Rationale and Supporting Information

Lake Tahoe West Landscape Restoration Strategy

Lake Tahoe West Restoration Partnership
Interagency Design Team

V1.0

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The Lake Tahoe West Landscape Restoration Strategy (Strategy) provides a collaborative framework to restore 59,000 acres of federal, state, local, and private lands on the west shore of Lake Tahoe. The Strategy was developed by the Lake Tahoe West Restoration Partnership, a collaborative effort to increase the resilience of the forests, watersheds, recreational opportunities, and communities across the landscape.

The Strategy comprises six overarching Goals, 27 Objectives, and a set of Strategy and Prioritization Guidelines intended to move the Lake Tahoe West landscape toward a resilient condition over a 20-year implementation period.

This supplemental document provides supporting information to explain how the Objectives and some of the Strategy and Prioritization Guidelines in the Landscape Restoration Strategy were derived. These elements were primarily based on the findings of the Lake Tahoe West Landscape Resilience Assessment (LRA), professional expertise of Lake Tahoe West team members, landscape and fine-scale modeling conducted as part of the effort to develop the Strategy, and analysis of key indicators of landscape resilience using an Ecosystem Management Decision Support tool. Managers will also use future research and literature as it becomes available to inform ongoing implementation of the Strategy.

Members of the Lake Tahoe West Interagency Design Team, representing partner agencies in Lake Tahoe West, developed this document.

Contents

Goal 1 – Forests recover from fire, drought, and insect and disease outbreaks

Forest structure and composition - Forest stand density, age and species distribution, and variable stand structure across the landscape promote resilience toward fire, drought, and insect outbreaks.

Objective 1A

Decrease tree density on 40,000 acres to move forests closer to within the range of natural variation for tree densities and to increase forest structural heterogeneity.

This Objective was developed based on analysis from the LRA and supported by LTW landscape modeling. Objective 1A specifies thinning 40,000 acres based on the LRA which concluded that 40,228 acres of the project area are considered less and least resilient for TPA (see Table 1). The range of resilience does not include associated information on tree size classes or forest seral stages. This metric does not include saplings and seedlings. However, using EcObject data on current conditions and volume removals by size class from actual timber cruises on LTBMU, percentages of biomass removals by size classes up to 38" DBH were calculated to meet stand density objectives based on the trees per acre indicator in the LRA. These percentages and the upper diameter limit of 38" represented a conservative increase from business as usual in order to bring the TPA indicator into resilience, and were used in LANDIS modeling for scenario 3 and could be used as a guide during prescription development. Methods and rationale for increased biomass removals and upper diameter limit of 38" DBH, including consideration of the Conservation Strategy for the California Spotted Owl in the Sierra Nevada (USDA 2019), are further described in Design Team scenario development materials.

This Objective recognizes that tree density varies based on topography and microsite conditions. For example, higher tree density and canopy cover can be supported on northeast aspects (North et al. 2009). Of these 40,228 acres, 980 acres are found on slopes >70%, the majority of which are in Desolation Wilderness and General Forest (Table 1). Slopes this steep can limit restoration in these areas and work may be completed through prescribed fire or managed wildfire.

Table 1. Acres of TPA less and least resilient breakdown by management zone.

Management Zone	Acres of TPA less-least resilient	Acres TPA less-least resilient with >70% slope
Wilderness	5,170	505
General Forest	9,320	268
Wildland Urban Interface Defense Zone	13,532	150
Wildland Urban Interface Threat Zone	12,206	57
Grand Total	**40,228**	**980**

When developing thinning prescriptions to meet this Objective, managers should consider maintaining heterogeneity in vertical structure consistent with the reference conditions in Table 2 below. Currently this translates to increasing vegetative cover at the top of the canopy and reducing cover in the bottom strata. This is associated with Objective 1B; as late seral forests grow and mid-seral forest stands are reduced, vegetation cover should increase at the top of the canopy.

Table 2 represents the percentage of target resilient conditions by vertical heterogeneity for forested vegetation types in comparison with current LTW project area conditions. In the LRA, vertical heterogeneity was evaluated using EcObject data from Illilouette Basin reference sites. Due to the limited available data, resilient conditions for each strata distribution class focus on the ranks and used the percentile range as a guide.

Table 2. The percentage of target resilient conditions by vertical heterogeneity for forested vegetation types and comparison with current LTW project area conditions.

Vertical Heterogeneity Class	Strata Distribution Class*	Target Resilient Condition Rank	LTW Rank	Lower % Range	Upper % Range	LTW % of forested landscape
Single old	Top Loaded	1	2	49.22	73.83	24%
Homogenous mid	Mid Loaded	2	3	13.52	20.28	22%
Codominant – attached	Bimodal – Codominance	3	5	11.39	17.08	6%
Tri-dominant – 3 equal classes	Continuous	4	4	3.32	4.97	17%
Single young	Bottom Loaded	5	1	2.05	3.07	28%
Codominant – detached	Bimodal – Subdominance	6	6	0.51	0.76	3%

* Description was developed to help explain the Strata Distribution Class from EcObject, without needing the product guide information. Additional information can be found in Appendix A.

Prioritization guideline vii. for this Objective discusses the removal of large trees (i.e. 30-38” DBH) which may be necessary to achieve Strategy Objectives such as meeting desired stand density targets and maintaining species diversity. This is line with the Revised Land and Resource Management Plan (USDA 2016) and the Conservation Strategy for the California Spotted Owl in the Sierra Nevada (USDA 2019), which recognize that there are circumstances when a tree greater than 30” DBH should be removed to meet restoration and resilience goals. Removals in size classes 30-38” used in LANDIS modeling scenario 3 reflect those circumstances. Additionally, the biomass removed in those size classes in scenario 3 is low to represent that this circumstance is rare, and focuses more heavily on trees <36” DBH to preferentially retain trees >35” DBH (per the CASPO Conservation Strategy USDA 2019). No trees 40” or greater would be removed (in compliance with the CASPO Conservation Strategy). Methods and rationale for choosing the upper diameter limit of 38” DBH are described in further detail in Design Team scenario development materials (ScenarioInputs4_5_18.docx).

Large trees are important characteristics of late seral habitat (Objectives 1B and 3A); average stand diameters do not shift into larger size classes as rapidly in stands without treatment. Selective removal of some large trees in a stand will protect existing large trees from stressors such as competition, disease, and insects. Consideration for removing large trees should be an interdisciplinary decision at the stand level and be based on current conditions. Evaluating the need for removing large trees should be based on ecological needs of the stand and the need to remove large trees to meet the desired treatment objectives, reducing treatment costs is not an adequate rationale for removing large trees. Research has pointed to some cases where ecological considerations may suggest removal of some large trees, in particular to adjust species composition. As one example, the fine-scale modeling of three aspen-conifer stands illustrated that removing conifers up to 30” DBH from those stands would help sustain aspen by maintaining open conditions. Treatments in the Stanislaus Experimental Forest cut a small number of trees over 30” DBH in order to implement prescriptions designed to restore reference horizontal structure, including small gaps, and a few more to maintain an even spacing of tree canopies; the researchers noted that that forest was unusually productive.

The LTW landscape modeling showed that areas with old trees (>150 years, Figure 1) will continue to increase across the landscape for several decades into the 21st century, and that increases in thinning treatments, as modeled in scenario 3, were associated with the most area with old trees. However, it is not possible to easily separate the drivers for that result to evaluate effects of thinning larger trees at the landscape scale. The increases seen in Scenario 3 may reflect its effectiveness of limiting mortality among older trees due to wildfire or insect disturbances. The model also provides for increases in growth among residual trees due to thinning, but it is not practicable to quantify those effects in terms of accelerated recruitment of individual large trees.

A recent study from outside of the Lake Tahoe basin in 80-year old second growth conifer forests found that thinning treatments accelerated growth of the remaining trees, but it did not observe increased recruitment of large trees (>24” DBH) within 6-14 years following thinning. However, the researcher thought that such recruitment would occur after a longer period of 20–25 years post-treatment. Because that study involved younger, smaller trees, it does not directly address the effects of thinning large trees on residual tree growth but does suggest that reducing competition supports accelerated growth of remaining trees, including remaining large trees. The purpose for considering removal of large trees is improve forest health and resiliency to insects, disease, drought and other disturbances, to reduce competition between large trees and to meet restoration objectives.

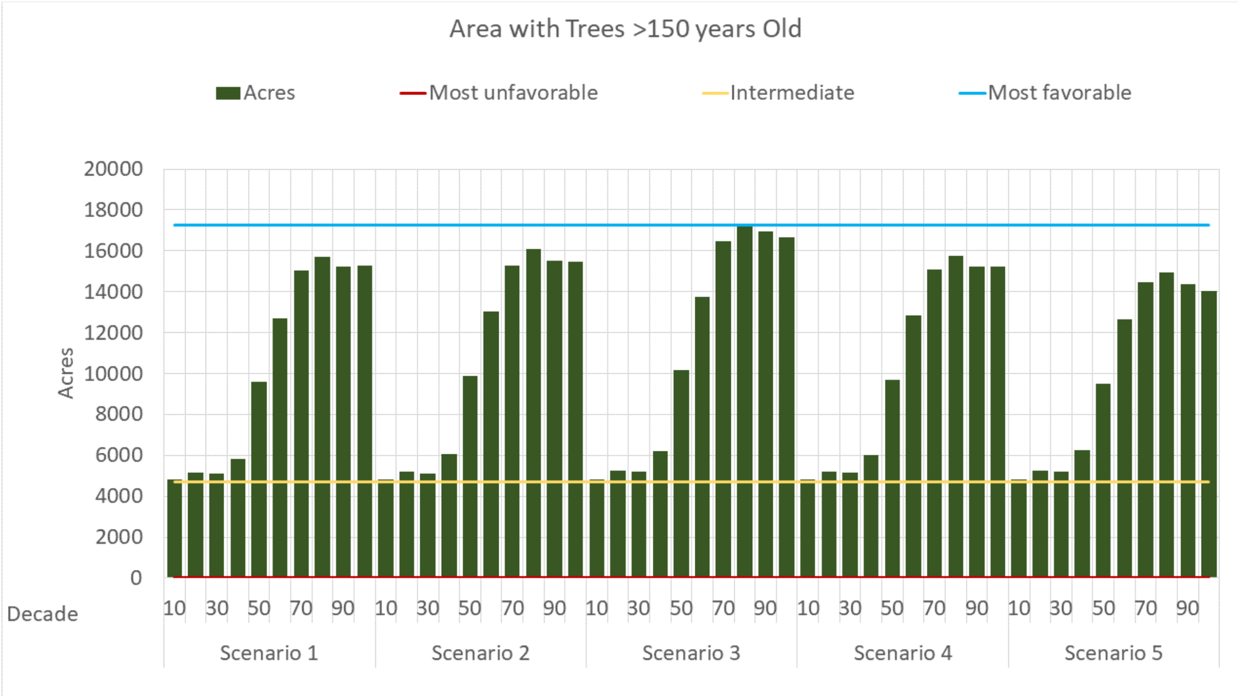

Figure 1. Average total area (in acres) within LTW that has any trees exceeding 150 years old based upon Round 1 modeling (using a single climate projection under an RCP4.5 emissions pathway). Note that scenario 3 outperforms other scenarios, and scenario 5 performs slightly worse.

Objective 1B

Reduce over-represented seral stages, increase under-represented seral stages, and set the landscape on a trajectory toward the natural range of variation on 23,000 acres.

This Objective was developed based on analysis from the LRA and supported by LTW landscape modeling.

The LRA evaluated the percentage of forest types by seral stage in a target resilient condition (TRC) compared to current LTW project area conditions (Table 3). To evaluate targets for the Strategy, we then translated the percent of the landscape into acres by combining the open and closed seral classes (Table 4). The current LTW project area conditions were based off of the total acres of yellow pine, mixed conifer, and red fir that exist in the LTW project area at the time of the 2010 LiDAR flight used in the LRA analysis, which equals 49,580 acres. We then identified a target minimum and maximum acres to be treated by seral class and forest type based on the TRC ranges and existing conditions (Table 5).

Table 3. Relative percentage of forest types by seral stage in a target resilient condition (TRC) and the current percent of the landscape defined by dominant forest type. Red text indicates over-representation, and orange indicates an under-representation. The LRA found the majority of the landscape contains over-represented seral stages and is therefore least resilient (87%); 3% of the landscape is less resilient, and 10% of the landscape is resilient (e.g. appropriately represented).

