A Model for Adaptive Management of the Front Range Collaborative Forest Landscape Restoration Project

Developed/proposed by the Landscape Restoration Working Group of the Front Range Roundtable as the basis for continued, effective, collaborative planning and implementation of the Colorado Front Range Collaborative Forest Landscape Restoration Project (CFLRP)

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Contents

The Colorado Front Range CFLRP has developed an adaptive management (AM) model to incorporate data to be developed by its Multiparty Monitoring Program (Clements and Brown 2011) into future goals and treatment actions for restoration of Front Range forest ecosystems (Figure 3). In this document, we provide a brief overview of key concepts and definitions in the topics of adaptive management and monitoring and then describe each step and cycle in our model (Figure 3) in more detail.

ADAPTIVE MANAGEMENT AND MONITORING – AN OVERVIEW

Our AM model assumes a definition provided by the National Research Council (2004):

> *Adaptive management promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process. Adaptive management also recognizes the importance of natural variability in contributing to ecological resilience and productivity. It is not a 'trial and error' process, but rather emphasizes learning while doing. Adaptive management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits. Its true measure is in how well it helps meet environmental, social, and economic goals, increases scientific knowledge, and reduces tensions among stakeholders.*

The key feature of this definition is the acknowledgment that AM is an active process ("learning by doing") that requires monitoring actions and adjusting future actions as knowledge is gained. As the definition suggests, it is not simply *ad hoc* course corrections made as past mistakes become undeniable. As DeLuca et al. (2010) write:

> Adaptive management is an iterative approach to management that is based on a series of feedback mechanisms in a continual cycle of evaluation, planning, action, and monitoring... Under adaptive management, learning is accelerated because management is conducted in a framework of experimentation, where cause–effect relationships between management actions and outcomes are treated as hypotheses to be tested. Each element of this process is fundamental to the success of the approach, and exclusion of any one element, including monitoring, scuttles the entire process and prevents learning.

Typically, AM is represented as a closed loop involving planning, implementing, monitoring, and adjusting (Fig. 1). The value of such a representation is that it makes clear that every step is necessary. Unfortunately, such a representation also implies that the process is sequential, when in fact, to be effective, monitoring must be done throughout the AM cycle. So important is this concept that Bliss et al. (2001) represented adaptive management as two cycles, interlocking as gears, comprised of a "monitoring cycle" and an "adaptive decision-making cycle" (Fig. 2), with monitoring engaged continuously throughout the adaptive management process. Figure 2 also makes clear that monitoring itself must be self-reflective – continuously planning, implementing, and re-evaluating.

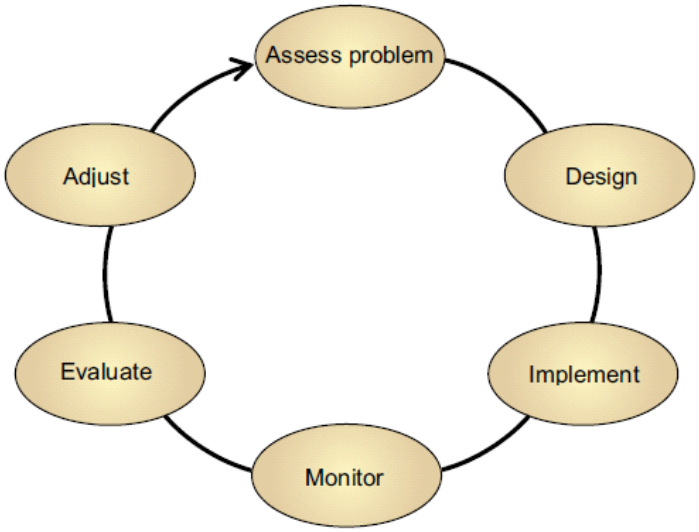

Figure 1. Typical representation of the adaptive management cycle as a closed, step-wise loop (from Williams et al. 2009)

