



Four Forest Restoration Initiative:

Stakeholders' Initial Science Needs Assessment

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Background

The Four Forest Restoration Initiative (4FRI) seeks to implement comprehensive forest restoration across much of the Mogollon Rim. Forest restoration at this scale and pace is unprecedented and involves considerable uncertainty. The 4FRI stakeholders recognized this uncertainty in *The Path Forward*, emphasizing the need to “maximize our opportunities to systematically learn our way through the process.” As a first step, the 4FRI Science and Monitoring Working Group conducted a science needs assessment to identify questions of highest priority among 4FRI stakeholders. This exercise had three primary objectives:

- **Ensuring that the 4FRI’s monitoring program is effective, efficient, and relevant to stakeholder concerns:** A monitoring program that achieves its goals and detects meaningful changes should address specific, management-driven questions determined prior to data collection.
- **Supplying the USFS with experimental design recommendations:** The 4FRI provides the opportunity to conduct experiments at unprecedented scales. To capitalize on this opportunity we must provide the Forest Service with recommendations on how treatments can be implemented in ways that meet experimental design standards and support reliable inference. This process will proceed effectively if the hypotheses/questions underlying the experiments are well-defined.
- **Providing a foundation for adaptive management:** Questions developed by stakeholders are an integral part of the of the adaptive management process, allowing tests of underlying assumptions and hypotheses regarding responses to restoration treatments.

On August 5, 2010, an electronic questionnaire was sent to members of the 4FRI Stakeholder Group. Respondents were asked to identify the five most important questions within each of six categories: geology and hydrology; forest structure and function; understory composition and function; fish, invertebrates, and wildlife; fire behavior; and socio-economics. Respondents were also encouraged to list additional questions that did not fit into these categories. For each question, stakeholders were asked to identify appropriate spatial and temporal scales for addressing the question. Responses were accepted until September 27, 2010, at which point sixteen responses from twelve organizations had been received (Table 1). The following is a synthesized presentation of those responses. Wherever possible, care has been taken to ensure the integrity of the responses; however, some questions were combined to reduce redundancy. It should be noted that the categorization, scale, and frequency are the opinions of the respondents and as such reflect stakeholders’ perceptions of the question at hand. Finally, it should be noted the order of presentation does not indicate priority.

Table 1. Respondents to the Four Forest Restoration Initiative Stakeholders’ First Science Needs Assessment.

Organizations that responded to First Science Needs Assessment	
Arizona Game and Fish Department	Northern Arizona University – Ecological Restoration Institute
Center for Biological Diversity	Northern Arizona University – Lab of Landscape Ecology and Conservation Biology
Coconino Rural Environmental Corps	Northern Arizona University – School of Earth Sciences and Environmental Sustainability
Eastern Arizona Counties Organization	Northern Arizona University – School of Forestry
Grand Canyon Trust The Nature Conservancy	Northern Arizona Wood Products Association United States Forest Service

Results of First Science Needs Assessment

Geological and Hydrological Response to Treatment

Question	Suggested Scale of Measurement (ac)	Suggested Sampling Frequency
<i>How are the boundaries of wetlands that have been invaded by woody species defined?</i>	100’s	Annual ¹
<i>Do forest treatments affect the hydrogeology and/or ecology of natural springs and wet meadows?</i>	100’s	Annual ¹
<i>How do the short- and long-term effects of mastication on soil composition and structure differ from the effects of fire on those same components?</i>	1,000’s	Annual ¹
<i>What are the effects of restoration treatments on soil properties such as compaction, stability, and erosion?</i>	1,000’s	Annual ¹
<i>How do different thinning intensities affect forest evapotranspiration?</i>	1,000’s	Annual ¹
<i>Does the size of forest openings affect snowpack accumulation, snow water equivalency, soil moisture or spring runoff?</i>	100’s	Annual ¹
<i>How will various thinning treatments and various intensities and recurrence intervals of prescribed fire affect surface water availability and runoff?</i>	1,000’s	Annual ¹

¹Measurements taken annually, but trends addressed at longer intervals

Geological and Hydrological Response to Treatment (cont'd)

Question	Suggested Scale of Measurement (ac)	Suggested Sampling Frequency
<i>Can initial increases in water yield following thinning be maintained using prescribed burning?</i>	1,000's – 10,000's	Annual ¹
<i>At a landscape scale, what is the relationship between tree density and water yield?</i>	10,000's – 100,000's	Annual ¹
<i>How long do changes in water quality and yield persist following treatment?</i>	10,000's – 100,000's	Annual ¹
<i>Do thresholds exist for the number of acres in a watershed that can be treated before negatively impacting water quality?</i>	10,000's – 100,000's	Annual ¹
<i>What are the hydrologic variances between Dry Mixed Conifer and Wet Mixed Conifer Ecosystems?</i>	100,000's	Decadal

¹Measurements taken annually, but trends addressed at longer intervals

Forest Structural and Functional Response to Treatment

Question	Suggested Scale of Measurement (ac)	Suggested Sampling Frequency
<i>What is the recovery time of carbon stocks removed by thinning and prescribed burning?</i>	1,000's	3-5 years
<i>How do different thinning intensities affect forest carbon balance?</i>	1,000's	Annual ¹
<i>Is mortality of pre-settlement trees due to fire less than 15% five years following treatment?</i>	1,000's	3-5 years
<i>Can adequate regeneration be maintained with increased levels of restoration treatments?</i>	1,000's	Decadal
<i>How does a diameter cap affect age class distribution in residual stands? Is regeneration maintained at adequate levels?</i>	1000s	Annual
<i>How can the longevity of forest restoration treatments in relation to fire effects be determined?</i>	10,000's	Annual ¹
<i>Within a treatment area, what percentage of area is in large (>.25ac) openings?</i>	10,000's	Annual ²
<i>What is the difference between pre- and post-treatment stand structure?</i>	100's – 1,000's	Annual ¹
<i>How is forest structure changing with different severity burning treatments?</i>	100's – 1,000's	Annual ¹
<i>Are treatments leaving groups of trees with interlocking crowns?</i>	100's – 1,000's	Annual ²
<i>Are treatments actually resulting in desired/modeled forest structure (i.e.: patchiness, size-class distribution, canopy cover/closure)?</i>	100's – 10,000's	Annual ¹
<i>Do forest pests remain at endemic levels?</i>	DNS ³	DNS ³
<i>What is post-treatment canopy cover (measured at multiple scales) and how does it change over time?</i>	100's – 10,000's	Annual ¹

