Tamalpais thistle should be excluded from grazing using temporary fencing or by actively managing animal behavior using appropriately located watering facilities or other shepherding techniques. Significant grazable acreage occurs in this area although grasslands are a mosaic of native serpentine and non-native annual grassland types.

In general, mid-winter to spring cattle grazing should be used to reduce the cover and abundance of exotic annual grasses while promoting native species richness, particularly native forbs in areas with serpentine soils. RDM[8] levels should be carefully monitored to avoid excessive grazing, particularly in serpentine grassland, where it may promote the establishment of invasive weeds including barbed goatgrass. Goatgrass is not currently mapped in this area but several prominent populations occur immediately north in the Pine Mountain South Gate grazing area.

12. Poison Spring Grasslands. This 121-acre potential grazing area is situated immediately northeast of Alpine Lake and is composed of dense oak woodland, chaparral, and open grassland with loamy soils. There are no mapped invasive weeds or rare plant occurrences in this potential grazing area. Grazing would be limited to contiguous grassland in the eastern portion of the area.

Moderate intensity, late-winter to spring cattle grazing in contiguous grasslands should focus on reducing the abundance of exotic annual grasses while increasing native species richness and cover.

Currently invasive weeds, including broom, are not problematic in this area and ongoing monitoring should ensure new infestations are carefully managed. Several areas of existing native perennial (coastal prairie) grassland should also be monitored to ensure management is benefiting existing native species, including perennial bunchgrasses. In general, oak woodlands in this area are dense and likely have relatively low herbaceous forage and may not be suitable for grazing.

13. Kent Pump Beginning. Located northwest of Alpine Lake, this 53-acre potential grazing area is primarily dominated by dense mixed hardwood forest interspersed with patches of chaparral. Open grassland and oak savannah occur immediately north of Alpine Lake Dam. Several areas supporting French broom are identified along the eastern perimeter of this area adjacent to Kent Pump Road. However, these areas are isolated and consist of few pioneer individuals and are not suitable for grazing management. No other occurrences of targeted invasive weeds or rare plants are known to occur in this area. Two non-contiguous grassland patches (21 and 28 acres, respectively) could support cattle grazing but their relatively small size, isolation, and infrastructure costs make grazing in these areas potentially infeasible. However, these areas would likely benefit from moderate intensity late-winter to spring grazing to reduce the abundance of exotic annual grasses while increasing native species richness and cover.

14. Grassy Knoll. The majority of this four-acre potential grazing area is dominated by dense Douglas-fir/mixed hardwood forest with several small grassland openings in the northern and southern portions. Medium-density broom occurs throughout much of the northwest portion of the area along Grassy Slope Road in grasslands or oak woodlands with reduced canopy cover. No other targeted invasive weeds or rare plants are known to occur in this area.

Cattle grazing is infeasible here due the small size of grazable land (4 acres). Targeted summer goat browsing should be implemented to control significant infestations of dense French broom occurring mostly along the eastern half of this area along the urban interface. Goat browsing will likely require temporary exclusion fencing to avoid impacts to adjacent native woody plant communities (e.g., hardwood forest, coastal scrub).

15. Cascade Creek. This 101-acre potential grazing area is composed of a mosaic of oak woodland and forest, chaparral, and grassland. Serpentine soils are not present in this area and one small occurrence of French broom is mapped in the south along Cascade Canyon Road. No other targeted invasive weeds or rare plants are known to occur in this area.

Primary grazing management objectives are to reduce the abundance of exotic annual grasses while increasing native species richness and cover. This area is well suited for cattle grazing as grassland and oak woodland are largely contiguous making it is more cost effective and logistically feasible than smaller, disjunct patches. If possible, grazing should be expanded into adjacent grassland to the east just beyond the area boundary.

16. Midpoint Meadows. One yellow starthistle occurrence is located in the center of this 38-acre potential grazing area immediately north of Fairfax Bolinas Road. Mt. Tamalpais thistle co-occurs with marsh zigadenus in a serpentine seep in the north-central portion of the area. Declining populations of both species were last observed in 1994, but are presumed extant. These populations are threatened by the succession of woody forest species into the meadows. There are additional extant occurrences of marsh zigadenus in the southern portion of the area in a drainage immediately north of Alpine Lake.

Grazing should be excluded from serpentine seeps and drainages supporting Mt. Tamalpais thistle and marsh zigadenus. Targeted periodic short duration, high-intensity late spring to summer goat grazing may control yellow starthistle. Cattle grazing must be carefully managed, as late-season or high-intensity grazing will likely exacerbate yellow starthistle infestations.

4.2 Water Quality Concerns

Livestock grazing has the potential to degrade water quality, but appropriate management practices can avoid or ameliorate these risks. Potential contaminants include sediment, temperature, nutrients, and pathogens. The latter two can present a health risk when downstream water is used for human consumption. It is important to note that the risks, benefits, and appropriate management practices vary by site, depending on topography, soil, species present, and other site-specific factors. Monitoring and adaptive management are key.

In general, riparian habitat and water quality benefit when riparian grazing is limited to mid- to late-spring in California. Grazing livestock will generally focus on annual herbaceous vegetation (including the adjacent uplands) during this timeframe. Grazing pressure on riparian vegetation increases in summer to mid-winter when green annual forage is scarce. Grazing during hot summer weather can also lead to increased loitering by livestock seeking shade or cool water. Minimizing rainy season grazing (when soils are saturated) protects riparian habitat and bank stability (Bush 2006; George et al. 2011). Grazing in spring and early summer has potential benefits relative to complete exclusion. Controlling annual vegetation can be important in promoting oak regeneration (McCreary 2001), controlling invasive weeds, and reducing fire risk (which itself negatively affects water quality).

Livestock are known to carry and shed several pathogens, including *Cryptosporidium, Escherichia coli*, *Giardia*, and *Salmonella*. Recent improvements in pathogen identification technology have revealed that fewer livestock-shed pathogens are human-infective than previously believed (Atwill 2015). A study of cow-calf operations in fourteen California counties found 0%–0.5% infection rates of human-infective strains of *Salmonella, Cryptosporidium* and *Giardia* (although 3% of the latter pathogen's samples were of undetermined strains) and a low (5%) rate of potentially human-infective *E. coli*. Most positive results were from a small percent of individual animals, or from two specific outbreaks. Calves were significantly more likely to shed *Cryptosporidium* and *Giardia* than older livestock. Other research indicates that for sheep, lambs up to five months old are more likely than older sheep to shed *Cryptosporidium*.

Maintaining sufficient RDM[8] in the uplands surrounding water bodies is an important and effective means of protecting water quality. RDM minimum standards for California annual grasslands are designed to minimize erosion, and therefore help to minimize the amount of sediment contributed by uplands (Bartolome et al. 2006). RDM minimum targets are also appropriate in leaving sufficient cover to slow or stop the transport of nutrients and pathogens, preventing them from entering water bodies and (for several nutrients and pathogens) facilitating the breakdown of the contaminant by sunlight (Li et al. 2005, Mander et al. 2000; Parkyn 2004; Hefting et al. 2005; Räty et al. 2010, Tate 2010). As little as a one-meter buffer of natural grassland can retain 95–99% of pathogens (Atwill et al. 2006; Tate et al. 2004). These measures lose effectiveness in the rainy season, especially during the first few rainfall events of the year, and during major storms (Tate et al. 2000). Grazing in or near drainages in the dry season, and to a lesser extent late in the rainy season or in dry periods between storms, improves buffer effectiveness and the opportunity for solar inactivation. Grazing of spring-fed wetlands can be beneficial in removing some nutrients from spring waters (Allen-Diaz et al. 2004).

The risk of impacts to water quality increases in areas where livestock congregate in or adjacent to a drainage or other water body, for instance if a loafing area, service area, bedding area, feeding/supplementing station, or water trough, is within 30 feet of a drainage (Tate et al. 2004; CLGPHMA 2012). Areas particularly susceptible to erosion include steep slopes with highly erodible soils (as classified by the Natural Resources Conservation Service Soil Survey), overhanging banks, and gullies. Steep banks, thickets of dense vegetation and other physical obstacles can restrict or minimize livestock access, especially if easier access or crossing points are nearby (Bush 2006; George et al. 2011). Fencing (e.g., large riparian pastures or small exclosures) and off-stream attractants (such as troughs and shade) can be important tools in controlling the timing and intensity of riparian grazing (Bush 2006, Hahn 1999, Willms et al. 2002).

5. Grazing and Browsing Habits of Domestic Livestock and Tule Elk (and Operational Requirements of Kind and Class of Animal)

5.1 Foraging Differences

Livestock are divided into groups based on their preferences for different types of vegetation and primary foraging methods. These groups include grazers (cattle and horses) which have a diet dominated by grasses and grasslike plants, browsers (goats), which consume primarily shrubs and forbs, and intermediate feeders (sheep), which have no particular preference for grasses, forbs, or shrubs (Holechek et al. 1998). Browsers generally consume large amounts of green grass in spring, but avoid dry, mature grass and often experience digestive upsets if forced to consume too much mature grass (Vallentine 1990).

Body size, anatomical differences in teeth, lips, and mouth structure, grazing ability, and differences in digestive systems account for some of the differences in foraging behavior. Mouth size directly affects the degree of selectivity that is physically possible. For example, livestock with small mouth-parts such as goats and sheep can more effectively utilize shrubs while selecting against woody plants.

In addition to physiological influences on diet selection, animal behavior can strongly affect what they choose to eat. Young animals learn foraging behaviors from their mothers and peers and can be taught to eat or avoid certain plants. In fact, researchers have taught livestock in experimental settings to consume some weed species, although this practice is extremely time consuming and impractical on an operational level. Additionally, consumption of weed species does not necessarily result in reduced populations of target plants. Depending on timing and frequency of weed consumption, grazing or browsing can actually increase some weed populations. Grazing of yellow starthistle (described above in Section 3.1.3) is a good example where removal or wrong timing can lead to increased flowering and reproduction.

Generalized livestock preferences for diet and topographic position and the associated suitability for MMWD vegetation management are summarized in Table 1 below.

5.1.1 Production Agriculture vs. Fees for Service Grazing

Meat and dairy animals. Ranchers raise a vast majority of the livestock in Marin County for production of saleable products including meat, fluid milk, and processed dairy products such as cheese. Ranchers rely on high-quality forage and supplemental feeds to ensure that their animals are in good health, reproduce successfully, and produce a high yield of milk or meat. With meat animals, weight gain is important since the animals or their meat are sold based on weight. Dairy animals, are valued based on their milk production, which is strongly influenced by their feed. Additionally, dairy animals are kept close to the milking parlor to facilitate ease of milking and to avoid burning unnecessary calories by walking long distances. The only type of production agriculture operation that would be likely to utilize its animals for vegetation management on MTW Lands would be beef ranchers who may be interested in grazing cattle on grasslands. However, this could lead to incidental browsing of shrubs and tree seedlings within those grasslands.

Vegetation management animals. Unlike meat and dairy animals, a more limited number of businesses keep animals for managing vegetation rather than producing a saleable product, although some do also produce meat animals as a byproduct. These operations earn income by charging a fee for vegetation

management service. Although animal and herd health are important to this type of operation, it is not as essential in terms of profitability. However, consumption of unsuitable feed, especially for prolonged periods, can weaken of sicken animals and require costly animal replacement.

5.1.2 Tule elk

Tule elk, which are native grazers/intermediate feeders, roamed California until the late 1880s. Tule elk are classified by the CDFW as game animals and can only be managed by this agency.

CDFW oversees several areas where tule elk have been reintroduced, all of which are extensive in size, providing adequate acreage to support planned populations. CDFW only establishes elk herds on lands that fall within the species' historic range, and that roughly include a minimum of 10,000 acres or high-quality appropriate habitat composed primarily of grasslands and open-canopied oak woodlands. Additionally, elk herd introductions have to be acceptable to neighbors. CDFW is not interested in having fenced herds, as this leads to the need to remove and relocate excess animals, a practice that they do not engage in. Furthermore, CDFW requires population control in managed elk herds, which is done through hunting programs in most areas of California. Birth control treatments for females have been used in some herds but have been abandoned due to high costs (Joe Hobbs, personal communication 2017).

Table 1. Generalized livestock preferences for diet and topographic position and suitability for MMWD vegetation management

Species	Class/ Type	Diet Preferences/Needs	Topographic Position Preferences	Suitability for MMWD Vegetation Management
Sheep	Meat	Intermediate feeder: high use of forbs, but also eat high volumes of grass and browse[14]	Well adapted to steep hills and rough terrain	Yes, where rare forbs are not present or during periods that they would not be damaged by grazing
	Dairy	Same but additional of supplemental feed in barn to ensure good milk production	Adapted to steep hills and rough terrain	No, must stay close to milking parlor
Goats	Meat	Browser to intermediate feeder: high forb use, but can utilize large amounts of browse and grass; highly versatile	Adapted to a wide variety of terrain	Yes, where rare forbs are not present or during periods that they would not be damaged by grazing
	Dairy	Same but additional of supplemental feed in barn to ensure good milk production	Adapted to steep hills and rough terrain	No, must stay close to milking parlor
Cattle	Dairy	Primarily dry forages in barn, with some grass, especially for organic production	Level to gently rolling ground	No, must stay close to milking parlor
	Dairy heifers	Grazer: mostly grasses, some seasonal use of forbs and browse	Prefer level to gently rolling terrain but will climb steep hills	Yes, in grasslands
	Beef, cow-calf	Grazer: mostly grasses, some seasonal use of forbs and browse	Prefer level to gently rolling terrain but will climb steep hills	Yes, in grasslands
	Beef, stockers	Grazer: mostly grasses, some seasonal use of forbs and browse	Prefer level to gently rolling terrain but will climb steep hills	Perhaps, in grasslands; stockers can be wild and difficult to manage
Horses	NA	Grazer: mostly grasses, minor amount of forbs and browse	Prefer level to gently rolling terrain	No, other species are better suited to MTW Lands
Tule elk	NA	Grazer and intermediate feeder	Widely adapted native ungulate	No, introduced herds must be managed by CDFW and require tall, sturdy fences for containment

[14] Browse refers to woody plant material ingested by animals.

5.2 Timing of Grazing, Duration, Intensity and Repeated Treatments

Grazing effects on target plants can vary dramatically based on timing of grazing. Seasonal conditions, age, or phenological stages of plant development may make plants more or less vulnerable to damage due to herbivory, which can be positive or negative, depending on grazing objectives. For example, if enhancement of seed production is desired, grazing should be deferred until after flowering and seed set. Where the opposite is desired—reduction of seed output by weed species—grazing or browsing would theoretically be desirable during flowering and before seed drop.

Despite this obvious potential effect of herbivory on flowering and seed set, numerous examples (some which can seem counterintuitive) exist where populations of flowering plants thrive despite, or because of, continuous grazing pressure. Timing of grazing/browsing should be keyed to specific site objectives but determining appropriate timing can be difficult where competing objectives that might best be served by different or even conflicting times of grazing occur. Carefully identifying and prioritizing objectives should take place before grazing/browsing timing is determined.

The duration of grazing episodes and stocking intensity[15] also greatly affect plant enhancement or control outcomes. Duration can last from only hours in extremely intensive grazing regimes, to year-round, which is common in California on dry Mediterranean grasslands. Some ranchers and consultants have popularized short-term, high-intensity grazing in recent decades. Proponents believe that such systems are inherently superior to more traditional, less intensive grazing. However, duration and intensity of grazing episodes should be tailored to meet grazing/browsing objectives, whether they are focused on animal weight gain or resource enhancement and no one particular regime has been shown to be generally superior to another.

Frequency of grazing episodes is another important variable that strongly influences outcomes of most grazing programs. With year-round continuous grazing, frequency does not come in to play, but frequency must be considered in any grazing regime that employs grazing for only a portion of each year. For example, grazing that is aimed at reducing barbed goatgrass populations may require only one, carefully timed grazing episode in spring to reduce seed development of this annual plant, while two grazing episodes may be required to reduce yellow starthistle due to its staggered germination and development.

Repeated grazing treatments may also be necessary in proposed grazing areas where objectives can best be met by targeting different plants at different times of year.

5.3 Targeted Grazing Versus Grazing to Meet Broader Objectives

The term targeted grazing is used in reference to livestock grazing that is managed to accomplish very specific outcomes. Usually used for conservation purposes, it can be focused on specific plant species or vegetation types, either to their detriment or benefit at specified places (Campbell-Craven 2017). This is in contrast to grazing that is conducted for broader purposes such as forage utilization or mimicking an ecosystem process (e.g., prehistoric ungulate effects). Traditionally, grazing in the region around MTW Lands has been conducted primarily for the economic production of animal products, including meat, dairy, and fiber, and for maintaining larger landscapes in particular conditions. For example, grazing has effectively been used to maintain grasslands and prevent type-conversion to

[15] Stocking intensity refers to the number of animals (or animal units) on a given area of land at any one time.

woody vegetation without this being specifically identified as a desired outcome. The study team focused on livestock grazing to target priority rare native plant habitat, weeds, vegetation types, and fire fuels for the conservation purposes described by MMWD (Section 2). Grazing contractors would be paid for their services and be under MMWD direction and monitoring to achieve specified priority resource conservation objectives.

5.4 Supplementary Alternative/Additional Treatments

Interviews with ranchers and contract graziers indicate that any grazing on MTW Lands will probably be conducted by outfits that own animals specifically for targeted contract work. Due to expected high costs and questionable effectiveness at achieving some of MMWD's vegetation management objectives, at least some of MMWD's vegetation management will continue to be achieved with non-grazing methods, including hand crews, heavy equipment, chainsaws, and weed-eaters. Mechanical and hand treatments are compared with grazing/browsing vegetation management methods in Table 2 below.

6. Survey of Potential Availability and Costs of Livestock Grazing Contractors

6.1 Background

L. Bush conducted telephone interviews with 13 ranchers and contract graziers to determine their interest and the availability of livestock for a potential grazing/browsing program on MTW Lands. For the most part, ranchers and contract graziers make up two very distinct groups with very different business models, though a few ranchers do some contract vegetation management work with their livestock. Generally, ranchers earn a living by producing and selling a product, including live animals, meat, fiber, milk, or processed dairy products. Labor is costly, so only essential labor is engaged. Cattle, sheep, and goat ranches (excluding dairies) typically operate with meager cash flow and low profit margins and so do not normally have many, if any, employees, although this depends on the size of the operation. Most ranchers are so busy with their livestock production operations that they are not interested in taking on contract vegetation management projects, which would involve hiring employees and possibly being away from the ranch during crucial periods in their animals' life cycles.

On the other hand, contract graziers earn income by providing labor-intensive vegetation management and ecological services for a fee. They may also produce meat and fiber as by-products of their business, but for the most part their financial goals are met through direct payment for services rather than by selling products.

6.2 Methodology

L. Bush compiled a list of potential contract graziers by searching the internet, communicating with other rangeland management professionals, and through referrals made by initial interviewees. She also interviewed several ranchers whom she knows from working in the field of rangeland management in Marin and Sonoma Counties for over 30 years.