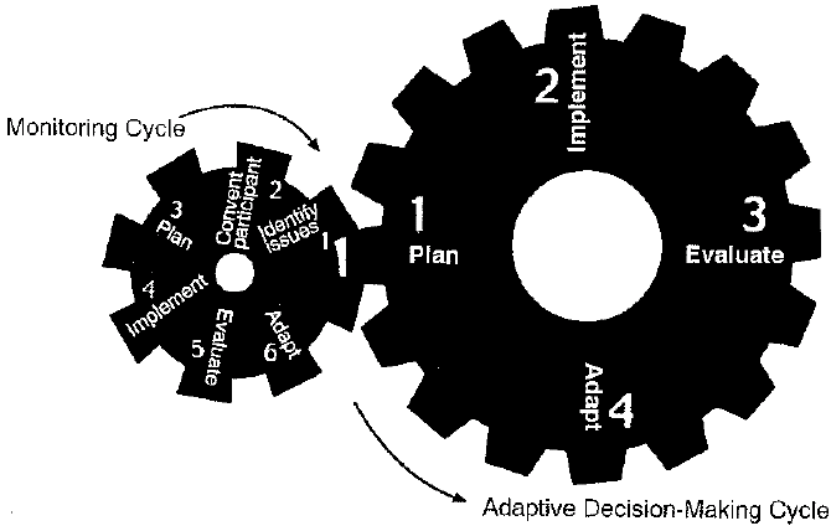

Figure 2. Adaptive management represented as a combination of two cycles of continuous monitoring and decision-making (from Bliss et al. 2001)

The various roles of monitoring have led to recognition of several types of monitoring (Table 1). As DeLuca et al. (2010) note, the most common form, called *implementation monitoring*, asks only whether or not a management action was performed as designed. This helps establish accountability, but it cannot determine whether the action achieved its intended result. That takes *effectiveness monitoring*. Hutto and Belote (2013) parse monitoring even more finely, describing the concepts of *surveillance monitoring*, which establishes the baseline conditions of ecosystems, and *effects monitoring*, which tests whether treatments are having unintended negative effects on the system. As is clear from Figure 2, there is a need also to evaluate the

monitoring program itself to ensure that it is meeting the needs of AM. Monitoring that evolves in response to new information is called *adaptive monitoring* (Lindenmayer and Likens 2009).

Table 1. Types of monitoring

Monitoring Type	Definition
Implementation monitoring	"[I]mplementation (or compliance) monitoring assesses whether or not a management action has been performed as designed" (DeLuca et al. 2010).
Effectiveness monitoring	"[E]ffectiveness monitoring determines whether an action has achieved its objective…[It] can provide data that specifically allow for the evaluation of the impact of the restoration activities on ecosystem attributes, diversity indices, wildlife health (e.g., fecundity, habitat quality, and migration activities), forest stand metrics, and socioeconomic variables (e.g., jobs, recreational opportunities, and tourism)" (DeLuca et al. 2010).
Surveillance monitoring	"Here, well-distributed (geographically stratified) locations are surveyed repeatedly across years in an on-going effort to uncover trends in target response variables...The purpose of this type of monitoring is to assess whether any change in a response variable exceeds some pre-determined threshold requiring management action" (Hutto and Belote 2013).
Ecological effects monitoring	"Ecological effects monitoring seeks to uncover unintended ecological consequences of management activity, and should be an integral part of any program designed to monitor management practices…Explicitly considering and monitoring potential ecological effects will help agencies and stakeholders make more informed decisions to minimize tradeoffs, seek complementarities among values, and optimize benefits among objectives" (Hutto and Belote 2013).
Adaptive monitoring	"A fundamental part of the adaptive monitoring paradigm is that the question setting, experimental design, data collection, analysis and interpretation are iterative steps…A monitoring program can then evolve and develop in response to new information or new questions" (Lindenmayer and Likens 2009).

Each of these types of monitoring applies to, and affects, different steps in the AM process. In Figure 3, we present a version of AM and show how monitoring answers different questions pertinent to the process. The figure shows the sequence of steps in AM, where monitoring is conducted in the process, and how the analysis of monitoring results can lead to modification of AM steps, if necessary. In this diagram, we simplify the analysis of monitoring results into those questions that address longer-term, landscape-scale goals, which we call *effectiveness monitoring* (left side of the diagram) [1], and those that address *adaptive monitoring* (right side of the diagram). In the Colorado Front Range CFLRP, *Implementation monitoring*[2] is conducted by the Forest Service as part of contract oversight and so is not included in our diagram, and *surveillance monitoring* is beyond the scope of the CFLRP AM process. The Colorado Front Range CFLRP effectiveness and adaptive monitoring process is represented as an inverted pyramid to emphasize the general trend from broad goals to specific outcomes – and back again. Below, we describe all the steps in the AM process and how they may be affected by monitoring results.

