THE FOREST RESILIENCE BOND

FINANCING AN ALL-LANDS APPROACH TO FIRE RISK REDUCTION, WATER RESOURCE PROTECTION AND FOREST RESTORATION

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Executive Summary

Many forests in the western U.S. are at a tipping point - overgrown stands, high tree mortality, and changing climate conditions all threaten the well-being of some of our most precious natural resources and the public services they provide. As a result, wildfires are growing larger and are burning more severely, with fire seasons themselves getting longer. In Colorado alone, over 6 million acres of forest land are outside their historic range of variability. With government and philanthropic funding unable to keep pace with the need for active management (USFS Online), it has become increasingly clear that the status quo is unsustainable.

Conservation-focused private investment has emerged as a promising potential source of capital for stakeholders seeking to scale forest restoration projects. When properly structured, private capital has the potential to shift risks from beneficiaries to investor, and can accelerate restoration, lowering the risk future fires pose.

It is challenging, however, to develop place-based projects that can attract private capital while meeting the needs of land managers, beneficiaries and investors. The limited supply of these projects that can deliver both environmental impact and competitive returns cannot meet the multi-billion-dollar demand for conservation finance investments- effectively leaving tremendous untapped resources "on the sidelines" that otherwise might be utilized to address forest management imperatives across the region.

To capitalize on this opportunity and efficiently and effectively connect private capital with restoration practitioners and beneficiaries, we have developed the Forest Resilience Bond (FRB), a public-private partnership that enables private capital to finance much-needed forest restoration across the western U.S. The FRB brings together a disparate and interdisciplinary group of academics, financiers, legal experts, landowners and managers, utilities, and federal and state agencies with a limited history of working together. While each stakeholder shares the common goal of fostering healthy, resilient forests, the Forest Resilience Bond can catalyze new partnerships among groups such as private landowners, conservation groups, federal agencies, downstream beneficiaries, and private investors.

This report is a synthesis of over two years' effort in deploying the FRB model on non-industrial private forest lands in the West, including the deal development approach, lessons learned, recommendations, and proposed next steps. This work was made possible by the generous support of the USDA NRCS Conservation Innovation Grant program and this report is intended to fulfill our grant obligations.

The team worked towards a Forest Resilience Bond pilot project on private lands along the Front Range of Colorado. Though a transaction is not imminent, the documented lessons learned provide a valuable resource to help build the field of conservation finance and encourage continued innovation to support private land management, especially as it relates to wildfire risk reduction, water resource protection, and forest management. Key lessons learned include the importance of identifying bottlenecks to project establishment, considering the number of beneficiaries (more is not always better), the importance of establishing an "anchor tenant" when pursuing projects, establishing USFS support, and being upfront about costs and expectations. If these lessons can be applied, the prospects for future application of the Forest Resilience Bond on private lands remain promising.

Introduction

Challenge: Overgrown Forests

U.S. forest land plays a critical role in the health and resilience of communities and the environment nationwide. The forests of the Front Range of Colorado, for example, provides water, clean air, and recreation opportunities for both the Denver metropolitan region and Colorado more broadly. But the value that forests provide is increasingly threatened as overgrown forest stands, high tree mortality, and changing climate conditions across the Western U.S. expose communities to heightened wildfire risk and severity, diminished and degraded water supplies, and other climate vulnerabilities.

Historically, recurring wildfire at regular intervals maintained a natural density of forest vegetation. For example, in the mixed-dry conifer stands prevalent across much of the West, fire would naturally occur every 5-30 years and clear out underbrush and other vegetation. The root causes of current forest conditions are multi-fold but none more pernicious than unilateral fire suppression. By 1935 the "10 a.m." policy dictated that all fires should be suppressed by 10 a.m. the day after they started. Even as scientific research began uncovering the positive effects of fire, the "10 a.m." policy of total suppression remained in effect for another 40 years. Today, many western forests have up to ten times as many trees compared to historical levels.

Overgrown forests and the growth of the wildland urban interface – human communities within the wildland and at greater risk of wildfire – present federal, state, and private land managers with the difficult task of deciding whether to (1) manage wildfires for resource benefit, at the risk of becoming uncontrollable and impacting nearby populations, or (2) actively fight wildfires, even though doing so allows further overgrowth and increases the risk of high-intensity fire in the future. The USFS and other firefighting agencies often continue fire suppression efforts to protect communities and the environment today despite the fact that such actions may come at the expense of those same communities and environment tomorrow. Overgrown conditions become even more problematic considering the effects of climate change. An increasingly hotter and drier climate made 2017 the most expensive wildfire season in U.S. history, and is contributing to tree mortality from extreme drought, pest infestation, and disease.

Decades of scientific research supported by federal and state agencies, academia, and non-governmental organizations demonstrates that removing overgrowth in a portion (40% or less) of a given watershed can moderate potential fire behavior with several co-benefits, including: protected water resources, avoided carbon emissions, job creation, and protected lives, homes, and habitat.

Overgrown vs. Restored Forest | Tahoe National Forest, California

Overgrown Restored

Image: WRI

Yet, in many important water supply watersheds across the region, ownership patterns require active management on non-federal lands to reach that ~40% threshold. Cross-jurisdictional treatments are essential to safeguarding the many values we depend on from our forests.

The USFS has identified between 65 and 82 million acres of federal land as requiring restoration treatments. And, according to research from AFF (Western Water Threatened), nearly 14 million acres at high fire risk in important water supply watersheds are private and family owned. Assuming an average cost of $1,000 an acre for treatments, a very conservative estimate, this translates to a $78-$95 billion dollar need. In Colorado, over 6 million acres of forest are in need of restoration, with 1.5 million of those acres on the Front Range alone.

Public and private land managers clearly lack the financial resources required to tackle this overwhelming restoration imperative on their own, but the landowners and managers aren't the only groups that would benefit from increasing the pace and scale of forest restoration. In fact, forest restoration generates positive impact and economic value for a wide array of beneficiaries. Downstream water and electric utilities rely on source watersheds for water supply and hydroelectricity generation. Water-dependent companies and transportation authorities benefit from protection to their supply chains, built infrastructure, and bottom lines. State governments, such as California, have designated carbon emissions from wildfires and rural unemployment as policy and funding priorities. In many cases, the multi-stakeholder value of forest restoration far exceeds its costs and makes a compelling economic case for investment, if only development-ready opportunities existed.

Opportunity for Private Capital

A recent report on investment for conservation found $31.7 billion of public capital committed to conservation from 2009 through 2015. At the same time, private investment accounted for another $7.3 billion during this period, almost half of which was deployed between 2014 and 2015. An upward trend is expected to continue as over 97% of survey respondents "planned to raise or reallocate more capital towards conservation impact investments in the next three years (2016 to 2018)" (Forest Trends, 2016).

While demand for conservation impact investment is robust, supply is failing to keep pace, as there is a limited pipeline of market-rate conservation investment opportunities. The 2016 survey notes a reported $3.1 billion of undeployed investor capital at the end of 2015, more than double the $1.5 billion reported at the end of 2014 and a clear sign that "investors were still looking for deals." Investors face a number of obstacles including difficulties in finding opportunities with (1) appropriate risk/return profiles (most common target internal rate of return ranged from 5% to 9.9%); (2) sufficient management track record; and (3) ample transaction size (Forest Trends, 2016).

Over 1/3rd of private capital for conservation remains undeployed

Source: Forest Trends

More than $300 billion is needed every year to protect the environment, yet less than 20% ($52 billion) — the majority of which comes from public and philanthropic sources — is currently being deployed. Simply put, this is a lost opportunity (Conservation Finance, 2016).

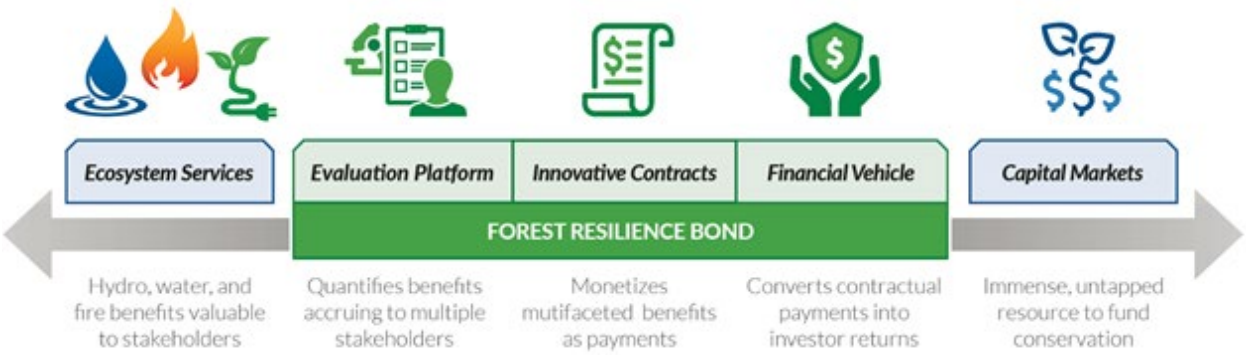
Scaling private financing for conservation also requires the development of clear and consistent contracting mechanisms, standardized ecosystem services measurement, and financial structuring to enable investment. Instead of relying exclusively on market-rate capital, flexible, blended and diverse capital sources can help ensure a sustainable development process that is focused on replicable, scalable projects, not just those that can happen most quickly. These funding sources include grant capital to support the early stages of concept development, stakeholder engagement, and concessionary funding such as program-related investments to validate new models through pilot projects. As initial pilots are successful and the model is proven, market-rate capital can play the integral role of replicating and scaling natural infrastructure investments like the Forest Resilience Bond.

Introducing The Forest Resilience Bond

Building off decades of academic research that establishes the ecological and economic benefits of forest restoration, Blue Forest Conservation, the World Resources Institute, and the American Forest Foundation partnered to pioneer the Forest Resilience Bond (FRB) to accelerate investment in forest health.

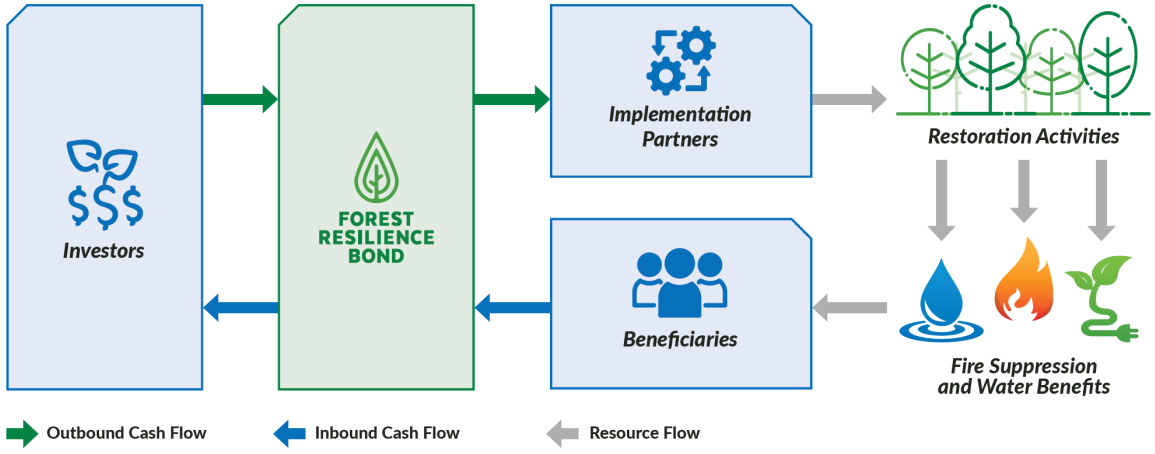
The FRB is a public-private partnership that enables private capital to finance much needed forest restoration. Beneficiaries of the restoration work such as the USFS, state and private landowners, water and electric utilities, and state governments make cost-share and pay-for-success payments over time (up to 10 years) to provide investors competitive returns based on the project's success.

The FRB is able to achieve this by combining three main components: (1) measuring of benefits conferred by restoration activities (also known as ecosystem services), (2) contracting to convert benefits into payments from beneficiaries, and (3) financial structuring to turn beneficiary payments into cash flows for investors. By integrating all three essential components into a single collective action platform, the FRB offers a sustainable source of capital for forest restoration.



The primary sources of cash flow for FRB projects are derived from monetizing water, avoiding costs by reducing fire risk, and other ecosystem services created by forest restoration activities. Beneficiaries are stakeholders in and around a watershed that directly benefit from fire-resilient forests. A typical transaction may include the following beneficiaries:

- Public and private land managers and owners, paying for completed implementation of restoration, which helps to achieve policy and management goals while also decreasing the risk of severe fire;
- Electric utilities, paying for potentially increased or protected hydroelectricity generation, avoided sedimentation, and protected infrastructure;
- Water utilities, paying for protection of water quality and/or improved water volumes; and
- State and local governments, paying for avoided fire suppression costs, avoided carbon emissions, protected communities, and job creation.