Persons contacted included two Marin County beef ranchers, two Sonoma-Marin sheep ranchers, and one Sonoma-Marin goat and beef rancher; and eight contract graziers from the greater Bay Area and Merced County. L. Bush conducted telephone interviews that lasted form several minutes to an hour. Ranchers who were not interested in contract grazing quickly stated their lack of interest while contract graziers all answered a series of questions after L. Bush provided the following background information to those who indicated an interest in providing vegetation management services to MMWD:

> MMWD has lands totaling several thousand acres where they are exploring the potential to use limited livestock grazing to:
>
> - Manage herbaceous and woody weed species
> - Manage grassland areas (totals about 1,100 acres over 16 areas)
> - Manage fuelbreak areas to reduce shrub and tree growth

MTW Lands include 16 potential grazing/browsing areas with more than two dozen potential staging areas (parking lots). Constraints and conditions include:

- Lack of fencing
- Lack of established watering locations and facilities, although some hydrants and springs could be tapped to provide water for distribution to grazing treatment areas
- Grazing/browsing may be very seasonal/short-term/intensive
- Some areas are on very rugged, remote terrain

- Some areas will require trailing the livestock to treatment sites
- None of the areas have been grazed since the 1940s, so forage quality may be low (due to thatch build up and succession adding woody and less palatable herbaceous species)
- Some areas/species may require goats and/or sheep, and some may be better for cattle

6.2.1 Survey Questions

Questions asked of all graziers included:

1. Do you have cattle, goats, and/or sheep (and supporting personnel) available for this kind of service?
2. Do you have transport, temporary fencing, and watering equipment to bring to, install, maintain, and use on-site?
3. Potential treatment areas range from several acres to several hundred acres; are the sizes of the targeted patches big enough to be worthwhile?
4. When would you be available?
5. What are your constraints (access, shelter, predation, compensation, etc.) and logistical needs?
6. What shelters, staging, guard dogs, and non-lethal predator controls would be required?
7. How far can you walk animals from staging areas?
8. Would your livestock eat this material:
    - grasses (general grassland vegetation plus tall fescue, barbed goatgrass, Harding grass, and common velvet grass)
    - yellow starthistle, fennel, and blackberry[16]
    - French broom
    - shrubs (possibly chaparral) and tree growth, including tan oak
9. Are there seasons when this would work best/worst?
10. What additional treatments or services would be necessary for MMWD to perform to prepare/condition this forage/browse?
11. If not feasible or attractive, what would make it so?
12. What would be your per-acre costs?
13. What would be your staging costs?

6.3 Survey Results

Of the contract graziers contacted, one operates with cattle, one with goats, one with sheep, and the remaining five use a mixture of sheep and goats depending on project requirements. The cattle grazier uses dairy heifers that belong to local dairies to manage vegetation on large estate properties. This cattle grazier serves landowners who are interested in the ecological benefits of grazing or need fire fuels reduced, but do not have their own livestock. At least one of the sheep graziers rents or borrows many of the sheep he uses on larger projects from ranchers or other sheep graziers.

Several of the livestock graziers have gotten into this business within the last few years, with the most well-established operating for 24 years and the newest operating for about two years. Several local companies that were listed on the Livestock for Landscapes website (Voth 2017) have gone out of business or did not respond to phone calls and emails. Livestock graziers contacted are headquartered

[16] Fennel and blackberry were included in the survey, and eggleaf spurge was excluded because the survey took place while the final list of weed species to be addressed was still in draft form.

in Marin, Sonoma, Lake, Contra Costa, Santa Clara, and Merced Counties. They are all able to travel to Marin County and most of them are used to travelling significant distances to work sites.

Only one of the beef ranchers indicated a possible interest in contract grazing, although he has not conducted this type of work in the past, while all eight of the contract graziers indicated an interest in working on MTW Lands and said they would be available to perform vegetation management for MMWD.

Herd Transportation and Portable Infrastructure. All of the contract graziers said they have the necessary equipment to transport animals to the site and manage them. Portable infrastructure includes electric mesh fencing and portable watering equipment. Several mentioned they are used to obtaining livestock water from hydrants.

Minimum Project Size. One grazier said he will do small, backyard-sized to one-acre projects, but most indicated that about five acres is their minimum project size. One specified a minimum project cost of $10,000. Several said that larger scale projects cost less per acre, as transportation costs can be spread over a larger number of acres. One grazier set five acres as a minimum overall project size, but stated that having large and small treatment areas within an overall project is acceptable.

Seasonal Availability. Most graziers said they can work year-round, but several with goats and sheep do not like to work in winter due to inclement weather and the fact that sheep generally lamb in winter. The one cattle grazier said that he manages animals year-round but that services would be less expensive between December and April when providing water to animals is not as critical. One sheep and goat grazier has developed a herd of wethers (castrated males) that work up until October and start again in February, before her other animals are working. One sheep and goat grazier mentioned that he works May through August but later than that ewes need to be fed to prepare for lambing in winter.

Constraints. None of the graziers expressed concern about the site constraints.

Requirements from MMWD. The things needed by graziers from MMWD are site access for trucks and gooseneck trailers or 18-wheelers (less expensive for large herds, but access usually prevents their use), site maps, staging areas for livestock and herders, space for herder trailers, permission to use all-terrain vehicles (“4-wheelers”) off-road on MTW Lands, and an adequate water supply. All are used to distributing water from water supply points.

Trailing/Walking Distance from Staging Areas. Most graziers indicated that they could trail livestock over fairly long distances from staging areas or between treatment sites. One mentioned that the ability to trail animals between treatment sites is easier thus cheaper than trucking between sites. The distance that animals can be trailed depends on terrain, but most graziers said animals and herders can walk one to five miles per day, with a total distance of between 10 and 30 miles.

Herd Protection**.** All but two of the livestock graziers use professional herders to guard and manage animals. All of the sheep and goat graziers also use guardian dogs, which they would not use on sites with significant public recreational use or near residences. Most of the sheep and goat graziers indicated that they could manage their herds without the dogs, but that herders or employees are always with the animals. One grazier uses guardian dogs to protect goats from theft.

Livestock Consumption of Target Species. Some graziers are familiar with specific plant species, some said they are not, and some seemed to have questionable knowledge of browsing/grazing effects on particular species. Two interviewees stated that animals will consume some species only as a percentage of their overall diet and that they need a large enough area around the patches of target species to select other more nutritious or less toxic plants. This was mentioned in relation to consumption of French broom. Most interviewees indicated whether or not their livestock will consume the plants they were asked about, but some specifically mentioned actual population decreases of the targeted weeds over time. However, this information is anecdotal and consumption and long-term effectiveness of browsing/grazing effects of these plants may vary greatly depending on site characteristics, grazing/browsing intensity and frequency, and timing of treatments. Consumption of plant material by livestock does not necessarily equal control of the targeted plants. Some targeted grazing research (Kyser et al. 2014) has demonstrated weed species control with livestock only under carefully prescribed experimental conditions, which could be difficult to impossible to reproduce in other settings. Additionally, research-driven grazing prescriptions can be very time consuming, thus expensive to replicate. Also, repeated treatments within the year and across multiple years (even perpetually) might be required, thus indicating higher long-term costs than a single treatment.

The following species were included in the survey:

> ***Tall fescue.*** Responses regarding livestock species' ability to consume and manage this species varied. Generally, responses indicate that multiple grazing treatments are needed with heavy stocking rates. Using intensive grazing, apparently all three livestock species will consume this plant.
>
> ***Barbed goatgrass*****.** The cattle grazier is familiar with this plant and said that cattle will eat barbed goatgrass, depending on phenology (i.e., it is palatable when very young). None of the other graziers seemed familiar with it.
>
> ***Harding grass*****.** Goats apparently consume Harding grass much more readily than do sheep. One grazier said that his goat and sheep herd will eat Harding grass, but consume the inflorescences first, often leaving a large round mass of basal stems and leaves. Cattle will also consume Harding grass, depending on phenology and the availability of other forage plants.
>
> ***Common velvet grass*****.** This is a coarse-textured plant with low palatability. Of the four graziers who are familiar with this species, two said that goats will eat it, one said that sheep will eat it, but that the animals' condition deteriorates on it over time, and one said that neither animal will eat common velvet grass but that they could be bedded down on it to try and damage it.
>
> ***Yellow starthistle*****.** This plant is familiar to most of the graziers. The one cattle grazier indicated a low success rate managing this plant with cattle. Most of the goat and sheep graziers have had some success managing yellow starthistle, with goats possibly eating it more readily than sheep. One interviewee mentioned that yellow starthistle should be grazed at least twice in May and June to knock it back, and most said that over a period of years, grazing with sheep and/or goats will deplete populations.
>
> ***French broom*****.** Many of those interviewed are familiar with French broom, although they may or may not know the difference between broom genera and species. Two graziers reported toxicity/nutritional issues with broom. One said that goats can only eat broom early in the year,

before bloom-time, because if consumed too late in the season it can interrupt estrus. Another said that broom contains toxic compounds that goats can tolerate more easily than sheep, although this person referred to browsing during flowering. A third person that has a large sheep and goat operation has never had toxicity issues with her animals when they eat broom. Two graziers stated that goats and sheep will consume French broom, but will not eat stalks over ¼" to ½" in diameter. One sheep grazier said that sheep will consume broom in quantities up to 25% of their diet, so they need access to a large enough area so that other plants can provide adequate nutrition.

***Tanoak*.** Interviewees' familiarity with this plant are questionable. Several seemed unable to differentiate it from the genus *Quercus*, despite attempted clarification. Two said that goats will eat tanoak early in the year and one said that sheep will not eat it.

***Poison hemlock*.** The survey did not include a question about this species, but the one cattle grazier mentioned observing a decrease in poison hemlock with cattle grazing, which is consistent with L. Bush's (co-author) observations over many years.

***Eggleaf spurge*.** The survey did not include a question about this species.

Himalayan blackberry (*Rubus armeniacus*). All interviewees who has experience with this plant said that goats and sheep will consume this plant. One cattle grazier described cattle consumption of Himalayan blackberry as "so-so." One sheep and goat grazier stated that sheep are not as effective on blackberry as goats are. One goat and sheep grazier stated that goats will target blackberry.

Fennel (*Foeniculum vulgare*). All sheep and goat graziers who were interviewed who were familiar with fennel said that both species readily eat this plant.

Best Season for Treatment. Answers to the question about the best season for grazing/browsing treatment of the species discussed above varied from "it depends on the species," to "early to late spring'" to "April through June", and "June and July, but earlier for broom." One goat grazier said that his animals can lose weight browsing in late summer, and thus he needs to provide supplemental alfalfa at that time of year.

Costs. L. Bush described MTW Lands to each grazier and requested rough per-acre costs.[17] Rough costs ranged from $250/acre to $1,200/acre per treatment, with several citing $400 to $500/acre for projects and areas with few complications, easy access, and where temporary fencing is simple to install. Two others quoted rough prices of $700 to $800/acre.

Logistical issues such as difficult access and steep terrain were cited as factors that can greatly increase the actual price. Project scale also affects price. Ease of setting up fencing was cited as affecting price, because areas with dense woody vegetation require extra labor for vegetation clearing before fencing can be installed.

[17] Graziers cannot be expected to provide accurate or precise costs or bids for specified projects without knowing the project size, number and location of treatment sites, desired timing of treatments, repetitions of treatments per year and between years, distance from staging areas to water, and more information on terrain at treatment sites.

One grazier said that yearlong access to MTW Lands would bring his costs down, and thus the price he would offer. One charges $800/acre plus transportation, which is charged every time a truck is loaded and moved (versus trailing animals between treatment areas). One said that his prices are lowest between August 15th and April 15th, which is his low season. One mentioned lowering costs if several neighboring agencies utilize his services. Another said that transportation in an 18-wheeler (semi-truck) is the most efficient and cheapest, so this would reduce costs, but is rarely practical (and is unlikely to be practical at any of the access and staging areas at MMWD). Trucks and gooseneck trailers are more commonly used but increase costs. Feasibility for MMWD to accommodate yearlong access and support for the grazing animals and associated personnel would likely involve designation of non-target sites near the targeted sites within MTW Lands or on neighboring properties. A long-term arrangement that allowed the contract grazier to use such areas for off-season keeping of their animals between jobs might work. This would also require supplemental feeding of the animals. The study team understands that the latter practice would be unacceptable to MMWD (A. Williams, MMWD, personal communication) due to the impossibility to obtain weed-free and GMO-free supplemental feed.

6.4 Other Comments

Planning Ahead. Two graziers spoke about taking reservations well in advance of the planned grazing/browsing treatment time. One takes deposits a year in advance to secure a time slot, and one prefers to have spring contracts secured the previous fall. If bids are requested by agencies in fall, graziers need to know bid results as soon as possible to allow adequate planning. Multi-year projects are more attractive, and allow contractors to plan for livestock demand, and obtain necessary animals in time for projects.

Some of the larger graziers have up to four or five herds working at one time, while smaller operators have only one herd, meaning that obtaining their services when demand is high would be difficult. Herds typically include from about 350 to 500 animals.

Chaparral Browsing. One grazier mentioned that sheep will not eat chaparral plants and one said that goats will defoliate Manzanita, but will not consume its woody parts.

Effectiveness. One grazier stated that browsing/grazing for weed management will not achieve the level of selectivity that mechanical treatments do. Another stated that grazing effectiveness and feasibility is always dependent on the livestock species and that he prefers using sheep near residences because they are easier to control than goats.

Nutrition and Animal Health. Several interviewees mentioned possible livestock health problems associated with intake of too much of a particular plant species or consumption of low-quality forage or browse, especially in late summer. Some mentioned the need to supplement with alfalfa under certain conditions, but said that it is not essential. One mentioned use of protein supplement tubs instead of dry feed. Two interviewees indicated a need to keep animals on their home ranches during birthing seasons (winter for sheep), and for several months leading up to that time so that pregnant animals receive optimal nutrition. One of the larger operations has a dedicated veterinarian and cares for retired animals their entire natural life, rather than slaughtering them.

6.5 Survey Conclusions

Considering the number of contract graziers who have businesses in the greater Bay Area and beyond, MMWD should be able to enter into a contractual agreement with one or more of these companies if staff and board members decide that vegetation management with livestock is something they wish to pursue. Given the rough terrain, other site constraints and very specific objectives of MMWD's vegetation management program, leasing these lands to production ranchers would be impractical since the amount of labor required to meet MMWD's specific objectives is considerable and beyond what most ranchers are equipped to provide. Additionally, much of the vegetation on MTW Lands would not provide high-quality forage for most livestock on an ongoing basis. Ideally, lands in Marin County would be used for local ranchers to help support their operations and Marin's agricultural economy, but given the constraints mentioned above, this is not practical on MTW Lands.

If targeted grazing/browsing is added to MMWD's vegetation management program, very clear communication between MMWD staff and contractors will be essential to help avoid ecological and other problems. Contractors should be knowledgeable about targeted plant species, sensitive plant species, and other environmental concerns and should be well prepared to deal with the public's concerns and questions about livestock and their effects on the landscape. If recreational access occurs at the same time and general locations as the grazing treatment, the contractors are likely to be asked such questions. Contractors must also be extremely attentive and responsive to any conflicts that arise with their animals so that problems do not escalate resulting in ecological damage, livestock illness, or conflicts with the public.

Cost Effectiveness. Due to the number of factors that affect costs for provision of grazing/browsing services, accurate costs for this work can only be obtained once a specific grazing/browsing program is designed and described in writing and with a map, then reviewed with potential contractors in the field. Project scale, exact locations of treatment sites, season of work, length of project (single treatments versus multiple treatments), distance from staging areas to exact treatment sites etc. are all considered by grazing browsing contractors when setting a price.

Grazing and browsing by livestock will not remove woody vegetation with stems beyond about ¼" to ½" in diameter, so it cannot be used to replace initial brush cutting or use of heavy equipment for fire fuel clearing. However, it can be used for on-going maintenance of cleared sites, although livestock may avoid some woody species meaning that grazing/browsing alone may not be completely effective.

The MMWD *Draft Biodiversity, Fire, and Fuels Integrated Plan* (Panorama Environmental, Inc. 2016: Table 7-2) provides a Summary of Costs for Vegetation Management Actions/Performance Criteria. It includes costs for performing various vegetation management tasks using mechanical methods and hand weed control. Additionally, MMWD identified other vegetation management needs not addressed there. Table 2 below summarizes projected per-acre costs for pertinent vegetation management tasks using mechanical and manual methods, potential effectiveness of grazing/browsing, and probable cost effectiveness of grazing and browsing methods compared to the mechanical and manual methods given the rough costs provided by interviewees.

Table 2. Comparison of mechanical/manual to grazing/browsing vegetation management methods

Mechanical/Manual Methods		**Grazing/Browsing Methods**	
Actions/Performance Criteria*	**Projected Per Acre Cost***	**Probable Effectiveness to Achieve Comparable Performance Criteria**	**Expected Cost Effectiveness**
1. Retreatment of fuels in existing fuelbreaks [MA-20.1]	$1,700	May be effective for many species, but not all targeted species or vegetation types Only if woody plant parts are ¼" to ½" or less	Yes, where species are palatable and wood is small diameter
2. Cyclical mowing of fine fuels [MA-20.2]	$360	Yes	No
3. Cyclical [hand] removal of broom in Optimized and Transitional Zones [MA-20.3]	$360	Not as effective as hand pulling, but may be effective for small plants	No
4. Roadside mowing [MA-20.4]	$2,000	Yes, for herbaceous vegetation, maybe for woody vegetation May be effective for many species, but not all targeted species or vegetation types Only if woody plant parts are ¼" to ½" or less	Yes
5. Dam maintenance [MA-20.5]	$2,000	Likely	Yes
6. New fuelbreak construction [MA-21]	$10,000	No. Animals will not remove large, woody material	N/A
7. Reduce accumulated fuels and brush in forests [MA-23.1]	$12,300	May be effective for many species, but not all targeted species or vegetation types Only if woody plant parts are ¼" to ½" or less	Yes
8. Douglas-fir thinning in oak woodlands and grasslands [MA-24.1]	$480	Sheep and goats will remove Douglas-fir seedlings, but may damage other forest species	No
9. Broom, initial removal in oak woodlands and grasslands [MA-24.3]	$6,000	No, will not remove mature plants – will defoliate and eat small stems	NA
10. Yellow starthistle [MA-24.5]	$1,200	Probably effective over several years	Possibly, if project is big enough to keep costs down. Required size is not known
11. Goat grass [MA-24.6]	$360	Probably effective over several years, but requires very carefully timed, intensive treatment	No
12. General grassland and thatch management for selected special-status plants [MA-24.2]	NA	Very effective with proper timing	Possibly if comparable to prescribed burn, $18,000/project or between $300-$600/acre depending on unit size and complexity

* Actions/Performance Criteria and Projected Costs #1-12 from Panorama Environmental, Inc. 2016, Table 7-2. p. 7-5; comparable action numbers in brackets.

7. Summary of Feasible Grazing Scenarios

Feasible grazing scenarios are described below for each of the high priority potential grazing areas identified by A. Williams (Appendix 2). Each area supports species that may be effectively enhanced (rare plants) or managed (weeds and fuelbreaks) with livestock grazing based on scientific literature and feedback from livestock operator surveys. In all cases, contract graziers would provide livestock management infrastructure to keep their animals contained in the defined treatment (targeted) areas, so presence or availability of grazing management infrastructure is not a factor in determining grazing feasibility, unless site-specific evaluations by contract graziers identify unknown limitations.

7.1 Prospective Grazing Scenarios for the Potential Grazing Areas

This section summarizes the conditions that contribute to feasibility and expected success of grazing and browsing in each of the 16 potential grazing areas.

1. Sky Oaks, 282 acres
Targets. French broom, common velvet grass, Harding grass, yellow starthistle, tall fescue, barbed grass, eggleaf spurge, and harlequin lotus.