Seral Stage[1]	**Yellow Pine**		**Mixed Conifer**		**Red Fir**	
	TRC	**Existing**	**TRC**	**Existing**	**TRC**	**Existing**
EDO	5-15%	8%	5-20%	11%	3-20%	25%
EDC	0%	0%	0%	0%	0%	1%
MDO	8-25%	29%	1-15%	31%	0-15%	36%

MDC	0-10%	56%	0-15%	54%	12-30%	34%
LDO	29-50%	1%	6-50%	1%	2-15%	1%
LDC	5-31%	6%	7-79%	3%	25-70%	4%

[1] Seral stage refers to overstory tree DBH (inches) and overstory tree canopy from above. Early development (ED): ≥5" & <25%; Mid development open (MDO): 5-19.9" & <40%; Mid development moderate (MDO): 5-19.9" & 40-70%; Mid development closed (MDC): 5-19.9" & >70%; Late development open (LDO): >20" & <40%; Late development moderate (LDM): >20% & 40-70%; Late development closed (LDC): >20" & >70%.

Table 4. Acres in the LTW landscape that are considered resilient (bounded by TRC low and TRC high) and the current acres of the landscape defined by seral stage and dominant forest type. (Note that for red fir and mixed conifer: due to rounding, percentages equal 101% and therefore existing acres are slightly higher than current acres).

Acres	**Yellow Pine**			**Mixed Conifer**			**Red fir**		
Seral Stage*	**TRC Low**	**TRC High**	**Existing**	**TRC Low**	**TRC High**	**Existing**	**TRC Low**	**TRC High**	**Existing**
Early	220	660	352	1,691	6,765	4,059	341	2,271	2,953
Mid	352	1,539	3,738	338	10,148	28,753	1,363	5,110	7,949
Late	1,495	3,562	308	4,398	43,637	1,353	3,066	9,653	568
Total Acres	2,067	5,760	4,397	6,427	60,550	34,165	4,770	17,034	11,470

Table 5. The minimum and maximum number of acres that would need to be treated to be within the range of resilient conditions as identified by the LRA based on current forest type.

	Yellow Pine			**Mixed Conifer**			**Red fir**		
	Min	**Max**	**Action**	**Min**	**Max**	**Action**	**Min**	**Max**	**Action**
Early			Within			Within	681	2,612	Reduce
Mid	2,199	3,386	Reduce	18,605	28,415	Reduce	2,839	6,587	Reduce
Late	1,187	3,254	Increase	3,044	42,284	Increase	2,498	9,085	Increase

We then incorporated the range of variability for forest acres on the landscape into the assessment to further develop this Objective. We incorporated this because the current existing area (49,580 acres) is not a static target. Rather, under historic conditions these three dominant vegetation types could have ranged from 15,896 acres to 80,659 acres (shown in bold in Table 6). Therefore, we evaluated the range of acres by combining resilient conditions for vegetation type and seral class (Table 7) and then identifying a target minimum and maximum acres to be treated by seral class and forest type (Table 8).

Table 6. Desired condition percentage of the landscape within each general vegetation type and comparison with current LTW conditions (from the LRA – refer to appendix A in LRA for additional information on development of these ranges). The last two columns on the right were calculated for the LRS to evaluate the range of acres for each vegetation type based on the entire LTW project area (59,875 acres).

Vegetation Type	**Lower % Range**	**Upper % Range**	**LTW % of forested landscape**	**Lower Acre Range**	**Upper Acre Range**
Aspen	0.002	1	0	1	589
Herbaceous (grassland, meadow, etc.)	1	6	0	589	3,533

Mixed Conifer	**8**	**28**	**57**	**4,710**	**16,485**
None (barren, lake, etc.)	4	7	3	2,355	4,121
Red Fir	**12**	**72**	**19**	**7,065**	**42,390**
Riparian	0.08	6	0	47	3,533
Shrub	1	14	4	589	8,243
Subalpine Forest	0.1	11	6	59	6,476
Yellow Pine	**7**	**37**	**7**	**4,121**	**21,784**

Table 7. Acres in the LTW landscape that are considered resilient based on historic data for vegetation type (see Table 6) and resilient condition for seral class (see Table 3) (bounded by TRC low and TRC high) and the current acres of the landscape defined by seral stage and dominant forest type. For the TRC low values we used the lower range for seral class and vegetation and for TRC high we used the high range for seral class and vegetation.

Acres	Yellow Pine			Mixed Conifer			Red fir		
Seral Stage*	**TRC Low**	**TRC High**	**Existing Resilient**	**TRC Low**	**TRC High**	**Existing Resilient**	**TRC Low**	**TRC High**	**Existing Resilient**
Early	206	3,268	352	236	3,297	4,059	212	8,478	2,953
Mid	330	7,624	3,738	47	4,946	28,753	848	19,076	7,949
Late	1,401	17,645	308	612	21,266	1,353	1,908	36,032	568

Table 8. The minimum and maximum number of acres that would need to be treated to be within the range of resilient conditions as identified by the LRA based on the historical range of variation for that vegetation type and seral stage (see Table 7).

	Yellow Pine			**Mixed Conifer**			**Red fir**		
	Min	**Max**	**Action**	**Min**	**Max**	**Action**	**Min**	**Max**	**Action**
Early			Within	762	3,824	Reduce			Within
Mid			Within	23,807	28,706	Reduce			Within
Late	1,093	17,337	Increase			Within	1,340	35,464	Increase

When treatment needs were evaluated based on current forest type acres (Table 5) versus the historic vegetation distribution (Table 8), acres of treatment needed to reduce mid-seral forests were very similar, 23,643 versus 23,807 respectively. We therefore identified a target of 23,000 acres. In addition, when we look towards historical vegetation, we identified that a minimum of 1,093 acres of late seral yellow pine and 1,340 acres of red fir should be added to the landscape. We therefore added prioritization guideline i. specifying to transition 2,400 acres of mid-seral mixed conifer forest to yellow pine and red fir late seral forest.

The need to consider treatments to encourage yellow pine and red fir forests was supported by landscape modeling results. Specifically, modeling suggested that white fir and incense cedar are likely to increase across the landscape while Jeffrey pine and especially red fir were projected to decrease. Over long periods, scenario 3 helped to sustain the relative abundance of Jeffrey pine, while scenario 5 increased it over time. Increased treatment, especially in scenarios with prescribed burning, was also associated with increasing the relative abundance of aspen. Changes in climate (specifically warmer temperatures/longer growing seasons) may have been responsible for the general declines in red fir in the model, while western white pine tended to increase in the model (though that particular result entails substantial uncertainty given the influence of white pine blister rust, which is challenging to model) Overall, these results suggest that increased treatments would help encourage shifts in species composition in desirable ways.

In order to increase late seral forests and decrease mid-seral we proposed targeting thinning in mid-seral stands that have a greater amount of larger diameter trees to promote quicker development of late seral conditions. Modeling results suggests that increased treatments can increase the amount of late seral forest age structure, although time is the primary driver for such development (Figure 2). It is important to note that late seral or "old growth" conditions are based upon more complex attributes than age structures alone. Other modeling and research has also found that thinning can promote desirable conditions associated with late seral conditions, including large tree boles, vertical diversity, tree-species diversity, and open-old growth forest structure, as noted in recent publications (Spies et al. 2018) (Ritchie 2020). The recent synthesis by Spies et al. (2018) also noted that thinning would likely reduce dead wood, which can be an important a component of late seral forests. However, it also noted that in forest types with historically frequent fires (like Lake Tahoe West), old-growth forests have "large old live and dead trees, but amounts of deadwood are low, canopies are generally open, and areas with multiple canopy layers are uncommon" (Spies et al. 2018). The field monitoring component of LTW research also found that thinning treatments were associated with a consistent and sustained reduction in dead tree basal area. Consequently, reliance on thinning and restoration of frequent fires are expected to help increase late seral forests.

The modeling results also suggested that over a full century, the amount of early seral forest and shrub habitats might be reduced as later seral forests increase (Figure 2). To address that risk of possible overshoot, management many need to incorporate or be more tolerant of more severe disturbances that increase early seral forests (including aspen) and shrubs. The following Objectives consider these issues.

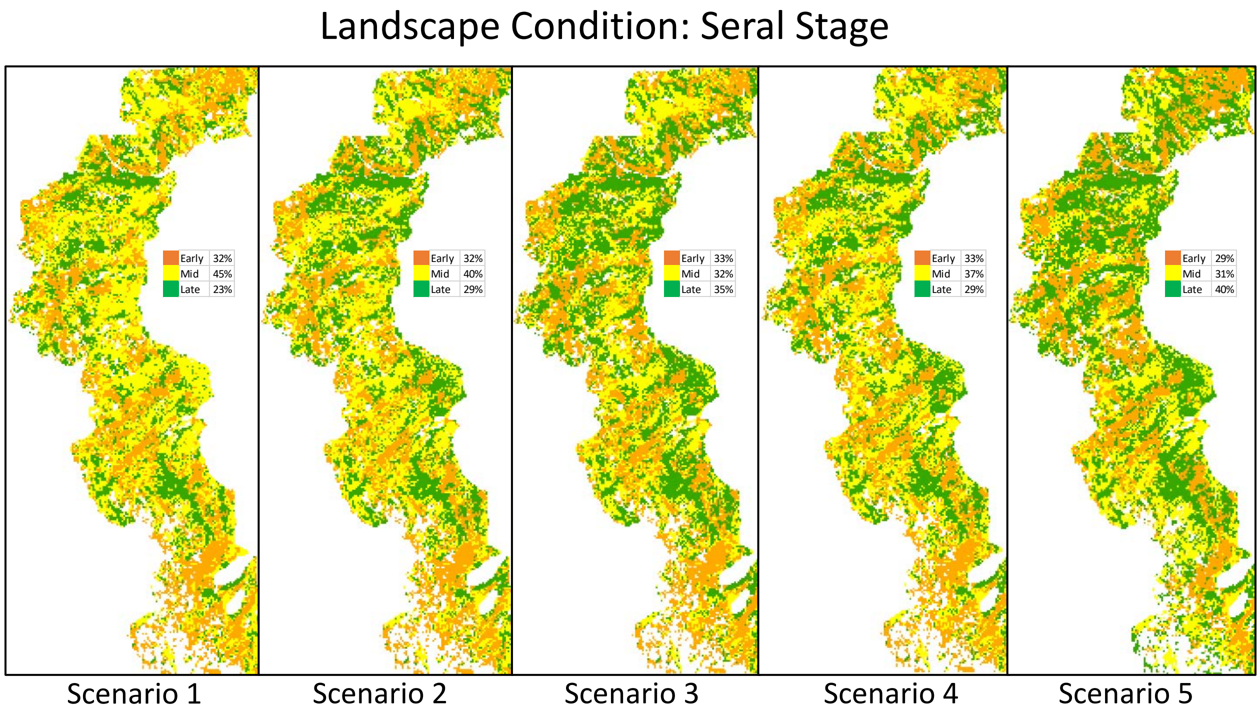

Figure 2. Projected areas of forest classified into early, mid-, and late seral stages.

Objective 1C

Use management actions and natural disturbance events to create or maintain forest openings on an aggregate of 21% of the forested landscape to increase structural heterogeneity.

This objective was developed based on analysis from the LRA and literature.

Similar to vertical heterogeneity, horizontal heterogeneity spatial patterns are important resilience indicators because they influence disturbance behavior, regeneration, snow retention, and habitat quality. Heterogeneity across the landscape will increase landscape resilience. Two data sources were used to evaluate horizontal heterogeneity in the LRA: EcObject data from Illilouette Basin reference sites and data from Lydersen et al. 2013. These two sources allowed the Design Team to bracket the range of target resilient conditions presented in Table 9. The sum of "Individual/Sparse" and "Open" determined the target range for forest openings, i.e. 21-34%.

Objective 1C is to use management actions and natural disturbance events to create or maintain forest openings on 21% of the landscape. Across the landscape there is an over-representation of clumps and an under-representation of open areas. A forest opening can have more than one tree but less than five trees per acre with canopy cover ranging from 10 to 30 percent. We then summarized the current literature and existing range of conditions to determine the size of openings (Table 10). To achieve this Objective, managers should aim to create the small openings through mechanical treatments or prescribed fire. Natural disturbances such as wind-blown tree fall will also create small openings, while larger disturbances such as wildfire will create the larger openings. When openings larger than 40 acres occur, additional management intervention may be suggested as discussed in Objective 1E below.

Table 9. The percentage of the landscape within each spatial variation class and comparison with current LTW conditions. Red text indicates over-representation, orange indicates an under-representation compared to the horizontal heterogeneity target condition ranges.