What differentiates the FRB from other approaches to forest restoration is not only the use of investor capital to finance implementation, but also the cost-sharing among beneficiaries. By bringing together multiple payors to share the financial burden of forest restoration, the FRB creates compelling economics for beneficiaries while diversifying cash flows and providing a return for investors. Additionally, using investor capital can shift the initial funding responsibility from landowners/managers to private investors, relieving strain on near-term appropriations and landowner budgets.

While the FRB represents a new approach to financing restoration, the investment structure itself is similar to infrastructure financing. Perhaps the most analogous example is the financing of a utility-scale

solar generation asset, in which funds are raised based on contracted cash flows from the future power that will be generated. Similar to the solar asset, forest restoration also creates value, which is monetized as cash flows for investors. The FRB is an example of natural infrastructure with fire, water, carbon, and social benefits serving as a basis for payments from beneficiaries to investors.

Advantages of Using the FRB to Deploy Private Capital

The FRB is a collaborative approach to forest restoration that brings together many stakeholders, including investors. With the right incentives, governance, and oversight, the goals of investors can align with those of the beneficiaries and other stakeholders. Aligning those groups' interests allows for private capital to play a critical role of decreasing costs and risks for beneficiaries. Of course, market rate investors need to realize a competitive return, but the various benefits of private capital can more than outweigh the cost of financing.

1. **Acceleration of restoration**: The use of private capital enables the acceleration of restoration work, which lowers the risk of future fires and therefore saves beneficiaries money.

   Assume beneficiaries have $2 million a year to spend on restoration for the next 10 years. Without financing, the beneficiaries complete $20 million of restoration evenly over the 10 years. After three years, only 30% of the restoration has been completed. On the other hand, consider if the same beneficiaries financed the full project. In this case, the $20 million could be deployed immediately (and assuming forester and contractor capacity is sufficient, potentially taking two to three years to complete). After three years, 100% of the restoration has been completed. By accelerating the restoration work within the 10-year window, beneficiaries enjoy reduced wildfire risk and other benefits on the entire project area in years 3-10, compared to the first scenario in which it takes 10 years to achieve the same risk reduction. The reduction in wildfire risk should yield cost savings over the 10-year window, which would help justify any added expense of financing.

2. **Larger, cheaper projects**: The use of private capital allows for larger projects, which are more efficient and save beneficiaries money.

   Economies of scale can be realized by aggregating and streamlining certain processes for a single project of $30 million relative to 10 projects of $3 million. For example, planning and securing finance commitments from multiple beneficiaries for 10 separate $3 million projects would be significantly more challenging and expensive than for a single $30 million project. Implementation contractors deploying equipment and people to the same area for a large project is more cost-efficient than moving around to many smaller projects in a larger region. Larger projects are also more likely to stimulate investment in cost-effective biomass solutions, further reducing costs.

3. **Reduced financial risk for beneficiaries**: Upfront financing from investors enables ex-post payments from beneficiaries, which lowers risk for beneficiaries.

   The FRB seeks to not only lower costs for beneficiaries but also to shift risk from risk-averse government agencies, private landowners and utilities to risk-tolerant investors. By using private capital to fund the upfront costs of restoration, beneficiaries can elect to only make payments

when the project is successful. For public and private landowners, success may be defined as completed restoration in a given area. For a utility, success may be defined as protected water quality by the restoration activities. Either way, the development team will work with beneficiaries for each project to develop contracts that stipulate what constitutes success and therefore warrants a payment. This contractual relationship allows for beneficiaries to make payments when the benefit is actually accruing, as opposed to beforehand. Investors then take on the project risk, as beneficiaries would not make payments if the agreed-upon level of success is not achieved.

4. **Cost sharing**: The combination of larger projects and ex-post payments results in better opportunities for cost sharing, which lowers costs for each beneficiary.

   Pursuing large projects is more likely to attract significant matching commitments from other beneficiaries, particularly when no upfront capital is required. Mobilizing large-scale commitments from public utilities, municipalities, state governments, and private corporations requires considerable planning and finance, which is made more difficult without the certainty that would be provided by a large, upfront landowner/manager commitment.

5. **Project catalyst**: Known existence of funding can motivate projects, which lowers risk for beneficiaries.

   Finally, many groups want to advance forest restoration but may be discouraged from pursuing projects if the source of funds is unknown. Significant time, planning, and resources are required to implement a restoration project, but the certainty of funding through financing such as the FRB could help motivate projects to advance and lower the risk of non-completion for beneficiaries.

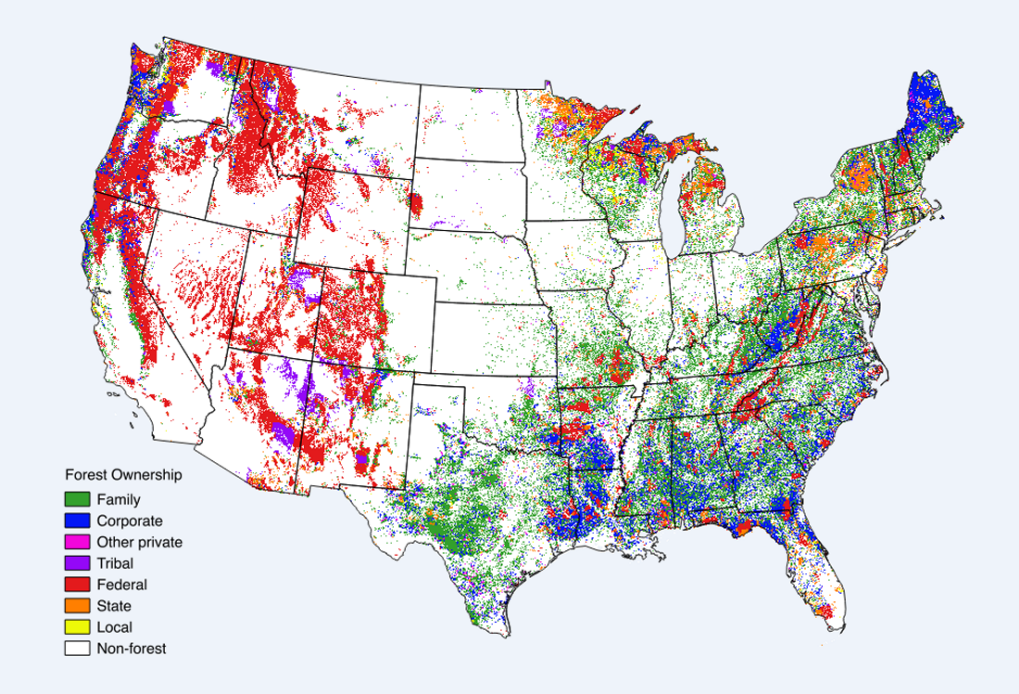
Private capital is not without its costs, but in the case of the FRB it carries several key advantages. Financing is a critical part of the FRB due to its ability to accelerate restoration work, create efficiencies, enable ex-post payments, maximize cost sharing, and motivate projects. As a result, the FRB is able to lower both costs and risks for beneficiaries while achieving unmet restoration goals.

Financing Fire Risk Reduction on Private Lands | *An All-Lands Approach*

Fire is the dominant force shaping western forests and given the preponderance of public lands across the region, wildfire is perceived to be largely a federal-lands "problem." Yet, as a natural disturbance process, fire does not heed the ownership lines we place on maps.

Research conducted by the American Forest Foundation (AFF) bears this out. According to AFF's assessment, in at least two western states, California and Washington, high fire risk acres on private and family lands actually outnumber high fire risk acres on public lands. Once more, when overlaying EPA and USFS-designated important water supply watersheds on high fire risk, more acres critical to clean and plentiful water are at risk from fire on private than on public lands. This work spotlights a critical point in the national dialogue of the West's fire challenge - namely that public water supply cannot be safeguarded without the engagement of private and family landowners (Western Water Threatened). Accordingly, fire management strategies — from addressing the fire resiliency of forests prior to the inevitable fire ignition to post-fire remediation — must likewise take a cross-boundary approach.

There are over 800 million acres of forestland in the U.S. and most of this land is privately owned. Approximately 36% of this land is owned by families and individuals, exceeding the 31% owned by the federal government (with corporations, state and local jurisdictions, and Tribes owning the remainder) (USFS Woodland Survey). The good news is that these non-industrial private forest (NIPF) landowners in the West recognize fire as a serious issue. In a 2015 public opinion survey (Western Water Threatened) of nearly 1,800 private landowners throughout the West, three in five identified fire as a serious concern and more than half said they worry about fire more now than five years ago. Whereas most understand the risk they face, relatively few have taken action to address that risk. Only one-quarter of those surveyed had taken steps to restore forest health by thinning stands and less than half said that they had created defensible space around their structures. This is despite the fact that 70% of these owners were motivated to reduce risk on their lands because of their sense of responsibility as a landowner.



Forest ownership in the United States. Source: USFS

These results were largely affirmed with interviews of 425 private landowners across exurban and rural counites in Montana, Oregon, California, and Colorado from November 11-December 11, 2017 commissioned as part of this Innovation Grant (See Appendix 1).

Wildfires are clearly a major concern among respondents. Wildfire risk is the only issue, among those we tested, to which more than 50% of respondents say they are very concerned. This level of concern is not surprising, considering three in five of these landowners have witnessed a wildfire in the last five years —particularly in California and Montana— and almost half say a wildfire has burned on neighboring forested property. Additionally, nearly three out of five respondents believe it is very or somewhat likely that a wildfire will affect their land or land neighboring theirs in the next five years. Interestingly, in these focus states, slightly more than half of respondents reported completing a forest restoration project on their land.

We are then faced with a conundrum. We understand that cross jurisdictional management is an imperative to address the West's fire challenge. We know that NIPF landowners are aware of the risk fire poses and are motivated to act - but that few have. What barrier prevents these landowners from taking action? In a word, cost.

Seventy-seven percent of respondents to that 2015 survey cited the high cost of management as a serious barrier to action. About half of 2017 interviewees believe they could do more to improve forest health on their land yet just one-third are familiar with financial assistance options for land management. Only 14% of landowners interviewed in 2017 have participated in a cost-share program, despite almost none reporting having had a negative experience. Facilitating action on private forest lands is a management imperative. NIPF landowners, despite their high motivation but current low-levels of engagement, are primed to act.

The following sections of this report describe the methods, prioritization, stakeholder engagement strategies, progress to date, and key lessons learned to deploy the FRB to address this private land restoration need and opportunity. These descriptions will help build the field of conservation finance and encourage continued innovation to support private land management, especially as it relates to fire risk reduction, water resource protection, and forest management.

Insights from The Yuba Project FRB

On November 1st, 2018, Blue Forest Conservation (BFC) and World Resources Institute (WRI) launched the inaugural FRB pilot project on the Tahoe National Forest, in the North Yuba River watershed. The project launch marks the progression of the FRB from an innovative idea to a tangible solution for scaling investment in forest health and mitigating wildfire risk.

With financing secured from The Rockefeller Foundation, Gordon & Betty Moore Foundation, Calvert Impact Capital, and CSAA Insurance Group, private capital will now fund the upfront costs of forest restoration. Multiple beneficiaries of restoration, including the U.S. Forest Service, State of California, and Yuba Water Agency, will share in the cost of reimbursing investors over time.

The investment kicked off a forest restoration project protecting 15,000 acres of forestland in the North Yuba River watershed using ecologically based tree thinning, meadow restoration, prescribed burning, and invasive species management—all specifically designed to reduce the risk of severe fire, improve watershed health, and protect water resources. The restoration treatments are prescribed by the Forest Service, benefit from public comment, and rely on the work of existing restoration crews.

The Yuba Water Agency, a utility provider that recognizes the benefits of restoration to local water and power resources, has committed $1.5 million over five years to reimburse investors. In addition, the state of California has committed $2.85 million in grant funding to the project from the state's California Climate Investment program and the Sierra Nevada Conservancy. The Tahoe National Forest will provide in-kind support and services and has provided all the resources associated with planning the project. The National Forest Foundation serves as one of the project's primary implementation partner, leading the forest restoration work on the ground.

As the prescribed forest management techniques are applied in the North Yuba River watershed, researchers from the Sierra Nevada Research Institute at UC Merced and the Natural Capital Project at Stanford University will monitor the impacts on water supply and other ecosystem services, providing data to quantify the benefits of restoration activities undertaken. Findings from this research could help catalyze future investment in forest restoration by showing how healthy landscapes can reduce fire risks.