Primary Objectives. Decrease of broom seed production and young plants with particular emphasis on sparse/pioneer occurrences; reduction/management of non-native perennial grasses including common velvet grass, Harding grass, and tall fescue; reduction/management of yellow starthistle, eggleaf spurge, and barbed goatgrass, all without negatively affecting harlequin lotus and other native plants and ideally enhancing harlequin lotus habitat.

Feasibility of Grazing/Browsing. Grazing appears to be physically feasible in this area as terrain and vegetation are generally appropriate.

Expected Success of Grazing/Browsing Treatments. Some reduction of French broom seedlings and defoliation of larger plants would likely be achieved with browsing by sheep and/or goats, although grazier interviews indicate that toxicity may be an issue for these animals. Reduction of common velvet grass and Harding grass by grazing may require cattle and is questionable due to the fact that intensive grazing, which may damage harlequin lotus, would be required. Reduction of yellow starthistle may be possible with short-duration, high-intensity goat grazing. If hand removal of eggleaf spurge is infeasible, targeted late-spring to summer goat grazing may reduce eggleaf spurge, but is not expected to eliminate this plant. Intensive and carefully timed grazing of barbed goatgrass for only a two- to three-week period after plants have bolted but prior to production of unpalatable flower heads may help control this plant (Brownsey et al. 2016). Moderate cattle and possibly goat grazing could enhance harlequin lotus habitat, although grazing by sheep may damage harlequin lotus plants due to sheep preference for forbs.

2. Porteous-Ross Reservoir-Worn Spring Middle, 115 acres
Targets. Broom with many areas occupied by more than 50% cover, particularly in the south near Phoenix Lake; one small patch of leafy spurge in open grassland near terminus of Worn Spring Road. No target rare plant populations in this grazing area.

Primary Objectives. Decrease of broom seed production and young plants; reduction/management of eggleaf spurge; management of grasslands and oak woodland understory to reduce the abundance of weeds and exotic annual grasses while increasing native species richness and cover.

Feasibility of Grazing/Browsing. Grazing appears to be physically feasible in this area as terrain and vegetation are generally appropriate. Grassland and oak woodlands suitable for grazing livestock dominate this area, providing appropriate forage for livestock.

Expected Success of Grazing/Browsing Treatments. Some reduction of French broom seedlings and defoliation of larger plants would likely be achieved with browsing by sheep and/or goats, although grazier interviews indicate that toxicity may be an issue for these animals. Moderate intensity, continuous late winter-spring cattle grazing in grasslands and oak woodlands may reduce the abundance of weeds and exotic annual grasses while increasing native species richness, but is unlikely to effectively manage broom. If hand removal of eggleaf spurge is infeasible, targeted late spring to summer goat grazing may reduce eggleaf spurge, but is not expected to eliminate this plant.

3. Pilot Knob, 59 acres
Targets. Two small patches of French broom along northern border and native perennial grasses.

Primary Objectives. Decrease of broom seed production and young plants, prevent future incursions of invasive plants and exotic annual grasses and enhance the native species composition in existing grasslands.

Feasibility of Grazing/Browsing. Grazing appears to be physically feasible in this area, although dense forest cover keeps it from being ideal grazing land.

Expected Success of Grazing/Browsing Treatments. Small patches of broom would be best managed by manual removal. Moderate intensity spring grazing prior to native perennial grass seed production may enhance these grass populations. However, grazing would need to be carefully monitored in this area to ensure native perennial bunchgrasses are not adversely affected.

4. Ridgecrest-Rock Spring-Potrero, 191 acres
Targets. Harding grass, tall fescue, Mt. Tamalpais thistle, harlequin lotus, marsh zigadenus, isolated and small patches of serpentine grassland.

Primary Objectives. Enhance wet meadow habitat for Mt. Tamalpais thistle, harlequin lotus, and marsh zigadenus by reducing or eliminating Harding grass and tall fescue; enhance serpentine grassland.

Feasibility of Grazing/Browsing. Grazing appears to be physically feasible although vegetation in this area is mostly forested with chaparral in the center of the area. Chaparral and forest are inappropriate vegetation types for grazing/browsing due to poor forage quality of plants and potential for damage to non-target plants. Non-native annual grassland, which occurs along the western border is suitable for grazing. Wet meadows that support Mt. Tamalpais thistle and harlequin lotus could be grazed individually or in conjunction with larger areas. Grazing should not take place where marsh zigadenus occurs due to the potential of poisoning livestock. Small patches of serpentine grassland are isolated and grazing in these areas is likely infeasible.

Cattle grazing in contiguous non-native annual grassland and oak woodland could occur from late winter to spring to reduce the abundance of exotic annual grasses while promoting increased native species richness and cover. Grazing could also be considered in contiguous grassland west of this area to improve habitat and prevent establishment and/or spread of invasive species, including yellow starthistle. Grazing infrastructure would need to be provided by contract graziers to keep animals off main roads and contained in treatment areas.

Expected Success of Grazing/Browsing Treatments. Due to the number of target species with competing needs, establishing a grazing program that could effectively meet all relevant objectives would be difficult. Wet meadows that support Mt. Tamalpais thistle and harlequin lotus could be grazed, but the level of grazing needed to damage Harding grass and tall fescue would likely also damage the rare plants. Hand removal would likely be more effective at reducing or eliminating tall fescue and Harding grass without damaging rare plants.

5. Pumpkin Pine-Fish-Lag Meadows, 179 acres.
Targets. French broom, common velvet grass, Harding grass, harlequin lotus and marsh zigadenus.

Primary Objectives. Decrease broom seed production and young plants; and enhance habitat for harlequin lotus and marsh zigadenus by reducing common velvet grass, Harding grass, and exotic annual grasses.

Feasibility of Grazing/Browsing. Grazing appears to be physically feasible in this area as terrain is generally appropriate. Suitable forage is available in grassland areas where common velvet grass, Harding grass, and harlequin lotus occur. Grazing should not take place where marsh zigadenus occurs due to the potential of poisoning livestock.

Expected Success of Grazing/Browsing Treatments. Some reduction of French broom seedlings and defoliation of larger plants would likely be achieved with browsing by sheep and/or goats, although grazier interviews indicate that toxicity may be an issue for these animals. Reduction of common velvet grass and Harding grass by grazing may require cattle and is questionable due to the fact that intensive grazing would be required, which may damage harlequin lotus. Additionally, due to overlap of marsh zigadenus and common velvetgrass , it would be difficult to treat all of the common velvetgrass, since areas containing marsh zigadenus should not be grazed.

6. Deer Park-Worn Spring North, 138 acres
Targets. Fuelbreak management, broom species, potential future Harding grass, common velvet grass, and yellow starthistle in grassland and oak savannah based on proximity of nearby occurrences of these species.

Primary Objectives. Decrease broom seed production and young plants; fuelbreak management; and prevention of Harding grass, common velvet grass, and yellow starthistle invasion from nearby occurrences.

Feasibility of Grazing/Browsing. Terrain does not pose an obstacle to grazing, although adequate forage is not provided by broom alone where infestations are dense, so any grazed/browsed areas would have to include adequate additional vegetation to sustain livestock without damaging non-target vegetation (e.g., chaparral, woodland).

Expected Success of Grazing/Browsing Treatments. Some reduction of French broom seedlings and defoliation of larger plants would likely be achieved with browsing by sheep and/or goats, although grazier interviews indicate that toxicity may be an issue for these animals. Fuelbreak management may be successful with browsing/grazing livestock depending on vegetation species composition and maturity of woody plants.

7. Bill Williams-Indian Crown, 18 acres
Targets. Broom, fuelbreak, eggleaf spurge.

Primary Objectives. Decrease of broom seed production and young plants (low-to medium-density broom); reduction/management of a population of eggleaf spurge in the central portion of the area immediately west of Indian Road; and fuelbreak management.

Feasibility of Grazing/Browsing. This is a small, narrow, steep site, directly abutting an urban interface to the east. Sheep and/or goats could traverse the steep terrain.

Expected Success of Grazing/Browsing Treatments. Some reduction of seedlings and defoliation of larger plants in the dense French broom patches that occur mostly along the eastern half of this area at the urban interface would likely be achieved with browsing by sheep and/or goats, although grazier interviews indicate that toxicity may be an issue for these animals. If hand removal of eggleaf spurge is infeasible, targeted late spring to summer goat grazing may reduce eggleaf spurge, but is not expected to eliminate this plant. Fuelbreak management may be successful with browsing/grazing livestock depending on vegetation species composition and maturity of woody plants.

8. Fawn Ridge-Deer Park, 57 acres
Targets. Broom, Harding grass, eggleaf spurge

Primary Objectives. Decrease broom seed production and young plants; reduction/management of Harding grass, reduction/management of eggleaf spurge; and fuelbreak management.

Feasibility of Grazing/Browsing. Grazing appears to be physically feasible in this area since terrain is appropriate, but grassland patches are largely disjunct and adjacent woodland has a nearly closed canopy, offering limited suitable forage. Due to the widespread distribution of broom, management would be best achieved in small, temporary enclosures areas to allow for better management of browsing behavior focusing on broom while avoiding impacts to woody communities and native plants.

Expected Success of Grazing/Browsing Treatments. Some reduction of French broom seedlings and defoliation of larger plants would likely be achieved with browsing by sheep and/or goats, although grazier interviews indicate that toxicity may be an issue for these animals. If hand removal of eggleaf spurge is infeasible, targeted late spring to summer goat grazing may reduce eggleaf spurge, but is not expected to eliminate this plant. Harding grass could be reduced by targeted, intensive grazing focused on this plant, but would not be eliminated by grazing. Fuelbreak management may be successful with browsing/grazing livestock depending on vegetation species composition and maturity of woody plants.

9. Azalea Hill, 231 acres
Targets. Marin western flax (in serpentine grassland and chaparral), barbed goatgrass, Mt. Tamalpais thistle (in serpentine seeps), and common velvet grass in non-serpentine grasslands.

Primary Objectives. Manage/reduce barbed goatgrass and other annual grasses that threaten Marin western flax; enhance Mt. Tamalpais thistle habitat; decrease of broom seed production and young plants; and reduce/manage common velvet grass.

Feasibility of Grazing/Browsing. Grazing is feasible in this area although numerous factors, including the localized occurrences of rare plants and invasive weeds and varying RDM[8] requirements for serpentine and annual grassland communities, complicate grazing management. In general, late winter to spring moderate intensity cattle grazing may reduce abundance of exotic annual grasses while promoting increased native species richness and cover.

Grazing for only a two- to three-week period after plants have bolted but prior to production of unpalatable flower heads may help control barbed goatgrass (Brownsey et al. 2016).

The area supporting Marin western flax and Mt. Tamalpais thistle could be grazed to reduce exotic annual grasses and thatch. Cattle grazing would be preferred over goat and/or sheep grazing, due to the increased ability for sheep and goats to selectively graze forbs and the possible damage to Mt. Tamalpais thistle by goats. If grazing occurs in areas supporting Marin western flax and Mt. Tamalpais thistle, plants should be carefully monitored to ensure impacts to this population are minimized. Grazing could be excluded during Marin western flax flowering, which can occur from April through July, though year-round cattle grazing appears to be compatible with Marin western flax on cattle-grazed sites within GGNRA.

Expected Success of Grazing/Browsing Treatments. Common velvet grass could be reduced, but not eliminated, by targeted, intensive grazing focused on this plant. Habitat for Mt. Tamalpais thistle and Marin dwarf flax may be enhanced through reduction of exotic annual grasses, including barbed goatgrass, with cattle grazing.

Some reduction of French broom seedlings and defoliation of larger plants in dense patches occurring mostly along the eastern half of this area at the urban interface may occur with sheep and/or goat browsing, although grazier interviews indicate that toxicity may be an issue for these animals.

10. Pine Mountain South Gate, 58 acres
Targets. Marin western flax, barbed goatgrass, and broom.

Primary Objectives. Manage/reduce barbed goatgrass and other annual grasses that threaten Marin western flax; and decrease broom seed production and young plants in low-density patches along the western perimeter adjacent to Fairfax-Bolinas Road.

Feasibility of Grazing/Browsing. Grazing is feasible in this relatively small area but numerous factors, including the localized occurrences of rare plants and invasive weeds and varying RDM[8] requirements for serpentine and annual grassland communities, complicate grazing management. The area supporting Marin western flax could be grazed to reduce exotic annual grasses and thatch. Cattle grazing would be preferred over goat and/or sheep grazing in areas that support Marin western flax, due to the increased ability for sheep and goats to selectively graze forbs, which could damage Marin western flax plants. If grazing occurs in areas supporting Marin western flax, plants should be carefully monitored to ensure impacts to this population are minimized. Grazing could be excluded during Marin western flax flowering, which can occur from April through July, though year-round cattle grazing appears to be compatible with Marin western flax on cattle-grazed sites within GGNRA.

Expected Success of Grazing/Browsing Treatments. Habitat for Mt. Tamalpais thistle and Marin dwarf flax may be enhanced through reduction of exotic annual grasses, including barbed goatgrass, with cattle grazing.

Some reduction of French broom seedlings and defoliation of larger plants in dense patches occurring mostly along the eastern half of this area at the urban interface may occur with sheep and/or goat browsing, although grazier interviews indicate that toxicity may be an issue for these animals.

11. Bathtub Gap-Carson Ridge, 207 acres
Targets. Marsh zigadenus, Mt. Tamalpais thistle, Marin western flax.

Primary Objectives. Enhance wet meadow habitat for Mt. Tamalpais thistle and marsh zigadenus; and manage annual grasses to reduce thatch where Marin western flax occurs.

Feasibility of Grazing/Browsing. Generally, grazing is feasible within this area, but should not take place where marsh zigadenus occurs due to the potential of poisoning livestock. Significant grazable acreage occurs in this area although grasslands are a mosaic of native serpentine and non-native annual grassland types.

The area supporting Marin western flax could be grazed to reduce exotic annual grasses and thatch. Cattle grazing would be preferred over goat and/or sheep grazing in areas that support Marin western flax, due to the increased ability for sheep and goats to selectively graze forbs, which could damage Marin western flax plants. If grazing occurs in areas supporting Marin western flax, plants should be carefully monitored to ensure impacts to this population are minimized. Grazing could be excluded during Marin western flax flowering, which can occur from April through July, though year-round cattle grazing appears to be compatible with Marin western flax on cattle-grazed sites within GGNRA.

Expected Success of Grazing/Browsing Treatments. Cattle grazing may enhance habitat for Mt. Tamalpais thistle and Marin dwarf flax through reduction of exotic annual grasses, including barbed goatgrass.

12. Poison Spring Grasslands, 121 acres
Targets. Native grassland species.

Primary Objectives. Enhancement of native grassland species by reducing grassland canopy density and thatch.

Feasibility of Grazing/Browsing. The chaparral and dense oak woodland within this area, which have little herbaceous forage, are unsuitable for grazing, but contiguous open grassland in the eastern portion of the area is suitable forage for livestock grazing.

Expected Success of Grazing/Browsing Treatments. Moderate intensity, late-winter to spring cattle grazing in grasslands is expected to reduce exotic annual grasses while increasing native species richness and cover.

13. Kent Pump Beginning, 53 acres
Targets. French broom.

Primary Objectives. Decrease broom seed production and young plants.

Feasibility of Grazing/Browsing. The dominance of dense mixed hardwood forest interspersed with patchy areas of chaparral mean that relatively little suitable livestock forage is available in this area. Several areas supporting French broom are identified along the eastern perimeter of this area adjacent to Kent Pump Road. However, these areas are isolated, consist of few pioneer individuals, and are not suitable for grazing management. Two non-contiguous grassland patches (21 and 28 acres, respectively) could support cattle grazing but their relatively small size, isolation, and infrastructure costs make grazing in these areas potentially infeasible.

Expected Success of Grazing/Browsing Treatments. Low success expected for reduction of broom by grazing/browsing.

14. Grassy Knoll, 4 acres
Targets. Native grassland species, medium-density broom in the northwest portion of the area along Grassy Slope Road in grasslands or oak woodlands with reduced canopy cover.

Primary Objectives. Enhancement of native grassland species by reduction of grassland canopy density and thatch; and reduction/management of broom.

Feasibility of Grazing/Browsing. The majority of this four-acre area is dominated by dense Douglas-fir/mixed hardwood forest with several small grassland openings in the north and south portions. Cattle grazing, which could benefit native grassland species, is infeasible in this area due the small grazable area (four acres). Sheep/goat browsing could be used to reduce seed production and small broom plants.

Expected Success of Grazing/Browsing Treatments. Grazing not feasible.

15. Cascade Creek, 101 acres
Targets. French broom and native grassland species.

Primary Objectives. Enhancement of native grassland species by reduction of grassland canopy density and thatch; and reduction/management of one small occurrence of French broom.

Feasibility of Grazing/Browsing. Grazing is feasible in this area within oak woodland and grassland, which would provide adequate forage for animals.

Expected Success of Grazing/Browsing Treatments. Grazing is expected to enhance native grassland species and some reduction of French broom seedlings and defoliation of larger plants would likely be achieved with browsing by sheep and/or goats, although grazier interviews indicate that toxicity may be an issue for these animals.

16. Midpoint Meadows, 38 acres
Targets. Mt. Tamalpais thistle, marsh zigadenus, and yellow starthistle.

Primary Objectives. Enhance habitat for Mt. Tamalpais thistle and marsh zigadenus by reduction of woody forest species; and reduce the one occurrence of yellow starthistle.

Feasibility of Grazing/Browsing. Grazing is feasible within this small area but would be complicated by the fact that marsh zigadenus, which should not be grazed due to its toxicity, co-occurs with Mt. Tamalpais thistle in one location. If marsh zigadenus is excluded from grazing, the area supporting Mt. Tamalpais thistle where marsh zigadenus does not occur could be grazed to reduce exotic annual grasses and thatch. Cattle or sheep grazing would be preferred over goat grazing, due to the potential for goats to damage Mt. Tamalpais thistle. Plants should be carefully monitored to ensure impacts to this population are minimized.

Expected Success of Grazing/Browsing Treatments. Sheep grazing would likely help slow woody plant invasion, although sheep will probably not kill woody plants larger than seedlings or small saplings. Reduction of yellow starthistle may be possible with short-duration, high-intensity goat grazing, although hand removal is probably more cost effective especially where occurrences are small or isolated.

7.2 Summary of Grazing/Browsing Effectiveness

Only one of the 16 grazing areas described in Section 7.1 above appears to have no feasibility for grazing: Grassy Knoll. Only one has high feasibility (both high expected effectiveness to meet management objectives and high cost-effectiveness): Poison Spring Grasslands. Seven others have low feasibility (combined effectiveness). However, 15 grazing areas have some degree of feasibility and would likely be grazed by a contract grazier if paid appropriately for the service.

Table 3 summarizes the study team's judgments about effectiveness of grazing at each of the potential grazing areas. Ranks are shown to indicate the priority that MMWD might give to each grazing area if they decide to proceed with further investigations, grazing plans, and eventual grazing contracts. It also indicates where to focus MMWD's initial testing of targeted grazing as a vegetation management method.

