Appendix E – Four Forests Restoration Initiative Adaptive Management, Biophysical and Socioeconomic, Mexican Spotted Owl and Arizona Bugbane Monitoring Plan

Outline of This Plan

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Introduction

The pace and scale of 4FRI is likely to affect many aspects of the ponderosa pine ecosystems of northern Arizona. The anticipated effects of our treatments are disclosed in the first analysis area Environmental Impact Statement (EIS). Monitoring will help determine if the intended effects are achieved, recognizing that our management should improve as monitoring information is collected and applied.

This section is intended to: 1) clarify the process for both monitoring and adaptive management in the 4FRI landscape; 2) clarify the requirements for monitoring; and 3) describe the collaboratively-developed monitoring and adaptive management plan that is the foundation of the multi-party monitoring framework. The 4FRI Collaborative Stakeholders Group (stakeholders) and the U.S. Forest Service (USFS) coordinated on the design of this monitoring and adaptive management plan, with the intent of integrating it in FEIS and implementing it within the entire 4FRI project. The 4FRI Stakeholder group will also create a Multi-Party Monitoring Board (Monitoring Board) which will work with the USFS to oversee monitoring prioritization, implementation, data storage and assessment. All monitoring results, including positive progress towards desired conditions, and unexpected benefits or challenges, will be used for stakeholder learning and developed into outreach material for broader dissemination.

The selected indicators are based on the desired conditions that were described in not only the purpose and need section but also within each specialist report for the 4FRI project. The emphasis of this project is the restoration of a fire adapted ecosystem. Restoration is defined as “the process of assisting the recovery of resilience and adaptive capacity of ecosystems that have been degraded, damaged, or destroyed. Restoration focuses on establishing the **composition, structure, pattern** and **ecological process** necessary to make terrestrial and aquatic ecosystems sustainable, resilient and healthy under current and future conditions.” (FSM 2020.5) The monitoring and adaptive management plan outlines how we will use a multi-scaled suite of indicators and sampling strategies to assess the changes that result from management actions and determine the degree to which they meet desired conditions. Monitoring is intended to determine whether management actions positively affect the ecological processes within the project area and the greater landscape.

While the 4FRI project as a whole encompasses a 2.4-million acre landscape, this analysis area only represents approximately one half of that area. The monitoring and adaptive management plan details the framework and process for monitoring within this analysis area; however, we intend to apply it across the entire initiative area.

Adaptive Management Process:

The 4FRI Project is a long-term forest restoration effort that is unprecedented in scale in the southwest region. Implementation of the entire project is anticipated to take over 20 years. Coupled with this size and scope, the project is occurring as the southwest is experiencing increased climatic changes, such as periods of extended drought and increased temperatures—the effects of which are unknown or at a minimum, untested. The uncertainties inherent in a project of this magnitude mandate that management actions be flexible to accommodate needed modifications. This adaptive management plan is intended to provide information that can help the Agency respond to changing conditions and new knowledge.

Adaptive management refers to a “rigorous approach for learning through deliberately designing and applying management actions as experiments” (Murray and Marmorek 2003). Monitoring of alternative management actions provides the data for the adaptive management process. When used in an adaptive management framework, monitoring should link landscape management with learning, and ultimately allow for improved efficiency in planning and implementation.

The USFS and Stakeholder Group have collaboratively developed the monitoring and adaptive management plan by taking the desired conditions, and selecting a suite of indicators and metrics that best measure trends towards those desired conditions. To assure that adequate metrics are used to assess trends, the indicators were selected based on attributes that can be easily measured, are precise, sensitive to changes over time, and that satisfy multiple objectives of the monitoring process (Eagan and Estrada-Bustillo 2011, Moote 2011, Derr et al. 2005). Once the indicators were selected, triggers (sometimes described by thresholds) were identified that signify a movement towards an undesired outcome; triggers can help indicate whether or not a change in management is advisable. In some cases, the most current scientific knowledge still does not provide sufficient information to identify quantitative triggers; when this occurs, monitoring data will be analyzed to help develop triggers for future management.

To assure success of the monitoring program, a clear link describing how monitoring information will be utilized in future decision-making is essential (Noon 2003, Williams 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). When there is sufficient information to develop a threshold that suggests a trend away from the desired conditions, this plan goes on to describe and outline the potential adaptive management actions. 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 USFS and the multi-party monitoring board will collaboratively evaluate the monitoring data 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, collecting more refined data, implementing the existing adaptive management action or developing a new adaptive management action. The Stakeholder group may choose to recommend adaptive management actions to the USFS. USFS staff may also develop new adaptive management actions internally. This is a collaborative process; however, ultimately, the deciding official determines what management actions will be implemented.

As the project matures and baseline data is collected, thresholds can be refined to describe specific quantitative ranges that will trigger adaptive management actions. Stakeholders and the USFS are committed to a strong adaptive management process. Concerned 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 Coatlition 2011). As such, we expect that the Stakeholders will continue to work closely with the USFS and recommend adaptive management actions.

The monitoring and adaptive management plan is intentionally designed as a living document. There is an expectation that indicators, metrics, methods, thresholds, adaptive management actions and monitoring priorities will change (adapt) over the course of the project as information is gained and new questions are revealed. The USFS will collaborate with the Stakeholder Group as we make changes and assess monitoring priorities throughout the life of this document. However, adaptive management actions and their anticipated effects must fall within the scope of those analyzed within the FEIS. If management actions or effects are anticipated to exceed the scope, additional NEPA analysis may be required.

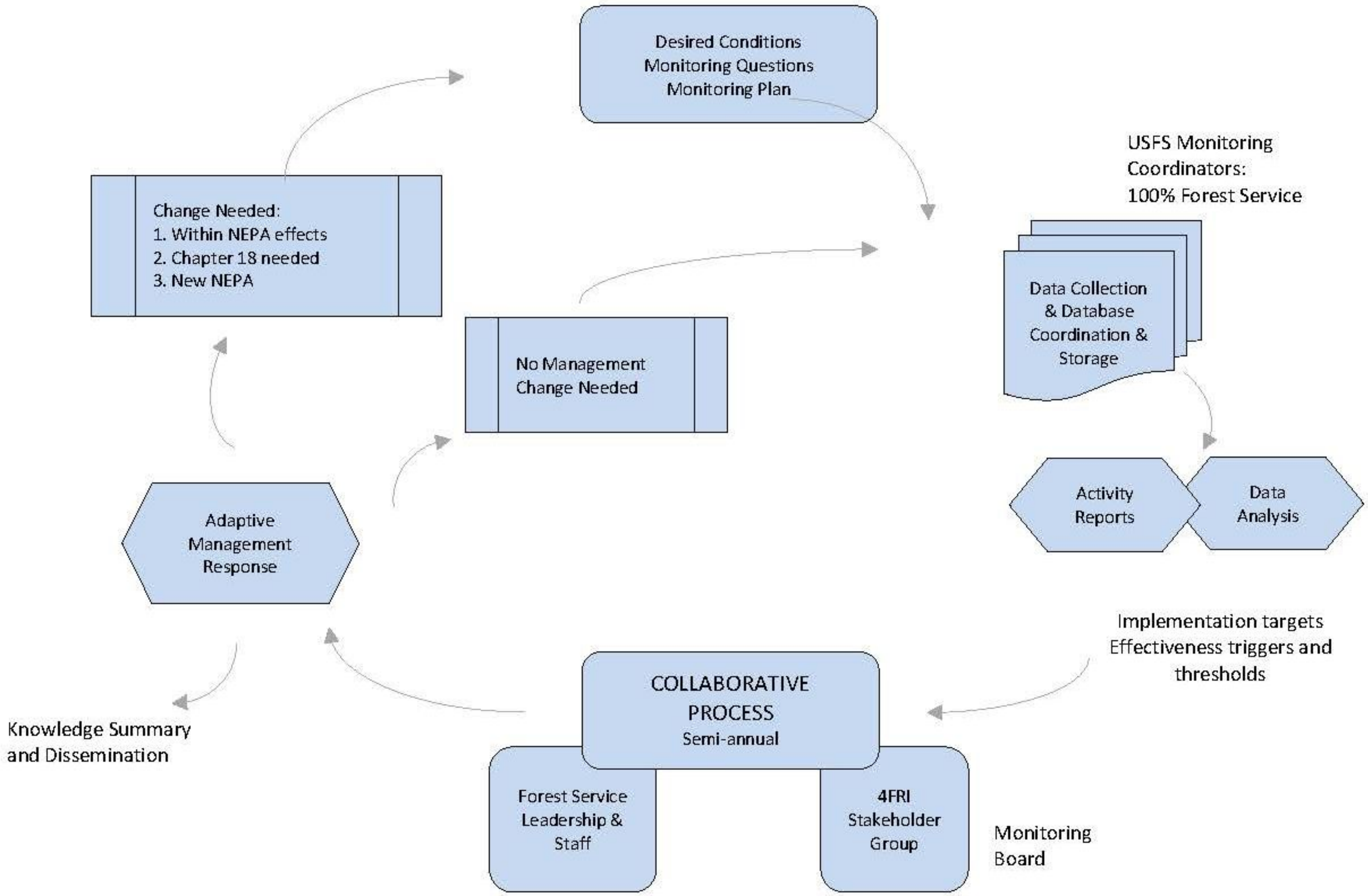

Figure 68. 4FRI adaptive management process

Monitoring

Requirements for Monitoring

The 4FRI Project is supported by multiple federal mandates, regulations, and funding programs. As such, there are different monitoring requirements for each of these programs.

Collaborative Forest Landscape Program

In 2010, the 4FRI project was selected for funding under the Collaborative Forest Landscape Program. The purpose of the Collaborative Forest Landscape 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 (U.S. Congress 2009).

Section g-3 of the Act specifies annual reporting on the accomplishments of each selected project. Annual reporting includes: 1) a description of all acres treated and restored through projects implementing the strategy; 2)an evaluation of progress, including performance measures and how prior year evaluations have contributed to improved project performance; 3) a description of community benefits achieved, including any local economic benefits; 4) the results of multiparty monitoring, evaluation, and accountability process. Items 1-3 are compiled locally and sent to the USFS's Washington Office for annual reporting. The multi-party monitoring (item 4) focuses on effectiveness monitoring and reporting timeframes are dependent on the variables measures but will be included in the 5, 10 and 15-year Collaborative Forest Landscape Restoration Act reporting. Multi-party indicator monitoring is accomplished through a partnership of USFS and partner funding and staff.

The Collaborative Forest Landscape Restoration Project requires multiparty monitoring and reports at 5, 10 and 15 years post the authorizing Act (2009) that include national indicators to assess project goals. Each year, the Four Forest Restoration Initiative receives congressionally appropriated funds under the CFLN budget line item. The amount varies annually; however, the USFS agrees to dedicate 10 percent of the annual CFLN funds to monitoring activities. Monitoring activities covered by this 10 percent allocation are expected to include some of the pre-treatment monitoring, post-treatment effectiveness monitoring and TES species monitoring; however, it will not typically cover implementation monitoring which is funded through the operational budget. More details are provided below.

As the first 15,000 – 30,000 acres of task orders within the 4FRI project area are implemented, monitoring activities will test the assumptions within this document, verify that desired conditions are being achieved, and help refine the adaptive management process. The USFS may use funding sources other than CFLN to support monitoring; however, collaborative partners are expected to support monitoring efforts by soliciting and contributing both in-kind and monetary funds from other sources. National forests may complete project level implementation and compliance monitoring with funding from stewardship retained receipts (see Stewardship Contracting below) as outlined in FSM 2409.19 section 67.2, 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.

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, 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.

Types of Monitoring

Ecological (also referred to as environmental) 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, monitoring can provide valuable feedback regarding the effects of land management on resource conditions (Palmer and Mulder 1999, Lindenmayer and Likens 2010).

Social monitoring is done to assess society’s perceptions on an issue or groups of issues. Changes in these perceptions are assessed through time as issues change in scope or context.

Economic monitoring is done to assess the economic impact of the 4FRI project. Monitoring activities related to land management can be further classified into three categories: implementation, effectiveness, and validation (Busch and Trexler 2003).

Implementation monitoring is designed to determine the extent to which a management action was carried out as designed (did we do what we said we were going to do?). Implementation monitoring is closely associated with Process monitoring as described above.

Effectiveness monitoring tracks the extent to which the management action achieved its ultimate objective. Effectiveness monitoring refers to an assessment of treatment effects, rather than to measuring whether they were applied as intended or whether they validate a pre-existing concept.

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.

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 that will be a result of the proposed actions. Monitoring efforts use indicators to determine how progress is made towards desired conditions. Thresholds and triggers can be considered as benchmarks that inform management directions (i.e. maintain or modify) (Ringold et al. 1999, Lindenmayer and Likens 2010). These desired conditions 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 taken from chapter 1, the purpose and need, as well as in chapter 3, the Effects Analysis. The desired conditions and the associated monitoring indicators, thresholds and triggers are presented in table 148. 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

Financial resources (both USFS and Stakeholder contributions) will be dedicated to monitoring. However, it is well understood that there will be insufficient funds to monitor all the indicators over the entire treatment area. A multiparty monitoring board will meet periodically to, among other things, prioritize indicator monitoring and identify geographic locations to be monitored. Budgetary limitations will dictate how much and what type of monitoring can be accomplished.

Implementation/compliance monitoring will meet legal and regulatory requirements (table 148) and will be completed annually by the Forest Service using the operational budget. Effectiveness monitoring is also a priority and a key component in meeting our adaptive management goals; however, only a subset of the 4FRI treatment areas will be monitored and, at any one location, only some of the monitoring indicators will be assessed. To help the multiparty monitoring board determine what effectiveness monitoring will be accomplished with available funds, this plan provides a tiered system for monitoring.

Prioritization of the indicators within each tier is expected. All of the Tier 1 indicators need not be monitored before those in Tier 2. Monitoring activities described in the Mexican Spotted Owl and Arizona Bugbane sections will take priority over all other monitoring activities since the biological opinion provided by the US Fish and Wildlife Service is contingent upon that monitoring. Indicators associated with socioeconomic monitoring are considered Tier 1 and will be prioritized along with all of the biophysical indicators.

As new information becomes available and new questions are raised, the indicators or their order of priority may change. Research, which is a part of validation monitoring, is independent of implementation and effectiveness monitoring and will be funded strictly by external entities. The results of relevant research should inform future monitoring prioritization and adaptive management decisions. Table 146 displays the effectiveness monitoring tiers and how they will be prioritized.

Table 146. Effectiveness monitoring tiers and prioritization

Tier 1	1	Multiparty • USFS • Stakeholders • Agency Partners	Effectiveness	Appropriated, Partner
Tier 2 (includes research)	2	Multiparty • USFS • Stakeholders • Agency Partners • Research Advocate	Effectiveness, Research, Validation	Appropriated, Partner, Research Advocate

Monitoring Scale

The 4FRI will implement management activities at scales beyond those typically used in the management of the National Forests. As such, it is helpful to provide clarification of the scales described in this document. The Forest Service and the Stakeholders sometimes use different terms to describe the same scales. For example, the Forest Service uses the term restoration unit to represent areas ranging in size from 10,000 acres to 100,000 acres. However, stakeholders consider some of the sizes within that range to be a treatment area and some to be a firescape. Table 147 provides a crosswalk of the terminology used by the Forest Service and the Stakeholders to describe various spatial scales. For ease of understanding, all terms have been simplified and grouped as “fine” or “broad” scales indicators. 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 “site” scale, depending on the questions and information needed to make informed decisions.

Table 147. Scale terms used by different groups and within this document

Size in Acres	Stakeholders: 4FRI Landscape Strategy	Forest Service: 4FRI EIS Coconino and Kaibab	Desired Conditions and Monitoring Indicators used in the Monitoring Plan
< 1	Group		Fine
1-1,000	Site	Stand	Fine
1,000-10,000	Treatment Area	Sub-unit	Broad
10,000-100,000	Treatment Area / Firescape	Restoration Unit	Broad
100,000-1,000,000+	Firescape, Analysis Area, Landscape	Analysis Area	Broad

Implementation Monitoring Plan

Introduction: Implementation monitoring is designed to determine the extent to which a management action 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 measureable progress towards the desired conditions established within this analysis and the forest plans. Appendix C describes a series of design features, BMPs and mitigations that are common to all action alternatives (B-

D). Appendix D contains the silvicultural design features and the implementation plan. The directions in these appendices are the foundation for all management actions.

