



Reducing Fire Risk and Sediment Yields in the Ashland Municipal Watershed¹
A Preliminary Feasibility-level Analysis of Green Infrastructure Options

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¹ The opinions expressed in this report are those of CSE and not necessarily reflective of those held by Geos Institute and Wild Earth Guardians.

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1.0 Overview and key findings

An emerging hypothesis in an increasing number of environmental management settings is that investments in green infrastructure solutions provide economically superior ways to achieve environmental quality outcomes or reduce disaster risk than conventional investments in technology-based or “gray” infrastructure. For example, the Center for Neighborhood Technology (2011) asserts “[t]he research shows that green infrastructure measures are as effective as conventional approaches in relieving flooding, and can be installed more cheaply and quickly.” Moreover, green infrastructure is considered a lasting source of ecosystem service benefits for communities that appreciates, rather than depreciates, over time.

Center for Sustainable Economy (CSE) and other partners have pioneered an analytical technique for quantifying the economic and financial tradeoffs between green and gray infrastructure in three decision-making contexts: (1) disaster risk reduction; (2) regulatory compliance; and (3) infrastructure investment (Talberth et al. 2013a). This technique – green vs. gray analysis (GGA) – extends conventional public infrastructure analysis models used to evaluate the cost effectiveness of technological solutions like new reservoirs by factoring the unique role wetlands, forests, riparian zones, and other green infrastructure elements play in enhancing water quality and flow or achieving other environmental objectives. GGA is used to determine whether investing in these green infrastructure options is a more cost effective approach (or similar in cost) than the traditional, technological approaches (which we refer to as “gray infrastructure” throughout this report).

GGA is completed in two distinct phases. In Phase I, a preliminary analysis is conducted based on existing, publicly available information. The Phase I analysis provides a rough order of magnitude⁴ estimate of costs for both green and gray options and identifies key assumptions that warrant further investigation, modeling, or research to better evaluate the green infrastructure approach. An example of a key assumption tested in Phase I is the assumption that a particular green infrastructure investment, say constructed wetlands, will result in a particular level of nutrient reduction in a nearby river. In Phase II, more detailed modeling is used to estimate the actual level of nutrient reduction associated with a particular investment. This more accurate estimate is important to the economic comparison between the gray and green options.

To this end, CSE has completed a Phase I analysis of investments in green infrastructure solutions to water quality concerns in Ashland Creek (watershed area of 18,790 acres), the largest source of surface water that the City of Ashland relies on for municipal water. Reeder Reservoir on Ashland Creek stores water (capacity of 280 million gallons) until it is withdrawn

⁴ Rough order of magnitude (ROM) estimates are standard for preliminary feasibility analysis since many specific cost factors remain unknown. An estimate range of \$10 - \$100 per acre for a green infrastructure option is an example. In Phase I, the range can be much narrower if existing information is relatively reliable.

and treated at the Ashland Public Works Water Treatment Plant (Corollo 2012). Over 98% of the lands in the watershed upstream of Reeder Reservoir are managed by the U.S. Forest Service. The water treatment plant treats approximately 3.4 million gallons of water per day (mgd) on average for Ashland Public Work Department's 19,770 customers. Peak usage is during the late summer when daily demand can reach about 7.0 mgd. It is worth noting that Ashland Public Works Department has an alternative water source for emergencies that affect the principle water supply's ability to meet demand (Corollo 2012).

The principle water quality concern for The City of Ashland's water supply is sediment. The segment of Ashland Creek that encompasses Reeder Reservoir is listed on the Oregon Department of Environmental Quality's list of water quality limited streams for this contaminant. A total maximum daily load (TMDL) has been established for the City of Ashland and the U.S. Forest Service with a goal of limiting sediment loading to 3.62 cubic yards of sediment per day (1,322 cubic yards of sediment per year). The effects of soil erosion following fires that burn at higher severities, sediment routing and mass wasting from improperly designed or seldom maintained roads, and erosion at undersized road-stream crossings on sediment delivery to Reeder Reservoir potentially limit the City of Ashland and the U.S. Forest Service from complying with the TMDL at Reeder Reservoir.