Selecting Colorado's Front Range as an FRB on Private Lands Pilot Location

Although the threat of fire to clean water supply is ubiquitous across the West, the risk profile of some states is more significant than others. Six states —California, Colorado, Idaho, Montana, Oregon, and Utah —account for roughly 88% of all high fire risk in important source watersheds on private and family land across the West. Within that focus area, and recognizing that the ability to successfully generate landowner interest in the FRB would be key to success of our pilot, we zeroed in on a subset of four states - California, Oregon, Montana, and Colorado - based on where we would be able to leverage AFF's prior investment in the infrastructure necessary to conduct outreach campaigns.

The team conducted cursory assessments across those four states to inform the selection of a pilot landscape, however, we quickly determined that socio-political factors would be as much of a predictor of success as biophysical factors. In both Montana and Oregon where AFF outreach infrastructure and capacity was built out, the landscape is very rural with sparse populations and correspondingly small water utilities. We determined that the likelihood of these utilities having the resources to become a major beneficiary of the FBR was low. And while California water utilities have relatively significant resources to invest in source water protection, there is a notable lack of forester capacity across the state to work with any landowners who would express interest in the FRB.

A USFS crew conducts a prescribed burn in Colorado's Front Range. Image: USFS/ Flickr

As a result, the team focused its energies early on in Colorado where 1) there was demonstrated engagement by utilities in source water protection, 2) the infrastructure to conduct broadscale outreach was in place, and 3) the threat of fire to water supply was manifest as was the importance of action on

NIPF lands. Within the state we then set out to characterize more specific place-based opportunities to pilot the FRB.

Over the next several months the team engaged stakeholders across the state and in four primary Colorado landscapes: 1) the Front Range, 2) the Southwest, 3) the San Luis Valley/Rio Grande National Forest, and 4) the White River National Forest.

It became quickly apparent that San Luis Valley landscape would be problematic owing to lack of apparent beneficiaries. Several discussions with Southwest area stakeholders were held and the conversations initially proved promising. The "3-2-3" Collaborative spans three national forests, two states, and three watersheds and is facilitated by the Mountain Studies Institute. The team engaged the Institute Director on applicability of the FRB to their efforts and participated in a Gates Family Foundation roundtable on payment for ecosystem services focused on scaling efforts like the 3-2-3. Ultimately, we deemed 3-2-3 effort not ideal for the FRB, in part due to uncertainty over the integration of the FRB with an established Water Fund in use by the collaborative - the Rio Grande Water Fund. And, after several attempts, we were unable to make inroads with applicable stakeholders in and around the White River National Forest.

As these discussions unfolded we were simultaneously evaluating opportunities to pilot the FRB on the Front Range, an area of the state acutely aware of the connection between the risk of fire and water supply. Denver Water, the state's largest water utility, has for several years partnered with the USFS (and more recently NRCS) to reduce risk in its source watersheds following several catastrophic fires. The Forests to Faucets partnership between Denver Water and the USFS had poured tens of millions of dollars into headwaters risk reduction with an increasing focus on complementary work on private lands. Other major utilities, from Colorado Springs to Fort Collins, were making similar investments. The good news was that beneficiaries along the Front Range were aware of the risk and motivated to invest; the challenge was that the Front Range proved to be a very crowded playing field with NGOs, utilities, and corporate partners each having a particular view of what defined success.

While discussions with stakeholders unfolded, the team continued to spatially assess the biophysical landscape in an effort to both 1) begin to evaluate both need and opportunity of risk reduction treatments along the ~300-mile-long Front Range and 2) lay a foundation to quantify return on investment to beneficiaries. More specifically and using AFF's Functional Linkages of Watershed Systems (FLoWS) model and WRI's datasets to establish environmental trends, we evaluated nearly 200 HUC 12 sub watersheds supplying five major metro areas (Ft. Collins, Boulder, Denver, Aurora, and Colorado Springs) across 9 primary criteria individually and in composite, including:

- Total catchment acres
- Total forest acres
- Private to total forest ratio
- Reservoir volume
- Number of utility intakes
- Average sub-watershed sediment increase post fire
- Average increase sediment at intakes post fire
- Average population served
- Average agricultural acres served

The results were mixed depending on which criteria were weighed. As we began to engage stakeholders with our findings, we came to appreciate that each utility had conducted similar assessments based on the document "Protecting Critical Watersheds in Colorado from Wildfire: A Technical Approach to Watershed Assessment and Prioritization" implemented by a private consulting firm, JW Associates. Further, utilities had already prioritized watershed treatment activities based on the JW assessment identifying areas known as Zones of Concern. While the methodology we established to assess need and opportunity of risk reduction activities is sound and replicable for areas not covered by JW Associates, the Conservation Innovation Grant (CIG) team looked to leverage these existing resources, specifically the buy-in and momentum behind them.

Water Utility Engagement

Rationale for Utility Engagement

In general, utilities rely on source watersheds for their water and hydroelectricity needs, but often do not own or manage the land within the watershed. This separation of ownership, despite overlapping geography and interests, creates a situation in which utilities are affected by the condition of landscapes that they do not control. Globally, we have begun to see water users —cities, companies, and water utilities —start to take action on behalf of customers that directly benefit from healthy and resilient watersheds. In 2015, these water users spent nearly $657M to manage water risks in their basins. These programs supported watershed management on an estimated 27 million acres across a combination of public and private lands (Bennett and Ruef 2016).

There are a number of examples in the U.S. of utilities working with other at-risk and concerned stakeholders to jointly fund and implement investments in watershed health. In practice, however, it rarely happens at a meaningful scale and only recently is beginning to intentionally approach the problem cross-jurisdictionally. This is a missed opportunity and one that the FRB can help make more attainable.

An example of fire-related risks that utilities can face is the 2002 Colorado Hayman Fire that burned more than 138,000 acres and destroyed 600 structures over six weeks, causing more than $42 million in home losses. Directly impacting communities, natural resources, and recreation, the fire also caused unprecedented sedimentation in a drinking water reservoir and made the landscape more prone to flooding. Denver and Aurora water providers spent $25 million over two years to remove the excess sediment in the reservoir and endured damaged infrastructure after heavy rains led to flooding (Blue Forest Conservation 2017). Learning from Denver and Aurora Water's experience, a number of other Colorado Front Range utilities have begun similar efforts to proactively manage their risks related to wildfire, including collaborations in and around Colorado Springs, Fort Collins, Loveland, and Greeley.

Investing in forest restoration through a collaborative platform such as the FRB can be a cost-effective approach to prioritize fire-resilient watersheds. Whether publicly or privately owned, all utilities are heavily regulated and tend to be risk-averse compared to many other industries. As such, the FRB is designed to minimize risk and maximize value for utility stakeholders while providing competitive returns to investors. As part of the FRB structure, utilities only reimburse a portion of the restoration costs and make their payments over a 10-year period, limiting the upfront investment required from the utility while allowing for ex-post payments (*i.e.*, after the benefit has been received). Restoration can

help utilities address a number of challenges related to fire risk to infrastructure, water quality, water quantity, sedimentation, and flooding. The FRB is an opportunity for utilities to capture these important benefits at a discounted price per acre, and at a lower level of risk, compared to pursuing a project alone (Blue Forest Conservation, 2017).

Engaging Utilities along the Front Range, CO

We recognized the importance of utility engagement towards achieving a successful FRB, as well as the need to leverage, rather than duplicate or compete with ongoing local forest health efforts. With this in mind, the CIG team systematically sought input, advice and opportunities from utility leaders and associated stakeholders from across the Front Range. We developed a multi-pronged utility and stakeholder engagement strategy based on the delivered feedback.

Our outreach began in February and March of 2017 with presentations through existing utility collaborations, including the Watershed Wildfire Protection Group and the Front Range Fuels Treatment Roundtable. These forums focus on promoting healthy watersheds by facilitating education and awareness, landscape prioritization, project implementation, and monitoring. Stakeholders included: U.S. Forest Service, NRCS, Colorado State Forest Service (CSFS), consultants (*e.g.* JW Associates), utilities, academia, Congressional legislative representatives, and local, regional, and national NGOs. Presentations to these groups allowed the CIG team to explain the value proposition of the FRB, understand utility and stakeholder priorities, questions, concerns and sensitivities, solicit feedback on how best to deepen engagement and most importantly, build relationships.

Building on the momentum of these presentations, the CIG team leveraged an existing relationship with the American Water Works Association (AWWA) focused on source water protection. AWWA served as both a validator and trusted voice to utilities on behalf of the CIG team, and a helpful advisor in relation to utility engagement. Together, AWWA and the CIG team organized a day-long Front Range utility workshop at the AWWA headquarters in Denver, CO in October 2017. Leading up to the workshop, a brief survey was developed (see Appendix 2) and shared with 12 utilities to better understand concerns and priorities for each utility in relation to watershed and catastrophic wildfire risks. The responses to this survey helped us prepare a workshop that was tailored to their priorities, needs, and inquiries regarding source water protection, financing, and the Forest Resilience Bond. The survey request was accompanied by background materials on the FRB.

Overall, responses from the utilities were fairly consistent:

- Every utility noted fire as a key risk and is already doing *something* about it;
- Most utilities are engaged in at least one existing partnership where increasing funding is a priority;
- Most of the effort to date is on public lands but, private land is deemed as important;
- Most utilities have worked to prioritize areas/acres; however, this prioritization has not necessarily driven site-specific action and/or the exercise is deemed outdated;
- Very few had done a Return on Investment (ROI) economic analysis related to fire risk reduction;
- Most utilities had gray infrastructure investments on the horizon – timing and scale varied considerably; and
- Every utility wanted to learn more about FRB as increasing financing and exploring new mechanisms was of key interest.

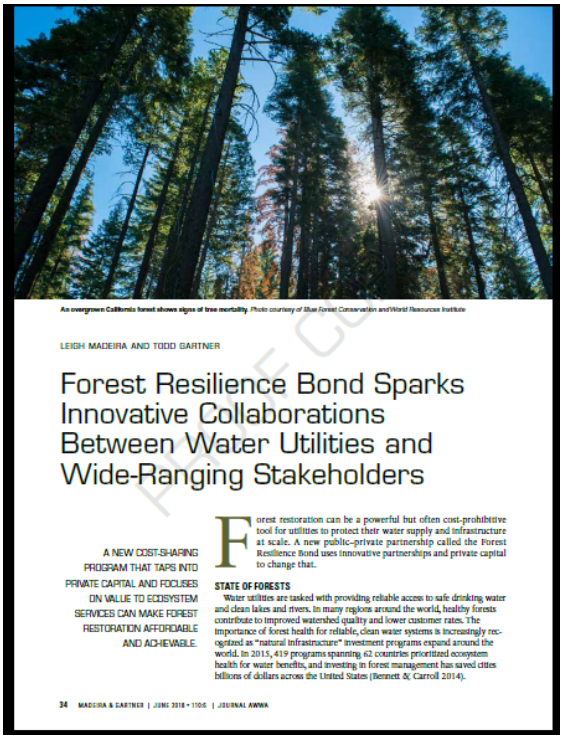
To dig into the survey responses in more detail, the CIG team then organized short follow-up/preparatory calls before the October gathering with each participant.

The in-person workshop was very successful and allowed for active discussion around three key themes:

- The FRB as a financing mechanism for forest health on public and private lands and utility risk reduction;
- Ecologic Measurement & Economic ROI; and
- Where are the Front Range Opportunities & Challenges?

Following the event several utilities stated a desire to dig deeper with the CIG team to explore opportunities for FRB application within their priority watersheds, including: Denver Water, Aurora, Northern Water, Golden, Thornton, Northglenn, and Westminster.

Following that working group engagement, surveys and utility-centric workshops, and in order to provide an additional validation point, the CIG partners continued to work with AWWA by authoring an FRB-focused article in the June 2018 AWWA Journal, received by over 13,000 US utilities and 50,000 individual members.



An overgrown California forest shows signs of tree mortality. *Photo courtesy of Blue Forest Conservation and World Resources Institute*

LEIGH MADEIRA AND TODD GARTNER

Forest Resilience Bond Sparks Innovative Collaborations Between Water Utilities and Wide-Ranging Stakeholders

A NEW COST-SHARING PROGRAM THAT TAPS INTO PRIVATE CAPITAL AND FOCUSES ON VALUE TO ECOSYSTEM SERVICES CAN MAKE FOREST RESTORATION AFFORDABLE AND ACHIEVABLE.

Forest restoration can be a powerful but often cost-prohibitive tool for utilities to protect their water supply and infrastructure at scale. A new public-private partnership called the Forest Resilience Bond uses innovative partnerships and private capital to change that.