¹Measurements taken annually, but trends addressed at longer intervals

²Assumption is that this measurement would be taken immediately following treatment

³DNS = Did not specify

Forest Structural and Functional Response to Treatment (cont'd)

Question	Suggested Scale of Measurement (ac)	Suggested Sampling Frequency
<i>Once desired/conditions are achieved are these conditions self-sustaining?</i>	100's – 100,000's	Decadal
<i>How do other sources of mortality (e.g.: bark beetles, mistletoe) affect the transition from post-treatment conditions to desired future conditions?</i>	100's – 100,000's	3-5 years - Decadal
<i>What are the ecological consequences of [not] implementing a large tree retention policy?</i>	100's – 100,000's	3-5 years – Decadal
<i>How is response to treatment affected by climate change?</i>	100's – 100,000's	3-5 years – Decadal
<i>Do reference-condition based treatments result in ecosystems that are resilient and adaptable to a changing climate?</i>	100's – 100,000's	3-5 years – Decadal
<i>How do different treatment regimes affect longevity and recruitment of large (>18" dbh) snags across the landscape?</i>	100's – 100,000's	3-5 years – Decadal
<i>Are the number of snags and amount of coarse woody debris being maintained within acceptable parameters?</i>	100's – 100,000's	3-5 years – Decadal
<i>Do treatments oriented to stand-level structural diversity translate to heterogeneity at the landscape scale?</i>	10,000's – 100,000's	Decadal
<i>Can remote-sensing techniques be refined to develop a better understanding of landscape-scale changes in forest structure?</i>	10,000's – 100,000's	3-5 years

¹Measurements taken annually, but trends addressed at longer intervals

²Assumption is that this measurement would be taken immediately following treatment

³DNS = Did not specify

Understory Compositional & Functional Response to Treatment

Question	Suggested Scale of Measurement (ac)	Suggested Sampling Frequency
<i>How does soil type (or TES unit) impact herbaceous response following overstory removal?</i>	100's	Annual ¹
<i>How does climate change alter the competitive balance between native and invasive species?</i>	100's	Annual ¹
<i>Has treatment resulted in an increased amount of forage available for domestic livestock grazing?</i>	1,000's	3-5 years
<i>How do sensitive and rare species respond to increased rates and intensities of treatment?</i>	1,000's	3-5 years
<i>Is understory biomass increasing towards pre-settlement levels?</i>	1,000's	3-5 years
<i>How has the carbon balance of the landscape changed as a result of treatment?</i>	100,000's	3-5 years
<i>How can the spread of invasives, especially cheatgrass, be mitigated?</i>	100's – 1,000's	3-5 years
<i>How do slash disposal techniques impact invasive species' response to treatment?</i>	100's – 1,000's	3-5 years

¹Measurements taken annually, but trends addressed at longer intervals

Understory Compositional & Functional Response to Treatment (cont'd)

Question	Suggested Scale of Measurement (ac)	Suggested Sampling Frequency
<i>Is understory diversity increasing towards pre-settlement or reference-site levels?</i>	100's – 1,000's	3-5 years
<i>If clumping and grouping are achieved, will ground cover be maintained given grazing pressure by both elk and livestock?</i>	100's – 10,000's	Annual ¹
<i>Can current soil resources support the expected increase in herbaceous cover?</i>	1,000's – 10,000's	3-5 years
<i>Under what locations and conditions do restoration treatments facilitate the spread of invasive species?</i>	100's – 100,000's	Annual ¹
<i>How do increased rates of treatment and climate change affect invasion by non-native species?</i>	100's – 100,000's	Annual ¹
<i>How are restoration treatments changing the spatial extent of invasive species?</i>	100's – 100,000's	Decadal
<i>How does the regional increase in restoration activity (e.g.: Jemez Mountain Project, UP Project, 4FRI) affect the abundance and distribution of invasive species?</i>	10,000's – 100,000's	Decadal

¹Measurements taken annually, but trends addressed at longer intervals

Fish, Invertebrate, and Wildlife Response to Treatment

Question	Suggested Scale of Measurement (ac)	Suggested Sampling Frequency
<i>What are post-beetle vegetative impacts on wildlife?</i>	10,000's	Annual
<i>Is there an optimal "clump" size that meets Northern Goshawk requirements and maximizes diversity of other species?</i>	100's – 1,000's	3-5 years
<i>How do terrestrial invertebrate communities respond to restoration treatments?</i>	100's – 10,000's ²	Annual ¹
<i>How do restoration treatments impact ground-nesting/seed-feeding birds and mammals?</i>	100's – 10,000's ²	3-5 years ²
<i>Do species-specific approaches to restoration (e.g.: Goshawk Guidelines) actually result in increased productivity of the target species?</i>	100's – 10,000's ²	3-5 years ²
<i>How do restoration treatments impact species that require "interior forest" conditions?</i>	100's – 10,000's ²	Annual ¹
<i>Do "open habitat" species respond to "groups" and "clumps"?</i>	100's – 10,000's ²	3-5 years ²
<i>How can models linking focal species to landscape characteristics be developed/improved?</i>	100's – 10,000's ²	Annual ¹²
<i>How do focal species respond to restoration treatments?</i>	100's – 10,000's ²	Annual ¹²
<i>If population levels cannot be assessed, what are appropriate surrogates?</i>	DNS ³	DNS ³