Indicator: We employ two indicators to monitor implementation. The first is a quantitative measure of area, volume or distance treated for each natural resource. The second measure is compliance; either the activities were completed in full compliance with all design features, best management practices and mitigations, or they were not.

Scale: As these indicators are related to implementation, they are evaluated at a spatial scale of either the treatment unit area or full task order area.

Method: Compliance with the design features, BMPs, mitigations and the implementation plan will be evaluated at multiple stages. During the development of formal prescriptions, the silviculturist will use the directions in Appendix C and Appendix D to develop the site-specific treatment design. The relevant directions will be brought forward as needed into contract documents. The contract administrators will monitor day to day activities of the contractors as they implement the treatments to ensure compliance. After the task order is completed, resource specialist will also evaluate the finished product to ensure that there is full compliance. Quantitative implementation monitoring ensures compliance through annual reporting requirements.

Data Source: The data sources for compliance indicators are typically sale administrators who monitor the day to day execution of each task order or resource specialists who conduct post-project inspections. The data sources for quantitative indicators 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 $500,000 – $700,000 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 compliance monitoring protocols. In the event of a reporting failure, the reports will be corrected to properly reflect the relevant land management activities. The reporting process will be re-evaluated and additional assurance measures may be put in place.

Table 148. Implementation monitoring questions and indicators

Monitoring Questions Derived from Desired Condition	Monitoring Indicator	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? When appropriate, were adaptive actions employed as described in chapter 2, Table 19?	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
Did management activities minimize or mitigate undesired impacts to scenery, recreation resources and recreation opportunities 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 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 Indicator	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 in accordance with design features, BMPs, and mitigation measures? When appropriate, were adaptive actions employed as described in chapter 2, Table 19?	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 prescribed burned, acres burned in managed fire	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 forest 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, Arizona Bugbane and Flagstaff pennyroyal; 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

Monitoring Questions Derived from Desired Condition	Monitoring Indicator	Assessment Method	Frequency of Measurement
Did management activities adequately protect Bebb's willow from fire and ungulates 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
Were planned prescribed fires coordinated with neighboring forests and other affected agencies and communities?	Compliance	Contract inspection 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	Contract inspection and specialist 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 crown fire potential and movement toward FRCC 1?	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	Contract inspection and specialist review	Ongoing and at post-project review

Biophysical Monitoring Plan

Biophysical Monitoring for Structure and Pattern:

The USFS distinguishes between desired conditions related to pattern versus those related to structure. Structure relates to the age distribution and the vertical spatial arrangement of the overstory of the forest, while pattern refers to the horizontal distribution of vegetation across a stand or a landscape.

Relevant Desired Conditions

I. **Conservation of Biological Diversity:**

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

b. Where fire use is not possible, mechanical treatments are designed to restore and/or maintain forest structure over time.

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

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

II. **Ecosystem Resilience:**

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

III. **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.

Description and Justification

Many of the desired conditions related to structural components of ponderosa pine forests specify a need for heterogeneous forests that more 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). 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 benefit and affect native plant and animal diversity will require a multi-scaled approach to characterizing several aspects of structural diversity. Wildlife and plants respond to their environment across multiple spatial and temporal scales (Wiens 1989). Indeed, 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" (i.e., 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, spatial aggregation

- **Age Structure (Diameter Distribution)**: While collecting this information pre-treatment and post-treatment will likely require a fairly intensive field effort, it will allow us to measure structural complexity in terms of age (size) structure and will 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:** Immediately post-treatment (either mechanical or prescribed fire); every 10 years thereafter.
  - **Threshold/Trigger:** No threshold determined for this indicator. Also see implementation plan which includes if and how the Large Tree Implementation Plan will be used for specific task orders.
  - **Adaptive Management:** Evaluate reasoning for implementing large tree removal. If needed, appropriate adaptive management actions will be developed.
- **Spatial Aggregation (Ripley's K and/or Getis Ord):** Measures of spatial aggregation can be used to determine "patchiness". Statistical tests such as Ripley's K and Getis Ord can be used to describe spatial properties such as the distribution and clustering of trees as well as canopy cover. These properties can be compared to those of "restored" areas to measure our progress towards historic conditions.
  - **Assessment:** Freely available pre- and post-treatment aerial photography of stands identified for treatment
  - **Frequency:** Immediately post-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 will be thoroughly reviewed and appropriate adaptive management actions will be developed.

Broad-Scale Assessment

Tier 1 Suggested Indicators: Canopy openness, patch size, patch configuration, patch diversity, and patch evenness.

- **Canopy Openness (Percent and Characteristics of Openings):** Because many of the treatment types being applied within 4FRI are designed explicitly to achieve a particular post-treatment percentage of canopy openness, we will measure the pre- and post-treatment percentage of canopy cover. This indicator in conjunction with the spatial aggregation statistics can help describe the degree to which 4FRI treatments are achieving “patchiness” and the degree to which those patches vary. Also, tracking the size and orientation of forest openings is important to determine their impacts on snowpack accumulation and retention that affect soil moisture, plant- available soil water and system resilience to climate variability.
    - ♦ **Assessment:** Utilize USFS tools 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).
    - ♦ **Frequency:** Immediately post-treatment (either mechanical or prescribed fire) or as soon as appropriate aerial photography becomes available; every 3-10 years thereafter.
    - ♦ **Threshold/Trigger:** A deviation from the structure described in table 64 of the Silviculture report
    - ♦ **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):** Patch area is a fundamental quantity for understanding landscape composition that can be used both to calculate a variety of other indicators as well as model species richness, occupancy, and distribution in conjunction with field data. Patch density can be used as an index for spatial heterogeneity across a landscape, but has the added utility of being comparable across areas of differing size (e.g., comparisons between treatment areas or restoration units) (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 spatial extents beyond the stand-level and can be calculated within the freely available 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 will be thoroughly reviewed and appropriate adaptive management actions will be developed.

- **Patch Configuration (Nearest neighbor distance distribution and Contagion):** 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 a fairly even distribution of patches across the landscape. Contagion measures both the intermixing of different patch types as well as 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).
  - ♦ **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 will be thoroughly reviewed and appropriate adaptive management actions will be developed.

- **Diversity and Evenness (Simpson's Diversity and Evenness Indices):** These measures have been historically associated with estimates of species diversity; however, in this case they are being used to assess the diversity of patch types across the landscape. Simpson's diversity index represents the probability that any two randomly drawn patches will be of a different type. A higher value indicates greater diversity of patch types. Similarly, larger values of evenness indicate greater landscape diversity (i.e., less dominance by any particular patch type). FRAGSTATS implements a variety of diversity and evenness indices; however, these were selected because they are considered easier to interpret (McGarigal and Marks 1995, Magurran 2004).
  - ♦ **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 will be thoroughly reviewed and appropriate adaptive management actions will be developed.

Tier 1 Suggested Indicators: Soil moisture relative to forest opening size and orientation

- Forest openings, depending on their size and orientation, promote greater snowpack accumulation and retention and hence greater soil water storage (Baker and Ffolliott 2003). Deeply rooted plants, such as mature ponderosa pines, that depend on moisture from winter precipitation are expected to be the most affected by changes in snowpack. Per-tree plant-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 perhaps even resistance to wildfire. If, however, restoration treatments push soil moisture in the opposite direction, recognizing such a trend is critical information that can direct adjustments in treatment approaches. 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
- **Frequency:** Pretreatment, post-treatment, annually during pre- and post-monsoon water stress periods
- **Threshold/Trigger:** Trends of decreasing soil moisture (after adjusting for climatic variability) in stands with similar treatment types and/or physiographic characteristics.
- **Adaptive Management:** 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.

Monitoring for Composition

Relevant Desired Conditions

I. **Conservation of Biological Diversity:**

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

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

   c. All pre-settlement trees are retained.

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

   e. Protect old-growth forest structure during planned and unplanned fires. [Implementation Monitoring]

   f. Natural and prescribed fires maintain and enhance but do not degrade habitat for listed, rare, and sensitive species.

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

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

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

II. **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.

III. **Conservation and Maintenance of Soil, Water, and Air Resources:** Emissions factors, smoldering and smoke residence times are reduced as fires burn more grass and less green or woody biomass over time.

Description and Justification

Many desired conditions are specified to reflect a number of aspects of forest composition. Both the USFS desired conditions for ponderosa pine and 4FRI Stakeholder desired conditions identify certain patch components (e.g., 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 pine 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 being used in the 4FRI NEPA analysis. However, stand replacing wildfire in ponderosa pine 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 both viability and natural patterns of distribution and abundance. Historically, viability has been difficult or impossible to assess particularly when resources are limited due to the difficulty of gathering reliable estimates of all of the 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 declines in a species such that it may become unviable particularly when the demographic data necessary for calculating fitness or viability are unknown. 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 4FRI 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, through multi-season extensions, provide information related to population trends. Estimating occupancy often require fewer detections than other density estimation techniques allowing for more precise estimates of rare or infrequently detected species (MacKenzie et al. 2003, MacKenzie et al. 2005). Furthermore, efforts to relate occupancy to habitat-relevant covariates allow estimation and prediction of changes in population state due to coarser-scale changes in land-use and climate (e.g., 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 (e.g. 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 will require significant resources to assess. Financial support from stakeholders and other organizations will be required to adequately monitor these indicators.

Fine-scale Assessment

Tier 1 Suggested Indicators: Rare Ecosystem Elements (Springs Protection)

Forest restoration thinning has the potential to improve the hydrogeology of springs by increasing soil water storage and groundwater recharge (McCarthy and Dobrowolski 1999). Because springs create rare habitat for multiple threatened species as well as more common wildlife species, understanding the relationship between treatments and spring responses is critical for making adaptive management decisions to optimize springs restoration projects. A collaborative group with skills in spring assessment is available to assist Coconino and Kaibab National Forests in selecting springs for monitoring and restoration. Current partners in the collaboration include Northern Arizona University (NAU), Grand Canyon Trust, Grand Canyon Wildlands Council and the Spring Stewards, but more partners may join in the collaboration at any time.

- **Assessment:**
  - ♦ Groundwater Dependent Ecosystems Protocol (USDA FS 2011)
  - ♦ Spring discharge measurements
- **Frequency:** Pre- and post-treatment, every two years following treatment for the first 6 years after treatment, then every 5 years.
- **Threshold/Trigger:**
  - ♦ No net increase in facultative and obligative wetland species at springs or wet meadows targeted for both forest and spring restoration.
  - ♦ Decrease in spring discharge (adjusted for climate variation) following treatments.
- **Adaptive Management:** Review spring restoration techniques. Review treatment methods in the recharge area. Make appropriate adjustments.

Tier 1 Suggested Indicators: Understory Species Composition (Percent Foliar Cover, Percent Bare Ground)

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 quadrats.
- **Frequency:**
  - Within 5 years of treatment for cover
  - Within 5 years of treatment for bare soil
  - Within 10 years of treatment for seedlings
- **Threshold/Trigger**:
  - Within 5 years of mechanical treatment, the cover should increase 20 percent +/- 5 percent (15-25 percent) above controls (Laughlin et al 2011).
  - Within 5 years of treatment (mechanical and/or fire), bare soil should comprise less than 20 percent of area affected by treatment.
  - 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).
- **Adaptive Management**:
  - If cover threshold is not reached, then re-evaluate treatment for management change, taking into account soils and burn treatment (e.g. reduce overstory basal area).
  - If bare soil exceeds 20 percent of area within plots, re-evaluate restoration treatment for modification.
  - If seedlings and saplings fall below this range across sub-units where regeneration is a desired condition, then evaluate implementation of BMPs to increase probability of successful regeneration. If regeneration falls above this range, then more aggressive prescription burning may be necessary to reduce plant density.

Tier 1 Suggested Indicators: Understory Species Composition (Invasive species)

With regards to invasive species control, the first and most important management strategy is preventing the establishment or spread of invasive species. The best way to achieve this is by increasing the health and resilience of native plant communities. Below is a list of species most likely to be affected by management.

Watch List: These species are currently not known to fall within 4FRI treatment areas, and if they do show up and are detected, aggressive eradication efforts should be a top priority and applied quickly.

These species include Malta starthistle (*Centaurea melitensis* L.), Russian olive (*Eleegnus angustifolia*), Himalayan blackberry (*Rubus armeniacus* and *Rubus discolor*), giant reed (*Arundo* donax), sulfur cinquefoil (*Potentilla recta*), tree of heaven (*Ailanthus altissima*), Siberian elm (*Ulmus pumila*), halogeton (*Halogeton glomeratus*), dyer's woad (*Isatis tinctoria*), Eurasian water-milfoil (*Myriophyllum spicatum*), oxeye daisy (*Leucanthemum vulgare*), and Canada thistle (*Cirsium arvense*).

High Risk: These species currently have limited geographic distribution within 4FRI treatment areas, and if current inventories indicate their presence within treatment areas, these species should be eradicated immediately.

These species include 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*), Mediterranean sage (*Salvia aethiopis*), Scotch thistle (*Onopordum acanthium*), tamarisk (*Tamarix* spp.), common teasel (*Dipsacus sylvestris*), and musk thistle (*Carduus nutans*).

Medium Risk: 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., pine- sagebrush ecotones). Weed treatment strategies be monitored for effectiveness to gauge return on investment.

These species include Dalmatian toadflax (*Linaria dalmatica*), bull thistle (*Cirsium vulgare*), and wild oats (*Avena fatua*).

Cheatgrass *(Bromus tectorum)*: Cheatgrass invasion of ponderosa pine systems after restoration-based treatments is a burgeoning issue of significant concern (Keeley and McGinnis 2007, McGlone et al. 2009a and b). Widespread invasion of cheatgrass often shifts invaded ecosystems into irreversible alternate stable 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 4FRI project. Preventative actions pre-treatment 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- and immediately post-disturbance (i.e., mechanical thinning, prescribed fire, and wildfire); every 5 years thereafter.
- **Thresholds/Triggers**:
  - ♦ Identification of new or existing “watch list” or “high risk” invasive species populations.
  - ♦ Identification of new or existing “medium risk” invasive species populations.
  - ♦ Identification of areas at high risk of cheatgrass introduction or spread.
- **Adaptive Management**:
  - ♦ If inventories, surveys and map checks indicate presence of 'high risk' or 'watch list' species (see narrative), evaluate all BMPs, especially for cleaning equipment moving from infested sites to clean sites. Consider aggressive treatments leading to population eradication. If treatments do not reduce the cover of “watch list” species by 90 percent in one year or “high risk” species by 50 percent in 2 years, consider new approaches to eradication.
  - ♦ 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 by 20 percent in 5 years, consider new approaches to weed 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):[5]
    - 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

Old Trees (Number of Old Trees): The 4FRI Landscape Strategy places a large emphasis on pre- settlement trees. Furthermore, higher levels of biodiversity have been attributed to those areas that still 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**: Immediately post-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 will be thoroughly reviewed and appropriate adaptive management actions will be developed.

Tier 2 Suggested Indicators: Habitat Suitability (Occupancy Probability)

Occupancy, in cases where sample sizes are large, can be defined as the proportion of total area occupied and 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

[5] If cheatgrass begins to dominate restoration sub-units after thinning and burning treatments within the 4FRI project area, consider delaying further treatments in areas of high risk until the Forest Service, stakeholders and experts can be convened to evaluate alternative management options.

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). Higher probabilities of occupancy may be interpreted to indicate more “use” of a habitat by a particular species. Information on songbird occupancy (based on existing Rocky Mountain Bird Observatory Data) will be used to evaluate changes in songbird species richness and its associated adaptive management strategy.

- **Assessment**: Field surveys of presence & absence at both treated and untreated sites
- **Frequency**: Immediately post-treatment and every 2 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 will be thoroughly reviewed and appropriate adaptive management actions will be developed.