STATE OF FORESTS

Water utilities are tasked with providing reliable access to safe drinking water and clean lakes and rivers. In many regions around the world, healthy forests contribute to improved watershed quality and lower customer rates. The importance of forest health for reliable, clean water systems is increasingly recognized as "natural infrastructure" investment programs expand around the world. In 2015, 419 programs spanning 62 countries prioritized ecosystem health for water benefits, and investing in forest management has saved cities billions of dollars across the United States (Bennett & Carroll 2014).

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AWWA article: *Forest Resilience Bond "Sparks" Innovative Collaborations between Water Utilities and Wide-Ranging Stakeholders (Madeira and Gartner 2018)*

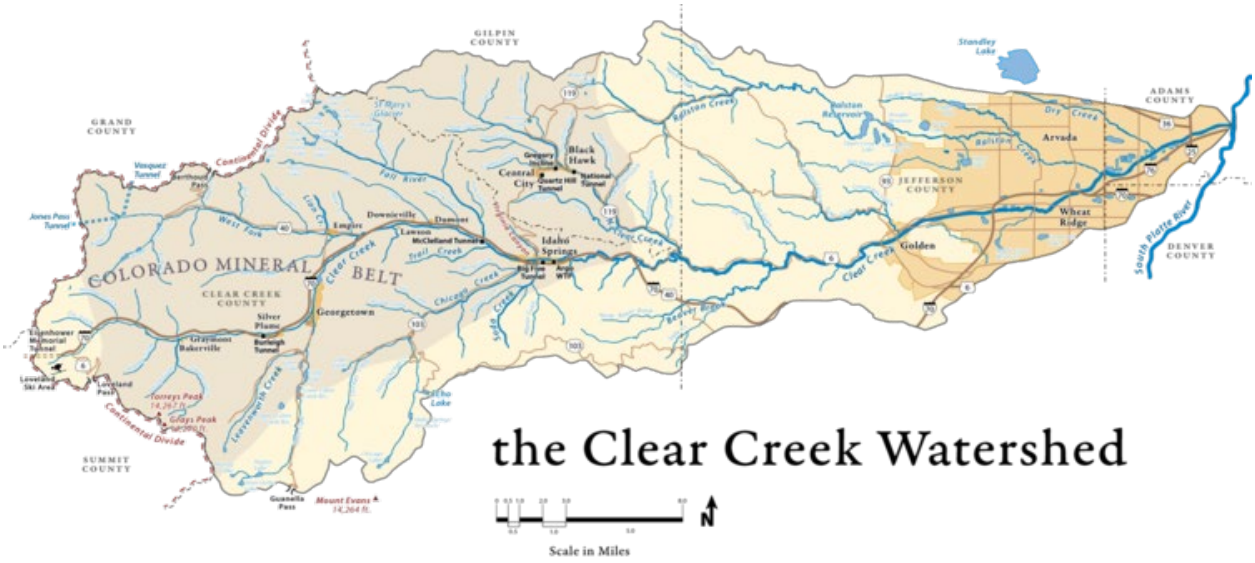
During the months following the AWWA co-hosted utility workshop, and mostly due to stretched utility capacity, Denver, Aurora and Northern elected to stay in touch and learn more as the FRB moved towards transactions in other locations, but to pause on their engagement relative to the CIG efforts. However, the Standley Lake utility consortium consisting of Golden, Thornton, Northglenn and Westminster elected to participate as a pilot candidate and more granularly explore next steps.

Clear Creek Watershed as a Potential Pilot

The Clear Creek Watershed and Standley Lake utility consortium (hereafter "Project Partners") possessed many biophysical and social attributes that suggested this would be an ideal pilot location for an FRB application on private lands in Colorado.

Hydrogeology and Water Demand

The sources of Clear Creek's major tributaries lie above 14,000 feet in the Rocky Mountains, from where the creek flows eastward for approximately 66 miles (106 km) to the canyon mouth at the City of Golden. From there, the river flows through the northwestern metropolitan Denver area (5,000 feet in elevation) to its confluence with the South Platte River (Figure 2). The watershed spans 575-square miles, 400 of which are located in the mountains west of Golden, designated as the Upper Clear Creek Watershed (CCWF n.d.). The majority, about 75%, of Clear Creek's annual flow derives from snow melt and occurs in May, June and July.



Clear Creek Watershed Map (CCWF n.d.)

The demand on Clear Creek makes it one of the most over-appropriated streams in Colorado (CCWF n.d.). While there is generally adequate water in Clear Creek to satisfy all water rights during high flow, during low flows, seniority of water rights determines priority of water use. The watershed contains numerous dams and reservoirs to store water during high flows and supports residential, agricultural and industrial needs year-round, particularly in the summer when demand is highest. In addition, water from Upper Clear Creek is diverted out of the basin to the Standley Lake water supply reservoir via several large canals. Standley Lake diverts and stores most of the Clear Creek flow during the months of November through March. The reservoir diverts a significant amount during the summer months as well.

Watershed Services and Values

Clear Creek watershed supplies water for several towns and cities; supports numerous industries, including those focused on recreation, mining and farming; and provides habitat for some of closest fisheries to the Denver metropolitan area.

Water supply: Clear Creek and its tributaries serve as a significant, and in many cases, only, water supply source for several municipalities and industries, including:

- Upper-watershed towns: Black Hawk, Central City, Empire, Georgetown, Idaho Springs, Silver Plume (≈10,000 total people)
- Lower-watershed cities: City of Golden (≈21,000 people) and Arvada (≈138,000 people)
- Standley Lake cities: Northglenn, Thornton, and Westminster (≈ 350,000 people) (City of Westminster et al. 2010)
- Private water supplier: Consolidated Mutual Water Supply Company
- Industry: Loveland Ski Area and Henderson Mine in the upper watershed, and Coors Brewing Company in the lower watershed.
- Agricultural users: Multiple private ditch companies

Recreation: Clear Creek is valued for its fisheries and recreation. The river is utilized extensively for fishing, kayaking, rafting, swimming, and small-scale recreational placer mining (Clear Creek Consultants *et al.* 2014). One-third of the watershed lies within the Arapaho & Roosevelt National Forests, which receives approximately 4.5 million visitors per year (USDA 2015).

Clear Creek whitewater rafting. Image: Alan/Flickr)

Mining: The 1859 discovery of gold in Clear Creek kicked off the Colorado Gold Rush and was followed shortly after by the discover of silver. Most mining concluded by the early 1940s, leaving abandoned mines behind. The Henderson Mine remains in operation, but the mine is scheduled to close to 2026 (Blevins 2017).

Infrastructure: Several important infrastructure features cross or lie within Clear Creek Watershed. The Interstate-70, a major cross-country corridor, follows Clear Creek through much of the watershed. A major transmission line operated by Xcel Energy also runs through the watershed. Xcel and other entities also operate hydropower dams on Clear Creek and its tributaries, including the 336 MW Cabin Creek hydroelectric plant.

Habitat: Clear Creek Canyon is home to abundant wildlife, native grasses, wildflowers, and ponderosa pine forests**.** Clear Creek provides habitat for a number of trout species, including the federally protected greenback cutthroat trout in some headwaters, as well as rainbow, brown, and brook trout. In addition, the watershed is also home to: golden and bald eagles, peregrine falcons, bighorn sheep, mountain goats, American pika, mink, porcupines, bobcats, and mountain lions, among other species.

Individually and collectively, these many watershed values underscored for the CIG team the myriad of user groups invested (if not investing) in the ecological well-being of the watershed and its forests. The

successful development of FRB projects requires identifying those stakeholders within a watershed that have a vested interest in seeing projects advance for the various reasons described above.

Standley Lake Utility Consortium Deep Dive – Investment Readiness Assessment

As part of the Conservation Innovation Grant process, the World Resources Institute, in collaboration with CIG partners and the Trust for Public Lands, modified and applied a Readiness Assessment Tool to evaluate strategic, feasible, and efficient opportunities for initiating the Forest Resilience Bond as a watershed investment program. Like documenting the range of watershed values and therefore potential beneficiaries, the readiness assessment provides an additional screen to evaluate the potential success of deploying the FRB.

The objective of the Readiness Assessment is to provide stakeholders with 1) an opportunity to internally reflect upon the consortium's capacity and gaps in relation to current and future work plans, 2) resources to externally communicate their vision, actions and needs to partners, customers, leadership and other stakeholders, and 3) understanding the key next steps to unlock financing.

WRI utilized a combination of desktop research and stakeholder interviews to collect a wide array of information regarding watershed services and beneficiaries, current land use and ownership, landscape condition, conservation stakeholders and funding, and landscape management plans and partnerships. From this information, WRI identified strengths and gaps in current conservation efforts, with recommendations for next steps for leveraging watershed investments and the likelihood of success of an FRB application. The investment readiness methodology is located in Appendix 3 of this report.

Readiness Assessment Conclusions and Recommendations

Efforts to initiate a watershed investment program in the Clear Creek watershed thus far have primarily focused on Building Momentum (Phase I), but the assessment found the Project Partners (aka Standley Lake utility consortium) were well positioned for advancing efforts further. Strong relationships, common concerns and risks, and successful prior watershed management efforts among the Standley Lake Cities (Westminster, Thornton, and Northglenn), Golden and Clear Creek County provide a strong foundation from which to build a watershed investment program (in this case the Forest Resilience Bond). However, relationships between the Project Partners, watershed stakeholders (*e.g.* upper watershed communities) and other landowners/managers (*e.g.* USFS, county land managers, Colorado State Forest Service, private landowners) are not as well developed. Efforts are ongoing to engage these stakeholders, establish mutual commitment and priorities, and potentially bring additional partners on board.

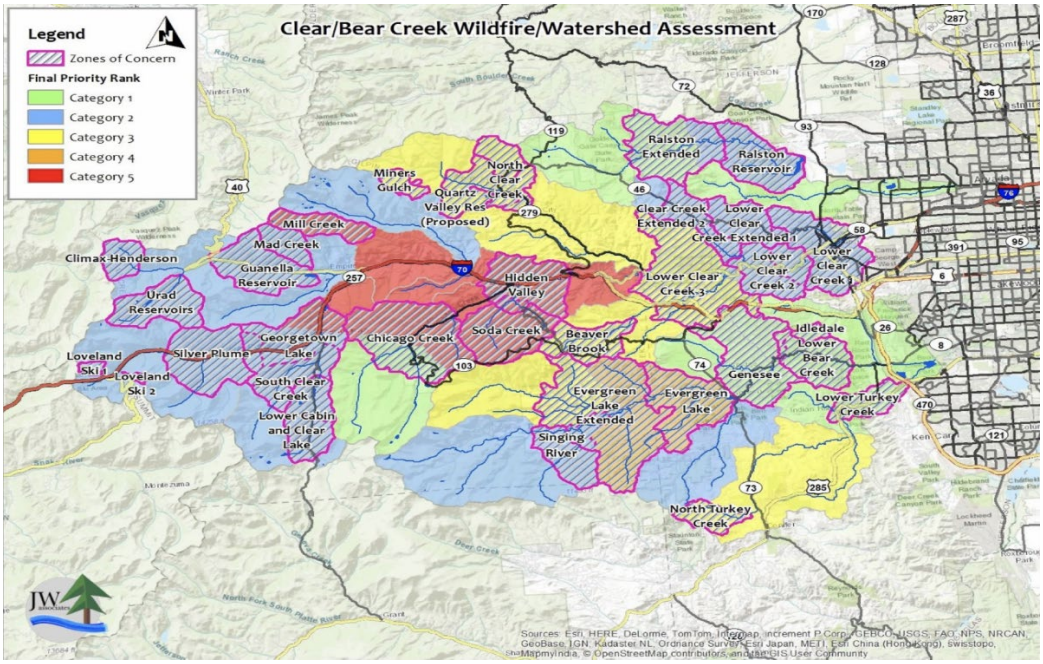
The Project Partners have the potential to benefit from a strong group of experienced advocates for watershed investment programs in the region, including WRI, Blue Forest Conservation , American Forest Foundation, and The Nature Conservancy (TNC). These advocates could fill many of the gaps in Project Partner's capacity identified through the Readiness Assessment, including the capacity to:

- Evaluate the business case and attract investors;

- Engage landowners and public managers; and
- Administer a program.