¹Measurements taken annually, but trends addressed at longer intervals

²Scale and frequency will be dependent on species in question

³DNS = Did not specify

Fish, Invertebrate, and Wildlife Response to Treatment (cont'd)

Question	Suggested Scale of Measurement (ac)	Suggested Sampling Frequency
<i>How can the relationship between population surrogates and actual population trends be assessed?</i>	DNS ³	DNS ³
<i>How do Northern Goshawk and its prey species respond to “evidence-based” treatment versus “Goshawk Guideline” treatments?</i>	1,000’s – 10,000’s	Annual ¹
<i>What is the cumulative spatial arrangement of “Goshawk Guideline” treatment implementation?</i>	100’s – 10,000’s ²	Decadal
<i>What is the temporal effect of the cumulative arrangement of “Goshawk Guideline” treatments on Northern Goshawk and its prey?</i>	100’s – 10,000’s ²	Decadal
<i>How do aquatic invertebrate and fish communities respond to changes in water availability resulting from restoration treatments?</i>	1,000’s – 10,000’s	Annual ¹
<i>How do aquatic communities respond to changes in water quality resulting from restoration treatments?</i>	1,000’s – 10,000’s	Annual ¹
<i>How do elk populations respond to restoration treatments?</i>	1,000’s – 10,000’s	3-5 years
<i>Does the spatial configuration of treatments affect elk habitat quality?</i>	1,000’s – 10,000’s	Decadal
<i>What elk population levels allow for the natural recruitment of aspen, Bebb’s willow, and other key riparian species?</i>	1,000’s – 10,000’s	Annual ¹
<i>How do larger treatment areas and increased rates of treatment affect habitat connectivity and corridor utilization by highly mobile species?</i>	10,000’s – 100,000’s	3-5 years - Decadal
<i>Which wildlife species’ populations could be threatened by restoration treatments?</i>	DNS ³	DNS ³
<i>What is the current status of those species that could be negatively impacted by restoration treatments?</i>	100’s – 100,000’s	Annual ¹
<i>What is the current status of candidate, threatened, endangered, and USFS sensitive species within the project area?</i>	100’s – 100,000’s	Annual ¹
<i>What steps can be taken to ensure that populations of candidate, threatened, endangered, USFS sensitive species, and those that may be negatively impacted by treatment remain viable throughout 4FRI implementation?</i>	100’s – 100,000’s	Annual ¹

¹Measurements taken annually, but trends addressed at longer intervals

²Scale and frequency will be dependent on species in question

³DNS = Did not specify

Fire Behavior Response to Treatment

Question	Suggested Scale of Measurement (ac)	Suggested Sampling Frequency
<i>Did strategic placement of treatments result in increased efficiency in altering fire behavior?</i>	10,000's	Annual ¹
<i>What is the optimal proportion of the landscape that must be treated for SPLAT/SPOT to achieve desired fire behavior?</i>	10,000s	Annual
<i>If follow-up treatments do not occur, how long will treatment-induced reductions in fire hazard persist?</i>	10,000's	Annual ¹
<i>Are there alternative strategies for treatment placement other than those currently considered?</i>	10,000's	Annual ¹
<i>Where, when, and under what conditions are natural ignitions being managed?</i>	100,000's	Annual ¹
<i>Have treatments reduced the risk of crown fire below the desired threshold?</i>	100,000's	3-5 years
<i>Has treatment resulted in an increased area where "natural" (planned or uncontrolled) fires are allowed to burn?</i>	100's – 10,000's	Annual ¹
<i>Given that fire-created snags are more ephemeral than those from other mortality sources; can a viable snag component be maintained with expected levels of fire management?</i>	100's – 10,000's	3-5 years
<i>How have changes in productivity, mortality, and species composition as a result of climate change altered fuel structure and loading?</i>	100's – 100,000's	Decadal
<i>Do 4FRI treatments allow the introduction of a fire regime that approximates pre-settlement conditions?</i>	100's – 100,000's	Decadal
<i>Do controlled burns achieve desired effects in continuing to reduce fuels?</i>	1000s-10,000s	Annual ¹
<i>How have 4FRI treatments altered the cost of fighting wildfires?</i>	1,000's – 100,000's	Annual ¹
<i>How has climate change altered fire regimes and what is the predicted effect of current rates of climate change on those regimes?</i>	10,000's – 100,000's	Decadal
<i>How do climate change predictions alter treatment arrangement and intensity to achieve desired changes in fire severity and behavior?</i>	10,000's – 100,000's	Decadal
<i>How can restoration treatments be designed and performed to mitigate the potential impacts of smoke?</i>	10,000's – 100,000's	Annual – 3-5 years
<i>What proportion of the landscape must be treated to prevent or significantly reduce the size and intensity of uncharacteristic fire?</i>	10,000's – 100,000's	3-5 years - Decadal
<i>How can restoration treatments be optimally placed to meet restoration goals and create the safest possible context for wildland and prescribed fire?</i>	10,000's – 100,000's	Annual ¹