Aside from complying with the water quality regulation, large amounts of sediment that settle in Reeder Reservoir dramatically decrease the reservoir's water storage capacity (reducing the city's supply of municipal water) and can overwhelm the water treatment plant's filtration capacity. Notwithstanding the effects of a wildfire that includes high proportions burning at higher severities⁵ and sediment yield, the Ashland Creek Watershed yields large amounts of sediment during intense rainfall events. Previous high flow events during rain on snow storm events (and the ensuing large floods) have filled Reeder Reservoir with sediment and required switching to alternative water sources while the reservoir was dredged to restore storage capacity and to await suspended sediment levels low enough to allow the water treatment plant to operate. Following a large flood event in 1964, 230,000 cubic yards of sediment were removed from Reeder Reservoir (though not all of that sediment accumulated during the flood). The 1974 flood delivered approximately 130,000 cubic yards and the flood of 1996/1997 delivered between 40,000 and 50,000 cubic yards.

In the wake of widespread fires in 2012 and multiple large fires in southern Oregon in 2013, concern from communities adjacent to forested areas increased over the potential costs of forest fires with large proportions of higher severity burn areas. Of particular concern are the effects of such fires on drinking water supplies. This concern has spurred interest in investigating the potential economic benefits of green infrastructure solutions that could reduce fire risk, restore watershed conditions to limit the amount of sediment that mobilizes during high intensity storms, and obviate the need for expensive "gray" water treatment technologies, dredging to remove sediment from the reservoir, and other fire-related costs. Ashland is not alone in this respect. Nationwide, it has been estimated that at least 3,400 cities and towns in 43 states serve roughly 66 million people with drinking water from rivers and streams that start in national forests. Of

⁵ As with most forests in the West, the forests of the Ashland Watershed historically have experienced a mixed severity pattern of burn. Even in the most intense fires, there are many acres that do not burn at all or at low or moderate severities.

those, 70 million acres are considered prone to high proportions of moderate and high severity blazes (Arrandale 2012).

This report is a preliminary economic assessment of potential benefits of investing in an ambitious package of green infrastructure actions including thinning, prescribed fire, and road reclamation and road mitigation. This Phase I assessment is based on publicly available information and provides fairly wide ranges for key parameters, such as activity costs and the probability of fire occurring in the Ashland Creek Watershed. The goal of this preliminary analysis is to develop rough estimates of the costs of green infrastructure approaches to evaluate if the potential benefits are great enough to warrant further investigation in a more precise Phase II study. Such an analysis would use detailed models to estimate the benefits of various green infrastructure treatments on sediment yield and incorporate more precise cost estimates based on current, local economic data.

To preliminarily model the benefits, we developed two scenarios that could unfold over the next twenty years. The first scenario is the business as usual (BAU) or “gray” scenario where no green infrastructure investments take place to decrease background sedimentation from roads and areas that are projected to burn at higher severities. Under this scenario, the watershed suffers a widespread fire with uncharacteristically high proportions of the forest burning at higher severity levels. Intense rain events would result in severe runoff with high sediment loads, particularly if those events followed a large-scale, high intensity fire. Under this scenario, Ashland Public Works and other public agencies would bear significant costs associated with fire suppression, damage to Reeder Reservoir, the need for alternate water supplies and post-fire rehabilitation. This scenario would also generate non-market costs such as the loss in passive use values⁶ for inventoried roadless areas, among others.