Prioritization of Clear Creek Watershed Towards an FRB Pilot

Initial prioritization was focused on results from a Wildfire Watershed Assessment performed for Clear Creek completed by JW Associates. The assessment is based on a Front Range working group report on watershed assessment and prioritization for wildfire protection. Information in these reports was 5-10 years old, and was in the process of being updated. The Chicago Creek sub-watershed was chosen for a "dry-run" test of the Forest Resilience Bond methodology, so we could run through the logistics of creating an FRB for the stakeholders and completing a potential assessment on how increased sediment after a wildfire would impact water supply. Lower Chicago Creek was identified to be both a Zone of Concern and in the highest wildfire priority (Category 5).



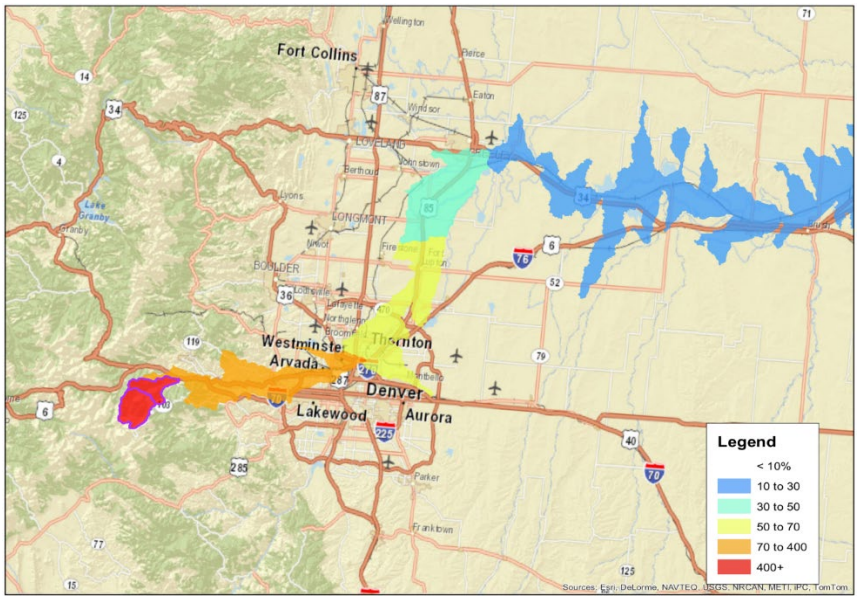
Wildfire watershed prioritization assessment for Clear Creek (JW Associates)

The landowner profile of the 12,000 acre lower Chicago Creek watershed showed 80% USFS, 10% private, 5% county, and 5% city. A treatment opportunity of 6,000 acres, with an average cost of $1,000/ac, would have resulted in a $6M restoration project. Potential stakeholders that could financially contribute to the cross-boundary project included the Arapahoe-Roosevelt National Forest, private landowners, Natural Resources Conservation Service (NRCS-EQIP), Clear Creek County, Idaho Springs, Echo Lake Park, Standley Lake Utilities, the city of Golden, and MillerCoors. Chicago Creek is not only a source watershed for Standley Lake but is also the entire water source for the town of Idaho Springs with a population of 1,700 people.

The Functional Linkages of Watersheds and Streams (FLoWS) Model uses hydrological processes to connect hillslopes with streams along a network data structure with topological relationships. The model is available as a python-based tool in the ESRI ArcGIS software. The NRCS runoff curve number

and soil erodibility are modified based on vegetation cover change following a wildfire. Typically, we would implement specific burn intensities from a spatially-explicit wildfire model to provide a range of impacts from low, moderate, and high intensity wildfires, but for the "dry-run" we opted to base the initial modeling exercise assuming the entire Chicago Creek watershed would burn at high intensity and as the most-extreme example.

Results of the FLoWS model produced estimates of a 1000% increase in sediment load within the sub-watershed, directly impacting the water supply of Idaho Springs and leading to significant increases in filtering and treatment costs. Downstream, where the intake for Standley Lake is located in the western Denver suburb of Arvada, annual sediment load immediately after a wildfire would increase by 100%. Again, these are the most extreme impacts of a high-intensity fire contained within Chicago Creek, while an actual wildfire of concern would impact a larger area of the watershed with variable intensity.



FLoWS model results of annual sediment load increases following a high-intensity wildfire in Chicago Creek.

Potential for treatments in lower Clear Creek

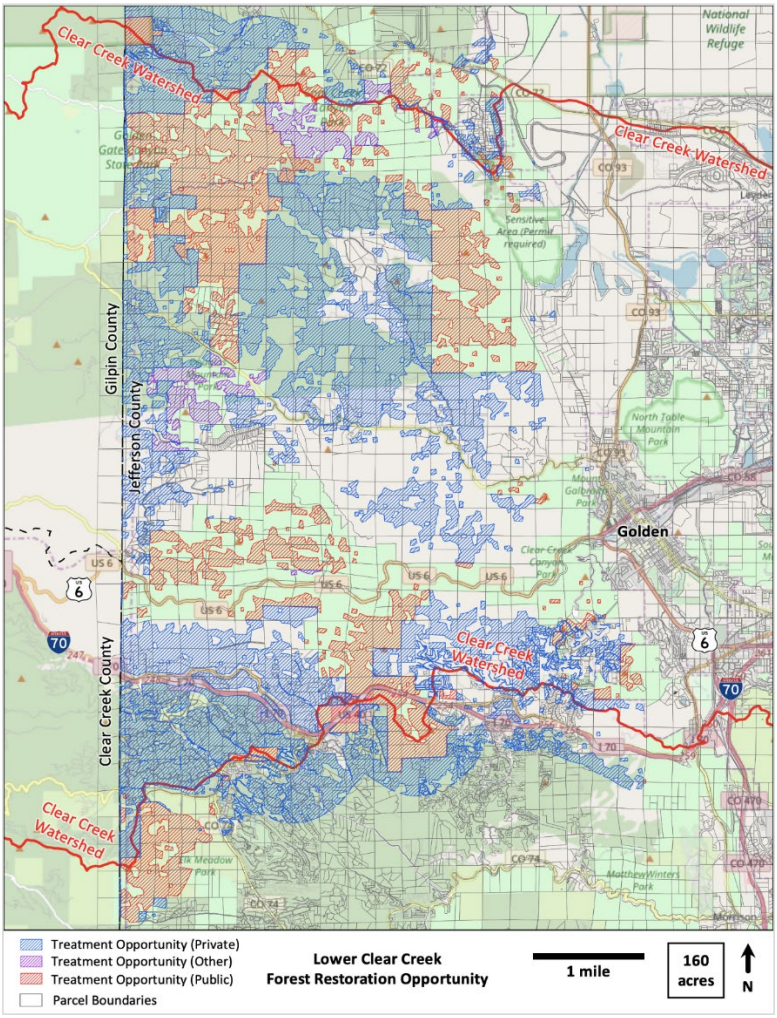
When presented with these findings and owing to the limited treatment opportunities given the steep terrain, the utilities identified zones of concern that included lower reaches of the watershed where there was a greater opportunity for fuel treatments, and a greater concentration of private lands. With that focus, the team evaluated ownership, stand type, slope, burn probability, and elevation to identify a scope of potential high value treatment areas across the lower part of Clear Creek watershed. The goal was to find a cohesive treatment area on public lands that we could then use as an anchor to build in adjacent and near-by private landowners.

Potential treatment regions were determined by:

1) Land ownership;
2) Forest vegetation community, and;

3) Slopes <40% (recommended by the Colorado State Forest Service).

Parcel ownership data was provided by AFF, vegetation community type was determined from the National Land Cover Database (NLCD 2011), and slope was calculated from a USGS 30-meter Digital Elevation Model (DEM).



Forest restoration treatment opportunities in lower Clear Creek, within Jefferson County, classified by public, private, and other (e.g. tribal) land ownership.

Engagement of State and Private Land Managers

With that prioritization in hand, the team engaged land managers working across the lower reaches of the watershed to inform further prioritization of treatment opportunities based on the ability to tie into past activities, planned activities, and their knowledge of likely-to-engage NIPF landowners.

A series of conversations ensued that included representatives from Denver Mountain Parks, Jefferson County Open Space, Jefferson Conservation District, and the Colorado State Forest Service culminating in a half-day, in-person meeting to review assessment findings and identify targeted project areas to

bring back to the utilities for investment consideration. Iteratively, the team began to review the landowner survey data in earnest for anticipated landowner outreach.

In addition to better understanding the attitudes and activities of NIPF landowners related to fire across the four target states, the 425 interviews we completed also tested messaging and messenger approaches to position the FRB as a solution. While the survey results in their entirety are appended to this report, the key finding was the importance of focusing on simplicity of messaging when presenting the FRB. Landowners, at least in initial discussions about how to finance treatments on their lands, need not be bothered with too many details. As conversations progress, there is ample time and opportunity to introduce particulars. We also affirmed that messengers matter and trusted local partners are essential owing to the general mistrust of governmental agencies.

Two project areas (northern and southern) were identified, both of which were located in the Lower Clear Creek Zone of Concern prioritized by the utilities. The first potential project (northern) proposed to engage large-parcel, private landowners bookended between Golden Gate State Park where Colorado Parks and Wildlife was currently conducting fuels treatments and White Ranch park where Jefferson County Open Space had recently finished treatments. This northern area flows into Ralston Creek and Ralston Reservoir (operated by Denver Water) and was therefore of limited interest to the Standley Lake utilities. The second potential project (southern) proposed was a more discrete area in the southern most reaches of the project area where Denver Mountain Parks was actively working and significant opportunities to engage adjacent NIPF landowners existed. Incorporating feedback from the utilities, the team re-engaged the foresters to further scope the southern project area.

Working closely with Denver Mountain Parks and the Colorado State Forest Service in particular, the team defined a 300-400 acre FRB pilot project that would build on current and planned work by Denver Mountain Parks and include proposed treatments on adjacent NIPF properties. The scoping document presented to the utilities included information on: elevation, slope, soils, vegetation, hydrology, fire hazard, desired future conditions, general treatment prescription, product utilization, and parameters around treatment landings, noxious weed prevention, and road construction/rehabilitation. In all, we estimated a total treatment cost of $900,000-$1,200,000, a substantial portion of which the utilities, as FRB beneficiaries, would cover.

Due to the project cost (@ ~$3000 per acre, reflecting “real-world project costs” such as planning, forester time, disposal of wood, etc.), relatively small acreage that could be treated, and challenge in scaling the FRB model to the larger watershed - the utilities elected to hold for now and focus on further strengthening cooperation that might lead to larger scale restoration in the years ahead. Though they may not be ready to move forward at this time, the analysis provided a valuable baseline and SWOT assessment for future action.

Lessons Learned

The evolution of the Forest Resilience Bond, and environmental impact investing in general, involves a systems level approach to fund and invest in environmental solutions. Engagement of all of the financially invested stakeholders is necessary. This engagement includes beneficiaries, government entities, investors, NGOs, and project implementers. Non-financial stakeholders such as community

representation and environmental interest groups, while not paying or receiving funds, should also be included in the process to ensure projects reflect local values and to incorporate community feedback.

This section includes lessons learned from the effort to establish a Forest Resilience Bond including private lands in Colorado, as well as some of the insights gained from establishing the first Forest Resilience Bond project in the Tahoe National Forest. These lessons learned are from the countless interactions the CIG team had with utilities, state agencies, private landowners, the Forest Service, and environmental NGOs in the area. Not only is engagement with each stakeholder group necessary, but thoughtful engagement with ongoing communication is needed for success.

The principal lessons learned from this project include the following:

Important to identify the unique and formative bottlenecks in getting restoration work done. On private lands in Colorado source watersheds, the bottleneck does not seem to be lack of funding per se but rather a pipeline of "shovel-ready" projects- owing in large part to significantly limited forester and contractor capacity on the ground. If anything, the market is over-saturated with partners looking to do projects and the FRB doesn't address a formative barrier- limited capacity. While planning and implementation will likely always be barriers, the ready need for capital is crucial to the viability of the FRB.

Strategically engaging land managers and utilities. The FRB needs both land owners/managers and other beneficiaries to sign contracts with a project level entity (investment vehicle) to make this financing possible. However, it can be difficult to gain traction with both parties when it is unclear to either party if the other stakeholder has interest. To secure the funding to support restoration efforts, beneficiaries like utilities must justify investment based on the parameters of project particulars. In other words, a beneficiary's willingness to invest is largely determined by specific outcomes from a viable, scoped project. Meanwhile, private land managers (including state agencies, conservation districts, and county and municipal land managers) are empowered to only aggressively pursue private land restoration opportunities when they are fairly assured of funding to implement work on private lands lest their work with landowners become an exercise of planning for planning sake. Both parties seek the surety that their investment will not be stranded. Beneficiaries are unable to commit financial resources without seeing a "fully-baked" project. And foresters are unable to commit limited bandwidth to engage landowners without some surety that implementation dollars are available.