¹Measurements taken annually, but trends addressed at longer intervals

Socio-economic Response to Treatment

Question	Suggested Scale of Measurement (ac)	Suggested Sampling Frequency
<i>What are the socially-acceptable sustainable balances between elk populations and aspen regeneration?</i>	100's	Annual
<i>What economic efficiencies have been gained as a result of landscape-scale restoration?</i>	10,000's	Annual ¹
<i>What is the net cost per acre to the USFS for restoration treatments?</i>	10,000's	Annual ¹
<i>How many jobs are created (directly and indirectly) as a result of 4FRI treatments?</i>	100,000's	3-5 years
<i>Are contractors able to balance their treatment costs over a given time period in order to achieve and economically viable average treatment cost?</i>	100,000's	Annual ¹
<i>Over what time period is it necessary for contractors to balance treatment costs to remain economically viable?</i>	100,000's	Annual ¹
<i>Is the USFS able to reduce planning/administration costs and increase planning/administrative efficiency over time as a result of 4FRI treatments?</i>	100,000's	3-5 years - Decadal
<i>How many businesses are utilizing the wood products resulting from 4FRI?</i>	100,000's	Annual ¹
<i>What is the value of capital investments attributed to industry resulting from 4FRI?</i>	100,000's	Annual ¹
<i>Has the number of communities at risk of severe fire changed as a result of 4FRI treatments?</i>	100,000's	3-5 years
<i>How have 4FRI treatments impacted recreational use within the project area?</i>	100,000's	Annual ¹
<i>What are the social consequences of increases in smoke as a result of prescribed burning?</i>	100,000's	Annual ¹
<i>Are contractors able to obtain an even flow of material from treatment areas?</i>	100,000's	Annual ¹
<i>Is the 4FRI region becoming more economically competitive?</i>	100,000's	3-5 years
<i>What is the federal government's "return on investment" resulting from 4FRI?</i>	100,000's	Decadal
<i>What is the response of hunters to a perceived change in game availability?</i>	100,000's	3-5 years - Decadal
<i>Can ecosystem service markets offset some of the costs of follow-up treatments (e.g. a watershed services market to pay for prescribed burning to maintain water yields)?</i>	100,000's	Annual
<i>How has the private sector responded to USFS Requests for Proposals?</i>	DNS	Annual ¹
<i>What are the impacts of various biomass utilization strategies on the human and economic system?</i>	DNS ²	Decadal
<i>What are stakeholders' attitudes toward treatments of different intensities?</i>	DNS ²	Annual ¹
<i>What communication strategies are most effective at explaining the benefits of 4FRI treatments?</i>	DNS ²	Annual ¹

¹Measurements taken annually, but trends addressed at longer intervals

²DNS = Did not specify

Socio-economic Response to Treatment (cont'd)

Question	Suggested Scale of Measurement (ac)	Suggested Sampling Frequency
<i>Are economics allowing treatments to take place at the pace and level of quality desired by 4FRI stakeholders?</i>	100's – 10,000's	3-5 years
<i>How much tax revenue has been generated at the city, county, state, and federal level?</i>	100's – 100,000's	Annual ¹
<i>What are the costs per acre to the USFS for planning, preparation, marking, contract administration, etc.</i>	1,000's – 10,000's	Annual ¹
<i>What is the revenue per acre to the federal government for forest products removed as part of 4FRI treatments?</i>	1,000's – 10,000's	Annual ¹
<i>What are the societal effects of climate change predictions of change in forest attributes?</i>	DNS ²	DNS ²

¹Measurements taken annually, but trends addressed at longer intervals

Additional Questions

Question	Suggested Scale of Measurement (ac)	Suggested Sampling Frequency
<i>How can efficiencies gained through adaptive management be tracked?</i>	10,000's	Annual ¹
<i>How can smoke management policies best accommodate landscape scale restoration?</i>	100,000's	3-5 years - Decadal
<i>How can USFS grazing policies and practices best accommodate landscape scale restoration?</i>	10,000's – 100,000's	Annual ¹

¹Measurements taken annually, but trends addressed at longer intervals

Conclusions and Future Directions

Review of the responses to the questionnaire reveals an extensive number of wide ranging questions representative of the diversity of the 4FRI Stakeholder Group. In general, responses focused on questions regarding impacts of treatment on water yield and quality, invasive species, sensitive wildlife species, reduction of fire risk, and determining whether treatments will be economically sustainable. Many questions specified here can likely be addressed through the 4FRI's Effectiveness Monitoring Program. For others, designed experiments will be required to determine cause and effect relationships. Finally, some questions lend themselves to management experiments that can be implemented as part of an overall adaptive management program. Identifying stakeholders' questions and the strategies for addressing them is a critical step; however, limited resources dictate that further prioritization of these questions will be necessary.

This report presents an extensive list of questions that could be addressed during 4FRI's implementation. Unfortunately, limited resources are likely to prevent the complete list of questions from being addressed. Therefore, we suggest that the list be prioritized to ensure that efforts are focused on questions with greatest importance to stakeholders. In the coming weeks, the Science and Monitoring Working Group will develop a strategy for prioritization. As 4FRI

progresses, stakeholders' goals and objectives are likely to change. Consequently, their questions and information needs are also likely to change. Science needs assessments are necessarily iterative and should be re-visited at regular intervals (e.g., annually). Future efforts may benefit from requesting the stakeholders to suggest the metrics relevant to answering their questions as this may help focus questions that are otherwise difficult to interpret. In the interim, this initial assessment provides a valuable "cross-check" to ensure that monitoring efforts are meeting the needs of stakeholders. Monitoring reports can be structured to directly address stakeholders' questions helping clarify results and identify gaps in knowledge. Finally, by providing systematically gathered information regarding stakeholders' needs, assessments such as this can be used to help leverage additional funds for conducting experiments that are beyond resources available for a long-term monitoring program.

