Table of Contents

Appendix E – Monitoring and Adaptive Management Plan

Introduction

This appendix describes the Monitoring and Adaptive Management Plan (MAMP) for the 4FRI Rim Country project area. It outlines how the Forest Service, in coordination with the 4FRI Multi-Party Monitoring Board and the 4FRI Stakeholder Group, can use a multi-scaled suite of indicators, metrics, and methods to assess the ecological, social, and economic changes that would result from treatments and related management activities implemented as part of this project.

As used in the MAMP, indicators refer to a resource, ecological component, or topic of interest, and metrics are units of information measured over time that document changes in a specific condition. For example, snowpack is an indicator, and its associated metrics include depth, density, and persistence. Where possible, the plan also describes thresholds, or triggers, that could indicate a need for adaptive management, along with suggested adaptive management actions.

This plan was adapted from the Adaptive Management, Biophysical and Socioeconomic, Mexican Spotted Owl and Arizona Bugbane Monitoring Plan from the first 4FRI EIS (USDA Forest Service 2015). As with that plan, the 4FRI Stakeholder Group and the USDA Forest Service collaborated on the design of this plan as a component of the 4FRI Rim Country EIS to guide monitoring and inform adaptive management within this project area. At the time the monitoring and adaptive management plan for the first 4FRI EIS was developed, the 4FRI Stakeholder Group explicitly acknowledged the need for monitoring prioritization and recognized that the Forest Service would not be financially responsible for all desired monitoring included in the Plan (Esch and Vosick 2016). For the Rim Country MAMP, the 4FRI Stakeholder Group and the Forest Service continue to recognize the need for prioritization and the fact that the not all of the biophysical effectiveness and socioeconomic monitoring is the financial responsibility of the Forest Service.

Previous and Ongoing 4FRI Monitoring

In 2015, the 4FRI Stakeholder Group chartered a Multi-party Monitoring Board that works with the full 4FRI Stakeholder Group and the Forest Service to oversee long-term monitoring and make adaptive management recommendations. Monitoring information, including progress toward desired conditions and unexpected benefits or challenges, has been, and would continue to be, used for stakeholder and Forest Service learning and may be developed into outreach material for broader dissemination, including recommendations for Forest Service management.

The information below describes collaborative monitoring efforts undertaken by the 4FRI Multi-Party Monitoring Board, 4FRI Stakeholder Group, and Forest Service to date. The majority of this monitoring has focused on the first 4FRI EIS project area, though the geographic scope of multi-party monitoring, as described in PL111-11, the Omnibus Public Land Management Act of 2009, which authorized the Collaborative Forest Landscape Restoration Program (U.S. Congress 2009), includes the entire Four Forest Restoration Initiative area.

The list below is not meant to be an exhaustive list of all the monitoring that is occurring within the 4FRI landscape; it merely discusses those specific monitoring initiatives associated with 4FRI multi-party monitoring.

Vegetation

Ground Plots

Building off of a pilot project on the Kaibab National Forest in 2014, the 4FRI Multi-Party Monitoring Board has collected pre-treatment data across 27 project areas since 2015 on the Kaibab and Coconino National Forests. This monitoring relies on plot surveys to establish pre-treatment diameter distributions of trees, trees per acre, ground cover types, and regeneration. Following mechanical thinning and burning treatments, plots will be re-surveyed to help understand the effects of treatments on overstory and understory structure and composition. The first post-treatment plots with corresponding pre-treatment survey data were surveyed in 2020 in the Chimney Springs project area. The Monitoring Board anticipates the collection of more post-treatment plot data and analysis thereof to be completed by the end of 2021.

Invasive Plants

For three years, a partnership comprising The Nature Conservancy, AmeriCorps, the 4FRI Multi-Party Monitoring Board, and the Forest Service has added to the Forest Service's capacity to conduct post-treatment monitoring of invasive species. To date, The Nature Conservancy-AmeriCorps team members have identified and mapped locations of invasive plant populations following thinning in three project areas on the Kaibab National Forest. This information was then used by the Forest Service to target invaded areas for treatment with herbicides.

Remote Sensing

Landscape Pattern Analysis

To quantify and describe the amount, pattern, and distribution of canopy cover within and around ponderosa pine forests of the South Kaibab and Coconino National Forests, the 4FRI Monitoring Board and Forest Service partnered with Northern Arizona University (NAU) to model spatial metrics based on high-quality aerial imagery acquired in 2014. The effort resulted in a repeatable method for modeling specific spatial metrics and a baseline against which to compare these metrics following implementation as it progresses across the areas sampled.

Unmanned Aerial Systems (UAS) and LiDAR

The 4FRI Monitoring Board has supported collection of pre- and post-treatment imagery using both unmanned aerial systems (drones) and LiDAR. This data collection serves multiple purposes: (1) to allow the comparison of pre- and post-treatment imagery to determine if treatments are effectively moving the forest towards desired conditions for structure and pattern, (2) to better understand the advantages and tradeoffs associated with each type of imagery collection, and (3) to help inform future decisions about selecting the most cost-effective options, how to prioritize monitoring efforts, and how to allocate monitoring funding.

Through a partnership with the U.S. Geological Survey (USGS), the Monitoring Board and Forest Service have collected aerial imagery using UAS at the Moonset project area (pre-treatment) on the Kaibab National Forest, and are planning to acquire UAS-based imagery over the Chimney Springs (post-treatment), and Clark (post-treatment) project areas on the Coconino National Forest.

The Monitoring Board and Forest Service have also worked together to support acquisition of pre-treatment, UAS-based imagery at Walker Hill. This will complement a study at Walker Hill by NAU and the Forest Service comparing different methods of tree designations.

In 2018 and 2019, the Monitoring Board and Forest Service partnered with the USGS to acquire LiDAR imagery covering large portions of the Coconino National Forest. This imagery can be used by the Coconino National Forest both for management and for monitoring related forest structure and pattern.

Wildlife

Bird Surveys

Northern Goshawk

In 2015 the Monitoring Board and Forest Service partnered with the Bird Conservancy of the Rockies (BCR - formerly called Rocky Mountain Bird Observatory) to survey northern goshawks in 15, 1,483-acre primary sampling units across three task orders prior to mechanical thinning. By "supplementing" these survey data with 2015 data from 21 primary sampling units on the Apache-Sitgreaves National Forests, BCR estimated that northern goshawks occupied 46 percent of suitable habitat across 4FRI with a coefficient of variation of 35 percent (Berven and Pavlacky 2016). These results can serve as a baseline against which to compare future northern goshawk surveys following treatment implementation.

Songbirds

To answer the question of how occupancy, species richness, and diversity of closed-canopy and open-canopy songbird species change following treatment, the Monitoring Board and Forest Service partnered with BCR to conduct surveys along gradients of stand and landscape structure across the Kaibab and Coconino National Forests. While the original intent was to conduct pre- and post-treatment surveys, the pace of treatment implementation in surveyed areas required a change to the study methods. Rather than comparing pre- and post-treatment metrics, BCR used 10 years of pre-treatment songbird survey data to estimate relationships of species occupancy, richness, abundance, occupancy dynamics, and population trends with vegetation attributes relevant to forest restoration. BCR also evaluated the strength of the evidence for those estimated relationships by comparing them to *a priori* hypotheses from existing literature that reflect current knowledge of avian species life history and ecology. Results of the study provide relatively strong evidence upon which to base hypotheses for treatment effects for 60 species, and the final report (Latif and Pavlacky 2020) provides guidelines for applying this knowledge toward future monitoring of southwestern frequent-fire ponderosa pine forests.

In 2019 the Monitoring Board contributed funding to the Forest Service Rocky Mountain Research Station for a power analysis to determine the sampling effort needed to detect changes following treatments and inform future monitoring efforts. The power analysis would help identify optimal survey designs by elucidating the tradeoff between survey effort/cost and accuracy of community and individual species' parameter estimates (Sanderlin et al. 2014). Results of this analysis are anticipated in 2021.

In addition to conducting a power analysis of sampling effort with 2019 monitoring funds, Rocky Mountain Research Station is also assessing the feasibility of using citizen scientists for songbird monitoring. This includes planning a pilot study that will inform decisions on integrating citizen science into existing songbird monitoring protocols to expand monitoring capacity across 4FRI.

Pronghorn Habitat Connectivity Modeling

To answer the question of how restoration treatments affect habitat connectivity for grassland species, the Monitoring Board and Forest Service partnered with Northern Arizona University in 2019 to use pronghorn collar data from 1995 to 2017 to model pre-treatment habitat quality and landscape migration permeability. Among other findings, the study identified certain constrictive "pinch-points" or bottleneck areas that exhibit high pronghorn movement among high quality habitat areas and that would be good candidates for treatments to reduce tree cover and improve near-ground visibility for pronghorn (Anderson and Dickson 2019).

Aquatics

Springs

Springs are a complex, diverse, and productive resource with important cultural and ecological values. They can function as indicators of changes in local and broader scale hydrologic function as well as general watershed health.

Since 2018 the Monitoring Board has worked with the Grand Canyon Trust (GCT) and Forest Service to monitor site-level effects of spring restoration at select sites on aquatic and emergent vegetation.

In 2018 the Monitoring Board and Forest Service partnered with the Springs Stewardship Institute (SSI) at the Museum of Northern Arizona to develop a landscape-scale monitoring program designed to detect ecosystem changes at springs following upland thinning and burning treatments (Schenk et al. 2019). In 2019 the Monitoring Board and Forest Service funded a five-year agreement with SSI to implement the monitoring plan they had developed at 56 springs across the Kaibab and Coconino National Forests.

Also, in 2019 the Monitoring Board and Forest Service entered into an agreement with NAU to continuously monitor flows at four springs on the Kaibab and Coconino National Forests. Results of this study will shed light on the links between restoration treatments, climatic events, and spring flow response.

Streams

With approximately 4,047 miles of stream courses, including 385 miles with perennial water flow, within the Rim Country project area, there is much interest in how these ecosystems will respond to restoration treatments. To address this, the Monitoring Board and Forest Service contributed funding in 2019 to the Forest Service Rocky Mountain Research Station to conduct a literature and existing data review and to develop stream monitoring recommendations that leverage existing data and will inform future data collection to answer questions about the effects of restoration treatments on watershed hydrology, geomorphology, stream function, and aquatic habitat.

Socioeconomics

Socioeconomic Monitoring Framework

In 2012 the "Socioeconomic Monitoring for the Four Forest Restoration Initiative" report was developed by the 4FRI Science and Monitoring Working Group (Mottek Lucas 2012). This Working Group was the forerunner of the 4FRI Multi-Party Monitoring Board, which was formally chartered by the 4FRI Stakeholder Group in 2015.

The purpose of this report was to provide a framework to guide socioeconomic monitoring of the first 4FRI landscape-scale Environmental Impact Statement (EIS) analysis area. The vision of this joint monitoring effort between the 4FRI Science and Monitoring Working Group and the Forest Service was to assess the accuracy of Forest Service estimates and provide data for adaptive management. In this way, the information provided by the Forest Service in the EIS, coupled with this monitoring framework, would be linked to support a thorough and on-going assessment of social and economic conditions in the study area.

Public and Forest Service Perceptions of 4FRI and Forest Restoration and Contractor Reporting Form

Initial socioeconomic monitoring for 4FRI was conducted in 2013 by Mottek Consulting, and findings were summarized in the "Four Forest Restoration Initiative Socioeconomic Monitoring Report" (Mottek Lucas 2013). Two focus groups were administered with the general public to represent the Forests within the first analysis area – one containing Flagstaff residents (representing the Coconino National Forest) and the other with Williams residents (representing the Kaibab National Forest). This project also included findings from six personal interviews (three each) with Forest Service personnel from the Coconino and Kaibab National Forests. The third component of this project included streamlining expenditure, revenue and employment data reporting by designing contractor protocols and a reporting form that could be used as a template to conduct future economic monitoring.

Though this work was funded by the National Forest Foundation and pre-dated the formal existence of the 4FRI Multi-Party Monitoring Board in its current form, it helped establish a baseline for future socioeconomic monitoring and informed public outreach/education.

4FRI Economic Contributions

To understand the extent of regional employment, income, and output, and to establish a baseline for economic monitoring, the Conservation Economics Institute conducted a regional economic contribution analysis of 4FRI activities for Federal fiscal year 2017 (Hjerpe and Mottek Lucas 2018). This project was approved by the Multi-Part Monitoring Board and funded by the Forest Service and through grants received from the Arizona Department of Forestry and Fire Management and Coconino County.

The authors conducted an assessment of expenditures and employment in five Arizona counties that were included as part of the defined regional economic contribution zone. Primary data was collected, which included surveys of all 4FRI wood utilization contractors. In total, including multiplier effects, fiscal year 2017 4FRI activities generated almost 1,000 full- and part-time jobs and more than 900 full-time-equivalent jobs in the region; approximately $150 million in regional output; $50 million in regional labor income; and 4FRI impacted over 140 different industry sectors in the region.

According to the authors, "Despite the impressive regional economic contributions, restoration accomplishments have seen limited growth since the inception of the 4FRI and remain well below original project objectives and forecasts." The authors concluded that the main barrier to ramping up 4FRI mechanical thinning accomplishments is the lack of profitability in thinning and processing small diameter ponderosa pine, and that successful restoration of southwestern ponderosa pine forests on a large scale will require supplemental funding.

Hjerpe et al. (2021) analyzed 4FRI's economic contribution and found that using primary data from 4FRI contractors provided for more conservative estimates for 4FRI economic contributions than the Forest

Service's TREAT model. The study also revealed that primary considerations for modeling forest restoration contributions include contractor surveys, appropriate investigation of the regional context, methodological transparency in bridging restoration expenditures to input-output models, and consideration of how to enhance restoration contributions.

Relationship to the First 4FRI EIS Adaptive Management and Monitoring Plan

Continuing with the goals outlined in the first 4FRI EIS, the purpose of the 4FRI Rim Country Project is to restore and maintain the structure, pattern, health, function, and vegetation composition and diversity in ponderosa pine and associated ecosystems. See chapter 1 of the FEIS for the full purpose and need of the project. Restoration is defined as "The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. Ecological restoration focuses on reestablishing the composition, structure, pattern, and ecological processes necessary to facilitate terrestrial and aquatic ecosystems' sustainability, resilience, and health under current and future conditions." (36 CFR 219.19).

Both the first 4FRI EIS and the Rim Country projects were part of the 2.4 million-acre 4FRI Collaborative Forest Landscape Restoration Project (CFLRP), as defined in the 4FRI CFLRP proposal (Schultz 2010). Multi-party monitoring for at least 15 years from project initiation, which was in 2010 for 4FRI, is a requirement for all CFLRPs (see "Required Monitoring" below). The 4FRI Multi-Party Monitoring Board works with the Forest Service to manage multi-party monitoring across the entire 4FRI landscape.

The Rim Country project area encompasses approximately 1.24 million acres immediately southeast of the first 4FRI EIS project area (Figure E-1). To account for learning since 2015 and differences in the landscape and ecosystems between the first 4FRI EIS project area and the Rim Country project area, the 4FRI Multi-Party Monitoring Board and the Forest Service updated and revised the monitoring and adaptive management plan from the first 4FRI EIS (USDA Forest Service 2015) to create the Rim Country MAMP. Many of the indicators and desired conditions are shared between both monitoring plans while some indicators are unique to each. However, the scope of 4FRI multi-party monitoring covers the entire 2.4 million-acre 4FRI landscape, so there is nothing to preclude monitoring any indicator in either of these two project areas, or even outside of them, if it is a shared priority, funding is available, and any necessary environmental reviews have been conducted.

The implementation monitoring discussed below generally applies to both the first 4FRI EIS area as well as the Rim Country project area, with the exception of certain species and areas that may occur only in the Rim Country project area.

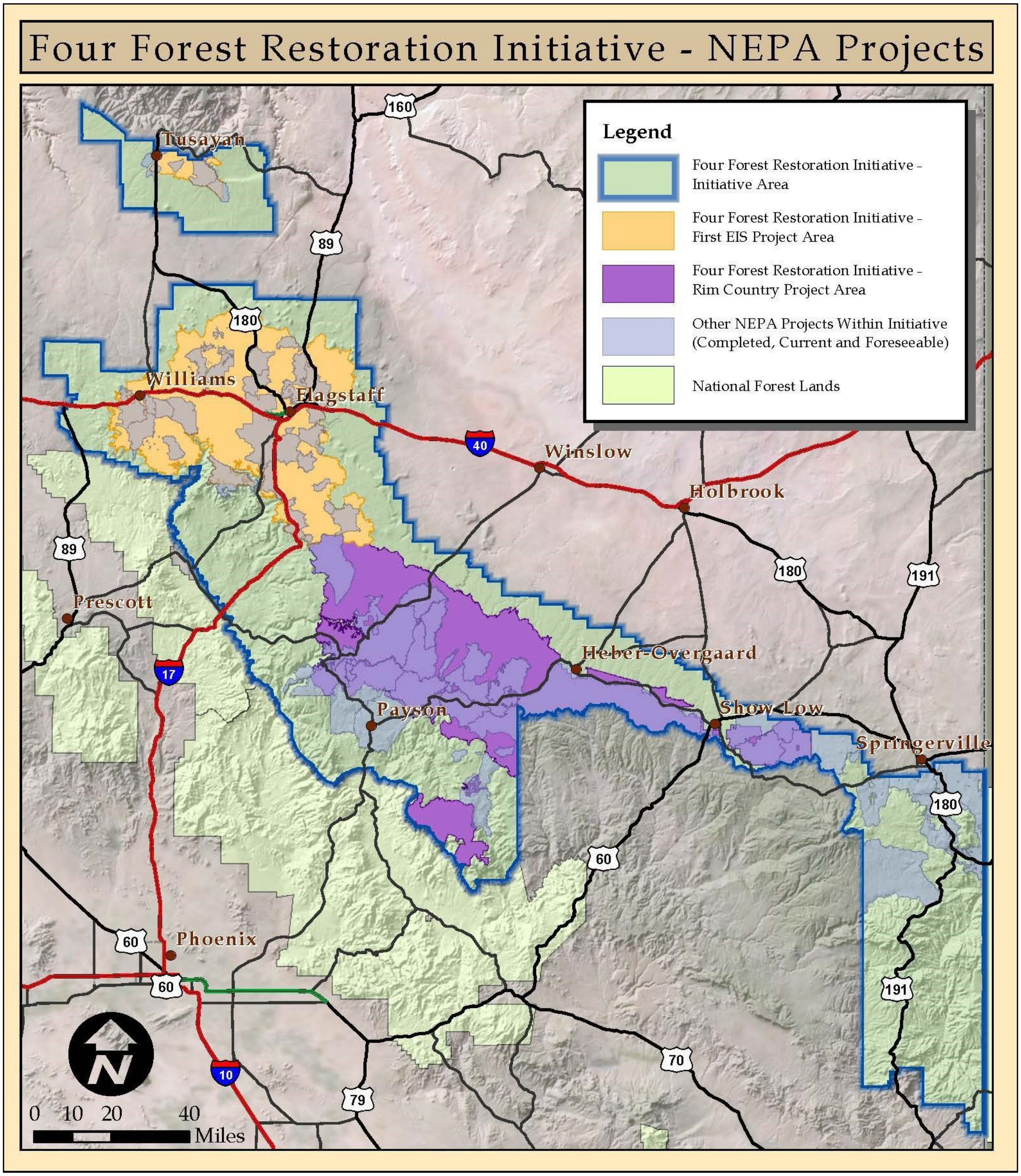

Figure E-1. NEPA projects within the 2.4-million-acre 4FRI footprint including Rim Country in purple

Adaptive Management Process

The 4FRI Rim Country project, like the first 4FRI EIS project, is a long-term forest restoration effort that is unprecedented in scale in the southwestern region of the United States. Implementation of the entire

Rim Country project would take place over a period of 20 years or when activities can be funded or completed. This work would occur as the Southwest is experiencing climatic changes, including periods of extended drought and increased temperatures. These changes are lengthening the wildfire season in the Southwest, shifting plant communities, and threatening native biodiversity, among other effects (Gonzalez et al. 2018). Together with the large scale and long duration of the project, this may require modifications of planned treatments before they are implemented. These changes would be in addition to any suggested changes identified through monitoring. This MAMP is intended to guide monitoring that can help the Forest Service learn from treatment effects and respond to changing conditions.

Adaptive management refers to a "rigorous approach for learning through deliberately designing and applying management actions as experiments" (Murray and Marmorek 2003). In an adaptive management process, monitoring of indicators prior to and in response to management actions provides information for understanding if those management actions are leading to progress toward desired conditions and/or towards thresholds that should trigger a change in management response.

The Forest Service and 4FRI Stakeholder Group have collaboratively developed this MAMP by selecting a suite of indicators and metrics for biophysical effectiveness and socioeconomic monitoring that best measure trends toward the desired conditions outlined in the Rim Country project analysis. To ensure that adequate metrics are used to assess trends, metrics were selected based on attributes that can be easily measured, are precise, are sensitive to changes over time, and satisfy multiple objectives of the monitoring process (Eagan and Estrada-Bustillo 2011, Moote 2011, Derr et al. 2005). Once the indicators and corresponding metrics were selected, thresholds (sometimes described as triggers) were identified that may signify a movement towards an undesired outcome. Thresholds can help indicate if a change in management is advisable. The Monitoring Board and Forest Service recognize that there are cases in which the best available scientific information available at the time of plan development is insufficient for identifying quantitative thresholds. In some of these cases, qualitative thresholds have been identified, and in other cases, we will evaluate monitoring data as they are collected to look for trends and will review new scientific studies to reassess whether appropriate thresholds can be identified.

The biophysical effectiveness and socioeconomic monitoring outlined below and in Table E-3 through Table E-22 represent the understanding, questions, and priorities shared by the 4FRI Multi-Party Monitoring Board and the Forest Service at the time of publication. There is an expectation that indicators, metrics, methods, thresholds, adaptive management actions, and monitoring priorities may change over the lifetime of the project. The Forest Service would collaborate with the 4FRI Stakeholder Group when changes are needed and assess monitoring priorities throughout the life of the project. Any changes made through this process will be reflected in updated versions of tables E-3 and E-4 through E-22 that will be posted on the Forest Service 4FRI Monitoring webpage (https://www.fs.usda.gov/main/4fri/monitoring). Before committing to specific new monitoring efforts or projects, the Forest Service and the Multi-Party Monitoring Board strive to balance the need for robust study designs with a limited budget and the opportunity costs associated with funding specific monitoring projects.

To ensure success of the monitoring program, a clear link describing how monitoring information will be utilized in future decision-making is essential (Noon 2003, Williams et al. 2009). In the past, this has been achieved administratively (Mulder et al. 1999, Sitko and Hurteau 2010), legally via the NEPA process (Buckley et al. 2001, CERP 2009), or through collaborative agreements (Gori and Schussman 2005, Greater Flagstaff Forest Partnership 2005).

Where there is sufficient information to develop a threshold that suggests a trend away from the desired conditions, this plan goes on to suggest potential adaptive management actions. The process for developing these thresholds is collaborative and includes Stakeholder and Forest Service input and joint fact finding. Initially, when a trigger or threshold is reached, the monitoring framework focuses on the need to assess if or how management actions have contributed to the outcomes. The Forest Service and the Multi-party Monitoring Board would collaboratively evaluate monitoring and other relevant data to establish causal relationships. Based on the evaluation, follow-up actions will be developed. These may include, for example, continued monitoring, collection of more refined data, a recommendation to implement the existing adaptive management action, or development of a new recommended adaptive management action.

The 4FRI Stakeholder Group may choose to recommend adaptive management actions to the Forest Service. Forest Service staff may also develop new adaptive management actions internally and share these with the 4FRI Stakeholder Group for additional discussion and input. This is a collaborative process. However, ultimately, one or more of the deciding officials from the Forest Service (such as the Forest Supervisors from the three Forests that are part of the Rim Country project), depending on which forest(s) the change in management would occur on, would determine what management actions will be implemented after reviewing monitoring information and assessments of the monitoring information. The deciding official(s), in conjunction with relevant resource specialists, would consider the recommended adaptive management actions and their anticipated effects to ensure they are within the scope of those analyzed within the FEIS. If, through this review, the deciding official(s) determine that a correction, supplement, or revision to the FEIS is not necessary, implementation of the recommended adaptive management actions may continue. If the effects of adaptive management activities are anticipated to exceed those analyzed in the FEIS, additional NEPA analysis may be required. The results of the review, sometimes called a supplemental information report (SIR), would be documented in the project file and would explain if a correction, supplement, or revision is needed, and if not, the reasons why (Forest Service Handbook 1909.15, section 18).

The 4FRI Stakeholder Group and the Forest Service are committed to a strong adaptive management process. Stakeholders are more likely to support management actions if they are confident that the results from those actions are not only carefully monitored but are also used to modify future actions (Rural Voice for Conservation Coalition 2011). As such, we expect that the 4FRI Stakeholder Group will continue to work closely with the Forest Service to recommend adaptive management actions as appropriate based on monitoring results.

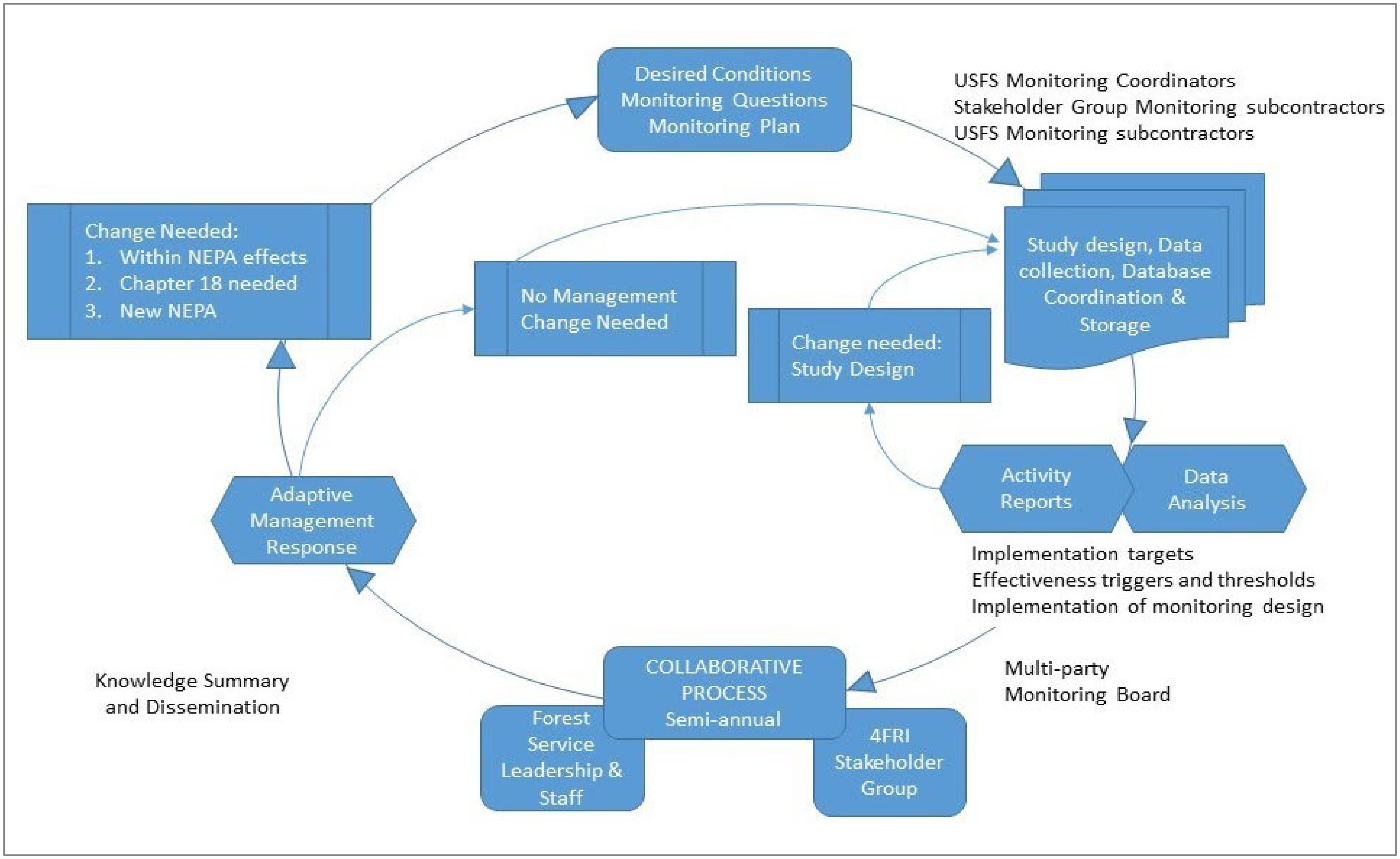

Figure E-2. 4FRI adaptive management process

Monitoring

Types of Monitoring

Biophysical (also referred to as ecological) monitoring is generally undertaken to determine whether the current state of the biophysical system matches or is trending toward some desired condition (Noon 2003). When conducted systematically and focused on effects of treatments (see effectiveness monitoring below), biophysical monitoring can provide valuable feedback regarding the effects of land management on resource conditions (Palmer and Mulder 1999, Lindenmayer and Likens 2010).