More beneficiaries are not always better. The Standley Lake consortium is a group of four utilities, which can be helpful since not one utility has to pay even a majority of the costs. But if just one of those utilities (or two in this case) is unsure or against the project, the whole consortium may fall apart.

It's critical to have an "anchor tenant" ("anchor beneficiary") when pursuing projects. During our work with beneficiaries we began to see an analogy between building a large-scale restoration project and a large-scale commercial development. In speculative commercial real estate investments, the viability of the whole project is often determined by signing up an "anchor tenant, a Whole Foods for example. Smaller commercial operators have an incentive to co-locate knowing that the anchor tenant will draw customers. By extension, an expansive restoration project is easier to sell to potential beneficiaries when they know a significant investment will be made by an "anchor tenant" knowing that smaller projects can tier to that larger investment. The Standley Lake utilities did not have the capital or desire to be that anchor tenant and thought it should be the Forest Service while the Forest Service unfortunately didn't have projects planned in this area. We shifted to work with county land managers to determine viable projects within their ownership in the watershed, but no longer had the opportunity

to include Forest Service as an anchor tenant. Even in future projects that include cross boundary opportunities with the Forest Service, we will need to address this anchor tenant issue as it could influence interest in participation by Environmental Quality Incentives Program (EQIP) eligible private landowners as well.

Sufficient scale is needed to attract utility interest. More acreage is preferred for a utility to know their participation is worth their time, because the protection to water quality is worth the utility's time. The proposed FRB pilot in Clear Creek Watershed did not have enough acres available for treatment, and no clear path to scale to a meaningful watershed-scale restoration effort.

Be upfront about costs and expectations, find leverage for beneficiaries. Ultimately, the Standley Lake utilities did not find the costs and expected benefits of the restoration work to be compelling enough. They also weren't comfortable with being the "anchor tenant" even though the costs would be shared among all four of them. The opportunity to bring in financial support from other types of beneficiaries (e.g. land managers, private landowners, state entities, etc.) to leverage the utility commitment is crucial. This is true in our non-CIG related work on the Forest Resilience Bond in California as well. We should have initiated the conversation around costs and expectations for financial commitments with the utilities in the early stages of engagement.

It's critical to have Forest Service support, even on private lands. The nature of watershed-scale fire risk reduction demands a cross-boundary approach. Downstream beneficiaries (like the Standley Lake utilities) understandably want to see sufficient project scale and more often than not, this means work on federal and non-federal lands alike. In this case, the National Forest and Regional Office of the Forest Service was supportive of the project but was unable to prioritize projects in the area that could anchor our cross-boundary work with county land managers and private landowners.

Finding sweet spot with "local" NGO's. A successful FRB project requires "fundraising." That is, cultivation of downstream beneficiaries, demonstrating their potential return on investment, leading to a solicitation of funding to support restoration work is an inherent aspect of the FRB model. And that fundraising can be perceived as a competition for limited attention and resources from a limited pool of potential funders. It's often challenging, as national NGOs, to find the sweet spot for coordinating and leveraging "asks" of funders/beneficiaries with the local NGO community. For example, MolsonCoors, like the Standley Lake utilities, relies on water from the Clear Creek watershed to brew its beer and was an obvious potential project beneficiary. Yet, local NGOs had significant reservations to pitching the brewery on the FRB model for concern of upending longstanding local cultivation efforts.

The challenge of aggregating private landowners. Successful strategies to aggregate private landowner investments need to be explored further. We recognize a challenge of deploying the FRB on private lands are transaction costs associated with contracts across a myriad of individual landowners. Unlike contracts with "major" beneficiaries like the USFS or utilities where the size of the contract themselves can offset transaction costs, establishing several (ideally dozens) of small contracts with NIPF landowners can significantly increase the overall project's transaction costs and diminish the potential ROI for investors and, thereby, limit the pool of investors. As a function of this pilot, we were not afforded the opportunity to tackle this challenge head on if only because we did not reach a point to engage individual landowners.

Being right is not enough. Even if a compelling business and risk reduction case is made, some stakeholders may not be quite ready to move forward, including beneficiaries like utilities. *Ability* to invest is as important as *willingness* to invest.

Strategically scoping economic assessment. Economic assessment is a lynchpin for multi-stakeholder finance platforms like the Forest Resilience Bond where information about distributional costs and benefits across stakeholders can bring stakeholders to the table and inform deal making. Yet economic assessment of interventions in inherently variable natural systems poses several methodological difficulties, setting up a tradeoff between analytical sophistication and both cost and time that challenges the analyst to strike the appropriate balance given the needs of stakeholders. This is especially true where the object of analysis is fire.

As noted, this Conservation Innovation Grant ultimately did not result in a pilot of the FRB on the ground and involving NIPF landowners as hoped for. Yet, what the preceding discussion makes clear is that the work completed led to invaluable learning that can and should inform future efforts to deploy the FRB on private lands. We are confident that the challenges we've addressed are not unique to Colorado or the Front Range, from aligning beneficiary and land manager needs to limited forester and contractor capacity to complete the work, and approaching new FRB opportunities with these in mind will greatly increase the chance of success.

Concurrent with this Conservation Innovation Grant, and informed through aspects of the stakeholder engagement and project development process in Colorado, some of the CIG partners have been working on an FRB project in California. While that project's focus is public not private lands, we believe that additional lessons from our experience can further inform future FRB application in cross-jurisdictional settings.

Lessons Learned from FRB Pilot in Tahoe National Forest

WRI, BFC, the Sierra Nevada Research Institute, and the Natural Capital Project worked together to explore methodological approaches for rapid economic assessment to underpin the FRB. This included a rapid economic assessment to inform live dialogue with the Yuba Water Agency around financial contributions to an FRB for a USFS forest health treatment in the North Yuba River watershed. This assessment helped to inform a unanimous vote by YWA's board to contribute $1.5 million to this FRB pilot. This effort generated several transferrable learnings.

Economic assessment can serve a range of critical functions in scoping projects, engaging stakeholders, and mobilizing finance for forest health treatments. Economic assessments can be used to raise awareness of the importance of forest health treatments and compare alternative treatment options. In support of multi-stakeholder finance platforms like the Forest Resilience Bond, economic assessment can also be used to identify major beneficiaries, guide negotiations over relative contributions from those beneficiaries, and provide the analytics those beneficiaries may need to justify investment to their constituencies - be they taxpayers, ratepayers, or shareholders.

The form of an economic assessment - its scope and sophistication - should be tailored to the function it is intended to serve. Several design decisions will affect the utility of results as well as the time- and resource-intensity of the analysis. Comprehensive and highly sophisticated analysis may not be

necessary to serve the desired function. In Tahoe National Forest, the project team made a series of design decisions in light of the intended function of the assessment as well as budget and time considerations. Key strategies for producing impactful assessments in limited resources include:

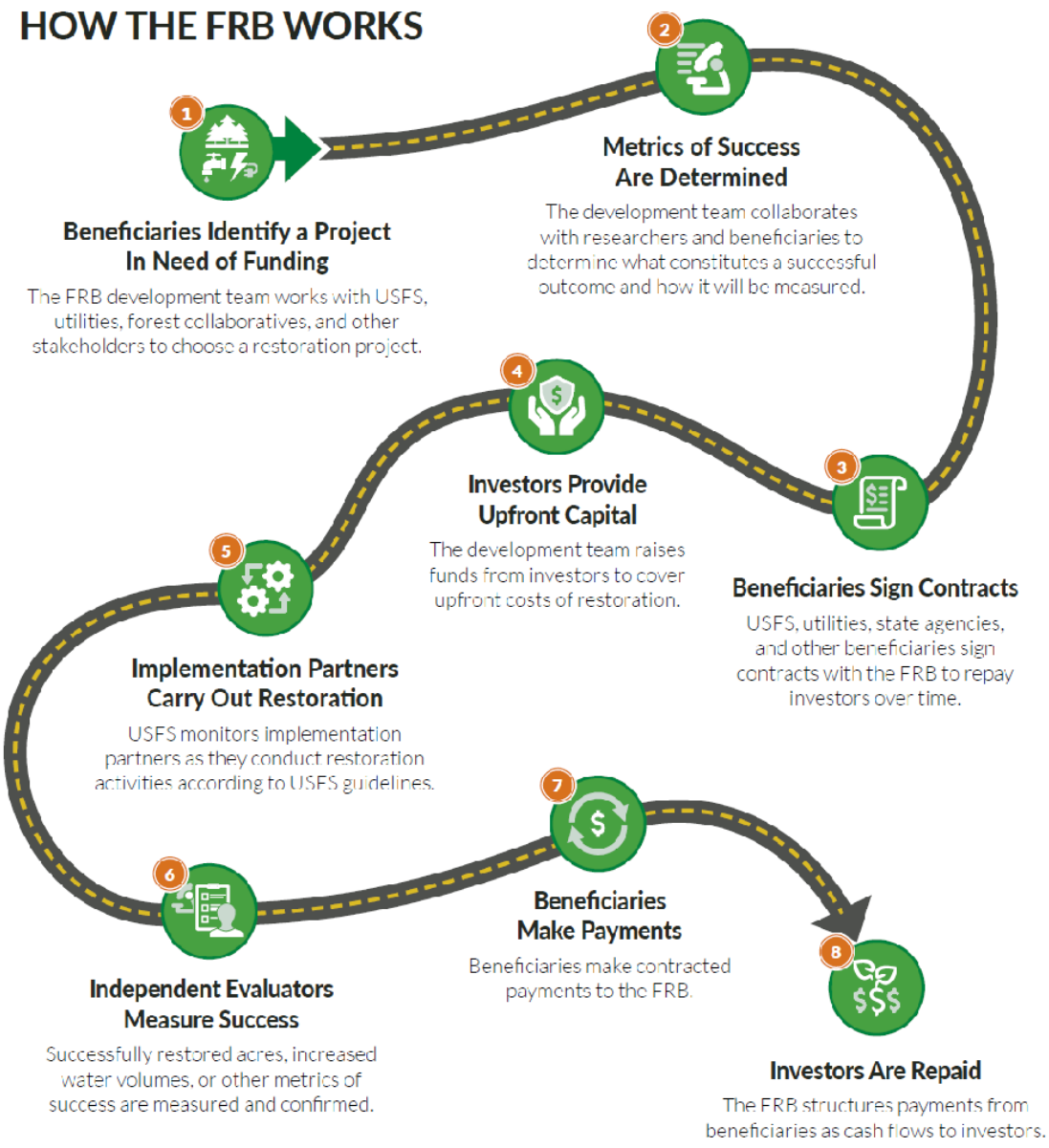
a. *Scope the valuation of costs and benefits to prospective anchor tenants in an FRB*. Although there are many benefits—and beneficiaries—of forest health treatments, resource constraints may prohibit a comprehensive valuation all potential beneficiaries. Scoping an assessment to the major players who could contribute to a bond (in the case of Tahoe National Forest—the Forest Service and the Yuba Water Agency) enables a focus on a subset of major fire impacts. These players can serve as initial payors, or anchor tenants, in a bond, which can then attract additional stakeholders. Resources permitting, future assessments can focus on valuing additional benefits to additional beneficiaries.

b. *Scope the treatment scenario to reflect scaled efforts*. Pilot projects actively under consideration by stakeholders may be relatively small compared to the opportunity, need, and ultimate stakeholder ambition. For example, in Tahoe National Forest, the proposed pilot project represented about 6 percent of the total area of the North Yuba River watershed. Although the value of such a pilot is significant in demonstrating the mechanics of the FRB, it became clear that stakeholders viewed the pilot as a stepping stone to significantly expanded treatments. The costs (and benefits) of initial pilots are typically modest—and studying them in great detail less impactful—relative to scaled treatment scenarios. Therefore, in addition to generating analytics specific to pilot treatments where possible, scoping a treatment scenario to reflect the larger goals can inform decision making around the ultimate objective in a given area, including the stepping stones toward that objective. In Tahoe, we scoped one treatment scenario to reflect the full extent of the watershed (not every acre treated, but a treatment that covers the entire watershed). In future assessments, downscaled scenarios could be added to reflect subsequent treatment projects in the pipeline.

c. *Draw from available data and literature where possible*. For each of the costs and benefits, site-specific modeling could lend greater sophistication and precision. However, sufficient data and research can be obtained to set parameters on most of the key inputs to an assessment without new modeling. Sensitivity analysis can then be used to indicate where site-specific modeling could meaningfully increase confidence in the results.

Key Elements for Success

Over the last three years, from the lessons learned from the Conservation Innovation Grant, we have learned more about the process to develop a Forest Resilience Bond project on private lands. And putting the project together in the following order is fundamental to successful project development:



Forest Resilience Bond project development roadmap.