Addendum: Prioritization of Needs Assessment Results

Following the compilation of the needs assessment results, the Science and Monitoring Workgroup initiated a process of prioritizing the questions identified in the needs assessment in a systematic approach. Expert groups were formed to prioritize questions within each of the defined categories. A template was developed to standardize each group's approach. Within each category, the expert group arranged questions into topics. Each topic was then identified as relevant to either monitoring or research, and then ranked as 1st or 2nd priority according to a list of criteria. An explanation of the rationale for the final ranking of each topic was provided. The expert groups were also encouraged to identify additional 1st priority topics missing from the needs assessment results. The results of the prioritization are provided in the table below. The purpose of this prioritization is to provide general guidelines on the most pressing information needs within 4FRI, so that they are available to any group who may have the resources and interest to conduct a research project

Notes:

¹ Italics indicate topics not raised by the needs assessment, but deemed important by the Science & Monitoring Working Group

² Codes for strengths/weaknesses are as follows:

Strengths:

- (1) Applied study;
- (2) Landscape-scale;
- (3) Improves general understanding;
- (4) Forecasting

Weaknesses:

- (1) Lacks strong application;
- (2) Can be derived from monitoring data;
- (3) Can be answered using existing literature;
- (4) Inappropriate temporal/spatial scale;
- (5) Vague

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GEOLOGY AND HYDROLOGY						
Topic¹	Needs assessment questions	Research	Monitor-ing	1st priority	2nd priority	Rationale²
Water yield	<p>Does the size of forest openings affect snowpack accumulation, snow water equivalency, soil moisture or spring runoff?</p> <p>How will various thinning treatments and various intensities and recurrence intervals of prescribed fire affect surface water availability and runoff?</p> <p>Can initial increases in water yield following thinning be maintained using prescribed burning?</p> <p>At a landscape scale, what is the relationship between tree density and water yield?</p>	X	X	X		<p>A. SRP is interested in all research questions which directly affect the water supply and the quality of that supply. Hence all questions research questions related to water quantity and quality are considered high priority. B. Research already been done enough [for some but not all treatment types] so low priority but some monitoring might be helpful. C. Applied study; landscape-scale; improves general understanding. Important to address initial and follow up treatments. D. The future of watershed services as an ecosystem service relies on accurate forecasting of water yield and adaptation of restoration treatments which can only be achieved through well designed research and monitoring.</p>
Water quality	<p>How long do changes in water quality and yield persist following treatment?</p> <p>Do thresholds exist for the number of acres in a watershed that can be treated before negatively impacting water quality?</p>	X	X	X		<p>A. SRP is interested in all research questions which directly affect the water supply and the quality of that supply. Hence all questions research questions related to water quantity and quality are considered high priority. B. This is a low priority unless treatment areas are directly connected to perennial waters. ADEQ has lack of on-site monitoring on many perennials and lakes. C. Applied study; improves general understanding; forecasting. Many will be interested in this both for human and wildlife uses. D. Aquatic systems as well as human water needs depend on the delivery of high quality water. Through research and monitoring forest treatments may be adjusted to achieve these objectives.</p>

GEOLOGY AND HYDROLOGY (cont'd)						
Topic¹	Needs assessment questions	Research	Monitor-ing	1st priority	2nd priority	Rationale²
Springs and wet meadows	How are the boundaries of wetlands that have been invaded by woody species defined?	X	X	X		A. A key concern for Forest. Our revised plan and our mgmt. emphases could use monitoring data and some compilation of research. B. Applied study; improves general understanding; forecasting. Important for riparian vegetation and wildlife niches. C. Much is yet to be discovered about the effects of forest management on springs and wet meadows. These are rare and sensitive environments that require special consideration.
Soils response to treatments	How do the short- and long-term effects of mastication on soil composition and structure differ from the effects of fire on those same components? What are the effects of restoration treatments on soil properties such as compaction, stability, and erosion?	X	X		X	A. We have lack of data and could use it to support both short (monitoring of BMP's) and long term effects. Infiltration, veg ground cover and erosion plots. B. Applied study; improves general understanding. Erosion control / reduction will be intimately tied to this project. C. Soil response to treatments is the fundamental interface where necessary adaptations in management practices can be discovered. Monitoring should be routine and BMPs adjusted accordingly.
Treatments effects on hydrologic processes	How do different thinning intensities affect forest evapotranspiration? What are the hydrologic variances between Dry Mixed Conifer and Wet Mixed Conifer Ecosystems?	X			X	A. Not too important if other parameters are addressed. B. 2, 3, 4.Landscape-scale; improves general understanding; forecasting. Some of this may be gathered by existing literature. C. Many of these relationships have been defined through previous research.
<i>Mercury monitoring</i>			X		X	A. Have 5 lakes impaired due to mercury in fish tissue. Should monitor before and after on connected and treated watersheds. Could compile more research too. Check with ADEQ TMDL for mercury.

OVERSTORY RESPONSE						
Topic¹	Needs assessment questions	Research	Monitor -ing	1st priority	2nd priority	Rationale²
Treatment effects on stand structure	<p>How does a diameter cap affect age class distribution in residual stands?</p> <p>Is regeneration maintained at adequate levels?</p> <p>What is the difference between pre- and post-treatment stand structure?</p> <p>How is forest structure changing with different severity burning treatments?</p> <p>Are treatments leaving groups of trees with interlocking crowns?</p> <p>Are treatments actually resulting in desired/modeled forest structure (i.e.: patchiness, size-class distribution, canopy cover/closure)?</p> <p>What is post-treatment canopy cover (measured at multiple scales) and how does it change over time?</p> <p>What are the ecological consequences of [not] implementing a large tree retention policy?</p> <p>Are the number of snags and amount of coarse woody debris being maintained within acceptable parameters?</p>	X	X	X		Strengths: 1,2,3,4. Not clear role of tree age/ecological consequences, too broad
Treatment effects on landscape structure	<p>Within a treatment area, what percentage of area is in large (>.25ac) openings? How is forest structure changing with different severity burning treatments? What is post-treatment canopy cover (measured at multiple scales) and how does it change over time? Do treatments oriented to stand-level structural diversity translate to heterogeneity at the landscape scale?</p>		X	X		Strengths: 1,2,3. What is rationale for >.25 ac?