Tier 1 Suggested indicator: Songbird Species Richness (Jackknife2, Chao 2, or ICE Species Richness Estimator)

While estimating the changes in the aforementioned forest structural components provides some indication of how 4FRI treatments may be contributing to diversity goals, documenting the ways in which restoration treatments facilitate ponderosa pine forests contribution to native diversity ultimately requires knowledge of how diversity is changing over time. We anticipate that the abundance of species will change due to treatment and incidence or occurrence-based estimators are a way of documenting the actual change in the number of species. These incidence based species richness estimators have been shown to be more accurate and potentially less biased than historical estimators of species richness (e.g., Shannon’s Index, Simpson’s Diversity Index) (Walther and Moore 2005). These estimators can be computed within EstimateS, (*http://viceroy.eeb.uconn.edu/estimates*), a freely available diversity-estimation software program, using existing, ongoing surveys conducted by Rocky Mountain Bird Observatory in conjunction with the Forests.

- **Assessment:** Field sampling of communities of interest (e.g., songbirds)
- **Frequency:** Immediately post-treatment (either mechanical or prescribed fire); every 3-5 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 will be thoroughly reviewed and appropriate adaptive management actions will be developed.

Tier 2 Suggested Indicators: Rare Ecosystem Elements (Percent Cover of Gambel Oak, Aspen, and other Riparian Communities)

Oak, aspen, and riparian areas contribute heavily to the diversity of ponderosa pine 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 communities due to increases in available water.

- **Assessment:** Assessment of plot-based percent cover while collecting diameter distribution data (or use of aerial imagery once techniques become available)
- **Frequency:** Immediately post-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 will be thoroughly reviewed and appropriate adaptive management actions will be developed.

Tier 2 Suggested Indicators: Snags, rare ecosystem elements, understory species composition; responses of rare, sensitive, threatened, and endangered species; habitat "suitability", species richness, evenness

Snags (Number, Size Distribution, Condition): 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:** Rapid assessment conducted while collecting diameter distribution data on plots (or use of aerial imagery once techniques become available)
- **Frequency:** Immediately post-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 will be thoroughly reviewed and appropriate adaptive management actions will be developed.

Broad-Scale Assessment

Tier 1 Suggested Indicators: Response of Rare, Threatened, and Endangered Species and Regional Sensitive Species (Population trends)

Treatments conducted under 4FRI may affect rare, 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 Northern Goshawk and 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 the monitoring proposed here. We will monitor Mexican Spotted Owl as directed by the biological opinion provided by U.S. Fish and Wildlife Service. Northern Goshawk will be monitored according to the field protocols established in the USFS National Goshawk Inventory Guidelines with additional modifications such as those developed by NAU's Lab of Landscape Ecology and Conservation Biology (LLECB) and the Kaibab National Forest and in current literature.

- **Assessment:**
  - ♦ Mexican spotted owl monitored as directed in the U.S. Fish and Wildlife Service biological opinion.
  - ♦ Northern goshawk occupancy monitored using USFS protocols (USDA FS 2006) with modifications developed by LLECB/KNF and current literature.
- **Frequency:** In accordance with the aforementioned protocols.
- **Thresholds/Triggers:**
  - ♦ As directed in the Mexican spotted owl section of the U.S. Fish and Wildlife Service biological opinion
  - ♦ If northern goshawk occupancy trends show a decline over a 5 to 10 year average at treatment and 4FRI landscape scales.
- **Adaptive Management:**
  - ♦ As directed in the Mexican spotted owl section of the U.S. Fish and Wildlife Service biological opinion and in consultation with U.S. Fish and Wildlife Service.
  - ♦ 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.

Tier 2 Suggested Indicators: Wildlife Response (Landscape Predictions of Songbird Species, Richness)

Field assessment of these indicators (with the exception of connectivity) 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 a multi-scalar inference by using other information collected from other field assessments identified here. These models can be used to create “map-based” depictions of occupancy and richness that can then be summarized at multiple scales. Development and subsequent validation of these models will be especially critical for threatened, endangered, sensitive, and rare species and will likely require partnership with research institutions. Ongoing field assessment of songbird populations and the subsequent ability to estimate occupancy as a function of forest structural covariates will be critical for this indicator.

- **Assessment:** Field sampling in conjunction with remote sensing
- **Frequency:** Annual interpretations of new satellite imagery
- **Thresholds/Triggers:** Any non-zero decline over a 5-year period within the functional groups listed below
- **Adaptive Management:**
  - ♦ **Closed Canopy Species:** Evaluate data and best science available, including upcoming research by AZ Game and Fish. Adaptive management could include implementing one of the following changes:
    - ▪ Increase group density for all treatments.
    - ▪ Increase group size for all treatments.

        - Reduce intensity of UEA 40-55 treatments within the treatment category to be applied to the next round of task orders.
        - Identify 25 percent of planned UEA 40-55 treatments and reduce intensity to 25-40 interspace.
    - **Open Canopy Species:** Evaluate implementing one of the following changes:
        - Increase the size of openings in all treatment types.
        - Identify 25 percent of planned UEA 25-40 treatments and increase intensity to 40-55
    - **Pine-Sage Species:** Alter timing of treatment to reduce impacts on sage; Delay post-treatment burning to allow sage recover
    - **Pine-Oak Species:** Evaluate implementing one of the following changes:
        - Restrict ungulate access to stands to allow oak regeneration.
        - Increase emphasis on management of oak component in non-"Restricted Habitat" stands

Tier 2 Suggested Indicator: Landscape Connectivity and Permeability

Changes in landscape connectivity and permeability for several species representing closed canopy (black bear OR grey fox) and open canopy (pronghorn) conditions. Building connectivity models for species that are predicated on various aspects of patch structure, density, and orientation provides an opportunity to evaluate the effects of landscape heterogeneity on a key ecosystem process. Furthermore, these models can be validated through the use of telemetry studies, a property not shared by fire models (our other landscape metric). While a variety of factors can and do influence connectivity, the models will be formulated to reflect specific hypotheses related to landscape structure.

- **Assessment**: Field sampling in conjunction with remote sensing
- **Frequency**: Immediately post-treatment; five years post-treatment, ten years post-treatment
- **Thresholds/Triggers:**
    - Restriction in bear/fox movement after treatment (reduced connectivity between patches)
    - No increase in pronghorn movement after treatment
- **Adaptive Management:**
    - Bear/Fox: Evaluate implementing one of the following changes:
        - Increase group size.
        - Decrease treatment intensity within known pathways
    - Pronghorn: Evaluate implementing one of the following changes:
        - Increase opening sizes.
        - Increase treatment intensity within known pathways

Biophysical Monitoring for Function (or Process)

Relevant Desired Conditions

I. Conservation of Biological Diversity:

   a. Ponderosa pine ecosystems provide the necessary … processes…that contributes to the diversity of native plant and animal species…
   b. Natural disturbance processes (e.g., 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. There is low potential for unnaturally severe fire to spread across the Restoration Unit.
   d. Wherever practicable, natural fire regimes regulate forest structure and composition.
   e. Planned and unplanned fires support diverse native understory communities and their associated biodiversity.

II. Ecological Resilience:

   a. Ponderosa pine ecosystems in the 4FRI are capable of adapting to or persisting with climate change without rapid, large scale type shifts.
   b. Low intensity frequent fire operates as the primary natural process maintaining forest structure and function.
   c. Mixed severity fire is sometimes used as a restoration tool in appropriate ecological and social settings (e.g., non-wildland-urban interface areas) to restore and maintain natural forest types[Implementation Monitoring – not addressed in this document]
   d. Forest insects and pathogens occur and operate at endemic levels.
   e. Ponderosa pine ecosystems in the 4FRI are capable of regeneration and recovery following natural disturbance (e.g., fire, outbreaks of insects and pathogens).
   f. A majority of the ponderosa pine ecosystems supports frequent, low-intensity fire.
   g. Mixed severity fire is used as a restoration tool where it is consistent with reference conditions and safe to do so. [Implementation Monitoring – not addressed in this document .
   h. Natural disturbance processes (e.g., fire, endemic pests, and pathogens) are within the natural range of variability.
   i. Strategically placed treatments allow fire managers to safely manage planned and unplanned natural ignitions fires in a way that benefits and enhances the resilience of forest ecosystems.
   j. Restoration results in forests that are trending toward natural variability, self-regulating, and positioned to adapt to climate change without large, rapid type shifts.

III. 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 fire).
   b. Sensitive soils are protected through use of appropriate timber harvesting equipment and techniques to reduce erosion and sedimentation that could otherwise damage aquatic life, increase flooding, reduce reservoir capacity, and increase costs of maintaining infrastructure in the vicinity of waterways. [Implementation Monitoring]

c. Fire is used as a management tool to support hydrologic function while minimizing impacts to soils and other natural resource values. [Implementation Monitoring]

d. Rare and ecologically valuable springs and wet meadows are protected and enhanced through appropriate restoration treatments where needed.

e. Ponderosa pine vegetation treatments are implemented so as to minimize negative impacts to water quality, soil productivity, and air quality. Short- term impacts are minimized through the implementation of best management practices and strategies.

f. Restored ponderosa pine ecosystems accommodate natural and other fires without uncharacteristic impacts to soil productivity and or watershed resources.

g. Ponderosa pine 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 or managed fire).

h. Hydrologic processes are re-established to restore springs and wet meadow ecosystems.

i. 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.

j. Stable, restored ecosystems foster watersheds that yield enhanced water quantity and quality and are resilient to climatic variability.

Description and Justification

The majority of 4FRI desired conditions 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.

Future climate models for the southwestern United States predict warmer and drier conditions (Seager et al. 2007). Potential impacts of climate changes include increased tree morality as a function of drought, fire, and pathogens. In addition, tree regeneration may be affected by loss of seed trees and drought-induced seedling mortality. Potential impacts of climate change are likely to be exacerbated under current forest conditions. Restoration treatments in ponderosa pine 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. 2008). Such effects are likely to buffer the ecosystem against climate change and enhance resilience at fine to coarse scales (Fulé 2008).

Ponderosa pine forests were historically resilient and persisted under a frequent, low-intensity 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 resiliency. 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).

Ponderosa pine trees are 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 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 is the inevitable consequence of 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 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 ponderosa pine forests. Yet, side effects of restoration treatments, such as soil compaction from heavy equipment and fire-related damage to the soil biotic community and soil nutrient balance, must be monitored to inform adaptive management.

Smoke is a natural consequence of ponderosa pine forest material combustion, 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 impacts on human health. While restoration activities accomplished by 4FRI will generate a substantial amount of smoke, coordinated efforts to manage underlying and prescribed conditions will help to mitigate the amount and quality of smoke released, and reduces total impacts 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 2 Suggested Indicators: Tree mortality, regeneration, insect pathogen dynamics, fuel hazard

Tree Mortality (Stand Density, Basal Area, and Species Composition): Monitoring for desired conditions with respect to ecosystem type shifts should focus on tree mortality and tree regeneration. Values for stand density, basal area, and percentage species composition can be used to track tree mortality as well as contribute to determining effects of restoration treatments on fire behavior.

- **Assessment:** Field sampling within treated sites
- **Frequency:** Immediately post-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 will be thoroughly reviewed and appropriate adaptive management actions will be developed.

Regeneration (Density of Seedlings, Poles and Saplings): Regeneration is the second critical component of 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 within treated sites
- **Frequency**: Immediately post-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 will be thoroughly reviewed and appropriate adaptive management actions will be developed.

Insect and Pathogen Dynamics (Bark Beetle Rating, Dwarf Mistletoe Rating, and Number of Trees Affected by Pests/Pathogens): 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 in order to track changes in levels of occurrence.

- **Assessment**: Field sampling within treated sites
- **Frequency**: Immediately post-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 will be thoroughly reviewed and appropriate adaptive management actions will be developed.

Fuel Hazard (Crown Bulk Density, Crown Base Height, and Surface Fuel Loading): Monitoring of forests' potential to support frequent, low-intensity fire should be focused on structural conditions and fuel loading.

- **Assessment**: Field sampling within treated sites
- **Frequency**: Immediately post-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 will be thoroughly reviewed and appropriate adaptive management actions will be developed.

Broad-Scale Assessment

Tier 1 Suggested Indicators: Fuel/fire hazard, fire occurrence, soil and watershed function

Fuel/Fire Hazard (Crown Bulk Density, Crown Base Height, Surface Fuel Loading, and Predicted Fire Behavior): These indicators allow assessment of the ability of restoration treatments to meet strategic goals with respect to large-scale, uncharacteristically severe fire. Data to assess these conditions can be obtained from remote sensing techniques (Landfire updates and future LIDAR as data becomes available), although ground truth and calibration plots are likely to be necessary.

- **Assessment**: Remote sensing information
- **Frequency**: Immediately post-treatment and every five years thereafter
- **Thresholds/Triggers:**
    - ♦ After 5 years, less than 25 percent of the analysis land area described as Fire Regime I is predicted to predominantly carry passive or active crown fire
    - ♦ After 10 years, less than 10 percent of the analysis land area described as Fire Regime I is predicted to predominantly carry passive or active crown fire
- **Adaptive Management:** Evaluate the potential causes and develop appropriate adaptive management actions.

Fire Occurrence (Severity and Size of Fires, Acres of High Severity Fire, Total Acres Burned,): As restoration progresses, the size and severity of wildfire should decrease. Use of freely-available information from the Monitoring Trends in Burn Severity program and Forest-level databases on managed fire can be used to assess how treatments affect size and severity of fires. It should be noted that this assessment is limited to those portions of the landscape where restoration treatments are complete.

- **Assessment**: Monitoring Trends in Burn Severity data
- **Frequency**: Available annually for all fires larger than 1000 acres
- **Thresholds/Triggers:**
    - ♦ 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

- **Adaptive Management:** Evaluate the potential causes (e.g. number of acres treated, prescription type) and develop appropriate adaptive management actions.

Tier 1 Suggested Indicator: Soil & Watershed Function (Water Balance)

An important component of forest restoration is to understand the link between forest health or functionality and ecosystem services such as water discharge to human communities. While paired watershed studies in Arizona's ponderosa pine forests have previously established that thinning can increase surface water yield for a period of 6-10 years (Baker 2003), none of the previous treatment types were consistent with restoration treatments, no studies examined the effects of follow-up treatments (e.g. re-establishment of the natural fire return interval), and none of the previous studies quantified the effects on recharge to shallow or regional groundwater aquifers. Also, since none of the previous treatments were on a scale of 4FRI, they did not they have the potential to significantly impact regional water availability or nor did they provided the opportunity to adapt to climate change.

A paired watershed study is planned within the 4FRI boundary that will take advantage of the restoration treatments for study the effects of large-scale treatments on water quality and quantity. A watershed function will be quantified through a water balance determination that includes measurements of precipitation, snow water equivalence (SWE), soil moisture, evapotranspiration (ET), water runoff, and groundwater recharge. Other indicators may be monitored, including sediment discharge from erosion and surface water quality (turbidity and total organic carbon) which may be directly affected by treatments. The watershed study may include collaboration from partners such as NAU, ERI, Salt River Project and potentially other.

- **Assessment**:
    - ♦ Field data: some snow water equivalence and soil moisture data
        - ▪ Automated data collection - weather stations, precipitation sampling, soil moisture probes, evapotranspiration, stream gages, water quality probes, water quality autosampler
        - ▪ Laboratory analysis - precipitation and runoff water quality (Chloride balance of precipitation and runoff can be used to estimate evapotranspiration and groundwater recharge. Turbidity and total organic carbon measure soil erosion due to thinning and fire treatments)
    - ♦ Remote sensing: snow water equivalence, soil moisture, evapotranspiration and groundwater
- **Frequency**: Immediately pre- and post-treatment; annual summary each year following treatment with biennial recommendations after 3 years monitoring
- **Thresholds/Triggers:**
    - ♦ Static or decreasing soil moisture post-treatment
    - ♦ Static or decreasing surface water discharge
    - ♦ Diminished water quality (measured by turbidity and total organic carbon)
    - ♦ Increase in water stress (after accounting for climate variability)

- **Adaptive Management:** Evaluate treatment methods and/or BMPs, and consider making adjustments or implementing additional mitigation measures

Tier 1 Suggested Indicator: Soil and Watershed Function (Sensitive Soils Protection)

Highly and moderately erodible soils and slopes are classified within the Terrestrial Ecosystem Survey Units (TESU). Forest management activities are planned to avoid impacting these areas to reduce compaction, erosion, and sediment transport downstream. TESU maps can be overlain with management activity maps to ensure that protection has occurred, and field plots could sample areas where mitigation measures were implemented to assess the percentage of area that has been affected.