The second scenario is a green infrastructure scenario wherein substantial investments are made in ecologically-based thinning, prescribed fire, road reclamation, and road and mitigation. These investments can reduce the risk and intensity of fires and of road failures, thus reducing impacts associated with wildfire to water quality and water storage. Decreasing these impacts also decreases the cost of providing drinking water. The scenario includes all of the activities contemplated as part of the Ashland Forest Resiliency Stewardship Project (AFR)⁷ above Reeder Reservoir as well as additional activities to reduce post-fire and post-storm water quality issues. While these green infrastructure activities will not eliminate the risk of fire, if successful, they will reduce the proportion of areas that burn at higher severities; suppression costs during the fire, impacts to water quality and water storage and the costs associated with these impacts at Reeder Reservoir, and post-fire or post-storm restoration costs. They will also reduce background sedimentation from roads that now contribute to water quality problems during peak flow events.

⁶ Passive use values represent people’s willingness to pay for protection of particular environmental resources. Passive use values are established through scientific survey methods.

⁷ The Ashland Forest Resiliency Stewardship Project is a ten-year stewardship project designed to reduce the risk of severe wildfire in the watershed and to protect water quality, older forests, wildlife, people, property and quality of life. A project overview and implementation updates are available online at: <http://ashland.or.us/Page.asp?NavID=12907>.

We modeled the difference in economic costs under both scenarios over a twenty-year period using the GGA methodology first developed and applied by Talberth et al. (2013a). The results provide a compelling case for further investigation of these green infrastructure options. Our key findings include:

- With no green infrastructure interventions, a fire with a pattern of severity that matches that of recent fires in the region that affects all of the lands above Reeder Reservoir would likely generate over \$36 million in costs in the form of fire suppression, restoration of burned lands, water storage reservoir dredging, alternate water supply, lost values associated with inventoried roadless lands, and carbon emissions.
- Investments in thinning, prescribed fire, road reclamation, and road mitigation would reduce the intensity of fires that occur and reduce sediment from roads, road stream crossings, and surface erosion in forest areas immediately after having experienced a fire that includes large proportions of high severity. The road work would also reduce sediment delivery during large floods caused by intense rain storms and rain on snow events. Over a 20-year period, investing in an ambitious portfolio of these green infrastructure options could generate up to \$20 million in savings after taking costs of implementation into account.
- The economic feasibility of investing in the package of green infrastructure options we analyzed is highly sensitive to assumptions about the probability of a watershed-wide fire occurring. If the probability of such a fire over a 20-year period is less than about 30%, then the amount of thinning would need to be scaled back, but with similar benefits, to be economically justifiable.
- The magnitude of potential cost savings associated with green infrastructure options modeled in this analysis warrants a more detailed investigation in Phase II using site-specific information and more detailed modeling to better capture the benefits of thinning, road reclamation, and road mitigation. The Phase II analysis would also be based on more specific green infrastructure prescriptions (including the extent of each action), accounting of carbon costs and benefits for the green infrastructure investments, and more accurate cost estimates.

The remainder of this report is structured as follows. In section 2, we provide details of the BAU scenario and its likely costs. In section 3, we provide details of the green infrastructure scenario and make a series of assumptions on how these investments could reduce fire related costs. In section 4, we complete the preliminary GGA modeling and report results for three cases: a baseline, a more optimistic case for green infrastructure, and a less optimistic case for green infrastructure. We offer concluding thoughts and discuss important considerations for a more detailed GGA analysis in section 5.0.

2.0 The Business as Usual or “Gray” Scenario – High severity fire in the Ashland Creek Watershed and status quo road network

Under the BAU or “gray” scenario, we assume that a large-scale fire with large proportions burning at high severity would occur in Ashland Creek Watershed above Reeder Reservoir and affect the entire watershed.⁸ We further assume that no additional fuels treatment or forest restoration activities would be implemented above and beyond what have been accomplished through the end of FY 2013. We also assume that there will be no additional investments in road reclamation or mitigation.