Table 3. Summary ranking of grazing and browsing effectiveness at potential grazing areas (high, medium, or low)

Potential Grazing Area	Rank for Expected Effectiveness in Meeting Management Objectives	Rank for MMWD Cost Effectiveness	Combined Rank
1. Sky Oaks	Medium	Medium	Medium
2. Porteous-Ross Reservoir-Worn Spring Middle	Medium	Low	Low+
3. Pilot Knob	Low	Low	Low
4. Ridgecrest-Rock Spring-Potrero	Low	Medium	Low+
5. Pumpkin Pine-Fish-Lag Meadows	Medium	Medium	Medium
6. Deer Park-Worn Spring North	Medium	Low	Low+
7. Bill Williams-Indian Crown	Medium	Low	Low+
8. Fawn Ridge-Deer Park	Medium	Low	Low+
9. Azalea Hill	Medium	Medium	Medium
10. Pine Mountain South Gate	Medium	Medium	Medium
11. Bathtub Gap-Carson Ridge	High	Medium	Medium+
12. Poison Spring Grasslands	High	High	High
13. Kent Pump Beginning	Low	Low	Low
14. Grassy Knoll	N/A	Low	N/A
15. Cascade Creek	Medium	Medium	Medium
16. Midpoint Meadows	High	Medium	Medium+

8. Potential Environmental Impacts of Grazing

The following outline identifies categories of potential environmental impacts, including impacts to public recreation, that could occur if the feasible grazing scenarios are implemented at suitable treatment sites on MTW Lands:

1. Rangeland Livestock and Livestock Operations
    a) Livestock Physical Mechanisms
        - Behavior—preference for forages, trailing
        - Traffic—hoof impact, presence in waters
    b) Grazier Operation Mechanisms
        - Associated facilities and vehicle parking
        - Vehicle traffic on internal and external roads and internal off-road
        - Service areas (sites of potentially excessive impact associated with supplementary feeding, watering, gathering, and travel along fences and through gates)
        - Installation and maintenance of grazing infrastructure

2. General Rangeland Ecosystem Health (Ford and Huntsinger 2007; BLM 1999)
    a) Forage Productivity and Quality
        - Poor forage condition requiring supplementation
    b) Soil Integrity and Cover (Bartolome, Frost, and McDougald 2006)
        - Erosion
        - Compaction, pitted, or muddy conditions
        - Too little or too much RDM[8] and cover in grasslands
    c) Water Quality and Watershed Health (Ward, Tate, and Atwill 2003)
        - Pathogens
        - Nutrients
        - Sediments
        - Hydrology—reduced infiltration, ground water retention, and water supply
    d) Pest Plants (Cal-IPC)
        - Increase of current infestations
        - New infestations
        - Spread of pest plants to adjacent properties
    e) Absence of Comprehensive Plans for Grazing Management, Monitoring, and Adaptation
        - Lack of compliance by grazier and lack of feedback by managers
        - Lack of accurate and tested grazing management objectives and performance standards
        - Lack of monitoring program with interpretation and sharing of results, reports, and recording system
        - Lack of adaptation of plans based on monitoring results and feedback according to triggering and response system

3. Ecological Integrity (USEPA 1999)
    a) Fragmentation of Habitat and Corridors between Habitat Patches
    b) Lack of Appropriate Disturbance Regimes
    c) Insufficient Structural Complexity
    d) Lack of Integration of Grazing with Other and Adjacent Land Uses

4. Desired Characteristics of Special-Status Species and Natural Communities (CDFW https://www.wildlife.ca.gov/Data/VegCAMP/Natural-Communities)
    a) Open grassland character
    b) Native grasses
    c) Oak woodland regeneration
    d) High-quality riparian woodlands and wetlands

5. Cultural Resource Integrity

6. Fire Fuels and Wildfire Risks (Stechman 1983)
    a) Excess fuels in High Risk Zones

7. Recreation and Aesthetics (Wolf, Baldwin, and Barry 2015; CCRC workshops http://www.elkhornsloughctp.org/training/show_train_detail.php?TRAIN_ID=Op891WS; http://www.elkhornsloughctp.org/training/show_train_detail.php?TRAIN_ID=KeK6VVR)
    a) Lack of Recreational Compatibility
        - Conflicts on internal MMWD roads and trails—perceived damage and threats; encounters with livestock, hoof imprints, and livestock waste; and encounters associated with off-leash dogs
        - Damage associated with a combination of recreational, maintenance, and livestock uses, including damage to cultural and aesthetic resources, littering, and disturbances to wildlife that alter their behavior
        - Mechanisms of potential impact (conflicts)—poor drainage on trails and roads, unhardened trail treads through vulnerable soils, and forced encounters due to merging or proximity of trails and grazing infrastructure
    b) Landscape Views—perceived damage associated with service areas and lack of appreciation of viewing livestock or pastoral settings
    c) Lack of Perception of Wilderness
    d) Potential Mitigations—novel approaches to public education and collaborative land management and better design and placement of trails and infrastructure

In addition to the listing of literature cited (next section), general references on grazing impact topics that may be useful to MMWD planners include:

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APPENDIX 1. Memo from Andrea Williams, MMWD (14 August 2017) – Plant Species to Potentially Target with Grazing

MARIN MUNICIPAL WATER DISTRICT

220 Nellen Avenue Corte Madera CA 94925-1169
www.marinwater.org

August 14, 2017
MA 5535

To: Lawrence Ford, LD Ford Rangeland Conservation Science
From: Andrea Williams, Marin Municipal Water District
Cc: Lisa Bush, Pete Van Hoorn, Justin Davilla
Re: Marin Municipal Water District Species Selection Background

The Marin Municipal Water District (MMWD) stewards over 20,000 acres of watershed lands, supporting over 1,000 plant species, water for 190,000 residents, and recreation for millions of visitors. More than 50 of these plants are considered rare by the state or federal government or the California Native Plant Society; over 100 are listed as invasive by the California Invasive Plant Council. In order to limit the scope of the contract, a maximum of 12 plant species are to be considered in potential grazing scenarios.

I made selections of priority species based on how prevalent the species was on watershed lands potentially subject to grazing; whether the species may serve as a representative for other similar species; and whether the population may be influenced by grazing. MMWD staff also decided to remove Nicasio and Soulajule lands from consideration, which further reduced potential species selection. These lands—Nicasio in particular—may be evaluated for grazing at a future date. Additionally, if grazing is shown to be feasible and beneficial on watershed lands, grazing plans will provide an additional opportunity to examine potential effects on species not currently included in this study.

Rare Plants Selected (Table 1):
Mt. Tamalpais thistle is a biennial plant that grows in wet, serpentine-influenced sites. Approximately 12 sites are extant in the county, nine of which are on watershed lands. This species is declining for several reasons: changes in hydrology, shading at forest edge sites, and lack of bare ground in wet meadow sites. Well-meaning but ignorant individuals may be killing plants, but other than a planted site we have no direct evidence of this. Mt. Tam thistle was chosen as a broadly distributed but rare and declining species, endemic and emblematic of the watershed, that may benefit from well-managed grazing.

Marin western flax is our only extant federally listed species within the area of focus. It can be found in three sites on watershed lands in serpentine grassland and edges of chaparral. Thought to be on the decline due to competition from other plants, it may also benefit from well-managed grazing.

Harlequin lotus grows in wet meadows on seven sites across the watershed. A low-growing, short-lived perennial, this species overlaps at one site with Mt. Tam thistle but otherwise is found in non-serpentine wet meadows on the watershed. It may be declining from a combination of hydrologic changes and competition from invasive plants (particularly perennial grasses).

Marsh zigadenus is another wet-meadow species, but it can be found in chaparral as well, and has an affinity to serpentine soils. So far it has been mapped at 18 locations across the watershed. A geophyte, and poisonous, it is unknown how the species will respond to grazing.

Rare Plants Not Selected (Table 2):
Most of the rare taxa were excluded from consideration because they were too uncommon, or grew in habitats unlikely to be grazed.

Weed Species Selected (Table 3):
Weedy plants were difficult to narrow down, but species chosen were those on which we currently spend the most time and/or money on, and those which are affecting the most high-quality habitat.

Weed Species Not Selected (Tables 4 and 5):
With over 100 weeds included on the Cal-IPC of Invasive Plant Inventory, giving a rationale for each would be time-consuming. Species that were uncommon or rare (Table 5) were not selected based on their low abundance; Table 4 contains rationales for more common species. Several of these were excluded simply due to lack of space on the priority list.

Native Species:
Not included are native woody species tanoak (*Notholithocarpus densiflorus*), coyote brush (*Baccharis pilularis*), and chaparral pea (*Pickeringia montana*), which also make up a large portion of our fuel reduction work. If there is time, some or all of these may be added to the list of species considered.

Table 1. Rare plant species selected for consideration

Scientific Name	Common Name	Lifeform	CRPR	CESA	FESA	Blooming Period	Habitat	MMWD Status*
Cirsium hydrophilum var. vaseyi	Mt. Tamalpais thistle	perennial herb	1B.2	None	None	May-Aug (Sep)	Meadows and seeps, serpentinite	C
Hesperolinon congestum	Marin western flax	annual herb	1B.1	CT	FT	Apr-Jul	Chaparral, grassland, serpentinite	R
Hosackia gracilis	harlequin lotus	perennial rhizomatous herb	4.2	None	None	Mar-Jul	Meadows and seeps	C
Toxicoscordion fontanum	marsh zigadenus	perennial bulbiferous herb	4.2	None	None	Apr-Jul (Aug)	Chaparral, meadows and seeps, serpentinite	C

Table 2. Rare plant species not selected

Scientific Name	Common Name	Lifeform	CRPR	CESA	FESA	Blooming Period	Habitat	MMWD Status*	Reason Excluded
Amorpha californica var. *napensis*	Napa false indigo	perennial deciduous shrub	1B.2	None	None	Apr-Jul	Broadleafed upland forest (openings)	C	Forest dweller
Amsinckia lunaris	bent-flowered fiddleneck	annual herb	1B.2	None	None	Mar-Jun	Coastal bluff scrub	WP	Unconfirmed/outside area of focus
Arabis blepharophylla	coast rockcress	perennial herb	4.3	None	None	Feb-May	Broadleafed upland forest, rocky	R	Single population in ungrazeable area
Arctostaphylos montana ssp. *montana*	Mt. Tamalpais manzanita	perennial evergreen shrub	1B.3	None	None	Feb-Apr	Chaparral, serpentinite	A	Abundant; unlikely to be affected by grazing
Arctostaphylos virgata	Marin manzanita	perennial evergreen shrub	1B.2	None	None	Jan-Mar	Forest openings, chaparral	R	Habitat succession /lack of fire reason for loss; unlikely to be affected by grazing
Aspidotis carlotta-halliae	Carlotta Hall's lace fern	perennial rhizomatous herb	4.2	None	None	Jan-Dec	Chaparral, woodland, rock outcrops; usually serpentinite	I	Incomplete knowledge of distribution
Astragalus breweri	Brewer's milk-vetch	annual herb	4.2	None	None	Apr-Jun	Meadows and seeps, grassland (often gravelly/ serpentinite)	R	Single population
Calamagrostis ophitidis	serpentine reed grass	perennial herb	4.3	None	None	Apr-Jul	Chaparral, meadows and seeps, grassland; serpentinite	A	Abundant; unlikely to be affected by grazing

Scientific Name	Common Name	Lifeform	CRPR	CESA	FESA	Blooming Period	Habitat	MMWD Status*	Reason Excluded
Calandrinia breweri	Brewer's calandrinia	annual herb	4.2	None	None	(Jan)Mar-Jun	Chaparral, Coastal scrub	R	Small annual in rocky, open areas unsuitable for grazing
Calochortus umbellatus	Oakland star-tulip	perennial bulbiferous herb	4.2	None	None	Mar-May	Chaparral, grassland; often serpentinite	A	Abundant; considered, but likely avoidance measures known
Calochortus uniflorus	pink star-tulip	perennial bulbiferous herb	4.2	None	None	Apr-Jun	Meadows and seeps	R	Only two populations
Calystegia collina ssp. *oxyphylla*	Mt. Saint Helena morning-glory	perennial rhizomatous herb	4.2	None	None	Apr-Jun	Chaparral, grassland; serpentinite	I	Ambiguous subspecies; in rocky, open areas unsuitable for grazing
Castilleja ambigua var. *ambigua*	johnny-nip	annual herb (hemiparasitic)	4.2	None	None	Mar-Aug	Marshes, grassland, vernal pools margins	R	Single population
Ceanothus decornutus	Nicasio ceanothus	perennial shrub	1B.2	None	None	Mar-May	Chaparral (maritime)	WR	Outside area of focus
Ceanothus gloriosus var. *exaltatus*	glory brush	perennial evergreen shrub	4.3	None	None	Mar-Jun(Aug)	Chaparral (maritime)	R	Single population in ungrazeable area
Ceanothus masonii	Mason's ceanothus	perennial evergreen shrub	1B.2	CR	None	Mar-Apr	Chaparral (maritime)	R	Single population in ungrazeable area
Cypripedium californicum	California lady's-slipper	perennial rhizomatous herb	4.2	None	None	Apr-Aug(Sep)	Bogs and fens, seeps and streambanks, usually serpentinite	X	Extirpated
Delphinium bakeri	Baker's larkspur	perennial herb	1B.1	CE	FE	Mar-May	Broadleafed upland forest, coastal scrub	WR	Outside area of focus
Dirca occidentalis	western leatherwood	perennial deciduous shrub	1B.2	None	None	Jan-Mar(Apr)	Riparian forest or woodland; greenstone	R	Populations in ungrazeable areas
Elymus californicus	California bottle-brush grass	perennial herb	4.3	None	None	May-Aug(Nov)	Forest openings, riparian woodland	C	Forest dweller
Eriogonum luteolum var. *caninum*	Tiburon buckwheat	annual herb	1B.2	None	None	May-Sep	Chaparral, grassland; serpentinite	A	Small annual in rocky, open areas unsuitable for grazing

Scientific Name	Common Name	Lifeform	CRPR	CESA	FESA	Blooming Period	Habitat	MMWD Status*	Reason Excluded
Fritillaria lanceolata var. *tristulis*	Marin checker lily	perennial bulbiferous herb	1B.1	None	None	Feb-May	Coastal scrub or prairie	WR	Outside area of focus
Fritillaria liliacea	fragrant fritillary	perennial bulbiferous herb	1B.2	None	None	Feb-Apr	Coastal prairie or scrub, often serpentinite	WR	Outside area of focus
Gilia capitata ssp. *tomentosa*	woolly-headed gilia	annual herb	1B.1	None	None	May-Jul	Coastal bluff scrub, grassland	WP	Unconfirmed/outside area of focus
Grindelia hirsutula var. *maritima*	San Francisco gumplant	perennial herb	3.2	None	None	Jun-Sep	Coastal scrub, grassland	P	Unconfirmed
Helianthella castanea	Diablo helianthella	perennial herb	1B.2	None	None	Mar-Jun	Forest, Chaparral, woodland, Coastal scrub, grassland	X	Extirpated
Hemizonia congesta ssp. *congesta*	congested-headed hayfield tarplant	annual herb	1B.2	None	None	Apr-Nov	Coastal grassland	WP	Unconfirmed/outside area of focus
Holocarpha macradenia	Santa Cruz tarplant	annual herb	1B.1	CE	FT	Jun-Oct	Coastal prairie, scrub, grassland	X	Extirpated
Horkelia tenuiloba	thin-lobed horkelia	perennial herb	1B.2	None	None	May-Jul(Aug)	Forest, Chaparral, grassland; wet or sandy spots	R	Few populations, largely in chaparral
Iris longipetala	coast iris	perennial rhizomatous herb	4.2	None	None	Mar-May	Coastal prairie, Meadows and seeps	WR	Outside area of focus
Kopsiopsis hookeri	small groundcone	perennial rhizomatous herb (parasitic)	2B.3	None	None	Apr-Aug	North Coast coniferous forest	R	Forest dweller
Leptosiphon acicularis	bristly leptosiphon	annual herb	4.2	None	None	Apr-Jul	Chaparral, grassland	R	Two small populations; may react to changes similar to Hesperolinon
Lessingia hololeuca	woolly-headed lessingia	annual herb	3	None	None	Jun-Oct	Coastal scrub, grassland	I	Unconfirmed
Lessingia micradenia var. *micradenia*	Tamalpais lessingia	annual herb	1B.2	None	None	(Jun)Jul-Oct	Chaparral, grassland; serpentinite	C	Small annual in rocky, open areas unsuitable for grazing

Scientific Name	Common Name	Lifeform	CRPR	CESA	FESA	Blooming Period	Habitat	MMWD Status*	Reason Excluded
Micropus amphibolus	Mt. Diablo cottonweed	annual herb	3.2	None	None	Mar-May	Broadleafed upland forest, Chaparral, woodland, grassland; rocky sites	I	Unconfirmed
Microseris paludosa	marsh microseris	perennial herb	1B.2	None	None	Apr-Jun(Jul)	Forest, woodland, coastal scrub, grassland	X	Extirpated (1940s specimen from Summit Ave Ridge)
Navarretia rosulata	Marin County navarretia	annual herb	1B.2	None	None	May-Jul	Forest, chaparral; rocky serpentinite	C	Small annual in rocky, open areas unsuitable for grazing
Pentachaeta bellidiflora	white-rayed pentachaeta	annual herb	1B.1	CE	FE	Mar-May	Woodland, grassland (often serpentinite)	X	Extirpated
Perideridia gairdneri ssp. *gairdneri*	Gairdner's yampah	perennial herb	4.2	None	None	Jun-Oct (Mar-Apr)	Grassland, vernal pools	R	Single population
Pityopus californicus	California pinefoot	perennial herb (achlorophyllous)	4.2	None	None	May-Aug	Forests, often wet	RI	Forest dweller
Pleuropogon hooverianus	North Coast semaphore grass	perennial rhizomatous herb	1B.1	CT	None	Apr-Jun	Forest openings, meadows and seeps	X	Extirpated
Pleuropogon refractus	nodding semaphore grass	perennial rhizomatous herb	4.2	None	None	(Mar)Apr-Aug	Forests, meadows and seeps	X	Extirpated
Quercus parvula var. *tamalpaisensis*	Tamalpais oak	perennial evergreen shrub	1B.3	None	None	Mar-Apr	Forests	I	Forest dweller
Ranunculus lobbii	Lobb's aquatic buttercup	annual herb (aquatic)	4.2	None	None	Feb-May	Woodland, coniferous forest, grassland, vernal pools; wet sites	X	Extirpated
Ribes victoris	Victor's gooseberry	perennial deciduous shrub	4.3	None	None	Mar-Apr	Broadleafed upland forest, chaparral; wet, shady openings	X	Extirpated

Scientific Name	Common Name	Lifeform	CRPR	CESA	FESA	Blooming Period	Habitat	MMWD Status*	Reason Excluded
Sidalcea hickmanii ssp. *viridis*	Marin checkerbloom	perennial herb	1B.1	None	None	May-Jun	Chaparral (serpentinite)	X	Extirpated
Stebbinsoseris decipiens	Santa Cruz microseris	annual herb	1B.2	None	None	Apr-May	Coastal scrub, grassland; open, sometimes serpentinite	R	Unconfirmed; at most one population in ungrazeable area
Streptanthus batrachopus	Tamalpais jewelflower	annual herb	1B.3	None	None	Apr-Jul	Closed-cone coniferous forest, chaparral; serpentinite	R	Small annual in rocky, open areas unsuitable for grazing
Streptanthus glandulosus ssp. *pulchellus*	Mt. Tamalpais bristly jewelflower	annual herb	1B.2	None	None	May-Jul(Aug)	Chaparral, grassland; serpentinite	C	Small annual in rocky, open areas unsuitable for grazing
Trifolium amoenum	two-fork clover	annual herb	1B.1	None	FE	Apr-Jun	Coastal bluff scrub, grassland (sometimes serpentinite)	X	Extirpated

MMWD Status*

A=Abundant (>30 pops or >100 ac)
C=Common (>3 pops)
R=Rare (3 or fewer pops)
I=Incomplete information
W=Nicasio or Soulajule (West Marin)
P=Possible (presence unconfirmed)
X=Extirpated

Table 3. Weed species selected for consideration.