While the USFS Soil Disturbance Protocol (Page-Dumroese et al. 2009) is a useful qualitative method for evaluating soil impacts from operator actions and for guiding BMPs and mitigation. This information 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 Disturbance Monitoring Protocol 2009 (WO82A and WO82B)
    - ♦ Bulk density and infiltration capacity
- **Frequency**: Immediately post -treatment and every 5 years thereafter, with more frequent follow -up in heavily impacted places to assess recovery
- **Thresholds/Triggers:**
    - ♦ Soil disturbance is over 15 percent of the treated area
    - ♦ Increasing bulk density trend
    - ♦ Decreasing infiltration rate trend
- **Adaptive Management:** Evaluate treatment methods and/or BMPs, and consider making adjustments or implementing additional mitigation measures

Tier 1 Suggested Indicator: Soil and Watershed Function (Soil Productivity)

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 pattern

Tier 2 Suggested Indicators: Tree mortality, Airshed function

Tree Mortality (Canopy Cover, Number of Pathogen-affected Patches, Size of Mortality Patches, and Percent of Landscape in Mortality Patches): These indicators can help assess 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 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 will be thoroughly reviewed and appropriate adaptive management actions will be developed.

Airshed Function (Air Quality): There are air quality attainment goals for each geographical “airshed” dictated by ADEQ. Several measures could be used to qualitatively assess the contribution of prescribed burning activities toward the attainment of those ADEQ goals including: the percent of prescribed burns within prescriptions that reduce smoke generation, the percent (by area) of prescribed fires conducted during high ventilation periods (May -September), modeled outputs of smoke from burned slash piles (grams/hectare treated), modeled outputs of smoke from broadcast burns (grams/hectare) and modeled output of smoke avoided from uncharacteristic wildfire (grams/hectare)

- **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 thoroughly reviewed and appropriate adaptive management actions will be developed.

Table 149 Suggested Indicators: Forest Service and multiparty monitoring needed for adaptive management [6]

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Method and Sampling Techniques	Fine Scale or Broad Scale	Trigger (Threshold indicating possible need for change)	Adaptive Management	Annual Cost Estimate
1	1	Composition	Effects to Threatened or Endangered Species are within those disclosed in the Biological Assessment for the 4FRI project	As directed in the U.S. Fish and Wildlife Service (USFWS) biological opinion	Various	As directed in the biological opinion	Broad Scale	As described in the biological opinion for this project	As directed in the Mexican spotted owl section of the USFWS biological opinion and in consultation with USFWS	Mexican spotted owl survey $10/acre; PAC survey $175
2	1	Composition	Effects to Regional Forester designated Sensitive species within those disclosed in the Sensitive Species Biological Analysis/ Evaluation for the project	Forest trends	Various	Regional field protocols	Broad Scale	When indicator trends suggest a need for listing under the Endangered Species Act	As appropriate in consultation with USFWS	TBD

[6] Fine Scale = Group, Site and Stand Scale; Broad Scale = Subunit, Restoration unit, Forest, Analysis Area, Landscape

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Method and Sampling Techniques	Fine Scale or Broad Scale	Trigger (Threshold indicating possible need for change)	Adaptive Management	Annual Cost Estimate
3	1	Structure	There is reduced potential for introduction, establishment, and spread of invasive species. Additionally, efforts are made to reduce existing infestations.	Invasive Plants	Species cover	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 BMPs, especially for cleaning equipment moving from infested sites to clean sites. Consider aggressive treatments leading to population eradication. If treatments do not reduce the cover of “watch list” species by 90 percent in one year or “high risk” species by 50 percent in 2 years, consider new approaches to eradication.	$80/acre
4	1	Structure	There is reduced potential for introduction, establishment, and spread of invasive species. Additionally, efforts are made to reduce existing infestations.	Invasive Plants	Species cover	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 by 20 percent in 5 years, consider new approaches to weed management.	$80/acre

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Method and Sampling Techniques	Fine Scale or Broad Scale	Trigger (Threshold indicating possible need for change)	Adaptive Management	Annual Cost Estimate
5	1	Structure	There is reduced potential for introduction, establishment, and spread of invasive species. Additionally, efforts are made to reduce existing infestations.	Invasive Plants	Cheatgrass	Resource specialist assessment	Fine Scale	Identification of areas at high risk of cheatgrass introduction, spread or dominance	Potential preventative measures are described in the narrative.	$80/acre
6	1	Structure	Restore forest structure and pattern, forest health, and vegetation composition and diversity. Ponderosa pine ecosystems are heterogeneous in structure and distribution at the analysis area scale. 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)	Landscape Structure	Landscape metrics (patch characteristics; configuration; diversity and evenness)	Remote sensing and spatial pattern analysis tools	Fine and Broad Scale	TBD	TBD	20,000
7	1	Composition	Understory vegetation composition and abundance are consistent with the natural range of variability.	Diversity (understory communities)	percent cover native species	Field collected - quadrats	Fine Scale	Within 5 years of mechanical treatment, the cover should increase 20 percent +/- 5 percent (15-25 percent) above controls	If this threshold is not reached, then re-evaluate treatment for management change, taking into account soils and burn treatment, (e.g. reduce overstory basal area).	*Included in Plot Costs Below

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Method and Sampling Techniques	Fine Scale or Broad Scale	Trigger (Threshold indicating possible need for change)	Adaptive Management	Annual Cost Estimate
8	1	Composition	Understory vegetation composition and abundance are consistent with the natural range of variability.	Diversity (understory communities)	Percent Bare Soil within treatment blocks	Field collected - quadrats	Fine Scale	Within 5 years of treatment (mechanical and/or fire), bare soil should comprise less than 20 percent of area affected by treatment.	If bare soil exceeds 20 percent of area within plots, re-evaluate restoration treatment for modification.	*Included in Plot Costs Below
9	1	Composition	Understory vegetation composition and abundance are consistent with the natural range of variability.	Diversity (understory communities)	Seedlings and saplings density	Field collected - quadrats	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.	If seedlings and saplings fall below this range across sub-units where regeneration is a desired condition, then evaluate implementation of BMPs to increase probability of successful regeneration. If regeneration falls above this range, then more aggressive prescribed burning may be necessary to reduce plant density.	*Included in Plot Costs Below

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Method and Sampling Techniques	Fine Scale or Broad Scale	Trigger (Threshold indicating possible need for change)	Adaptive Management	Annual Cost Estimate
10	1	Process	There is low potential for unnaturally severe fire to spread across the Restoration Unit.	Fuel/Fire Hazard	Crown bulk density, crown base height, surface fuels, and predicted fire behavior	Remote sensing and modeling	Broad Scale	§ After 5 years, less than 25 percent of the analysis land area described as Fire Regime I is predicted to predominantly carry passive or active crown fire § After 10 years, < 10 percent of the analysis land area described	Evaluate the potential causes and develop appropriate adaptive management actions.	10000
11	1	Process	There is low potential for unnaturally severe fire to spread across the Restoration Unit.	Fire Occurrence	Severity and size of fire; acres of high severity fire; and total acres burned	Remote sensing and modeling	Broad Scale	§ 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	Evaluate the potential causes (e.g. number of acres treated, prescription type) and develop appropriate adaptive management actions.	TBD

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Method and Sampling Techniques	Fine Scale or Broad Scale	Trigger (Threshold indicating possible need for change)	Adaptive Management	Annual Cost Estimate
12	1	Process	Sensitive soils are protected through use of appropriate timber harvesting equipment and techniques to reduce erosion and sedimentation that could otherwise damage aquatic life, increase flooding, reduce reservoir capacity, and increase costs of maintaining infrastructure in the vicinity of waterways.	Soils	Sensitive soil protection	Remotely sensing and field methods	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	TBD
13	1	Process	Sensitive soils are protected through use of appropriate timber harvesting equipment and techniques to reduce erosion and sedimentation that could otherwise damage aquatic life, increase flooding, reduce reservoir capacity, and increase costs of maintaining infrastructure in the vicinity of waterways.	Soils	Soil productivity	Field methods	Fine Scale	C:N ratios increasing from 12-14 toward 30, indicating a reduction in nitrogen availability that would impact plant productivity	Evaluate treatments in light of soil processes and make adjustments in treatment methods and forest pattern.	TBD

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Method and Sampling Techniques	Fine Scale or Broad Scale	Trigger (Threshold indicating possible need for change)	Adaptive Management	Annual Cost Estimate
14	1	Process	Sensitive soils are protected through use of appropriate timber harvesting equipment and techniques to reduce erosion and sedimentation that could otherwise damage aquatic life, increase flooding, reduce reservoir capacity, and increase costs of maintaining infrastructure in the vicinity of waterways.	Soils	Soil moisture	Soil moisture sensors, time domain reflectometer and gravimetric analysis	Broad Scale	Trends of decreasing soil moisture (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.	?
15	1	Process	Restored ponderosa pine ecosystems accommodate natural and other fires without uncharacteristic impacts to soil productivity and watershed resources.	Watershed Function	Springs protection	Groundwater Dependent Ecosystems Protocol, discharge measurements	Fine Scale	Triggers: 1. No net increase in facultative and obligative wetland species at springs or wet meadows targeted for both forest and spring restoration, 2. Decrease in spring discharge (adjusted for climate variation) following treatments	Review spring restoration techniques. Review treatment methods in the recharge area. Evaluate making appropriate adjustments such as improving structure of patches and openings to promote snow accumulation and retention to enhance recharge.	TBD

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Method and Sampling Techniques	Fine Scale or Broad Scale	Trigger (Threshold indicating possible need for change)	Adaptive Management	Annual Cost Estimate
16	1	Structure	Ponderosa pine ecosystems are heterogeneous in structure and distribution at the analysis area scale. Openings and densities vary within the analysis area to maintain a mosaic appropriate to support resilience of individual trees and groups of trees. Ponderosa pine 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.	Canopy Openness	Canopy cover	Remote sensing, spatial pattern analysis tools or field sampling	Fine and Broad Scale	A deviation from the structure described in Table 64 of the Silviculture report.	Assess potential sources of deviation and increase monitoring efforts in areas with unexpected deviations	TBD
17	1	Structure	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 and richness: closed canopy species	Field (RMBO songbird surveys), RS, Modeling, Statistics	Fine and Broad Scale	Fine Scale-TBD Broad Scale-Any non-zero decline over a 5-year period	Fine Scale- TBD Broad Scale-Evaluate implementing one of the following changes: § Increase group density for all treatments. § Increase group size for all treatments [based on AGFD experiment]. § Reduce intensity of all UEA 40-55 treatments . § Identify 25 percent of planned UEA 40-55 treatments and reduce intensity to 25-40	$1000 per grid (1 grids per 1,000 acres?)

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Method and Sampling Techniques	Fine Scale or Broad Scale	Trigger (Threshold indicating possible need for change)	Adaptive Management	Annual Cost Estimate
18	1	Structure	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 and richness: open canopy species	Field (RMBO songbird surveys), RS, Modeling, Statistics	Fine and Broad Scale	Fine Scale-TBD Broad Scale-Any non-zero decline over a 5-year period	Fine Scale-TBD Broad Scale- Evaluate implementing one of the following changes: § Increase the size of openings in all treatment types. § Identify 25 percent of planned UEA 25-40 treatments and increase intensity to 40-55	TBD
19	1	Structure	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 and richness: pine-sage species	Field (RMBO songbird surveys), RS, Modeling, Statistics	Fine and Broad Scale	Fine Scale-TBD Broad Scale-Any non-zero decline over a 5-year period	Fine Scale- TBD Broad Scale-Evaluate altering timing of treatment to reduce impacts on sage; Evaluate delaying post-treatment burning to allow sage recover	TBD
20	1	Structure	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 and richness: pine-oak species	Field (RMBO songbird surveys), RS, Modeling, Statistics	Fine and Broad Scale	Fine Scale-TBD Broad Scale-Any non-zero decline over a 5-year period	Fine Scale- TBD Broad Scale-Evaluate implementing one of the following changes: § Increase the size of openings designated for oak regeneration § Restrict ungulate access to stands to allow oak regeneration. § Increase emphasis on management of oak component in non-“Restricted Habitat” stands	TBD

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Method and Sampling Techniques	Fine Scale or Broad Scale	Trigger (Threshold indicating possible need for change)	Adaptive Management	Annual Cost Estimate
21	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.	Northern goshawk	Occupancy	USFS National Goshawk Inventory Guidelines with modifications developed by LLECB/KNF and current literature	Broad Scale	If northern goshawk occupancy trends show a decline 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	TBD
22	1	Structure	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)	Changes in landscape connectivity and permeability: bear/fox	Field sampling in conjunction with remote sensing	Broad Scale	Restriction in bear/fox movement after treatment (reduced connectivity between patches)	Evaluate implementing one of the following changes: § Increase group size. § Decrease treatment intensity within known pathways	125000
23	1	Structure	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)	Changes in landscape connectivity and permeability: pronghorn	Field sampling in conjunction with remote sensing	Broad Scale	No increase in pronghorn movement after treatment	Evaluate implementing one of the following changes: § Increase opening sizes. § Increase treatment intensity within known pathways	125000

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Method and Sampling Techniques	Fine Scale or Broad Scale	Trigger (Threshold indicating possible need for change)	Adaptive Management	Annual Cost Estimate
24	1	Structure, Composition & Process	Ponderosa pine ecosystems are composed of all age and size classes within the analysis area and are distributed in patterns more consistent with reference conditions.	Diameter Distributions	Tree diameters, density	Field Methods	Fine Scale	TBD	TBD	$2000/plot to install, $1000 to remeasure includes analysis time. (500m grid; 1 plot per 25ha, 61.2 acres)
25	2	Structure, Composition & Process	Protect old-growth forest structure during planned and unplanned fires.	Old Trees	Old tree density, conditions	Field Methods	Fine Scale	Any loss old tree that is cut outside of those identified as allowed in the Old Tree Implementation Plan	TBD; however, when an old tree is cut, the cause or rationale will be reviewed by the MPMB	(*Included in Plot costs)
26	2	Structure	Forest insects and pathogens occur and operate at endemic levels.	Insect Pathogens	Bark beetle rating, dwarf mistletoe rating, number of trees affected by pests	Field Methods	Fine Scale	TBD	TBD	(*Included in Plot costs)
27	2	Composition	Rare and ecologically valuable springs and wet meadows are protected and enhanced through appropriate restoration treatments where needed. Oak and Aspen stands are maintained and enhanced across the landscape.	Rare/ Unique Habitats	Percent cover	Field Methods	Fine Scale	TBD	TBD	TBD

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Method and Sampling Techniques	Fine Scale or Broad Scale	Trigger (Threshold indicating possible need for change)	Adaptive Management	Annual Cost Estimate
28	2	Process	Restored ponderosa pine ecosystems accommodate natural and other fires without uncharacteristic impacts to soil productivity and watershed resources.	Watershed Function	Water balance	§ Field data: some snow water equivalence and soil moisture data § Remote sensing: snow water equivalence, soil moisture, evapotranspira tion and groundwater	Broad Scale	§ Static or decreasing soil moisture post-treatment § Static or decreasing surface water discharge § Diminished water quality (measured by turbidity and total organic carbon) § Increase in water stress (after accounting for climate variability)	Evaluate treatment methods and/or BMPs, and consider making adjustments or implementing additional mitigation measures	TBD
29	2	Process	Ponderosa pine 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 or managed fire).	Air Quality	Smoke output	Modeling	Broad Scale	TBD	TBD	USFS - 1st Analysis EIS
30	2	Structure, Composition & Process	Ponderosa pine ecosystems are composed of all age and size classes within the analysis area and are distributed in patterns more consistent with reference conditions.	Snags	Snag sizes, density, conditions	Field Methods	Fine Scale	TBD	TBD	(*Included in Plot costs)

Indicator No.	Monitoring Tier	Ecological Framework	Desired Condition or Resource and monitoring Questions	Indicator	Indicator Metric	Method and Sampling Techniques	Fine Scale or Broad Scale	Trigger (Threshold indicating possible need for change)	Adaptive Management	Annual Cost Estimate
31	2	Structure, Composition & Process	Protect old-growth forest structure during planned and unplanned fires.	Tree Mortality	Stand Density, basal area, and species composition, Canopy cover, number of pathogen-affected patches, size of dead patches and percent of mortality on landscape	Field Methods, NFHM and Remote sensing	Fine and Broad Scale	TBD	TBD	(*Included in Plot costs)
32	2	Process	A majority of the ponderosa pine ecosystems supports frequent, low-intensity fire.	Fuel Hazard	Crown bulk density, crown base height, and surface fuels	Fuel load	Fine Scale	TBD	TBD	(*Included in Plot costs)

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 will 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 U.S. Forest Service (USFS). 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 will augment effective management actions that will 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 (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 4FRI project for the First Analysis Area Environmental Impact Statement (EIS). Both the 4FRI Science and Monitoring Working Group (S&MWG) and the USFS will contribute to monitoring the socioeconomic aspects of the project. The 4FRI project is funded through the Omnibus Land Management Act of 2009, Title IV-Forest Landscape Restoration. The 4FRI socioeconomic monitoring process is geared towards 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 uncharacteristic 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 USFS in the "Environmental Consequences" section of the EIS. In the EIS, the USFS will assess the social and economic elements of 4FRI implementation. This analysis will include the Coconino and Kaibab National Forests and Coconino, Yavapai and Maricopa counties. Although Maricopa County is not within the Kaibab and Coconino National Forests, it is included in the analysis due to the social and economic linkages between Maricopa County and the assessment area.