OVERSTORY RESPONSE (cont'd)						
Topic¹	Needs assessment questions	Research	Monitor-ing	1st priority	2nd priority	Rationale²
Treatment effects on processes (fire, mortality & regen)	Is mortality of pre-settlement trees due to fire less than 15% five years following treatment? Can adequate regeneration be maintained with increased levels of restoration treatments? Is regeneration maintained at adequate levels? How can the longevity of forest restoration treatments in relation to fire effects be determined? How do different treatment regimes affect longevity and recruitment of large (>18" dbh) snags across the landscape?	X	X	X		Strengths: 1,2,3,4. Objective is to retain presettlement structures, regeneration. Necessary for sustainability
<i>Do mechanical and fire trts. create clumpy/groupy structure in residual stands or increase aggregated arrangement of residual trees compared to pre-treatment?</i>			X	X		Strengths: 1,3,4
Climate change	How is response to treatment affected by climate change?	X		X		Too broad, not overstory focused but is high priority
Effects and interactions of insects/pathogens on structure	Do forest pests remain at endemic levels? How do other sources of mortality (e.g.: bark beetles, mistletoe) affect the transition from post-treatment conditions to desired future conditions?	X	X		X	Vague, levels of pathogens and treatment levels not specified, annual aerial surveys currently done
	Once desired/conditions are achieved are these conditions self-sustaining? Do reference-condition based treatments result in ecosystems that are resilient and adaptable to a changing climate?					Ecosystem question, too broad

OVERSTORY RESPONSE (cont'd)						
Topic¹	Needs assessment questions	Research	Monitor-ing	1st priority	2nd priority	Rationale²
	Can remote-sensing techniques be refined to develop a better understanding of landscape-scale changes in forest structure?					Remote sensing question, not relevant

UNDERSTORY RESPONSE						
Topic¹	Needs assessment questions	Research	Monitor-ing	1st priority	2nd priority	Rationale²
Native understory responses to treatments	<p>How does soil type (or TES unit) impact herbaceous response following overstory removal?</p> <p>Has treatment resulted in an increased amount of forage available for domestic livestock grazing?</p> <p>Is understory biomass increasing towards pre-settlement levels?</p> <p>Is understory diversity increasing towards pre-settlement or reference-site levels?</p> <p>If clumping and grouping are achieved, will ground cover be maintained given grazing pressure by both elk and livestock?</p> <p>Can current soil resources support the expected increase in herbaceous cover?</p>		X	X		Interests included spatial variability related to soils/TES, biomass, composition, herbivore effects.
Invasive plant responses to treatments	<p>Under what locations and conditions do restoration treatments facilitate the spread of invasive species?</p> <p>How are restoration treatments changing the spatial extent of invasive species?</p>		X	X		Interests relate to introduction and spread of invasives within treated areas.

UNDERSTORY RESPONSE (cont'd)						
Topic¹	Needs assessment questions	Research	Monitor -ing	1st priority	2nd priority	Rationale²
Result of increased rate and intensity of treatments	<p>How do sensitive and rare species respond to increased rates and intensities of treatment?</p> <p>How do increased rates of treatment and climate change affect invasion by non-native species?</p> <p>How does the regional increase in restoration activity (e.g.: Jemez Mountain Project, UP Project, 4FRI) affect the abundance and distribution of invasive species?</p>	X	X	X		Interests in effects of increasing number and size of treatment areas on various plant guilds (e.g., sensitive, rare, invasive). May be difficult to determine with monitoring data alone due to potential lack of controls and comparisons.
Invasives mitigation	<p>How can the spread of invasives, especially cheatgrass, be mitigated?</p> <p>How do slash disposal techniques impact invasive species' response to treatment?</p>	X		X		Research question related to alternative methods, including slash treatments, for mitigating spread of invasive plant species. Important questions also relate to inventory of existing populations of exotic plants (e.g., cheatgrass & knapweeds) and how that info can be used to place treatments and avoid areas where spread is likely to be exacerbated by treatment.
Climate change effects	How does climate change alter the competitive balance between native and invasive species?	X			X	Interested in climate change effects on native vs. invasive 'balance.' Not directly applicable to 4FRI.
Carbon balance	How has the carbon balance of the landscape changed as a result of treatment?		X		X	Interested in change in carbon balance as a result of treatment. Not directly applicable to 4FRI.

WILDLIFE						
Topic¹	Needs assessment questions	Research	Monitor -ing	1st priority	2nd priority	Rationale²
Explanatory variables:						
Spatial pattern (stand level)	Is there an optimal “clump” size that meets Northern Goshawk requirements and maximizes diversity of other species? Do “open habitat” species respond to “groups” and “clumps”?	X	X	X		Little information exists, strong application to treatment implementation
Connectivity/ landscape arrangement of treatments	What is the cumulative spatial arrangement of “Goshawk Guideline” treatment implementation? What is the temporal effect of the cumulative arrangement of “Goshawk Guideline” treatments on Northern Goshawk and its prey? Does the spatial configuration of treatments affect elk habitat quality? How do larger treatment areas and increased rates of treatment affect habitat connectivity and corridor utilization by highly mobile species?	X		X		Little information exists, landscape-scale, applied
Goshawk Guideline/evidence-based treatments	Do species-specific approaches to restoration (e.g., Goshawk Guidelines) actually result in increased productivity of the target species? How do Northern Goshawk and its prey species respond to “evidence-based” treatment versus “Goshawk Guideline” treatments? What is the cumulative spatial arrangement of “Goshawk Guideline” treatment implementation? What is the temporal effect of the cumulative arrangement of “Goshawk Guideline” treatments on Northern Goshawk and its prey?	X		X		Little information exists, applied
Rare habitat (riparian, wet meadows, springs)		X		X		Some information exists, somewhat applicable although these areas are often unmanaged