Scientific Name	Common Name	Lifeform	Habitat on watershed	Comments
Aegilops triuncialis	Goatgrass	Annual	Grassland, often serpentine	Populations large, accessible; currently hand-pull populations annually
Centaurea solstitialis	Yellow starthistle	Annual	Grassland, occasionally serpentine	Populations large, accessible; currently hand-pull populations annually
Conium maculatum	Poison hemlock	Perennial	Wet meadows and scrub, often disturbed areas	Poisonous to people; not currently managed; don't want to increase populations by disturbing wet meadows
Euphorbia oblongata	Eggleaf spurge	Perennial	Grasslands, woodlands, forest edges	Spreading quickly; some sites managed
Festuca arundinacea	Reed fescue	Perennial	Wet meadows and grasslands	Populations large, accessible; currently hand-dig outlier populations in high-value habitat
Genista monspessulana	French broom	Shrub	Woodlands, grasslands, scrub, riparian corridors	Over 1400 acres infested; at max effort can hand-pull approximately 700
Holcus lanatus	Common velvetgrass	Perennial	Wet meadows and grasslands	Spreading in wet areas and high-value habitat
Phalaris aquatica	Harding grass	Perennial	Wet meadows and grasslands	Populations large; currently hand-dig outlier populations in high-value habitat

Table 4. Common weed species not selected

Scientific Name	Common Name	Lifeform	MMWD Status*	Habitat on watershed	Reason Excluded
Aira caryophyllea	Silvery hairgrass	Annual	A	Grasslands on thin/poor soil	Not impactful
Allium triquetrum	White flowered onion	Perennial	C	Forest edges, often moist areas	Not impactful or in grazeable areas
Anthoxanthum odoratum	Sweet vernal grass	Annual	C	Grasslands	Considered; second-tier species
Avena barbata	Slim oat	Annual	A	Grasslands	Impacts grassland composition but not fuels, recreation, or rare species management
Brachypodium distachyon	Purple false brome	Annual	A	Grasslands on thin or poor soil, sometimes serpentine	Considered; possibly unpalatable due to high silica content
Briza maxima	Rattlesnake grass	Annual	A	Grasslands	Impacts grassland composition but not fuels, recreation, or rare species management
Bromus diandrus	Ripgut brome	Annual	A	Grasslands	Impacts grassland composition but not fuels, or rare species management
Bromus hordeaceus	Soft chess	Annual	A	Grasslands	Impacts grassland composition but not fuels, recreation, or rare species management

Scientific Name	Common Name	Lifeform	MMWD Status*	Habitat on watershed	Reason Excluded
Bromus madritensis ssp. rubens	Foxtail brome	Annual	C	Grasslands	Impacts grassland composition but not fuels or rare species
Carduus pycnocephalus	Italian thistle	Annual	A	Grasslands and scrub, generally disturbed sites	Does not impact fuels or rare species managementl often in disturbed sites
Centaurea melitensis	Tocalote	Annual	C	Grasslands, generally disturbed sites	Usually in already disturbed sites, not a habitat converter
Cirsium vulgare	Bullthistle	Perennial	C	Grasslands and scrub	Usually in already disturbed sites, not a habitat converter
Cotoneaster pannosus	Woolly cotoneaster	Shrub	C	Forests, scrub	Considered; palatable to deer
Crataegus monogyna	Hawthorn	Shrub	C	Forests, scrub, grasslands	Considered; palatable to deer once cut to below browse line
Crocosmia Xcrocosmiiflora	Monbretia	Perennial	C	Wetland-riparian	In ungrazeable areas
Cynodon dactylon	Bermuda grass	Perennial	C	Wet grasslands	Impacts grassland composition but not fuels, recreation, or rare species management
Cynosurus echinatus	Dogtail grass	Annual	A	Grasslands	Impacts grassland composition but not fuels, recreation, or rare species management
Cytisus scoparius	Scotch broom	Shrub	C	Grasslands and scrub	Possibly covered under French broom
Dactylis glomerata	Orchardgrass	Perennial	A	Grasslands	Impacts grassland composition but not fuels, recreation, or rare species management
Ehrharta erecta	Upright veldt grass	Perennial	C	Forests, scrub	Mostly in forests
Erodium cicutarium	Coastal heron's bill	Annual	C	Grasslands and scrub	Impacts grassland composition but not fuels, recreation, or rare species management
Festuca myuros	Rattail sixweeks grass	Annual	C	Grasslands, scrub, disturbed sites	Usually in already disturbed sites, not a habitat converter
Geranium dissectum	Wild geranium	Annual	C	Grasslands, scrub, disturbed sites	Usually in already disturbed sites, not a habitat converter
Geranium molle	Crane's bill geranium	Annual	C	Grasslands, scrub, disturbed sites	Usually in already disturbed sites, not a habitat converter
Helminthotheca echioides	Bristly ox-tongue	Annual	C	Grasslands, scrub, disturbed sites	Usually in already disturbed sites, not a habitat converter
Hypochaeris glabra	Smooth cats ear	Annual	C	Grasslands on thin/poor soil	Impacts grassland composition but not fuels, recreation, or rare species management
Hypochaeris radicata	Hairy cats ear	Perennial	A	Grasslands, scrub, disturbed sites	Usually in already disturbed sites, not a habitat converter
Medicago polymorpha	California burclover	Annual	C	Moist grasslands, disturbed sites	Usually in already disturbed sites, not a habitat converter

Scientific Name	Common Name	Lifeform	MMWD Status*	Habitat on watershed	Reason Excluded
Mentha pulegium	Pennyroyal	Perennial	A	Wetlands	Unlikely to be grazed
Myosotis latifolia	Wide leaved forget me not	Perennial	A	Forest edges	Most sites along disturbed roadsides, forest edges
Myriophyllum spicatum	Water milfoil	Perennial	C	Aquatic	Submerged aquatic
Oxalis pes-caprae	Bermuda buttercup	Perennial	C	Grasslands, scrub, disturbed sites	Most sites along disturbed roadsides, forest edges
Plantago lanceolata	Ribwort	Perennial	A	Grasslands, scrub, disturbed sites	Usually in already disturbed sites, not a habitat converter
Poa pratensis	Kentucky blue grass	Perennial	A	Moist grasslands	Impacts grassland composition but not fuels, recreation, or rare species management
Polypogon monspeliensis	Annual beard grass	Annual	C	Wet, disturbed areas	Most sites along reservoir shores or in already disturbed zones
Rumex acetosella	Sheep sorrel	Perennial	A	Grasslands, scrub, disturbed sites	Impacts grassland composition but not fuels, recreation, or rare species management
Rumex crispus	Curly dock	Perennial	C	Wet sites	At the edge of common/uncommon; not apparently impactful where found
Rytidosperma penicillatum	Purple awned wallaby grass	Perennial	C	Grasslands, scrub, chaparral	Considered
Sonchus asper	Spiny sowthistle	Annual	C	Grasslands, scrub, disturbed sites	Usually in already disturbed sites, not a habitat converter
Spartium junceum	Spanish broom	Shrub	C	Grassland, rocky areas, scrub, riparian, disturbed sites	Possibly covered under French broom
Taraxacum officinale	Red seeded dandelion	Perennial	C	Grasslands, forest edge, scrub, disturbed sites	Usually in already disturbed sites, not a habitat converter
Torilis arvensis	Field hedge parsley	Annual	A	Grasslands, scrub, disturbed sites	Usually in already disturbed sites, not a habitat converter
Trifolium hirtum	Rose clover	Annual	A	Grasslands and scrub	Impacts grassland composition but not fuels, recreation, or rare species management
Vicia villosa	Hairy vetch	Annual	C	Grasslands	Impacts grassland composition but not fuels, recreation, or rare species management

Table 5. Weed species not selected due to rarity on watershed lands

Scientific Name	Common Name	Lifeform	MMWD Status*	Comment
Acacia dealbata	Silver wattle	Tree	R	
Acacia melanoxylon	Blackwood acacia	Tree	U	
Ageratina adenophora	Thoroughwort	Perennial	R	Population under manual control

Scientific Name	Common Name	Lifeform	MMWD Status*	Comment
Agrostis avenacea	Pacific bentgrass	Perennial	R	
Agrostis stolonifera	Redtop	Perennial	R	
Anthemis cotula	Dog fennel	Annual	P	
Arundo donax	Giant reed	Perennial	R	
Asparagus asparagoides	African asparagus fern	Vine	R	
Avena fatua	Wildoats	Annual	R	
Bellardia trixago	Mediterranean lineseed	Annual	W	
Bellis perennis	English lawn daisy	Perennial	R	Lawn weed
Bromus tectorum	Downy chess	Annual	U	Considered
Buddleja davidii	Butterfly bush	Tree	P	
Carthamus lanatus	Woolly distaff thistle	Annual	W	
Centaurea calcitrapa	Purple star thistle	Annual	U	Populations scattered, often roadside; able to hand-pull annually
Convolvulus arvensis	Field bindweed	Perennial	U	
Cordyline australis	Cabbage tree	Tree	R	
Cortaderia jubata	Andean pampas grass	Perennial	U	
Cotoneaster franchetii	Cotoneaster	Shrub	U	
Cotoneaster lacteus	Milkflower cotoneaster	Shrub	R	
Cotula coronopifolia	Brass buttons	Perennial	R	
Cytisus striatus	Portuguese broom	Shrub	R	Possibly covered under French broom
Delairea odorata	Cape ivy	Perennial	R	Populations under manual control
Digitalis purpurea	Foxglove	Perennial	R	Populations under manual control
Dipsacus fullonum	Wild teasel	Perennial	R	Populations under manual control
Dipsacus sativus	Indian teasel	Biennial	W	
Dittrichia graveolens	Stinkwort	Annual	R	Populations under manual control
Echium candicans	Pride of madeira	Shrub	R	
Egeria densa	Brazilian water weed	Perennial	U	Aquatic
Erigeron karvinskianus	Latin american fleabane	Perennial	R	
Erodium brachycarpum	White stemmed filaree	Annual	R	
Erodium moschatum	Whitestem filaree	Annual	R	
Eucalyptus globulus	Blue gum	Tree	R	

Scientific Name	Common Name	Lifeform	MMWD Status*	Comment
Ficus carica	Common fig	Tree	R	
Foeniculum vulgare	Fennel	Perennial	U	Populations controlled manually; sites small, dispersed
Hedera canariensis	Canary ivy	Vine	R	
Hedera helix	English ivy	Vine	U	
Helichrysum petiolare	Licorice plant	Shrub	P	
Hirschfeldia incana	Mustard	Perennial	U	
Hypericum perforatum	Klamathweed	Perennial	U	Biocontrol available
Ilex aquifolium	Holly	Tree	R	
Iris pseudacorus	Horticultural iris	Perennial	R	
Lactuca serriola	Prickly lettuce	Annual	U	Most of ours is L. saligna
Leucanthemum vulgare	Oxe eye daisy	Perennial	R	
Ligustrum lucidum	Glossy privet	Tree	R	
Lupinus arboreus	Coastal bush lupine	Shrub	W	
Marrubium vulgare	White horehound	Perennial	R	
Melilotus albus	White sweetclover	Annual	R	
Nerium oleander	Oleander	Tree	R	
Olea europaea	Olive	Tree	R	
Oxalis corniculata	Creeping wood sorrel	Perennial	U	
Pennisetum setaceum	Fountaingrass	Perennial	R	
Phoenix canariensis	Canary island date palm	Tree	R	
Plantago coronopus	Cut leaf plantain	Annual	R	
Prunus cerasifera	Cherry plum	Tree	U	
Pyracantha angustifolia	Firethorn	Shrub	U	Considered
Raphanus sativus	Jointed charlock	Annual	W	
Rubus armeniacus	Himalayan blackberry	Shrub	U	Considered
Senecio minimus	Coastal burnweed	Annual	U	
Silybum marianum	Milk thistle	Annual	U	
Ulex europaeus	Gorse	Shrub	R	Single small population
Vinca major	Vinca	Perennial	U	Populations under manual control
Watsonia meriana	Bulbil bugle lily	Perennial	P	
Zantedeschia aethiopica	Callalily	Perennial	R	

MMWD Status*
A=Abundant (>30 pops or >100 ac)
C=Common (>10 pops)
U=Uncommon (3-10 pops)
R=Rare (3 or fewer pops)
W=Nicasio or Soulajule (West Marin)
P=Possible (presence unconfirmed)

APPENDIX 2. Maps Prepared by Andrea Williams, MMWD (14 July 2017) – Potential Grazing Areas in Mt. Tamalpais Watershed

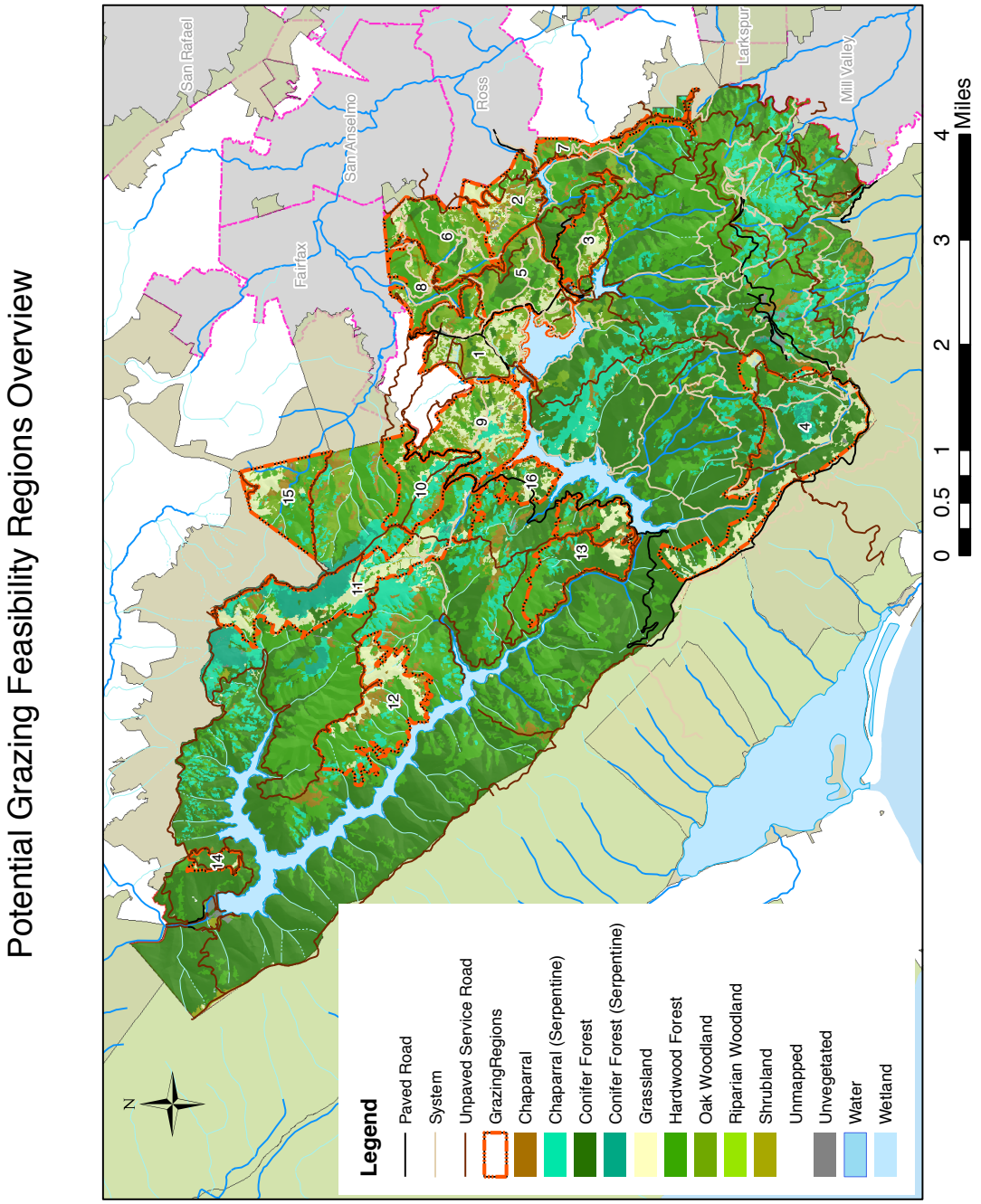
Notes on the Maps of Potential Grazing Areas with Major Vegetation Types and Infrastructure Prepared by A. Williams:

- These are preliminary maps for the potential grazing areas to be modified in a future Grazing Management Plan or other planning documents.
- Most areas are contiguous and boundaries are based on MMWD's existing vegetation management units rather than feasibility for grazing.
- The map numbers indicate the priority from most to least.
- Parking lots for recreational access as well as non-recreational access for graziers are shown as a magenta "P," and represent reasonable sites to stage grazing operations.
- Other existing infrastructure that could be used to support grazing are shown.
- No fencing exists around the grazing areas to contain the grazing livestock.
- In the spreadsheet (not maps), the vegetation layer is separate from the broom layer (i.e., broom is not its own veg type in the veg map) so the conditional formatting is as follows: deeper green means higher percentage of the region is a particular veg type (within-region comparison); deeper red means the region is more heavily broom-infested compared to other regions.
- *Brachypodium distachyon* occurs in most grasslands, although only points are shown.
- *Aegilops triuncialis* and *Centaurea solstitialis* occur as polygons, although only points are shown.