There are two main components to the USFS social and economic analysis that include: 1) the affected environment description and, 2) the assessment of environmental consequences. The USFS analysis of the social and economic affected environment description in the EIS considers population and demographic characteristics and trends (e.g. population change and educational attainment), employment and income data (e.g. economic specialization and median income), 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 will include estimates of employment and income consequences during the 4FRI implementation lifecycle. Input- output-analyses using IMPLAN (http://www.implan.com) will estimate the employment and income effects of the 4FRI project. Ultimately, the estimates from IMPLAN can be compared to actual economic outcomes that will be collected as primary data from contractors, subcontractors, etc.

The USFS environmental consequences analysis estimates will be primarily a qualitative assessment and will describe how 4FRI implementation activities will affect quality of life, non-market economic values and employment and income in the study area. For quality of life, some of the key indicators are: 1) Particulate matter (PM) pollution from wildfire and prescribed fire (air quality modeling) and how PM pollution may lead to reduced quality of life through activity days, respiratory events, hospital admissions, etc.; 2) recreation opportunities (e.g., 4FRI implementation may temporary displace some activities; uncharacteristic wildfire can have long-term displacement consequences, etc.) and; 3) local economic sustainability; this will extend the quantitative economic discussion of employment and income to the social sphere to discuss how changing economic conditions affect community well-being. Non-market values will be measured chiefly through ecological indicators provided by other USFS specialists in their analysis (e.g. effects on habitat, water quality, soil quality, etc.). The economic efficiency of 4FRI implementation will also be analyzed by the USFS by using data on federal and private expenditures and the projected benefits of ecological restoration.

To supplement the USFS socioeconomic monitoring data and analyses, through multiparty monitoring, the 4FRI Collaborative will utilize the information contained in this report to complete both social and economic monitoring of the 4FRI project. Although this report contains an extensive list of possible objectives that could be monitored, based on the 4FRI Collaborative's priorities and the information gaps contained in the USFS required socioeconomic monitoring, specific objectives/questions will be targeted. To assure the project's success and longevity, it is recommended that socioeconomic monitoring is conducted before project implementation and there is immediate and ongoing execution within approximately the first five years of project implementation (Personal Communication, Nielsen 2011). Once socioeconomic monitoring data verifies the 4FRI project is socially and economically on track, the pressing need to conduct this type of monitoring will dissipate and the priority socioeconomic factors can be monitored less frequently to assess longitudinal changes.

The purpose of the joint effort of the S&MWG and the USFS monitoring process is to assess the accuracy of USFS estimates and provide data for adaptive management. In this way, the information provided by the USFS 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 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 (University of Oregon 2011) were developed through broad stakeholder input. As objectives were developed, considerations were based on those that the stakeholder group and/or the USFS have the ability to influence and adapt (University of Oregon 2011). Monitoring questions were matched to the objectives to ensure the questions asked provide 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; Eagan 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 will provide necessary information to assess a variety of programmatic (cumulative) monitoring objectives/questions that can be tracked over time (University of Oregon 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 (appendix C and

D). 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, respective 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 the project matures, and a baseline is established, these triggers can be adjusted to more specific acceptable quantitative ranges that will indicate whether or not adaptive management is necessary for each specific objective/question that is being assessed. In addition, once a contract(s) is awarded and contractors' business plans are identified, economic triggers can be more clearly delineated 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 telephone survey to residents in the first analysis area can provide necessary data for multiple monitoring questions. As economic studies are planned and conducted, when contractor surveys are designed and distributed before project implementation, several indicators can be tracked 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 (Royce 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 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 2014).

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 (e.g. “local”), a concise, self-determined definition is necessary to pinpoint the sampling frame, or scale, of the population under study (University of Oregon 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, we should 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 included 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 include 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 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, 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 typically 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 USFS employees. In general, telephone surveys delivered by a live interviewer tend to be the most reliable method to collect data as the response rate is much higher, thus reveling results that are more indicative of the group that is being studied. Also, telephone survey methodology, although not perfect, provides a sampling frame that is most inclusive of a population. A note of caution - automated telephone surveys will not yield reliable results for many reasons such as, the respondent's identity is not verified (e.g. a child on the phone), there may be screener questions that verifies specific information about a respondent in the household and there is no assurance that the question was understood and did not need to be repeated. 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).

Data collection of telephone surveys is streamlined through the use of computer programs, such as Computer Assisted Telephone Interviewing (CATI). These programs allow for survey question programming and results are recorded as the interview is conducted. Not only does this improve data collection entry error but also, the phone numbers in the sample are randomized (Random Digit Dialing -RDD) and shown on the screen for the interviewer to call. In addition, programs such as these allow for responses, whether they are closed- or open-ended, to be directly exported into programs such as Statistical Package for the Social Sciences (SPSS) for analysis.

For the 4FRI project, generally if researchers are seeking broad public opinion and attitudes about a number of issues, telephone surveys will yield results that can be generalized to the population. For more specific economic data, if secondary data is available from reliable sources, these will be used. In addition, 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, USFS personnel and community leaders such as, the 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. (Environmental Protection Agency 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

The first collaborative performance evaluation has been conducted through a Survey Monkey instrument developed in conjunction with the 4FRI Stakeholders and the US Institute for Conflict Resolution (October 2011, Appendix E). In addition, a separate evaluation conducted by Northern Arizona University (W. Greer, E. Nielsen) and Colorado State University (T. Cheng) that includes a 4FRI Case History and a Collaborative Governance Case History will supplement the 4FRI Collaborative’s effectiveness and performance measures (May 2012). The intent is to track performance over time and to adaptively manage the Collaborative so that improvements are made to key areas identified by stakeholders.

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.

Additionally, to capture local economic conditions, economic base theory, a causal model, can be employed that divides the local economy into two sectors: 1) a basic, or non-local and 2) non-basic, or local. This theory is grounded on the premise that the basic sector, or those businesses that are dependent on non-local firms to buy their products, is the driver of the local economy. Thus, the local economy is strongest when it is not dependent on local factors and can better insulate itself from local economic downturns. This distinction is important because the means of strengthening a local economy is to develop and enhance the basic sector (McClure 2009).

Prioritization

Although there are a multitude of monitoring objectives/questions in both the social and economic frameworks, due to identified preferences of the stakeholders and limitations in resources, objectives/questions need to be prioritized by the 4FRI Stakeholders. A basis for prioritizing the questions/objectives are issues and concerns that are relevant to the communities that are directly affected by the ensuing forest restoration efforts as well as those across 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.

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 in to 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 USFS, 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 USFS. Due to the groundbreaking nature of the 4FRI project and the lack of science based adaptive management within the USFS, solidifying the adaptive management process is a critical step in ensuring the project’s success. Stakeholders that 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 150 and table 151 show the socioeconomic monitoring framework.

Table 150. Four Forest Restoration Initiative socioeconomic monitoring framework for social systems

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
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.						
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).	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 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.	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 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.
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: http://www.fs.fed.us/emc/applit/(Cortner et. al 2003).	Track annually for first 5 years post/analysis area.	Objections database available at: http://www.fs.fed.us/emc/applit/ (Cortner et. al 2003).	Objections and lawsuits for 4FRI projects are delaying project implementation.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
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 and managed fires.						
The public is knowledgeable/ understands the byproduct of smoke from prescribed/managed/ pile fires (presence & duration.)	Is the public knowledgeable/ understands why prescribed/managed/pile fires 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. USFS 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.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
The public accepts/supports the byproduct of smoke from prescribed/managed/pile fires (presence & duration.).	Does the public accepts/support the byproduct of smoke from prescribed/managed/pile fires?	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. USFS 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.						
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.						
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	USFS 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.	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.	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 land owners 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-USFS 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	1. Headwaters Institute. 2. State, private, tribal, municipal grant/project reports. 3. USFS by Forests. 4. 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.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
V. GOAL: Social values and recreational opportunities are protected and/or enhanced through forest restoration activities.						
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 USFS, 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 2011). 2. Headwaters Institute 3. AZG&F The Economic Importance of Fishing and Hunting (utilizes IMPLAN input/output model) (Silberman2002). 4. USFWS National Survey of Fishing, Wildlife, Hunting, & Wildlife Assoc. Recreation (USDI FWS 2006). 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 USFS, 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.	1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area. 4. 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.	1. Focus group, interview and survey results. 2. 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.	1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area. 4. 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.	1. Focus group, interview and survey results. 2. Headwaters Institute.	The public perceives that aesthetic values are not enhanced as forest restoration activities are occurring.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
VI. GOAL: Rural communities play an active part in reducing fire risk by implementing FireWise actions and creating defensible space around their property.						
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.						
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.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
The public is knowledgeable/understands the 4FRI Collaborative'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 5 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 US Forest Service (USFS) as forest restoration activities are implemented.						
The public is aware of the USFS's involvement/role with the 4FRI Collaborative.	Is the public aware of the USFS's involvement/role with the 4FRI Collaborative?	Public awareness for the USFS'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 USFS's involvement/role with the 4FRI Collaborative.
The public is aware of the USFS's involvement with the 4FRI Project.	Is the public aware of the USFS's involvement with the 4FRI Project?	Public awareness for the USFS'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 USFS's involvement with the 4FRI Project.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
The public is supportive of the USFS's involvement with the 4FRI Collaborative.	Is there public support/acceptance for the USFS's involvement with the 4FRI Collaborative?	Public support for the USFS'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 USFS's involvement with the 4FRI Collaborative.
The public is supportive of the USFS's involvement with the 4FRI Project.	Is there public support/acceptance for the USFS's involvement with the 4FRI Project?	Public support for the USFS's involvement 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 supportive of the USFS's involvement with the 4FRI Project.
IX. GOAL: The general public is aware, knowledgeable and supportive of 4FRI implemented treatments within the analysis area.						
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.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
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.	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 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.	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 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, prescribed and managed fires, 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, prescribed and managed fires, 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.						
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.	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 educational and outreach programs.	Annual	1. Focus group, interview and survey results. 2. USFS by forest. 3. 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.	1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area. 4. Survey local youth group coordinators. 5. 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.	1. Focus groups with community members. 2. Interviews with land managers/key decision-makers. 3. Telephone survey with residents in study area. 4. Oversample low income/minority populations. 5. 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 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 populations opportunity to participate in the 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. 4. Oversample low income/minority populations. 5. 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.

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 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.						
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.).

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF (Undesirable Conditions)
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.	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.	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.

Table 151. Four Forest Restoration Initiative socioeconomic monitoring framework for economic systems

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
I. GOAL: The byproducts of mechanical forest restoration offset the costs of treatment implementation.						
Wood byproduct sales exceed the costs of implementation (Contractors are operating at a profit and the USFS 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 USFS contracting costs decreasing?	Q1: 1. Operational costs of treatments: a. Mobilization: to move equipment from site to site, to move operators (daily) from homebase 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 a semi-annual or quarterly basis ((4FRI Stakeholder Group 2010c).	Dependent on business plan(s).	1. Contractor surveys 2. USFS business plans (D. Jaworski Personal Communication 2011). 3. Contracts: federal databases a.USAspending.gov b. USFS Natural Resource Manager Database (University of Oregon 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.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
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.						
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, 2. Restaurant, 3. Groceries, 4. Gas/Oil, 5. Other transportation, 6. Activities, 7. Admissions/ Fees, 8. Souvenirs/ Other expenditures (USDA FS 2011). 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: USFS, AZG&F, USFWS reports tracked with investments made in forest restoration from fees/licenses/ private revenues.	5 years (USDA FS 2011; USDI FWS 2006)	Q1: 1. National Visitor Use Monitoring Program (USDA FS 2005). 2. Headwaters Institute Q2: 1. AZG&F The Economic Importance of Fishing and Hunting (utilizes IMPLAN input/output model) (Silberman 2002). 2. USFWS National Survey of Fishing, Wildlife, Hunting, & Wildlife Assoc. Recreation (USDI FWS 2006). 3. 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/: a. Transport, b. Treating, c. Developing new/existing water supplies, d. Capture, e. 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). a. Operation & maintenance expenses b. Taxes/transfers c. Capital additions/replacement d. Debt services (principle/interest) e. Allocated indirect costs f. 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 2. Beaver Creek Watershed Study 3. Castle Creek Watershed Study (Arizona Forest Resource Task Group 2010). 4. Watershed Conditions Framework (USFS). Q4/Q5/Q6: 1. City of Flagstaff Utilities (Water) Dept. 2. Long-term Financial Plan & Rate & Fee Study (City of Flagstaff 2010). 3. 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.

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 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?	1. Wetland & Stream Ecosystems Compensation. 2. Endangered Species Compensation. 3. 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.
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: USFS, 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: USFS, contractors. 2. Headwaters Economics (population/housing). 3. USFS budget staff (D. Jaworski Personal Communication 2011) 4. 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.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
III. GOAL: Rural communities receive direct and indirect economic benefits and ecosystem services as a result of forest restoration and resilient forests.						
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 (University of Oregon 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 1992).	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.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
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 (University of Oregon 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 1992).	Annual	1. Contractor reporting form/survey. 2. Headwaters Institute (EPS-HDT Socioeconomic profiles). 3. Bureau of Labor Statistics (Stynes 1992).	Forest restoration activities have not created a sufficient number of indirect jobs.
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 1992).	Annual	1. AZ Dept. of Revenue. 2. City reports. 3. County reports. 4. US Census Bureau. 5. U.S. Department of Labor, Bureau of Labor Statistics. 6. 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.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
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. 2. Capital expenditures of project materials. 3. Subcontract thinning services (Sitko and Hurteau 2010). Q2: 1. Sales/property taxes generated by employees (direct & indirect) (by county). 2. School revenues generated by avg. family. 3. 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	1. Contractor reporting form/survey. 2. U.S. Bureau of Economic Analysis (Sitko and Hurteau 2010). 3. 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.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
Forest restoration activities will increase recreation/tourism in rural communities in Arizona.	Q1: Has recreation increased as forest restoration activities have occurred? Q2: Has tourism increased as forest restoration activities have occurred? Q3: Has tourism related jobs/housing increased as forest restoration activities have occurred?	Q1: 1. AZG&F license sales by County. 2. Visitor days Q2: 1. Lodging 2. Restaurant 3. Groceries 4. Gas/Oil 5. Other transportation 6. Activities 7. Admissions/Fees 8. Souvenirs/Other expenditures (USDA FS 2005). 9. Tourism tax (e.g. Flagstaff Bed, Board & Booze (BBB) tax). Q3: 1. Travel and tourism jobs (seasonal employment). 2. Housing related to tourism jobs.	Economic Impact Analysis: Track flow of economic activity associated with tourism.	5 years (USDA FS 2011; USDI FWS 2006).	1. National Visitor Use Monitoring Program (USDA FS 2005). 2. AZG&F The Economic Importance of Fishing and Hunting (utilizes IMPLAN input/output model) (Silberman 2002). 3. USFWS National Survey of Fishing, Wildlife, Hunting, & Wildlife Assoc. Recreation (USDI FWS 2006). 4. Sales Tax by City (if applicable, Tourism tax). 5. AZG&F 6. Headwaters Institute (EPS-HDT SE profiles). 7. Visitor surveys.	Q1: Recreation has decreased as forest restoration activities have occurred. Q2: Tourism has decreased as forest restoration activities have occurred. Q3: Tourism related jobs/housing has decreased as forest restoration activities have occurred.
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 (University of Oregon 2011).	Comparative analysis of local contract awards vs. non-local number of contracts and respective value).	Every ten years or length of the contract.	1. Contracts: federal databases 2. USAspending.gov 3. USFS Natural Resource Manager Database (University of Oregon 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).