Effectiveness monitoring tracks the extent to which a management activity achieved its ultimate objective. Effectiveness monitoring of treatments can be applied to examine movement towards or away from biophysical and socioeconomic objectives (desired conditions). Effectiveness monitoring focuses on assessment of treatment effects, considered alongside other factors that may affect outcomes (including grazing history, variations in annual precipitation, changes in population, etc.), rather than to measuring whether they were applied as intended or whether they validate a pre-existing concept.

Implementation monitoring is used to determine the extent to which a management activity was carried out as designed (did the Forest Service do what it said it was going to do?).

Social monitoring is used to assess society's perceptions on an issue or group of issues. Changes in these perceptions may be assessed through time as issues change in scope or context.

Economic monitoring is used to assess the economic impact of land management activities. Because people's perceptions of issues are often strongly influenced by how those issues affect their economic status, social and economic monitoring may be grouped together under the umbrella of socioeconomic monitoring.

Validation monitoring assesses the degree to which underlying assumptions about ecosystem relationships are supported (Block et al. 2001, Busch and Trexler 2003). Validation monitoring is often closely associated with research and is not integrated in this monitoring plan.

Required Monitoring

4FRI is supported by and must comply with multiple Federal laws, mandates, regulations, and funding programs, some of which include different monitoring requirements. The Forest Service is obligated to meet monitoring requirements described in this section. In contrast, the monitoring described under the "biophysical effectiveness monitoring" and "socioeconomic monitoring" headings is contingent upon sufficient funding, as recognized by the 4FRI Stakeholder Group during development of the Monitoring and Adaptive Management Plan for the first 4FRI EIS in 2013: "…limited resources make it impossible for the Forest Service to commit to monitoring all of these effects alone." (4FRI Stakeholder Group 2013).

Collaborative Forest Landscape Restoration Program

In 2010, 4FRI was selected for funding under the Collaborative Forest Landscape Restoration Program (CFLRP). The purpose of the Program is to encourage the collaborative, science-based ecosystem restoration of priority forest landscapes through a process that: (1) encourages ecological, economic, and social sustainability; (2) leverages local resources with national and private resources; (3) facilitates the reduction of wildfire management costs, including through reestablishing natural fire regimes and reducing the risk of uncharacteristic wildfire; and (4) demonstrates the degree to which various ecological restoration techniques achieve ecological and watershed health objectives and affect wildfire activity and management cost; and where the use of forest restoration byproducts can offset treatment costs while benefitting local rural economies and improving forest health (Pub. L. 111-11).

Section g(3) of the Omnibus Public Land Management Act of 2009, the enabling legislation of the CFLRP specifies annual reporting on the accomplishments of each selected project. Annual reporting includes: (A) a description of all acres treated and restored through projects implementing the strategy; (B) an evaluation of progress, including performance measures and how prior year evaluations have contributed to improved project performance; (C) a description of community benefits achieved, including any local economic benefits; and (D) the results of multi-party monitoring, evaluation, and an accountability process. Items A through C were compiled locally and sent to the Forest Service Washington Office for annual reporting as required during the 10-year period (2010 to 2019) when 4FRI received CFLRP-specific funding. The multi-party monitoring (Item D) focuses on biophysical and socioeconomic effectiveness monitoring.

Section g(4) specifies that "The Secretary shall, in collaboration with the Secretary of the Interior and interested persons, use a multiparty monitoring, evaluation, and accountability process to assess the positive or negative ecological, social, and economic effects of projects implementing a selected proposal for not less than 15 years after project implementation commences." While the Act requires multiparty monitoring, it provides no specific requirements beyond those associated with annual reports during the 10-year funding period, and the 5-, 10-, and 15-year ecological indicator reports (Pub. L. 111-11). Beyond these requirements, the determination of indicators, methods, and duration of multiparty monitoring is left to the collaboratives.

The 5-, 10-, and 15-year ecological indicator reports include standard national indicators to assess project goals, while also allowing for inclusion of project-specific monitoring results. Reporting timeframes for multi-party effectiveness monitoring vary by indicator and metric, but where available, results were included in the 5- and 10-year reports (available at https://www.fs.usda.gov/main/4fri/monitoring). Per the CFLRP requirements, the 15-year report, due in 2024 for 4FRI, will include results for wildfire risk, watershed, habitat, and invasive species monitoring indicators, consistent with the key monitoring questions in the 5- and 10-year reports. Effectiveness monitoring results that were not available in 2019 when the 10-year report was completed will augment these national indicators. Additionally, socioeconomic data based on the Treatment for Restoration Economic Analysis Toolkit (TREAT) and ongoing partner investments in the 2.4-million-acre 4FRI footprint will be included in the 15-year report.

Each Federal fiscal year from 2010 through 2019, 4FRI received congressionally appropriated funds under a CFLRP-specific budget line item. The amount varied annually; however, the Forest Service agreed to dedicate 10 percent of the annual CFLRP funds to monitoring activities. Fiscal year 2019 marked the conclusion of the 10-year CFLRP funding commitment, including the 10 percent dedicated to 4FRI multi-party monitoring. Beginning in fiscal year 2020, Federal funding for 4FRI multi-party monitoring has fluctuated based on the availability of discretionary appropriated funds from various budget line items.

Monitoring activities covered by the ten percent allocation during the first ten years of 4FRI included the socioeconomic monitoring and pre- and post-treatment effectiveness monitoring described above in the "Previous and Ongoing 4FRI Monitoring" section. This funding also paid for vegetation monitoring in Mexican spotted owl protected activity centers that were part of the management experiment described in and required by the U.S. Fish and Wildlife Service's Biological Opinion for the first 4FRI EIS project (USDI Fish and Wildlife Service 2014).

As treatments that are part of the 4FRI Rim Country project are implemented, monitoring activities will track whether thresholds are reached, verify that activities are moving toward the desired conditions, and help inform the adaptive management process. To date, the majority of 4FRI multi-party effectiveness monitoring has been accomplished through partnerships between the Forest Service and partner organizations. While the Forest Service may continue to contribute funds toward multi-party monitoring, collaborative partners are expected to support monitoring efforts by soliciting and contributing both in-kind and monetary funds from other sources.

Monitoring Required by Other Laws, Regulations and Policies

Implementation/compliance monitoring is carried out on an ongoing basis as part of meeting legal and regulatory requirements (Table E-1). Forest Service databases of record used to track and report on implementation monitoring are updated annually by the Forest Service. The Forest Service funds implementation monitoring and may use funding from stewardship-retained receipts (see Stewardship Contracting below), as outlined in Forest Service Manual 2409.19 Section 67.2, to complete project-level implementation and compliance monitoring when there is interest and support from local collaborative partners. Retained receipts may defray some of the direct costs of local multi-party monitoring and support the collaborative monitoring process by paying for facilitation, meeting rooms, travel, incidental expenses, data collection, and dissemination of monitoring findings to the public.

Monitoring Required by the U.S. Fish and Wildlife Service's Biological Opinion

Monitoring required as part of the terms and conditions in the Rim Country project Biological Opinion, as issued by the U.S. Fish and Wildlife Service, is described in the Biological Opinion. This monitoring is non-discretionary and must be undertaken to ensure that the Forest Service's actions comply with the Endangered Species Act. The monitoring requirements in the Biological Opinion are distinct from the multi-party monitoring required by the Collaborative Forest Landscape Restoration Program. While monitoring requirements in the Rim Country Biological Opinion may be the same, or similar to monitoring requirements in Biological Opinions of other projects, they apply only to the Rim Country project.

Monitoring Required by the USDA Forest Service, Southwestern Region Mexican Spotted Owl Management Strategy

Monitoring requirements from the Regional Mexican Spotted Owl Management Strategy are described in detail in appendix F of the Rim Country Project FEIS.

Stewardship Contracting

Stewardship contracting is only one of several administrative tools that can be used for project implementation. While the use of stewardship contracts is beyond the scope of this NEPA analysis and monitoring plan, there are monitoring requirements associated with stewardship that have been included in this collaboratively developed monitoring and adaptive management plan. Currently, the authorizing language for stewardship contracting only requires programmatic process monitoring of (1) the status of development, execution, and administration of stewardship contracts or agreements; (2) the specific accomplishments that have resulted; and (3) the role of local communities in development of agreements or contract plans.

Treatment Tracking

To ensure that the acreage and intensity of implemented treatments will be within the scope of the effects analysis, a robust treatment tracking system is necessary and will be summarized at the Forest scale. A system will be put in place that will track several key elements of proposed treatments from the planning process through to implementation. This system will be maintained at the administrative unit and will be updated in as close to real time as feasible. At a minimum, this system will track:

- Area proposed for treatment as part of the Rim Country project, including stand ID and/or unique stand identifier and treatment type
- Actual treatment assigned post-IDT walkthrough (pre-implementation), from the prescription
- Actual cut unit polygons, post layout, including stand ID and treatment type

See appendix D of the FEIS (Rim Country Implementation Plan for Alternatives 2 and 3) for more details.

Implementation Monitoring

Implementation monitoring is used to determine the extent to which a management activity was carried out as designed. Not only is this a regulatory requirement, but also a means by which the Forest Service is able to demonstrate measurable progress toward the desired conditions derived from the land management plans and integrated into the Rim Country Project. Appendix C describes the design features, best management practices (BMPs), and mitigation and conservation measures that are common to all action alternatives. Appendix D contains the Rim Country Implementation Plan. The direction in these appendices forms the foundation for all management activities.

Metric: We employ one of two metrics to monitor implementation. One metric is a quantitative measure of area, volume, or distance treated for each management activity. The second is compliance: either the activities were completed in full compliance with all design features, best management practices, or mitigations, or they were not.

Scale: Because these metrics are related to implementation, they are evaluated at a spatial scale of either the treatment unit area or timber sale area.

Method: Compliance with the design features, BMPs, mitigations and conservation measures, and the implementation plan will be evaluated at multiple stages. Initial field visits will validate the predicted conditions used for analysis and treatment assignment. Based on the information gathered during these visits, the silviculturist will use both the guidance found in Appendix C and Appendix D, including the site-specific condition-based decision framework to develop appropriate treatment prescriptions for each stand. The relevant direction will be brought forward as needed into contract documents. The contract administrators will monitor activities of the contractors as they implement the treatments to ensure that they followed the implementation plan and resource specialists will evaluate the finished product to ensure that there is full compliance with applicable design features, BMPs, mitigations and conservation measures. Quantitative implementation monitoring tracks treatment progress through annual reporting requirements internal to the Forest Service.

Data Source: The data sources for compliance metrics are typically sale administrators who monitor the execution of each project, task order, agreement, or contract; or resource specialists who conduct post-project inspections. The data sources for quantitative metrics are the Forest Service databases of record.

Cost: The cumulative cost associated with ensuring compliance and proper reporting across all the resource areas is expected to range from roughly $850,000 to $1,200,000 annually. The costs cover contract administration, inspection, data recording and resource specialist reviews.

Trigger/Threshold: The trigger for adaptive management is a compliance failure or failure to report land management activities.

Adaptive Management: In the event of a compliance issue, the adaptive management action will be to re-evaluate the implementation process to determine the source of the failure and, if necessary, develop additional implementation/compliance monitoring protocols. In the event of a reporting failure, the reports will be corrected to properly reflect the relevant land management activities and the reporting process may be re-evaluated and additional assurance measures may be put in place to ensure proper and timely reporting.

Table E-1. Implementation monitoring questions and metrics

Monitoring Questions Derived from Desired Condition	Monitoring Metric	Assessment Method	Frequency of Measurement
Are ponderosa pine restoration treatments occurring within the project area?	Acres thinned /green tons removed, acres prescribed burned	Database Records	Reported annually
If mechanical treatments occurred, were they implemented in accordance with design features, BMPs, mitigation measures and the silvicultural implementation guide?	Compliance	Contract inspection and specialist review	Ongoing and at post-project review
Did treatments designed to naturalize non-system roads occur?	Miles of road effectively closed to motor vehicle traffic	Database Records	Reported annually
If roads were closed to motor vehicle traffic, were the treatments implemented in accordance with design features, BMPs, and mitigation measures?	Compliance	Contract inspection and specialist review	Ongoing and at post-project review
If roads were used, were they maintained or rehabilitated after use in accordance with design features, BMPs, and mitigation measures?	Compliance	Contract inspection and specialist review	Ongoing and at post-project review
If roads were used, were undesired impacts to surrounding resources minimized or mitigated in accordance with design features, BMPs, and mitigation measures?	Compliance	Contract inspection and specialist review	Ongoing and at post-project review
If temporary roads were created, were they decommissioned prior to the close of the associated task order as required in the Collaborative Forest Landscape Restoration Act?	Compliance	Contract inspection and specialist review	Ongoing and at post-project review
Were design features, BMPs, and mitigation measures to minimize or mitigate undesired impacts to scenery, recreation resources and recreation opportunities implemented according to Appendix C?	Compliance	Contract inspection and specialist review	Ongoing and at post-project review
Did management activities minimize or mitigate undesired impacts to soil and water in accordance with design features, BMPs, and mitigation measures?	Compliance	Contract inspection and specialist review	Ongoing and at post-project review
Did management activities maintain or promote long-term soil productivity in accordance with design features, BMPs, and mitigation measures?	Compliance	Contract inspection and specialist review	Ongoing and at post-project review

Monitoring Questions Derived from Desired Condition	Monitoring Metric	Assessment Method	Frequency of Measurement
Did channel restoration treatments occur?	Miles and acres of channel restored	Database Records	Reported annually
If channel restoration treatments occurred, were they implemented appropriately using the aquatic toolbox and in accordance with design features, BMPs, and mitigation measures?	Compliance	Contract inspection and specialist review	Ongoing and at post-project review
Did management activities minimize impacts to water resources in a manner that adheres to the Clean Water Act, State and Federal Water Quality Standards, and the intergovernmental agreement between the Southwestern Region and the ADEQ	Compliance	Contract inspection and specialist review	Ongoing and at post-project review
Did management activities occur in Mexican spotted owl habitat?	Acres of vegetation treated/green tons removed, acres treated by prescribed fire/acres of wildfire with beneficial effects	Database Records	Reported annually
If management activities occurred in Mexican spotted owl habitat, were they implemented in accordance with design features, BMPs, mitigation measures, and the project biological opinion?	Compliance	Contract inspection and specialist review	Ongoing and at post-project review
Were design features, BMPs, mitigation measures and land management plan requirements met for not only threatened, endangered, sensitive species, but also the other wildlife species listed in Appendix C?	Compliance	Contract inspection and specialist review	Ongoing and at post-project review
Did treatments designed to reduce or manage noxious weeds and invasive species occur?	Acres treated	Database Records	Reported annually
Did management activities minimize or mitigate the spread of noxious weeds, invasive species or non-native species in accordance with design features, BMPs, and mitigation measures?	Compliance	Contract inspection and specialist review	Ongoing and at post-project review
Did management activities minimize or mitigate undesired impacts to sensitive plants, species of conservation concern, and rare endemic plant species, (see Rim Country Botany specialist report (Crisp 2021) for a list of sensitive plants that occur in the project area) and preserve special areas in accordance with design features, BMPs, and mitigation measures?	Compliance	Contract inspection and specialist review	Ongoing and at post-project review
Did management activities prevent, minimize or mitigate damage to grazing range sites and infrastructure in accordance with design features, BMPs, and mitigation measures?	Compliance	Contract inspection and specialist review	Ongoing and at post-project review
Did management activities limit disruption to grazing activities and ensure post-fire range readiness in accordance with design features, BMPs, and mitigation measures?	Compliance	Contract inspection and specialist review	Ongoing and at post-project review

Monitoring Questions Derived from Desired Condition	Monitoring Metric	Assessment Method	Frequency of Measurement
Did range managers ensure range readiness in accordance with design features, BMPs, and mitigation measures prior to resuming livestock grazing after a management activity or fire?	Compliance	Range Management Specialist inspection and review	Ongoing and at post-project review
Did range, silviculture, and fire managers ensure that sufficient surface fuels were present in accordance with design features, BMPs, and mitigation measures prior to implementing planned prescribed fires?	Compliance	Specialist inspection and review	Ongoing and at post-project review
Were planned prescribed fires coordinated with neighboring forests and other affected agencies and communities?	Compliance	Public Affairs and specialist review	Ongoing and at post-project review
Did prescribed fires occur in accordance with ADEQ requirements and did they minimize or mitigate undesired impacts to wildlife, soil, water, vegetation, and air quality in accordance with design features, BMPs, and mitigation measures?	Compliance	National Forests of AZ Smoke Liaison to ADEQ and specialists review	Ongoing and at post-project review
Did management activities minimize old and large tree mortality?	Compliance	Contract inspection and specialist review	Ongoing and at post-project review
Did management activities result in reduced potential for undesirable fire behavior and effects?	Compliance	Contract inspection and specialist review	Ongoing and at post-project review
Did the Forest Service consult with the SHPO, ACHP and tribes as required and comply with the requirements of the NHPA and the Southwestern Region PA with the AZ SHPO?	Compliance	Contract inspection and specialist review	Ongoing and at post-project review
Did management activities prevent, minimize or mitigate undesired impacts to cultural resources in accordance with design features, BMPs, and mitigation measures?	Compliance	Contract inspection and specialist review	Ongoing and at post-project review
Was the public provided information and notification related to vegetation treatments and prescribed fires in accordance with design features, BMPs, and mitigation measures?	Compliance	Public Affairs and specialist review	Ongoing and at post-project review

Monitoring: Desired Conditions, Indicators, Thresholds, and Triggers

A vital component of a successful adaptive management and monitoring program is an explicit statement of desired conditions. As proposed activities are implemented, monitoring efforts use indicators to determine what progress is being made in moving toward desired conditions. Thresholds and triggers can be considered as benchmarks that inform management direction (for example, maintain or modify) (Ringold et al. 1999, Lindenmayer and Likens 2010). These indicators should provide information that results in timely adjustment of management activities to better meet objectives and support informed decision making (Noon et al. 1999, Noon 2003).

In the 4FRI monitoring program, the monitoring indicators are organized by desired conditions that guide the project strategy. The desired conditions are derived from land management plans and integrated into the Rim Country project. The desired conditions and the associated monitoring indicators, thresholds, and triggers are presented in Table E-3. Quantitative standards have been used wherever possible, but many of the desired conditions are qualitative and generalized. Indicator ranges have been described where possible for both desirable as well as undesirable conditions. Triggers and thresholds were developed through literature reviews, expert input, and social values.

Prioritization: Monitoring Tiers

Regardless of the source of monitoring funds, it is well understood that there will be insufficient funds to monitor all the indicators over the entire project area. The Multi-party Monitoring Board meets periodically to, among other things, prioritize indicator monitoring and identify geographic locations to be monitored. Budgetary limitations dictate how much and what type of monitoring can be accomplished and the Forest Service and the Multi-Party Monitoring Board strive to balance the need for robust study designs with a limited budget and the opportunity costs associated with funding specific monitoring efforts.

Effectiveness monitoring is a priority and a key component in meeting our adaptive management goals; however, only a subset of the Rim Country treatment areas will be monitored and, at any one location, only some of the monitoring indicators will be assessed. To help the Multi-party Monitoring Board determine what effectiveness monitoring will be accomplished with available funds, this plan provides a tiered system for monitoring prioritization.

The tier assignments are suggestions based on shared priorities at the time of publishing, and prioritization of the indicators within each tier is expected. All of the tier 1 indicators need not be monitored before those in tier 2. Socioeconomic indicators are not assigned to a specific tier. The social systems and economic frameworks in the socioeconomic monitoring section contain an extensive list from which specific monitoring questions and indicators may be prioritized based on the Multi-Party Monitoring Board's priorities and the information gaps in the Forest Service-required socioeconomic monitoring. Once socioeconomic monitoring data verify that the 4FRI project is socially and economically on track, the need to conduct this type of monitoring will decrease and the priority socioeconomic indicators can be monitored less frequently to focus on longer-term changes as project implementation progresses.

As new information becomes available and new questions are raised, the indicators or their order of priority may change. Likewise, methods for assessing and sampling are suggestions based on knowledge and availability at the time of publishing. As such, they may differ from the actual methods chosen by the Multi-Party Monitoring Board and Forest Service to monitor any individual indicator. Assessment and sampling methods chosen for indicators will be drawn from a combination of published literature and protocols and subject matter expertise. Any validation monitoring (research) conducted would be independent of implementation and effectiveness monitoring and would be funded strictly by external entities. However, the results of relevant research should inform future monitoring prioritization, methods, and adaptive management decisions. Table E-2 displays the effectiveness monitoring tiers and how they will be prioritized.

Table E-2. Effectiveness monitoring tiers and prioritization

Monitoring Tier	Priority for Completion	Who Will Complete	Type of Monitoring	Type of Funding
Tier 1	1	MPMB Forest Service 4FRI Stakeholder Group Agency Partners	Effectiveness, Socioeconomic	Appropriated, Partner
Tier 2 (includes research)	2	MPMB Forest Service 4FRI Stakeholder Group Agency Partners Research Advocate	Effectiveness, Socioeconomic, Research, Validation	Appropriated, Partner, Research Advocate

Monitoring Scale

For ease of understanding, all terms have been simplified and grouped as “fine” or “broad” scale indicators, with fine scale monitoring at the group and stand level, and broad scale monitoring taking place from the treatment area up to the landscape scale. To the extent possible, the scale of measurement of individual indicators has been selected to appropriately inform management actions (Wasserman et al. 2019). In some cases, it is appropriate to measure an indicator at both scales. However, this does not preclude monitoring efforts that may make finer distinctions. For example, some monitoring can occur at both, or either, the “group” and “stand” scale, depending on the questions and information needed to make informed decisions. In some cases, technological advances or availability of new datasets or products may facilitate evaluation of indicators and metrics at scales not anticipated.

Biophysical Effectiveness Monitoring Plan

Table E-3 summarizes the desired conditions, indicators, metrics, thresholds, and potential adaptive management actions described below in the biophysical effectiveness monitoring plan.

Biophysical Monitoring for Structure and Pattern

In the context of forest ecosystems, structure relates to the horizontal and vertical distribution of components of a forest stand including the height, diameter, crown layers, and stems of trees, shrubs, herbaceous understory, snags, and down woody debris, while pattern refers to the arrangement of forested areas and openings on the landscape. In the context of aquatic ecosystems, structure describes the biotic and abiotic physical characteristics such as floodplain connectivity or gravel size for fish spawning. Pattern describes the distribution of those attributes throughout space.

Relevant Desired Conditions

Conservation of Biological Diversity

a. Ponderosa pine and mixed conifer ecosystems provide the necessary structure, abundance, distribution that contributes to the diversity of native plant and animal species.

b. Where meeting management objectives with planned or unplanned ignitions alone is not possible, mechanical treatments are designed to restore and/or maintain forest structure over time, as defined in the desired conditions for that vegetation type and/or management area (e.g., wildland-urban interface).

c. Ponderosa pine ecosystems are composed of all age and size classes within the Initiative area and are distributed in patterns consistent with reference conditions.

d. Ponderosa pine ecosystems are heterogeneous in structure and spatial pattern at the Initiative scale. Openings and densities vary within the analysis area to maintain a mosaic appropriate to support resilience of individual trees and groups of trees.

e. Forest structure and density in dry mixed conifer are similar to ponderosa pine forest.

Ecosystem Resilience

a. Ponderosa pine and mixed conifer ecosystems are restored to natural tree densities to maintain availability of moisture and nutrients to support adaptation to climate change without rapid, large-scale type shifts.

b. All pre-settlement trees are retained in accordance with the Rim Country project Old Tree Implementation Plan (OTIP) in Appendix D.

Conservation and Maintenance of Soil, Water, and Air Resources

a. Forest structure supports a variety of natural resource values and processes, including hydrologic function, which meets ecological and human needs.

b. Forest openings are designed to improve snow accumulation and subsequent soil moisture and surface water yield.

c. Watersheds, riparian areas, and aquatic ecosystems have functional soil, vegetation, morphology, and flow regimes, consistent with site and watershed potential. These systems provide diverse habitats for an array of native obligate and facultative plant and animal species.

d. Streams and aquatic habitats support native fish and other aquatic species, providing the quantity and quality of aquatic habitat within the natural range of variation. This includes increasing habitat complexity such as pools and large woody debris, reducing downcutting and sedimentation, improving riparian areas that provide channel stability and leaf litter, and stream shading to maintain water temperatures.

e. Long-term soil productivity is protected by maintaining or improving soil condition and function.

f. Surface soil hydrologic function is in satisfactory condition with well aggregated, granular surface soil structure and tubular pores with sufficient porosity to effectively infiltrate water.

g. Watershed function is maintained or improved towards functioning properly and exhibit high geomorphic, hydrologic, and biotic integrity relative to their natural potential condition.

Description and Justification

Many of the desired conditions related to structural components of ponderosa pine and mixed conifer forests specify a need for heterogeneous forests that closely approximate reference conditions.

Investigations of historical ponderosa pine conditions indicate that forests were generally open in structure wherein trees occurred in multi-aged clumps of differing size among abundant understory plant communities (Mast et al. 1999, Waltz et al. 2003, Sánchez Meador et al. 2011). This fine-scale structure and spatial pattern is also found in studies of historical dry mixed conifer forests (Reynolds et al. 2013). It has been suggested that restoration treatments that focus on creating this structure of uneven-aged tree groups interspersed with openings of various sizes will provide the greatest benefit in terms of biological diversity and ecosystem function (Sabo et al. 2009, Kalies et al. 2010).

Determining the extent to which restoration treatments affect native plant and animal diversity will require approaches for characterizing structural diversity at multiple spatial and temporal scales (Wiens 1989). Management that creates or maintains structural complexity at the stand or patch scale while preserving a diverse assemblage of stands (or patches) that differ in size and spatial arrangement at broader scales has been identified as a necessary component of managing forested systems for diversity (Lindenmayer et al. 2006). Understanding the contribution of forest structure and composition to biodiversity is further complicated by the potential existence of "domains of scale" (such as areas where a process may behave predictably, but beyond which the process may change in an unpredictable and non-linear way) and that any single scale of measurement is likely to be arbitrary with respect to the process of interest (Wiens 1989).

Forest structure is a multi-dimensional attribute that is not assessed adequately by any single measure. Similarly, heterogeneity in forest structure occurs at multiple scales requiring multiple indicators (Cushman et al. 2008). Thus, two distinct sets of indicators will be used to assess changes in forest structure that result from 4FRI-implemented treatments.

Fine-scale Assessment

Tier 1 Suggested Indicators: age structure, patch spatial aggregation, regeneration, aquatic habitat suitability, stream morphology

- **Age Structure (Diameter Distribution) (Indicator 22):** While collecting this information pre-treatment and post-treatment is intensive, it would allow us to measure structural complexity in terms of age (size) structure and would also provide information for calculating changes in density and basal area that result from treatment.
    - **Assessment:** Field sampling of tree diameter (both pre- and post-treatment) of treated sites.
    - **Frequency:** As soon as possible following treatment (either mechanical or prescribed fire); every 10 years thereafter.
    - **Threshold/Trigger:** No threshold determined for this indicator. Also see the Large Tree Implementation Plan in Appendix D (implementation plan), which specifies specific conditions under which large young trees may be cut.
    - **Adaptive Management:** Evaluate reasoning for implementing large tree removal. If needed, appropriate adaptive management action recommendations will be developed.