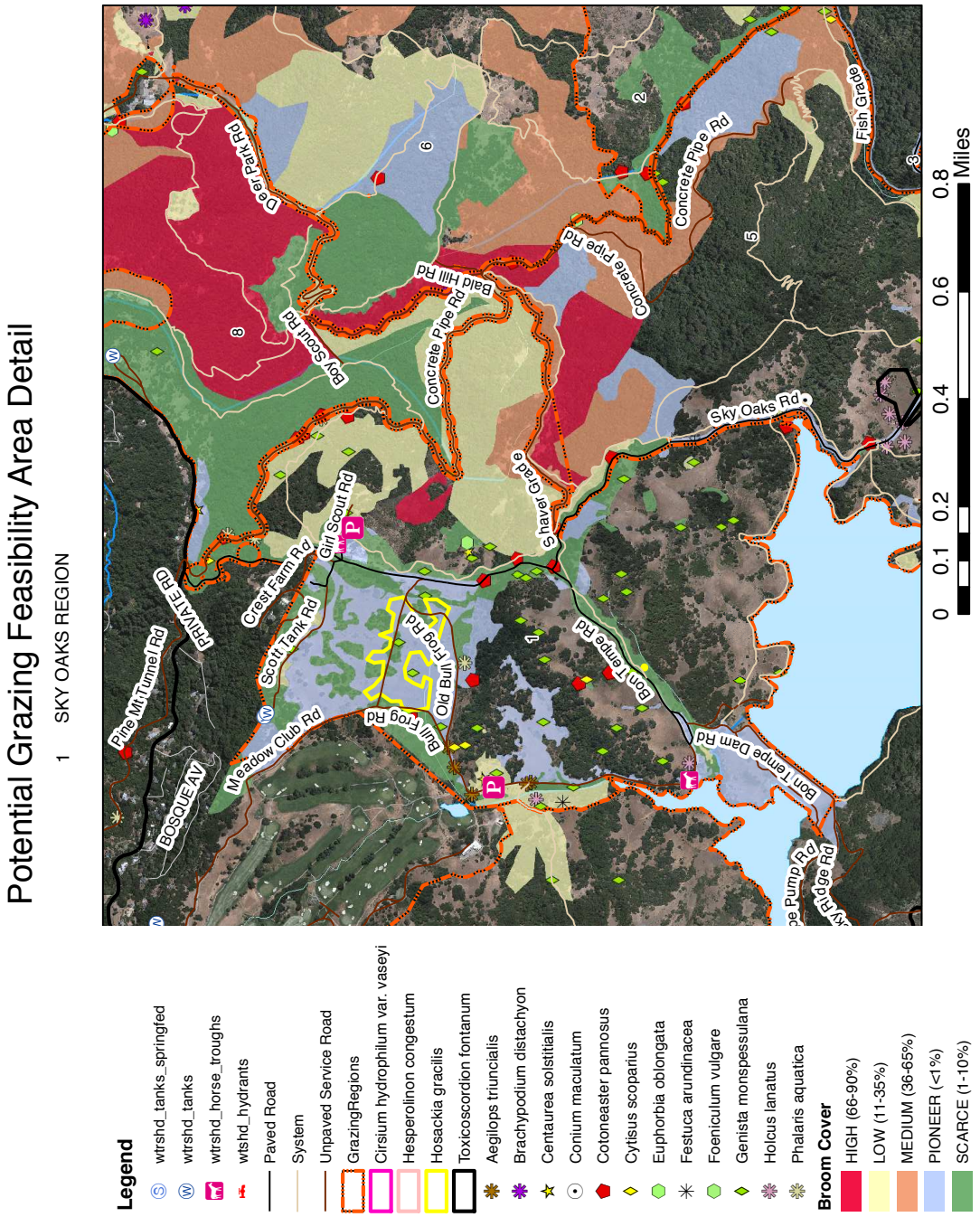
List of Maps of Potential Grazing Areas (prepared by Andrea Williams, MMWD)

- Overview Map of 16 Potential Grazing Areas within Mt. Tamalpais Watershed
- Map 1. Sky Oaks Potential Grazing Area
- Map 2. Porteous-Ross Reservoir-Worn Spring Middle Potential Grazing Area
- Map 3. Pilot Knob Potential Grazing Area
- Map 4. Ridgecrest-Rock Spring-Potrero Potential Grazing Area
- Map 5. Pumpkin-Pine-Fish-Lag Meadows Potential Grazing Area
- Map 6. Deer Park-Worn Spring North Potential Grazing Area
- Map 7. Bill Williams-Indian Crown Potential Grazing Area
- Map 8. Fawn Ridge-Deer Park Potential Grazing Area
- Map 9. Azalea Hill Potential Grazing Area
- Map 10. Pine Mountain South Gate Potential Grazing Area
- Map 11. Bathtub Gap-Carson Ridge Potential Grazing Area
- Map 12. Poison Spring Grasslands Potential Grazing Area
- Map 13. Kent Pump Beginning Potential Grazing Area
- Map 14. Grassy Knoll Potential Grazing Area
- Map 15. Cascade Creek Potential Grazing Area
- Map 16. Midpoint Meadows Potential Grazing Area

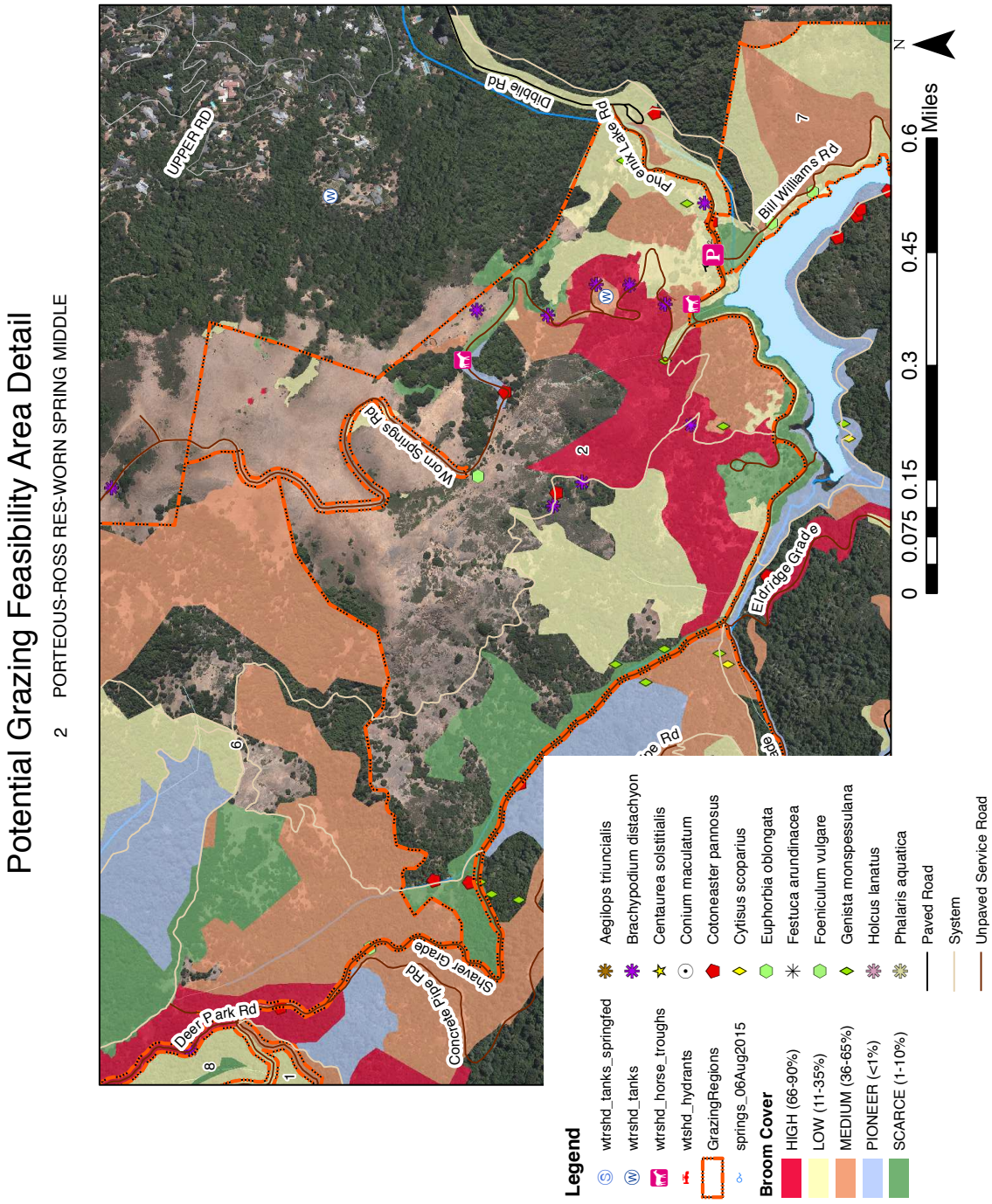
Overview Map of 16 Potential Grazing Areas within Mt. Tampalais Watershed (prepared by Andrea Williams, MMWD)



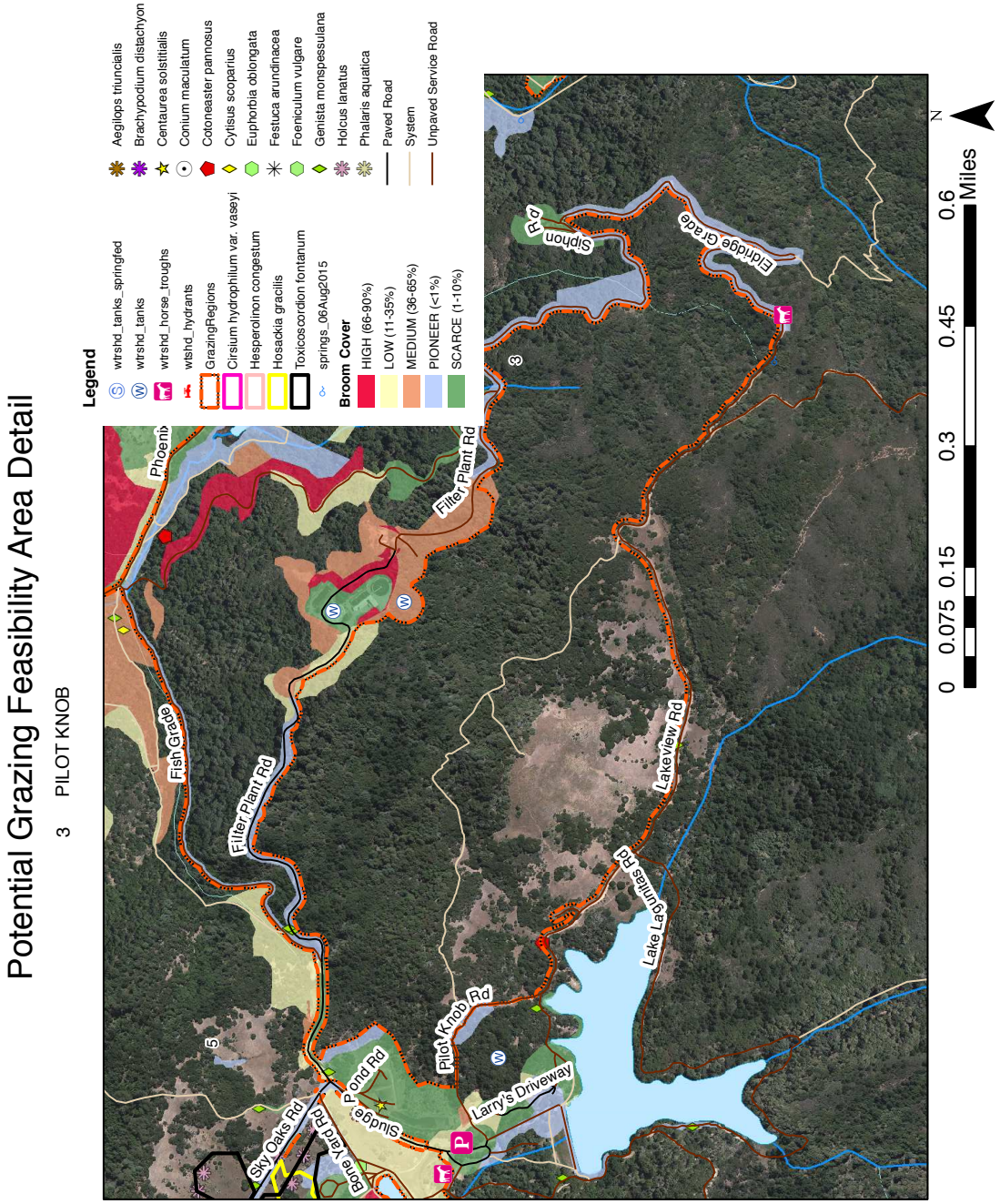
Map 1. Sky Oaks Potential Grazing Area (prepared by Andrea Williams, MMWD)



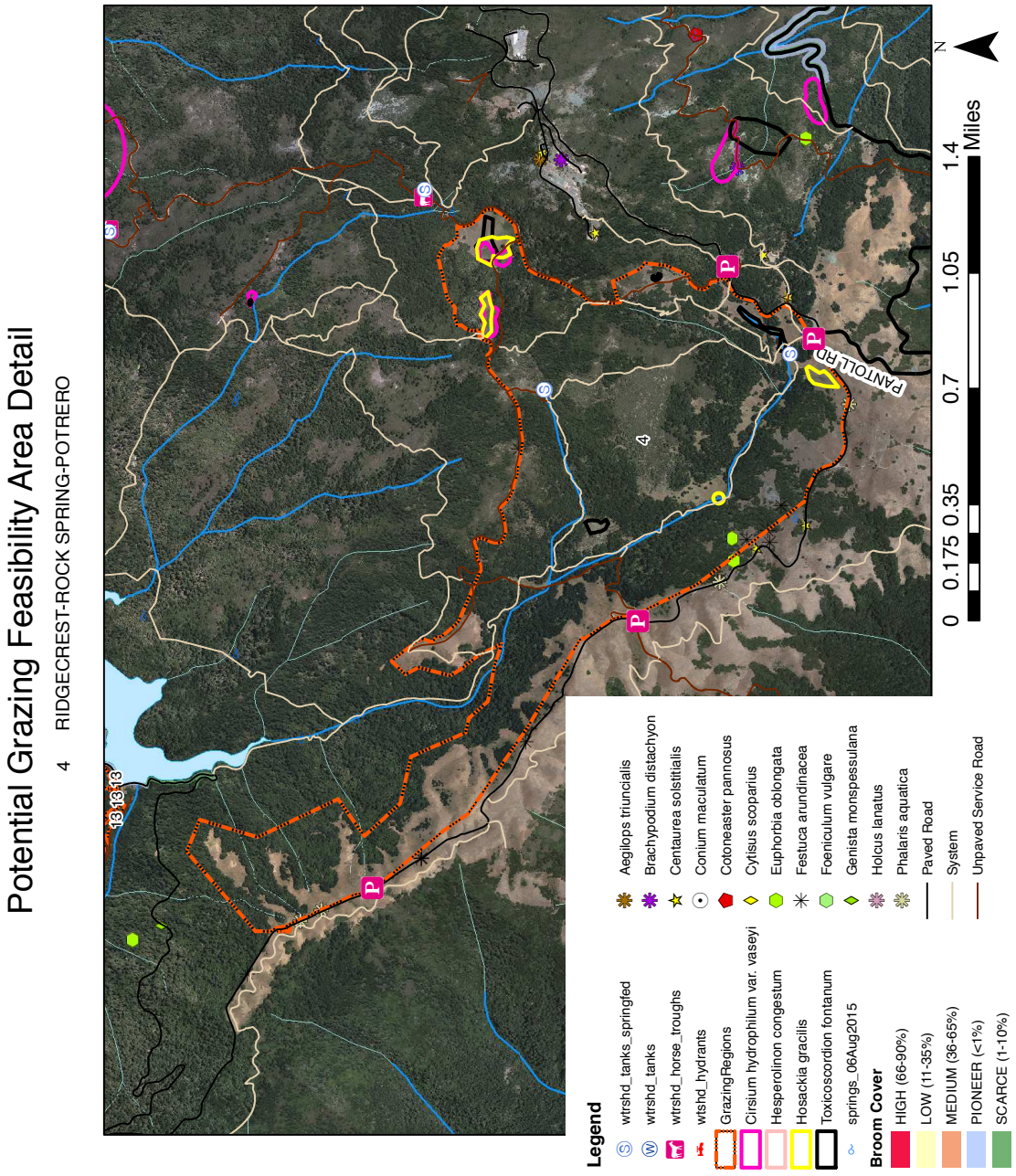
Map 2. Porteous-Ross Reservoir-Worn Spring Middle Potential Grazing Area (prepared by Andrea Williams, MMWD)



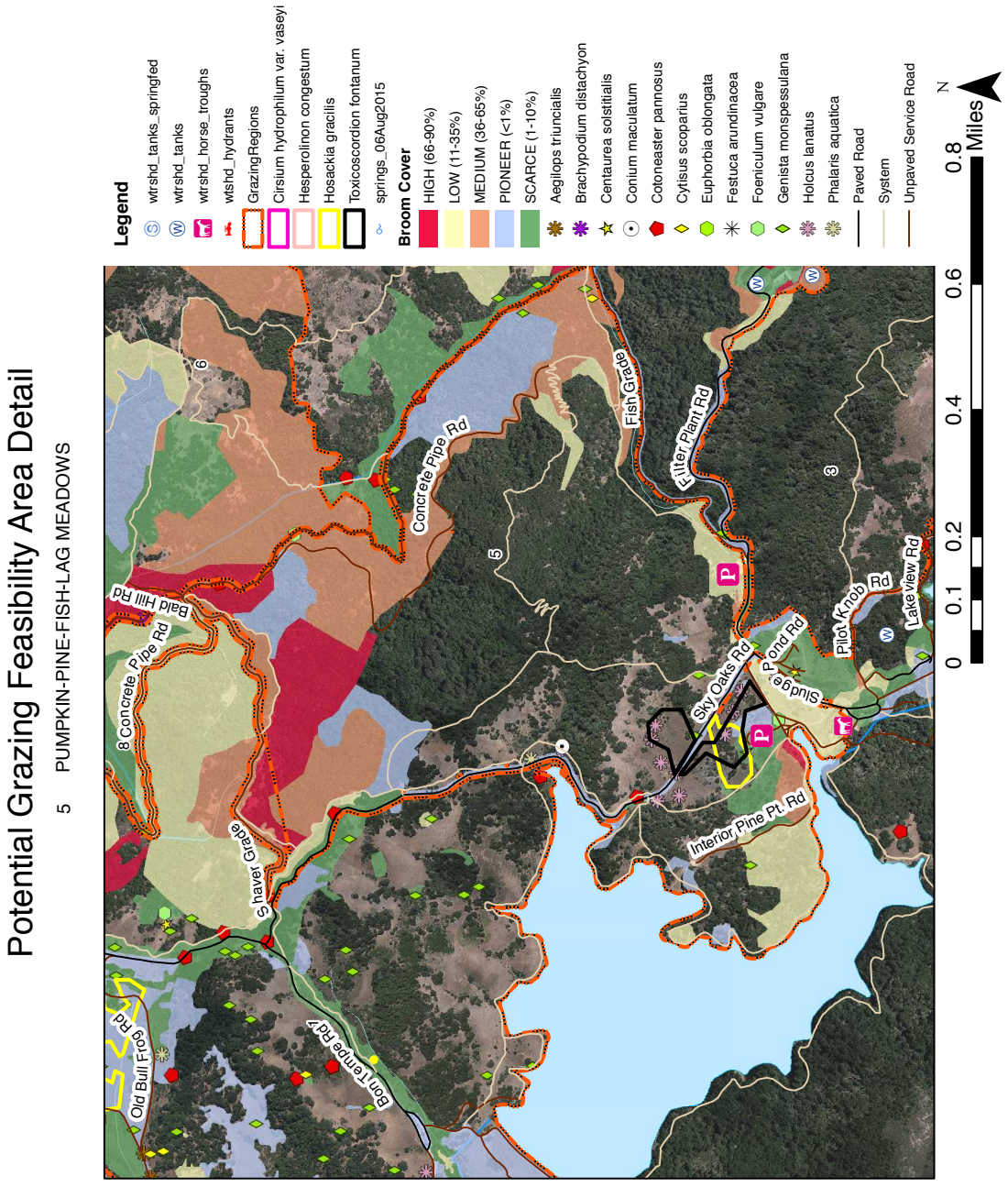
Map 3. Pilot Knob Potential Grazing Area (prepared by Andrea Williams, MMWD)