[1] What Hutto and Belote (2013) call "ecological effects" monitoring we consider part of effectiveness monitoring because this type of monitoring can be designed to identify both the intended consequences of monitoring (i.e. progress toward desired conditions) as well as any anticipated undesired effects, which should be described as part of the characterization of desired conditions.

[2] The Roundtable Landscape Restoration team is still working on a diagram and narrative outline implementation monitoring.

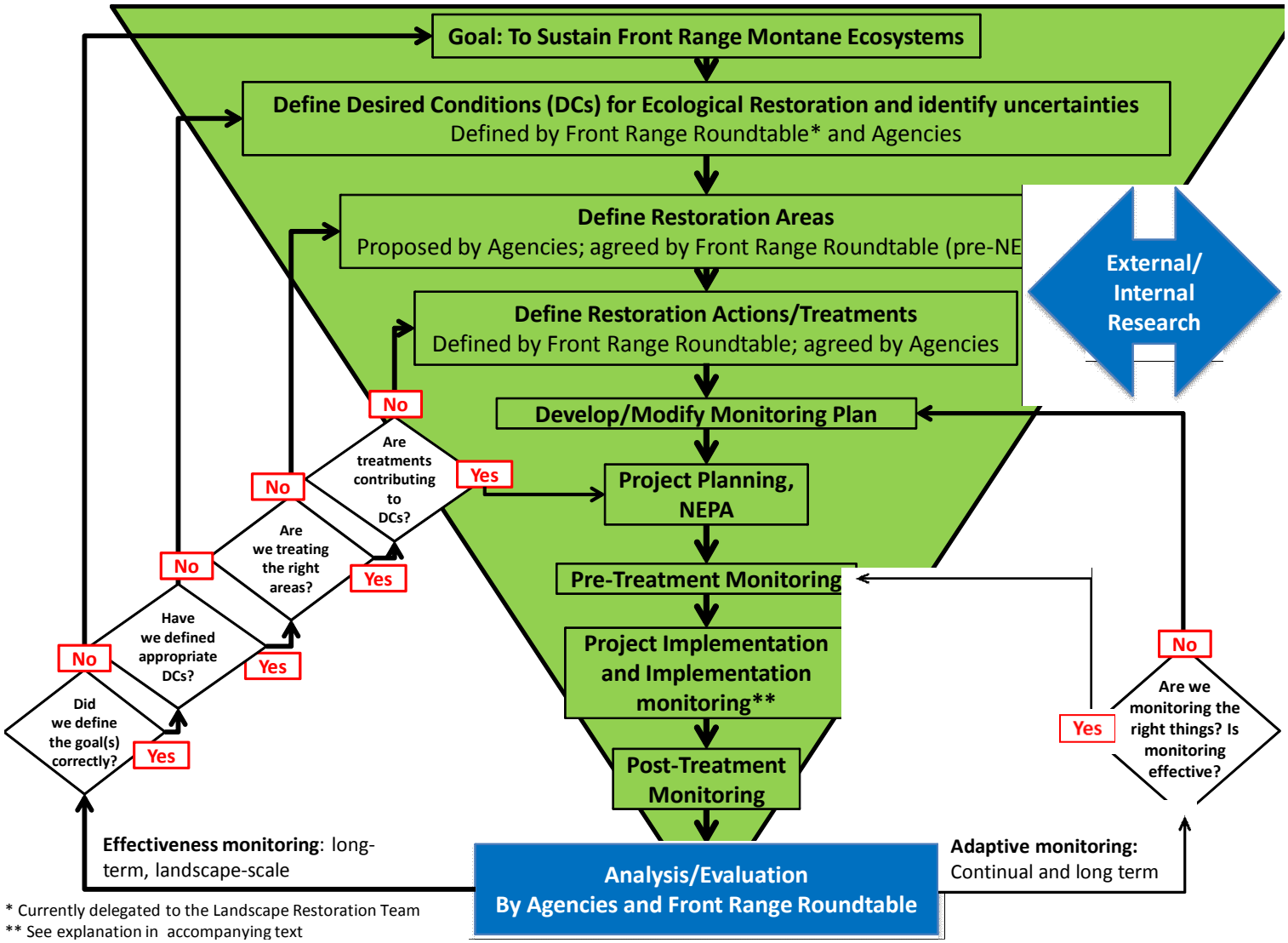

Figure 3. The Front Range Collaborative Forest Landscape Restoration Project Adaptive Management model.