So then, what makes a potential project a strong Forest Resilience Bond candidate on private lands?

We've learned that it is not sufficient to "start" discussions with either land managers or beneficiaries. The former needs the surety of investment to allocate limited capacity to scope project particulars and the latter needs those particulars to commit funding. This presents a chicken and egg challenge that requires iterative and non-linear engagement with both land managers and repayment beneficiaries, effectively co-creating a project together.

We've learned that much of the work that goes into an FRB is iterative even as it is important to recognize key milestones:

- Identification of a large landowner (federal, state, or private) with an interest in a restoration project to serve as an anchor tenant;
- Identification of sufficient acreage (>1,000 acres), planned for restoration to reduce fire risk, helps make the business case for investment;
- Identification of interested downstream beneficiaries willing and able to invest in watershed protection;
- Ensuring local implementation capacity is sufficient to tackle the work scoped and is trusted by the FRB partners;
- Limit conflicting goals with other environmental NGOs in the region who could feel competition regarding land manager relationships, competition for fundraising, or leverage the existing relations and bring them on to potential projects as willing partners;
- Finding champion representatives at each beneficiary organization who have capacity and organizational authority to entertain an FRB engagement.

While these milestones are key to success, they are also a useful approach to quickly identify project flaws. Until such time as the FRB becomes an accepted means by which to engage downstream beneficiaries in forest restoration efforts, project developers should be quick to identify those barriers and move on to other project candidates, rather than attempt to create the right enabling conditions. Stakeholder engagement takes an enormous amount of time and should be limited on candidate projects with low project implementation opportunity. In this nascent stage of project development of conservation finance, if a project is unlikely to move forward, project developers should arrive at that decision as quickly as possible.

Summary and Looking Ahead

As this Conservation Innovation Grant comes to an administrative end, our team has thus far been unable to initiate a Forest Resilience Bond pilot project on private lands in Colorado. That leaves the question of whether there is a future for the FRB in Colorado and on private lands. The answer, as one might expect, is it depends.

Colorado's Front Range presents both significant strengths and weaknesses as a candidate for deploying the FRB as this report details. First, the team notes generally strong support for forest restoration and land management activities on this landscape. From public land managers to private landowners, and from utilities to elected members of state and local government, reduction in fire risk is a key concern. Furthermore, the need for forest management is well understood and accepted in this landscape.

However, the landscape on the Front Range includes many small parcels that must be cost-effectively aggregated. It's geography (steep slopes), lack of forest product industry, and expansive wildland-urban interface contribute to high dollar per acre treatment costs. There is also a wide array of local, national, and international NGOs involved in a wide variety of conservation projects in this area that is competing for limited beneficiary funding. Lastly, "shovel ready" restoration projects on private land as well as implementation capacity is limited that in turn limits the ability to structure FRB candidate projects.

The FRB was clear and compelling to many utility stakeholders. However, it was the smaller utilities that stood to benefit the most. This is largely due to their limited funding ability, inability to access traditional financial markets at scale, limited human resource capacity to plan and implement projects, and limited

research and analysis capacity. We found a number of utilities who, despite the best intentions and efforts, were unable to secure a partnership agreement with the USFS, let alone enter into a cooperative agreement or manage a project on their own. The service provided by the FRB to alleviate this strain was of critical import. Furthermore, these utilities had limited engagement with the financial markets, meaning that deal structuring and fund raising would be problematic to tackle without the help of the FRB. This, of course, presented a double-edged sword for while these smaller utilities had the most the gain, they proved to also be the least equipped so serve as our anchor tenant.

Finding suitable land management opportunities also presented a significant challenge. Our lessons learned section highlights the need for an anchor tenant (large landowner, public or private). Despite the lack of planned actions on National Forest System land to serve as that anchor tenant, the team attempted to facilitate a project with local land managers and private landowners serving in that anchor tenancy role. While enthusiasm and engagement of those private land managers was high, it was challenging to acquire the scale of commitment to meet the needs of utilities or investors, particularly without those utilities willing to commit to investing that would have given managers the ability to attempt to grow the project. Just as utilities need ample land management activities to protect their infrastructure and source water, investors require a sizeable investment to warrant their time in the due diligence process. While the team was able to develop a project that would require ~$1,000,000 in funding, this was simply too small for investors and did not offer enough risk reduction to incentivize utility payment. In fact, the FRB pilot project in the Tahoe National Forest, which raised $4,000,000 from private investors was on the smaller end of acceptable projects, requiring concessions from investors on their minimum investment size for structured finance or infrastructure investment opportunities.

Despite the promise that planning aggregation could hold, the implementation capacity constraints on this landscape (and across much of the West) were widely touted by almost all stakeholders. As the joke goes, a restoration crew in Colorado is “a guy, a dog, and pick-up truck”, but a big crew has two dogs. While there is truth behind this joke, there are still pockets of implementation capacity that have been supported or prioritized by local communities. Unfortunately, this is not a problem that financing can solve in a vacuum – in fact, bringing more financial resources to a strained system could actually enflame the issue by further straining capacity, causing restoration costs to skyrocket, and limiting or interrupting currently planned projects.

Lastly, the challenge of aggregating private landowners remains significant. Both contract transaction costs and project implementation costs must be minimized. The former impacts investor return and the latter impacts per acre treatment cost and therefore the scale of a project that can entice beneficiaries to invest. Going forward, FRB development teams will benefit from working more closely with local stakeholders earlier in the process. In some cases across the West, with limited private landowner acres available to treat in any given watershed, the FRB is unlikely to meet the size requirements from utilities and investors without including the cross-boundary opportunities provided by federal or state anchor tenants.

The development team believes that opportunities to apply the Forest Resilience Bond financing mechanism abound across the Western U.S. particularly on large land ownerships. Critical factors in determining the next Forest Resilience Bond private land pilot project will include an assessment of state government funding, level of establishment of local forest collaboratives, network of land owners and managers through RCDs, land trusts, and other similar entities, and willingness to participate by other stakeholders such as utilities, local governments, and private companies.

One state that looks particularly promising is California. While there is limited state-owned land, there is an enormous portion of the state that is categorized as State Responsibility Areas, in which CAL FIRE is responsible for fire suppression. What began under the leadership of Governor Jerry Brown has continued into the new administration of Governor Gavin Newsom with the commitment to spending the state's cap and trade dollars through the newly branded California Climate Investment Program. The state's support for healthy forests has increased 10-fold in just three short years with over $200,000,000 available through competitive and non-competitive grant programs. Similar to the NRCS EQIP program, California Forest Improvement Program provides reimbursement up to 90% of project cost for small private landowners. These reimbursements highlight the need for creative financing as many landowners do not have the initial capital outlay required to engage in these projects. And yet, we are aware that many of the same challenges we encountered in Colorado, from forester and implementation capacity to a highly fragmented landscape, are present in California as well.

While utility awareness might be highest in Colorado, California utilities have been forced to deal with the ever-present reality of fire as the state has seen two of its worst fire seasons in recorded history in 2017 and 2018. This new willingness to support this work is a welcomed change and is following closely in the footsteps of Colorado, which saw some of the most important and earliest partnership related to watershed investment programs designed to reduce the risk of catastrophic wildfire. The size of the utility is of equal importance; it is unlikely that Denver Water needs to the services provided by the Forest Resilience Bond, but it is clear that most of their local colleagues that are smaller in size would benefit greatly.

California is far from the only state where an FRB might be valuable financing tool. The development team is committed to bringing this work to Oregon and Washington as well, which invest significantly less than California, but the state spending is trending in the right direction with new commitments in WA state recently announced. Furthermore, utilities understand the risk of wildfire and already support the local restoration economy, consisting of contractors, small and large diameter mills, and value-added wood products and bio energy facilities, in a way that is much more developed than what can be found in California and Colorado. In short, there may be less money, but more capacity, which is an ideal application of financing mechanism such as the FRB.

Appendix Items

1) **AFF Landowner Survey Results**
2) **Selection of Utility Survey Questions**
3) **Investment Readiness Methodology**
4) **Basic Economic Assessment Framework**

Appendix 1 – AFF Landowner Survey Results

Read Survey Results Online Here

Appendix 2 - Selection of Utility Survey Questions

Selection of Survey Questions:

- What watershed-related risks is your utility most concerned about?
- Which watersheds or areas in your watershed(s) are of most concern?
- Has your utility or have your partners prioritized acres within your watershed(s) for source water protection (SWP) interventions?
- Are any of your SWP efforts or initiatives currently focused on private, federal, or state lands?
- Is your utility participating in any partnerships/consortiums for source water protection or fire management? If so, which partners are you working with?
- Does your utility have a dedicated budget for source water protection?
- What is the current source of funding for source water protection at your utility?
- Are you currently exploring or interested in exploring additional financing mechanisms to fund source water protection?
- How do you measure or estimate success for your ongoing or planned SWP projects?
- Are you able to quantify or estimate the economic value from these projects?
- Does your utility have any major infrastructure investments planned over the short or medium term?
- What additional information would be most useful to you in learning more about the Forest Resilience Bond?

Appendix 3 - Investment Readiness Methodology

The Readiness Assessment builds upon a three-year comparative case study analysis developed by WRI and Colorado State University of the common approaches and underlying enabling conditions that led to the establishment and growth of 13 source water protection investment programs across the United States (Ozment *et al.* 2016). From this study, WRI developed a diagnostic Readiness Assessment Tool that distills a wealth of information across 10 key parameters of importance at different stages of watershed investment program development (see Table 1 below). This information is useful for evaluating program strengths and gaps to prioritize next steps for consortiums looking to increase their engagement and investment in source water projection. Contacted stakeholders included: major landowners and land managers, water utilities, water users, and watershed-based conservation groups.

Table 1Key Parameters

Phase of Program Development	**Key Parameters**
Phase I: Building Momentum Identifying a clear need and purpose for a watershed investment program; securing commitment from key stakeholders.	1. Biophysical Risks and Opportunities 2. Partnerships 3. Vision of Success 4. Champions and Advocates
Phase II: Designing the Program Assessing the scientific and economic underpinnings of the program; creating a strategy to achieve program goals	5. Watershed Investment Plan 6. Business Case 7. Financing and Investors
Phase III: Implementing the Action Plan Actively and adaptively managing the program to make investments; tracking the results of those investments	8. Landowner Engagement 9. Program Administration 10. Monitoring and Evaluation

Readiness Assessment Results

Table 2 summarizes the results of applying the Readiness Assessment Tool in the Clear Creek/ Standley Lake watershed.

Table 2. Lessons from Each Phase of Watershed Investment Program Development

Phase of Program Development	**Lessons Learned**	**Clear Creek / Standley Lake Status**
Phase I: Building Momentum Identifying a clear need and purpose for a watershed investment program; securing commitment	Identify risks (e.g., wildfire, drought, etc.) and seize opportunities to rally support	• Well understood and agreed upon watershed risks, with emphasis on fire risk • Stakeholders prioritize risks slightly differently based on their water source(s), location in the basin, and water / land use priorities. • May need to increase efforts to communicate fire risk to other stakeholders

Phase of Program Development	Lessons Learned	Clear Creek / Standley Lake Status
from key stakeholders	Build partnerships to fill essential roles and responsibilities	• Long-standing partnerships exist and Project Partners have mutual respect for one another • Some work may be necessary to build relationships between upstream and downstream stakeholders as well as private landowners • Roles and responsibilities have yet to be designated
	Articulate a clear vision of success	• Agreement on a future vision of healthy forests and improved water quality • Vision statement needs development
	Cultivate champions and advocates to build program support (e.g., from water utilities, local government, NGOs, landowners, etc.)	• Strong leaders, but lack of an existing overarching entity with the capacity to take ownership over a new watershed program • May need to identify a champion from the upper watershed and or private landowners, due to lack of strong prior relationships • Many regional advocates for watershed investment may lead to competition for investors and funding, particularly due to TNC's work in the Front Range
Phase II: Designing the Program Assessing the scientific and economic underpinnings of the program; creating a strategy to achieve program goals	Develop a scientifically informed watershed investment plan	• Substantial existing research from which to build a preliminary investment plan • More detailed and updated research is necessary to fully develop an investment plan
	Evaluate the business case for investment	• No existing economic studies of costs and benefits of forest restoration • Need for a quantitative, or at least qualitative, evaluation of the business case for investment
	Identify investors (e.g., water utilities, companies, foundations, etc.) and financing mechanisms for initial and long-term funding	• Promising funding sources identified, but not fully vested or secured
Phase III: Implementing the Action Plan Actively and adaptively managing the program to make investments; tracking	Engage landowners and public managers to conserve, restore, and sustainably manage natural infrastructure	• Preliminary engagement with public managers, but relationship not solidified • May want to consider partnering with a land trust, extension agency, state agencies, etc. to engage private landowners
	Define roles and plans for program administration	• Need to identify program administration roles, identify funds for administration, and develop a decision-making strategy

Phase of Program Development	Lessons Learned	Clear Creek / Standley Lake Status
the results of those investments		• Blue Forest Conservation, or an affiliate, could administer the program if Forest Resilience Bond effort proceed • Potential capacity challenges
	Monitor and evaluate performance (e.g., acres of forestland protected, acres treated for fire risk reduction, or acres restored after wildfire, water quality, sediment transport, etc.)	• Substantial baseline data available for Clear Creek • Other Colorado watershed investment programs provide a blueprint for developing a monitoring plan

Source: (Ozment *et al.* 2016)

Appendix 4 - Basic Economic Assessment Framework

At its heart, economic assessment of forest health treatments is a cost-benefit analysis. Total costs and benefits are tallied for one or more treatment scenarios and compared to a no-treatment scenario. Depending on how the assessment is scoped, it can serve as a return on investment (ROI) analysis for a given beneficiary, or address a wider range of public and private economic costs and benefits. However, the central object of the analysis is fire. Even where fire risk is well-understood, fire is unpredictable. Therefore, the economic assessment must operate in an "expected value" framework, in which costs and benefits that are contingent on the occurrence of fire are discounted to reflect the probability that such a fire occurs in the studied scenarios.