WILDLIFE (cont'd)						
Topic¹	Needs assessment questions	Research	Monitor -ing	1st priority	2nd priority	Rationale²
<i>Tree size</i>		X		X		Some information exists, applicable
Tree density	How do restoration treatments impact species that require “interior forest” conditions?	X	X		X	Has been addressed in the literature, can be derived from monitoring data
Forest health (pests, mistletoe)		X	X		X	Has been addressed in the literature, can be derived from monitoring data
Habitat features (snags, CWD)		X	X		X	Has been addressed in the literature, can be derived from monitoring data
Herbivory	What elk population levels allow for the natural recruitment of aspen, Bebb’s willow, and other key riparian species?	X	X		X	Has been addressed in the literature, can be derived from monitoring data
Response variables:						
Invertebrates	What are post-beetle vegetative impacts on wildlife? How do terrestrial invertebrate communities respond to restoration treatments? Do forest pests remain at endemic levels?	X	X	X		Little information exists
Aquatic species	How do aquatic invertebrate and fish communities respond to changes in water availability resulting from restoration treatments? How do aquatic communities respond to changes in water quality resulting from restoration treatments?	X	X	X		Little information exists, not highly applicable to forest treatments

WILDLIFE (cont'd)						
Topic¹	Needs assessment questions	Research	Monitor-ing	1st priority	2nd priority	Rationale²
Northern goshawk and prey	<p>Is there an optimal “clump” size that meets Northern Goshawk requirements and maximizes diversity of other species?</p> <p>Do species-specific approaches to restoration (e.g.: Goshawk Guidelines) actually result in increased productivity of the target species?</p> <p>How do Northern Goshawk and its prey species respond to “evidence-based” treatment versus “Goshawk Guideline” treatments?</p> <p>What is the temporal effect of the cumulative arrangement of “Goshawk Guideline” treatments on Northern Goshawk and its prey?</p>	X	X	X		Highly applicable, some information exists, landscape-scale
Predators	<p>How do larger treatment areas and increased rates of treatment affect habitat connectivity and corridor utilization by highly mobile species?</p>	X		X		Little information exists, landscape-scale
Special status species	<p>Which wildlife species’ populations could be threatened by restoration treatments?</p> <p>What is the current status of those species that could be negatively impacted by restoration treatments?</p> <p>What is the current status of candidate, threatened, endangered, and USFS sensitive species within the project area?</p> <p>What steps can be taken to ensure that populations of candidate, threatened, endangered, USFS sensitive species, and those that may be negatively impacted by treatment remain viable throughout 4FRI implementation?</p>	X	X	X		Some information exists, highly applicable

WILDLIFE (cont'd)						
Topic¹	Needs assessment questions	Research	Monitor -ing	1st priority	2nd priority	Rationale²
Big game (elk)	How do elk populations respond to restoration treatments? Does the spatial configuration of treatments affect elk habitat quality? What elk population levels allow for the natural recruitment of aspen, Bebb's willow, and other key riparian species? What are the socially-acceptable sustainable balances between elk populations and aspen regeneration?	X	X		X	Can/has been addressed in the literature, lacks strong application (tend to be generalists)
Songbirds	How do restoration treatments impact ground-nesting/seed-feeding birds and mammals?	X	X		X	Has been addressed in the literature
Small mammals	How do restoration treatments impact ground-nesting/seed-feeding birds and mammals?	X	X		X	Has been addressed in the literature
Methodological questions:						
Wildlife-habitat relationship modeling (using surrogate species)	How can models linking focal species to landscape characteristics be developed/improved? How do focal species respond to restoration treatments? If population levels cannot be assessed, what are appropriate surrogates? How can the relationship between population surrogates and actual population trends be assessed?	X	X	X		Highly applicable, landscape-scale

FIRE BEHAVIOR						
Topic¹	Needs assessment questions	Research	Monitor -ing	1st priority	2nd priority	Rationale²
Ecological role	<p>Have treatments reduced the risk of crown fire below the desired threshold?</p> <p>Has treatment resulted in an increased area where “natural” (planned or uncontrolled) fires are allowed to burn?</p> <p>Given that fire-created snags are more ephemeral than those from other mortality sources; can a viable snag component be maintained with expected levels of fire management?</p> <p>Do 4FRI treatments allow the introduction of a fire regime that approximates pre-settlement conditions?</p>	X	X	X		Existing literature can provide much information but opportunities for research exist.
Spatial and landscape pattern impacts	<p>Did strategic placement of treatments result in increased efficiency in altering fire behavior?</p> <p>What is the optimal proportion of the landscape that must be treated for SPLAT/SPOT to achieve desired fire behavior?</p> <p>Are there alternative strategies for treatment placement other than those currently considered?</p> <p>What proportion of the landscape must be treated to prevent or significantly reduce the size and intensity of uncharacteristic fire?</p> <p>How can restoration treatments be optimally placed to meet restoration goals and create the safest possible context for wildland and prescribed fire?</p>	X	X	X		Crucial to 'get it right' to ensure the treatments are effective and achieve desired goals. Some existing literature but plenty of good research opportunities exist.
Time (temporal treatment effects)	<p>If follow-up treatments do not occur, how long will treatment-induced reductions in fire hazard persist?</p> <p>Do controlled burns achieve desired effects in continuing to reduce fuels?</p>	X	X	X		This is important information to guide treatments but not important for initial treatment design and implementation. Some existing literature.

FIRE BEHAVIOR (cont'd)						
Topic¹	Needs assessment questions	Research	Monitor -ing	1st priority	2nd priority	Rationale²
Smoke emissions	How can restoration treatments be designed and performed to mitigate the potential impacts of smoke?	X	X		X	Some existing literature. Important but not necessary to get initial treatments in place.
Climate change	How has climate change altered fire regimes and what is the predicted effect of current rates of climate change on those regimes? How do climate change predictions alter treatment arrangement and intensity to achieve desired changes in fire severity and behavior? How have changes in productivity, mortality, and species composition as a result of climate change altered fuel structure and loading?	X			X	Important but not necessary in the design of treatments.