GOAL SETTING

The first step in the process is to define the goals that stakeholders have gathered to achieve. It is very important that all stakeholders hold the same understanding of the goal(s), or they may work at odds. A common understanding and clear articulation of project goals is essential to effective collaboration. Stakeholders who do not share the same goal are engaged in negotiation, not collaboration. In the case of the Front Range Roundtable and the Colorado Front Range CFLRP, the goal is to bring the dry montane forests of the Front Range into a condition that can sustain desired ecosystem values in the presence of inevitable wildfire.

The relevant monitoring question pertaining to this step is whether the goal is still appropriate. As monitoring data are collected and analyzed, it may be discovered that the original problem is not as it seemed. For example, it is possible (though not likely) that monitoring would reveal that the current condition of the forest would have no effect on the sustainability of forest values in response to wildfire. At that point, we would need to modify our understanding of the situation. It is essential to the success of the adaptive management process that the appropriateness of the goal statement be reviewed based on knowledge gained through monitoring.

DEFINE DESIRED CONDITIONS FOR ECOLOGICAL RESTORATION AND DEFINE UNCERTAINTIES

In this step, stakeholders describe the kind of forest they want to see in the future, including the undesirable conditions they want to avoid. For the Colorado Front Range, conditions prior to about 150 years ago are believed to have supported fire behavior that, if it occurred today, would not threaten the sustainability of forest values. The Roundtable's 2006 report *Living with Fire* provided a general summary of desired conditions, describing "a complex mosaic of forest structures with patches of variable tree densities and ages that favor retention of the older trees." The CFLRP proposal expanded on this description, calling for work "to substantially decrease the density of ponderosa pine and Douglas-fir in the lower montane favoring ponderosa pine, [and] to create a more diverse age structure. Treatments would increase meadows, patchiness and herbaceous understory across the landscape while maximizing ponderosa pine old growth."

In the adaptive management process, review of monitoring results would include evaluation of whether desired conditions have been appropriately described as well as whether they have been (or will be) achieved. Already, our work to develop monitoring protocols has revealed that more precision is needed in the characterization of desired conditions simply to facilitate evaluation of treatment success, and we have initiated a process to improve our characterization. In practice, monitoring plan design, project planning, and implementation of both management actions and monitoring actions are all likely to reveal whether desired conditions have been appropriately described; evaluation of monitoring results should explicitly consider whether modification of the desired condition objectives is needed.

The characterization of desired conditions is fundamentally a statement about the ecosystem dynamic that will exist when sustainability is achieved. It is therefore implicitly a statement how we believe the ecosystem functions, and characterization of desired conditions involves description of the dynamics and disturbance regimes that will sustain ecosystem composition and structure over time across a changing landscape. It is not about describing a static reference

condition. An extremely useful step in that evaluation is the explicit consideration of **uncertainties** in our knowledge about the function of the system. This acknowledgment of uncertainty both helps with the identification of variables to monitor and can help with the development of a research program to improve our understanding of the ecosystem.

DEFINE RESTORATION AREAS

Once the problem and desired conditions have been defined, it is important to identify where work will be prioritized. Prioritization is essential because resources are simply too limited to address problem conditions everywhere they exist; resources should be focused where they provide the greatest return on investment. In its 2006 report *Living with Fire*, the Front Range Roundtable identified 1.5 million acres that would benefit from treatment to improve either community safety (700,000 acres) or the health of lower montane forests (800,000 acres). Within this area, 400,000 acres could be treated to achieve both goals. In its CFLRP proposal, the Roundtable modified the boundary of the restoration zone to include higher elevation, dry mixed-conifer forest in the upper montane zone as well, adding an unspecified area to the 800,000 acres identified earlier in which restoration was considered a high priority. The CFLRP proposal described a program of work that would treat 32,000 acres of national forest land within this project area, only some of which had been identified at the time the proposal was written. The precise location of remaining treatments within this vast area will be determined by stakeholders based on careful evaluation of landscape condition. Our group is currently working to test a structured method for treatment area prioritization.