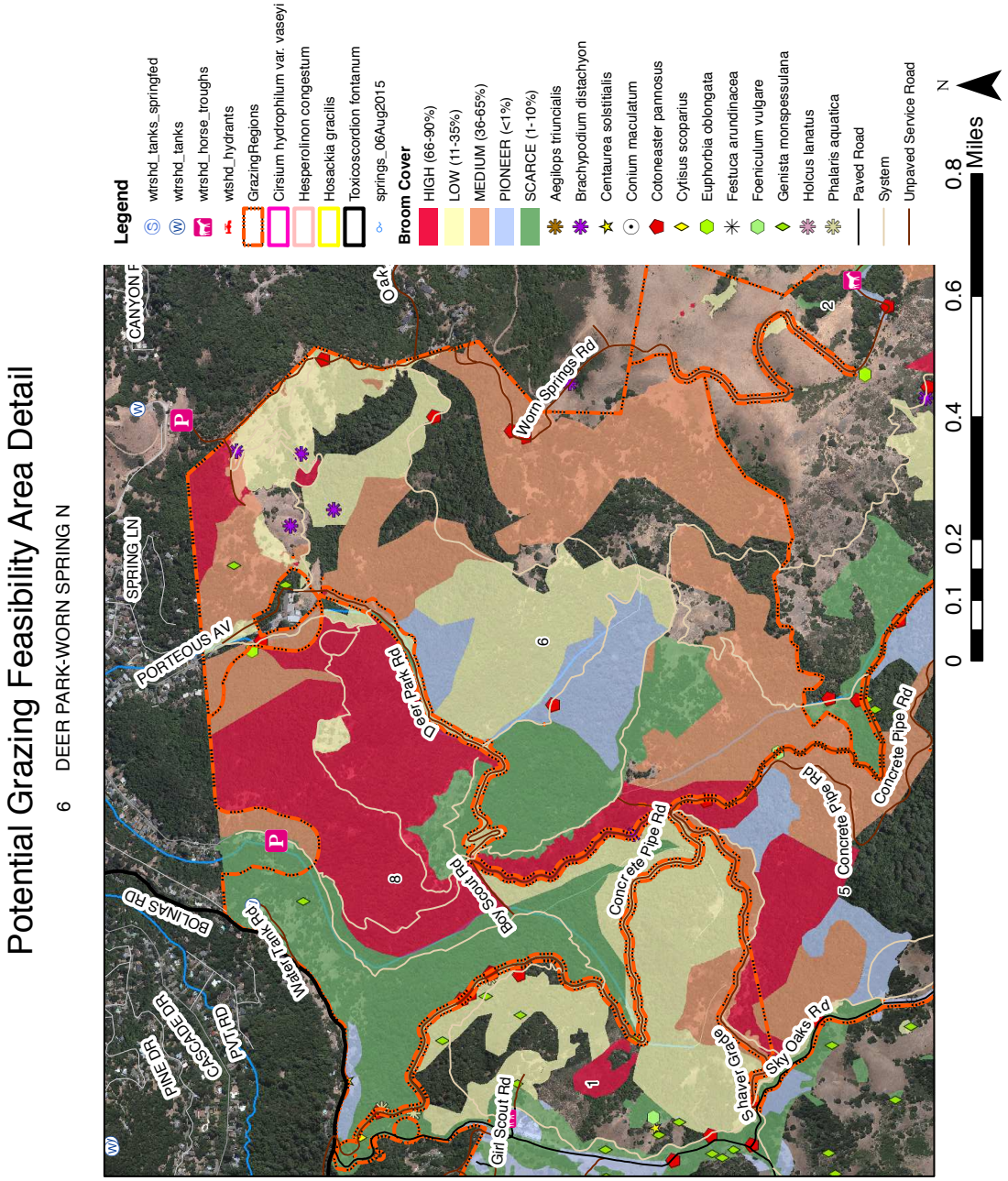
Map 4. Ridgecrest-Rock Spring-Potrero Potential Grazing Area (prepared by Andrea Williams, MMWD)



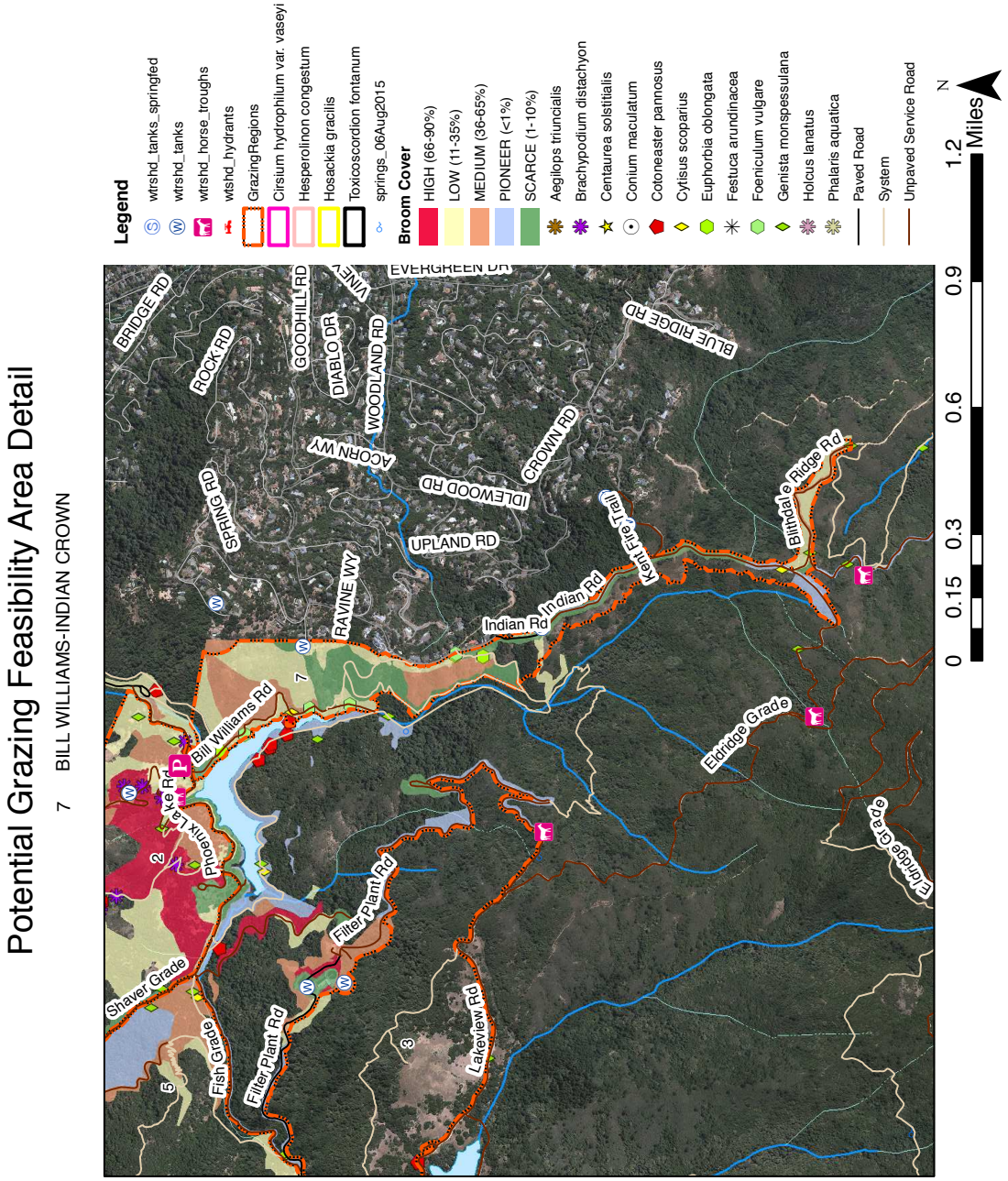
Map 5. Pumpkin Pine-Fish-Lag Meadows Potential Grazing Area (prepared by Andrea Williams, MMWD)



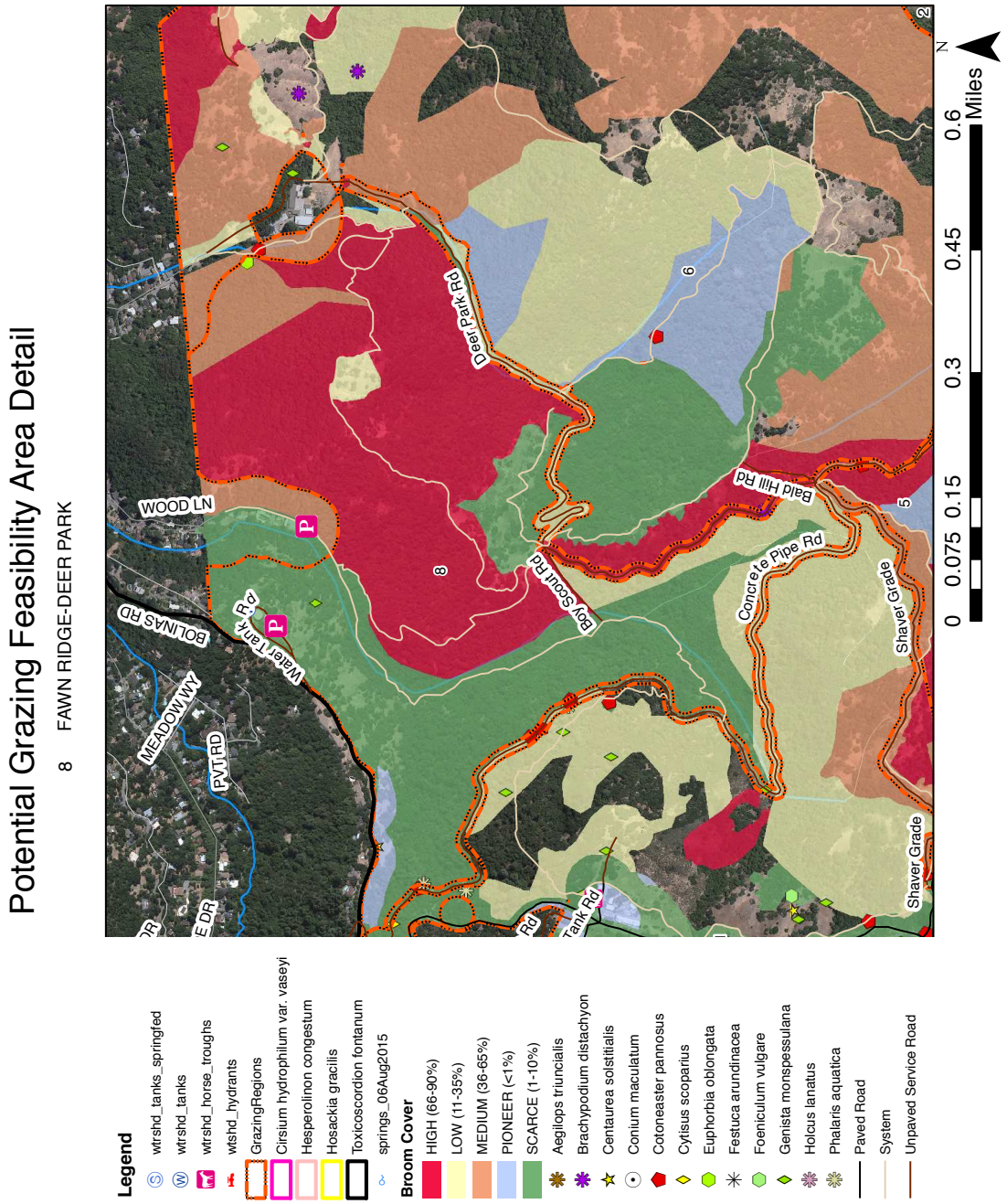
Map 6. Deer Park-Worn Spring North Potential Grazing Area (prepared by Andrea Williams, MMWD)



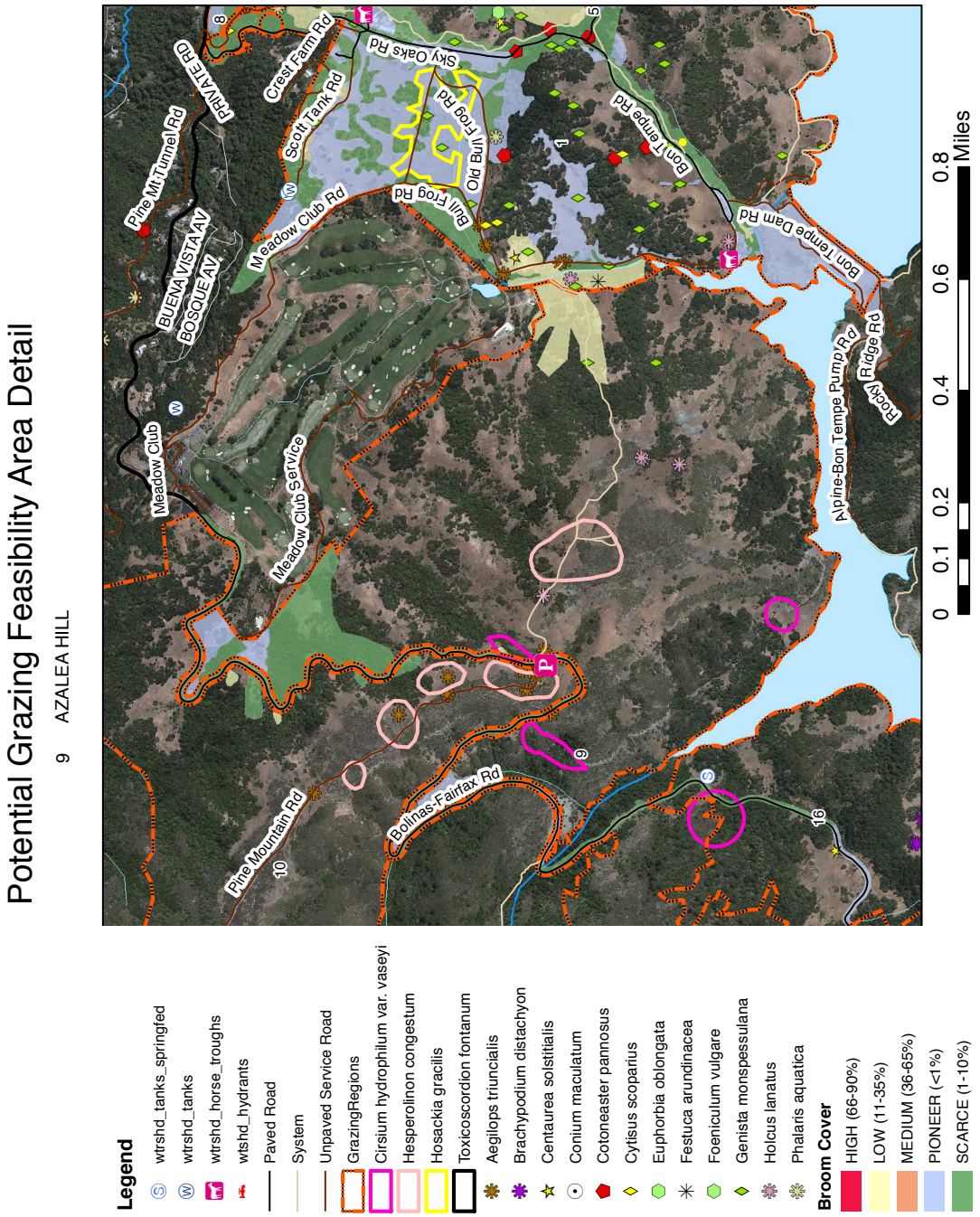
Map 7. Bill Williams-Indian Crown Potential Grazing Area (prepared by Andrea Williams, MMWD)



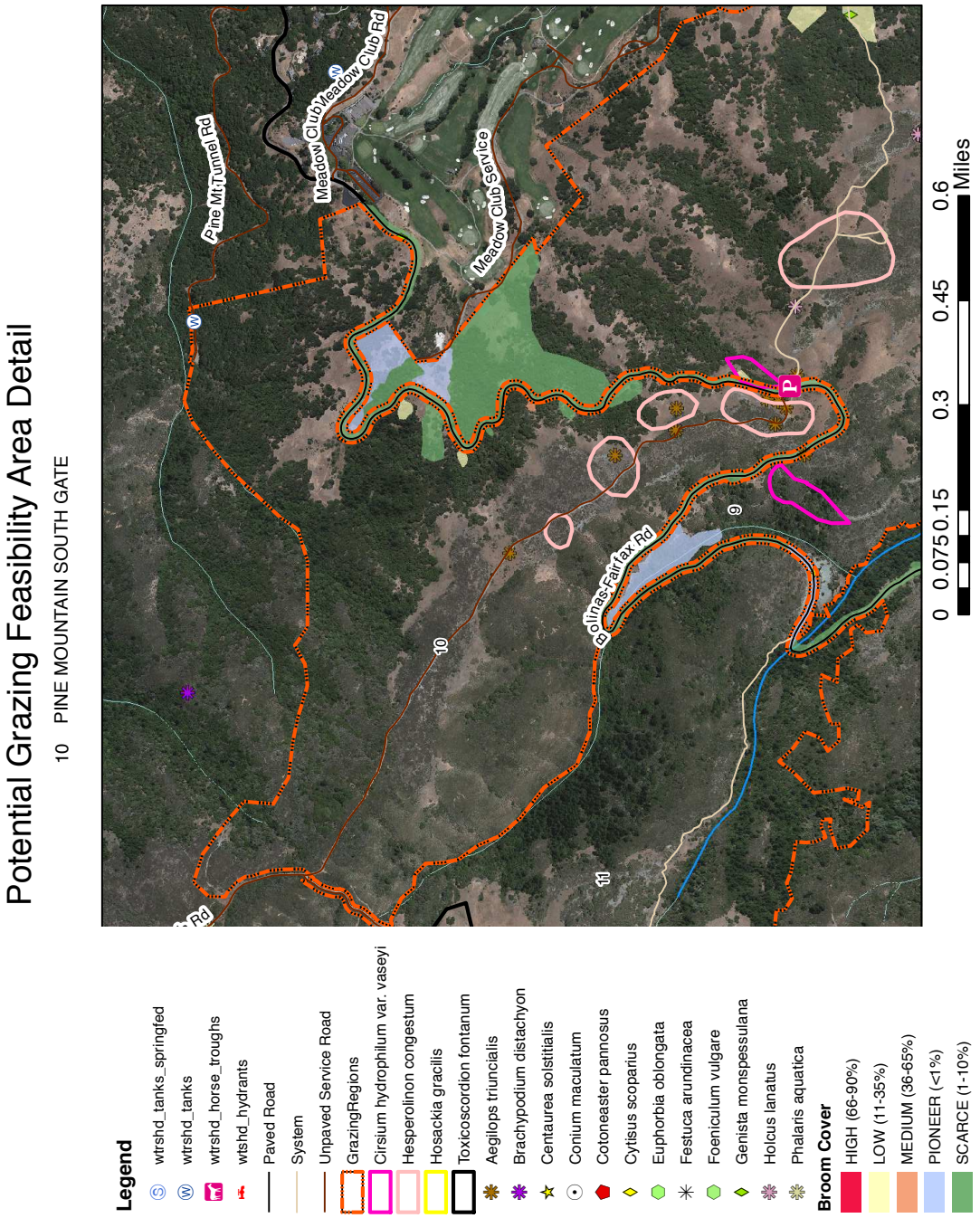
Map 8. Fawn Ridge-Deer Park Potential Grazing Area (prepared by Andrea Williams, MMWD)