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
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.						
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. USFS Natural Resource Manager Database (University of Oregon 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.						
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; University of Oregon 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. USFS Natural Resource Manager Database (University of Oregon 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.
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.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
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 USFS employees designated for project planning, administration, and implementation. 2. # of FTE private sector employees designated for harvesting & processing. 3. USFS workload (dependent on current conditions-e.g. shift from overgrown forest to savannah system, shift from planning to implementation). 4. USFS workforce by position.	1. # of FTE USFS employees designated vs. # of USFS 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. USFS workload vs. USFS positions (M. Lata Personal Communication 2011).	Tracked annually across ten years or length of the contract.	1. USFS by forest. 2. Headwaters Institute (EPS-HDT Socioeconomic profiles). 3. Bureau of Labor Statistics (Stynes 1992). 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.						
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: USFS, 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. USFS 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.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
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)	USFS 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.
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?	1. Frequency of wildfires. 2. 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	USFS by Forests (Greater Flagstaff Forest Partnership 2010).	Wildfire suppression efforts frequency and duration are increasing as forest restoration projects are implemented.
Managed fire frequency and duration are increasing.	Are managed fire frequency and duration increasing as forest restoration projects are implemented over time?	1. Frequency of managed fires. 2. Duration of managed fires.	Frequency and duration of managed fires 5 years post-4FRI implementation vs. frequency and duration of managed fires 5 years pre-4FRI implementation.	5 years	USFS by Forests (Greater Flagstaff Forest Partnership 2010).	Managed fire frequency and duration 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?	1. Frequency of prescribed fires. 2. 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	USFS by Forests (Greater Flagstaff Forest Partnership 2010).	Prescribed fire frequency and duration are increasing as forest restoration projects are implemented.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
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 2011c).	Costs of prescribed fires 10 years post-4FRI implementation vs. costs of prescribed fires 10 years pre-4FRI implementation.	10 years	USFS 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	USFS 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.						
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.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
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?	1. Sales ($ value) of wood products. 2. 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?	1. Number of local businesses processing small diameter wood products. 2. Number of non-local businesses processing small diameter wood products. 3. Amount of wood (volume) products processed locally. 4. Amount of wood (volume) products processed non-locally (Greater Flagstaff Forest Partnership 2005).	1. Compare # of local vs. non-local businesses (percent each). 2. Compare local vs. non-local business volume of wood product production (percent each).	5 years	1. Contractor surveys. 2. Contracts, federal databases a. USAspending.gov b. USFS Natural Resource Manager Database (University of Oregon 2011).	The proportion of biomass processed locally is lower than biomass processed outside of the defined local area.
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	1. Contractor surveys. 2. Contracts, federal databases a. USAspending.gov b. USFS Natural Resource Manager Database (University of Oregon 2011).	Q1/Q2: The amount of wood products (small diameter and value-added) that are distributed locally are not increasing.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
Investment, research and development in utilization of wood biomass are increasing.	Is investment, research and development in utilization of wood biomass increasing?	1. Number of forest product industries involved in market research for small diameter wood uses. 2. Amount invested by businesses for development and research. 3. Type and amount of market analysis. 4. 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	1. Contractor/ business surveys. 2. 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.

Objective	Monitoring Question	Monitoring Indicator(s) (Metric)	Assessment	Frequency of Assessment	Data Source	Threshold IF… (Undesirable Conditions)
GOAL: There is a predictable wood supply throughout the life of the 4FRI project.						
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 USFS 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 USFS 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. USFS business plans (D. Jaworski Personal Communication 2011). 3. Contracts: federal databases a. USAspending.gov b. USFS Natural Resource Manager Database (University of Oregon 2011). 4. Headwaters Institute Q4: Objections database available at: http://www.fs.fed.us/emc/applit/ (Cortner et. al 2003).	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 Protection 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
- USFS United States Forests Service
- FWS United States Fish & Wildlife Service

Attachment 1. Mexican Spotted Owl Project Monitoring

Prepared by: Shaula Hedwall, U.S. Fish and Wildlife Service and the 4FRI Core Team

As part of the Four Forest Restoration Initiative Project (4FRI), fuels reduction and prescribed burning activities will occur within Mexican spotted owl protected activity centers (PACs). By definition, PACs are occupied habitat. The effects of treatments to owls and nesting/roosting habitat are not fully known. The Mexican spotted owl Recovery Team felt that PACs can be afforded substantial protection by emphasizing fuels reduction and forest restoration in surrounding areas outside of PACs and nesting and roosting habitat. They also stated that this by no means advocates for a “hands-off” approach in PAC habitat, recognizing that in some cases protection of PAC habitat requires management actions. Some PACs could benefit from well-designed treatments. The Mexican spotted owl Recovery Plan, First Revision (USDI FWS 2012) provides guidance for these treatments and emphasizes the need for monitoring and feedback loops for adaptive management. Well-designed monitoring could provide valuable information on the effects of activities on owls and their habitat. In the long-term, properly designed treatments are known to create habitat conditions that are recognized as not only improving nesting and foraging opportunities, but also reducing the risk of habitat loss to unmanaged wildfires. However, in order to understand the short-term effects of thinning and burning on Mexican spotted owls and their habitat, the Forest Service (FS) and the U.S. Fish and Wildlife Service (FWS) worked together to develop a monitoring plan that focuses on the years immediately before, during and after treatment.

During project analysis, the FS and the U.S. Fish and Wildlife Service collaboratively reviewed 117 PACs in the general 4FRI area. Forest conditions were individually evaluated within each PAC in terms of their potential to support resident Mexican spotted owls and their prey. PAC assessments included dominant forest type (e.g., pine-oak, mixed conifer), habitat structure, available demographic data (based on ongoing occupancy surveys or past research), topographic attributes (e.g., aspect and slope), human access, designated wilderness boundaries, recent and ongoing projects affecting PAC habitat, fire history, status of current habitat and, ultimately, whether mechanical treatments could potentially move the forest towards desired conditions described in the Recovery Plan. It was agreed that no mechanical treatments would occur in core areas.

Once the status of each PAC was determined, potential mechanical treatments were considered in terms of whether they could:

3. Decrease the amount of time needed to increase tree height and diameter;
4. Decrease overall tree density while maintaining overall canopy cover, and
5. Reduce the threat of surface fires becoming crown fires and increase canopy base height to improve flight zone (i.e., improve owl foraging ability).

PACs were not considered for treatment if they were treated in previous projects (n = 32), habitat was not suitable for 4FRI treatments (PACs occurred in habitats outside the scope of 4FRI such as mixed conifer, designated wilderness, or canyon habitat; n = 20), habitat had been previously burned (n = 10), habitat conditions inside PACs were such that treatment was not necessary (n = 11), the balance of conditions inside and outside PACs were such that treating outside the PACs would be adequate and active management would not be necessary inside the PACs (n = 24), or there simply was not enough information available to identify a need for treatment (n = 2).

Because historical fire return intervals have not been met across most of this landscape, prescribed fire was recommended for all PACs, including a recommendation for using prescribed fire in core areas.

Ultimately, we concluded that 99 of the 117 PACs assessed did not need mechanical treatments. Most of the remaining 18 PACs selected for mechanical treatment are not only believed to have among the lowest quality habitat (in terms of number/density of large trees, canopy cover and other predictors of owl nesting and roosting sites), but also have the greatest potential for long-term improvement if mechanical treatments are implemented.

The U.S. Fish and Wildlife Service and the FS completed field reconnaissance of a subset of PACs chosen for treatments (see the 4FRI Wildlife Specialist Report for more detail). The U.S. Fish and Wildlife Service also reviewed field observations for most of the other PACs proposed for both mechanical thinning and prescribed fire. Vegetation simulation modeling was done to develop potential treatments tailored to individual stand conditions within each PAC. Modeling indicated mechanical treatments could move 10,741 of 35,566 acres (31 percent of total PAC acres) onto a trajectory that better meets the above criteria for habitat within the 18 PACs (see the 4FRI Silviculture report).

While existing occupancy data for these 18 PACs is not comprehensive, there is strong evidence from other PACs supporting the assertion that occupancy rate declines as habitat quality declines. In other words, some of the PACs with low habitat quality are likely to be only intermittently occupied, if at all. There is an acknowledged risk that measuring the effects of treatment on Mexican spotted owl PACs of marginal quality may be confounded by intermittent occupancy prior to treatment. A short-term absence of occupancy post-treatment could be indistinguishable from pre-treatment use if occupancy was originally intermittent. It is, nevertheless, valuable to monitor short-term impacts of treatments in low quality habitat as these are the areas in greatest need of treatment. Additionally, the results may be leveraged with those of other related monitoring efforts to better describe broader trends and there is potential that this effort could set-up long-term monitoring efforts that better address changes to forest structure and the resulting effects to Mexican spotted owls.

The proposed monitoring plan would pair treated and reference PACs within the project area to compare occupancy, reproductive success, and habitat changes. There will be two groups of study PACs. The first group will consist of PACs receiving thinning and burning treatments and corresponding paired reference PACs (Group 1) and the second group of PACs will consist of PACs receiving prescribed fire-only treatments and their corresponding paired reference PACs (Group 2). Criteria for pairing selected treatment and reference PACs will include the following:

- Both treatment and reference PACs must be currently occupied by a pair of spotted owls. It is recognized that this may be problematic due to the potential for inconsistent occupancy in some of the PACs.
- Both treatment and reference PACs should consist of similar habitat (e.g., percentage of pine-oak, etc.).
- Both treatment and reference PACs should have similar environmental conditions (e.g., fire history, management history, etc.).
- Treatment and reference PACs should not have other confounding factors (e.g., heavy recreation, multiple land managers, etc.)

- Treatments in selected PACs should ideally occur across the majority of their spatial extent to maximize the ability to detect cause and effect.
- Reference PACS may come from a pool of PACs including those not proposed for any treatment or PACs where treatment has been deferred in order to maintain an “untreated” condition during the monitoring period. In order to achieve maximum similarity, reference PACs may also be selected from PACs outside of the 4FRI project area.
- PACs may be stratified by treatment type, year of treatment, etc.

Guiding Question:

- How do planned thinning and fire treatments affect habitat in the short-term and do the resulting changes affect short-term occupancy and reproductive success in treated versus untreated PACs?

Identified Response Variables:

- Owl occupancy (the percent of PACs occupied before and after treatments).
- Owl reproductive success (ideally the number of fledglings observed per adequately checked pair before and after treatments).
- Habitat change (post-treatment changes for key variables selected from Table C.2 (USDI FWS 2012, pp. 276-277) showing description of desired conditions [DCs]) in forest cover types typically used by Mexican spotted owls for nesting and roosting.

Planned Treatments:

- Treatments will likely be variable in spatial extent and intensity (intensity measured by degree of change in key habitat variables related to desired conditions [see Table C.1]).

General Study Design Approach:

- Monitoring will contrast a set of reference PACs to a set of treatment PACs for each PAC treatment group. As stated above, reference PACs will match the environmental conditions as closely as possible in PACs where treatments are proposed. Treatment PACs will be prioritized for management actions soon after the initiation of the 4FRI. If reference PACs are selected from PACs with assigned treatments, then those treatments will not occur for at least 5 years.
    - ♦ Group 1 PACs are proposed to have both thinning and prescribed fire treatments and will be drawn from those PACs listed in Table 5 of the biological opinion or as described above. Three treatment PACs and 3 paired reference PACs will be selected for Group 1 comparisons. Final treatment PACs and reference PACs will be collaboratively identified by the FS and U.S. Fish and Wildlife Service after occupancy is determined.
    - ♦ Group 2 PACs are proposed to have prescribed fire-only treatments and will be drawn from those listed in Table 6 of the biological opinion or as described above. Three treatment PACs and 3 paired reference PACs will be selected for Group 2 comparisons. Final treatment PACs and reference PACs will be collaboratively identified by the FS and U.S. Fish and Wildlife Service after occupancy is determined.
- Surveys for occupancy and reproductive success will be conducted for at least 2 seasons before treatment.

- Surveys for occupancy and reproductive success will also be conducted in consecutive years post-treatment starting with the year of mechanical treatment and continuing until 2 years post-prescribed fire treatments. We expect this will total at least 5-6 years of surveys per PAC requiring 3-6 visits per PAC per year.
- Vegetation data will be collected prior to treatment, then 1 year post-mechanical treatment and 2 years post-fire treatment for a total of 3 visits per PAC.
- Vegetation and spotted owl survey protocols will remain consistent across treatments groups and throughout the monitoring period. Combined, this effort could require anywhere from 300 to about 550 PAC visits.

Sampling Considerations:

- Sample response variables have been selected to allow estimation of the short-term effects of treatment on occupancy, reproductive success, and habitat desired conditions.
- Mexican spotted owl data will come from standard survey protocols and should ideally yield determinations of occupancy and reproductive success
- Vegetation data will come from nested variable radius and fixed plot surveys, large diameter woody debris transects and spatial analysis of 1-meter resolution aerial photography. These methods should yield measures of tree species diversity, basal area, large tree frequency (more than 12 inches and more than 18inches d.b.h.), canopy cover and horizontal structural diversity. We have a protocol developed for monitoring conducted on the Flagstaff Watershed Protection Project with U.S. Fish and Wildlife Service and ERI that could be used or modified.

Potential Analytic Approaches:

- Simple treatment effect stratified by treatment type and geographic area/cover type. Two-sample tests, ANOVA, regression-based approaches, power dependent on sample size and variability.
- Subsequent analyses only if treatment effects are apparent – gradient analysis, AIC based model selection if sample size permits use of treatment /habitat covariates.

Quality Control / Assurance

- The monitoring plan is a result of agreements reached with the U.S. Fish and Wildlife Service during the consultation process for the 4FRI.
- FS and U.S. Fish and Wildlife Service will coordinate and plan monitoring work cooperatively
- A written annual report with survey results will be submitted to U.S. Fish and Wildlife Service

Attachment 2. Arizona Bugbane Administrative Study: Fire Effects

The FS is collaborating with the U.S. Fish and Wildlife Service to finalize a strategy to monitor the impacts of prescribed fire on Arizona bugbane.

Introduction

Arizona bugbane is endemic to northern and central Arizona. It requires shade from forest or riparian overstory. Arizona bugbane is known to occur in mesic habitats, typically along the bottoms and lower slopes of steep, narrow canyons, where the overstory often includes a combination of coniferous and deciduous tree species. Important overstory species include Douglas fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), big tooth maple (*Acer saccharum* ssp. *grandidentatum*), Arizona alder (*Alnus oblongifolia*) and red osier dogwood (*Cornus stolonifera*).

Preliminary modelling data for Arizona bugbane indicates that it occurs primarily on a certain soil type, soil unit 555. This unit is composed of colluvium material and formed from sandstone and limestone. It tends to occupy a northern aspect, which provides cooler and moister conditions and has a severe erosion hazard. The dominant plant communities are composed of ponderosa pine and mixed conifer with Gambel oak and various shrubs. Within our area of interest, Arizona bugbane also occurs on soil unit 549, which is a colluvium soil of cherty bedrock. Here, the dominant overstory species include ponderosa pine and gambel oak (USDA Forest Service, 1995).