Although predicting the probability of large wildfire events over a given time frame is a complex modeling task, for the purposes of this analysis it is not necessary to determine that probability with any certainty. It is a modeling variable with no established value, however, more refined work in a final GGA will need to hone in on the expected probability of such a fire to assess the avoided costs for different fire forecast scenarios. For this preliminary analysis, we assume that a BAU fire will occur sometime within the next 20 years with certainty (i.e., P = 1.0).

In terms of impacts, we first assume that the BAU fire would match the pattern of severities noted in recent fires in the Klamath-Siskiyou region. As a reference, we used three detailed assessments for the Biscuit, Quartz, and Big Bar Complex fires in northern California and southern Oregon (Azuma et al. 2004; Alexander et al. 2006). Across these three fires, the average burn intensities were as follows: unburned to low severities (52%), moderate severity (28%) and high severity (20%). This pattern falls within the distribution of fire severities assumed by the Forest Service in its analysis of the Ashland Forest Resiliency project (AFR), which assumes that “40 to 50 percent of the burn area would be predicted to have moderate to high severity fire, under a large-scale wildland fire scenario” (SMRD 2008a).⁹ Table 1 displays the assumed distribution of acreages across fire severity classes for the analysis area.

Table 1:
BAU Fire Event Scenario for the Ashland Creek Watershed Above Reeder Reservoir
(P = 1.0 over 20 years)¹⁰

Burn severity	Burned acreage
Unburned to low severity	6,602
Moderate severity	3,556
High severity	2,540
<i>Total:</i>	12,698

⁸ The Ashland Creek HUC-6 watershed encompasses 18,790 acres. Of these, 12,698 acres are located upstream of Reeder Reservoir. Reeder Reservoir stores water and serves as the point of diversion for most of the City of Ashland’s drinking water supply (ODEQ 2007).

⁹ The analysis of burn severity with and without the AFR is reported in the FEIS at III-48.

¹⁰ In green-gray analysis, a 20 year time frame is the standard because many capital investments like new water treatment facilities are designed for this general life and their funding is often spread out over this period. The time frame can be varied, however, as needed.

The consequences of a burn with this pattern of severity would be wide ranging, and generate substantial short and longer-term costs for public agencies and user groups. First, substantial fire suppression costs would be incurred by both the Forest Service and other state and federal agencies during the fire. Suppression costs in the region have ranged from \$300 to \$1,200 per acre in recent fires (Azuma 2004; USFS 2012). After a fire, agencies would rehabilitate the area over a 1-3 year time period. Rehabilitation activities would include soil stabilization, mulching, and reseeded. These costs are often 50-60% of suppression costs.

Before such rehabilitation activities could be completed, and certainly during the wet season following the fire, debris, sediment, and ash delivery could spike during severe storm events. As the Forest Service notes, the greatest indirect effect a BAU fire “would occur when large landscape-scale wildland fires severely burn the forest and soils, and cause debris flow landslides that transport sediment to area streams and Reeder Reservoir. The increased volume of sediment would not only limit the amount of water storage capacity available for the City of Ashland’s municipal water supply, but may also adversely affect water quality” (SMRD 2008a).¹¹

The potential impacts and costs of such a fire in the Ashland municipal watershed on the city’s water supply were examined in detail by a team from Southern Oregon University (Bergbauer et al. 2011). Their analysis assumed that a fire with high proportions of moderate and high severities would produce at least 130,000 cubic yards of sediment into Reeder Reservoir, an amount that was recorded during the great floods of 1974. In all likelihood, they suggest, there would be multiple sedimentation spikes that would occur and so this estimate of 130,000 cubic yards of sediment is likely low.

Assuming there are two spikes, the second with about half the sediment load (65,000 cubic yards) and using a low bound cost of \$100 per cubic yard to remove and dispose of these sediments suggests a minimum post-fire cost of \$19.5 million. They also estimated costs to Ashland Public Works for obtaining alternate water sources from the Talent Irrigation District (TID) until water quality conditions in Reeder improved enough to resume using it as a source of municipal water. The overall costs of treating 2.14 million gallons per day of TID derived water were expected to double the baseline treatment costs of \$160 per million gallons.