SOCIAL SCIENCE						
Topic¹	Needs assessment questions	Research	Monitor -ing	1st priority	2nd priority	Rationale²
Public and 4FRI Stakeholder support (acceptance) for 4FRI restoration initiatives/projects	What are stakeholders' attitudes toward treatments of different intensities?		X	X		Both public and 4FRI Collaborative stakeholder support is critical to 4FRI's success.
Maintain and/or enhance the quality of life of residents/visitors in the 4FRI area (recreation, smoke, etc.)	How have 4FRI treatments impacted recreational use within the project area? What are the social consequences of increases in smoke as a result of prescribed burning? What is the response of hunters to a perceived change in game availability?		X	X		Maintaining/enhancing quality of life for residents/visitors to the 4FRI's forests is critical to 4FRI's success.

SOCIAL SCIENCE (cont'd)						
Topic¹	Needs assessment questions	Research	Monitor -ing	1st priority	2nd priority	Rationale²
Knowledge of and participation in 4FRI educational/outreach programs	What communication strategies are most effective at explaining the benefits of 4FRI treatments?		X	X		Knowledge of and participation in 4FRI educational/outreach programs will encourage support for the 4FRI.
Community protection/private property's defensible space within the 4FRI area	Has the number of communities at risk of severe fire changed as a result of 4FRI treatments?		X	X		Community protection and knowledge/application of defensible space is critical to 4FRI's success.
<i>Knowledge/understanding of 4FRI restoration principles/processes</i>			X	X		Knowledge/understanding of restoration principles/processes will encourage support for the 4FRI.
<i>Awareness of the 4FRI restoration efforts</i>			X	X		Awareness of the 4FRI project is the first step in garnering support for the 4FRI project.
<i>Public support/perceptions towards the USFS and the 4FRI Stakeholder Group</i>			X	X		Positive public support/perceptions of the USFS and the 4FRI Collaborative are critical to 4FRI's success.
Climate change	What are the societal effects of climate change predictions of change in forest attributes?	X			X	Question is very broad and determination will be based on long-term research.
<i>Public involvement in 4FRI restoration efforts</i>			X		X	Public involvement should be encouraged; however, this is not imperative to the success of the 4FRI project.

ECONOMICS						
Topic ¹	Needs assessment questions	Research	Monitor-ing	1st priority	2nd priority	Rationale ²
Industry and Private Sector	<p>Are contractors able to balance their treatment costs over a given time period in order to achieve and economically viable average treatment cost?</p> <p>Over what time period is it necessary for contractors to balance treatment costs to remain economically viable?</p> <p>How many businesses are utilizing the wood products resulting from 4FRI?</p> <p>What is the value of capital investments attributed to industry resulting from 4FRI?</p> <p>Are contractors able to obtain an even flow of material from treatment areas?</p> <p>How has the private sector responded to USFS Requests for Proposals?</p> <p>What are the impacts of various biomass utilization strategies on the human and economic system?</p> <p>Are economics allowing treatments to take place at the pace and level of quality desired by 4FRI stakeholders?</p>		X	X		Interests include the ability of industry to establish necessary infrastructure and profitably operate to help reduce or eliminate operational treatment costs to the federal government.

ECONOMICS (cont'd)						
Topic¹	Needs assessment questions	Research	Monitor -ing	1st priority	2nd priority	Rationale²
US Forest Service	<p>What is the net cost per acre to the USFS for restoration treatments?</p> <p>Are contractors able to balance their treatment costs over a given time period in order to achieve and economically viable average treatment cost?</p> <p>Is the USFS able to reduce planning/administration costs and increase planning/administrative efficiency over time as a result of 4FRI treatments?</p> <p>Are contractors able to obtain an even flow of material from treatment areas?</p> <p>What is the federal government's "return on investment" resulting from 4FRI?</p> <p>How has the private sector responded to USFS Requests for Proposals?</p> <p>Are economics allowing treatments to take place at the pace and level of quality desired by 4FRI stakeholders?</p> <p>What are the costs per acre to the USFS for planning, preparation, marking, contract administration, etc?</p> <p>What is the revenue per acre to the federal government for forest products removed as part of 4FRI treatments?</p> <p>How have 4FRI treatments altered the cost of fighting wildfires?</p>		X	X		Interests include the ability of the Forest Service to reduce internal costs and implement treatments and reduced or zero to federal government. Without reduced costs, 4FRI fails.

ECONOMICS (cont'd)						
Topic¹	Needs assessment questions	Research	Monitor-ing	1st priority	2nd priority	Rationale²
Local economies	How many jobs are created (directly and indirectly) as a result of 4FRI treatments? What are the impacts of various biomass utilization strategies on the human and economic system? How much tax revenue has been generated at the city, county, state, and federal level?		X		X	If industry is succeeding effects on local economies will share related effects.
Ecosystem services	Can ecosystem service markets offset some of the costs of follow-up treatments (e.g. a watershed services market to pay for prescribed burning to maintain water yields)?		X		X	Difficulty in measuring and uncertainty regarding establishment of actual viable markets makes such questions less applied.

CARBON						
Topic¹	Needs assessment questions	Research	Monitor-ing	1st priority	2nd priority	Rationale²
What is the recovery time of carbon stocks removed by thinning and prescribed burning as compared to severe disturbance? How do different thinning intensities affect forest carbon balance?		X	X	X		All questions improve our general understanding of existing and forecasted carbon balances, and offer applied information that could be used to utilize the nascent carbon markets. Although much of each question can be answered using monitoring data, additional research will be needed to gain a complete understanding of the carbon cycle, which is necessary to fully answer the questions.
How has the carbon balance of the landscape changed as a result of implementation of treatments with varying thinning intensities?		X	X	X		