Spatial Variation Class (terminology used in Lydersen et al. 2013)	Lower % Range	Upper % Range	% of LTW forested landscape
Individuals/Sparse[1]	1	7	1%
Open (Gaps)	20	27	8%
Stand initiation[2]	17		18%
Scattered clumps (2-4 trees, low cover)	13	36	34%
Clump (medium 5-9 trees)	11	15	28%
Dense clump (large, >10 trees)[3]	0.5	66	6%
All clumps[4]	48		68%

[1] Note sparse class was lumped into individuals, however based on how data was processed this could have been lumped into scattered clumps as well, lowering the range of scattered clumps to 7%.
[2] Stand initiation was likely considered a “gap” under Lydersen, however this class in EcObject indicates that the gap could transfer to forested stand while other gaps may not and therefore this was kept separate. This class would be considered early seral.
[3] Note this is a very large range. 0.5 is from Illilouette and 66% is from Lydersen.
[4] This was calculated by summarizing all clumps from the Illilouette data.

*Sum of “Individual/Sparse” and “Openings” determines range target for forest openings, i.e. 21-34%

Table 10. Literature and EcObject data to support target gap size for management.

Opening Type	Minimum patch size (acres)	Maximum patch size (acres)	Mean patch (acres)
Reference Sites Individuals/Sparse[1]	0.01	1.65	-
Reference Sites Open[1]	0.1	46.11	-
Proposed Openings from Small Scale Disturbance [2]	0.1	0.5	0.25
Openings from Large Scale Natural Disturbance[3]	0.5	40	-

[1] These values were derived from EcObject reference data (see LTW LRA).
[2] Proposed opening criteria was developed using best available science (Knapp et al. 2012, North and Sherlock, 2012, Lydersen et al. 2013) and considering the patch sizes derived from the EcObject reference data. These gaps would be created through small scale natural and managed disturbances such as tree fall, mechanical treatments, or prescribed fire.
[3] Openings created through natural disturbance may be larger in size and could range up to approximately 40 acres, which was derived from the LRA (EcObject reference data), and would be greater than an individual or sparse small tree opening (> 0.5 acres).

The percent of the current forested landscape in small disturbance openings as defined by the LRA totals 9% of the landscape (Table 9). However, this represents one point in time and does not reflect the dynamic nature of succession. Gaps are expected to follow natural succession processes and develop into future mature trees, while new gaps are expected to continually develop from natural disturbances and management actions. The Strategy therefore states to create or maintain gaps recognizing this is a dynamic process. The current forested landscape makes up about 50,000 acres, so this would equate to maintain gaps on a minimum of 10,500 acres up to 17,000 acres. These openings could be achieved through the ranges defined in Table 11.

Table 11. Target for the Percentage of Openings across LTW.

How to Achieve Openings	Percent of Landscape Lower Range %	Percent of Landscape Upper Range %
Target Reference Landscape[1]	21	34
Existing Landscape[2]	9	9
Proposed Openings[3]	8	8
Natural Disturbance Openings[4]	4	17
Total of Landscape	**7**	**34**

[1] These values were derived from EcObject reference data (see LTW LRA) and are the sum of "Individuals/Sparse" and "Open (Gaps)."
[2] The percent of the current landscape in small disturbance openings as defined by the LRA totals 9% of the landscape (see LRA; sum of "Individuals/Sparse" and "Open (Gaps)"). This represents one point in time and does not reflect the dynamic nature of succession.
[3] Proposed opening criteria was developed using GTR-237 (Knapp et al. 2012, North and Sherlock 2012). This percentage would occur over a 10 year period. The range over a 10 year period would be 3 – 17 percent with an average of 8 percent.
[4] The remaining openings on the landscape would be created through natural disturbances. The openings from natural disturbance are the Total Target Landscape for Openings minus the Proposed Openings from management.

Objective 1D

Conduct restoration treatments in approximately 400 acres of aspen and/or other riparian hardwood forest types.

The target acres associated with this Objective are based specifically on aspen, because that is where the majority of past activities have occurred. However, the Strategy recognizes that there are other types of non-aspen riparian forest (e.g. alder dominated stands) and therefore leaves this Objective open to also consider treatment of those forest types as well. The target resilient condition for aspen stands is to maintain at least 355 acres on west shore (USFS, CTC, CA State Parks), though Table 6 shows there could be up to almost 600 acres. Resilient aspen stands have multi-aged stems, most trees are less than 100 years old, aspen trees comprise greater than 75% of the overstory and understory, there is adequate regeneration to perpetuate the stand (more than 500 stems per acre that are 5 to 15 feet tall), and there is good undergrowth beneath the canopy (adapted from Campbell and Bartos 2001).

Currently, there are approximately 355 total acres of aspen: USFS has at least 275 acres, CA State Parks has about 60 acres, and the California Tahoe Conservancy has about 20 acres. Stands generally have excessive conifer trees in the upper and middle canopy (USFS, CA State Parks, and Conservancy data and observations). Riparian hardwood forests, like aspen, have excessive densities of upland species, especially conifers (USFS observations; Berrill et al. 2016; Berrill et al. 2017). Treatments should promote healthy aspen and riparian plant communities.

Aspen restoration has occurred on the west shore, but multiple entries are needed to achieve restoration towards resilience. In the past, the USFS has restored about 25-90 acres/year while CA State Parks restored 30 acres in 2007 (Source: Svetlana Yegorova). Managers should consider staggered treatment of aspen stands because treatment of more than 100 acres of aspen every 5 years could be too intense of a treatment, with massive conifer removal at one entry, and could lead to significant blowdown of aspen. Monitoring of blowdown associated with treatment could help to identify appropriate intensity and re-entry intervals.

Landscape modeling suggested that greater use of fire could help counter trends toward displacement of aspen by conifers, however, that modeling did not specifically include target treatments in aspen stands. However, fine scale modeling of fire and structural dynamics in stands with aspen found that treatment in aspen stands would moderate wildfire effects and help to sustain aspen and its associated ecosystem services see fine-scale modeling in aspen stands in Lake Tahoe West Science Report (forthcoming; will be available here). The results showed that removing conifers up to 30” DBH would greatly reduce canopy consumption if a wildfire were to burn through the stand, and that it would also reduce the rate of spread during severe fire weather conditions. That modeling found that removal of conifers between 14” and 30” DBH created non-conifer gaps and shifted fuels to aspen-dominated litter. This finding was consistent with previous research by Berrill et al. (2016), which found that removal of conifers up to 30” (and potentially some larger conifers) was important for extending treatment longevity and restoring aspen dominance.

Objective 1E

Facilitate reforestation after large-scale disturbance events.

This Objective was developed based on analysis from the LRA and literature. Managers should consider reforestation after large disturbances to promote or maintain species and genetic diversity in anticipation of changing climate. The strategies and prioritization guidelines for this Objective further specify to consider active reforestation when disturbances result in openings (Objective 1C) greater than 40 acres or when total acreage of openings exceeds 34% of the entire forested area. Multiple openings smaller than 40 acres may total to exceed the 34% threshold and may merit consideration of intervention, while in other cases a few openings greater than 40 acres may exist but total less than the 34% threshold and may not merit consideration of intervention. These specifications are based on supporting information provided above regarding Objective 1C. The Strategy specifies a goal of maintaining 21% of the landscape as forest openings, with the acceptable range described above in supporting information for Objective 1C as 21-34% based on Illilouette Basin reference sites and data from Lydersen et al. 2013. As also described above for Objective 1C, when openings created by natural disturbances are greater than 40 acres, managers should consider possible intervention and active reforestation actions. Managers may also want to replant smaller patches (i.e. <40 acres) for various reasons such as species composition or social concerns.

Managers might consider intervening when openings created from high severity wildfire exceed the proposed threshold for revegetation, however there may be cases where openings greater than 40 acres could be allowed to remain. Collins and Stephens (2010) reported that in the Illilouette basin, about half the area burned in high severity was in stand-replacing patches larger than 60 ha (150 acres). While such large high severity patches are an important component of the fire regime (Safford and Stevens 2017), Objective 2A below aims to prevent patches larger than 40 acres within the Wildland Urban Interface and General Forest. Cases where patch sizes larger than 40 acres are created through natural disturbance will likely represent a changed condition and require a new environmental analysis for any proposed actions.

While the LRA specifies a need to increase the amount of openings on the landscape, and the Strategy allows for doing so both through intentional creation of openings through management activities and through natural disturbances, care should be given if the total area of openings that result from natural disturbances exceed the thresholds described in Objective 1C. Consequently, reforestation is an action that can be considered in these cases to help maintain Objective 1C.

Goal 2 – Fires burn at primarily low to moderate severity and provide ecological benefits

Fire - Fire burns in an ecologically beneficial way that perpetuates a mosaic of forest conditions, has predominantly low and moderate intensities, and retains or improves wildlife habitat quality.

Objective 2A

Strategically locate and treat 7,900 - 9,000 acres of the Threat Zone and General Forest to limit high severity fire to contiguous patches less than 40 acres in size.

This Objective was developed based on analysis from the LRA, recent literature, and supported by LTW landscape modeling.

Fire severity patch size identifies areas on the landscape that are more or less prone to large patches of high severity fire and high tree mortality if a wildfire should burn in that area. Fire modeling based on the fire simulator was used to evaluate high severity patch size. During development of the LRA, the Design Team assumed that anything >6' flame length could be a high severity fire. The landscape model LANDIS classified 4-8' flame lengths as moderate severity and >8' as high severity.

There are 29,000 acres within LTW that are Wildland Urban Interface Threat Zone and General Forest. Of these, 9,300 acres are projected to experience high-severity patches greater than 40 acres (LRA). The remainder of that area may still experience high severity fire but not in continuous patches larger than 40 acres.

Safford and Stevens (2017) indicate that 3-15% of pre-EuroAmerican settlement fires in yellow pine and mixed conifer forests burned at high severity. Therefore, within the areas of predicted continuous high severity patches, 85% (7,900 acres) to 97% (9,000 acres) should be thinned to reduce potential fire severity to align with estimates of NRV severity distributions. Untreated areas, which are more vulnerable to high-severity fire, should range in size from 0.5 to 40 acres, and should have an average size of 3.5 acres. The target of 7,900 - 9,000 acres as defined in this Objective is a relatively small portion of the LTW landscape but should be focused on treatments to create firebreaks and break up potential high-severity patches greater than 40 acres.

Landscape modeling supported the proposition that increasing treatment through thinning and prescribed burning would reduce the incidence of high-severity patches greater than 40 acres. Greatly increasing prescribed burning (Scenario 5) was associated with sharp reductions in such large patches initially, although they tended to increase over the century; meanwhile, increased thinning (Scenario 3) also reduced the amount of large patches and the fire-focused Scenario 4 had more intermediate effects (Figure 3).

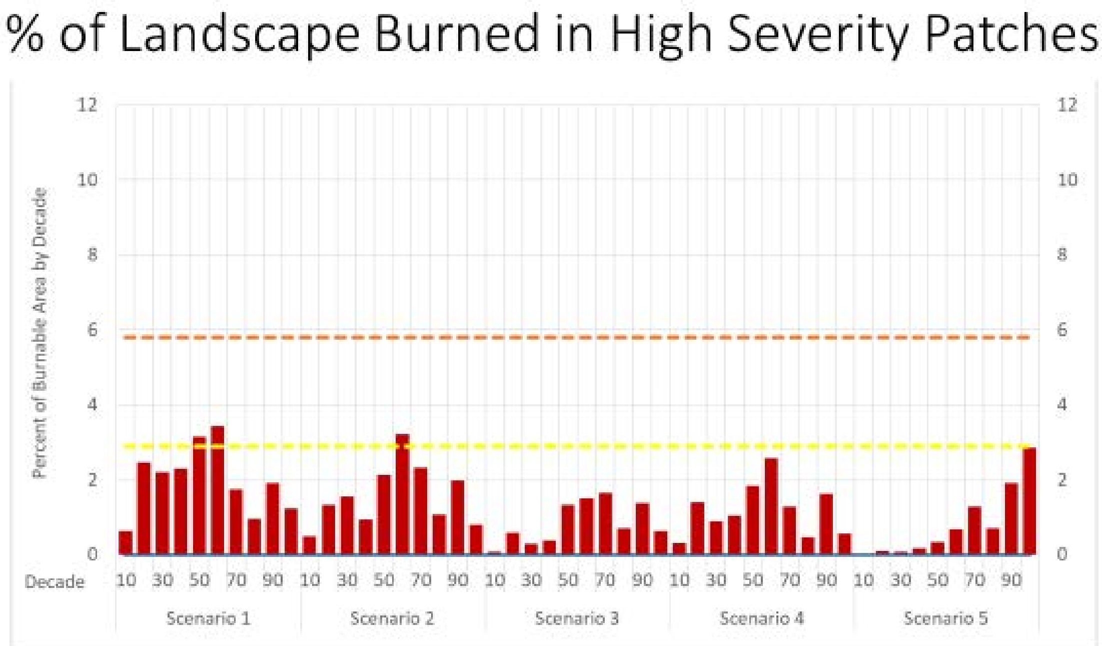

Figure 3. Percent of landscape burned each decade in large (>40 acre) high severity patches. The yellow line represents a value based upon a study in the Illilouette basin after several decades under a restored fire regime, while the dark orange line is twice that value.