Prioritization of future treatment areas will be guided in part by data collected during effectiveness monitoring. As this monitoring is limited to effects only within and near treated areas, it is not an optimal way to determine the locations of additional priority treatment areas, but it can help identify whether treatments seem to be achieving progress toward desired conditions. If they are not, either the treatment implementation or the criteria for identifying priority areas for treatment should be changed. The important step in the AM process is to ask, based on knowledge gained through monitoring, whether the criteria used to identify priority restoration areas are still appropriate.

DEFINE RESTORATION ACTIONS/TREATMENTS

Once priority treatment areas have been identified, a general plan defining and describing the approach to forest restoration must be developed. This document will/should describe the kinds of activities that will be used to achieve the desired conditions in general terms. It should document the silvicultural and other tools that will be used as well as constraints on the use of those tools (e.g., maximum opening sizes based on desired conditions) and restrictions on where those tools should be used (e.g., proximity to roads and communities).

This step should yield a written framework for restoration that will inform the public about the broad outlines of the long-term restoration program and help guide development of the monitoring plan and the specific restoration treatment ("project") plans. This is also the step where budgets should be developed, including the budget for monitoring. The document should clarify processes and stakeholder/Roundtable responsibilities for critical elements of the restoration program such as treatment implementation, monitoring, data storage, data analysis, communication, and AM decision-making. To date, the closest articulation of this framework is

the CFLRP proposal. A worthwhile question to ask through the monitoring process is whether the existing proposal provides sufficient characterization of the long-term restoration program to serve as a basis for monitoring, project planning, and AM, now that CLFRP funds have been awarded. If not, stakeholders should use it as the basis for a fully revised restoration plan to provide for these critical needs.

The question of whether the restoration plan is still adequate should be asked routinely as part of effectiveness monitoring, as monitoring results are evaluated. Does the approach to forest restoration described in the proposal/plan appear to be achieving desired conditions without causing undesired effects? This is the essential question of effectiveness monitoring and should be the focus of the monitoring plan.

DEVELOP/MODIFY MONITORING PLAN

The monitoring plan should flow directly from the articulation of restoration actions and treatments in the restoration plan. Monitoring should be designed to answer the fundamental question: Are treatments achieving desired effects without causing anticipated negative effects?

In our figure, we have drawn an arrow from the analysis/evaluation step back to the development/modification of the monitoring plan, to represent adaptive monitoring. There are a lot of ways to approach adaptive monitoring, from periodic self-reflection of the monitoring committee to establishment of a monitoring program as a rigorous experiment itself. The important point here, though, is that stakeholders evaluate the monitoring plan to assess whether it is continuing to serve the needs of the long-term restoration program. If it is not, it should be revised.

The question of who conducts monitoring should also be addressed in the monitoring plan. Depending on the desires and capacity of the collaborative, stakeholders may be very involved in the collection of monitoring data, or they may rely on the agency implementing the treatments (for the CFLRP, this is the US Forest Service) to collect data. The Roundtable currently employs a hybrid approach, with the Forest Service collecting "Tier 1" data through Common Stand Exams and stakeholders collecting other important "Tier 2" information through a separate but complementary process.

PROJECT PLANNING, NEPA

Once the project framework and monitoring plan are in place, specific guidance to implement restoration should be developed in the form of a Project Plan. A project affecting federal land must adhere to the strictures of the National Environmental Policy Act and requires a Project Plan and environmental review that meet NEPA's requirements for specificity. The challenge here is to write a plan that meets those requirements but is still capable of improving over the life of the plan in response to knowledge gained through monitoring. The key to success of this so-called "adaptive NEPA" will be the inclusion of "triggers" that commit to changes in course depending on the results of monitoring (Nie and Schultz 2011). It is the responsibility of the U.S. Forest Service to develop the Project Plan with input from the public.