- **Patch Spatial Aggregation (Ripley's K and/or Getis-Ord Gi*) (Indicator 39):** Measures of spatial aggregation can be used to determine "patchiness." Statistical tests such as Ripley's K and Getis-Ord Gi*can be used to describe spatial properties such as the distribution and clustering of trees as well as the distribution of canopy cover. These properties can be compared to those of "restored" areas to measure our progress towards historic conditions.
  - **Assessment:** Multiple tools, including some developed by the Remote Sensing and Application Center (RSAC) to process input images (NAIP, LiDAR, etc.) into canopy/ non canopy patches and assess for spatial pattern (Landscape Indices, FRAGSTATS) or field methods where appropriate.
  - **Frequency:** As soon as possible following treatment (either mechanical or prescribed fire) or as soon as appropriate aerial photography becomes available; every 10 years thereafter.
  - **Threshold/Trigger:** No threshold has been identified for this indicator. It will be developed as new information becomes available.
  - **Adaptive Management:** No management action has been identified at this time. However, once a threshold has been identified, the corresponding data would be reviewed and appropriate adaptive management action recommendations would be developed.
- **Regeneration (Density of Seedlings, Poles and Saplings) (Indicator 9):** Density of regeneration can be an indicator of future stand structure and can indicate a need for management actions such as prescribed fire. Species composition of regeneration can also assist in determining whether type shifts are occurring. These measurements require field sampling since it is not possible to assess regeneration accurately using remote sensing technology.
  - **Assessment:** Field sampling of seedling and sapling density and species composition within treated sites.
  - **Frequency:** As soon as possible following treatment and every five years thereafter.
  - **Thresholds/Triggers:** Within 10 years of treatment, seedling and sapling density should be within 0.4 to 3.6 plants/hectare/decade on volcanic soils (Mast et al. 1999). Weather patterns, starting conditions as measured by pre-treatment data collection, and treatment/disturbance history, such as fire return interval, should be considered in evaluating thresholds. No threshold has been identified for species composition of regeneration or for regeneration rates on limestone soils. These may be developed as new information becomes available.
  - **Adaptive Management:** If seedlings and saplings fall below the range above at broad scales where regeneration is a desired condition, then evaluate changes to increase probability of successful regeneration. If regeneration falls above this range, then more frequent and/or more intense prescribed burning may be necessary to reduce plant density. For species composition and regeneration rates on limestone soils, no management actions have been identified at this time. However, once thresholds have been identified, the corresponding data will be reviewed and appropriate adaptive management action recommendations will be developed.
- **Aquatic Habitat Suitability (Indicator 31):** Focuses on whether the biotic and abiotic habitat is available for aquatic species such as native fish, invertebrates, and herpetofauna, including consideration of water quality, persistence and habitat structure for native fish, and invertebrate populations. Treatment impacts from forest thinning and burning activities within the watershed

could have an influence. An excess of sediment affecting water quality is a potential impact. Also, channel, or aquatic restoration actions near the focal site could have impacts.

- **Assessment:** Draw from existing protocols such as the USDA Groundwater Dependent Ecosystems Levels I and II Inventory Field Guides (USDA 2012a and 2012b), the User's Guide for the Rapid Assessment of the Functional Condition of Stream-Riparian Ecosystems in the American Southwest (Stacey et al. 2006), or the USDA Effectiveness Monitoring for the Aquatic and Riparian Component of the Northwest Forest Plan: Conceptual Framework and Options (Reeves et al. 2004). Site assessments in perennial water locations can be measured before and after treatment.
- **Frequency:** 1 to 2 times before treatment, and every 2 years afterwards for up to 10 to 15 years.
- **Threshold/Trigger:** Decrease in habitat suitability indices after accounting for non-treatment factors such as climate variability.
- **Adaptive Management:** Evaluate source of degradation and address through changes in actions. Consider adding mitigation measures or structural improvements to stream.

- **Stream Morphology (Indicator 32):** Refers primarily to channel health in stream systems. Downcutting, erosion, and disconnection between the stream channel and the floodplain are indicators of poor morphology. These factors have a large influence on the restoration potential of a site and could be influenced by watershed-level processes or site-specific factors.
  - **Assessment:** Draw from existing protocols such as the USDA Groundwater Dependent Ecosystems Level I Inventory Field Guide (USDA 2012) or the User's Guide for the Rapid Assessment of the Functional Condition of Stream-Riparian Ecosystems in the American Southwest (Stacey et al. 2006). Possible metrics include channel stability, floodplain and riparian connectivity, channel roughness, presence of meanders, and bank stability. Unmanned Aircraft Systems (drones) may offer advantages for monitoring changes in channel and floodplain morphology.
  - **Frequency:** At least one time before treatment, and every 2 years afterwards for up to 10 to 15 years.
  - **Threshold/Trigger:** Degradation in condition of channel morphology/indices after accounting for non-treatment factors such as climate variability.
  - **Adaptive Management:** Evaluate source of degradation and address through changes in actions. Consider adding mitigation measures or structural improvements to riparian zone.

Tier 2 Suggested Indicator: riparian soil condition

- **Riparian Soil Condition (Indicator 35)** refers to the quality, depth and density of soils within the floodplain. Soil condition influences how well the system captures and holds moisture which influences processes downstream as well as site productivity. Past and ongoing grazing practices and erosion can degrade soil condition.
  - Assessment: Draw from existing protocol. Possible metrics include water-holding capacity, bulk density, soil aggradation/ erosion rates, rainfall/ runoff response directly above and downstream of focal area.
  - Frequency: 1 time before treatment, and every 5 years afterwards for up to 10 to 15 years.

- Threshold/Trigger: Decrease in water-holding capacity or increases in bulk density; increase in erosion rates after accounting for non-treatment factors such as climate variability.
- Adaptive Management: Evaluate source of decline and address through changes in actions. Consider adding mitigation measures or stabilization features.

Broad-Scale Assessment

Tier 1 Suggested Indicators: canopy openness, patch size, patch configuration, landscape connectivity and permeability

- **Canopy Openness (Percent and Characteristics of Openings) (Indicator 16):** Measure the pre- and post-treatment canopy openness (percent canopy cover and percent opening together equal 100 percent) along with the spatial aggregation statistics to describe the degree to which treatments are achieving "patchiness" and the degree to which those patches vary. Also, track the size and orientation of forest openings to determine their impacts on snowpack accumulation and retention (Broxton et al. 2015), which, in turn, affect soil moisture, plant-available soil water and system resilience to climate variability.
    - **Assessment:** Multiple tools, including some developed by the Remote Sensing and Application Center (RSAC) to process input images (NAIP, LiDAR, etc.) into canopy/ non canopy patches and assess for spatial pattern (Landscape Indices, FRAGSTATS) or field methods where appropriate.
    - **Frequency:** Pre-treatment (using either existing imagery or imagery collected for this purpose) As soon as possible following treatment (either mechanical or prescribed fire) or as soon as appropriate imagery becomes available; every 3-10 years thereafter.
    - **Threshold/Trigger:** No threshold has been identified for this indicator. It will be developed as new information becomes available.
    - **Adaptive Management:** Assess potential sources of deviation, including prescription and implementation; increase monitoring efforts in future task orders.
- **Patch Size (Patch area, Patch density, Patch Size Distribution) (Indicator 38):** Patch area is a fundamental quantity for understanding landscape composition that can be used in conjunction with field data to model species richness, occupancy, and distribution. Patch size, density, and distribution can be used as an index for spatial heterogeneity across a landscape with the added utility of being comparable across areas of differing size (McGarigal and Marks 1995). Distribution of patch size provides information on the variability of patch sizes within a particular class (e.g., groups, openings, etc.). These data, in conjunction with mean patch size, can provide information on key aspects of landscape heterogeneity and composition, particularly as patch size changes as a result of restoration treatments. These indicators can provide an indication of the ability of restoration treatments to achieve heterogeneity (and diversity) at a broad scale and can be calculated with the FRAGSTATS program (McGarigal et al. 2002).
    - **Assessment:** Categorical maps (e.g., groups, openings, etc.) based on satellite imagery and/or aerial photography.
    - **Frequency:** Annually to track broad-scale change or when suitable imagery becomes available.

  - **Threshold/Trigger:** No threshold has been identified for this indicator. It will be developed as new information becomes available.
  - **Adaptive Management:** No management action has been identified at this time. However, once a threshold has been identified, the corresponding data would be reviewed and appropriate adaptive management action recommendations would be developed.

- **Patch Configuration (Nearest neighbor distance distribution, Contagion, Simpson's Diversity and Evenness Indices) (Indicator 6):** These two indicators provide information on landscape configuration (i.e., the spatial arrangement of patches, treatment areas, etc.). Nearest neighbor distances that are narrowly distributed (i.e., little variation) tend to indicate an even distribution of patches across the landscape. Contagion measures the intermixing of different patch types and their spatial distribution. These two indicators provide a characterization of heterogeneity in terms of landscape configuration (i.e., spatial relationships among differing patch types) and has been used to characterize a variety of different landscapes (McGarigal and Marks 1995, Cushman et al. 2008). These indicators are also available within FRAGSTATS (McGarigal and Marks 1995, McGarigal et al. 2002). Simpson's Diversity and Evenness measures are typically associated with estimates of species diversity; however, they can also be used to assess the diversity of patch types across the landscape. A higher value indicates greater diversity of patch types. Similarly, higher evenness values indicate greater landscape diversity (i.e., less dominance by any particular patch type). FRAGSTATS includes a variety of diversity and evenness indices; however, Contagion and Simpsons were selected because they are easier to interpret (McGarigal and Marks 1995, Magurran 2004).
  - **Assessment:** Categorical maps groups, openings, etc.) based on satellite imagery and/or aerial photography.
  - **Frequency:** Annually to track broad-scale change or when suitable imagery becomes available.
  - **Threshold/Trigger:** No threshold has been identified for this indicator. It will be developed as new information becomes available.
  - **Adaptive Management:** No management action has been identified at this time. However, once a threshold has been identified, the corresponding data would be reviewed and appropriate adaptive management action recommendations would be developed.

- **Changes in landscape connectivity and permeability for closed canopy species (Indicator 20) and open canopy species (Indicator 21):** Forest treatments are anticipated to open and restore forest structure, while creating more heterogeneity to accommodate both closed and open canopy species. Building landscape connectivity models for species representing closed canopy (e.g., black bear, gray fox) and open canopy conditions (e.g., pronghorn) is a tangible way to estimate the effects of forest treatments on habitat quality and population connectivity for these representative species. Focusing modeling on known migration pathways is an additional way to concentrate on the most important areas from a population connectivity perspective. These models can be built and/or validated using telemetry data. While a variety of factors influence connectivity, the models can be formulated to reflect specific hypotheses related to landscape structure. Indicators 20 and 21 can be used in conjunction with remotely sensed habitat covariates to track changes at larger scales and provide information on landscape distribution patterns. In addition, hierarchical modeling could provide multi-scalar inference by using other wildlife species' detection information collected from field assessments (e.g., hair traps, collars). These models could be used to create "map-based" depictions of occupancy that can then be summarized at multiple scales. Development and subsequent validation of these models would be especially critical for threatened, endangered, sensitive, and rare species and would likely require partnership with Forest Service Research & Development and research institutions.

- **Assessment:** Field sampling in conjunction with remote sensing.
- **Frequency:** As soon as possible following treatment; 5 years post-treatment, 10 years post-treatment.
- **Thresholds/Triggers:** Closed canopy species: A 20 percent or greater decrease in modeled connectivity in known migration pathways. Pronghorn: A 5 percent or greater decrease in modeled omnidirectional connectivity and least cost pathways (using same techniques and area as pre-treatment model).
- **Adaptive Management:**
    - **Closed canopy species:** Evaluate implementing changes such as increasing group sizes or decreasing treatment intensity within known pathways.
    - **Pronghorn**: Evaluate implementing changes such as increasing opening sizes, increasing treatment intensity within known pathways, or identifying key locations for treatment for connectivity.

Tier 2 Suggested Indicators: soil moisture and snowpack depth, density, and persistence relative to forest opening size and orientation

- **Soil Moisture and Snowpack Depth, Density, and Persistence (Indicator 15):** In the Southwest, climate models predict overall drying throughout the 21st century, driven by declines in winter precipitation that will reduce snowpack and lead to earlier onset of snowmelt (Seager and Vecchi 2010). In general, canopy reduction in Arizona forests decreases snow interception and sublimation in the canopy and, depending on elevation and aspect, can reduce ground sublimation and increase snowpack accumulation and persistence (Sankey et al. 2015, Svoma 2017). Forest openings, depending on their size and orientation, promote greater snowpack accumulation and retention and hence greater soil water availability and storage (Baker and Ffolliott 2003, Broxton et al. 2015). Deeply rooted plants, such as mature ponderosa pines, that depend on moisture from winter precipitation are expected to be affected by changes in snowpack. Available soil moisture is expected to be higher in thinned ponderosa pine stands than in unthinned stands (Zou et al. 2008), which should promote plant vigor, resilience to climate variability and resistance to wildfire. If, however, restoration treatments (when considered alongside other factors, including grazing) reduce soil moisture, recognizing such a trend is information that can direct adjustments in treatments. Monitoring of lower elevations, south facing slopes and shallow soils that are susceptible to drying are a priority.
    - **Assessment:** Soil moisture measurements made using soil moisture probes, portable Time Domain Reflectometer (TDR) and/or gravimetric analysis at shallow and deep rooting depths according to a statistical design. Soil moisture may be analyzed within the context of a paired watershed study, but additional monitoring could also be conducted at sensitive sites such as lower elevations, south facing slopes and shallow soils. Snowpack metrics may be analyzed using any one or a combination of remote sensing, snow telemetry (SNOTEL) or other automated snow monitoring and field sampling/snow surveys. Broxton et al. (2019) describe methods for estimating watershed-scale snow water equivalent using LiDAR snow depth measurements and on-the-ground measurements of snow depth and density.

- **Frequency:** Pre-treatment, post-treatment; annually during pre- and post-monsoon water stress periods; following snow events and periodically through the winter snowpack season.
- **Threshold/Trigger:** Trends of decreasing soil moisture or snowpack depth and persistence (after adjusting for climatic variability) in stands with similar treatment types and/or physiographic characteristics.
- **Adaptive Management:** Evaluate treatments and adjust treatment methods and forest pattern as appropriate, especially at lower elevations, on south-facing slopes and on shallow soils that are susceptible to drying.

Biophysical Monitoring for Composition

This section reflects monitoring related to the makeup and diversity of species across terrestrial and aquatic systems, in both vegetation and wildlife.

Relevant Desired Conditions

Conservation of Biological Diversity

a. Ponderosa pine and mixed conifer ecosystems provide the necessary composition… that contributes to the diversity of native plant and animal species.

b. Ecologically functional populations of native species that include common, listed, rare, and sensitive species persist in natural patterns of distribution and abundance.

c. Understory vegetation composition and abundance are consistent with the natural range of variability.

d. Planned and unplanned fires maintain and enhance but do not degrade habitat for listed, rare, and sensitive species.

e. Planned and unplanned fires support diverse native understory communities and their associated biodiversity.

f. Habitat management is contributing to the recovery of listed species.

g. Populations of native species occur in natural patterns of distribution and abundance.

Ecosystem Resilience

a. There is reduced potential for introduction, establishment, and spread of invasive species. Additionally, efforts are made to reduce existing infestations.

b. Exotic species are rare or absent and do not create novel ecological communities following disturbance.

Conservation and Maintenance of Soil, Water, and Air Resources

a. Smoke impacts on air quality-related values are minimal.

b. Watersheds, riparian areas, and aquatic ecosystems have functional soil, vegetation, morphology, and flow regimes, consistent with site and watershed potential. These systems provide diverse habitats for an array of native obligate and facultative plants and animal species.

Description and Justification

Terrestrial Systems

Forest composition is the subject of many desired conditions. Both the Forest Service desired conditions and 4FRI Stakeholder Group's desired conditions identify certain patch components (Gambel oak (*Quercus gambelii)*), snags, coarse woody debris, and old growth) that contribute disproportionately to habitat values and the diversity of a patch or landscape (Bennetts et al. 1996, Kotliar et al. 2002, Bunnell and Houde 2010). In contrast, desired conditions for the understory and wildlife are specified both for their contributions to diversity and their ability to indicate ecosystem functionality.

Monitoring of understory composition could be used as an indication of both ecosystem resilience and soil productivity. Reductions in overstory tree volumes can be correlated with increased understory production (Laughlin and Grace 2006, Laughlin et al. 2005), and this increased understory productivity is a key assumption in the 4FRI Rim Country environmental analysis. However, stand-replacing wildfire in ponderosa pine and mixed conifer forests may lead to shifts toward exotic, invasive species dominance in understory plant communities (Crawford et al. 2001). Minimal or temporary increases over time in invasive species populations indicate high ecological resilience. Establishment and rapid spread of invasive species populations may lead to native species replacement and indicate low ecological resilience. Additional consideration for soil properties will be given below; however, for the purposes of this document soil productivity is interpreted as the ability of the soil to sustain native vegetation.

Many of the desired conditions for wildlife species are specified with respect to viability, natural patterns of distribution, and abundance. Historically, viability has been difficult or impossible to assess due to the difficulty of gathering reliable estimates of relevant population rates. Literature searches can provide a valuable starting point; however, case studies of viability rarely reveal generalizations useful for conservation management (Traill et al. 2007). As a potential solution to this issue, Flather et al. (2011) recommend focusing on those factors most likely to cause a species to become unviable. Monitoring of population response (particularly productivity and abundance) of threatened, endangered, and rare species should be focused on those areas directly impacted by treatment (e.g., Mexican spotted owl protected activity centers within some yet to be determined distance of restoration treatments or wildfire) as these are likely to be directly impacted by the presence of personnel, equipment, and infrastructure associated with treatments and disturbance.

The majority of species affected by the Rim Country project are likely to be affected through changes in habitat, particularly at larger scales. Site occupancy can be used in a monitoring context to reflect the current state of the population and population trends. Estimating occupancy often requires fewer detections than other density estimation techniques allowing for more precise estimates of rare or infrequently detected species (MacKenzie et al. 2003, MacKenzie and Royle 2005). Additionally, relating occupancy to habitat variables allows estimation and prediction of population changes due to changes in land use and climate (Dickson et al. 2009, Mattsson and Marshall 2009). Deriving these habitat-occupancy relationships using high-resolution satellite imagery provides the opportunity to identify the impacts of more localized changes (for example, forest restoration treatments) across larger spatial scales.

Monitoring for forest composition will require both field measurements and sophisticated modeling techniques to determine the degree to which restoration treatments are achieving desired conditions at all scales. Given uncertainties in the response of both wildlife and invasive species, this monitoring is especially important. Many of the indicators identified below would require significant resources to assess. Financial support from the 4FRI Stakeholder Group and other organizations would be needed to adequately monitor these indicators.

Aquatic and Riparian Systems

Healthy riparian and aquatic ecosystems are important aspects of watershed function and can provide the conditions necessary to create and sustain habitat for a variety of native species. Springs ecosystems in particular are biodiversity hotpots and the health of these ecosystems is a key component of broader forest and watershed resilience to disturbance, including a changing climate. The treatments proposed within Rim Country are designed to restore upland, aquatic, and riparian systems, including springs ecosystems.

Desired conditions for watersheds and riparian and aquatic ecosystems are to have functional soil, vegetation, morphology, and flow regimes, consistent with site and watershed potential. Conditions of soil, vegetation, stream and spring morphology, and flow regime are important determinants of aquatic and riparian habitat suitability. Properly functioning aquatic systems have biophysical attributes that maintain geomorphic integrity and provide diverse habitats, including thermal refugia for aquatic species and conditions conducive to successful feeding and reproduction of aquatic wildlife. The following categories encompass the general attributes of aquatic ecosystems, riparian and watershed structure, composition and process as they relate to restoration activities. These categories were derived from the 4FRI Rim Country Implementation Plan (FEIS, Appendix D), USDA Watershed Condition Framework and Functional Condition of Stream-Riparian Ecosystems in the American Southwest.

Fine-scale Assessment

Tier 1 Suggested Indicators: understory species composition (vegetative cover, bare soil, presence of native riparian obligate plant species, invasive plant species) wildlife species occupancy, richness, and diversity

- **Understory species composition/vegetative cover (Indicator 7):** Native species composition and the percentage of bare mineral soil provide an indication of soil productivity. In addition, restoration treatments have potential to increase abundance of native plant communities (Laughlin et al. 2006, Moore et al. 2006, McGlone et al. 2009b); however, invasive plant species may also increase in cover on sites where restoration thinning, prescribed fire, and livestock grazing occur (McGlone et al. 2009b). Native plant communities that are minimally disturbed during thinning or burning activities may better resist compositional shifts toward invasive species (Korb et al. 2004, McGlone et al. 2011). While assessment at the "Group" scale is not necessary, stand-scale assessment will require field sampling that can be accomplished more easily with university and volunteer partners.
    - **Assessment:** Field-collected quadrat assessments.
    - **Frequency:** Within 5 years of treatment.
    - **Threshold/Trigger:** Within 5 years of mechanical treatment and taking subsequent planned and unplanned fires into account, the cover should increase 20 percent ± 5 percent (15 to 25 percent) above pre-treatment (Laughlin et al 2011). Starting conditions as measured by pre-treatment data collection should be considered in evaluating thresholds.
    - **Adaptive Management:** If cover threshold is not reached, then re-evaluate treatment for management change, taking into account, grazing, soils, and burn treatment (e.g., reduce overstory basal area).

- **Bare soil (Indicator 8):** Native species composition and the percentage of bare mineral soil provide an indication of soil productivity. In addition, restoration treatments have potential to increase abundance of native plant communities (Laughlin et al. 2006, Moore et al. 2006, McGlone et al. 2009b); however, invasive plant species may also increase in cover on sites where restoration thinning, prescribed fire, and livestock grazing occur (McGlone et al. 2009b). Native plant communities that are minimally disturbed during thinning or burning activities may better resist compositional shifts toward invasive species (Korb et al. 2004, McGlone et al. 2011). While assessment at the "Group" scale is not necessary, stand-scale assessment will require field sampling that can be accomplished more easily with university and volunteer partners.
    - **Assessment:** Field collected quadrat assessments.
    - **Frequency:** Within 5 years of treatment for bare soil.
    - **Threshold/Trigger:** Within 5 years of treatment (mechanical and/or fire), bare soil should comprise less than 20 percent of area affected by treatment. Starting conditions as measured by pre-treatment data collection should be considered in evaluating thresholds.
    - **Adaptive Management:** If bare soil exceeds 20 percent of area within plots, re-evaluate restoration treatment for modifications, taking into account soils and burn treatment.
- **Presence of native riparian obligate plant species (Indicator 33):** Native plant species near water sources provide vital habitat and support proper function of riparian systems.
    - **Assessment:** Draw from existing protocols such as the BLM Multiple Indicator Monitoring (MIM) of Stream Channels and Streamside Vegetation (Burton et al. 2011). Possible metrics include native riparian plant diversity, extent, cover, structural complexity, vigor, demography, recruitment, survival.
    - **Frequency:** Once before treatment, every 2 years after for up to 10-15 years
    - **Threshold/Trigger:** Decrease in extent, cover, diversity, recruitment, or survival of native riparian vegetation after accounting for non-treatment factors such as climate variability.
    - **Adaptive Management:** Evaluate source of decline and address through changes in actions. Consider adding mitigation measures or structural improvements to encourage establishment and retention of native riparian obligate species.
- **Diversity of wildlife communities (closed canopy songbird species: Indicator 17, open canopy songbird species: Indicator 18):** While estimating changes in forest structural components provides some indication of how treatments may contribute to diversity goals, documenting the ways restoration treatments affect overall species diversity requires knowledge of how diversity is changing over time. Species abundance is expected to change due to treatment, and incidence- or occurrence-based estimators (e.g., multi-species occupancy models (Dorazio et al. 2006; MacKenzie et al. 2006; Royle and Kéry 2007)) are a way of documenting the actual change in species populations. These species richness estimators have been shown to be more accurate and potentially less biased than historical estimators (e.g., Shannon's Index, Simpson's Diversity Index) (Walther and Moore 2005). Songbird species associated with closed canopy are expected to respond differently (e.g., decreased occupancy and/or abundance) to treatments compared to songbird species associated with open canopy. Occupancy, defined as the proportion of total area occupied, can provide a useful alternative to density or abundance,

especially for uncommon species (MacKenzie et al. 2006). More generally, occupancy can also be interpreted as the probability of locating an individual of species x in location y. This interpretation (probability of occupancy) reflects an *a priori* expectation that a site will be occupied based on a hypothesis about the underlying process determining occupancy. The former interpretation (proportion of area occupied) is the realization of that process, given large sample sizes (MacKenzie et al. 2006). Occupancy, species richness, and diversity can be computed using data from previous and ongoing surveys using a Before-After-Control-Impact (BACI) design conducted by Bird Conservancy of the Rockies in conjunction with the Forests.

  - **Assessment:** Field sampling of wildlife communities of interest (e.g., songbirds).
  - **Frequency:** As soon as possible following treatment (either mechanical or prescribed fire); every 3-5 years thereafter.
  - **Threshold/Trigger:** No threshold has been identified for these indicators at the fine scale. They will be developed as new information becomes available. Any decline (trend that does not include zero) with species richness and diversity at the broad scale, after accounting for non-management activities over a to-be-determined period.
  - **Adaptive Management**:
    - For closed-canopy species at the fine scale, no adaptive management action has been identified at this time. At a broad scale evaluate opportunities to increase closed canopy, decrease edge, and/or increase patches.
    - For open-canopy species, no adaptive management action has been identified at this time.

- **High-risk and "watch list" invasive plants species (Indicator 3):** So-called "watch list" species are currently not known to fall within the Rim Country project area, though if they are detected, aggressive and rapid eradication efforts should be a top priority. These species include Malta starthistle (*Centaurea melitensis L.*), Himalayan blackberry (*Rubus armeniacus* and *Rubus discolor*), giant reed (*Arundo donax*), sulfur cinquefoil (*Potentilla recta*), halogeton (*Halogeton glomeratus*), dyer's woad (*Isatis inctorial*), Eurasian water-milfoil (*Myriophyllum spicatum*), and Canada thistle (*Cirsium arvense*). High risk species currently have limited geographic distribution within the Rim Country project area, and if current inventories indicate their presence within treatment areas, these species should be eradicated immediately. High-risk species include tree of heaven (*Ailanthus altissima*), leafy spurge (*Euphorbia esula*), camelthorn (*Alhagi maurorum*), yellow starthistle (*Centaurea solstitalis*), spotted knapweed (*Centaurea biebersteinii*), diffuse knapweed (*Centaurea diffusa*), Russian knapweed (*Acroptilon repens),* white top (*Cardaria draba*), Russian olive (*Eleagnus angustifolia*), oxeye daisy (*Leucanthemum vulgare*), Mediterranean sage (*Salvia aethiopis*), Scotch thistle (*Onopordum acanthium*), tamarisk (*Tamarix* spp.*),* common teasel (*Dipsacus sylvestris*), musk thistle (*Carduus nutans*), and Siberian elm (*Ulmus pumila*).
  - **Assessment:** Percent cover of native and non-native species based on field sampling.
  - **Frequency:** Pre- and immediately post-disturbance (e.g., mechanical thinning, prescribed fire, and wildfire); every 5 years thereafter.
  - **Threshold/Trigger:** Identification of new or existing "watch list" or "high-risk" invasive species

  - **Adaptive Management:** If inventories, surveys, and map checks indicate presence of “high-risk” or “watch list” species, evaluate design features, best management practices and mitigation measures in Appendix C, especially for cleaning equipment moving from infested sites to clean sites and management activities (including grazing and recreation) that may be a contributing factor. Consider aggressive treatments leading to population control or modifications to other management activities. If treatments do not reduce the cover of “watch list” species in treated populations by 90 percent in one year or “high-risk” species by 50 percent in two years in treated populations, consider new approaches to eradication.