It is important to recognize that most landscape fire models, including LANDIS, have not evolved to account for complex topographic-fire-atmospheric interactions that have been associated with many of the "megafires" such as the King Fire that resulted in extremely large patches of high severity burn. Such outcomes have been associated with extreme fire-driven winds up steep canyons with dry fuels (Coen et al. 2018). The potential for such extremely large and severe fires appears much reduced for the LTW landscape, which is more mesic than parts of the Sierra Nevada. Yet given substantial uncertainty in fire dynamics under a changing climate, increasing treatment to further reduce the likelihood of extreme events may be a rational part of a risk reduction strategy. Coen et al. (2018) suggested that managers may want to emphasize fuel reduction treatments on steep slopes in canyons to reduce the potential for extreme events.

Objective 2B

Increase the use of prescribed fire to remove understory fuels and promote changes in vertical structure; by year 20, prescribed fire is used on approximately 80% of operational burn days.

The need for the increased use of fire is supported by the LRA. The LRA found that there is "overall high departure from pre-settlement fire regimes [Table 12]. Some areas, such as riparian areas, meadows, and grasslands, were not assigned a condition class due to uncertainty with historic fire regimes. Spatially in the LTW project area, areas closer to Lake Tahoe are least resilient and areas further from Lake Tahoe in canyons and at higher elevations are ranked as less resilient. While the majority of the LTW project area is substantially departed, some areas of high elevation red fir and limited patches of yellow pine stands are less departed. The red fir patches are most prevalent on the south side of the landscape near and within Desolation Wilderness, and on the west side near Granite Chief Wilderness. These high elevation areas would have historically burned with less frequency. The lower elevation yellow pine areas are typically near areas with riparian vegetation" (LRA).

Table 12. Percentage of the LTW landscape in each condition class. Mean condition class is based on Fire Return Interval Departure data, which quantify the difference between current and pre-settlement fire frequencies.

Condition Class	% of LTW	Description
Condition Class 1 (0 – 33% departure)	3%	Resilient
Condition Class 2 (33 – 67% departure)	19%	Less Resilient
Condition Class 3 (> 66% departure)	78%	Least Resilient

The landscape modeling found that all the scenarios would reduce fire return interval, as the incidence of wildfire increases over time, and prescribed fire increases under the two fire-focused scenarios (4 and 5). An important consideration is that FRI and FRID measures do not directly account for the fire severity, just the frequency. Climate change alone is expected to reduce FRI, but if those fires occur with much higher severity than desired, these trends may not necessarily be considered as promoting resilience. In terms of both frequency and severity, scenario 5 moves the landscape closest to the pre-settlement fire regime (Figure 4).

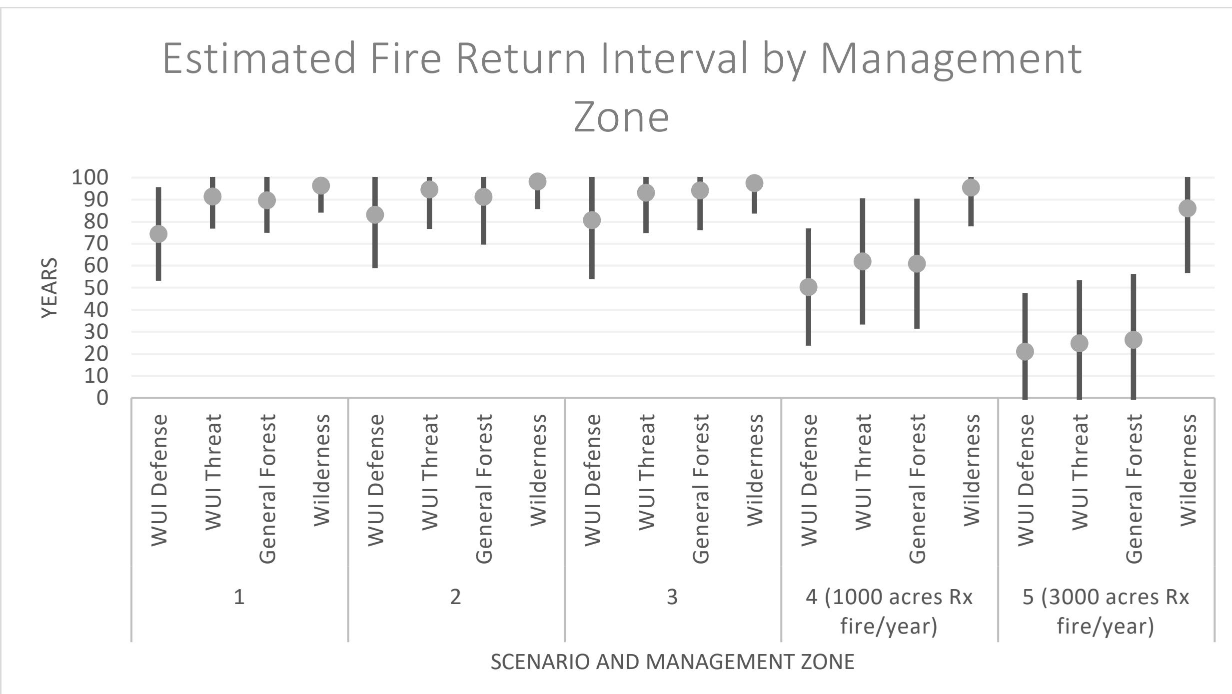

Figure 4. Estimated fire return interval by management zone across scenarios.

Recognizing that there are many challenges to implementing prescribed fire, we may not be able to achieve specific acre targets for this Objective, but felt it was important to utilize more available opportunities. An analysis of available burn days by Striplin et al. 2020 found that there was approximately 96 days per year of operable burn days based on three factors: historical "burn day" allowances by the California Air Resources Board (CARB), suitable fire weather conditions, and resource availability (often, whether firefighters would be available rather than managing wildfires elsewhere).

They also found that multi-day burn windows were much rarer, and such windows were particularly rare during July-September when more fires likely burned under natural conditions. Availability was highest during the spring months. Consequently, managers may need to rely more heavily on fall burns (which could be aligned with Washoe cultural burning), as well as spring burns and even winter burns (which may become increasingly feasible as the climate warms) in order to achieve the Objective of using more available days.

The landscape modeling results suggest that days of intentional burning increased under each scenario from 0 under scenario 1 to a level approaching and exceeding the historical average of burn days under scenario 5 (Table 13).

Table 13: Landscape modeling results for annual days of prescribed understory and pile burning under different scenarios for Lake Tahoe West only; about 100 acres/day were simulated as burned under scenario 4, and 180 acres/day under scenario 5.

Scenario	Annual days of prescribed understory and pile burning
1	0
2	7.2-10.3
3	23.9-32.6
4	36.1-38.1
5	88.1-104.2

These results suggest that the high level of prescribed burning under scenario 5 would pose substantial feasibility challenges for several reasons. First, the days of burning in the Table represent only burning for Lake Tahoe West, while the burn day availability metrics were for the entire basin. It is unlikely that all burn days would be available for burning in LTW given the potential for competing demands from other areas. Second, managers may need to burn larger areas over multiple days to accommodate large increases in prescribed burning, yet multiple-day windows are much less frequent. Third, the days of intentional burning indicator was evaluated only relative to operational feasibility, and it did not directly evaluate the likelihood of resulting in particular impacts. Accordingly, to realize the level of burning represented by scenario 5, considerable learning through adaptive management may be needed to ensure that smoke impacts and other outcomes remain in desirable ranges.

On the other hand, the analysis by Striplin et al. (2020) recognizes that the number of operable burn days are not absolutely fixed, and each of the individual components could be modified. Managers may be able to work with air quality regulators to increase opportunities to burn; it also may be possible to increase public tolerance of smoke, as well as to mitigate the impacts of daily burns over time, but such learning may require time. Striplin et al. (2020) also suggested that increasing resources and relaxing prescriptions to allow for greater mortality may both be important to facilitate increases in burn days. Because much recent burning in the basin has been very conservative in terms of severity, the latter approach may also need to be phased in through adaptive management to ensure that fire outcomes remain within desired conditions. These findings support a gradual increase in prescribed burning.

This Objective is focused on meeting the prescribed fire utilization target by year 20, because the Design Team recognized that thinning would need to occur in some areas prior to prescribed fire due to current forest conditions. This sequential approach is supported by previous research which has suggested various challenges or tradeoffs in the use of prescribed fire to remove fuels and restore desirable stand structure. For example, previous research at the Teakettle Experimental Forest suggested that prescribed burns in untreated stands did not carry as well or burn with as much intensity, and that the combination of thinning and prescribed burning was a more effective treatment (North et al. 2007). At a broader scale, recent synthesis has suggested to phase in fire following initial treatments both to address such ecological needs and to facilitate social adaptation to increased use of fire (Long et al. 2014).

Objective 2C

Increase the use of wildfire from natural ignitions that occur within the Wildland Urban Interface Threat Zone, General Forest, and Wilderness to mimic natural or desired fire regimes, and to remove understory fuels and promote changes in vertical structure.

When naturally ignited wildfires occur, they provide opportunities for fire managers to utilize natural fire as a restoration tool to achieve ecological restoration goals. The ability to utilize naturally ignited wildfire is dependent on a complex set of variables, including the proximity to values at risk, fire weather and fuel conditions, availability of resources, and other regional or national conditions that are outside the control of local fire managers. For these reasons, the ability to increase the use of naturally ignited wildfire to meet restoration objectives will be highly contingent on the success of land managers to implement broad scale treatments across the landscape that reduce fuels and improve forest conditions that provide improved resilience of the forests of LTW to wildfire.

Science modeling results suggest that fire will become more frequent over the next 100 years, with climate change being a key driver. The LANDIS modeling was modified to try to account for use of managed natural ignitions outside of the Wildland Urban Interface zones, though the actual application of such methods would likely be far more sophisticated than can be captured in a landscape dynamics model. Nevertheless, the results suggested that many such ignitions would self-extinguish without burning much area, and that area burned was highly variable from one year to the next, averaging only 200 acres/year. While that level would be a substantial increase from recent years, managers may be able to manage such ignitions to successfully burn more area over time. The science team also found that managed natural ignitions would likely be less expensive (costing about $1500/acre based upon the Long Fire) to implement on a per acre basis than thinning and wildfires.

Increasing forest resilience to wildfire at the landscape scale will give fire managers more confidence to take advantage of naturally ignited wildfires when they occur under conditions that meet restoration and fire management objectives. Recognizing that the frequency of fire will likely increase, having conditions that allow use of natural ignitions provides ongoing opportunity to maintain resilient forest conditions across much of the Lake Tahoe West landscape.

Goal 3 – Terrestrial and aquatic ecosystems support native species

Native species and ecological communities - The diverse and interacting networks of native species and ecological communities, and the habitats that support them, are present across the landscape to support and sustain their full suite of ecological and cultural roles, life history requirements, and to enhance plant and wildlife diversity.

Objective 3A

Create an increasing trend in the acres and quality of reproductive habitat for late seral-associated species.

The target resilient condition is to have more acres of reproductive habitat than currently exist.

The current acres of high and moderate quality reproductive habitat for California spotted owl, Northern Goshawk, and Pacific marten in LTW are provided Table 14 below. California Wildlife Habitat Relationship (CWHR) data produced by the California Department of Fish and Wildlife cross-walked with 2010 LiDAR data was used to examine habitat quality. Data for spotted owl come from the Conservation Strategy for the California Spotted Owl in the Sierra Nevada (v.1, April 2019). Data for goshawk come from the Sierra Nevada Forest Plan Amendment Record of Decision (Framework, 2004) and the Survey Methodology for Northern Goshawk in the Pacific Southwest Region, US Forest Service (Aug 9, 2000). We extrapolated because specific CWHR types, size classes, and densities were not provided in those references. Marten generally prefers similar habitat in terms of large trees and canopy cover and like goshawk can inhabit areas at higher elevations than spotted owl, so the CWHR type, size classes, and densities are the same for marten as for northern goshawk.

Table 14. California Wildlife Habitat Relationship (CWHR) types and the respective acreage in LTW for three species of concern.