Arizona Bugbane and Fire

Arizona bugbane often grows in rocky areas with poor soil where surface fuel may be discontinuous in and/or around the populations. Current knowledge of fire effects on Arizona bugbane is based largely on observations from two local wildfires: the Fry Fire in 2003, and the Slide Fire in 2014, both on the Coconino National Forest (Crisp et al. 2004, 2014 personal observation). The Fry Fire covered 180 acres of upland and canyon habitats in Fry Canyon and was of mixed severity. The highest severity fire effects in areas with individual Arizona bugbane plants initially included loss of the above ground portions. On a subsequent visit in 2004, some Arizona bugbane plants were observed resprouting along the fire line near the canyon bottom, including in some severely burned areas. Observers noted a variety of plant sizes and ages, ranging from immature plants to adults with mature fruits. An adult plant with fruits and blackened soil at the base is shown in (figure 69). The lower portion of the canyon supports mixed-conifer forest and is more mesic than the upland ponderosa pine forest along the rim of the canyon. Arizona bugbane populations were informally monitored again in 2005 and 2010, and plants were persisting and thriving. Although quantitative data has not yet been compiled from the Slide Fire, similar effects immediately post-fire were observed in most affected populations (figure 69 and figure 70). As such, it is possible that Arizona bugbane may be adapted to fire, although the historic fire frequency in areas where it is found may be less than in the surrounding vegetated areas.

A literature search did not return any published data for fire effects to Arizona bugbane. However, based on taxonomic information for the genus Cimicifuga in the Flora of North America, members of the genus Cimicifuga have long-lived perennial rhizomes (see Vol. 3 page 177) that would persist after the top portions of the plants senesces in the fall. This allows the plants to regenerate from the underground rhizomes when conditions are favorable in the spring. Pyke et al. (2010) addressed the persistence of plants after wildfires using several traits including life form. Perennial species such as bugbane are categorized as cryptophtyes (see table 1 of article). Plants with this life form are generally one of the most protected from death during fire because the soil insulates the underground portions of the plants. In these cases, the top portions of the plant may be killed, but the underground structures, such as rhizomes, are able to persist (Pyke et al. 2010).

A related species in the same genus, *Actaea rubra*, has been studied in the Northwestern US. Data are available on the Fire Effects Information System website (Crane 1990). In that species, the tops of plants are removed by fire and then plants regenerate from thick underground caudices, but seedlings did not appear for several years post-fire.

Figure 69. Arizona bugbane plants near the fire line on Fry Fire September 2004

Figure 70. Arizona bugbane sprouting from roots about a month after the Slide Fire burned though this population

Given the frequency of fire in the areas surrounding the populations (figure 71) it seems unlikely that it would not have some adaptations. Even if separated from the frequent fire areas, there would be years when embers would spot near or in populations, an occurrence that is more likely in dry years, or between the end of the spring precipitation and the onset of monsoons.

Historic and recent Fire

Over a 25 year period, the majority of natural ignitions within an area of approximately 55,000 acres around known populations of Arizona bugbane occurred from May to September (table 152). Yet in order to help maintain control, prescribed fires are typically implemented before May or after mid-September. It is possible that implementing prescribed fire at these times may produce stress on bugbane, because the plant's adaptations are likely related to fires occurring during this peak period. The Fry Fire and the Slide Fire are known to have burned into an Arizona bugbane population between May and September.

There is an unnaturally high surface fuel buildup in areas surrounding these populations and possibly within them as well. Although we do not know the details of its fire adaptations, there are concerns about the potential for unnaturally high severity fire effects in and around bugbane populations. Therefore, it seems advisable, based on the limited information available, to use prescribed fire in a manner that seems most likely to benefit the species and to document the effects for informing future management actions.

Table 152. Number of ignitions by month over a 25-Year period within the area shown in figure 71

January	February	March	April	May	June
0	0	1	1	12	30
July	August	September	October	November	December
146	106	39	17	1	0

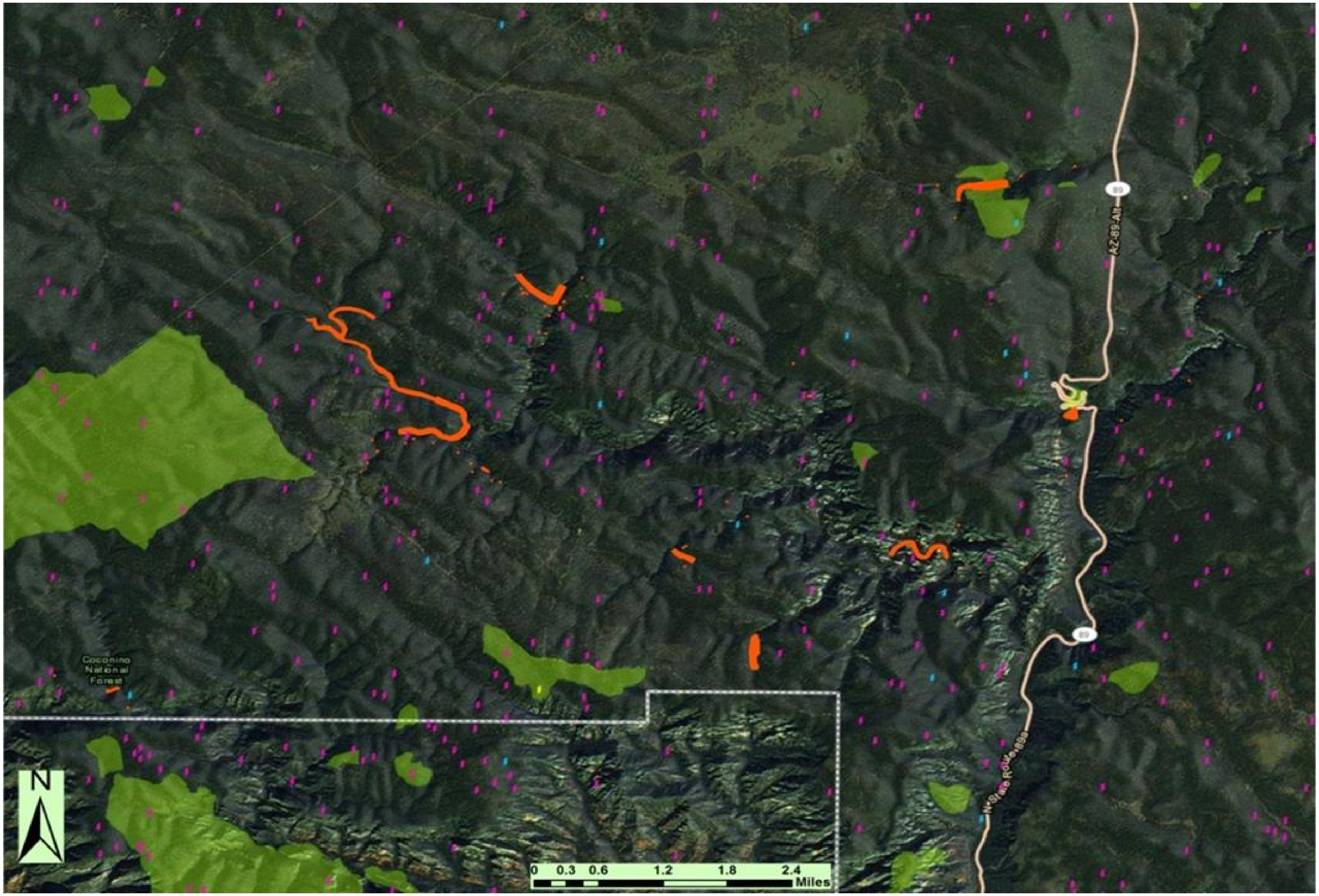

Figure 71. Arizona bugbane populations are shown in orange. Lightning fires locations are shown as: Yellow = January through April; Pink = May through September; Blue = October through December. 2) Perimeters of lightning fires that grew to 10 acres or larger are in green.

Study Design

To address concerns over the potential fire effects to Arizona bugbane, we are proposing to incorporate into the 4FRI analysis a prescribed burning and monitoring project for population sites in the Upper West Fork area that are currently proposed for treatment. The burning and monitoring project may be carried out as part of this analysis or as a separate administrative study.

Pre-and post-monitoring would occur across multiple Arizona bugbane populations. Areas outside of the 4FRI analysis area may be used for controls or treatment after consultation with district personnel. All activities would be subject to limitations such as human safety, timing restrictions as they apply to Mexican spotted owl nesting seasons, burn windows, wilderness considerations, etc.

As part of 4FRI implementation, prescribed burning may occur in or near some populations of Arizona bugbane. Direct effects to Arizona bugbane could include death or top killing of individual plants, or parts of plants. Indirect effects may come from the decreased shade from decreased canopy cover if trees or portions of tree crowns are killed in the surrounding area; increased sprouting and/or flowering resulting from the post-fire nutrient pulse and decreased litter cover; increased seedling establishment from increased area of exposed mineral soil; or other more complex effects resulting from changes to surface albedo, precipitation reaching the soil, decreased competition, and/or other changes resulting from the fire and the antecedent conditions. Under the current NEPA analysis, mitigations would include managing prescribed fires to keep severity low in and near the bugbane.

This monitoring/burning project was designed by Fire Ecologist, Mary Lata and Forest Botanist, Debra Crisp. We would coordinate with the U.S. Fish and Wildlife Service and a fire specialist in the selection of sites in the West Fork Area for study.

The proposed study area consists of stands within the Upper West Fork Mexican spotted owl PAC (figure 72 and table 156). No bugbane test burning would occur in the core area. The Recovery Plan (USDI FWS 2012) does not recommend burning in Mexican spotted owl PACs during the breeding season (March 1 to August 31) except when non-breeding is confirmed or inferred that year. The area would be surveyed for Mexican spotted owl before implementation of the raking and burning treatments to determine reproductive status of Mexican spotted owl in the PAC.

Table 153. Arizona bugbane locations and sites in the Upper West Fork PAC

Restoration subunit	Date Collected	Location	Site	Alternative C
3-5	9/12/2012	167	33	Burn Only
3-5	9/12/2012	167	34	Burn Only
3-5	9/12/2012	176	3	Burn Only
3-5	9/1/1980	176	7	Burn Only
3-5	9/12/2012	176	10	Burn Only

The study would include 2 to 3 different treatments as follows:

1. Control (a population with characteristics and location as similar as possible to the one being treated, or a portion of a single large population if treated and untreated areas can be separated by at least 50 meters): The control area would not be burned although, as stated above, it would receive whatever mechanical treatments have been prescribed for the area, and would serve as a comparison for the other two treatments.

2. Prescribed fire (as stated above, this area would be at least 50 meters from a control, or as similar as possible to a control): This area would be subjected to a burning treatment as proposed for the location/site and already incorporated in this alternative. Fire within and adjacent to the bugbane population would be managed to produce only low severity effects.
3. Partial raking with no burning (a portion of the control population): The intent of this treatment is to mimic historical levels of litter and duff under characteristic fire levels without necessarily using fire as a treatment. It would be included in the design if there are sufficient populations or they are sufficiently large to accommodate additional treatments. If historically, these areas burned periodically, even if it was a lower frequency than surrounding areas (there are no site-specific, definitive data for fire frequency in Bugbane populations) it is likely that there would normally have been less litter and duff than is currently observed.

Fireline would be created as needed to aid in administering consistent fire treatments. Individual treatments including controls would be separated by at least 50 meters to minimize the risk of effects from adjacent controls.

The preferred time for conducting burn treatments would be between May and August, when fire would have been historically expected to burn in this area. However, since most areas containing bugbane are near or adjacent to Mexican spotted owl habitat, timing restrictions for Mexican spotted owl may take precedence over the burning treatment and a fall burn would be implemented. A fall burn would be expected to be less harmful than a spring burn because individual plants would have had the preceding growing season to produce and store energy. In addition, plants are emerging in the spring and allocating stored energy to growth and reproduction. Raking (if used) and fire line construction (if needed) would occur immediately prior to the ignition of fire to assure that there is no effect from timing of the raking or the fireline construction. The area to be burned will be on the downhill side (if there is a slope) in order to prevent overland flow from carrying nutrients from the burned area into one of the non-burned areas, potentially biasing results.

Unless safety concerns preempt it, the fire would be monitored during ignition and burning to document fire behavior (rate of spread, flame depth) as it burned through the bugbane. Scorch would be kept to less than five feet in and adjacent to bugbane populations.

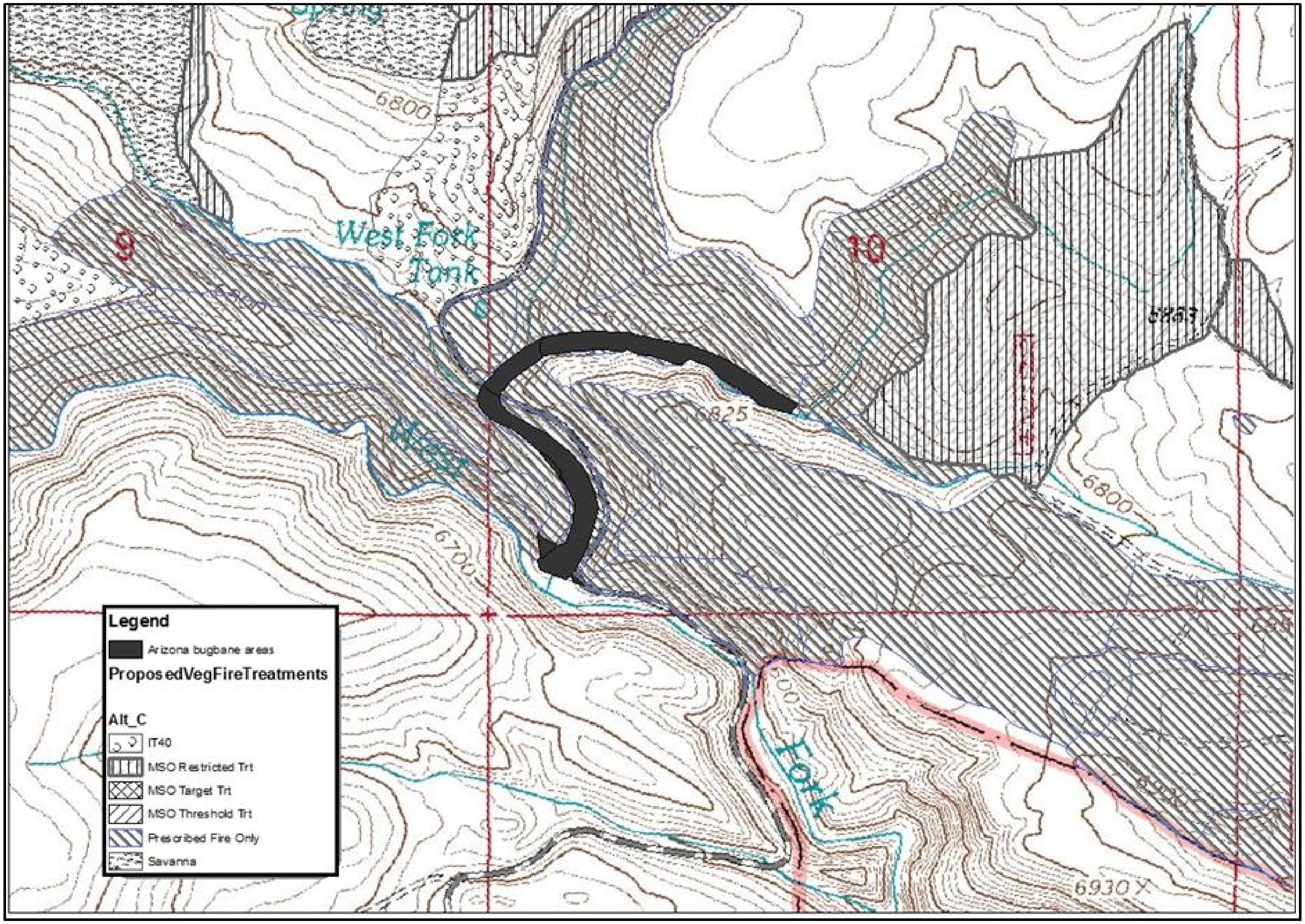

Figure 72. Map of the treatment areas. Arizona bugbane is shown in black.

Design Features

1. Implementation will require coordination between the Forest Botanist, District Wildlife Biologists, Fuels, Fire Ecologist and Wildlife Biologist, and the U.S. Fish and Wildlife Service.
2. If Mexican spotted owl associated with the Upper West Fork PAC are determined to be non-nesting or are absent based on protocol surveys in zones selected for burning treatments, we would likely burn between May and August. If Mexican spotted owl are nesting, then the burn would occur in the late/summer or fall.
3. Three or more replicates are needed. Areas outside of the current 4FRI analysis area can be considered for use as controls and possibly for burning. Consultation with district personnel should occur before treatment areas outside of 4FRI are selected.