- **Medium-risk invasive plant species (Indicator 4):** These species have widespread distribution within 4FRI treatment areas in large populations, with either no effective treatment, or cost-prohibitive effective treatment, or for which effectiveness of current treatment strategies is unknown or not monitored. Areas should be prioritized for treatment based on risk to conservation value (presence or proximity of TES species) and areas of high wildlife habitat value (e.g., ecotones). Weed treatment strategies should be assessed for effectiveness to gauge return on investment. Medium-risk species include Dalmatian toadflax (*Linaria dalmatica*), bull thistle (*Cirsium vulgare*), and wild oats (*Avena fatua*).
  - **Assessment:** Percent cover of native and non-native species based on field sampling.
  - **Frequency:** Pre- and immediately post-disturbance (e.g., mechanical thinning, prescribed fire, and wildfire); every 5 years thereafter.
  - **Threshold/Trigger:** Identification of new or existing “medium-risk” invasive species populations.
  - **Adaptive Management:** If inventories, surveys, and map checks indicate presence of medium-risk species, consider controlling these species on individual basis especially when high value areas or habitats are at risk. If treatments do not reduce the cover of medium-risk species by 20 percent in treated populations in five years, consider new approaches to weed management.

- **Cheatgrass (*Bromus tectorum*) (Indicator 5):** Cheatgrass invasion of frequent fire conifer systems after restoration-based treatments is an issue of significant concern (Keeley and McGinnis 2007, McGlone et al. 2009a and b). Widespread invasion of cheatgrass often shifts ecosystems into irreversible states where cheatgrass-mediated fire intervals exclude native understory plants (Brandt and Rickard 1994, D’Antonio and Vitousek 1992, Brooks et al. 2004). Means of prevention and treatment have not been adequately tested or found successful in ponderosa pine systems; however, the risk of ecological transformation caused by cheatgrass warrants aggressive monitoring and adaptive management in the Rim Country project area. Pre-treatment preventative actions will be just as critical as adaptive management responses post-treatment and will require identification of areas at risk for cheatgrass invasion prior to project implementation, such as areas where cheatgrass is already present or ecotonal areas adjacent to existing cheatgrass populations.
  - **Assessment:** Percent cover of native and non-native species based on field sampling.
  - **Frequency:** Pre-disturbance and within two years following disturbance (e.g., mechanical thinning, prescribed fire, and wildfire); every 5 years thereafter.

- **Threshold/Trigger:** Identification of new or existing cheatgrass populations.
- **Adaptive Management:** If inventories, surveys, and map checks indicate areas with a high risk of cheatgrass introduction or spread, treatments could include (but should not be limited to):[1]
  - Chemically treating and native reseeding of small infestations of cheatgrass prior to thinning and burning
  - Avoiding whole-tree skidding and other actions that cause significant soil disturbance
  - Removing slash and avoiding creation of large slash piles resulting from thinning operations
  - Properly manage grazing so that perennial grasses are maintained
  - Deferring burns in heavily infested areas
  - Delaying burns and lengthening fire return intervals post-thinning to allow native perennials time to establish
  - Applying native, perennial seed (e.g., bottlebrush squirrel tail, which has shown promise in successfully competing with cheatgrass) after fire.
  - Cleaning equipment and clothing after working in infested areas

Tier 2 Suggested Indicators: old trees; presence, abundance, and/or diversity of native riparian obligate animal species; rare ecosystem elements (Gambel oak, aspen, and riparian communities); snags

- **Old Trees (Number of Old Trees) (Indicator 23):** The 4FRI Landscape Strategy places a large emphasis on pre-settlement trees. Furthermore, higher levels of biodiversity have been attributed to those areas that contain old-growth components (Binkley et al. 2007) and these components may be susceptible to mortality immediately post-treatment (Fulé et al. 2007, Roccaforte et al. 2010). Evidence suggests, however, that this mortality can be avoided through a variety of "protection" measures and that over time restoration treatments can increase the vigor of old trees (Kolb et al. 2007).
  - **Assessment:** Rapid assessment conducted while collecting diameter distribution data on plots (or use of aerial imagery once techniques become available) or other evidence.
  - **Frequency:** As soon as possible following mechanical treatment and one year following prescribed fire; every 5 years thereafter.
  - **Threshold/Trigger:** Any old tree cut outside of the criteria identified in the Old Tree Implementation Plan.

[1] If cheatgrass (*Bromus tectorum*) begins to dominate at broad scales after thinning and burning treatments within the Rim Country project area, consider delaying further treatments in areas of high risk until the Forest Service, members of the 4FRI Stakeholder Group, and experts can be convened to evaluate alternative management options.

  - **Adaptive Management:** No management action has been identified at this time. However, when an old tree is cut, the cause or rationale will be reviewed by the Monitoring Board.

- **Presence, abundance, and/or diversity of native riparian obligate animal species (Indicator 34):** This measure would assess if riparian systems are supporting native animal species, such as tiger salamanders, northern/Chiricahua leopard frogs, terrestrial gartersnakes, white-nosed coatis, common black hawks, song sparrows, warbling vireos, and yellow warblers. Native riparian obligate animal species can be indirect indicators of secondary benefits to riparian habitat of restoration activities.
  - **Assessment:** Draw from existing protocol. Possible metrics include species presence or abundance, species diversity, modeled population size, etc.
  - **Frequency:** Once before treatment, every 2-5 years after.
  - **Threshold/Trigger:** Decrease in species presence or abundance, diversity, or modeled population size after accounting for non-treatment factors such as climate variability.
  - **Adaptive Management:** Evaluate source of decline and address through changes in actions. Consider adding mitigation measures or structural habitat improvements.
- **Oak, aspen, and riparian areas (Indicator 25):** Rare ecosystem elements contribute heavily to the biodiversity of frequent fire forests in the Southwest. For example, pine-oak forests tend to have a greater diversity of songbirds and small mammals than ponderosa forests that lack an oak component (Block et al. 2005, Jentsch et al. 2008). Removal of overstory competition from ponderosa pine and more regular low-severity fire are likely to alter the cover and composition of the oak component within treated stands. Removal of ponderosa pine competition may also encourage aspen regeneration and increase the size of riparian plant communities due to increases in available water.
  - **Assessment:** Plot-based and/or remotely sensed (e.g., LiDAR, UAS-based) assessment of percent cover.
  - **Frequency:** One to two years following treatment (either mechanical or prescribed fire); every 5 years thereafter.
  - **Threshold/Trigger:** No threshold has been identified for this indicator. It will be developed as new information becomes available.
  - **Adaptive Management:** No management action has been identified at this time. However, once a threshold has been identified, the corresponding data would be reviewed and appropriate adaptive management action recommendations would be developed.
- **Snags (Number, Size Distribution, Condition) (Indicator 27):** The number and size of snags present will be sampled within treated sites due to their role in providing valuable habitat for a variety of wildlife species (e.g., Kotliar et al. 2002) and the potential for restoration treatments to alter snag composition within treated sites (Bagne et al. 2008, Hessburg et al. 2010). In addition, assessing the condition of the snags (sound vs. soft) can provide an indication of the expected longevity for those snags.
  - **Assessment:** Plot-based rapid assessment and/or remotely sensed (e.g., LiDAR, UAS-based) quantification of numbers and sizes of snags.

- **Frequency:** As soon as possible following mechanical treatment and one year following prescribed fire; every 5 years thereafter.
- **Threshold/Trigger:** No threshold has been identified for this indicator. It will be developed as new information becomes available.
- **Adaptive Management:** No management action has been identified at this time. However, once a threshold has been identified, the corresponding data would be reviewed and appropriate adaptive management action recommendations would be developed.

Broad-Scale Assessment

Tier 1 Suggested Indicators: response of threatened and endangered species; response of regional forester's sensitive species and species of conservation concern

- **Response of threatened and endangered species (Indicator 1);** response of regional forester's sensitive species and species of conservation concern (Indicator 2): Treatments conducted under 4FRI may affect rare, sensitive, threatened, or endangered species through a variety of mechanisms and at a variety of scales. This is particularly true for wildlife species such as the Mexican spotted owl. Understanding the effects of treatment on productivity (and thus viability) of these species likely requires a research effort beyond the scope of this plan. The Forest Service, independently from the 4FRI Multi-Party Monitoring Board, will monitor the Mexican spotted owl and other listed species as directed by the Rim Country Biological Opinion provided by U.S. Fish and Wildlife Service and as described in the Southwestern Region Mexican Spotted Owl Management Strategy (see "Required Monitoring" section above).
    - **Assessment:** Mexican spotted owl and other listed species: methods and sampling as required in the U.S. Fish and Wildlife Service biological opinion and as described in the Southwestern Region Mexican Spotted Owl Management Strategy. Regional forester sensitive species and species of conservation concern: methods and sampling per established protocols.
    - **Frequency:** In accordance with the relevant biological opinion or established protocol, as applicable.
    - **Thresholds/Triggers:** As directed by the U.S. Fish and Wildlife Service biological opinion for listed species. For sensitive species and species of conservation concern, when indicator trends suggest a need for listing under the Endangered Species Act
    - **Adaptive Management:** As required in the U.S. Fish and Wildlife Service Biological Opinion and in ongoing coordination with U.S. Fish and Wildlife Service. Consider comparing to regional monitoring data trends. Additional Mexican spotted owl monitoring may be conducted even if there are no statistically significant declines. For sensitive species and species of conservation concern, as appropriate in consultation with Forest Service biologists and U.S. Fish and Wildlife Service.

Tier 2 Suggested Indicators: northern goshawk occupancy

- **Northern goshawk occupancy (Indicator 19):** Treatments conducted under 4FRI may affect rare, sensitive, threatened, or endangered species through a variety of mechanisms and at a variety of scales. Northern goshawk will be monitored according to the field protocols established in the Forest Service National Goshawk Inventory Guidelines or as appropriate based on approved methods.

- **Assessment:** Northern goshawk occupancy: Forest Service protocols (Joy et al. 1994) as modified by Forest Service survey guidance (USDA FS 2017) or as appropriate based on approved methods.
- **Frequency:** In accordance with the aforementioned protocols.
- **Thresholds/Triggers:** If northern goshawk occupancy trends show a non-zero decline (occupancy trend confidence interval or credible interval does not overlap zero) over a 5- to 10-year average at treatment and 4FRI landscape scales.
- **Adaptive Management:** Evaluate treatments and consider increasing or focusing monitoring on area where northern goshawk is declining. Consider comparing to regional monitoring data trends. Additional monitoring may be conducted even if there is no statistically significant decline.

Biophysical Monitoring for Function or Process

Monitoring in this section captures how ecosystem functions or processes are maintained or changed with restoration, including hydrologic processes, ecosystem type shifts, fire size and severity, forest pests and pathogens, soil stability and sedimentation, and the generation of smoke.

Relevant Desired Conditions

Conservation of Biological Diversity:

a. Ponderosa pine and mixed conifer ecosystems provide the necessary processes that contributes to the diversity of native plant and animal species.
b. Wherever practicable, natural fire regimes regulate forest structure and composition.
c. Planned and unplanned fires support diverse native understory communities and their associated biodiversity.

Ecological Resilience:

a. Ponderosa pine and mixed conifer ecosystems in the 4FRI are capable of adapting to, or persisting with, climate change without rapid, large-scale cover type shifts.
b. Natural disturbance processes (e.g., frequent low-intensity fire, drought mortality, endemic levels of forest pests and pathogens) are the primary agents shaping forest ecosystem structure, dynamics, habitats, and diversity over time.
c. Natural disturbance processes (e.g., frequent low-intensity fire, endemic pests and pathogens) are within the natural range of variability.
d. Wildland fires burn within the range of frequency and intensity of natural fire regimes. There is low probability for uncharacteristically severe fire to spread at broad scales.
e. Forest insects and pathogens occur at endemic levels.
f. Ponderosa pine and mixed conifer ecosystems in the 4FRI are capable of regeneration and recovery following natural disturbance (e.g., fire, outbreaks of insects and pathogens).
g. Strategically placed treatments allow fire managers to safely manage planned and unplanned fires in a way that benefits and enhances the resilience of forest ecosystems.

h. Restoration results in forests that are trending toward natural variability, self- regulating, and positioned to adapt to climate change without large, rapid cover type shifts.

Conservation of Soil, Water, and Air Resources:

a. Soil productivity, watershed function, and air quality are not at risk of being degraded by uncharacteristically severe disturbances (e.g., landscape-level high-severity wildfire).
b. Soil productivity is within the capability of the site and soils function properly in terms of their ability to resist erosion, infiltrate water and recycle nutrients. Coarse woody debris, including downed logs, provides for long-term soil productivity. Soil productivity and functions contribute to the resiliency and adaptability of terrestrial and riparian ecosystems to climate change.
c. In fire-adapted ecosystems, wildland fire improves, maintains, and/or protects public safety, ecosystem function, vegetation composition and structure, property and infrastructure, wildlife habitat, and socio-economic values.
d. Rare and ecologically valuable springs, wet meadows, and other riparian areas are protected and enhanced through appropriate restoration treatments where needed.
e. Restored frequent fire ecosystems accommodate natural and other fires without uncharacteristically severe impacts to soil productivity and or watershed resources.
f. Vegetation within the analysis area is managed strategically and at a level appropriate to prevent degradation of air quality beyond regulatory standards due to wildfire.
g. Hydrologic processes are re-established to restore the groundwater that feeds springs and wet meadow ecosystems, and other riparian areas.
h. Strategically placed treatments allow fire managers to manage planned and unplanned fires in locations, seasons and conditions that maximize smoke dispersion and minimize smoke impacts.
i. Watersheds, riparian areas, and aquatic ecosystems have functional soil, vegetation, morphology, and flow regimes, consistent with site and watershed potential. These systems provide diverse habitats for an array of native obligate and facultative plants and animal species.
j. Riparian zones along streams can filter sediment, capturing and/or transporting bedload (aiding floodplain development, improving flood-water retention, improving or maintaining water quality), and providing ground water recharge within their natural potential.
k. Streams and aquatic habitats support native fish and other aquatic species, providing the quantity and quality of aquatic habitat within the natural range of variation. This includes increasing habitat complexity such as pools and large woody debris, reducing downcutting and sedimentation, improving riparian areas that provide channel stability and leaf litter, and stream shading to maintain water temperatures.

Description and Justification

The majority of desired conditions for the Rim Country project focus on the need to maintain ecosystem processes within the natural range of variability. While the desired conditions are numerous, indicators for assessing them fall into several major categories: ecosystem type shifts, fire size and severity, forest pests and pathogens, soil stability and sedimentation, and the generation of smoke.

An ecosystem that is resilient shows persistence in relationships and low probability of extinction (Holling 1973). A resilient system absorbs fluctuations in state variables (e.g., population numbers) and processes. Persistence and return of characteristic ecosystem structure and function following disturbance indicate high ecological resilience. Rapid, large-scale type shifts indicate low ecological resilience.

Modeling has shown that the variability in the North Pacific jet is expected to present as a north-south wobbling, with uncertain effects on anticyclonic activity associated with the North American monsoon that supplies most warm-season precipitation in the Southwest (Barnes and Polvani 2013). Lu et al. (2018) integrated water vapor wave activity into modeling to show predicted increases in length and frequency of landfalling atmospheric rivers with an associated ~20 percent increase in hydrological extremes on the West Coast. Similarly, Espinoza et al. (2018) found, under the Representative Concentration Pathway (RCP) 8.5 warming scenario, that atmospheric river frequency increased 45% and the integrated water vapor transport increased 30 percent for the West Coast. Historically, atmospheric rivers affecting the Southwest tend to be low-frequency, longer duration events that contribute a large proportion of the cool-season precipitation across the region (Dettinger et al. 2011). Singh et al. (2018) modeled five intense historical atmospheric river events that affected the Salt and Verde River basins under future climate scenarios. They found that overall, precipitation increased, with changes in precipitation spatially heterogenous. In addition, projected warming resulted in a higher proportion of precipitation falling as rain, which, could result in decreased snow accumulation and an increased likelihood of rain-on-snow events and associated flooding (Singh et al. 2018). Climate change has already intensified severity of drought in the Colorado River Basin and has reduced snowpack (Gonzalez et al. 2018) and there is general agreement among future climate models for the Southwest in projecting overall warmer and drier conditions, including more drought and decreases in snowpack and streamflow (Gonzalez et al. 2018, Seager et al. 2007). Modeling by Seager and Vecchi (2010) showed warming and drying trends manifesting in reductions in winter precipitation, decreased snowpack, and earlier onset of snowmelt across the southwestern U.S.

Climate change resulted in doubling of acres burned in wildfires in the western U.S. between 1984 and 2015 compared to what would have burned in the absence of climate change (Gonzalez et al. 2018). As a result of increased heat, wildfire, and bark beetle outbreaks mainly attributable to climate change, tree mortality across the western U.S. doubled from 1955 to 2007 (Gonzalez, et al. 2018). Coupled with decreased tree regeneration driven by loss of seed trees and drought-induced seedling mortality (O’Donnell et al. 2018), these dynamics can lead to decreases in aboveground biomass and type conversion in species forest composition. Under current forest conditions, potential impacts of climate change are likely to be worse than they would be under historic forest conditions. By returning forests to a condition closer to the natural range of variability, restoration treatments may delay shifts in species composition, slow the loss of aboveground biomass, and decrease the amount of time that disturbed sites remain unforested due to predicted changes in climate (O’Donnell et al. 2018). Restoration treatments in ponderosa pine and mixed conifer forests have the potential to increase growth and vigor of residual trees, lower potential for crown fire, provide growing space and microsites for tree regeneration, and increase available resources for native plant communities (Laughlin et al. 2006, Kolb et al. 2007, Roccaforte et al. 2010). Such effects are likely to buffer the ecosystem against climate change and enhance resilience at fine to broad scales (Fulé 2008).

Ponderosa pine and dry mixed conifer forests were historically resilient and persisted under a frequent, low-severity fire regime. Current forest conditions are outside the historical range of variability in terms of tree density and structure. Fire under current structural conditions has greater potential to be stand-replacing, indicating conditions of low ecological resilience. Restoration treatments that reduce forest density and fuel loading can in turn reduce potential for stand-replacing crown fire (Fulé et al. 2001, Roccaforte et al. 2009).

Tree species within the Initiative area coevolved with native insect herbivores and pathogens. Forests with endemic levels of insects and pathogens do not experience large-scale and long-term type shifts. Epidemic levels of insects and pathogens may lead to rapid ecological shifts, which represents conditions of low ecological resilience.

Bark beetles, dwarf mistletoe, and to some extent, root diseases are the major damaging insects and pathogens of ponderosa pine and mixed conifer forests (Wilson and Tkacz 1996). Overly dense forest conditions may lead to increased susceptibility to these agents and result in extensive tree mortality (Wilson and Tkacz 1996, Negrón et al. 2000). Restoration thinning can enhance tree resistance to various insects and pathogens (Kolb et al. 2007). Severe fire effects, whether from prescribed burning or wildfire, can increase susceptibility to damaging insects and pathogens (McHugh et al. 2003).

Hydrologically, there are five fundamental watershed functions, and two secondary functions: (1) collection of the water from rainfall, snowmelt, and storage that becomes runoff, (2) storage of various amounts and durations, (3) discharge of water as runoff (4) sediment transport, and (5) groundwater recharge. In fact, the first and third of these functions have long been incorporated in the commonly-used terms, "catchment" and "watershed"; storage refers to water being detained within an area between "catching" and "shedding." Ecologically, the watershed functions in two additional ways: (1) it provides diverse sites and pathways along which vital chemical reactions take place, and (2) it provides habitat for the flora and fauna that constitute the biological elements of ecosystems.

Large, uncharacteristically severe wildfires such as the Rodeo-Chediski, Schultz, and Wallow fires have had deleterious effects on watershed function through downcutting of channels, soil erosion, and excessive sediment transport (Gottfried et al. 2003, Moody and Martin 2009). Mechanical thinning and prescribed burning can help maintain hydrologic function of southwestern frequent fire forests. Though they only modeled restoration treatments in low-mid-(ponderosa pine) and high-mid-elevation (dry mixed conifer) ecoregions within their study area (treatments in high-elevation spruce-fir and low-elevation pinyon-juniper ecoregions were not included), O'Donnell et al. (2018) found that expected annual sediment yield decreased relative to the no treatment scenario across all ecoregions under both the low and high restoration rate scenarios. Modeling by Moreno et al. (2016) of thinning treatments similar to those proposed in the first 4FRI EIS project area showed that restoration can have mixed effects on various hydrological components. Over 20 years, thinning reduced canopy interception and shading, transpiration, vadose zone moisture, and snow-water equivalent, which led to increases in net radiation, surface temperature, wind speed, soil water evaporation, surface water runoff and groundwater recharge. Aspect and soil hydraulic conductivity, or infiltration rate, influenced these changes, with south-facing slopes showing stronger responses to atmospheric losses, and lowered infiltration rates from compaction leading to increases in mean and maximum surface water yields (Moreno et al. 2016).

Because of complex interactions among these factors, potential unintended effects of restoration treatments, such as soil compaction from heavy equipment and fire-related damage to the soil biotic community and soil nutrient balance, should be monitored, particularly in the context of other ongoing management activities (including grazing), to inform adaptive management.

Smoke is a natural consequence of wildland fire and can be managed through a variety of prescribed conditions that managers use in controlling fire, including fuel moisture content, fuel loading and arrangement, air temperature, relative humidity, wind direction and speed, and seasonality of burn (lower atmosphere ventilation). Smoke from forest combustion is also a contributor to visual haze, and the timing, amount, and quality of its generation from controllable sources such as prescribed burns is regulated by the Arizona Department of Environmental Quality (ADEQ) because of smoke's effects on human health.

While restoration activities would generate a substantial amount of smoke, coordinated efforts to manage vegetation conditions and to implement prescribed fire under favorable weather conditions would help to mitigate the amount and quality of smoke released and would reduce total effects on air quality.

With the exception of tree mortality and regeneration dynamics, the ecosystem processes described above operate at broad scales. Thus, assessing progress towards desired conditions will require a variety of remotely sensed and modeled data to interpret the effects of restoration treatments within the context of the larger landscape. Developing more robust and accurate models of these processes will benefit greatly from information gathered as part of a field sampling effort.

Fine-Scale Assessment

Tier 1 Suggested Indicators: groundwater response

- **Groundwater Response (Depth to groundwater, baseflow and riparian soil moisture) (Indicator 30):** Monitoring of groundwater flow should be focused on the water flow at springs and seeps and indicators of persistent soil moisture in associated riparian areas.
    - **Assessment:** Several approaches are possible, but (semi-)continuous sampling, such as with pressure transducers or soil moisture probes, within treated and untreated watersheds would be ideal.
    - **Frequency:** Annually
    - **Thresholds/Triggers:** Decreases in subsurface water volume, spring/seep flow, riparian soil moisture after accounting for non-treatment factors such as climate variability
    - **Adaptive Management:** If decrease or no change in subsurface water, evaluate treatment methods and consider changing treatment intensity. If increase in subsurface water, consider replicating treatment methods elsewhere.

Tier 2 Suggested Indicators: tree mortality, regeneration, insect pathogen dynamics, fuel loading, soil chemistry/productivity

- **Tree Mortality (Canopy Cover, Number of Pathogen-affected Patches, Size of Mortality Patches, and Percent of Landscape in Mortality Patches) (Indicator 28):** These indicators can help assess likelihood of ecosystem type shifts and changes in mortality dynamics across the larger 4FRI landscape particularly those that result from endemic pests and pathogens. Freely available data from the National Agricultural Image Program (NAIP) and the National Forest Health Monitoring (NFHM) Program can be used to generate these estimates.
    - **Assessment:** NFHM assessment and NAIP imagery.
    - **Frequency:** NFHM data is available annually, NAIP imagery is available every 2-3 years
    - **Thresholds/Triggers:** No threshold has been identified for this indicator. It will be developed as new information becomes available.
    - **Adaptive Management:** No management action has been identified at this time. However, once a threshold has been identified, the corresponding data would be reviewed and appropriate adaptive management action recommendations would be developed.

- **Insect and Pathogen Dynamics (Bark Beetle Rating, Dwarf Mistletoe Rating, and Number of Trees Affected by Pests/Pathogens) (Indicator 24):** Monitoring of insects and pathogens should focus on levels of tree mortality as described above. In addition, bark beetle and mistletoe rating systems (Hawksworth 1977, Sánchez-Martínez and Wagner 2002) should be used in field plot measurements to track changes in levels of occurrence.
    - **Assessment:** Field and remote sensing methods, including Forest Service aerial detection surveys.
    - **Frequency:** As soon as possible following treatment and every 5 years thereafter.
    - **Thresholds/Triggers:** No threshold has been identified for this indicator. It will be developed as new information becomes available.
    - **Adaptive Management:** No management action has been identified at this time. However, once a threshold has been identified, the corresponding data would be reviewed and appropriate adaptive management action recommendations would be developed.
- **Soils (Soil chemistry/productivity) (Indicator 14):** Forest management actions may sometimes cause a reduction in the ability of plants to use nitrogen (an essential nutrient) from soil; these changes are related to soil productivity and can be identified by tracking shifts in the Carbon:Nitrogen ratio (Steve Overby personal communication 2012). Soil productivity can be impacted by restoration activities, especially where soils and soil organisms are disturbed by mechanical treatments and prescribed fire (Owen et al. 2009). Also, changes in forest pattern that affect exposure to solar radiation and soil moisture can change biochemical processes that influence the balance of soil nutrients (Paul and Clark 1996). Because soil nutrition is fundamentally important for plant metabolism, tracking soil nutrition is an effective approach for assessing the effects of restoration treatments on some aspects of forest health.
    - **Assessment:** Test carbon- to-nitrogen ratios from soil samples collected according to a statistical design.
    - **Frequency:** Pre-treatment, post-treatment, annually in the first 3 years if a shift in Carbon:Nitrogen is found following treatment until ratio recovers or stabilizes, otherwise every 5 years.
    - **Thresholds/Triggers:** Carbon:Nitrogen ratios increasing from ratio values of 12-14 upwards to 30, indicating a reduction in nitrogen availability that would impact plant productivity.
    - **Adaptive Management:** Evaluate treatment methods and consider changes in treatment methods and target forest patterns.

Broad-Scale Assessment

Tier 1 Suggested Indicators: fuel/fire hazard, fire behavior, fire size, fire severity, fire risk, surface water response, and watershed condition

- **Fuel Loading/Hazard (Surface and crown fuel loads and distribution) (Indicator 10):** Monitoring of forests' potential to support uncharacteristically severe wildfire should be focused on structural conditions and fuel loading.
    - **Assessment:** Field sampling within treated sites and remote sensing methods

  - **Frequency:** As soon as possible following treatment and every five years thereafter
  - **Thresholds/Triggers:** No threshold has been identified for this indicator. It will be developed as new information becomes available.
  - **Adaptive Management:** No management action has been identified at this time. However, once a threshold has been identified, the corresponding data would be reviewed and appropriate adaptive management action recommendations would be developed.
- **Fire Behavior (Conditional flame length, 8-foot flame length exceedance probability, fire perimeter overlays) (Indicator 11):** Monitoring of these metrics would help assess the ability of restoration treatments to meet strategic goals with respect to fire spread, risk to values on the landscape, firefighter safety, and controllability.
  - **Assessment:** FSim, FlamMap, and/or IFTDSS modeling.
  - **Frequency:** As soon as possible following treatment and every 5 years thereafter.
  - **Thresholds/Triggers:** No threshold has been identified for this indicator. It will be developed as new information becomes available.
  - **Adaptive Management:** No management action has been identified at this time. However, once a threshold has been identified, the corresponding data would be reviewed and appropriate adaptive management action recommendations would be developed.
- **Fire Size, Severity, and Risk ((Modeled and/or Observed) Histogram of Burn Severity, Total Acres of High Severity Fire, Patch Size Distribution of High Severity Fire) (Indicator 12):** As restoration progresses, the probability for large and uncharacteristically severe wildfires exhibiting rapid spread should decrease. This assessment may make use of information from the Monitoring Trends in Burn Severity (MTBS), Rapid Assessment of Vegetation Condition after Wildfire (RAVG), and/or FlamMap programs to assess how treatments affect size, spread, and severity of fires.
  - **Assessment:** Remote Sensing and Modeling (FlamMap, MTBS, RAVG).
  - **Frequency:** Available annually for all fires larger than 1,000 acres; as large enough (TBD) portions of HUC6 watersheds are treated.
  - **Thresholds/Triggers:** MTBS - Patch size of adjacent pixels expressing stand-replacing fires is greater than 50 acres after 5 years. Patch size of adjacent pixels expressing stand-replacing fires is greater than 10 acres after 10 years. FSim - Increase in size and probability of high-severity fire where ecologically inappropriate.
  - **Adaptive Management:** Evaluate the potential causes (e.g., number of acres treated, prescription type) and develop appropriate adaptive management action recommendations.
- **Surface Water Response to Precipitation Events (baseflow discharge, flow duration, total yield, precipitation/runoff response) (Indicator 29):** Monitoring of surface water flow should be focused on the surface water response to precipitation events. Consider paired-watershed study design. Measurement scale should match treatment scale.
  - **Assessment:** Field sampling, such as pressure transducers, within treated and control watersheds or before and after-treatment in the same watershed(s). Stage/discharge relationships.