Species	CWHR high and moderate quality reproductive habitat[1]	Acres in LTW
California spotted owl	High – EPN, JPN, LPN, MHC, MHW, MRI, PPN, RFR, SMC, WFR 5M, 5D, 6.	2,767
	Moderate - MHC, MHW, MRI, PPN, RFR, SMC, WFR 4M, 4D.	19,012
Northern goshawk	High - EPN, JPN, LPN, MHC, MHW, MRI, PPN, RFR, SMC, WFR, SCN 5M, 5D, 6.	2,797
	Moderate - EPN, JPN, LPN, MHC, MHW, MRI, PPN, RFR, SMC, WFR, SCN 4M, 4D.	23,208
Pacific marten	High - EPN, JPN, LPN, MHC, MHW, MRI, PPN, RFR, SMC, WFR, SCN 5M, 5D, 6.	2,797
	Moderate - EPN, JPN, LPN, MHC, MHW, MRI, PPN, RFR, SMC, WFR, SCN 4M, 4D.	23,208

[1] CWHR size classes include: eastside pine (EPN), Jeffrey pine (JPN), lodgepole pine (LPN) montane hardwood-conifer (MHC), montane hardwood (MHW), montane riparian (MRI), ponderosa pine (PPN), red fir (RFR), Sierran mixed conifer (SMC), white fir (WFR), and Subalpine Conifer (SCN). CWHR size and density classes include: 4 = tree size QMD 11-24 inches, 5 = > 24 inches; M = moderate cover (40-59%), D = dense cover (60-100%).

[2] EcObject using eveg data for CWHR, current as of LiDAR data collected in 2010.

The data in Table 14 are coarse and broad, reflecting general habitat associations for the species throughout their ranges in the Sierra Nevada and not specific to the Lake Tahoe Basin where each of these species have been detected to regularly use moderate (CWHR size class 4) quality habitat for reproduction and even lesser quality habitat (e.g. CWHR size classes 3).

Reproductive habitat was selected because it is the most limiting factor in female occupancy and reproductive success. This habitat is also underrepresented on the LTW landscape when compared to reference conditions (late seral closed canopy, see seral stage Objective 1B above).

Note, for the purposes of monitoring, actions to trend currently unsuitable or moderately suitable habitat in the direction of suitability may be tracked as acres treated to trend habitat toward suitable reproductive habitat.

LTW habitat modeling for these species suggested that habitat suitability for old forest-associated predators like California spotted owl, Pacific marten, and northern goshawk is projected to increase with time, driven by increases in older/larger trees (see seral stage Objective 1B above). Key factors in the habitat quality models were total biomass, areas with old trees (in various age classes), and mid-late seral stages. Overall in the landscape modeling, the recruitment of late seral forest outpaced losses from high severity wildfire or bark beetle outbreaks. That successional trend is associated with increasing probability that areas will support wildlife territories over time.

The projected effects of different management scenarios varied widely across the three species, reflecting different drivers to be important for each one. Modeling also suggested that increased thinning under scenario 3 would result in the most habitat for female Pacific marten, while heavy burning under scenario 5 would be less favorable. On the other hand, increased prescribed burning under scenario 5 would yield the most favorable conditions for northern goshawk. Trends for spotted owl were the most variable, with different scenarios performing better for different time periods. However, the modeling suggested that spotted owl had the most limited habitat of the three species, and it considered elevation as a hard constraint on the species. Consequently, that species did not increase as much as the other two, who were not limited by elevation. Modeling suggested that increasing treatments under scenario 3 might slow the increase in spotted owl habitat in the short term, but that it would limit the cumulative percent of spotted owl territories burned by high severity wildfire over 100 years.

As more general guidance, researchers suggest that treatments should aim to mimic the heterogeneity associated with natural fire regimes. A recent study (North et al. 2017) indicated that tall trees (>48 m) were a particularly important indicator of owl habitat suitability, while trees less than 16 m were avoided; that finding is consistent with a focus on thinning smaller trees as represented in the landscape modeling. Large diameter snags and coarse woody debris are important characteristics for each of these three species. These species may not only nest or den in these features but can use them to search for prey. As part of this Objective to improve habitat quality for the species, Table 15 and Table 16, from the LTBMU Land and Management Plan (USDA, Forest Service 2016), show the desired amount of snags and woody debris for each of the forest types in the late seral forest growth stage. For spotted owl, goshawk, and marten, we recommend that these levels be considered the lowest possible levels to be considered suitable habitat for the species. Importantly, the largest snags and coarse woody debris are the most valuable to the species. High levels of small diameter (< 20 inch) coarse woody debris and snags would detract from the suitability of the habitat.

Table 15. Lowest possible amount of snags to be suitable habitat for each of the forest types in the late seral forest growth stage.

Forest Type	Snags (>15" dbh/acre)
White fir-mixed conifer	6
Jeffrey pine	3
Red fir	7

Table 16. Lowest possible amount of coarse woody debris to be suitable habitat for each of the forest types in the late seral forest growth stage.

Forest Type	Coarse Woody Debris (tons/acre)
White fir-mixed conifer	10
Jeffrey pine	6
Red fir	20

Objective 3B

Restore and maintain at least 780 acres of meadows.

There are currently an estimated 105 meadows that cover 780 acres in the LTW project area (UC Davis 2017). This estimate is likely low for both meadow numbers and total acreage, as the Meadow Layer is a compilation of previously mapped and remotely observed meadows but does not represent all meadows. The 780 acres is derived from a remote sensing and heads-up digitization mapping on aerial imagery. It may be that much more area exists with the right soils and hydrologic condition that could support meadow habitats. As a result of the historic fire suppression efforts on the west shore, many meadows are encroached by conifers, primarily lodgepole pine, and some meadows may be overgrown entirely. These meadows are in a variety of conditions, though much of that area has not been assessed. None of the landscape modeling evaluated meadows specifically since they are too fine-scale. We do not currently know the condition of the 780 acres identified as meadow by the UC Davis Meadows Compilation, so the first Strategy Guideline is to determine the actual extent of meadows in LTW.

Increasing the removal of conifer species in meadows by hand thinning or fire should increase the extent of meadow habitat. However, since meadows are so dynamic and susceptible to impacts of climate change, we felt the best objective would be to maintain, at a minimum, the current amount of meadow area, though not necessarily in the same places.

The following conditions should be present to maximize the future resilience of meadows: A variety of meadow types should be maintained. Meadows should include a mosaic of habitats and successional plant communities that support native plant and animal populations, including aquatic species dependent upon cool and high-quality water flows. Natural processes occur to maintain desired vegetation structure, species diversity, and nutrient cycling. Healthy stands of willow, alder, cottonwood, and aspen are present where they would naturally occur. Meadows are inherently dynamic systems and can grow or disappear on the landscape with interannual variation and changes in microclimate.

For the LRA we focused on the best available datasets at that time considering climate change, however we recognize that in the future there will be complementary datasets that could be used. Meadows that are well connected and provide future climate refugia may be more resilient to future disturbances and would potentially provide more stable habitat for terrestrial and aquatic species. The LRA defined meadow refugia as areas where the magnitude of change in minimum temperature and annual precipitation is minimal, as measured from a baseline period of 1910-1939 and focused on temperature, precipitation, and water balance variables (Maher et al. 2017). The Design Team focused on evaluating refugia based on minimum temperature (2010-2039) and annual precipitation modeled from the GFDL-A2 (warmer and drier climate scenario) (Table 17) (Maher et al. 2017).

Table 17. Number of meadows and percentage of LTW area that provides climate refugia based on the meadows included in the study.

Meadow Refugia	Description	# of Meadows	% of LTW Meadow Area
Provide climate refugia for **both** temperature and precipitation	Resilient	29	35%
Do not provide climate refugia for temperature **or** precipitation	Less Resilient	6	12%
Do not provide climate refugia	Least Resilient	59	53%

In a resilient condition, meadow areas exhibit a high degree of hydrologic connectivity horizontally upstream and downstream, both laterally across the floodplain and vertically between surface and subsurface flows. Meadows that are well-connected and provide future climate refugia may be more resilient to future disturbances and would potentially provide more stable habitat for terrestrial and aquatic species. In the LRA, meadows were evaluated for connectivity in terms of distance, topography, water courses, and roads and trails based on Morelli et al. (2016) and Maher et al. (2017) (Table 18).

Table 18. Number of meadows and percentage of LTW area and their connectivity in terms of distance, topography, water courses, and roads and trails, based on the meadows included in the study.

Refugial meadows with connectivity rankings	Description	# of Meadows	% of LTW Meadow Area
Really Well Connected	Resilient	62	79%
Well Connected	Less Resilient	5	6%
Least connected	Least Resilient	27	15%

Detailed hydrologic modeling indicated that removal of small trees in forest thinning treatments would increase snowmelt, which could potentially translate into increased water runoff into meadows (see Objective 4C). This could improve the extent and condition of meadows and reduce impacts from drought and climate change.

Objective 3C

Improve the habitat condition and promote climate refugia for native aquatic and terrestrial wildlife species.

The target resilient condition is a landscape that supports the life history requirements of native species with high-quality well-connected habitat. Currently, sensitive areas, including stream environment zone (SEZ) and Protected Activity Centers, have a range of conditions. The other Objectives under this Goal emphasize actions that would improve habitat condition of these sensitive areas. However, the other Objectives do not address the presence of roads and trails, yet these landscape features occur in high densities in the LTW project area and can negatively impact habitat condition. Some impacts from roads and trails include habitat fragmentation, increasing edge habitat, and introducing humans and non-native species into areas of potentially important climate refugia.

There are spatial data for the density and length of roads and trails in sensitive habitats in the LTW project area, however there is a need to determine if and what types of impacts are occurring. Opportunities to remedy impacts would be developed on a case-by-case basis. The density of trails and roads is based on data provided in the TRPA-managed spatial information for impervious coverage. The LRA found that 74% of the landscape is within ¼ mile of a road or trail. Twenty-four percent of the LTW project area is between ¼ and ½ mile of a road or trail, and only 2% of the landscape has no roads or trails within ½ mile. There are only limited areas near and within the Desolation Wilderness that are over ½ mile from human development. Below is a list of miles of roads and trails that were calculated for the LRS:

- 162 miles of roads in SEZ
- 82 miles of trails in SEZ
- 7 miles of roads in owl and goshawk Protected Activity Centers
- 20 miles of trails in PACs

The LRS did not specify an exact acreage or mileage target for improvements under this Objective because we do not currently know the extent of degradation from roads and trails.

Riparian areas are part of this Objective because they may be important movement corridors for wildlife during the prolonged dry season characteristic of the Sierra Nevada (North et al. 2009). With changing climate conditions, dry periods may extend, making healthy riparian corridors an important landscape element. The LRS did not specify an acreage target for restoration of riparian areas because we do not fully know the extent of connectivity/disconnectivity of riparian corridors.

In addition to SEZs and PACs, Lake Tahoe West aims to improve and protect aquatic habitat in perennial streams. Again, roads and trails can have negative impacts by interrupting aquatic connectivity and introducing humans and non-native species into potentially important climate refugia. The LRA found:

- 93 miles of perennial streams
- 10 streams surveyed from 2007-2014 for non-native fish species. All of these streams contained non-native fish species, but ranged from 0% native species caught to 92% native species caught (USDA December 2016).

Characteristics of aquatic habitats that can act as climate refugia are colder streams (13-15 degrees C for Lahontan Cutthroat Trout; Bear et al. 2007), stream beds with more microclimates, streams with more consistent water flow, streams with consistent water depth, and riparian corridors (20-60 m wide; Collins, et al. 2006). Currently all 10 streams surveyed in LTW have non-native species. Data for this indicator come from the LTBMU Basin-wide native non-game fish assessment 2007-2014 comprehensive report (USDA 2016). Non-native fish removal should occur strategically based on which streams are slated for LCT reintroduction.

Objective 3D

Resize, replace, remove, and/or reconfigure 10 identified barriers to improve passage of native aquatic organisms.

This Objective was defined based on the LRA and the historic rate of restoration. There are 32 identified man-made barriers that are impassable to sculpin as of 2011, meaning 80% of the aquatic landscape is inaccessible (Vacirca 2010). Streams with no man-made barriers are assumed to have a higher amount of aquatic organism connectivity. These streams are considered more resilient because aquatic organisms are able to move throughout the stream to find refugia in times of drought or climate change. Madden creek and Cascade creek were the only creeks identified as resilient with no barriers.

The target resilient condition is that there are no barriers impassable to sculpin (Professional Judgement, Sarah Muskopf, USFS aquatic biologist). Sculpin were selected as the threshold because they are native to these creeks and are relatively weak swimmers (limited jumping ability to get over barriers). Therefore, if sculpin have made it up the creek then one can assume that most other fish that comprise the food web are present as well.