In addition to water-related costs, passive use values associated with the portions of the McDonald Peak inventoried roadless area (IRA) within the Ashland Creek Watershed would be lost on areas affected by higher severity burns. Roughly 7,380 acres of this IRA are found within the watershed and a burn pattern identical to our overall burn pattern assumption would result in a loss of passive use values on roughly 3,500 acres.

An assessment by Loomis and Richardson (2000) calculated an annual per acre passive use value of \$6.72 for the western U.S., exclusive of Alaska. This translates into \$9.11 per acre in present dollars. While eventually passive use values would recover, it may take several decades until the IRA supports its natural endowment of wildlife, water resources, and recreational opportunities.

As with all wildfires, there would be a spike in emissions of stored carbon dioxide as vegetation burns. For wildfire, it has been estimated that 41.0 megagrams of carbon per hectare (mg C/ha)

¹¹ FEIS at III-68.

are emitted in the lower 48 (EPA 2011). Using current federal guidance on the social costs of carbon (\$36/metric ton CO₂-equivalent) this translates into a damage estimate \$1,476 per hectare, or roughly \$600 per acre.¹²

While the magnitude of these costs would be difficult to predict, all are likely to apply at some level in a fire with a severity pattern that matches recent wildfires in the region (what is expected under the BAU scenario). Table 2 summarizes the BAU scenario in terms of the extent fire severities, cost elements, and duration of costs using mid-point values for the cost ranges discussed above. For short-duration costs, costs are expressed in real time nominal units. For passive use values, costs represent the present value of the cost stream over 50 years and for carbon emissions the social costs of carbon per ton (\$36) is a present value cost over 100 years.

Table 2 summarizes the total costs for a BAU fire in the Ashland Creek Watershed, would be approximately \$36 million for the cost categories included in our analysis.

Table 2:
Midpoint Cost Estimates for BAU Fire Event

Cost element	Units	Impact/ extent	Duration	Cost
Fire suppression	acres	12,698	event	\$9,523,500
Burned area rehabilitation	acres	6,096	3 years	\$2,742,768
Costs of sediment removal	y ³	195,000	1 year	\$19,500,000
Alternate water sources	gpd	2.14 million	90 days	\$30,816
Lost passive use values	acres	-3,542 roadless acres	50 years	\$830,332
Carbon emissions	tons	101,584 mtons released	event	\$3,657,024
<i>Total:</i>				\$36,284,440

3.0 Green Infrastructure Scenario – Investments to reduce fire risk and impacts to water quality and storage

In this section, we describe a green infrastructure investment scenario that is designed to reduce the risk of large-scale, higher severity fires in the Ashland Creek Watershed above Reeder Reservoir and subsequent economic costs of addressing water quality and storage issues from high sediment loads. Extensive stakeholder-driven planning processes have been completed over the past decade to develop a range of community-supported interventions throughout the watershed. These include the City Forest Lands Restoration Project (AFLC 2003), the Community Wildfire Protection Plan (APW 2004) and the Ashland Forest Resiliency Stewardship Project (AFR).

Key components of these plans include prescriptions designed to thin and reduce fuel loadings on forest stands that are deemed as being unnaturally dense due to the combined effects of fire suppression, grazing, and logging. Common elements also include aggressive use of prescribed fire, prescribed natural fire (i.e. letting fires with a pattern of lower intensities burn), and burning

¹² For current federal guidance on SCC, see: Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866 ,Interagency Working Group on Social Cost of Carbon, United States Government.

of slash after thinning operations. In addition to thinning and prescribed burning, the green infrastructure option we model includes a number of interventions designed to reduce the impacts that roads commonly have on sediment yield. Roads contribute to increased fire risk, exacerbate water quality impairment during the rainy season following a BAU fire event, and can contribute substantial amounts of sediment during intense rainfall or rain on snow event. Moreover, these roads chronically contribute sediment during even modest rainfall and snowmelt events by routing sediment to streams or by erosion at undersized road-stream crossings.