- **Frequency:** Short term (1 to 5 years) and long term (10 to 30 years).
- **Thresholds/Triggers:** After accounting for climate and weather variability, significant decreases in baseflow or flow duration or total yield; significant increases in peak flows downstream of treatment areas.
- **Adaptive Management:** If increase in peak flow or decrease in baseflow or total yield, evaluate treatment methods, prescriptions, and design features and consider making adjustments or implementing additional design features.

- **Watershed Condition (integrative score based on several watershed condition indicators) (Indicator 36):** Watershed condition, as defined in the USDA FS Watershed Condition Framework (USDA 2011) is a nationally consistent reconnaissance-level approach for classifying watershed condition, using a comprehensive set of 12 indicators that are surrogate variables representing the underlying ecological, hydrological, and geomorphic function and processes that affect watershed condition. Nationally, watershed condition reassessment is done on a five-year cycle. However, scaling down the 12 indicators in the Framework to translate them into metrics that can be assessed in the field and compared to the previous watershed condition classifications could facilitate consistent monitoring of changes in watershed condition through time.
  - **Assessment:** Field sampling within treated and control watersheds or before and after treatment in the same watershed(s) based on the 12 indicators, or subset of indicators, in the Watershed Condition Framework.
  - **Frequency:** Medium-term response expected (5 to 15 years) post treatment.
  - **Thresholds/Triggers:** Sustained decrease (across repeated measurements) in any of the metric(s) or an overall decline in cumulative watershed condition score/health.
  - **Adaptive Management:** Evaluate source of decline and address through changes in actions. Consider adding mitigation measures or stabilization features.

Tier 2 Suggested Indicators: airshed function, fire return interval, soil and watershed function

- **Airshed Function (Air Quality) (Indicator 26):** There are air quality attainment goals for each geographical "airshed" under the jurisdictional authority of the ADEQ. Several measures could be used to qualitatively assess the contribution of prescribed burning activities toward the attainment of those ADEQ goals including: the percentage of the project area over which prescribed burns would reduce smoke generation from re-burning or wildfires over time, the percentage (by area) of prescribed fires conducted during high ventilation periods (May -September), modeled outputs of smoke from burned slash piles (tons/acre treated), modeled outputs of smoke from broadcast- or under-burns (tons/acre) and modeled output of smoke avoided from uncharacteristically severe wildfire (tons/acre)
  - **Assessment:** Model runs, ADEQ attainment or exceedance ranking.
  - **Frequency:** During prescribed and other burns.
  - **Thresholds/Triggers:** No threshold has been identified for this indicator. It will be developed as new information becomes available.
  - **Adaptive Management:** No management action has been identified at this time. However, once a threshold has been identified, the corresponding data will be reviewed and appropriate adaptive management action recommendations will be developed.

- **Fire Return Interval (Years since previously burned (planned and/or unplanned ignitions), FRI over decades) (Indicator 37):** When combined with cover type/s, Fire Return Interval (FRI) is a useful indicator for evaluating how far an area has departed from a characteristic fire regime. For Montane Ponderosa Pine forest types, the recent FRI is 38 years. This is almost double the desired maximum average for maintenance burning in ponderosa pine on the Mogollon Rim. The FRI is 59 years for Ponderosa Pine-Evergreen Oak, 65 years for dry mixed conifer, and 113 for grasslands in the project area. These FRIs represent an average that includes areas that have burned much more frequently and areas that have burned at a much longer frequency. These higher than desired fire return intervals have contributed to the degree of departure from historic conditions that puts over 51 percent of the area proposed for treatment area at risk of moderate- to high-severity fire effects based on recent severity proportions (Wahlberg et al. 2019).
    - **Assessment:** Spatial analysis of fire history (e.g., fire history layer, FACTS, WILDCAD), peer-reviewed fire history studies (sampled fire scars).
    - **Frequency:** Every 2 to 5 years.
    - **Thresholds/Triggers:** No threshold has been identified for this indicator. It will be developed as new information becomes available.
    - **Adaptive Management:** No management action has been identified at this time. However, once a threshold has been identified, the corresponding data would be reviewed and appropriate adaptive management action recommendations would be developed.
- **Soil and Watershed Function (Bulk density, infiltration rate, soil disturbance) (Indicator 13):** Highly and moderately erodible soils and slopes, which are classified within the Terrestrial Ecosystem Survey Units (TESU), may be susceptible to negative effects following treatment activities. While forest management activities and design features, BMPs, and conservation and mitigation measures are designed to avoid impacting these resources and areas, TESU maps can be overlain with management activity maps to identify areas for sampling to assess potential effects and post-treatment trends in soil condition. The Forest Service Soil Disturbance Monitoring Protocol (Page-Dumroese et al. 2009a and 2009b) is a useful qualitative method for evaluating soil impacts from operator actions and for guiding BMPs and mitigation, and it can be supported with additional quantitative measurements that can be used in statistical analyses of trends (DeLuca and Archer 2009).
    - **Assessment:** Remotely sensed data, TESU maps, field plots, Forest Service Soil Disturbance Monitoring Protocol (Page-Dumroese et al. 2009a and 2009b), Bulk density and infiltration capacity.
    - **Frequency:** As soon as possible following treatment and every 5 years thereafter, with more frequent follow -up in heavily impacted places to assess recovery.
    - **Thresholds/Triggers:**
        - Fine scale: Increasing bulk density trend and/or decreasing infiltration rate trend.
        - Broad scale: Soil disturbance is over 15 percent of the treated area.
- **Adaptive Management:** Evaluate treatment methods and/or BMPs and consider making adjustments or implementing additional mitigation measures.

Table E-3. Suggested Indicators: Forest Service and multiparty monitoring needed for adaptive management

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Methods and Sampling Techniques	Fine Scale or Broad Scale	Trigger (threshold indicating possible need for change)	Adaptive Management
1	1	Composition	Effects to Threatened or Endangered Species are within those disclosed in the biological assessment of the project.	As required in the U.S. Fish and Wildlife Service biological opinion and Southwestern Region MSO Management Strategy	See biological opinion	As directed in the relevant biological opinion	Broad Scale	As described in the project biological opinion	As required in the relevant U.S. Fish and Wildlife Service biological opinion and in ongoing coordination with U.S. Fish and Wildlife Service
2	1	Composition	Effects to Regional Forester-designated sensitive species/species of conservation concern are within those disclosed in the biological assessment for the project. See Indicator 19 for northern goshawk.	Draw from established protocols	Draw from established protocols	Draw from established protocols	Broad Scale	When indicator trends suggest a need for listing under the Endangered Species Act	As appropriate in consultation with Forest Service biologists and U.S. Fish and Wildlife Service

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Methods and Sampling Techniques	Fine Scale or Broad Scale	Trigger (threshold indicating possible need for change)	Adaptive Management
3	1	Composition	There is reduced potential for introduction, establishment, and spread of invasive species. Additionally, efforts are made to reduce existing infestations.	Invasive Plants	Species cover (“watch list” and “high-risk” species)	Field methods	Fine Scale	Identification of new or existing “watch list” or “high risk” invasive species populations	If inventories, surveys and map checks indicate presence of 'high risk' or 'watch list' species (see narrative), evaluate all design features, especially for cleaning equipment moving from infested sites to clean sites and management activities (including grazing and recreation) that may be a contributing factor. Consider aggressive treatments leading to population control or modifications of other management activities. If treatments do not reduce the cover of “watch list” species in treated populations by 90 percent in one year or “high risk” species by 50 percent in two years in treated populations, consider new approaches to control.
4	1	Composition	There is reduced potential for introduction, establishment, and spread of invasive species. Additionally, efforts are made to reduce existing infestations.	Invasive Plants	Species cover (“medium-risk” species)	Field methods	Fine Scale	Identification of new or existing “medium risk” invasive species populations	If inventories, surveys and map checks indicate presence of 'medium risk' species (see narrative), consider controlling these species on individual basis especially when high value areas or habitats are at risk. If treatments do not reduce the cover of “medium risk” species in treated populations by 20 percent in five years in treated populations, consider new approaches to weed management.

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Methods and Sampling Techniques	Fine Scale or Broad Scale	Trigger (threshold indicating possible need for change)	Adaptive Management
5	1	Composition	There is reduced potential for introduction, establishment, and spread of invasive species. Additionally, efforts are made to reduce existing infestations.	Invasive Plants	Species cover (Cheatgrass (*Bromus tectorum*))	Resource specialist assessment	Fine Scale	Identification of areas at high risk of cheatgrass introduction, spread, or dominance	Potential adaptive management measures are described in the narrative.
6	1	Structure & Pattern	Restore forest structure and pattern, forest health, and vegetation composition and diversity. Ponderosa pine ecosystems are heterogeneous in structure and spatial pattern, consistent with reference conditions, at the Initiative scale. Forest structure and density in dry mixed conifer are similar to ponderosa pine forest. Openings and densities vary within the analysis area to maintain a mosaic appropriate to support resilience of individual trees and groups of trees. (Many additional)	Patch Configuration	Nearest Neighbor Distance Distribution; Contagion; Diversity and Evenness Indices	Multiple tools, including some developed by the Remote Sensing and Application Center (RSAC) to process input images (NAIP, LiDAR, etc.) into canopy/ non canopy patches and assess for spatial pattern (Landscape Indices, FRAGSTATS) or field methods where appropriate	Fine and Broad Scale	No threshold has been identified for this indicator. It would be developed as new information becomes available.	No management action has been identified at this time. However, once a threshold has been identified, the corresponding data would be reviewed and appropriate adaptive management action recommendations would be developed.
7	1	Composition	Understory vegetation composition and abundance are consistent with the natural range of variability.	Diversity and Abundance (understory communities)	Substrate and plant functional group percent cover	Field collected – quadrats, point – line intercept	Fine Scale	Within 5 years of mechanical treatment, and accounting for subsequent fires, the total cover should increase 20 percent +/- 5 percent (15-25 percent) above pre-treatment	If this threshold is not reached, then re-evaluate treatment for management change, taking into account grazing, soils, and burn treatment, (e.g., reduce overstory basal area).

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Methods and Sampling Techniques	Fine Scale or Broad Scale	Trigger (threshold indicating possible need for change)	Adaptive Management
8	1	Composition	Understory vegetation composition and abundance are consistent with the natural range of variability.	Diversity and abundance (understory communities)	Percent bare soil within treatment areas	Field collected – quadrats, point-line intercept	Fine Scale	Within 5 years of treatment (mechanical and/or fire), less than 20 percent of area affected by treatment relative to starting conditions should be bare soil	If bare soil exceeds 20 percent of area within plots, re-evaluate restoration treatment for modifications, taking into account soils and burn treatment.
9	1	Structure & Pattern	Understory vegetation composition and abundance are consistent with the natural range of variability.	Regeneration	Density and species composition of seedlings, poles, and saplings and within treated sites	Field sampling of seedling and sapling density and species composition within treated sites	Fine Scale	Within 10 years of treatment, seedling and sapling density should be within 0.4 to 3.6 plants/ hectare/ decade on basalt soils (Mast et al. 1999). Starting conditions as measured by pre-treatment data collection should be considered in evaluating thresholds. No threshold has been identified for species composition of regeneration or for regeneration rates on limestone soils. These may be developed as new information becomes available.	If seedlings and saplings fall below the range above at broad scales where regeneration is a desired condition, then evaluate changes to increase probability of successful regeneration. If regeneration falls above this range, then more frequent and/or more intense prescribed burning or mechanical treatments may be necessary to reduce plant density. For species composition and regeneration rates on limestone soils, no management actions have been identified at this time. However, once thresholds have been identified, the corresponding data would be reviewed and appropriate adaptive management action recommendations would be developed.

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Methods and Sampling Techniques	Fine Scale or Broad Scale	Trigger (threshold indicating possible need for change)	Adaptive Management
10	1	Function & Process	Wildland fires burn within the range of frequency and intensity of natural fire regimes. There is low probability for uncharacteristically severe fire to spread at broad scales.	Fuel loading / hazard	Crown bulk density, crown base height, surface fuels	Field and Remote sensing	Fine and Broad Scale	No threshold has been identified for this indicator. It would be developed as new information becomes available.	No management action has been identified at this time. However, once a threshold has been identified, the corresponding data would be reviewed and appropriate adaptive management action recommendations would be developed.
11	1	Function & Process	Wildland fires burn within the range of frequency and intensity of natural fire regimes. There is low probability for uncharacteristically severe fire to spread at broad scales.	Fire Behavior	Conditional flame length, 8-foot flame length exceedance probability, fire perimeter overlays	FSim, FlamMap, and/or IFTDSS modeling	Broad Scale	No threshold has been identified for this indicator. It will be developed as new information becomes available.	No management action has been identified at this time. However, once a threshold has been identified, the corresponding data would be reviewed and appropriate adaptive management action recommendations would be developed.
12	1	Function & Process	Wildland fires burn within the range of frequency and intensity of natural fire regimes. There is low probability for uncharacteristically severe fire to spread at broad scales.	Fire size, severity, and risk	(Modeled and/or observed) histogram of burn severity; total acres of high severity fire; patch size distribution of high severity fire	Remote Sensing and Modeling (FlamMap, MTBS, RAVG)	Broad Scale	MTBS - Patch size of adjacent pixels expressing stand-replacing fires is greater than 50 acres after 5 years. Patch size of adjacent pixels expressing stand-replacing fires is greater than 10 acres after 10 years. FSim - Increase in size and probability of high-severity fire where ecologically inappropriate.	Evaluate the potential causes (e.g., number of acres treated, prescription type) and develop appropriate adaptive management action recommendations.

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Methods and Sampling Techniques	Fine Scale or Broad Scale	Trigger (threshold indicating possible need for change)	Adaptive Management
13	2	Function & Process	Soil productivity and functions are sustained and functioning properly within the capability of the site, so the soil has the ability to resist erosion, infiltrate water and recycle nutrients. Coarse woody debris, including downed logs, provides for long-term soil productivity. Soil productivity and functions contribute to the resiliency and adaptability of terrestrial and riparian ecosystems to climate change.	Soil and Watershed Function	Bulk density, infiltration rate, soil disturbance	Remotely sensed data, TESU maps, field plots, Forest Service Soil Disturbance Monitoring Protocol (Page-Dumroese et al. 2009a and 2009b), Bulk density and infiltration capacity	Fine and Broad Scale	Fine Scale: Increasing bulk density trend. Decreasing infiltration rate trend. Broad Scale: Soil disturbance is > 15 percent of the treated area.	Evaluate treatment methods and/or BMPs, and consider making adjustments or implementing additional mitigation measures
14	2	Function & Process	Soil productivity and functions are sustained and functioning properly within the capability of the site, so the soil has the ability to resist erosion, infiltrate water and recycle nutrients. Coarse woody debris, including downed logs, provides for long-term soil productivity. Soil productivity and functions contribute to the resiliency and adaptability of terrestrial and riparian ecosystems to climate change.	Soils	Soil chemistry/ productivity	Test carbon- to-nitrogen ratios from soil samples collected according to a statistical design.	Fine Scale	C:N ratios increasing from 12-14 toward 30, indicating a reduction in nitrogen availability that would impact plant productivity	Evaluate treatment methods and consider changes in treatment methods and target forest patterns.

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Methods and Sampling Techniques	Fine Scale or Broad Scale	Trigger (threshold indicating possible need for change)	Adaptive Management
15	2	Structure & Pattern	Forest openings are designed to improve snow accumulation and subsequent soil moisture and surface water yield.	Soils and snowpack	Soil moisture and snowpack depth, density, and persistence.	Soil moisture sensors, time domain reflectometer and gravimetric analysis, snow telemetry monitoring, snow surveys, remote sensing	Broad Scale	Trends of decreasing soil moisture or snowpack depth and persistence (after adjusting for climatic variability) in stands with similar treatment types and/or physiographic characteristics.	Evaluate treatments and make adjustments in treatment methods and forest pattern as appropriate, especially at lower elevations, on south facing slopes and on shallow soils that are susceptible to drying.
16	1	Structure & Pattern	Ponderosa pine ecosystems are heterogeneous in structure and spatial pattern at the Initiative scale. Openings and densities vary within the analysis area to maintain a mosaic appropriate to support resilience of individual trees and groups of trees. Frequent fire ecosystems provide the necessary composition, structure, abundance, distribution and process that contribute to the diversity of native plant and animal species across the 2.4-million-acre 4FRI landscape. Forest structure and density in dry mixed conifer are similar to ponderosa pine forest.	Fine: Opening patch size, pre- and post-treatment Broad: Patch (canopy and opening) metric assessment for heterogeneity metrics such as Getis-Ord Gi* or Edge-to-Area ratio, Canopy Openness	Percent Canopy cover and percent opening (together = 100%); Patch metrics (including size minimum/maximum/ median/range) for both canopy and openings	Multiple tools, including some developed by the Remote Sensing and Application Center (RSAC) to process input images (NAIP, LiDAR, etc.) into canopy/ non canopy patches and assess for spatial pattern (Landscape Indices, FRAGSTATS) or field methods where appropriate.	Fine and Broad Scale	No threshold has been identified for this indicator. It would be developed as new information becomes available.	No management action has been identified at this time. However, once a threshold has been identified, the corresponding data would be reviewed and appropriate adaptive management action recommendations would be developed.

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Methods and Sampling Techniques	Fine Scale or Broad Scale	Trigger (threshold indicating possible need for change)	Adaptive Management
17	1	Composition	Viable, ecologically functional populations of native species that include common, listed, rare, and sensitive species persist in natural patterns of distribution and abundance.	Diversity (wildlife communities)	Songbird species occupancy, richness, and diversity: closed canopy species considering vegetation type, elevation, and topography	Field (coordinated songbird surveys, fine-scale vegetation surveys), Remote-sensing, Modeling, Statistics	Fine and Broad Scale	Fine Scale- TBD, metrics for indicator species Broad Scale- Any decline (trend that does not include zero) with species richness and diversity (community/ guilds) accounting for non-management activities over a TBD period	Fine Scale- TBD Broad Scale- Evaluate opportunities to increase closed canopy, decrease edge, increase patches
18	1	Composition	Viable, ecologically functional populations of native species that include common, listed, rare, and sensitive species persist in natural patterns of distribution and abundance.	Diversity (wildlife communities)	Songbird species occupancy, richness, and diversity: open canopy species considering vegetation type, elevation, and topography	Field (coordinated songbird surveys, fine-scale vegetation surveys), Remote-sensing, Modeling, Statistics	Fine and Broad Scale	Fine Scale- TBD, metrics for indicator species Broad Scale- Any decline (trend that does not include zero) with species richness and diversity (community/ guilds) accounting for non-management activities over a TBD period	No management action has been identified at this time.

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Methods and Sampling Techniques	Fine Scale or Broad Scale	Trigger (threshold indicating possible need for change)	Adaptive Management
19	2	Composition	Viable, ecologically functional populations of native species that include common, listed, rare, and sensitive species persist in natural patterns of distribution and abundance.	Northern goshawk	Occupancy	Forest Service protocols (Joy et al. 1994) as modified by Forest Service survey guidance (USDA FS 2017) or as appropriate based on approved methods.	Broad Scale	If northern goshawk occupancy trends show a non-zero decline (occupancy trend confidence interval or credible interval does not overlap zero) over a 5- to 10-year average at treatment and 4FRI landscape scales.	Evaluate treatments and consider increasing or focusing monitoring on area where northern goshawk is declining. Consider comparing to regional monitoring data trends. As a high-profile species, additional monitoring may be conducted even if the decline is not a statistically significant
20	1	Structure & Pattern	Viable, ecologically functional populations of native species that include common, listed, rare, and sensitive species persist in natural patterns of distribution and abundance.	Landscape connectivity and permeability	Changes in landscape connectivity and permeability for migrating closed canopy species (e.g., black bear, gray fox)	Modelling and field sampling (hair traps, collars) in conjunction with remote sensing	Broad Scale	A 20% or greater decrease in modeled connectivity in known migration pathways	Evaluate implementing changes such as increasing group sizes or decreasing treatment intensity within known pathways
21	1	Structure & Pattern	Viable, ecologically functional populations of native species that include common, listed, rare, and sensitive species persist in natural patterns of distribution and abundance.	Landscape connectivity and permeability	Changes in landscape connectivity and permeability: pronghorn	Modelling in conjunction with remote sensing	Broad Scale	A 5% or greater decrease in modeled omnidirectional connectivity and least cost pathways for pronghorn (using same techniques and area as pre-treatment model)	Evaluate implementing changes such as increasing opening sizes, increasing treatment intensity within known pathways, or identifying key locations for treatment for connectivity

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Methods and Sampling Techniques	Fine Scale or Broad Scale	Trigger (threshold indicating possible need for change)	Adaptive Management
22	1	Structure & Pattern	Ponderosa pine and mixed conifer ecosystems are composed of all age and size classes within the Initiative area and are distributed in patterns consistent with reference conditions.	Diameter Distributions	Tree diameters, density	Field Methods	Fine Scale	No threshold determined for this indicator. Also see the Large Tree Implementation Plan in Appendix D (implementation plan), which specifies specific conditions under which large young trees may be cut	Evaluate reasoning for implementing large tree removal. If needed, appropriate adaptive management action recommendations would be developed.
23	2	Composition	Ponderosa pine and mixed conifer ecosystems are composed of all age and size classes within the Initiative area and are distributed in patterns consistent with reference conditions.	Old Trees	Old tree density, conditions	Rapid assessment conducted while collecting diameter distribution data on plots (or use of aerial imagery once techniques become available) or other evidence	Fine Scale	Any loss old tree that is cut outside of those identified as allowed in the Old Tree Implementation Plan	No management action has been identified at this time. However, when an old tree is cut, the cause or rationale would be reviewed by the Monitoring Board
24	2	Function & Process	Forest insects and pathogens occur and operate at endemic levels.	Insects and Pathogens	Bark beetle rating, dwarf mistletoe rating, number of trees affected by pests, acres of mortality	Field and remote sensing methods, including FS aerial detection surveys	Fine and Broad Scale	No threshold has been identified for this indicator. It would be developed as new information becomes available.	No management action has been identified at this time. However, once a threshold has been identified, the corresponding data would be reviewed and appropriate adaptive management action recommendations would be developed.

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Methods and Sampling Techniques	Fine Scale or Broad Scale	Trigger (threshold indicating possible need for change)	Adaptive Management
25	2	Composition	Rare and ecologically valuable springs, wet meadows, and other riparian areas are protected and enhanced through appropriate restoration treatments where needed. Oak and Aspen stands are maintained and enhanced across the landscape.	Rare Ecosystem Elements	Percent cover of oak, aspen, and riparian areas	Plot-based and/or remotely sensed (e.g., LiDAR, UAS-based) assessment of percent cover	Fine Scale	No threshold has been identified for this indicator. It would be developed as new information becomes available.	No management action has been identified at this time. However, once a threshold has been identified, the corresponding data would be reviewed and appropriate adaptive management action recommendations would be developed.
26	2	Function & Process	Vegetation within the analysis area is managed strategically and at a level appropriate to prevent degradation of air quality beyond regulatory standards (through wildland fire)	Air Quality	Smoke output	Model runs, ADEQ attainment or exceedance ranking	Broad Scale	No threshold has been identified for this indicator. It would be developed as new information becomes available.	No management action has been identified at this time. However, once a threshold has been identified, the corresponding data would be reviewed and appropriate adaptive management action recommendations would be developed
27	2	Composition	Ponderosa pine and mixed conifer ecosystems are composed of all age and size classes within the Initiative area and are distributed in patterns consistent with reference conditions.	Snags	Number, size distribution, and condition of snags	Plot-based rapid assessment and/or remotely sensed (e.g., LiDAR, UAS-based) quantification of numbers and sizes of snags	Fine Scale and broad scale	No threshold has been identified for this indicator. It would be developed as new information becomes available.	No management action has been identified at this time. However, once a threshold has been identified, the corresponding data would be reviewed and appropriate adaptive management action recommendations would be developed.
28	2	Function & Process	Ponderosa pine and mixed conifer ecosystems are composed of all age and size classes within the Initiative area and are distributed in patterns consistent with the natural range of variability.	Tree Mortality	Canopy Cover, Number of Pathogen-affected Patches, Size of Mortality Patches, and Percent of Landscape in Mortality Patches	NFHM assessment and NAIP imagery	Fine and Broad Scale	No threshold has been identified for this indicator. It would be developed as new information becomes available.	No management action has been identified at this time. However, once a threshold has been identified, the corresponding data would be reviewed and appropriate adaptive management action recommendations would be developed.

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Methods and Sampling Techniques	Fine Scale or Broad Scale	Trigger (threshold indicating possible need for change)	Adaptive Management
29	1	Function & Process	Watersheds, riparian areas, and aquatic ecosystems have functional soil, vegetation, morphology, and flow regimes, consistent with site and watershed potential. These systems provide diverse habitats for an array of native obligate and facultative plants and animal species.	Surface water in response to precipitation events	Baseflow discharge, flow duration, total yield, precipitation/runoff response	Pressure transducers, within treated and control watersheds or before and after-treatment in the same watershed(s). Stage/ discharge relationships Consider paired-watershed study design.	Broad Scale	After accounting for climate and weather variability, significant decreases in baseflow or flow duration or total yield; significant increases in peak flows downstream of treatment areas	If increase in peak flow or decrease in baseflow or total yield, evaluate treatment methods, prescriptions and design features and consider making adjustments or implementing additional design features.
30	1	Function & Process	Watersheds, riparian areas, and aquatic ecosystems have functional soil, vegetation, morphology, and flow regimes, consistent with site and watershed potential. These systems provide diverse habitats for an array of native obligate and facultative plants and animal species.	Groundwater response	Depth to groundwater, baseflow, riparian soil moisture, spring/seep flow	Pressure transducers or other flow rate measurements, soil moisture probes	Fine and Broad Scale	Decreases in subsurface water volume, spring/seep flow, riparian soil moisture after accounting for non-treatment factors such as climate variability.	If decrease or no change in subsurface water, evaluate treatment methods and consider changing treatment intensity. If increase in subsurface water, consider replicating treatment methods elsewhere.

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Methods and Sampling Techniques	Fine Scale or Broad Scale	Trigger (threshold indicating possible need for change)	Adaptive Management
31	1	Structure & Pattern	Watersheds, riparian areas, and aquatic ecosystems have functional soil, vegetation, morphology, and flow regimes, consistent with site and watershed potential. These systems provide diverse habitats for an array of native obligate and facultative plants and animal species.	Aquatic habitat suitability; water quality, persistence and habitat structure for native fish, invertebrates	Draw from existing protocols (see narrative above for examples). Possible metrics include: Water quality/temperature, sediment loads, EPT, channel stability, channel shading, underbank cover, overbank cover, course woody debris, depth of pools, persistence of water in deep pools, substrate embeddedness, hydraulic habitat diversity, macroinvertebrate species assemblage and abundance.	Many field methods/ indices exist such as: Functional Condition of Stream-Riparian Ecosystems in the American Southwest and AGFD Native Stocking Habitat Assessment	Fine Scale	Decreases in habitat suitability indices after accounting for non-treatment factors such as climate variability or wildfire.	Evaluate source of degradation and address through changes in actions. Look for possible changes in watershed function after timber harvest and fire. Consider adding mitigation measures or structural improvements to stream.
32	1	Structure & Pattern	Watersheds, riparian areas, and aquatic ecosystems have functional soil, vegetation, morphology, and flow regimes, consistent with site and watershed potential. These systems provide diverse habitats for an array of native obligate and facultative plants and animal species.	Stream morphology	Draw from existing protocols. Possible metrics include channel stability, floodplain and riparian connectivity, channel roughness, presence of meanders, bank stability.	Many field methods exist such as: Rapid Assessment of the Functional Condition of Stream-Riparian Ecosystems in the American Southwest. Remote methods (e.g., UAS/drones)	Fine Scale	Degradation in condition of channel morphology/indices after accounting for non-treatment factors such as climate variability.	Evaluate source of degradation and address through changes in actions. Consider adding mitigation measures or structural improvements to riparian zone.