Based on the EIP tracker, 11 culverts have been replaced in the Basin over the last 10 years. Assuming LTW is 1/3 of the Basin then 3-4 culverts replaced in 10 years is realistic for LTW. Recently, USFS (Theresa Cody) has replaced a culvert every 2-3 years which would equal 3-5 culverts every 10 years. Thus 10 culverts replaced over 20 years is a realistic objective.

Objective 3E

Implement new and expand existing early detection rapid response programs for invasive species management.

The target resilient condition is to prevent new introductions, decrease the number of terrestrial and aquatic non-native species, and decrease the acreage of existing high-priority aquatic and terrestrial invasive species infestations (see definitions for high priority species below). Terrestrial and aquatic habitats are continuously under pressure of invasion by non-native invasive species. There is limited or no “innate” natural resilience in native terrestrial and aquatic plant communities to invasions as far as we know. Undisturbed or intact communities may be more resistant to invasions than degraded ones (e.g., Davis et al, 2000). However, to restore forested and meadow communities LTW aims to increase the pace and scale of forest thinning and prescribed burning. Forest thinning has been found to be associated with an increase of invasive species diversity across the western United States (Willms et al, 2017). Therefore, invasion resilience requires active management such as regular surveys for new species introductions, implementation of practices that prevent new species introductions (e.g.

watercraft and forest thinning equipment cleaning), and rapid response to new introductions before they have the chance to spread.

Early Detection Rapid Response (EDRR) is the primary strategy for attaining this Objective. EDRR includes targeted searches for and treatment with the goal of eradication of non-native invasive species that are not yet present in the Lake Tahoe basin or present but are not widespread (individual patch size <0.25 acres). Rejmanek and Pitcairn (2002) show empirical evidence for successful eradication of infestations under 0.25 acres.

Terrestrial species target resilient condition:

- 45 miles of all state highways are surveyed annually.
- 40 miles of county roads, paved, and high use dirt roads and trails are surveyed every 3 years.
- 100% of facilities areas are surveyed every 3 years.
- 60 miles of high use trails (to be determined by manager) are surveyed every 3 years.
- 100% of recent restoration projects receive at least 2 survey visits within 5 years of restoration.
- 100% of meadows and riparian corridors in the Wildland Urban Interface are surveyed every 5 years.
- 100% of new Class One targeted[1] detections are treated within 2 years of detection and treated annually until populations are eradicated. EDRR populations are expected to be small in size, which makes this goal more feasible. Area of existing Class One populations (2018 level) has not increased.
- 80% of soil-disturbing projects receive best management practice inspections prior to project start.

By area, LTW is 30% of the Lake Tahoe Basin so the numbers below were derived by dividing the Basin annual totals by 3 (data as of 2017) (EIP Tracker). This represents the current amount of the landscape that is surveyed and treated:

- 72 acres surveyed for terrestrial invasive species annually
- 272 acres treated for terrestrial invasive species annually

For this Objective, the Design Team decided that terrestrial surveys should focus on areas that are likely to receive new introductions: paved and dirt roads that receive high levels of traffic, and perhaps the first mile or two of trails near roads. Restoration is also a disturbance that often allows an opportunity for invasion. Increased pace and scale of restoration implies increased pace of potential introductions of non-native invasive species. Therefore, areas where restoration activities have taken place recently should also be monitored for new invasive plant occurrences; particularly areas that are not forested and are resource-rich (where trees are not the dominant species) such as meadows, riparian areas, and burned open areas.

All agencies currently have best management practice (BMP) policies aimed at preventing new introductions, but there are no resources to check compliance with the BMPs. An analogy to that would be having a voluntary rather than the existing mandatory boat inspection program that is part of Lake Tahoe's Aquatic Invasive Species prevention program. Each agency's plant programs need additional resources to inspect projects for BMP compliance.

[1] For terrestrial plant species, the targeted list is the Lake Tahoe Weed Management Area's (LTWMA) Class One list (http://tahoeinvasiveweeds.org/weeds/priority.php).

For aquatic invasive species, the target resilient condition is similar:

- No known populations of aquatic invasive species currently in LTW. The targeted list is Eurasian watermilfoil, curlyleaf pondweed, bullfrogs, and warm water fish (TRPA 2014).
- Vulnerable habitats are surveyed regularly for new infestations and any detections are treated rapidly.

Currently, the aquatic invasive species found in the LTW boundary are Eurasian watermilfoil, curlyleaf pondweed, bullfrogs, and warm water fish. This represents the current amount of the landscape that is surveyed and treated:

- 6 acres surveyed for aquatic invasive species annually
- 5 acres treated for aquatic invasive species annually

For the aquatic piece of this Objective, Whitney Brennan estimated that there are 13 acres of vulnerable habitat (lagoons, creek mouths, and streams up to Highway 89) in LTW. These should be surveyed regularly. In addition, using current control techniques it is feasible to eradicate aquatic invasive plants over the next 20 years. For some other invasive species such as bullfrogs, effective control techniques may need to be developed over time.

Goal 4 – Healthy creeks and floodplains provide clean water, complex habitat, and buffering from floods and droughts

Water: Quality, Supply, and Hydrologic Function - Properly functioning riparian ecosystems exist across the landscape. Water reliability, quantity, quality, and connectivity are buffered against precipitation variability and disturbance.

Objective 4A

Restore road and trail network including stream crossing structures (e.g. culverts, rock fords) to accommodate future increased stream flows and prevent erosion and water quality impacts.

Channel crossings on roads and trails that have functioning culverts, rock armoring, or have other appropriate best management practices (BMPs) can reduce the potential for channel erosion at those crossings, and therefore sediment loading. The target resilient condition is that all roads and trails are properly located, built, and maintained to prevent erosion and water quality impacts; furthermore, all road/trail stream crossings are sized correctly and are operating efficiently to prevent erosion and water quality impacts. Such designs need to accommodate increased flows of water, sediment, and debris under climate change and wildfire. Modeling results indicated that loads would be substantially higher under future climate conditions and following wildfires.

LTW modeling on the forest road network considered general effects of increasing the use of forest roads to support harvest, or, conversely, recontouring existing roads to restore a more natural condition. Although mass erosion rates from roads typically are one to several orders of magnitude higher than from other land uses based on unit area, roads usually occupy a relatively small fraction of the landscape. The science team found that road networks in the Lake Tahoe basin are generally well-maintained and are present at lower densities compared to other national forest areas. For that reason, the impacts associated with forest roads appear to be lower than have been found in other areas. Specifically, sediment from the current LTW forest road network was estimated to be less than 1% of that from the hillslopes. However, the analysis found that closing unpaved roads that are currently trafficked would reduce sediment delivery by 20 percent. There are legacy roads on the landscape that are no longer needed which could be considered for removal or restoration so that they are not interacting with watercourses and potentially causing erosion. The results also identified segments that may be particularly high sediment producers. Additional modeling in the Blackwood watershed identified sizeable networks of abandoned or “ghost” roads; targeted rehabilitation of such features could further reduce sediment delivery. These findings indicate that there is room for improvement in the road network, and accordingly, promoting and maintaining good road conditions and BMPs is a priority for this Objective.

Achieving the LTW Strategy will require the use of the forest road network for access and management activities, but this will likely increase sediment delivery increase from the road network. Modeling found that actively using unpaved forest roads would, on average, increase sediment delivery by 19 times on those road segments used for access, for the years in which the thinning operations are active. However, following active use for harvest, those estimated loads would rapidly return to the current values. Consequently, the increased sediment delivery associated with harvesting operations could be approximated by multiplying the estimated delivery by the fraction of time that the roads are actually used for harvest (for example, if the roads are likely to be opened for harvest 4 years out of 20, then the increase might be about 4.6 times current loads from those road segments). These calculations do not account for potential sediment reduction benefits for harvest because of reduced impacts from wildfires, nor the reduction in erosion following wildfire because of the potential deposition of eroded sediments on the road surface. The report on the Emerald Fire (Lake Tahoe West Science Report forthcoming; will be available here) illustrated that road systems and associated detention basins can also serve to mitigate erosion following wildfires. Maintaining road BMPs, including stream crossings, to reduce the impacts from active roads is crucial. Furthermore, keeping fires to smaller areas may increase the potential for those downstream systems (including natural landscape features such as meadows) to process sediments from burned areas without being overwhelmed.

Stream crossings across the landscape will be evaluated and restored as part of local vegetation management or other restoration projects. The Strategy calls for managers to focus stream crossing improvements in locations that are also a priority for aquatic organism passage (Objective 3E) and in meadow locations where failures are likely to contribute to meadow degradation. Some roads will be necessary for upland thinning treatments, but it may be feasible to decommission and restore unneeded legacy roads. Managers will identify where increasing the capacity of stream crossing structures to allow for increased flows of water, sediment, and debris crossings is needed. Priority will be given to crossings that may be vulnerable to failure following wildfires or prescribed fire (particularly due to undersized culverts), to avoid exacerbating channel incision or limiting transport of sediment and woody debris. Larger crossings that may need additional analysis and/or engineering will be more difficult to improve but should be considered.

Objective 4B

Restore currently identified stream reaches and enhance up to 9 miles of stream channel to improve function, reduce excessive bed and bank erosion, and meet Total Maximum Daily Load recommendations.

The target resilient condition is that sediment transport processes influence erosion and deposition such that streams are in dynamic equilibrium, as appropriate for the geologic setting, valley type, and geomorphology. Streams do not exhibit signs of chronic sediment overloading (aggradation) or accelerated (human-caused) bank and bed erosion (incision and gully formation). Coarse woody debris forms and maintains pool and cover habitats. The physical structure and vegetative condition of streambanks minimizes erosion and sustains desired habitat diversity. In-stream flows and floodplain inundation frequencies sustain healthy aquatic habitat conditions, and naturally reproducing populations of native plant and animal species.

There are approximately 4.19M feet (almost 800 miles) of natural stream channel on the west shore (TARIv2. Spatial Informatics Group, 2015). The condition of every foot is unknown however the Lake Tahoe TMDL Pollutant Reduction Opportunity Report (California Water Boards 2008) identified priority watersheds.

The Strategy Objective was defined using the historic rate of river restoration in the Basin. The approximately 4.19M feet of natural stream channel on the west shore represents 31% of the streams in the Basin. According to EIP Tracker (laketahoeinfo.org) data for the last ten years, there is an annual average of 2,720 feet of stream enhanced, and 5,008 feet of stream restored (Table 19). Applying that historic average rate to LTW, we could expect to enhance 846 ft/year and restore 1,557 ft/year.

Combining these and looking out to 20 years we can expect to restore or enhance about 48,000 feet or 9 miles.

Table 19. Historic rate of stream enhancement and restoration in the Tahoe Basin reported in the EIP Tracker.

Year	Enhanced (linear ft)	Restored (linear ft)	Total (linear ft)
2007	0	5,300	5,300
2008	0	0	0
2009	4,429	3,200	7,629
2010	680	0	680
2011	330	7,917	8,247
2012	1,317	15,800	17,117
2013	1,470	3,100	4,570
2014	2,000	5,000	7,000
2015	4,534	67	4,601
2016	10,676	13,500	24,176
2017	4,488	1,210	5,698
Total	**29,924**	**55,094**	**85,018**
Total annual average	2,720	5,008	7,728
LTW annual average	846	1,557	2,403
LTW 20 years	**16,916**	**31,145**	**48,061**

It is unknown at this time if there is that much river restoration needed, however accounting for enhancement actions, it seems like a feasible objective. Additional assessment of the streams is necessary to determine current condition and find areas of concern. Any assessment will need to be repeated to find areas meeting the restoration criteria, which are out of dynamic equilibrium. The restoration criteria were defined by best professional judgement by the Design Team. In consultation with hydrologists at each Agency and from the EIP Tracker, the following reaches are identified as needing restoration (the first two are specified in the Strategy):

- Ward Frontal Watershed- Restoration (US Forest Service; EIP project 01.02.02.0029)
  - Install large wood along 3,000 feet of Ward Creek, to enhance aquatic habitat and channel stability. Restore approximately 2,000 feet of Ward Creek through floodplain grading and new channel construction.
- Blackwood Creek Restoration Phase 4 (US Forest Service; EIP project 01.02.02.0046)
  - Proposed adaptive management work repairing a few sections and adding more woody debris/boulder structures
- Ward Creek downstream of Hwy 89
  - Privately owned, difficult to get access
- Blackwood Creek downstream of Hwy 89
  - Privately owned, difficult to get access
- Burton Creek (CA State Parks; EIP project 01.02.05.0014)
  - Section being restored along with Antone Meadow Restoration by CA State Parks and TCPUD pipe replacement
- Polaris Creek (EIP project 01.02.02.0040)

    - Proposed restoration to the outlet around Lake Forest campground and ball fields
- Meeks Creek (US Forest Service; EIP project 01.02.02.0038)
    - Section being restored along with Meeks Meadow Restoration Project

Objective 4C

Complete upland thinning treatments to increase snowpack retention, groundwater recharge, and resultant late-summer water availability.