Pre-treatment Data

The following data would be collected before burning occurred. The data should be collected less than two weeks prior to treatment, but as close to the implementation of the burn as possible. Fuel moisture data must be collected within a few days of implementation, and not before a precipitation event preceding the fire.

Data to be Collected

Collection of the plant data one year prior to the implementation of the treatment, within one week of the date of implementation one year after treatment and then three years after treatment. For example, if the prescribed fire is implemented on September 1st, data would be collected between August 25th and September 7th in years one and three following the burn.

1. **Stems per area**. Individual stems will be counted as opposed to clumps of plants to avoid the need to determine underground connectivity of the plants. The intent of this metric is to document changes in plant vigor by measuring changes in the number of stems per area
2. **Spatial area** occupied by the sample population. The intent of this metric is to document the expansion or contraction of the population over time.
3. Evidence of other activities at the site such as grazing by wildlife and/or livestock, recreation, etc.
4. Evidence of past natural events such as flooding, storm damage, insect mortality in the overstory, etc.
5. Canopy/shading including abiotic structures such as cliffs that may be providing shade to the bugbane groups being treated. We anticipate that canopy cover would be measured by a spherical densiometer or a similarly appropriate tool. The same type of instrumentation should be used for each visit and, if possible, the same person/s should collect the data each year since the sample size is small and the collection of this type of data is likely to vary significantly between surveyors.
6. Soil type should be recorded for each site (figure 73).
7. These data should be collected for populations in each treatment (untreated, raking and burning).

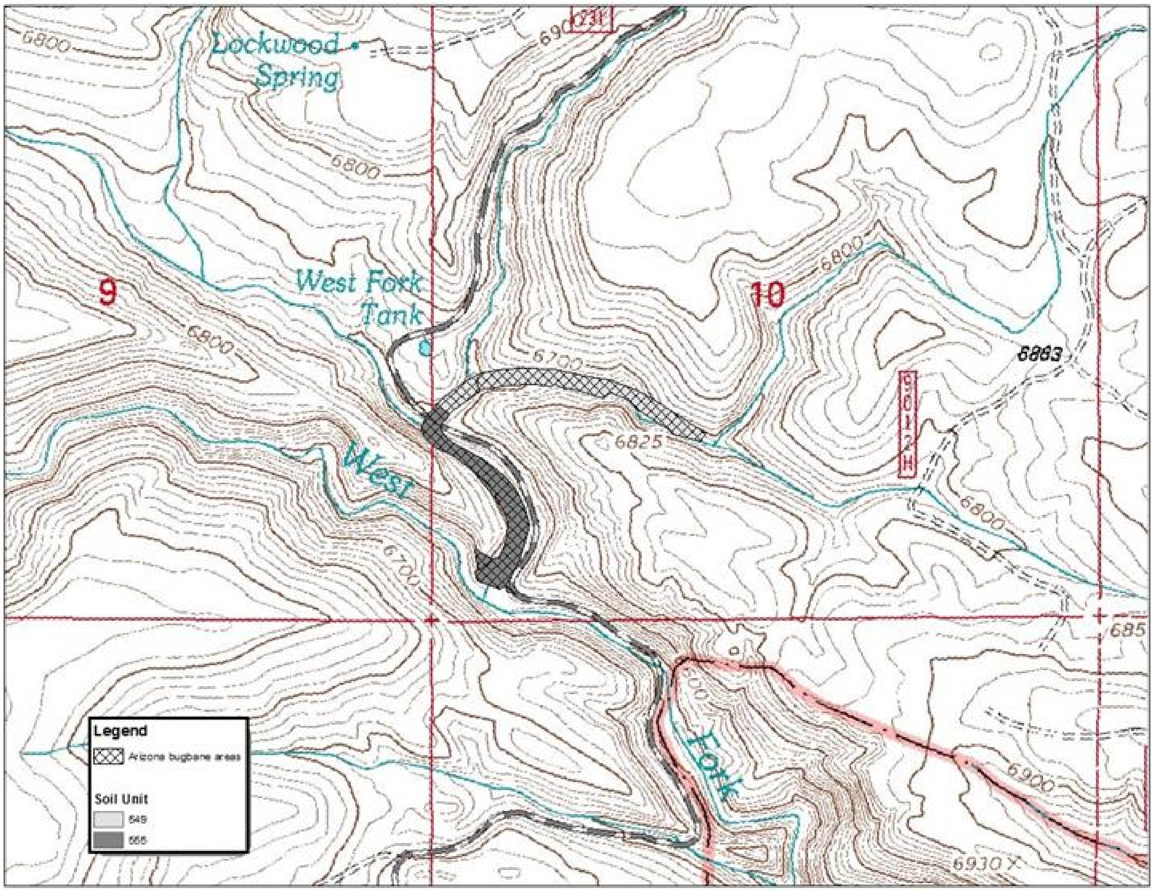

Figure 73. Map showing soil units in Arizona bugbane areas to be treated

Fire/fuels

1. Surface fuel loading (litter, duff, downed woody material (pre and post)). This will be determined by establishing a Brown’s fuel transect.
2. Exposed mineral soil (pre and post)
3. Timing of fire (month/week/day)
4. Fuel moisture (particularly litter and duff)
5. Rate of spread, flaming depth (used to determine residence time)
6. Fire weather at the site.
7. Precipitation on the site, gathered from the nearest reliable source.

Brown’s lines should be read at each visit to the treatment population (untreated, raking, and burning), along with exposed mineral soil. Recent deadfall and tree mortality rates should also be recorded.

Weather

Weather data for the date of collection and the season prior should be noted in order to consider the effects of weather on plant growth at the treatment sites.

Reporting

Data sheets will be prepared and data recorded in a standard manner on each visit to assure data consistency. Data sheets and field notes will be entered electronically into the 2670 Arizona bugbane file in an area established and designated for the monitoring/study. Data will also be shared with the U.S. Fish and Wildlife Service, 4FRI monitoring coordinator and other interested parties.

Attachment 3. Alternatives B through E Springs, Channel and Road Adaptive Management Actions

Table 154. Selected alternative springs, channels, and roads adaptive management actions

Evaluation Criteria	Desired Condition	Existing Condition	Possible Management Actions*	Monitoring Measure	Trigger Indicating Additional Action is Needed (What/When)	Adaptive Options*
Roads and unauthorized routes located in upland (non-meadow) and in meadows	Soils are in satisfactory condition so that soil can resist erosion, recycle nutrients, and absorb water. Understory species (grasses, forbs, and shrubs) diversity is consistent with site potential and provides for infiltration of water and reduction of accelerated erosion. The understory has a variety of heights of cool and warm season vegetation.	Up to 904 miles of road/route are in unsatisfactory soil condition due to accelerated erosion, lack of effective ground cover, and compaction.	1.Reestablish former drainage patterns, stabilize slopes, and restore vegetation; 2.Block the entrance to a road or install water bars; 3.Remove culverts, reestablish drainages, remove unstable fills, pull back road shoulders, and scatter slash on the roadbed; 4.Eliminate the roadbed by restoring natural contours and slopes; and 5.Other methods designed to meet the specific conditions associated with the unneeded road.	• Miles of road treated • Soil condition assessment	Soil condition is impaired or unsatisfactory as defined in a soil condition assessment. Time is 5 years after treatment.	• Additional drainage • Additional revegetation efforts (including mulching) • Short-term fencing to protect revegetation • Complete removal of roadbed

Evaluation Criteria	Desired Condition	Existing Condition	Possible Management Actions*	Monitoring Measure	Trigger Indicating Additional Action is Needed (What/When)	Adaptive Options*
Roads and unauthorized routes located in the filter strips of identified riparian and nonriparian stream courses	Soils are in satisfactory condition so that the soil can resist erosion, recycle nutrients, and absorb water. Understory species (e.g., grasses, forbs, and shrubs) diversity is consistent with site potential and provides for infiltration of water and reduction of accelerated erosion. The understory has a variety of heights of cool and warm season vegetation.	All roads are in unsatisfactory soil condition due to accelerated erosion, lack of effective ground cover, and compaction.	1. Reestablish former drainage patterns, stabilize slopes, and restore vegetation; 2. Block the entrance to a road or install water bars; 3. Remove culverts, reestablish drainages, remove unstable fills, pull back road shoulders, and scatter slash on the roadbed; 4. Eliminate the roadbed by restoring natural contours and slopes; and 5. Other methods designed to meet the specific conditions associated with the unneeded road.	• Miles of road treated • Soil condition assessment	Soil condition is impaired or unsatisfactory as defined in the soil condition assessment. Time is 5 years after treatment.	• Additional drainage • Additional revegetation efforts (including mulching) • Short-term fencing to protect revegetation

Evaluation Criteria	Desired Condition	Existing Condition	Possible Management Actions*	Monitoring Measure	Trigger Indicating Additional Action is Needed (What/When)	Adaptive Options*
Undeveloped spring in a forested setting. Vegetation and soils range from satisfactory condition (waterflow is occurring) to vegetation/ soils are below potential or are impaired/ unsatisfactory (there is no evidence of waterflow from spring).	Springs and associated streams and wetlands have the necessary soil, water, and vegetation attributes to be healthy and functioning at or near potential. Waterflow patterns, recharge rates, and geochemistry are similar to historic levels and persist over time. Water quality and quantity maintain native aquatic and riparian habitat and water for wildlife and designated beneficial uses, consistent with water rights and site capability. Plant distribution and occurrence are resilient to natural disturbances. Soils are in satisfactory condition.	Undeveloped springs occur on both forests in a forested setting. Note: Of the total number of springs, there are six springs on the Coconino NF that are located in forested areas, but the status of development is unknown.	If vegetation/soils are satisfactory options include: • Remove tree canopy to pre-settlement condition within 2–5 chains of the spring; • Apply for water right if none exists; • Prescribe burn, or • No action. If vegetation/soils are below potential or are impaired/unsatisfactory options include: • Remove tree canopy to pre-settlement condition within 2–5 chains of the spring; • Apply for water right if none exists; • Remove noxious weeds; • Prescribe burn; or • Identify stressor and provide protection measure for the stressor (fence, jackstraw, remove/relocate road/trail etc.) and/or • Other methods designed to meet the desired conditions.	Properly functioning condition (PFC), Museum of Northern Arizona level 1 monitoring, waterflow (possible new direction for spring monitoring from FS), photo points	Drop in proper functioning condition class, monitoring displays a dropping trend. Monitoring every 1–10 years	• ID stressor, protect from stressor (fence/ jackstraw, close road, relocated road, etc.) • No action

Evaluation Criteria	Desired Condition	Existing Condition	Possible Management Actions*	Monitoring Measure	Trigger Indicating Additional Action is Needed (What/When)	Adaptive Options*
Developed springs in a forested setting. Vegetation and soils range from satisfactory condition (waterflow is occurring) to vegetation/ soils are below potential or are impaired/ unsatisfactory (there is no evidence of waterflow from spring).	Springs and associated streams and wetlands have the necessary soil, water, and vegetation attributes to be healthy and functioning at or near potential. Waterflow patterns, recharge rates, and geochemistry are similar to historic levels and persist over time. Water quality and quantity maintain native aquatic and riparian habitat and water for wildlife and designated beneficial uses, consistent with water rights and site capability. Plant distribution and occurrence are resilient to natural disturbances. Soils are in satisfactory condition.	There are 26 springs on the Kaibab NF that are located in forested areas and the status of development is unknown. There are 40 developed springs on the Coconino NF that are located in forested areas. There are six springs on the Coconino NF that are located in forested areas and the status of development is unknown.	Negotiate with holders of water rights that are non-Forest Service at Alto, Chimney, Dairy, Double, Garden, Griffiths, Howard, Little Elden, Lower Hull, Mud, Pat, Sawmill, Seven Anchor, and Upper Hill Springs on the Coconino National Forest and springs on the Kaibab NF to explore the possibility of releasing water above their water right for riparian conditions. If vegetation/soils are below potential or are impaired/unsatisfactory: • Remove tree canopy to pre-settlement condition within 2–5 chains of the spring, • Prescribe burn, • Remove existing water right (see list above) to expand current riparian conditions, • Identify stressor and provide protection measure for the stressor (fence, jackstraw, remove/relocate road/trail etc.), and/or • Apply other methods designed to meet the desired conditions.	proper functioning condition, Museum of Northern Arizona level 1 monitoring, waterflow (possible new direction for spring monitoring from FS), photo points	Drop in proper functioning condition class, monitoring displays a dropping trend. Monitoring every 1–10 years	• ID stressor, protect from stressor (fence/ jackstraw, close road, relocated road, etc.) • No action

Evaluation Criteria	Desired Condition	Existing Condition	Possible Management Actions*	Monitoring Measure	Trigger Indicating Additional Action is Needed (What/When)	Adaptive Options*
Undeveloped spring in a meadow setting. Vegetation and soils range from satisfactory condition (waterflow is occurring) to vegetation/ soils are below potential or are impaired/ unsatisfactory (there is no evidence of waterflow from spring).	Springs and associated streams and wetlands have the necessary soil, water, and vegetation attributes to be healthy and functioning at or near potential. Waterflow patterns, recharge rates, and geochemistry are similar to historic levels and persist over time. Water quality and quantity maintain native aquatic and riparian habitat and water for wildlife and designated beneficial uses, consistent with water rights and site capability. Plant distribution and occurrence are resilient to natural disturbances. Soils are in satisfactory condition.	Springs occur on the two national forests that are not developed and occur in a meadow setting. There is one spring on the Coconino NF (Scott Spring) that is located in meadow areas, but the status of development is unknown. There is one spring on the Kaibab NF that is located in meadow areas, but the status of development is unknown.	If vegetation/soils are satisfactory: • Apply for water right if none exists, • Prescribe burn, and/or • Take no action. If vegetation/soils are below potential or are impaired/unsatisfactory: • Apply for water right if none exists, • Remove noxious weeds, • Prescribe burn, • Identify stressor and provide protection measure for the stressor (fence, jackstraw, remove/relocate road/trail etc.), and/or select • Other methods designed to meet the desired conditions.	proper functioning condition, Museum of Northern Arizona level 1 monitoring, waterflow (possible new direction for spring monitoring from FS), photo points	Drop in proper functioning condition class, monitoring displays a dropping trend. Monitoring every 1–10 years	• ID stressor, protect from stressor (fence/ jackstraw, close road, relocate road, etc.) • No action

Evaluation Criteria	Desired Condition	Existing Condition	Possible Management Actions*	Monitoring Measure	Trigger Indicating Additional Action is Needed (What/When)	Adaptive Options*
Developed spring in a meadow setting. Vegetation and soils range from satisfactory condition (waterflow is occurring) to vegetation/ soils are below potential or are impaired/ unsatisfactory (there is no evidence of waterflow from spring).	Springs and associated streams and wetlands have the necessary soil, water, and vegetation attributes to be healthy and functioning at or near potential. Waterflow patterns, recharge rates, and geochemistry are similar to historic levels and persist over time. Water quality and quantity maintain native aquatic and riparian habitat and water for wildlife and designated beneficial uses, consistent with water rights and site capability. Plant distribution and occurrence are resilient to natural disturbances. Soils are in satisfactory condition.	Springs occur on the two national forests that are developed and occur in a meadow setting. There are four springs on the Coconino NF that are located in meadow areas and are developed.	If vegetation/soils are satisfactory: • Prescribe burn, • Re-plumb spring to allow for water above existing water right to be released to expand current riparian conditions, and /or • Other methods designed to meet the specific conditions associated. If vegetation/soils are below potential or are impaired/unsatisfactory: • Prescribe burn, • Remove noxious weeds, • Re-plumb spring to allow for water above existing water right to be released to expand current riparian conditions, • Identify stressor and provide protection measure for the stressor (fence, jackstraw, remove/relocate road/trail etc.), and/or • Other methods designed to meet the desired conditions.	proper functioning condition, Museum of Northern Arizona level 1 monitoring, waterflow (possible new direction for spring monitoring from FS), photo points	Drop in proper functioning condition class, monitoring displays a dropping trend. Monitoring every 1–10 years	• ID stressor, protect from stressor (fence/ jackstraw, close road, relocated road, etc.) • No action