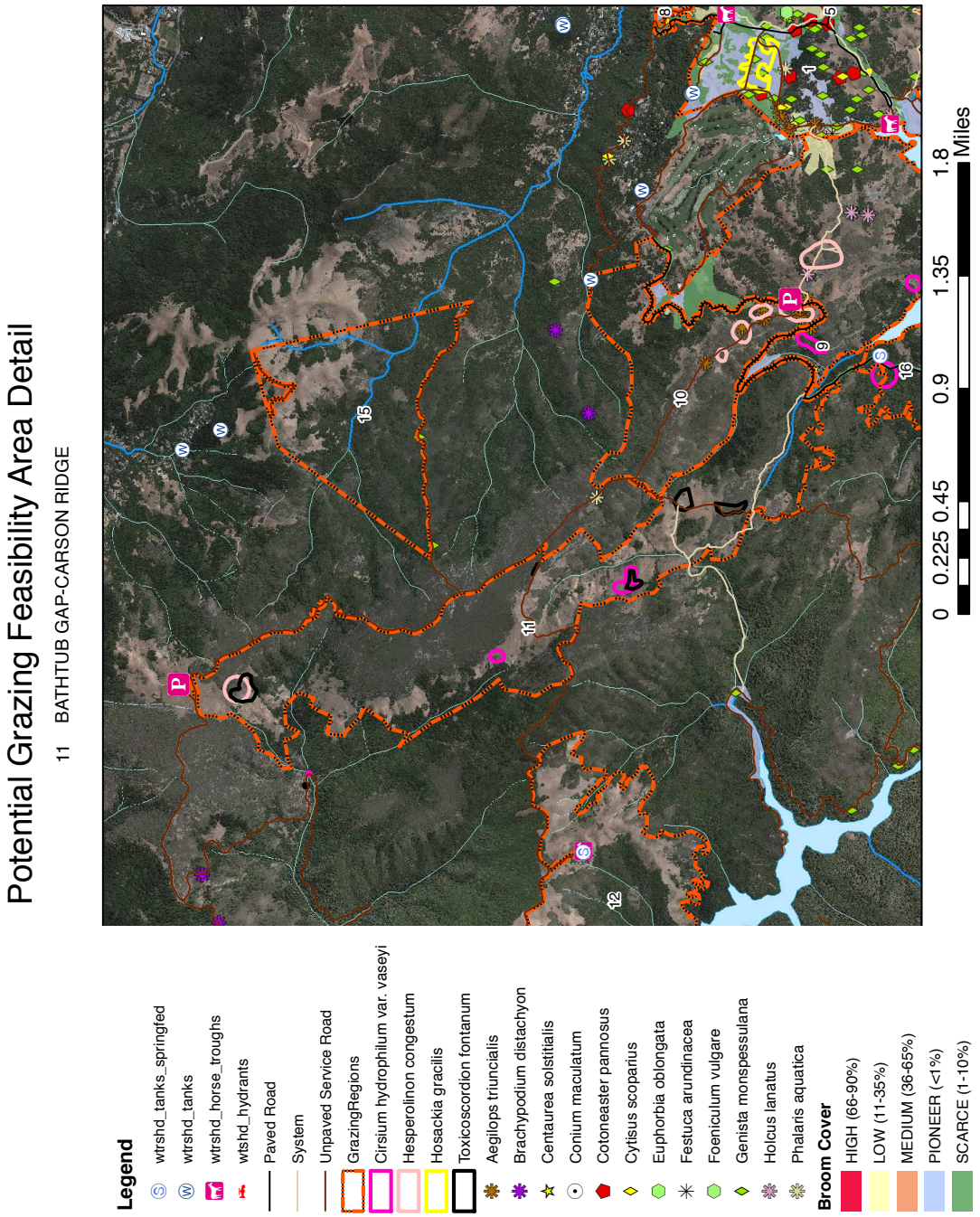
Map 9. Azalea Hill Potential Grazing Area (prepared by Andrea Williams, MMWD)



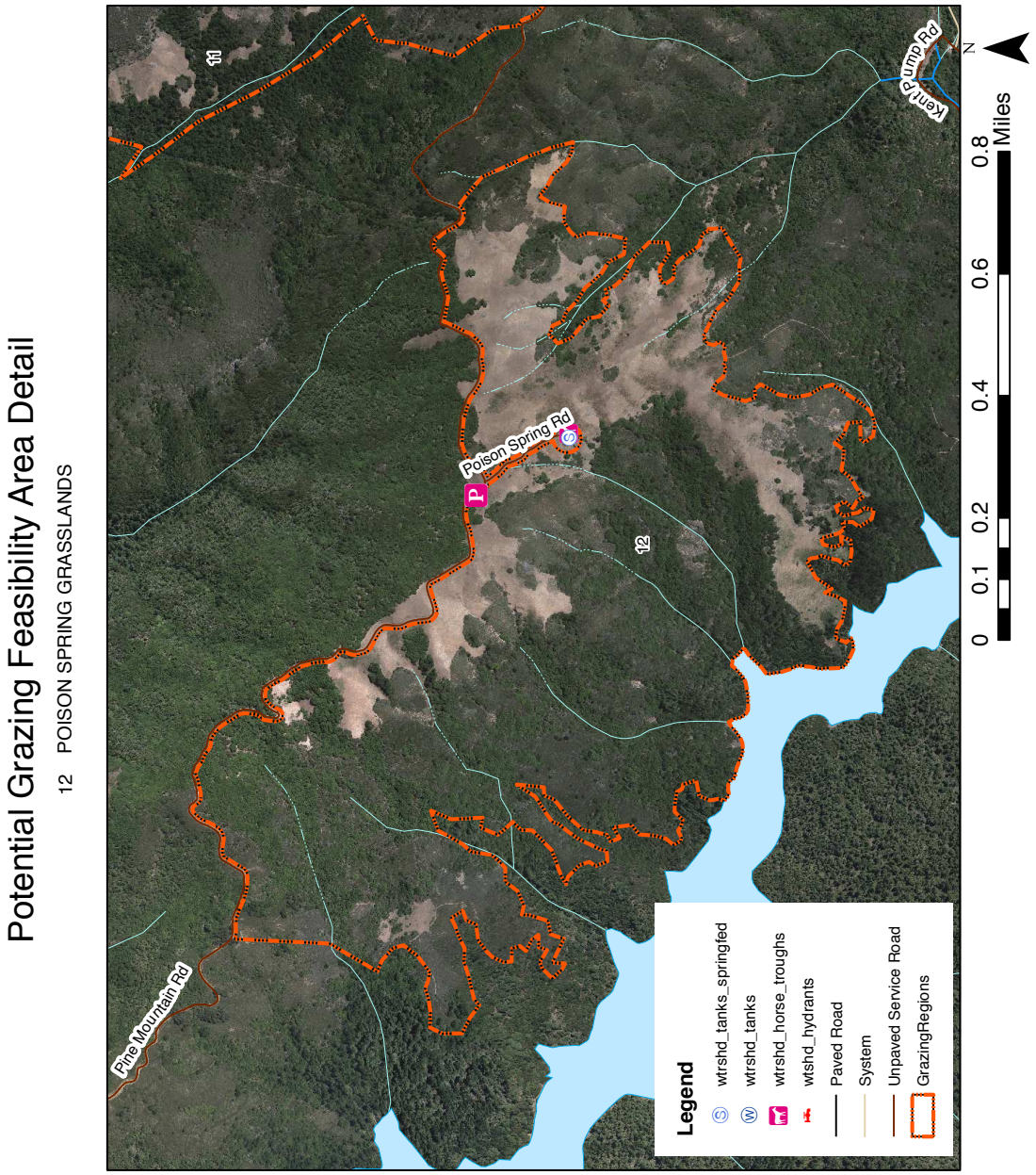
Map 10. Pine Mountain South Gate Potential Grazing Area (prepared by Andrea Williams, MMWD)



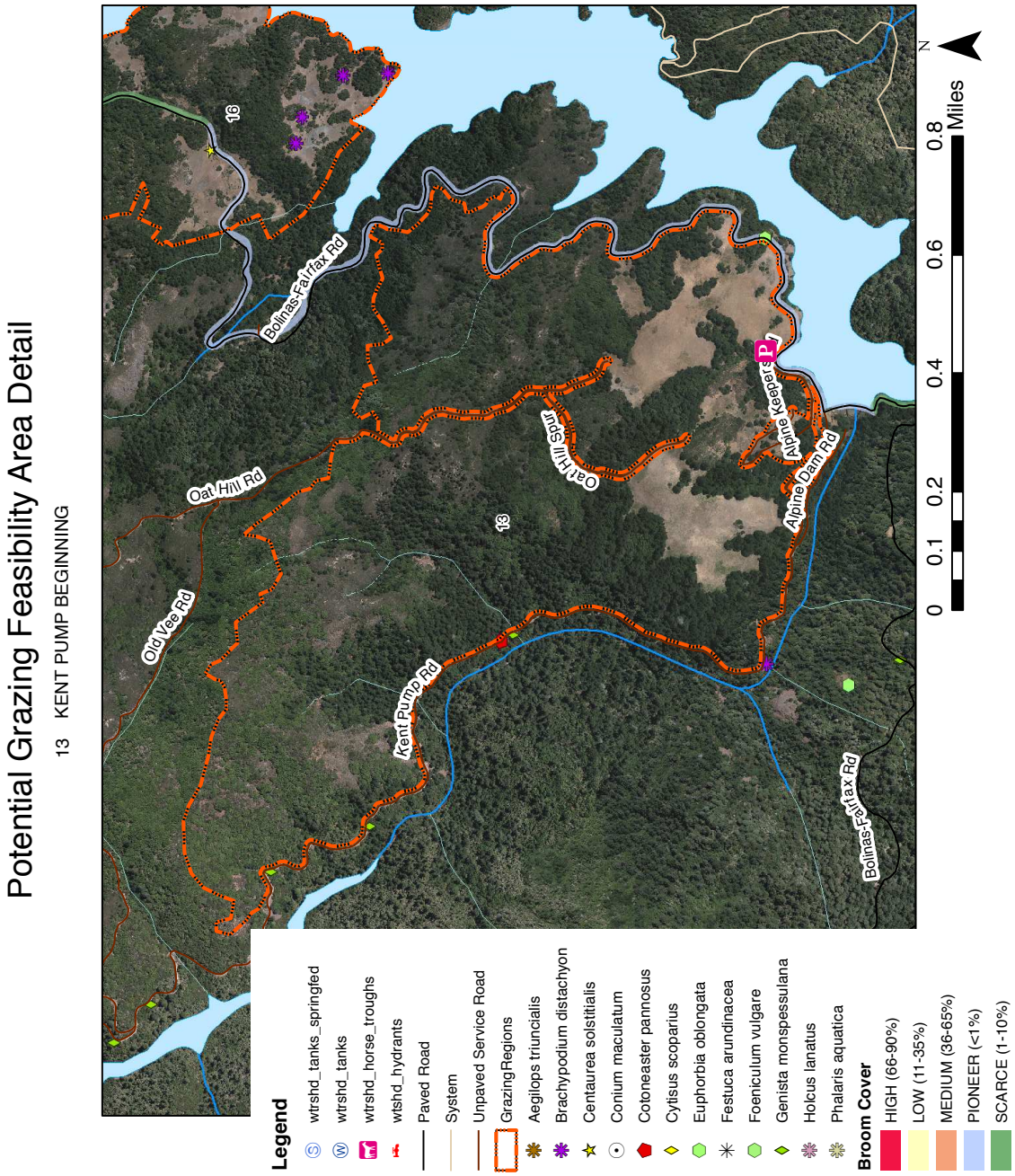
Map 11. Bathtub Gap-Carson Ridge Potential Grazing Area (prepared by Andrea Williams, MMWD)



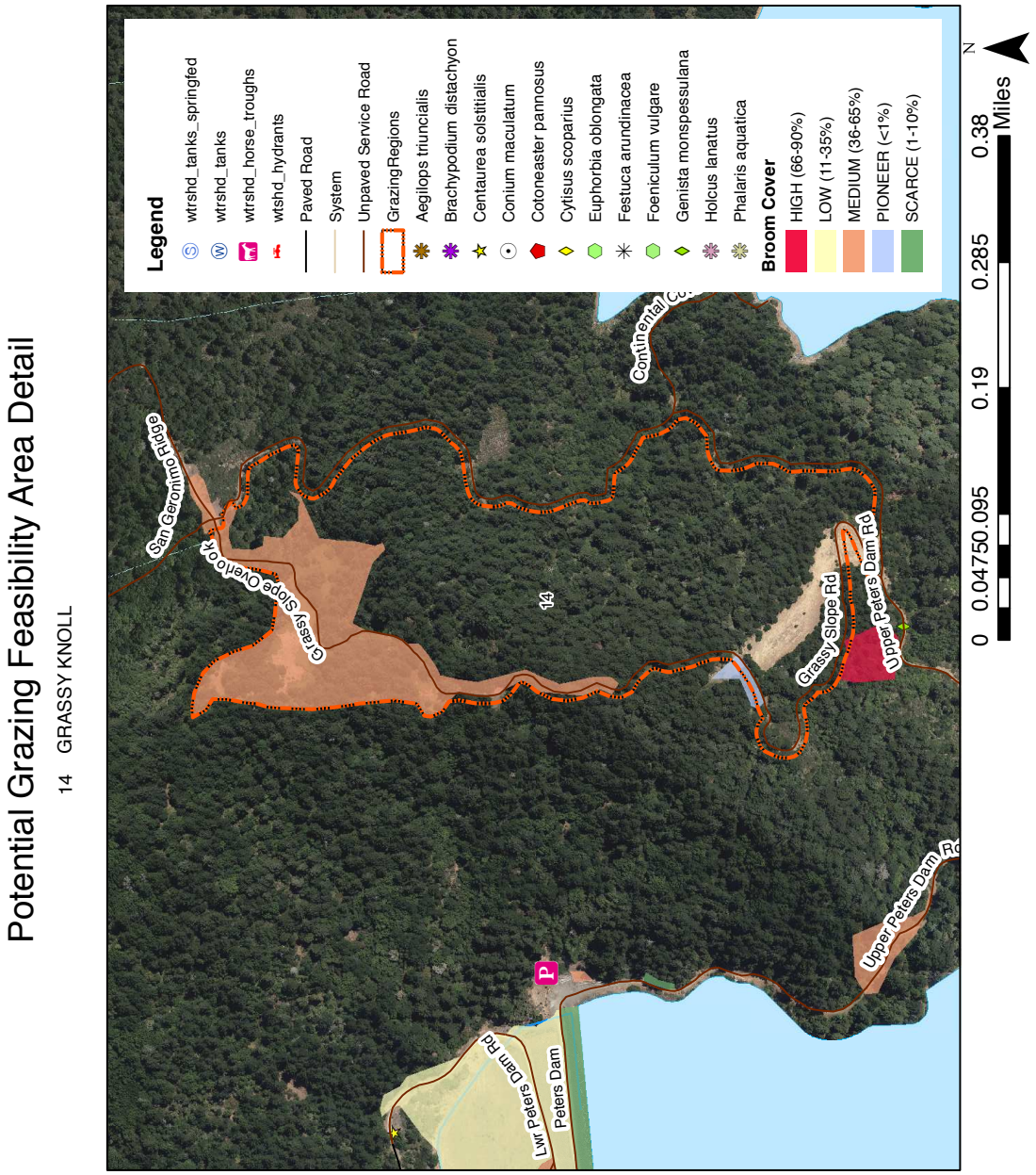
Map 12. Poison Spring Grasslands Potential Grazing Area (prepared by Andrea Williams, MMWD)



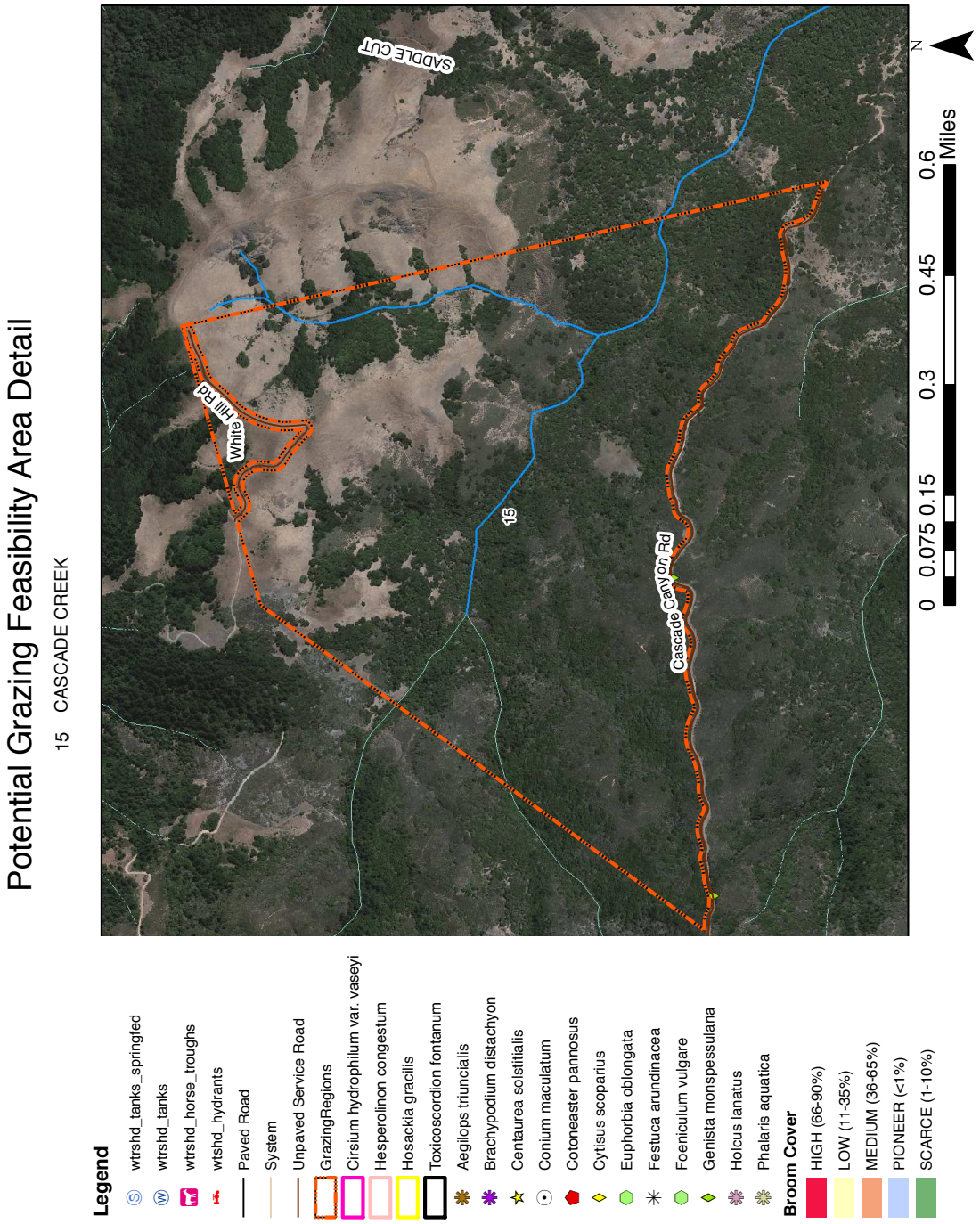
Map 13. Kent Pump Beginning Potential Grazing Area (prepared by Andrea Williams, MMWD)



Map 14. Grassy Knoll Potential Grazing Area (prepared by Andrea Williams, MMWD)



Map 15. Cascade Creek Potential Grazing Area (prepared by Andrea Williams, MMWD)



Map 16. Midpoint Meadows Potential Grazing Area (prepared by Andrea Williams, MMWD)