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Methods and Sampling Techniques	Fine Scale or Broad Scale	Trigger (threshold indicating possible need for change)	Adaptive Management
33	1	Composition	Watersheds, riparian areas, and aquatic ecosystems have functional soil, vegetation, morphology, and flow regimes, consistent with site and watershed potential. These systems provide diverse habitats for an array of native obligate and facultative plants and animal species.	Native obligate riparian plant species	Draw from existing protocols. Possible metrics include native riparian plant diversity, extent, cover, structural complexity, vigor, demography, recruitment, survival, etc.	Draw from existing protocols such as the BLM Multiple Indicator Monitoring (MIM) of Stream Channels and Streamside Vegetation (Burton et al. 2011). Possible metrics include native riparian plant diversity, extent, cover, structural complexity, vigor, demography, recruitment, survival.	Fine Scale	Decrease in extent, cover, diversity, recruitment, or survival of native riparian vegetation after accounting for non-treatment factors such as climate variability.	Evaluate source of decline and address through changes in actions. Consider adding mitigation measures or structural improvements to encourage establishment and retention of native riparian obligate species.
34	2	Composition	Watersheds, riparian areas, and aquatic ecosystems have functional soil, vegetation, morphology, and flow regimes, consistent with site and watershed potential. These systems provide diverse habitats for an array of native obligate and facultative plants and animal species.	Native obligate riparian animal species such as tiger salamanders, leopard frogs, terrestrial gartersnakes, white-nosed coatis, common black hawks, song sparrows, warbling vireos, and yellow warblers	Draw from existing protocol. Possible metrics include species presence, abundance, or diversity, modeled population size, etc.	Draw from existing protocol. Possible metrics include species presence or abundance, species diversity, modeled population size, etc.	Fine Scale	Decrease in species presence or abundance, diversity, or modeled population size after accounting for non-treatment factors such as climate variability	Evaluate source of decline and address through changes in actions. Consider adding mitigation measures or structural habitat improvements.

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Methods and Sampling Techniques	Fine Scale or Broad Scale	Trigger (threshold indicating possible need for change)	Adaptive Management
35	2	Structure & Pattern	Watersheds, riparian areas, and aquatic ecosystems have functional soil, vegetation, morphology, and flow regimes, consistent with site and watershed potential. These systems provide diverse habitats for an array of native obligate and facultative plants and animal species.	Riparian soil condition	Draw from existing protocol. Possible metrics include water-holding capacity, bulk density, soil aggradation/ erosion rates, rainfall/ runoff response directly above and downstream of focal area.	Consult soil scientists.	Fine Scale	Decrease in water-holding capacity or increases in bulk density; increase in erosion rates after accounting for non-treatment factors such as climate variability.	Evaluate source of decline and address through changes in actions. Consider adding mitigation measures or stabilization features.
36	1	Function & Process	Watersheds are properly functioning consistent with site and watershed potential.	Watershed condition	12 metrics as outlined in Watershed Condition Framework 1. Water Quality 2. Water Quantity 3. Aquatic Habitat 4. Aquatic Biota 5. Riparian/ Wetland Vegetation 6. Roads and Trails 7. Soils 8. Fire Regime or Wildfire 9. Forest Cover 10. Rangeland Vegetation 11. Terrestrial Invasive Species 12. Forest Health	This is an integrative measure. Data collected for questions 33-39 can be combined for this indicator. Forest Service watershed condition framework. https://www.fs.fed.us/biology/resources/pubs/watershed/maps/watershed_classification_guide2011FS978.pdf. Existing data exists for all 5th codes	Broad scale (6th code watershed)	Sustained decrease (across repeated measurements) in any of the metric(s) or an overall decline in cumulative watershed condition score/health	Evaluate source of decline and address through changes in actions. Consider adding mitigation measures or stabilization features.

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Methods and Sampling Techniques	Fine Scale or Broad Scale	Trigger (threshold indicating possible need for change)	Adaptive Management
37	2	Function & Process	Fire return intervals are consistent with the natural range of variability for the target vegetation type	Fire return interval (FRI)	Years since previously burned (planned and/or unplanned ignitions), FRI over decades	Spatial analysis of fire history (e.g., fire history layer, FACTS, WILDCAD), peer-reviewed fire history studies (sampled fire scars)	Broad	No threshold has been identified for this indicator. It would be developed as new information becomes available.	No management action has been identified at this time. However, once a threshold has been identified, the corresponding data would be reviewed and appropriate adaptive management action recommendations would be developed.
38	1	Structure & Pattern	Restore forest structure and pattern, forest health, and vegetation composition and diversity. Ponderosa pine ecosystems are heterogeneous in structure and spatial pattern, consistent with reference conditions, at the Initiative scale. Forest structure and density in dry mixed conifer are similar to ponderosa pine forest. Openings and densities vary within the analysis area to maintain a mosaic appropriate to support resilience of individual trees and groups of trees. (Many additional)	Patch Size	Patch area (including minimum/maximum/ median/range, density, distribution)	Multiple tools, including some developed by the Remote Sensing and Application Center (RSAC) to process input images (NAIP, LiDAR, etc.) into canopy/ non canopy patches and assess for spatial pattern (Landscape Indices, FRAGSTATS) or field methods where appropriate	Fine and Broad Scale	No threshold has been identified for this indicator. It would be developed as new information becomes available.	No management action has been identified at this time. However, once a threshold has been identified, the corresponding data would be reviewed and appropriate adaptive management action recommendations would be developed.

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Methods and Sampling Techniques	Fine Scale or Broad Scale	Trigger (threshold indicating possible need for change)	Adaptive Management
39	1	Structure & Pattern	Restore forest structure and pattern, forest health, and vegetation composition and diversity. Ponderosa pine ecosystems are heterogeneous in structure and spatial pattern, consistent with reference conditions, at the Initiative scale. Forest structure and density in dry mixed conifer are similar to ponderosa pine forest. Openings and densities vary within the analysis area to maintain a mosaic appropriate to support resilience of individual trees and groups of trees. (Many additional)	Patch Spatial Aggregation	Spatial Aggregation metrics (e.g., Getis-Ord Gi* or Edge-to-Area ratio, Ripley's K)	Multiple tools, including some developed by the Remote Sensing and Application Center (RSAC) to process input images (NAIP, LiDAR, etc.) into canopy/ non canopy patches and assess for spatial pattern (Landscape Indices, FRAGSTATS) or field methods where appropriate	Fine and Broad Scale	No threshold has been identified for this indicator. It would be developed as new information becomes available.	No management action has been identified at this time. However, once a threshold has been identified, the corresponding data would be reviewed and appropriate adaptive management action recommendations would be developed.

Socioeconomic Monitoring

Introduction and Background

Preparation and tracking of both the social and economic impacts of the Four Forest Restoration Initiative (4FRI) project is paramount to the success of the project. Social awareness, knowledge and support coupled with economic viability, such as a prepared workforce, adequate infrastructure, and reliable wood supplies, are critical factors that would be primary drivers of the project's progression. Typically, social and economic monitoring has not been a priority and was identified as one of the five major challenges by the Rural Voice for Conservation Coalition's (RVCC) Issue Paper (2011) in stating, "There is insufficient monitoring of the social and economic impacts of land management" and they further stressed this as a key recommendation for the Forest Service. Robbins and Daniels (2011) affirm this by reiterating, "…that the socioeconomic aspects of restoration are 'underemphasized, or often ignored all together'" (Aronson et al. 2010). Thus, ensuring integration of ecological, social and economic impacts would augment effective management actions that would address multiple criteria necessary for community health and sustainability.

As the monitoring frameworks were conceptualized, beginning with a broad vision for both social and economic factors affected by restoration can be drawn from the 4FRI Stakeholder Group's foundational documents, such as the Path Forward (4FRI Stakeholder Group 2010a). Within the Path Forward, the importance of integrating monitoring that includes ecological, social and economic impacts was raised in stating, "Landscape-scale restoration efforts should adopt and make full use of rigorous science, including research, monitoring, and adaptive management that enhances our understanding about their ecological, social, and economic implications" (4FRI Stakeholder Group 2010a).

Purpose and Application

The purpose of this report is to provide a framework to guide socioeconomic monitoring of the Four Forest Restoration Initiative (4FRI), which includes the Rim Country project. Both the 4FRI Multiparty Monitoring Board (MPMB) and the Forest Service contribute to monitoring the socioeconomic aspects of the project. From 2010 through 2019 the 4FRI was funded, in part, through a fund established by the Omnibus Land Management Act of 2009, Title IV-Forest Landscape Restoration (Pub. L. 111-11). The 4FRI socioeconomic monitoring process is geared toward the purpose of the Act:

The purpose of this title is to encourage the collaborative, science-based ecosystem restoration of priority forest landscapes through a process that:

1. Encourages ecological, economic, and social sustainability;
2. Leverages local resources with national and private resources;
3. Facilitates the reduction of wildfire management costs, including through reestablishing natural fire regimes and reducing the risk of uncharacteristically severe wildfire; and
4. Demonstrates the degree to which--
    a. various ecological restoration techniques--
        i. achieve ecological and watershed health objectives; and
        ii. affect wildfire activity and management costs; and

b. the use of forest restoration byproducts can offset treatment costs while benefitting local rural economies and improving forest health.

The monitoring objectives identified in this report overlap with many of the key social and economic issues analyzed by the Forest Service in the "Environmental Consequences" section of the Rim Country EIS. In the EIS, the Forest Service assessed the social and economic elements of 4FRI implementation. This analysis included the Apache-Sitgreaves, Coconino, and Tonto National Forests and associated counties.

There are two main components to the Forest Service social and economic analysis that include: (1) the affected environment description and, (2) the assessment of environmental consequences. The Forest Service analysis of the social and economic affected environment description in the EIS considers population growth, wildfire suppression costs, forest products industry employment, and socioeconomic vulnerability and environmental justice concerns (e.g., the distribution of minority and low-income populations in the study area and their relationship to the Forest lands). This incorporated an assessment of employment and income contributions resulting from the implementation of 4FRI phase one (Hjerpe and Mottek Lucas 2018), using primary employment data collected in Federal fiscal year 2017, which included surveys of all 4FRI wood utilization contractors, and a discussion of how these results deviated from original projections.

The Forest Service environmental consequences analysis estimates present both quantitative and qualitative assessments to describe how Rim Country implementation activities would affect ecosystem services (such as, recreation and livestock grazing), vulnerable and environmental justice communities, forest product production and employment and income in the study area. Input-output analysis using IMPLAN (http://www.implan.com) estimates the employment and income effects of the Rim Country project. Non-market values of ecosystem services would be measured chiefly through ecological indicators provided by other Forest Service specialists in their analysis (e.g., effects on habitat, water quality, soil quality, etc.). The economic efficiency of Rim Country implementation would also be analyzed by the Forest Service by using data on Federal and private expenditures and the projected benefits of ecological restoration.

To supplement the Forest Service socioeconomic monitoring data and analyses, the 4FRI Multi-Party Monitoring Board may utilize the information contained in this section to complete both social and economic monitoring of the 4FRI. Although this plan contains an extensive list of objectives that could be monitored, specific monitoring questions and indicators may be prioritized based on the Multi-Party Monitoring Board's priorities and the information gaps in the Forest Service-required socioeconomic monitoring. To assure the Initiative's success and longevity, it is recommended that socioeconomic monitoring be conducted before project implementation and that there is immediate and ongoing execution within approximately the first five years of project implementation (Personal Communication, Nielsen 2011). Once socioeconomic monitoring data verify that the 4FRI project is socially and economically on track, the need to conduct this type of monitoring would decrease and the priority socioeconomic indicators can be monitored less frequently to focus on longitudinal changes as project implementation progresses.

The purpose of the joint effort of the Multi-Party Monitoring Board and the Forest Service monitoring process is to assess the accuracy of Forest Service estimates and provide data for adaptive management. In this way, the information provided by the Forest Service in the EIS, coupled with this monitoring framework, are linked to support a thorough and on-going assessment of social and economic conditions in the study area.

Methodology in Developing Social and Economic Monitoring Framework

The 4FRI Science and Monitoring Working Group, which was later succeeded by the Multi-Party Monitoring Board, developed both social and economic monitoring frameworks to assess relevant socioeconomic factors that will determine these effects in planning, implementation and adaptive management of the 4FRI project. Relative to other land management activities, monitoring issues that need to be addressed within ecological restoration projects are broader and should encompass objectives that affect the widest variety of stakeholders (Egan and Estrada-Bustillo 2011; Fulé 2003). As a starting point, social and economic desired conditions from the Landscape Restoration Strategy for the First Analysis Area (landscape restoration strategy) (4FRI Stakeholder Group 2010b) were compiled from the report (appendix A). Additional economic desired conditions were extrapolated from appendix A of the landscape restoration strategy report. Within the landscape restoration strategy report, both economic and social desired conditions were defined within three spatial scales that include landscape, analysis area and firescape. These spatial scales are more applicable to biophysical conditions; therefore, for the purpose of developing this monitoring framework, the socioeconomic desired conditions were not delineated by these spatial scales. At times, the original sets of desired conditions were either repeated within each scale or they were not applicable as a socioeconomic desired condition for monitoring.

Once the final set of desired conditions, or broad goals, were determined, firm, measurable monitoring objectives (Sundstrom et al. 2011) were developed through broad and extensive stakeholder input. As objectives were developed, considerations were based on those that the stakeholder group and/or the Forest Service have the ability to influence and adapt (Sundstrom et al. 2011).

Monitoring questions were matched to the objectives to ensure that the questions addressed essential information that is needed to measure the stated objectives. Indicator selection was based on attributes that can be easily measured, are precise, and concisely describe current conditions (Moote 2011) as well as those that are sensitive to changes overtime (Moote 2011; Egan and Estrada-Bustillo 2011). In addition, indicators that can satisfy multiple objectives should be recognized to assist in the efficacy of the monitoring process (Derr et al. 2005). The methods used to evaluate the selected indicators are described in the “Toolbox” section of this report. Once the appropriate assessment(s) were delineated, the recommended frequencies of the assessments, how often the monitoring data and analyses are completed, were matched to the assessment. Lastly, data sources, whether primary or secondary, were delineated to retrieve the necessary data to answer the questions. It is important to note that these frameworks should be viewed as a “continuing, inclusive and evolutionary process” (A. Egan Personal Communication 2011) that is malleable and adaptive over time.

Consideration of temporal and spatial scales is critical to the monitoring process and effects should be addressed at micro and macro levels as well as in the short- and long-term. For example, results from project-level monitoring would provide necessary information to assess a variety of programmatic (cumulative) monitoring objectives/questions that can be tracked over time (Sundstrom et al. 2011).

The social and economic framework matrices included in this report are not exhaustive; however, provide a basis for framing a 4FRI social and/or economic monitoring project. For example, there may be several monitoring questions for a specific objective; however, the associated monitoring questions may not be relevant and/or appropriated funding will only support answering one of the monitoring questions. Similarly, there is a fairly comprehensive list of indicators; however, not all will be measured for a respective monitoring project. In the end, the purpose of the study, the constituency requesting the information, how the information will be used, and available funding will ultimately dictate a specific methodology of the monitoring project.

Due to the groundbreaking nature of the landscape scale 4FRI project and the unpredictability of the results, the "If Statements" or triggers for adaptive management, are described as "Undesirable Conditions" (Personal Communication, T. Cheng 2011). The "Undesirable Conditions" have been initially expressed as broad qualitative statements that will delineate trends. As socioeconomic monitoring projects are completed, and baseline information is established, these triggers can be adjusted to more specific acceptable quantitative ranges that will indicate whether adaptive management is necessary for each specific objective/question that is being assessed. Similarly, awarded contracts and contractor business plans can inform the development of economic triggers and assessments can be designed to determine whether implementation is in line with contractors' business plans.

In most cases, when socioeconomic studies are conducted, several monitoring questions can be addressed simultaneously, thus increasing the efficiency of the monitoring project. For example, a mail survey to residents in the first analysis area can provide necessary data for multiple monitoring questions. Similarly, as economic studies are planned and conducted, contractor surveys can track several indicators and these data can be used for multiple monitoring requirements.

Program Evaluation

As monitoring protocols are established and implemented for the 4FRI project, program evaluation can be used as an appropriate social science methodology. Program evaluation is a set of "systematic procedures used in seeking facts or principles" so that theoretical positions can be tested (Royse et al. 2010). Program evaluation follows a simple research design procedure that includes four main steps: 1. formulate a problem or question, 2. develop a research design for data collection efforts, 3. collect data, and 4. analyze the data (Royse et al. 2010). Although this design is similar to a traditional research design, the underlying distinction is based on the results. In most instances, in a research design, results can be generalized to a broader population, while results from a program evaluation may only be applicable to the specific project or multiple projects that have distinct similarities. Moreover, program evaluation is designed to facilitate a "structured comparison" so that conclusions have a type of relative valuation (Royse 2010).

Ideally monitoring should be conducted before and after implementation so that pre- and post-measurements can be compared. Due to the ongoing and malleable nature of monitoring, a process evaluation can be conducted throughout the life of the project that provides a program's description, a program's monitoring protocol and quality assurance measures (Royse et al. 2010). Due to the nature of process evaluation, operations are documented and will provide the necessary information to replicate or convey the technology of a specific project. Process evaluations are typically used for research and demonstration projects as they provide information that will inform what was learned during project implementation (Royse et al 2010).

To take this one step further, a program logic model developed by the W. K. Kellogg Foundation (2004) supports this application whereas evaluations are seen as adaptive, applying mid-course adjustments as needed, while at the same time, documenting its successes (W.K. Kellogg Foundation 2004). This evaluative approach also encourages a broad participatory base of all involved stakeholders, from developing the question to analyzing the data. The logic model does not just focus on the outcome but explains what you are doing, the expected results and a series of outcomes from immediate to long-term

(W.K. Kellogg Foundation 2004). Moreover, this model helps to identify whether the project is on-track and emphasizes learning as an ongoing process - an integral part of the evaluation.

Institutional Review Board (IRB)

When collecting information on human subjects, an Institutional Review Board (IRB) should complete a review of the proposed project. As subjects participate in research projects, he/she should be informed that their participation is voluntary and all of their answers are confidential and reported as an aggregate, or as a group response. If research is conducted remotely, through the telephone or the Internet, informed consent is completed verbally or in a screen that is read by the respondent. If participants are interviewed face-to-face, participants should sign consent forms before the interview/focus groups begin. The consent and reviews protect the rights of human subjects when used in research and prevent unethical treatment during the process (Northern Arizona University 2021).

Tool Box for Assessment

Scale – Sampling Frame

As the purpose of socioeconomic studies is conceptualized, and objectives/questions are designed to study a specific population ("local"), a concise, self-determined definition is necessary to pinpoint the sampling frame, or scale, of the population under study (Sundstrom et al. 2011). Since this definition is dependent on the purpose of the study and, ultimately how the information will be used, it could vary considerably from study to study. The definition of the study's population, or the sampling frame, should reflect one or more factors that include geographic (natural, physical), administrative, social, and/or economic boundaries/conditions that are adequately representative of the location, political and/or public service jurisdictions, group of people or economic factors (Environmental Protection Agency 2002).

Study Design

Both social and economic monitoring should begin with an assessment of current conditions by establishing baseline data before project implementation and/or education and outreach programs or events. Once a baseline is established, proceeding data collection should occur after major interventions to assess the change from the baseline to post-intervention and continue to assess changes longitudinally to track them over time. Depending on the selected social or economic analysis, accounting for specific issues and concerns within the population or the designated area of the study (e.g., community, city, county, EIS Analysis Area, etc.) should be considered and integrated in the study design (Egan and Estrada-Bustillo 2011). In addition, the study's design will be dependent on the goals of the study, the constituency, or who is requesting the monitoring results, and ultimately, how the monitoring information will be used. Ideally, socioeconomic monitoring should be a priority and should be implemented immediately and tracked for the first five years to assure the project's success (Personal Communication, Nielsen 2011).

The type of study that is initiated will dictate whether the purpose of the study is exploratory, descriptive or explanatory. Exploratory studies are typically conducted when researchers are breaking new ground, want to better understand the issue at hand, test the feasibility of developing a more extensive study and/or develop methods to employ in a subsequent study (Babbie 2010). Descriptive research is precise reporting or measurements and answers the what, when, how and where questions, and explanatory research reports relationships among the area of study and answers the question, why (Babbie 2010). In general, as socioeconomic research designs are conceptualized, more than one study type will be integrated in its design.

To illustrate utilizing multiple study types in assessing social systems affected by the 4FRI project, understanding the general publics' perceptions will most likely take two types of research to adequately answer the monitoring questions. First, an exploratory study that consists of focus groups of the general public and personal interviews with land managers will provide information that is specific to the defined area of study (e.g., 1st Analysis Area, city, county, Forest, etc.). Once this qualitative data is analyzed, this information will give researchers a basis for a more structured (quantitative/qualitative) descriptive and/or explanatory study that is geared towards the population in question. For example, if exploratory studies were conducted in the first and second analysis areas, commonalities and differences can be identified between the subpopulations and subsequently, questions relevant to both populations can be formulated as well as modules that are specific to each subpopulation.

Another key driver in the study's design is how the information will be used. If the constituency requesting monitoring data requires findings to be representative of the population in question, probability sampling must be employed. This occurs if all of the individuals in the population have an equal chance of being selected and the selection method is randomized. If this is the case, the results of the study can be generalized to the population as a whole (Babbie 2010). Probability sampling verifies the sample is not biased and enables estimates of the precision that the results reflect the study's population (Fowler 2002). These results can be statistically verified with a sampling error, the degree of inaccuracy in the sampling design, as well as a confidence level, that the results are representative of the population. Non-probability sampling can be appropriate when a complete list of the study's population is unavailable, resources are limited, study requirements do not dictate stringent probability sampling results, or the purpose of the study is exploratory. For example, "purposive sampling" is appropriate when a select number of key informants provide information needed to understand the key issues and is either used to understand specific circumstances and/or develop a more stringent study that can be generalized to a broader population.

To the greatest extent possible, the Multi-Party Monitoring Board would ensure that the results of socioeconomic studies are reliable (results consistently yield similar findings) and valid (results adequately represent the concept under consideration) (Royse et al. 2010). However, at times, there is a tradeoff between reliability and validity. Factors such as the purpose of the study, the constituency, and how the results will be used, will aid in determining the degree to which a greater emphasis should be placed on reliability or validity or whether this distinction is necessary.

Data Sources

Data sources listed in both the social and economic frameworks include both primary and secondary data. The social analyses primary data collection includes focus groups, interviews, surveys and content analysis. Data collections of this type, if federally sponsored, are subject to the Paperwork Reduction Act (PRA) and must receive PRA clearance from the Office of Management and Budget prior to implementation. Secondary data sources for social analyses include reports by forests, government reports (city, county, state, and Federal) and Federal and private databases, such as Headwaters Institute and Firewise Communities USA.

The economic analyses primary data sources include contractor, visitor and business surveys. These data collections, if federally sponsored, are also subject to PRA clearance. Secondary data for the economic analyses includes various government reports (forest, municipal, state, and Federal), previous studies and government databases used in similar studies. As monitoring projects are developed and conducted, data sources in the frameworks will be reassessed and refined and new data sources will be added.

Literature Review

Generally, upon initiation of a socioeconomic study, background research through a literature review is conducted to assess previous research on the topic. More specifically, previous studies can assist with determining a study's design, questionnaire/protocol development, relevant data sources and various analyses that were used and, whether previous studies reveal consistent findings. In addition, this information can reveal whether there are consistent flaws in previous research that may be remedied (Babbie 2010).

Census Research

Census data provide information that is inclusive of all individuals in a population (Fowler 2002). Census data covers 200 specific topics that describe a population or a "community" that includes demographic information such as employment, education, income, a population's size, and "urban" versus "rural" communities (EPA 2002). Census data can also be used to verify that the demographic data in the study group is reflective of the demographics of the area under study.

Survey Research

The choice of data collection mode, whether it's through the mail, telephone, internet, personal interviews or group administration will be based on the sampling frame, the research question, characteristics of the sample, required response rates, question format, availability of trained staff and facilities and funding available for the project (Fowler 2002).

Surveys are one of the best methods used to describe a population's attitudes and orientations that are too large to observe directly and provide a standardized measurement across individuals in a given population (Fowler 2002). There are self-administered questionnaires and survey administered by interviewers. Self-administered surveys through the mail or on the Internet are generally less representative of a population due to typical low response rates. In administering Internet surveys, many times the population is not representative as the sampling frame is not inclusive of the entire population, nor is the Internet regularly accessible to a broader population. However, Internet surveys can be appropriate to populations that have known computer access, such as Forest Service employees. In general, surveys, coupled with valid operationalization of concepts through appropriately worded questions, provide uncanny accuracy of a population's beliefs and attitudes (Babbie 2010). In addition, data collection through surveys can also provide a population's characteristics (demographics) that can be linked to the responses thus, increasing understanding of specific group's perceptions or beliefs (EPA 2002).

For more specific economic data, if secondary data is available from reliable sources, these will be used. Primary data collected through self-administered surveys from contractors or others involved in the restoration process are the best method, as contractors need to track the information and refer to their records. In collecting primary data from contractors, the sooner they are aware of these efforts and receive the survey forms/files, the easier it will be for them to track the necessary information.

Personal Interviews and Focus Groups

Personal interviews that occur face-to-face can be appropriate when the questions require: qualitative in-depth answers, high response rates, interviewer observation, longer interviews, rapport building and allow for multi data collection modes that could include diagrams (Fowler 2002). Personal interviews can include key informants that will provide valuable in-depth information such as, Forest Service personnel and community leaders like County Board of Supervisors. Focus groups are a useful tool and usually engage 12-15 people in a guided discussion of a topic. The participants would not statistically represent segments of the population; therefore, this mode of observation is used to more deeply explore a topic and become more familiar with the issues under consideration (Babbie 2010). These results can be used to design a descriptive or explanatory study and/or used for strategic planning efforts (EPA 2002).

Content Analysis

Content analysis is used when various mediums of communication provide information in either a written form, such as newspaper articles, or in a multimedia format such as movies, speeches, photos, etc. (EPA 2002). These analyses reveal recorded historic human communication or the artifacts of a social group (Babbie 2010). Content analysis will reveal what has been communicated and the analysis will answer the question "why" it was communicated and "what was the effect" of the communication (Babbie 2010). To complete the qualitative analyses of the various formats, a software program, NVivo (2012), can be used for evaluation of the data.

Collaborative Performance

In Fiscal Year 2011, the first collaborative performance evaluation was conducted through a Survey Monkey instrument developed in conjunction with the 4FRI Stakeholder Group and the US Institute for Conflict Resolution (Mottek Lucas 2012, Appendix E). A follow-on survey was administered to the 4FRI Stakeholder Group in 2012 (Mottek Lucas 2012). The initial intent was to track performance over time and to adaptively manage the collaborative group so that improvements are made in key areas identified by stakeholders.