This Objective was developed based on LTW water quantity modeling. The target resilient condition is that snowpack is maintained to mitigate expected declines in snow due to climate change. Increasing snow retention has potential to increase groundwater recharge and late season water availability for downstream aquatic features. It also provides additional water for the remaining upland trees to reduce the risk of mortality from drought stress.

The water quantity modeling found that removal of understory conifers (up to 65 feet/20 m tall) are projected to increase water yield (Harpold et al. 2020, Krogh et al. 2020). This benefit was most pronounced in relatively dense stands, particularly at lower elevations. The initial analysis of the Rubicon study area (Harpold et al. 2020) suggested that such favorable areas were more common in north-facing stands, but the second analysis across Ward and Blackwood watersheds found south-facing areas might be most promising (Krogh et al. 2020). That result was consistent with other guidance to target lower densities on south-facing slopes. Because hand thinning generally permits removal of trees up to 14” DBH, mechanical treatments might be necessary to remove trees up to the 20 m class (such trees might be up to 16-18” DBH) and to remove the volume of material in dense stands.

More specifically, research by the water quantity modeling team found that thinning trees below 10 m and 20 m increased melt volume by 6% and 12%, respectively, at the watershed scale. However, there was substantial variability, with some areas experiencing increases in melt volume up to 80%, while areas with little tree cover even experiencing decreases. Reductions in Leaf Area Index (LAI) were associated with increases in melt volume for all snow zones, but the effects were larger at middle to low elevations where forests are denser. Consequently, across a range of watersheds in Lake Tahoe West, responses to thinning were greater in watersheds that are more densely forested, such as Burton, McKinney, and Little Rubicon Creek, than in the Eagle and Cascade Creek watersheds, which have less dense forests. The former group is predominantly composed of low elevation forests, while the latter watersheds are large, steep, and extend to higher elevations.

For the integrated analysis, the science team used LAI values from LANDIS as an indicator of water quantity, with decreases in LAI being associated with beneficial water flows. LANDIS modeling suggested decreases in LAI on the order of a 20% across broad landscape areas under a scenario with heavy thinning under scenario 3 (Figure 5). That level of reduction may be consistent with the expected changes from the water quantity modeling where they explicitly removed all trees below a certain height in a study area, however, the reported potential gains of 10-20% may be limited to favorable areas with many young trees rather than occurring across the entire landscape.

The fine-scale hydrologic analyses in LTW did not directly consider fire treatments; however, the landscape modeling suggested the fire-focused scenarios would reduce LAI, with the largest reductions under scenario 5 (Figure 5). However, the hydrologic effects of fires may be more complex than simple removal of small trees. Fires might also alter soil conditions; since undisturbed soils in the basin are often naturally hydrophobic, fires have potential to reduce or exacerbate those conditions. Further research in an adaptive management framework would help to evaluate how fire compares to thinning. However, Boisramé et al. (2016) reported preliminary findings that in the Illilouette Creek Basin, restoration of a natural fire regime after decades of fire suppression may have increased or stabilized water yields, while also promoting other objectives such as restoration of meadow areas. Those results also lend support to greater use of fire to promote landscape resilience Objectives as proposed in the Strategy.

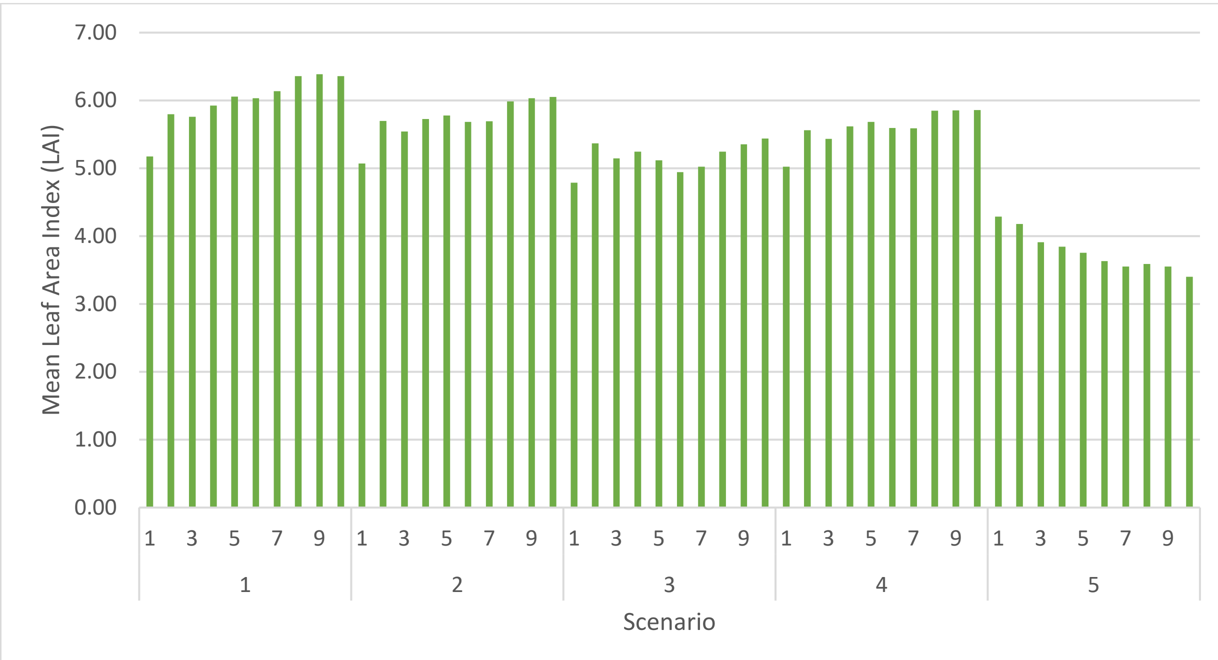

Figure 5. LANDIS-II outputs of landscape mean Leaf Area Index (LAI) values by management scenario over time, under a CanESM RCP4.5 climate projection. Reductions in LAI were shown to have an impact on snow melt and water yield.

Objective 4D

Treat around areas with highly erosive soils to reduce fire risk, and conduct thinning where necessary with special considerations.

This Objective was informed by studies in the basin, results of the WEPP water quality model, and integration with LANDIS landscape scenario modeling. The WEPP model was used to model soil erosion potential under a variety of different conditions, including:

- current conditions (see results in Table 20 below)
- uniform forest thinning
- uniform fire under four different severities (prescribed burning, low, moderate, and high severity wildfire)

The water quality modeling projected that erosion and pollutant loading would increase in that order, with moderate to high-severity fires having the potential to generate very large sediment yields, especially on naturally erosive soils. Potential for very fine sediment is greatest in watersheds underlain by volcanic soils, specifically Ward and Blackwood (Table 20).

The Lake Tahoe TMDL estimated loads of 41 x 10^{18} fine sediment particles (<16 microns) and 12 metric tons per year of total phosphorus from undeveloped forested upland runoff for the entire Lake Tahoe Basin. Table 20 was based upon sediment yield, rather than amount of fine sediment particles, however the proportions of sediment and phosphorus per watershed are similar to the analysis supporting the TMDL (Simon 2006). Blackwood, Ward, and Eagle Creek watersheds have the highest amount of hillslope soil loss and discharge of sediment, phosphorus, and very fine sediments.

Table 20. Current condition, baseline water quality estimates from WEPP model for modeled watersheds, from north to south within LTW.

#	Watershed Name	HUC 7	Total contributing area to outlet (ha)	Total hillslope soil loss (tonne/yr)	Total channel soil loss (tonne/yr)	Sediment discharge (tonne/yr)	Phosphorus discharge (kg/yr)	Sediment Yield of Particles Under 0.016 mm (tonne/yr)
1	Dollar	Burton Creek/Lake Forest/Dollar Creek Frontal	262.8	0.2	11.3	11.5	13.4	2.2
2	Lake Forest	Burton Creek/Lake Forest/Dollar Creek Frontal	110.7	0.0	1.5	1.5	2.7	0.3
3	Barton	Burton Creek/Lake Forest/Dollar Creek Frontal	188.2	0.2	11.7	11.9	12.1	2.3
4	Burton	Burton Creek/Lake Forest/Dollar Creek Frontal	1345.1	3.7	132.6	135.6	144.6	25.6
5	Tahoe State Park	Burton Creek/Lake Forest/Dollar Creek Frontal	268.6	0.2	18.2	18.3	19.7	3.5
6	Unnamed	Middle Truckee River	122.5	0.0	2.9	2.9	4.6	0.6
7	Ward	Ward Creek Frontal	2314.2	748.6	14596.4	302.6	343.5	69.1
8	Unnamed	Ward Creek Frontal	160.3	0.3	27.9	28.2	28.9	5.4
9	Blackwood	Blackwood	2671.1	1196.0	990.4	1073.1	989.7	279.8
10	McKinney	McKinney Creek	1309.4	13.3	216.4	202.3	3129.9	41.4
11	General	General Creek	1819.7	52.0	234.8	123.4	166.6	41.3
12	Meeks	Meeks Creek	1981.5	364.7	313.8	189.7	240.6	56.2
13	Sierra	Lonely Gulch	211.4	9.1	20.3	28.6	29.2	4.4
14	Lonely Gulch	Lonely Gulch	246.2	0.2	59.1	59.3	54.1	11.4
15	Paradise Flat	Lonely Gulch	149.3	0.1	18.1	18.0	17.9	3.4

16	N. of Rubicon	Lonely Gulch	295.2	10.4	43.6	52.3	49.2	8.7
17	Rubicon	Lonely Gulch	386.9	131.7	45.2	104.8	91.9	14.1
18	Eagle	Eagle Creek-Emerald Bay Frontal	1647.1	10399.2	647.0	716.7	903.2	274.1
19	Cascade	Cascade Creek	845.7	2148.0	352.9	322.4	292.3	115.5
20	Tallac	Outside of LTW	877.5	238.1	150.6	156.6	148.3	36.4
	TOTALS		**17213.4**	**15316.0**	**17894.7**	**3559.7**	**6682.4**	**995.7**

The TMDL did not anticipate a large reduction in phosphorus or fine sediment load from undeveloped watersheds, aside from forest roads (discussed separately). The TMDL largely ignored risk of wildfire on sediment and phosphorus loads, except to state that additional controls might be needed in the future to address them. The TMDL also required that forest fuel reduction projects not cause forest uplands to exceed the load allocation for fine sediment particle and nutrient loads.

The integrated water quality analysis combined LANDIS outputs of future disturbances with WEPP predictions of hillslope soil loss and phosphorus loads. The modeling suggests that the impact of increasing area disturbed (through thinning in scenario 3 and mostly prescribed burning in scenarios 4 and 5) was not fully offset by avoided impacts from wildfires. In the near term, more treatment increased sediment loads compared to the suppression-only scenario, but the loads under the suppression-only scenario generally increased so that overall performance became more similar over time. Another analysis indicated that loads would likely increase over time as changes in climate increased storm events; that dynamic was not explicitly factored into the modeling results, but it suggests that one might discount near-term disturbances more heavily. Consequently, management scenarios that incur more treatment initially while reducing future risks from wildfires would appear more favorably, which is consistent with the Strategy.

The initial modeling of water quality suggested that prescribed fire could increase fine sediment and phosphorus loading to streams and Lake Tahoe. Those results reflected an assumption that prescribed fire would result in residual ground cover following treatment similar to what would be produced from a low-intensity wildfire (about 70%). However, much prescribed burning in the Lake Tahoe basin appears to be conducted at such low intensity that ground cover is maintained at higher levels (>80%) and in patches that deter erosion, according to a study by Harrison et al. (2016). Additional analysis using those higher levels of residual ground cover found results that were comparable to thinning, with low risk of erosion. However, there may still be a higher risk of erosion from prescribed burning on steeper slopes and erosive soil types; estimate of those impacts may depend on more context-specific guidance regarding how burns might be implemented in such areas. Additional analysis is underway to evaluate factors that influence erosion rates in steeply sloped areas, and to more closely evaluate potential loads from mechanical thinning in such areas.