In our diagram, the effectiveness monitoring loop closes on this step only if treatments are effective. If monitoring shows them to be ineffective, a new restoration framework is needed, as is a new monitoring plan and new project planning. This would seem to defeat the purpose of "adaptive NEPA;" however, in our scheme, the triggers built into the plan come into play not through effectiveness monitoring, but through implementation monitoring conducted as part of contract/project oversight. If the triggers are set up correctly, they will allow for modification of restoration practices at the project implementation stage without modification of the plan. If, however, required changes are beyond the scope of the triggers in the plan, a new Project Plan will be needed.

PRE-TREATMENT MONITORING

The monitoring plan should spell out the methods, scale, and timing of pre-treatment monitoring; pre-treatment monitoring should involve confirming the appropriateness of project locations and initiating the monitoring work. While adherence to the monitoring plan is preferred, the adaptive monitoring loop does encourage evaluation and possible modification of monitoring methods throughout implementation of the project plan, and when changes are necessary, the monitoring plan should be modified. Caution should be used in data collection and comparison if methods were changed between seasons (only data sets collected with the same methods from one year to the next can be compared in statistical analyses.)

If possible, pre-treatment data should be evaluated prior to implementation of the treatments to help confirm pre-treatment conditions and/or guide details of treatment implementation, as well as reveal any needs to modify monitoring methods to better measure both pre-treatment and post-treatment conditions. Although the figure implies that changes to monitoring methods would also result in modification to the Project Plan/NEPA, minor modifications to methods triggered by adaptive monitoring may be made at this step as long as they are consistent with the project plan/NEPA, with amendment of the monitoring plan affecting only development of the <u>next</u> project plan.

PROJECT IMPLEMENTATION

Much could be said about project implementation, but it is largely outside the scope of this diagram. Also, most restoration activities will be conducted by Forest Service crews or by contractors, either purchasers of timber sale contracts or contractors providing stewardship services, so there is little direct role for the collaborative in implementation. We include it in the diagram only to indicate that we understand implementation is the key component of the adaptive management process. Without implementation, there is no process!

POST-TREATMENT MONITORING

Post-treatment monitoring is expected to replicate the pre-treatment monitoring protocol such that pre- and post-treatment conditions can be directly compared in the analysis/evaluation step. However, as post-treatment monitoring occurs, it may identify unexpected effects and challenges associated with treatments, as well as progress toward desired conditions and/or occurrence of unanticipated undesired effects. Whether the ecological changes are positive or negative, expected or unexpected, this step may catalyze modification of the methods in the monitoring plan for the future, and/or changes to the design or implementation of the treatments. Possibly, new methods that were not needed in the pre-treatment forest will have to be added to measure

post-treatment change adequately. Careful analysis/evaluation will reveal whether change is needed based on the post-treatment monitoring results.

ANALYSIS/EVALUATION

In their recent guidance for fuel management in dry mixed-conifer forests, Jain et al. (2012) consider a number of questions relevant to analysis and evaluation, including, "How, when, and by whom will monitoring data be analyzed? " and "Where will monitoring data be stored, archived, and documented?" They note:

> [T]aking time to ensure data integrity, security, and accessibility over time is critical. The data have to be: (1) accessible to managers and researchers; (2) archived in stable formats on stable media…; (3) resistant to corruption and accidental destruction; (4) accompanied by detailed metadata containing sufficient descriptive information about the data and their collection that others can use to interpret the data, possibly for purposes beyond what was initially envisioned; and (5) stored and archived as corporate data backed by a long-term information management commitment.

With regard to involvement in analysis, the authors explain:

> Ideally, when monitoring is an interdisciplinary enterprise with multiple constituencies, there will be multiple analysts representing a range of disciplinary expertise with a stake in analyzing the data to address different questions. If data are publicly available, there can be entire networks of university and agency research analysts that may be interested in exploring the data…, but building at least some analysis capacity in-house will likely lead to more timely results and provide the flexibility to employ exploratory analysis that ultimately addresses a broad range of questions about treatment effectiveness and efficiency.