Other notable 4FRI collaborative studies include:

1. *Power Dynamics at Multiple Scales in Collaborative Forest Management: Analysis of the Four Forest Restoration Initiative (Greer 2017).*
2. *The Four Forest Restoration Initiative (4FRI): The Role of Collaboration in Achieving Outcomes (Esch and Vosick 2016).*
3. *The History of the Four Forest Restoration Initiative: 1980s–2010 (Egan and Nielsen 2014).*
4. *Administrative and Legal Review Opportunities for Collaborative Groups (Brown 2015).*

Economic Analyses

Economic analyses are essential tools for planning, prioritizing and evaluating restoration projects (Robbins and Daniels 2011). Economics will provide a suite of tools to inform decision-making and improve transparency in selecting projects (Robbins and Daniels 2011). Based on a recent review of literature in describing economic concepts in the context of ecological restoration, Robbins and Daniels (2011) outline decision-analysis frameworks that incorporate an inclusive array of restoration benefits and costs. A "travel costs method" is employed to determine values associated with recreational sites by assessing visitor time and expenditures. "Stated preference method" or assessing willingness to pay for environmental improvements is used when indirect values, such as watershed protection, are being assessed. The stated preference method can be measured by a "contingent valuation," or how much individuals are willing to pay for a policy or project. As an alternative, an "experimental choice method" can be employed as a non-monetary valuation that asks individuals to choose from a set of alternatives and rank their preferences. "Benefit costs analysis" includes total benefits or revenues and costs (using a weighted distribution of each) of a project over time with a defendable discount rate. Alternatively, "cost effective analysis" can provide a framework to compare relative costs of alternative methods geared towards achieving the same outcome. Lastly, "multi-criteria decision analysis" uses nonmonetary values through relative quantitative or qualitative performance scores. This review also revealed that although direct costs and revenues should be easy to capture, they are rarely reported. To address this lack of accounting, as suggested early in this report, streamlining expenditure, revenue and employment data reporting with prepared protocols and contractor reporting forms as well as creating a centralized data base prior to project implementation, should assist in closing this gap.

Regional economic contribution analysis is a method of tracking indirect and induced effects incited by restoration expenditures throughout a regional economy (Hjerpe et al. 2021). Regional economic contribution analysis is similar to economic impact analysis but is more appropriate for activities that are recurring each year as opposed to a novel economic activity (Watson et al. 2007). A good delineation for determining whether economic impacts or contributions are the appropriate method is the timing of the project. With projecting *ex ante* economic activities, generally applying economic impact analysis is preferred. Conversely, in tracking *ex post* economic activities, generally economic contribution analysis is best (Watson et al. 2015).

Prioritization

Although there are a multitude of monitoring objectives/questions in both the social and economic frameworks, due to identified preferences of the 4FRI Stakeholder Group and limitations in resources, specific objectives/questions may need to be prioritized by the 4FRI Stakeholder Group. One method for prioritizing the questions/objectives would be to focus on the issues and concerns that are relevant to the communities that are directly affected by forest restoration efforts, as well as those issues of interest to the four Forests and the State.

In a study conducted by Egan and Estrada-Bustillo (2011), a model to prioritize socioeconomic indicators was developed through a Delphi process. Based on project objectives and availability of resources, results indicate there are three levels of indicators that include: 1) a core set that utilizes minimum effort at the forest or stand level; 2) includes the set of core indicators and balances ecological with socioeconomic dimensions and is used for long-term projects requiring more time and expertise and; 3) includes the first two sets of indicators; however, the primary focus is socioeconomic outcomes and is used across jurisdictions on landscape-scale projects and requires the highest level of expertise and resources. In addition to the recommended intensity of the socioeconomic monitoring, specific indicators can be weighted in using an average/median rating. Based on these results, overall socioeconomic objectives/questions can be identified, will provide guidance in selecting the best indicators for the assessment, and can guide resource allocation for a given project.

Socioeconomic Importance of Adaptive Management

To complete the adaptive management loop, an initial assessment of the public's awareness, knowledge and support of pressing issues, as well as critical economic factors and conditions, is necessary to determine effects of outreach as well as implementation. Once these factors are understood, hypothesis testing of changes in behavior are developed, empirical data is collected and tracked to monitor the effectiveness of future outreach and implementation efforts. These steps tie back into the logic model that explains what you are doing, the expected results and a series of outcomes from immediate to long-term (W.K. Kellogg Foundation 2004). Using this model helps to identify whether the project is on-track and emphasizes learning as an ongoing process - an integral part of the evaluation and a critical component of the adaptive management model.

According to a study conducted by Brown and Squirrell (2010), adaptive management is premised on flexibility and job security that enables risk taking. To integrate consistent adaptive management within the Forest Service, results from this study suggest the need to establish mutual trust between key stakeholders, such as other agencies, nongovernmental organizations, citizens, politicians and the courts, and the Forest Service. Due to the groundbreaking nature of the 4FRI project and the lack of science based adaptive management within the Forest Service, solidifying the adaptive management process is a critical step in ensuring the project's success. Stakeholders who are concerned about potential management outcomes are more likely to support management actions if they are confident results from these actions are carefully monitored (Rural Voice for Conservation Coalition 2011). In the end, monitoring should not be viewed as an added expense, but as an instrument that can ultimately reduce overall costs by minimizing ineffective management practices and potentially reducing objections and litigation (Rural Voice for Conservation Coalition 2011). Table E-4 through Table E-22 show the socioeconomic monitoring frameworks.

Socioeconomic Monitoring Framework

I. GOAL: There is broad public awareness, understanding, knowledge and support for collaboratively based forest restoration decisions, processes, and outcomes, including the use of fire as a management tool.

Table E-4. Four Forest Restoration Initiative socioeconomic monitoring framework for social systems, Goal I

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
There is broad public awareness for collaboratively based forest restoration.	Is the public aware of the collaboratively- based 4FRI forest restoration project (e.g., current decisions, processes and outcomes)?	Awareness of the collaboratively-based 4FRI forest restoration project (e.g., current decisions, processes and outcomes).	Focus groups with community members. Interviews with land managers/key decision-makers. Telephone survey with residents in study area.	Pre- post-implementation outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	The public is unaware of the collaboratively-based 4FRI forest restoration project (e.g., current decisions, processes and outcomes).
There is broad public understanding/ knowledge for collaboratively based forest restoration.	Is the public knowledgeable of the collaboratively-based 4FRI forest restoration efforts (e.g., current decisions, processes and outcomes)?	Public's understanding/ knowledge for collaboratively-based forest restoration.	Focus groups with community members. Interviews with land managers/key decision-makers. Telephone survey with residents in study area.	Pre- post-implementation outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	The public is not knowledgeable of collaboratively-based forest restoration.
There is broad public support/acceptance for collaboratively based forest restoration.	Is there broad public support/acceptance for the collaboratively-based 4FRI forest restoration project (e.g., current decisions, processes and outcomes)?	Support/ acceptance for collaboratively based 4FRI forest restoration project (e.g., current decisions, processes and outcomes).	1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area.	Pre- post-implementation outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	The public does not support/accept collaboratively-based forest restoration.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
Number of objections and lawsuits for 4FRI projects are minimized.	Are the number of objections and lawsuits for 4FRI projects at a minimum and/or decreasing?	Number & length of time of lawsuits.	Objections database available at: https://www.fs.fed.us/objections/objections_list.php?r=110300	Track annually for first 5 years post/analysis area.	Objections database available at: https://www.fs.fed.us/objections/objections_list.php?r=110300	Objections and lawsuits for 4FRI projects are delaying project implementation.
There is broad public awareness for the use of fire as a management tool.	Is the public aware of the use of fire as a management tool?	Public awareness for the use of fire as a management tool.	1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area.	Pre- post-implementation outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	The public is unaware of the use of fire as a management tool.
There is broad public understanding/ knowledge for the use of fire as a management tool.	Does the public understand/have knowledge of the use of fire as a management tool?	Public understanding/ knowledge for the use of fire as a management tool.	1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area.	Pre- post-implementation outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	The public does not have the understanding/ knowledge for the use of fire as a management tool.
There is broad public support/acceptance for the use of fire as a management tool.	Does the public support/accept the use of fire as a management tool?	Public support/acceptance for the use of fire as a management tool.	1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area.	Pre- post-implementation outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	The public does not support/accept the use of fire as a management tool.

II. GOAL: The public is knowledgeable/understands, accepts/supports the byproduct of smoke from prescribed fires and wildfires with beneficial effects.

Table E-5. Four Forest Restoration Initiative socioeconomic monitoring framework for social systems, Goal II

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
The public is knowledgeable/ understands the byproduct of smoke from prescribed fires and wildfires with beneficial effects (presence & duration)	Is the public knowledgeable/ understands why prescribed fires and wildfires with beneficial effects are necessary and will have the byproduct of smoke?	Public knowledgeable / understanding of why prescribed fire is necessary and will have the byproduct of smoke.	1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area. 4. Forest Service complaint logs.	Pre- post-implementation outreach. Track annually for first 5 years post.	Focus group, interview, and survey results.	Public does not understand why prescribed fire is necessary and will have the byproduct of smoke.
The public accepts/supports the byproduct of smoke from prescribed fires and wildfires with beneficial effects (presence & duration)	Does the public accept/support the byproduct of smoke from prescribed fires and wildfires with beneficial effects?	Public acceptance/ support of the byproduct of smoke from prescribed fire.	1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area. 4. Forest Service complaint logs.	Pre- post-implementation outreach. Track annually for first 5 years post.	Focus group, interview, and survey results.	Public does not accept/support the byproduct of smoke from prescribed fire.

III. Goal: The public understands, accepts, and supports fire's natural role in forest ecosystems.

Table E-6. Four Forest Restoration Initiative socioeconomic monitoring framework for social systems, Goal III

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
The public understands fire's natural role in forest ecosystems.	Does the public understand fire's natural role in forest ecosystems?	Public understanding fire's natural role in forest ecosystems.	1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area.	Pre- post-implementation outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	Public does not understand fire's natural role in forest ecosystems.
The public accepts/ supports fire's natural role in forest ecosystems.	Does the public accept/support fire's natural role in forest ecosystems?	Public acceptance/ support for fire's natural role in forest ecosystems.	1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area.	Pre- post-implementation outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	Public does not accept/support fire's natural role in forest ecosystems.

IV. GOAL: Rural communities are protected from high-severity fire and their quality of life is enhanced through forest restoration.

Table E-7. Four Forest Restoration Initiative socioeconomic monitoring framework for social systems, Goal IV

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
Rural communities' risks from high-severity fire are reduced.	Is the frequency and size of high severity fires decreasing?	1. Frequency of wildfires. 2. Size (acres) of wildfires	Frequency and size of wildfires 5 years post-4FRI implementation vs. frequency and duration of wildfires 5 years pre-4FRI implementation	5 years	Forest Service by Forests (Greater Flagstaff Forest Partnership 2010)	Rural communities' risk from high-severity fire are not decreasing

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
Rural community residents' perceived risk of high-severity fire is reduced.	[If frequency and size of high severity fires are decreasing] Do rural community residents' perceive rural communities are being protected from high-severity fire?	Rural community residents' perception of risk of high severity fires.	Focus groups with community members. Interviews with land managers/key decision-makers. Telephone survey with residents in study area.	Pre- post-implementation outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	Rural community residents' perceived risk of high-severity fire is not decreasing.
Landowners adjacent to or in the proximity of the four forests (e.g., state, private, tribal, municipal, etc.) are encouraged to participate in restoring all forested lands in Northern Arizona.	Q1: Are landowners adjacent to or in the proximity of the four forests participating in restoring their forested lands? Q2: What programs are in place to encourage landowners to treat their lands?	Q1/Q2: 1. Land ownership, location, number and total dollar value of: State Fire Assistance grants, Tribal Forest Protection Act, AZ Forest Health Program, Forest Stewardship Program, etc. 2. Fire behavior including adjacent non- Forest Service-administered lands.	Q1: Tracking land ownership/location and respective treatments (fire behavior). Q2: 1. Tracking outreach efforts to state, private, tribal, municipal landowners. 2. Tracking land ownership, location number and total $ value of grants awarded.	5 years	Headwaters Institute. State, private, tribal, municipal grant/project reports. Forest Service by Forests. 4FRI Stakeholder Group.	Landowners adjacent to or in the proximity of the four forests (e.g., state, private, tribal, municipal, etc.) are not encouraged to participate/are not restoring forested lands in northern Arizona.

V. GOAL: Social values and recreational opportunities are protected and/or enhanced through forest restoration activities

Table E-8. Four Forest Restoration Initiative socioeconomic monitoring framework for social systems, Goal V

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
Recreational opportunities are protected through forest restoration activities.	Q1: Are recreational opportunities protected as restoration projects are implemented? Q2: Does the public perceive recreational opportunities are protected through forest restoration activities?	Q1: Number & type of recreational activities. Q2: Public perception of protection of recreational opportunities through forest restoration activities.	Q1: Analysis of Forest Service, AZG&F, USFWS reports. Q2: 1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area.	Pre- post-implementation outreach. Track annually for first 5 years post.	Q1: 1. National Visitor Use Monitoring Program (USDA FS 2021) 2. Headwaters Institute 3. AZG&F The Economic Importance of Fishing and Hunting (utilizes IMPLAN input/output model) (Silberman 2002). 4. USFWS National Survey of Fishing, Wildlife, Hunting, & Wildlife Assoc. Recreation (USDI FWS 2016). 5. Visitor surveys. Q2: Focus group, interview and survey results.	Recreational opportunities are not protected as forest restoration activities occur.
Recreational opportunities are enhanced through forest restoration activities.	Q1: Are recreational opportunities improving as restoration projects are implemented? Q2: Does the public perceive recreational opportunities are improving as forest restoration activities are occurring?	Q1: Number & type of recreational activities. Q2: Public perception of improving recreational opportunities as forest restoration activities are occurring.	Q1: 1. Analysis of Forest Service, AZG&F, USFWS reports. 2. Visitor surveys Q2: 1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area.	Pre- post-implementation/ outreach. Track annually for first 5 years post.	As above.	Q1: Recreational opportunities are not improving as restoration projects are implemented. Q2: Public perceives recreational opportunities are not improving as forest restoration activities are occurring.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
Aesthetic values are protected through forest restoration activities.	Does the public perceive aesthetic values are protected through forest restoration activities?	Public perception that aesthetic values are protected through forest restoration activities.	Focus groups with community members. Interviews with land managers/key decision-makers. Telephone survey with residents in study area. Comparative analysis of field trips to treated vs. untreated sites (*timing relevant to post-implementation is critical-minimum one- year post).	1. Pre- post-implementation/ outreach. Track annually for first 5 years post.	Focus group, interview and survey results. Headwaters Institute.	The public perceives that aesthetic values are not being protected as forest restoration activities are occurring.
Aesthetic values are enhanced through forest restoration activities.	Does the public perceive aesthetic values are enhanced through forest restoration activities?	Public perception that aesthetic values are enhanced through forest restoration activities.	Focus groups with community members. Interviews with land managers/key decision-makers. Telephone survey with residents in study area. Comparative analysis of field trips to treated vs. untreated sites (*timing relevant to post-implementation is critical-minimum one- year post).	1. Pre- post-implementation outreach. Track annually for first 5 years post.	Focus group, interview and survey results. Headwaters Institute.	The public perceives that aesthetic values are not enhanced as forest restoration activities are occurring.

VI. GOAL: Rural communities play an active part in reducing fire risk by implementing FireWise actions and creating defensible space around their property.

Table E-9. Four Forest Restoration Initiative socioeconomic monitoring framework for social systems, Goal VI

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
Rural community residents are aware/ knowledgeable of FireWise principles/ FireWise communities.	Are rural community residents aware/ knowledgeable of FireWise principles/FireWise communities?	Public awareness/ knowledge for FireWise principles.	1. Focus groups with community members. 2. Interviews with fire prevention managers. 3. Telephone survey with residents in study area.	Pre- post-Implementation outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	Rural community residents are unaware/not knowledgeable of FireWise principles/ FireWise communities.
Rural community residents are aware/ knowledgeable of implementing defensible space.	Are rural community residents aware/ knowledgeable of implementing defensible space?	Public awareness/ knowledge of implementing defensible space.	1. Focus groups with community members. 2. Interviews with fire prevention managers. 3. Telephone survey with residents in study area.	Pre- post-implementation outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	Rural community residents are unaware/not knowledgeable of implementing defensible space.
Number of communities that are recognized as FireWise increases.	Are the number of communities that are recognized as FireWise increasing?	Number of communities recognized as FireWise.	Track no. of communities recognized as Firewise.	Pre- post-implementation /outreach. 5 years.	Firewise Communities USA (http://www.firewise.org/Communities/ USA-Recognition-Program.aspx).	Number of communities that are recognized as FireWise is not increasing.

VII. GOAL: there is broad public support for the 4FRI Collaborative as forest restoration activities are implemented

Table E-10. Four Forest Restoration Initiative socioeconomic monitoring framework for social systems, Goal VII

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
The public is aware of the 4FRI Collaborative.	Is the public aware of the 4FRI Collaborative?	Public awareness of the 4FRI Collaborative.	1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area.	Pre- post-implementation outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	The public is not aware of the 4FRI Collaborative.
The public is knowledgeable/ understands the 4FRICollaborative's role in the 4FRI Initiative.	Is the public knowledgeable/understands the 4FRI Collaborative's role in the 4FRI Initiative?	Public's knowledge of the 4FRI Collaborative's role in the 4FRI Initiative.	1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area.	Pre- post-implementation/ outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	The public does not understand the 4FRI Collaborative's role in the 4FRI Initiative.
The public is supportive of the 4FRI Collaborative.	Is the public supportive of the 4FRI Collaborative?	Public support for the 4FRI Collaborative.	1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area.	Pre- post-implementation outreach. Track annually for first years post.	Focus group, interview and survey results.	The public is not supportive of the 4FRI Collaborative.

VIII. GOAL: There is public support for the USDA Forest Service as forest restoration activities are implemented

Table E-11. Four Forest Restoration Initiative socioeconomic monitoring framework for social systems, Goal VIII

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
The public is aware of the Forest Service's involvement/role with the 4FRI Collaborative.	Is the public aware of the Forest Service's involvement/role with the 4FRI Collaborative?	Public awareness for the Forest Service's involvement/ role with the 4FRI Collaborative.	1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area.	Pre- post-implementation outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	The public is not aware of the Forest Service's involvement/ role with the 4FRI Collaborative.
The public is aware of the Forest Service's involvement with the 4FRI Project.	Is the public aware of the Forest Service's involvement with the 4FRI Project?	Public awareness for the Forest Service's involvement/ role with the 4FRI Project.	1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area.	Pre- post-implementation outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	The public is not aware of the Forest Service's involvement with the 4FRI Project.
The public is supportive of the Forest Service's involvement with the 4FRI Collaborative.	Is there public support/acceptance for the Forest Service's involvement with the 4FRI Collaborative?	Public support for the Forest Service's involvement with the 4FRI Collaborative.	1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area.	Pre- post-implementation outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	The public is not supportive of the Forest Service's involvement with the 4FRI Collaborative.
The public is supportive of the Forest Service's involvement with the 4FRI Collaborative.	Is there public support/acceptance for the Forest Service's involvement with the 4FRI Collaborative?	Public support for the Forest Service's involvement with the 4FRI Collaborative.	1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area.	Pre- post-implementation outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	The public is not supportive of the Forest Service's involvement with the 4FRI Collaborative.

IX. GOAL: The general public is aware, knowledgeable and supportive of 4FRI implemented treatments within the analysis area

Table E-12. Four Forest Restoration Initiative socioeconomic monitoring framework for social systems, Goal IX

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
The general public is aware of 4FRI implemented treatments within the analysis area.	Is the general public aware of 4FRI implemented treatments within the analysis area?	Public awareness of 4FRI implemented treatments within the analysis area.	1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area.	Pre- post-implementation outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	The general public is unaware of 4FRI implemented treatments within the analysis area.
The general public is knowledgeable/ understands 4FRI implemented treatments (mechanical thinning, road alteration, etc. as necessary tools) for ecological restoration within the analysis area.	Is the general public knowledgeable/ understands 4FRI implemented treatments for ecological restoration within the analysis area?	Public knowledge/ understanding 4FRI implemented treatments (mechanical thinning, road alteration, etc.) as necessary tools for ecological restoration within the analysis area.	Focus groups with community members. Interviews with land managers/key decision-makers. Telephone survey with residents in study area.	Pre- post-implementation/ outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	The general public is not knowledgeable/ does not understand 4FRI implemented treatments (mechanical thinning, road alteration, etc.) as necessary tools for ecological restoration within the analysis area.
The general public is supportive of 4FRI implemented treatments within the analysis area.	Is the general public supportive of 4FRI implemented treatments within the analysis area?	Public support for 4FRI implemented treatments within the analysis area.	Focus groups with community members. Interviews with land managers/key decision-makers. Telephone survey with residents in study area.	Pre- post-implementation/ outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	The general public is not supportive of 4FRI-implemented treatments within the analysis area.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
There is ample notification to the public of 4FRI-implemented projects that may include road construction, mechanical thinning, planned and unplanned ignitions etc.	Q1: Does the public believe there is ample notification of restoration projects? Q2: What campaigns and public notifications are in place to inform the public of restoration treatments and/or prep for those treatments?	Q1: Public perception of notification of restoration projects/ activities. Q2: Website postings, newspaper, radio, direct signage in the forest, 4FRI 800#, etc.	Q1: 1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area. Q2: Number, type, content analysis of public campaigns/ notifications	Pre- post-implementation outreach. Track annually for first 5 years post.	Q1: Focus group, interview and survey results. Q2: Results from content analysis.	Q1: Public perception of notifications of 4FRI-implemented projects is not sufficient (road construction, mechanical thinning, planned and unplanned ignitions, etc.). Q2: An insufficient amount of campaigns and public notifications are in place to adequately inform the public of restoration treatments and/or prep for those treatments.

X. GOAL: The general public is aware of 4FRI educational and outreach programs and has the opportunity to participate in the 4FRI effort.

Table E-13. Four Forest Restoration Initiative socioeconomic monitoring framework for social systems, Goal X

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
The general public is aware of 4FRI educational and outreach programs.	Is the general public aware of 4FRI educational and outreach programs?	Public awareness of 4FRI educational and outreach programs.	1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area.	Pre- post-implementation outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	The general public is unaware of 4FRI educational and outreach programs.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
The general public has the opportunity to participate in the 4FRI educational and outreach programs.	Does the general public have the opportunity to participate in the 4FRI educational and outreach programs?	Public's opportunity to participate in the 4FRI educational and outreach programs.	Focus groups with community members. Interviews with land managers/key decision-makers. Telephone survey with residents in study area. Number, frequency, type of educational and outreach programs.	Annual	Focus group, interview and survey results. Forest Service by forest. 4FRI Collaborative Stakeholder group.	The general public has not had ample opportunity to participate in the 4FRI educational and outreach programs.
Youth are aware of 4FRI educational and outreach programs.	Are youth aware of 4FRI educational and outreach programs?	Youth awareness for 4FRI educational and outreach programs.	1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area.	Pre- post-implementation outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	Youth are not aware of 4FRI educational and outreach programs.
Youth has the opportunity to participate in the 4FRI educational and outreach programs.	Do youth have the opportunity to participate in the 4FRI educational and outreach programs?	Opportunities for youth to participate in the 4FRI educational and outreach programs.	Focus groups with community members. Interviews with land managers/key decision-makers. Telephone survey with residents in study area. Survey local youth group coordinators. Number, frequency, type of youth programs related to the 4FRI effort.	Pre- post-implementation outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	Youth have not had ample opportunity to participate in the 4FRI educational and outreach programs.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
Low income/minority populations are aware of 4FRI educational and outreach programs.	Are low income/minority populations aware of 4FRI educational and outreach programs?	Awareness of low income/ minority populations of 4FRI educational and outreach programs.	Focus groups with community members. Interviews with land managers/key decision-makers. Telephone survey with residents in study area. Oversample low income/minority populations. Number, frequency, type of outreach programs geared toward low income/minority populations related to the 4FRI effort.	Pre- post- implementation outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	Low income/minority populations are unaware of 4FRI educational and outreach programs.
Low income/minority populations have the opportunity to participate in the 4FRI educational and outreach programs.	Do low income/minority populations have the opportunity to participate in the 4FRI educational and outreach programs?	Low income/ minority population's opportunity to participate in the 4FRI educational and outreach programs.	Focus groups with community members. Interviews with land managers/key decision-makers. Telephone survey with residents in study area. Oversample low income/minority populations. Number, frequency, type of outreach programs geared towards low income/minority populations related to the 4FRI effort.	Pre- post- implementation outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	Low income/minority populations have not had ample opportunity to participate in the 4FRI educational and outreach programs.
The general public has the opportunity to participate in the 4FRI effort.	Does the general public have the opportunity to participate in the 4FRI effort?	Public's opportunity to participate in the 4FRI effort.	1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area. 4. Number, frequency, type of outreach programs for public participation in the 4FRI effort.	Pre- post- implementation/ outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	The general public has not had ample opportunity to participate in the 4FRI effort.

XI. GOAL: Treatments within the analysis area minimize short-term impacts and enhance vegetation characteristics valued by Forest users over the long-term

Table E-14. Four Forest Restoration Initiative socioeconomic monitoring framework for social systems, Goal XI

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
Treatments within the analysis area minimize short-term impacts such as skid trails, decks, excessive slash, roads etc.	Q1: What are the short-term impacts of concern to Forest users? Q2: Are treatments within the analysis area minimizing short-term impacts such as: skid trails, decks, excessive slash, roads etc.?	Q1: Treatments' short-term impacts of concern to forest users. Q2: Public's perception of short-term impacts of treatments.	Q1: Review BMP monitoring reports. Q2: 1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area. 4. Field trips/focus groups to restoration sites.	Pre- post-implementation outreach. Track annually for first 5 years post.	Q1: BMP Reports Q2: Focus group, interview, field trip and survey results.	Treatments within the analysis area are not minimizing short-term impacts of concern to forest users (e.g., skid trails, decks, excessive slash, etc.).
Treatments within the analysis area enhance vegetation characteristics valued by Forest users over the long-term.	Q1: What are the vegetative characteristics valued by Forest users over the long term? Q2: Do these treatments enhance vegetation characteristics valued by Forest users over the long term?	Q1: Vegetative characteristics valued by Forest users over the long term. Q2: Public's perception of vegetative characteristics that are valued by Forest users over the long term.	Focus groups with community members. Interviews with land managers/key decision-makers. Telephone survey with residents in study area. Field trips/focus groups to restoration sites.	Pre- post- implementation outreach. Track annually for first 5 years post.	Focus group, interview and survey results.	Treatments within the analysis area do not enhance vegetation characteristics that are valued by Forest users over the long-term.

I. GOAL: The byproducts of mechanical forest restoration offset the costs of treatment implementation

Table E-15. Four Forest Restoration Initiative socioeconomic monitoring framework for economic systems, Goal I

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
Wood byproduct sales exceed the costs of implementation (Contractors are operating at a profit and the Forest Service does not have to pay contractors' treatment costs).	Q1: Do byproduct sales exceed operational costs? Q2: Are treatments adequately sequenced to enable contractors to offset their overall operational costs? Q3: Are Forest Service contracting costs decreasing?	Q1: 1. Operational costs of treatments: a. Mobilization: to move equipment from site to site, to move operators (daily) from home base to site. b. Loading: cutting, skidding, delimbing, piling slash, loading stems. c. Haul: transport costs from landing to processing site (time & distance). 2. Amount of wood and its value (4FRI Stakeholder Group 2010c). 3. Degree of deviation from business plan(s). Q2: 1. No. of task orders and location. 2. Wood yields/task order ((4FRI Stakeholder Group 2010c).	Q1: Operational costs of treatments vs. amount of wood & its value ((4FRI Stakeholder Group 2010c). Q2: Average wood yields vs. No. of task orders balanced on semi-annual or quarterly basis ((4FRI Stakeholder Group 2010c).	Dependent on business plan(s).	1. Contractor surveys 2. Forest Service business plans (D. Jaworski Personal Communication 2011). 3. Contracts: Federal databases a. USAspending.gov b. Forest Service Natural Resource Manager Database (Sundstrom et al. 2011). 4. Headwaters Institute	Q1: Operational cost of treatments exceeds byproduct sales. Q2: Average wood yields per task order does not support contractors operating at a profit.