The essential ingredients for any economic assessment of forest health treatment include the following:

1. **Baseline fire risk**. This is the annual probability that a fire occurs in the study area without treatment.
2. **Post-treatment fire risk**. Treatments will lower risk, but are unlikely to reduce the probability of fire to zero. The risk reduction benefits of treatment may also dissipate over time without subsequent interventions.
3. **Value of fire impacts should fire occur**. Key cost categories include:
    a. Fire suppression. The cost of suppressing a large fire can vary considerably based on a range of factors, including weather, fuel conditions, topography, and ease of access to the fire area, as well as resource allocation decisions - such as whether firefighters must vigorously protect life and property in the wildland-urban interface or can allow a fire to burn in more remote areas. A sampling of suppression cost estimates from prior western fires (Western Forestry Leadership Coalition) indicate no clear trend in terms of cost per acre burned, with suppression costs ranging from $100/acre (Rodeo-Chedeski fire) to over $700/acre (Cerro Grande).
    b. Fire damage to property. Fire can destroy homes and commercial property—including timber—and damage a wide range of infrastructure like powerlines and powerhouses, roads, and recreation facilities. Valuing expected property damage from fire requires identifying major assets at risk of fire, valuing those assets, and making informed assumptions about the portion of that value that would be lost in a large fire.
    c. Several water-related impacts like degraded water quality and associated treatment costs, reservoir sedimentation, and flooding and debris flows. Fire significantly reduces the amount of rainfall required to trigger debris flows. Post-fire debris flows can occur several times in a year, and this increased sensitivity typically persists for two years (Western Forestry Leadership Coalition). Debris flows can damage infrastructure, clog intakes, and cause unplanned outages at hydropower facilities. Together with increased sedimentation, dragging and dredging reservoirs may be required. Watershed rehabilitation is typically needed in the aftermath of a large fire to prevent the worst runoff effects and can be costly itself.
    d. Greenhouse gas emissions. Large fires can release significant volumes of greenhouse gases. Stand-replacing fires can also diminish future carbon sequestration in the study area.
    e. Degraded air quality. Wildfire smoke exposure is associated with respiratory morbidity and even mortality. These health impacts and their economic costs can be significant but also difficult to evaluate ex ante for any given fire.

f. Lost economic activity in the affected area. Tourism and other economic activity can decline due to the loss of aesthetic and recreational resources to fire.

The cost categories included in the scope of assessment should be tailored to the purpose and audience of the assessment.

4. **Value of "secondary effects" of treatment**. Although the bulk of the assessment hinges on changes in the probability of fire and its impacts, treatment can have other costs and benefits. For example, treatments may be designed to restore habitat, or to produce biomass for economically valuable applications like energy or building materials. In some ecological areas, treatment may also increase streamflow to downstream users. Treatment may also cause near-term loss of forest carbon stocks, increased sedimentation, or other effects.
5. **Costs of treatment**. The financial cost of implementing the treatment - including both upfront costs and any maintenance costs over time.

At the most basic level, the expected benefits of a treatment in any given year can be estimated as:

$$Expected\ Benefits_n = p(F)_{bn} \times c(F)_{bn} - p(F)_{tn} \times c(F)_{tn}$$

where $p(F)_{bn}$ is the probability of fire in the baseline scenario in year *n*, $c(F)_{bn}$ is the cost of fire should it occur in the baseline scenario in year *n*, $p(F)_{tn}$ is the probability of fire in the treatment scenario in year *n*, and $c(F)_t$ is the cost of fire should it occur in the treatment scenario in year *n*. Treatment may reduce the probability of fire as well as the cost of fire should a fire occur (by reducing the size or severity of a fire and/or needed suppression efforts).

These benefits can be summed across the period of analysis (1-*n)* and discounted to the present. Baseline and post-treatment fire risk can be held constant across years or adjusted to reflect expected changes in fire risk over time (e.g., increasing fire risk without treatment; declining effectiveness of treatment as cleared vegetation regrows). The present value can then be added to the estimated value of any secondary effects of treatment. Finally, subtracting present value costs from present value total expected benefits then yields an expected net present value of treatment.

Each of the ingredients described above presents its own challenges for scoping an assessment, data collection, and methodology. We focus here on estimating baseline and post-treatment fire risk. Fire is inevitable. Fire-prone landscapes are supposed to burn. The real question is the probability of a large-scale catastrophic fire. These are the fires that drive the greatest impacts for water, carbon, property, and human life. The Forest Service uses the term "large fire" to refer broadly to fires that escape initial attack suppression efforts and exceed 300 acres.

Capabilities for modeling fire risk in baseline and alternative scenarios are continually improving. The Forest Service developed the Large Fire Simulator (FSim) to characterize the risk of ignitions that escape initial attack and lead to large fires. FSim runs tens of thousands of simulations of the fire season with different weather sequences drawing from local weather stations, monthly distributions of wind speed and direction, spatial data on fuel and topography, and modeled probability of containment based on local factors. FSim produces polygons that reflect the perimeters of simulated fires, along with the ignition points for those simulated fires.

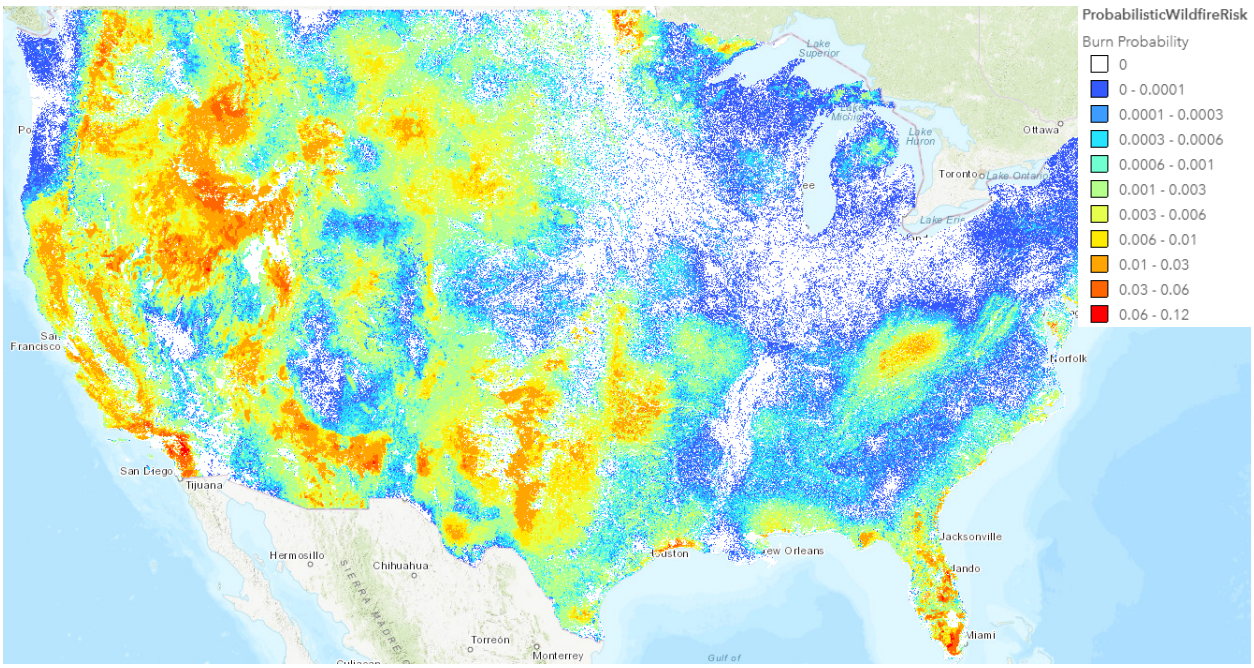
While FSim enables sophisticated characterization of fire risk, dedicated FSim modeling is likely impractical for most localized economic assessments due to time and resource requirements. Here we outline two basic alternative approaches that are lower cost and more accessible: using published estimates of annual burn probability, and deeper spatial analysis of simulated fires. We also reviewed the much-anticipated USFS Wildland Fire Investment Planning System (WFIPS), but found the functionalities in the current alpha version ill-suited for this application.[1]

Annual Burn Probability – Every few years as underlying fuels data are updated, the Forest Service runs these data through FSim for the continental United States and publishes annual burn probability in the form of 270-meter resolution raster data, which can viewed online. Annual burn probability is derived by dividing the total number of times a pixel burned in an FSim simulated fire by the total number of simulations.

Annual burn probability data are easily accessible, national in coverage, and provide a quick but general characterization of annual burn probability given the likelihood of success of "initial attack" suppression efforts. However, these data do not provide information about the potential fire risk reduction value of treatment. This depends on the location of treatment relative fire travel paths, and the effect of treatment on fire spread rate under weather conditions associated with large fires. Without dedicated fire behavior modeling of specific treatments, simplifying assumptions about the efficacy of forest health treatments must be made to estimate post-treatment fire risk and impacts.

The Forest Service prepares a fire and fuels report for prospective treatments in national forests that evaluates the effectiveness of treatments in reducing fire spread rate relative to likely effectiveness of control efforts. Fire and fuels reports can be used to approximate post-treatment large fire probability where an ignition occurs within the treatment area . For example, if the rate of spread post-treatment on all acres is estimated to fall below the rate that is containable through control efforts, post-treatment fire risk (probability of large fire) can be assumed to fall to zero. Similarly, if the rate of spread on a percentage of acres is expected to remain above likely containment post-treatment, the risk reduction can be discounted accordingly.

[1] The WFIPS interface allows a user to select a county or a forest district for treatment. The user cannot prescribe a custom treatment area (i.e., draw a treatment polygon). Consequently, WFIPS outputs may be generally representative of treatment effects in the specified area but do not reflect a specific, proposed treatment scenario. Additionally, the system currently cannot be applied to private lands. In areas with federal and private lands in close proximity, outputs on adjacent federal lands may be a reasonable indicator of effects on private lands. Finally,



Annual burn probability across the conterminous US produced by the USFS large wildfire simulator (Fsim).

However, in the treatment scenario, risk from large fires that ignite outside of the treatment area may persist. The annual burn probability metric masks the ignition points of large fires simulated on any given pixel. As a result, relying on this metric alone to derive post-treatment burn probability likely results in an overestimation of risk reduction from treatment. Additionally, for treatments in private forestlands, treatment effectiveness information will need to be generated or obtained from Forest Service studies in nearby areas with similar ecological characteristics. Otherwise, simplifying assumptions will need to be made.

Deeper Spatial Analysis of Simulated Fires – More granular insight into post-treatment probability of large fires can be generated by working directly with FSim data from prior simulations by the Forest Service - the polygons representing the boundaries of fires in a landscape in simulated fire seasons. These polygons are not directly published but can be obtained from the Forest Service's Fire Lab. Working directly with the FSim polygons allows the analyst to account for the location of the ignition points for simulated large fires. The procedure described above can be applied exclusively to the portion of simulated large fires that ignite within the treatment area - *i.e.*, to those that would be avoided as a result of treatment. In the treatment scenario, risk from large fires that ignite outside of the treatment area would persist and could be accounted for. Note that treatments may reduce the impacts from these fires due to lower burn severity within the treatment area; however, additional site-specific modeling would be required to capture these effects.