The Roundtable is fortunate to have an abundance of technical expertise to contribute to analysis and evaluation, but many details remain to be worked out. In our diagram, we have identified several of the key questions that must be evaluated and how the answers lead into different steps in the AM process. It is likely that the analysis/evaluation step will reveal a number of issues that were not adequately addressed in each of the previous steps of the AM process and thus require modification.

EXTERNAL/INTERNAL RESEARCH

Our figure also includes a two-headed arrow intended to represent the fact that research may inform and be informed by project development, implementation, and monitoring, and by activities external to the CFLRP. In some cases, this research may be identified by CFLRP stakeholders and conducted by them such that results directly inform the CFLRP, or it may be conceived of and conducted external to the CFLRP but inform future implementation of the AM cycle. In either case, results could have important implications for any step of the AM process, and guidelines should be developed by the collaborative regarding the most effective ways to communicate research needs and learn from research results. Ideally, such exchanges of information would be integrated with the analysis and evaluation of monitoring data described above.

REFERENCES

Bliss, J., G. Aplet, C. Hartzell, P. Harwood, P. Jahnige, D. Kittridge, S. Lewandowski, and M. Soscia. 2001. Community-based ecosystem monitoring. J. Sustain. For. 12:143–168.

Clements, J., and P. M. Brown. 2011. Front Range Roundtable, Collaborative Forest Landscape Restoration Project 2011: Ecological, Social, and Economic Monitoring Plan. Colorado Forest Restoration Institute, available at http://warnercnr.colostate.edu/images/pictures/upload/cfri/Roundtable-CFLRP-Monitoring-Plan-062511.pdf.

Deluca, T.H., Aplet, G.H., B. Wilmer, and J. Burchfield. 2010. The unknown trajectory of forest restoration: a call for ecosystem monitoring. Journal of Forestry 108(9):288-295.

Front Range CFLR proposal:
http://www.frontrangeroundtable.org/uploads/CFLRProposalFrontRange.pdf with map:
http://www.frontrangeroundtable.org/uploads/CFLRProposalFrontRangeMapColor.pdf

Front Range CFLRP Monitoring plan:
http://www.frontrangeroundtable.org/uploads/Roundtable_CFLRP_Monitoring_Plan_062511.pdf with addendums:

- Common Stand Exam addendum:
  http://www.frontrangeroundtable.org/uploads/CFLRP_Plan_Addendum_1_hg_110712_updated_fs_cse_monitoring_techniques_for_cflr_project.pdf
- Social and Economic Monitoring addendum:
  http://www.frontrangeroundtable.org/uploads/FR_CFLR_SE_monitor_plan_ammendment.pdf

Front Range CLFPR Annual Reports:

- 2010:http://www.frontrangeroundtable.org/uploads/AnnualReportCOFrontRange12_02_2010.pdf
- 2011:http://www.frontrangeroundtable.org/uploads/CFLR_FY11_Annual_Report_Revised03_26_2012.pdf
- 2012:http://www.frontrangeroundtable.org/uploads/FY12_Annual_Report_CO_Front_Range_Final_11_14_12.pdf

Hutto, R., and R.T. Belote. 2013. Distinguishing four types of monitoring based on the questions they address. Forest Ecology and Management 289:183-189.

Jain, Theresa B.; Battaglia, Mike A.; Han, Han-Sup; Graham, Russell T.; Keyes, Christopher R.; Fried, Jeremy S.; Sandquist, Jonathan E. 2012. A comprehensive guide to fuel management practices for dry mixed conifer forests in the northwestern United States. Gen. Tech. Rep. RMRS-GTR-292. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 331 p.

National Research Council. 2004. Adaptive Management for Water Resources Planning. The National Academies Press. Washington, DC.

Nie, M. and C. Schultz. 2011. Decision making triggers in adaptive management. Report to USDA Pacific Northwest Research Station, NEPA for the 21st Century. 66p.

Williams, B. K., R. C. Szaro, and C. D. Shapiro. 2009. Adaptive Management: The U.S. Department of the Interior Technical Guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC.
http://www.doi.gov/initiatives/AdaptiveManagement/TechGuide.pdf

CONTRIBUTORS

The following team members have participated in the Landscape Restoration Working Team during the course of the development of this proposed adaptive management model:

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