II. GOAL: The economic value of ecosystem services provided by restored forests (such as the value of recreation or water) are captured and reinvested to support forest restoration and ecosystem management

Table E-16. Four Forest Restoration Initiative socioeconomic monitoring framework for economic systems, Goal II

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
The economic value of ecosystem services provided by restored forests, such as the value of recreation/ tourism, are captured and reinvested to support forest restoration and ecosystem management.	Q1: What is the increase (percent) in direct service revenues related to recreation/tourism? Q2: What is the increase (percent) in revenues associated w/fee imposed recreation activities (e.g., hunting, fishing, pass/entry fees etc.)? Q3: 1. Has a portion of the determined value of increased recreational revenues been reinvested in forest restoration? 2. How many collaborators are involved in contributing to this program?	Q1: 1. Lodging, Restaurant, Groceries, Gas/Oil, Other transportation, Activities, Admissions/ Fees, Souvenirs/ Other expenditures (USDA FS 2021). Q2: 1. AZG&F license sales by County. 2. Visitor fees. Q3: Dollar value of fees invested in forest restoration activities.	Q1-Q3: Travel cost method using: Forest Service, AZG&F, USFWS reports tracked with investments made in forest restoration from fees/licenses/ private revenues.	5 years (USDA FS 2021; USDI FWS 2016)	Q1: 1. National Visitor Use Monitoring Program (USDA FS 2021). 2. Headwaters Institute Q2: 1. AZG&F The Economic Importance of Fishing and Hunting (utilizes IMPLAN input/output model) (Silberman 2002). USFWS National Survey of Fishing, Wildlife, Hunting, & Wildlife Assoc. Recreation (USDI FWS 2016). Visitor surveys. Q3: S&MWG database	Q1/Q2: Direct service revenues and license fees related to recreation/tourism are decreasing as forest restoration activities are occurring. Q3: A portion of revenues generated from recreation and tourism are not being reinvested in forest restoration activities.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
The economic value of ecosystem services provided by restored forests, such as the value of water, are captured and reinvested to support forest restoration and ecosystem management.	Q1: What is the effect in water yield, pre- post-restoration? Q2: What is the effect in sedimentation, pre- post-restoration? Q3: What is the economic value of increase/loss of water yield? Q4: [If increased] Has a portion of the determined value of increased water yield been reinvested in forest restoration? Q5: Are restoration projects reducing the costs of producing a potable water supply? Q6: How many collaborators are involved in contributing to this program and what is the $ value of each?	Q1/Q2: SRP Paired Watershed Study Costs associated w/: Transport, Treating, Developing new/existing water supplies, Capture, Delivery Q3-Q5: Watershed fund revenues (e.g. assess a fee to each water consumer based on use per 5,000 gallons per month (Santa Fe Watershed Association 2009; City of Flagstaff 2010). Operation & maintenance expenses Taxes/transfers Capital additions/replacement Debt services (principle/interest) Allocated indirect costs Administration (City of Flagstaff 2010).	Q1/Q2: SRP Paired Watershed Study compares results to Beaver Creek and Castle Creek Watershed Studies (Arizona Forest Resource Task Group 2010). Q3-Q5: Determined value of increased water yield vs. proportion of this value invested in forest restoration activities.	Dependent on SRP Study and Promotion of Ecosystem Services Investment.	Q1/Q2: 1.SRP/NAU Beaver Creek Watershed Study Castle Creek Watershed Study (Arizona Forest Resource Task Group 2010). Watershed Conditions Framework (Forest Service). Q4/Q5/Q6: City of Flagstaff Utilities (Water) Dept. Long-term Financial Plan & Rate & Fee Study (City of Flagstaff 2010). S&MWG database.	Q1: Water yield is decreasing as restoration activities are occurring. Q2: Sedimentation is increasing as restoration activities are occurring. Q3: A portion of revenues generated from watershed restoration and protection are not being reinvested in forest restoration activities. Q5: Restoration projects are not assisting in reducing the costs of producing a potable water supply.
The economic value of ecosystem services provided by restored forests, such as wildlife habitat creation and preservation, are captured and reinvested to support forest restoration and ecosystem management.	Are forest restoration activities maintaining and enhancing habitat for wildlife to an extent that biodiversity offsets and compensation programs can be implemented and resulting funds are reinvested into forest restoration activities?	Wetland & Stream Ecosystems Compensation. Endangered Species Compensation. Conservation Banking (Madsen et al. 2010).	Value of compensation for preservation of wetland and stream ecosystems and endangered species vs. the proportion reinvested into forest restoration activities (Madsen et al. 2010).	10 years	USFWS NMFS (Madsen et al. 2010).	Forest restoration activities are not maintaining and enhancing habitat for wildlife to an extent that biodiversity offsets and compensation programs can be implemented and resulting funds are reinvested into forest restoration activities.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
The economic value of ecosystem services provided by restored forests, such as wildfire cost savings, are captured and reinvested to support forest restoration and ecosystem management.	Q1: What are the fire suppression costs incurred 5 years post 4FRI implementation and how does this compare to 5 years pre 4FRI implementation? Q2: What is the amount of cost savings (avoided costs vs. treatment costs) of wildfire suppression that has been reinvested in forest restoration activities?	Q1: Federal, state and local suppression costs, Private property losses (insured & uninsured), Damage to utility lines, Damage to recreation facilities, Loss of timber resources, Aid to evacuees (WFLC 2010), Resurveying land boundaries (M. Lata Personal Communication 2011). Q2: 1. Acres treated & $ amount/acre of risk reduction. 2. Dollar value reinvested in restoration activities.	Wildfire suppression costs 5 years post-4FRI implementation (control for increases in population and housing) vs. the amount of cost savings that is reinvested in forest restoration activities.	5 years post-implementation	Q1: 1. Direct suppression costs obtained from: Forest Service, BLM, NRCD, NIFC, State, County, FEMA, DHS, Insurance companies, American Red Cross (Western Forestry Leadership Coalition 2010). Q1/Q2: 1. Direct treatment costs obtained from: Forest Service, contractors. Headwaters Economics (population/housing). Forest Service budget staff (D. Jaworski Personal Communication 2011) S&MWG database.	Q1: Fire suppression costs are not decreasing (5 years post 4FRI when compared to 5 years pre 4FRI). Q2: A proportion of cost savings of wildfire suppression has not been reinvested in forest restoration activities.

III. GOAL: Rural communities receive direct and indirect economic benefits and ecosystem services as a result of forest restoration and resilient forests

Table E-17. Four Forest Restoration Initiative socioeconomic monitoring framework for economic systems, Goal III

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
Forest restoration activities will create direct quality jobs in rural communities in Arizona.	Q1: How many direct jobs have been created by forest restoration activities? Q2: What is the quality of the jobs? Q3: Are the jobs filled by local residents? Q4: How many direct jobs have been filled by low-income/minority populations?	Q1-Q3: Number, Types (FT vs. PT vs. seasonal), Positions, percent of jobs over total employment (Egan and Estrada-Bustillo 2011) Average length of employment, percent receiving benefits or payments in lieu of, Wages (average/worker, family-supported), Locations, percent of contracts w/ on the job training, Safety (percent and number of contracts without job related injuries/illnesses resulting in lost work time), percent and number of local workforce (resident zip codes), Distance traveled to work (Sundstrom et al. 2011).	Economic Impact Analysis: Direct reporting of primary and secondary data.	Annual	1. Contractor reporting form/survey. 2. Headwaters Institute (EPS-HDT Socioeconomic profiles). 3. Bureau of Labor Statistics (Stynes 1997).	Q1: Forest restoration activities have not created a sufficient number of direct jobs. Q2: Forest restoration activities have not created a sufficient number of quality jobs (e.g., FT, positions, benefits, trainings, safety, etc.). Q3: Forest restoration activities have not created a sufficient number of jobs that are filled by local residents.
Forest restoration activities will create indirect jobs in rural communities in Arizona.	How many indirect jobs have been created by forest restoration activities?	Direct Jobs: Number, Types (FT vs. PT), Average length of employment (Sundstrom et al. 2011).	Region specific dollar-tracking and multiplier effects of direct employment (for every dollar spent by a business, some number of dollars are created) (Egan and Estrada-Bustillo 2011, Sitko and Hurteau 2010, Stynes 1997).	Annual	Contractor reporting form/survey. Headwaters Institute (EPS-HDT Socioeconomic profiles). Bureau of Labor Statistics (Stynes 1997).	Forest restoration activities have not created a sufficient number of indirect jobs.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
Forest restoration activities will create increased retail sales/services in rural communities in Arizona.	Q1: Has city/county sales tax on goods and services increased as forest restoration activities have occurred? Q2: Have retail sales/service revenues increased as forest restoration activities have occurred?	Q1: City/county sales tax on goods and services. Q2: Retail sales & services revenue.	Dollar-tracking and multiplier effects (region-specific) (Sitko and Hurteau 2010) of business activity (Stynes 1997).	Annual	AZ Dept. of Revenue. City reports. County reports. US Census Bureau. U.S. Department of Labor, Bureau of Labor Statistics. Arizona Indicators (Morrison Institute of Public Policy 2011).	Q1: City/county sales tax on goods and services has not increased as forest restoration projects have been implemented. Q2: Retail sales & services revenue has not increased as forest restoration projects have been implemented.
Forest restoration activities will create increased tax revenues (e.g., property tax, business expenditures) in rural communities in Arizona.	Q1: Have taxes generated from forest industry business expenditures increased as forest restoration activities have occurred? Q2: Have property/sales tax/school revenues generated from forest industry employees (direct/indirect jobs) increased as forest restoration activities have occurred?	Q1: 1. Sales of wood products. Capital expenditures of project materials. Subcontract thinning services (Sitko and Hurteau 2010). Q2: 1. Sales/property taxes generated by employees (direct & indirect) (by county). School revenues generated by avg. family. Sales tax generated by avg. per capita expenditures on consumable goods/supplies (by county) (Sitko and Hurteau 2010).	Q1/Q2: Total net employee revenue based on jobs estimates and economic contributions from forest industry employees (direct/indirect). Indirect jobs: use regional multiplier effect, input/output modeling) (Sitko and Hurteau 2010).	Annual	Contractor reporting form/survey. U.S. Bureau of Economic Analysis (Sitko and Hurteau 2010). Headwaters Institute (EPS-HDT Socioeconomic profiles).	Q1: Taxes generated from forest industry business expenditures have not increased as forest restoration activities are implemented. Q2: Property/sales tax/school revenues generated from forest industry employees (direct/indirect jobs) have not increased as forest restoration activities are implemented.
Forest restoration activities will increase recreation/tourism in rural communities in Arizona.	Q1: Has recreation increased as forest restoration activities have occurred?		Forest restoration activities will increase recreation/tourism in rural communities in Arizona.	Q1: Has recreation increased as forest restoration activities have occurred?		Forest restoration activities will increase recreation/tourism in rural communities in Arizona.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
Opportunity for local contractors to conduct restoration work increases.	Q1: Have opportunities for local contractors to conduct restoration work increased? Q2: What is the proportion of local to non-local awards? Q3: Where are the contractors located?	Q1/Q3: Location of businesses (zip code by county) Q2: Percentage of local contracted businesses (contractor and subcontractors) and total contractual amount for each (Sundstrom et al. 2011).	Comparative analysis of local contract awards vs. non-local number of contracts and respective value).	Every ten years or length of the contract.	Contracts: Federal databases USAspending.gov Forest Service Natural Resource Manager Database (Sundstrom et al. 2011).	Q1: Opportunities for local contractors to conduct restoration work has not increased. Q2/Q3: Local awards are proportionally lower than non- local awards (# of contracts and respective value).
Construction and/or improvement of infrastructure required for forest restoration activities increase revenues to local businesses.	Have revenues to local businesses providing supplies for infrastructure increased?	Revenues of local businesses providing supplies for infrastructure.	Economic Impact Analysis: Track flow of economic activity associated with construction and/or improvement of infrastructure.	Dependent on timing of infrastructure development /improvement.	1. Contractor reporting form/survey. 2. Local business reporting form/survey. 3. U.S. Bureau of Economic Analysis (Sitko and Hurteau 2010).	Revenues to local businesses Supporting construction and/or improvement of infrastructure does not increase.

IV. GOAL: The average net cost per acre of treatment and/or prep, administrative costs in the 4FRI project/analysis area are reduced significantly

Table E-18. Four Forest Restoration Initiative socioeconomic monitoring framework for economic systems, Goal IV

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
The average net cost (operational costs of the contract) of treatment per acre in the 4FRI project area over a thirty-year period (the life of the project) is decreasing over time.	Are the average net cost of treatment per acre that are attached to the contract in the 4FRI project area decreasing as new contracts are released and awarded?	Operational cost (per acre) attached to the contract (D Fleishman Personal Communication 2011).	Tracking and comparison of operational costs of contracts.	Every ten years or length of the contract.	1. Contracts: Federal databases: a. USAspending.gov b. Forest Service Natural Resource Manager Database (Sundstrom et al. 2011).	The average net costs of treatment per acre that are attached to the contract in the 4FRI project area are increasing as new contracts are released and awarded.
The average net cost of treatment per acre in the analysis area for preparation and administration costs are reduced over time.	Q1: What is the difference in average net cost of treatment per acre in the analysis area for preparation and administrative costs associated with different restoration designations (e.g., description vs. prescription)? Q2: Is average net cost of treatment per acre in the analysis area for preparation and administration costs reduced over time?	Costs include: 1. Project prep 2.Task order/ contract administration 3. Planning under NEPA/NFMA 4. Project management 5. Project-level monitoring 6. Contract monitoring (4FRI Stakeholder Group 2010c; Sitko and Hurteau 2010).	Q1: Cost effective analysis (Robbins and Daniels 2011). Q2: Tracking and comparison of prep and admin costs of contracts.	Every ten years or length of the contract.	Southwestern Region Restoration Task Group (4FRI Stakeholder Group 2010b).	Q1: Various restoration designation costs are not analyzed and compared. Q2: The average net cost of treatment per acre in the analysis area for preparation and administration costs is increasing over time.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
Mechanical treatment costs are reduced. * See Rx fire costs GOAL: Wildfire management costs are reduced; aggressive fire suppression is unneeded or rare (below).	Are mechanical treatment costs decreasing over time?	1. Move equipment and operators 2. Cutting 3. Skidding 4. Delimbing 5. Loading 6. Slash piling 7. Road Maintenance 8. Overhead (4FRI Stakeholder Group 2010c).	Tracking of mechanical costs over time.	5 years	Contractor surveys.	Mechanical treatment costs increasing over time.

V. GOAL: Sufficient harvest and manufacturing capacity exists to achieve restoration of at least 300,000 acres in the next ten years

Table E-19. Four Forest Restoration Initiative socioeconomic monitoring framework for economic systems, Goal V

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
Sufficient contractor capability exists to harvest approx. 30,000 acres per year.	Is there sufficient contractor capability to harvest approx. 30,000 acres per year?	1. Total number of contracts by work type, size and distribution (# of task orders & corresponding acres) (Mosley & Davis, 2010; Sundstrom et al. 2011; 4FRI Stakeholder Group 2010c). 2. Financial incentive programs (e.g., grants, loan guarantees, tax incentives) available to contractors (4FRI Stakeholder Group 2010c).	1. Track contracts by work type, size and distribution. 2. Track financial incentive programs.	Every ten years or length of the contract.	1. Contracts, Federal databases a. USAspending.gov b. Forest Service Natural Resource Manager Database (Sundstrom et al. 2011). 2. Contractor surveys 3. Headwaters Institute-Payments from Federal lands (financial incentive programs).	There is insufficient contractor capability to harvest approx. 30,000 acres per year.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
Sufficient private infrastructure exists to utilize woody biomass extracted from approx. 30,000 acres per year.	Is there sufficient private infrastructure to utilize woody biomass extracted from approx. 30,000 acres per year?	1. Volume of material produced per biomass plant vs. volume utilized. 2. Location of private infrastructure relative to harvesting activities.	Track type of infrastructure, location and corresponding processing capability.	Tracked annually across ten years (or length of the contract).	Contractor surveys.	There is insufficient private infrastructure to process woody biomass extracted from approx. 30,000 acres per year.
A sufficient workforce (public & private) exists to harvest and utilize wood byproducts extracted from approx. 30,000 acres per year.	Is there a sufficient workforce (public & private) to harvest and utilize wood byproducts extracted from approx. 30,000 acres per year?	1. # of FTE Forest Service employees designated for project planning, administration, and implementation. 2. # of FTE private sector employees designated for harvesting & processing. 3. Forest Service workload (dependent on current conditions- e.g., shift from overgrown forest to savanna system, shift from planning to implementation). 4. Forest Service workforce by position.	1. # of FTE Forest Service employees designated vs. # of Forest Service employees needed to plan/administer/ implement 30,000 acres per year. 2. # of private employees trained and hired vs. # of employees needed to harvest/process 30,000 acres per year. 3. Forest Service workload vs. Forest Service positions (M. Lata Personal Communication 2011).	Tracked annually across ten years or length of the contract.	1. Forest Service by forest. 2. Headwaters Institute (EPS-HDT Socioeconomic profiles). 3. Bureau of Labor Statistics (Stynes 1997). 4. Contractor reporting form/survey.	There is an insufficient workforce (public & private) to harvest and process woody biomass extracted from approx. 30,000 acres per year.

VI. GOAL: Wildfire management costs are reduced; aggressive fire suppression is unneeded or rare

Table E-20. Four Forest Restoration Initiative socioeconomic monitoring framework for economic systems, Goal VI

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
Direct wildfire suppression costs in 4FRI treated areas are reduced.	Q1: Are direct costs associated with wildfire suppression in 4FRI treated areas decreasing as forest restoration projects are implemented over time? Q2: What is the difference between direct wildfire suppression costs in 4FRI treated areas and treatment (planning, prep, admin & operational) costs?	Q1: Wildfire Suppression Costs: (as above). Q2: 1. Planning, prep, admin costs: (as above). 2. Operational Costs: (as above).	Q1: Wildfire suppression costs 5 years post-4FRI implementation (control for increases in population and housing) vs. wildfire suppression costs 5 years pre-4FRI implementation. Q2: Wildfire suppression costs 5 years post-4FRI implementation vs. treatment costs (planning, prep, admin & operational costs).	5 years	Q1: 1. Direct suppression costs obtained from: Forest Service, BLM, NRCD, NIFC, State, County, FEMA, DHS, Insurance companies, American Red Cross (Western Forest Leadership Coalition 2010). 2. Headwaters Institute (EPS- HDT Socioeconomic profiles). 3. Forest Service budget staff (D. Jaworski Personal Communication 2011). Q2: 1. Southwestern Region Restoration Task Group (4FRI Stakeholder Group 2010c). 2. Contractor surveys.	Q1: Direct costs associated with Wildfire suppression are increasing as forest restoration projects are implemented over time. Q2: Direct wildfire suppression costs are higher than treatment (planning, prep, admin & operational) costs.
Short-term (direct) rehabilitation costs are reduced.	Are short-term (direct) rehabilitation costs associated with wildfire rehabilitation decreasing as forest restoration projects are implemented over time (e.g., Burned Area Emergency Rehabilitation (BAER))?	BAER funds appropriated (tracked annually) (Western Forest Leadership Coalition 2010).	BAER expenditures 5 years post-4FRI implementation vs. BAER expenditures 5 years pre-4FRI implementation.	5 years (annual expenditures)	Forest Service BAER expenditure database (Western Forest Leadership Coalition 2010).	Short-term (direct) rehabilitation costs associated with wildfire rehabilitation are increasing as forest restoration projects are implemented over time.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
Wildfire suppression frequency and duration in 4FRI treated areas are reduced.	Are wildfire suppression efforts in 4FRI treated areas frequency and duration decreasing as forest restoration projects are implemented over time?	Frequency of wildfires. Duration of wildfires.	Frequency and duration of wildfires 5 years post-4FRI implementation vs. frequency and duration of wildfires 5 years pre-4FRI implementation.	5 years	Forest Service by Forests (Greater Flagstaff Forest Partnership 2010).	Wildfire suppression efforts frequency and duration are increasing as forest restoration projects are implemented.
Frequency and duration of wildfires with beneficial effects are increasing.	Are frequency and duration of wildfires with beneficial effects increasing as forest restoration projects are implemented over time?	Frequency of wildfires with beneficial effects. Duration of wildfires with beneficial effects.	Frequency and duration of wildfires with beneficial effects 5 years post-implementation vs. frequency and duration of wildfires with beneficial effects 5 years pre-implementation.	5 years	Forest Service by Forests (Greater Flagstaff Forest Partnership 2010).	Frequency and duration of wildfires with beneficial effects are decreasing as forest restoration projects are implemented.
Prescribed fire frequency and duration are reduced.	Are prescribed fire frequency and duration decreasing as forest restoration projects are implemented over time?	Frequency of prescribed fires. Duration of prescribed fires.	Frequency and duration of prescribed fires 10 years post-4FRI implementation vs. frequency and duration of prescribed fires 10 years pre-4FRI implementation.	10 years	Forest Service by Forests (Greater Flagstaff Forest Partnership 2010).	Prescribed fire frequency and duration are increasing as forest restoration projects are implemented.
Prescribed fire costs are reduced.	Are prescribed fire costs decreasing as forest restoration projects are implemented over time?	1. Burn plans 2. Prep work 3. Cutting hand lines" 4. Implement burn 5. Monitor burn (4FRI Stakeholder Group 2010c).	Costs of prescribed fires 10 years post-4FRI implementation vs. costs of prescribed fires 10 years pre-4FRI implementation.	10 years	Forest Service budget staff (D. Jaworski Personal Communication 2011).	Prescribed fire costs are increasing as forest restoration projects are implemented.
Reduce size, and frequency of pile burns.	Q1: Is the frequency and size of pile burns decreasing as forest restoration projects are implemented over time? Q2: Is the volume of slash that is chipped (not burned) increasing?	Q1: 1. Frequency of pile burns. 2. Size of pile burns. Q2: Volume of slash that is chipped.	Q1: Frequency and size of pile burns 10 years post-4FRI implementation vs. frequency and size of pile burns 10 years pre-4FRI implementation. Q2: Volume of slash chipped 10 years post-4FRI implementation vs. volume 10 years pre-4FRI implementation.	10 years	Forest Service by Forests (Greater Flagstaff Forest Partnership 2010).	Size and frequency of pile burns is increasing and volume of slash that is chipped is decreasing as forest restoration projects are implemented.

VII. GOAL: There is a sufficient market place for small diameter wood products

Table E-21. Four Forest Restoration Initiative socioeconomic monitoring framework for economic systems, Goal VII

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
A sufficient market exists to consume wood biomass products.	Is there a sufficient market to sell wood biomass products?	1. # of businesses and type of wood biomass material purchased (e.g., clean chips, dirty chips, roundwood and sawtimber) (Sitko and Hurteau 2010). 2. Dollar amount and/or percent of available inventory/sales businesses purchased.	Economic Impact Analysis: include # of businesses, type of small diameter wood material purchased and dollar amount and/or percent of available inventory/sales businesses purchased.	5 years	Business surveys	There is an insufficient market to sell small diameter wood products.
Economic value of wood biomass products is sufficient to profitably process small diameter wood products.	Does the market value of wood products exceed production costs?	Sales ($ value) of wood products. Production costs: raw materials (wood products), hauling, petroleum products, mill equipment/ parts, heavy equipment/parts, electricity, vehicle parts/tires, and transport equipment (Sitko and Hurteau 2010).	Financial analysis: Compare sales of wood products to production costs.	5 years	Business surveys	The market value of wood products does not exceed production costs.
Increase the amount of wood products (wood biomass and value-added) that are processed locally.	What is the proportion of biomass processed locally vs. non-local?	Number of local businesses processing small diameter wood products. Number of non- local businesses processing small diameter wood products. Amount of wood (volume) products processed locally. Amount of wood (volume) products processed non-locally (Greater Flagstaff Forest Partnership 2005).	Compare # of local vs. non-local businesses (percent each). Compare local vs. non-local business volume of wood product production (percent each).	5 years	Contractor surveys. Contracts, Federal databases USAspending.gov Forest Service Natural Resource Manager Database (Sundstrom et al. 2011).	The proportion of biomass processed locally is lower than biomass processed outside of the defined local area.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
Increase the amount of wood products (wood biomass and value-added) that are distributed locally.	Q1: Where are the wood products distributed? Q2: What is the proportion of end-products distributed locally vs. non-local?	Q1: Location of wood product distribution. Q2: Volume/quantity of wood products distributed locally and non-local.	Compare location of wood product distribution and proportion of volume of wood products distributed locally vs non-local.	5 years	Contractor surveys. Contracts, Federal databases USAspending.gov Forest Service Natural Resource Manager Database (Sundstrom et al. 2011).	Q1/Q2: The amount of wood products (small diameter and value-added) that are distributed locally are not increasing.
Investment, research and development in utilization of wood biomass are increasing.	Is investment, research and development in utilization of wood biomass increasing?	Number of forest product industries involved in market research for small diameter wood uses. Amount invested by businesses for development and research. Type and amount of market analysis. Number of companies applying for grants that support small diameter market research (Greater Flagstaff Forest Partnership 2005).	Track # involved in market research for small-diameter wood uses, amount invested, type and intensity of market research, # of companies applying for grants supporting small diameter product development.	5 years	Contractor/ business surveys. Headwaters Institute	Investment, research and development in utilization of small diameter trees is not increasing.
Uses for wood biomass and/or value-added products are expanded and diversified.	Q1: What is the type and proportion of the production of wood biomass end-products? Q2: Are uses for wood biomass and/or value- added products expanding and diversifying?	Q1/Q2: Percentage production of: Pellets, Pallets, Molding, Small lumber, Biomass-energy, Livestock bedding, Soil fertilizers, (Sitko and Hurteau 2010) OSB, Plywood, Particle board, Fiberboard, Roundwood products (4FRI Stakeholder Group 2010c).	Compare percent of production of type of wood products and track over time.	5 years	Contractor/business surveys.	Q1/Q2: Uses for small diameter material and/or value-added products are not expanding and diversifying.

VIII GOAL: There is a predictable wood supply throughout the life of the 4FRI project

Table E-22. Four Forest Restoration Initiative socioeconomic monitoring framework for economic systems, Goal VIII

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
Ensure the availability of forest material at a sustainable, consistent level to support appropriate forest product industries throughout the life of the 4FRI project.	Q1: Are the length of contracts sufficient to recover costs and realize return on investment? Q2: Do contracts provide the flexibility to respond to fluctuating markets (e.g., pile and burn slash vs. removal) & redetermination of wood product's value? Q3: Do contracts provide guaranteed treatable acres that will provide a return on investment? Q4: Are objections and lawsuits for 4FRI projects hampering the project's progression?	Q1: 1. Length of contracts. 2. Operational cost incurred to complete contracts (as above). 3. Wood yields and respective value/contract. 4. Number of acres/year Forest Service admin planning are complete. Q2: 1. Pile/burn costs 2. Slash removal costs 3. Wood product value Q3: 1. Avg. wood yield/ treatable acres/contract 2. Operational cost incurred to complete contracts (as above). Q4: Number and length of time (each) of objections and lawsuits that are delaying the 4FRI project's progression.	Q1: Economic Impact Analysis: 1. Operational costs vs. wood yields and respective value. 2. # of acres Forest Service admin/planning are complete vs. # of acres/contract. Q2: Contract analysis of: 1. Pile/burn slash costs vs. removal costs. 2. Valuation of wood products. Q3: Avg. wood yield per treatable acres/contract and its respective value vs. operational costs. Q4: # & length of time of lawsuits; # of delayed treatable acres, volume and its value.	Ten years or length of the contract.	Q1-Q3: 1. Contractor surveys 2. Forest Service business plans (D. Jaworski Personal Communication 2011). 3. Contracts: Federal databases a. USAspending.gov b. Forest Service Natural Resource Manager Database (Sundstrom et al. 2011). 4. Headwaters Institute Q4: Objections database available at: https://www.fs.fed.us/objections/objections_list.php?r=110300	Q1: The contracts are not long enough to recover costs and realize a return on investment. Q2: Contracts do not provide the flexibility to respond to fluctuating markets & redetermination of wood product's value. Q3: Contracts do not provide guaranteed treatable acres that will yield a return on investment. Q4: Objections and lawsuits for 4FRI projects are significantly delaying the project's progression (acres treated & respective value).

Acronyms used within Socioeconomics Framework Tables

- AZG&F: Arizona Game & Fish Department
- BAER: Burned Area Emergency Rehabilitation
- BLM: Bureau of Land Management
- DHS: Department of Homeland Security
- FEMA: Federal Emergency Management Agency
- NEPA: National Environmental Policy Act
- NIFC: National Interagency Fire Center
- NFMA: National Forest Management Act
- NMFS: National Marine Fisheries Service
- NRCD: Natural Resource Conservation Districts
- SRP: Salt River Project Power & Water
- SWRRTG: Southwestern Region Restoration Task Group
- WMSC: White Mountain Stewardship Contract
- FWS: United States Fish & Wildlife Service

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