Goal 5 – Human communities live safely with fire and enjoy and steward the landscape

Community – Recreational, residential, and tribal cultural communities are integrated into restoration efforts. Society lives safely with wildfire and is accepting of both fire as a natural process and as a management tool. The landscape provides accessible diverse year-round recreation opportunities while protecting sensitive resources.

Objective 5A

Within the Wildland Urban Interface Defense Zone, complete 100% (5,000 acres) of initial entry fuels reduction treatments within the first 5 years and maintain fuels conditions to meet fire behavior objectives.

There are 5,000 acres of remaining defense zone treatments within LTW. 8,000 acres of initial treatments have already been completed. Treatment of the remaining 5,000 acres will help to reduce the Fire Risk within the defense zone and nearest to the built environment. This Objective was calculated directly from remaining initial entry treatments in Lake Tahoe West. Most of these treatments are contained within West Shore Wildland Urban Interface, PTEIR, or urban lots and are already in planning or implementation.

Once the remaining 5,000 acres are treated, there will be 13,000 acres of completed initial treatments within the Defense Zone. Completed treatments will need to be maintained into the future to continue to meet fire behavior objectives and protect communities.

Modeling found that scenarios that involved more intensive levels of treatment (Scenarios 3 and 5) reduce the amount of high severity fire in the Wildland Urban Interface and the risk of wildfire to residential properties better than less intensive thinning exclusive to the Wildland Urban Interface (Scenario 2). This result diverged somewhat from previous work in the Blackwood and Ward watersheds (Stevens et al. 2017), which found that Wildland Urban Interface-focused thinning would be similar to or even somewhat better than a broader landscape restoration strategy. An important difference is that Stevens et al. 2017 analysis did not account for landscape dynamics over time, but instead compared the effects of targeting different locations for treatment. That analysis also did not have a prescribed burning component.

Objective 5B

Achieve compliance with fire clearing requirements for habitable structures.

The Objective target is that 100% of habitable structures comply with fire clearing requirements on an annual basis. Creating defensible space and reducing the likelihood of structure ignition from embers improves community fire adaptation and enables expanded use of fire as a restoration tool.

Habitable structures within LTW are subject to Public Resource Code 4291, which requires landowners to clear flammable materials and vegetation near their homes. The code is enforced by CAL FIRE. Basin agencies provide multiple assistance services to facilitate code compliance including site visits, slash disposal, and work assistance. Compliance is tracked in a Basin-wide database.

Objective 5C

Increase actions to mitigate smoke impacts to downwind communities and vulnerable populations.

Fuel treatments reduce the risk of high intensity fire, but also present tradeoffs in regards to smoke production (prescribed or managed fire). Landscape modeling found that increased levels of thinning under scenario 3 and increased prescribed burning under scenario 4 and 5 would greatly reduce the incidence of extreme emission days. However, both increased pile burning under scenarios with thinning, and increased prescribed burning under the fire-focused scenarios, would increase the number of low and moderate emission days. There is a general relationship between daily emissions and smoke impacts to downwind communities, including vulnerable populations (Long et al. 2018), however, smoke impacts are highly contingent on weather conditions, which are difficult to model. Modeling of an individual prescribed burn by the science team suggested that there could be impacts from such events, although managers have greater ability to manage impacts from prescribed burning than for wildfires. However, with increasing levels of such burning, it may be harder to target optimal conditions.

For this Objective, we prefer to target increasing mitigation actions because trying to quantify the number or describe the type of actions to take is too challenging given the possibility of technological advances in warning systems (and other communication tools). Communication practices, including signage and notification to advise people of prescribed burning, as well as advance modeling of potential impacts from burns could help to anticipate and mitigate potential impacts to the public. Previous research has suggested that such practices, as well as use of air resource advisors on large prescribed burns, would help to mitigate such impacts (Long et al. 2018).

Objective 5D

Increase actions to improve public awareness of the benefits of prescribed fire as a means to reduce the risk of high-severity wildfire.

Prescribed fire is an important forest management tool, and the Strategy aims to increase use of prescribed fire to manage forest fuels and to provide ecological benefits. Public awareness and acceptance are critical for successful implementation of this Objective. Outreach and communication to stakeholders and residents, including positive opportunities for citizen-manager engagement, can build trust in managers and understanding of prescribed fire benefits (e.g. Toman et al. 2014).

The Tahoe Fire and Fuels Team (TFFT) and its Fire Public Information Team (Fire PIT) is the primary group that delivers coordinated messaging to Lake Tahoe Basin residents and visitors. Lake Tahoe West partner organizations are members of the TFFT and will continue to work through this venue and others to enhance public awareness.

Objective 5E

Continue engaging with the Washoe Tribe and tribal members in stewardship of the area, including the application of tribal traditional knowledge and practices.

The Washoe Tribe has been actively engaged in planning restoration treatments at Meeks Meadow, as well as providing input on restoration at other sites around the basin. The Tribe has a strong interest in applying traditional knowledge and practices, including cultural burning, to enhance the quality of culturally important resources and to strengthen intergenerational interactions between their members and the lands at Lake Tahoe. The Tribe has noted declines in many species of plants and animals that are traditional foods, including Belding's ground squirrel, marmot, fish, and deer, which the Tribe hopes to see enhanced.

The Washoe Tribe is working collaboratively with the Forest Service through a Stewardship Agreement to conduct the Meeks Meadow Restoration project. This project will remove conifer encroachment from Meeks Meadow, re-introduce fire to the meadow, and monitor and maintain meadow conditions with support of Washoe Tribe Members. Additionally, the Washoe Tribe is providing crews through the Calaveras Healthy Impacts Products Solutions (CHIPS) non-profit program in support of forest restoration projects throughout the Lake Tahoe Basin on National Forest System lands.

In consultation with staff from the Washoe Tribe and review of presentations and other materials regarding culturally important resources, we identified the following indicators of cultural resource quality for analysis using the EMDS system: low intensity/severity fire, deer, mountain quail, northern flicker, aspen, water quantity. This subset of indicators should not be construed as representing the full spectrum of important cultural values, but merely as representative surrogates for the purpose of evaluating strategies. For example, the landscape models do not address many of the understory and riparian/wetland plant species that are of high cultural importance.

Overall, the EMDS found that Scenario 3 yielded the best outcomes for mule deer and flicker habitat, while Scenario 5 performed well due to its emphasis on using low-severity fire, capacity to promote aspen, and potential to increase water availability by reducing leaf area index (not shown in Table 21). The Strategy's emphasis on gradually building up the use of fire might help to realize the benefits of such treatments for cultural resources, especially in culturally important areas such as meadows.

Table 21: Mean values for cultural resource indicators by scenario.

Scenario	% area burned per decade at low-intensity	% Aspen-dominated area	% Mule deer high quality habitat	% Mountain quail high quality habitat	% Northern flicker high quality habitat
1	4.2	0.38	21.0	32.4	22.8
2	4.9	0.37	22.4	32.6	23.7
3	5.7	0.41	24.5	32.2	24.3
4	12.6	0.40	22.2	32.4	23.3
5	53.3	1.09	21.1	24.3	20.7

Objective 5F

Support and maintain existing recreation access, opportunities, and experience. Where opportunities exist, incorporate actions into project design to enhance high-quality, equitable recreation experiences while protecting natural resources.

The Strategy anticipates that there will be impacts to recreation from project implementation and calls for managers to be proactive about reducing impacts to maintain support for LTW restoration.

The modeling results indicated that increased levels of treatment would reduce the days of very high emissions from wildfires, both year-round and in the summertime. Summertime wildfires such as Angora and Rim have had tremendous impacts on recreational activity by forcing evacuations, cancellations of outdoor events, and curtailment of outdoor activity. Even low and moderate emissions from prescribed burning could potentially have impacts on recreation. Increased thinning under Scenario 3 was most effective in reducing overall emissions of fine particles to the air, and those emissions could be further reduced through utilization of harvested biomass.

Managers will achieve this Objective by working with local recreation groups including Tahoe Area Mountain Biking Association (TAMBA), Tahoe Rim Trail Association (TRTA), Sustainable Recreation EIP Working Group, and the SR 89 corridor planning effort. Other groups who may have an interest include backcountry skiers and rock climbers.

When planning and implementing projects, managers should work with existing groups and users, being careful to prevent loss of access where possible. Maintain open communication throughout the project process to identify potential conflicts between recreation and natural resource protection and to engage recreation stakeholders to find solutions. As much as possible, provide outreach and public notice to user groups. Anticipating recreation impacts from project implementation and providing outreach and public notice to user groups is part of the NEPA/CEQA process.

Objective 5G

Communicate proactively and effectively with residents, businesses, the public, and other stakeholders about restoration activities.

The Lake Tahoe West Restoration Partnership recognizes that public acceptance and awareness is critical to successfully implement restoration activities identified in the Strategy. Proactively communicating and seeking input can help identify and resolve issues early on and may also help agencies identify opportunities to enhance project benefits, such as potential recreation benefits, of interest to stakeholders and the public. This Objective relies on providing tailored communications and multiple avenues of communication to enable strong two-way communication between Lake Tahoe West agencies and the public.

The modeling results suggest that there are many benefits from investing in increased treatments in LTW, but there are also some tradeoffs, particularly with respect to the upfront costs of treatments and days of intentional burning, either from pile burning or prescribed understory burning. The modeling suggests that a suppression-only strategy or a business-as-usual strategy will not prove sufficient to withstand the pressure of increased wildfire activity associated with climate change. Furthermore, economic results suggest that the benefits in terms of reduced risks to life and property in WUI areas and potential benefits of avoided smoke impacts from extreme wildfires may be some of the most important public benefits to consider. Communication approaches may want to consider these key trends and benefits when articulating the need for increased treatment.

Goal 6 – Restoration is efficient, collaborative, and supports a strong economy

Work takes place across jurisdictions and the treatment of multiple resources in the same entry increases project efficiency. Restoration under Lake Tahoe West creates regional economic benefits for multiple industries and local employment opportunities.

Objective 6A

Harvest forest products sustainably and utilize them to minimize carbon emissions through long-term carbon storage, bioenergy, or other products.

This Objective is included in recognition that biomass resulting from forest restoration activities in the Lake Tahoe West landscape has the potential to provide climate mitigation benefits and contribute to emissions reduction goals in the state of California. Although harvested wood product carbon stocks are generally small compared to in-forest carbon stocks, they are an important forest carbon pool (Christensen et al. 2019). Modeling results indicated that there would be more carbon stored and avoided emissions of particulates within the Lake Tahoe Basin by utilizing harvested biomass for wood products and biomass. Sustainably harvested wood products can provide an important means for climate mitigation by increasing the carbon in the harvested wood product pool, or through wood energy and material substitution effects (FCAT 2017, CNRA 2017, Malmsheimer et al. 2011, McKinley et al. 2011, Smith et al. 2014). The California Forest Carbon Plan (FCAT 2017) specifically includes a goal to innovate solutions for wood products and biomass utilization to support ongoing forest management activities, including but not limited to actions that increase the total volume of carbon stored through greater use of durable wood products from California forests, particularly in buildings and actions to create innovative products.

Objective 6B

Increase consistent business opportunities that provide regional economic growth and additional benefits to vulnerable populations.

Limited infrastructure capacity for forest management, wood processing, and biomass utilization, and the limited appropriately trained or licensed supporting workforce, are major impediments to forest restoration and ongoing forest management (FCAT 2017, CNRA 2017). The Lake Tahoe West landscape provides a wide range of ecosystem goods and services, such as wood products and recreation opportunities, that can support local and regional businesses and economies. This Objective recognizes that landscape restoration can enhance these benefits in numerous ways, including by providing job training and local employment opportunities and by recruiting low-income or otherwise vulnerable populations for such opportunities. Increasing the pace and scale of landscape restoration offers the opportunity to scale up such opportunities and economic benefits compared to current conditions, which also serves to facilitate forest restoration activities.

Objective 6C

Increase the number of projects that incorporate multi-benefit restoration objectives across multiple ecosystem types and land jurisdictions.

This Objective is intended to ensure that multi-benefit projects are completed that span jurisdictions, ownerships, and ecosystem types. To do this, managers must develop partnerships and efficiencies in environmental review, permitting, and project implementation. Agencies will utilize partnership opportunities such as Joint Powers agreements and Good Neighbor Authority to share resources, allow work on one another's property, and improve restoration efficiency.

For example, managers should complete upland forest removal treatments concurrent with adjacent SEZ restoration projects where it increases project efficiencies and will improve the resilience of both systems. Historically, managers have restored upland areas but cut out the SEZ because of permitting issues or have completed a river restoration project but overlooked the tree removal needs in the same area. While it may be more complicated, projects need to consider all resources and land types to achieve all the Strategy Objectives.

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