For purposes of this analysis, we assume that all of these activities would be completed over a 5-year period. Details of the green infrastructure option are provided below.

3.1 Thinning and follow up activities

The AFR and Community Wildfire Protection Plan (CWPP) provides a basis for preliminary estimates of the amount of thinning and follow up maintenance activities to include in this analysis. In the context of the AFR project, stakeholders have identified 7,600 acres needing various levels of treatments, including thinning. The primary goal of these treatments is “to influence fire behavior by altering available fuel, fuel arrangement, fuel moisture, and species composition” (SMRD 2008b). Of the 7,600 acres, approximately 2,090 acres had been treated by July 2013 according to the AFR project website for fuels reduction, largely outside of the project area that is the focus of this analysis, to protect adjacent private property and prevent wildfire from moving into the municipal watershed from below.¹³ Remaining treatment needs have yet to be refined by project stakeholders.¹⁴ For now, we assume that the 5,510-acre balance represents a reasonable estimate of the minimum acreage recommended for some form of treatment by the stakeholder group to achieve fire risk reduction goals. In terms of what portion of this acreage would be suitable for thinning, we can use previous AFR prescriptions as a basis.

The AFR project is being implemented in a sequence of “blocks” staged over ten years.¹⁵ Each block is located within one of four major treatment areas: (1) fuel discontinuity treatment areas; (2) strategic ridgeline treatment areas; (3) research natural area treatment areas; and (4) roadside treatment areas (SMRD 2008a). Previous block prescriptions and AFR project updates can be used as a rough approximation of the composition of future treatments above Reeder Reservoir.¹⁶ An analysis of prescriptions for Blocks 1, 2, and 3, which are available through the AFR web portal, and an analysis of the AFR work completed to date suggests that roughly 35 – 45% of the proposed treatment area would be considered for at least one form of thinning. For purposes of this analysis we adopt the midpoint (40%) for our baseline analysis. Applying this to the 5,510-

¹³ Ongoing updates on AFR implementation are available online at: <http://ashland.or.us/Page.asp?NavID=13128#Ground-based%20Thinning>.

¹⁴ At the time of this report, responses to information requests to AFR partners about treatment needs above Reeder are still pending, and so we rely on existing information as a basis. And while the FEIS for the AFR includes detailed maps of potential treatment areas, the actual acreages will not be known until layout of treatment blocks. As the Forest Service notes, “treatments represents a maximum potential and is used for analysis. Acreage of actual treatments may be reduced during implementation” (SMRD 2008a, FEIS at II-47).

¹⁵ A map of current blocks targeted for treatment through FY 2014 is available online at: <http://ashland.or.us/Page.asp?NavID=14475>.

¹⁶ See: Silvicultural prescriptions for AFR Blocks 2 and 3, Available online at: <http://ashland.or.us/Page.asp?NavID=12192>.

acre treatment area above Reeder Reservoir yields 2,204 acres of potential thinning, which we adopt as our estimate for this analysis.

3.2 Prescribed fire and pile burning

Many of the forest types located within the Ashland Creek Watershed are fire adapted. They need regularly occurring fires that clear out competing underbrush and maintain their ecological functionality. Over a century of fire suppression, grazing and logging has had consequences on forest health, affecting species composition, stand density, productivity, pathogens, water yield, and wildlife use. Encouraging wildfires to burn at a pattern of lower intensities than would be expected is a major component of the forest resiliency strategies proposed by AFR for the Ashland Creek Watershed.

In the context of the AFR and the CWPP, there are two key uses of fire: (1) prescribed fires that mimic low intensity wildfires and (2) pile burning that reduce the slash and debris created by thinning operations. Prescribed fire “involves the controlled application of fire to understory vegetation and downed woody material when fuel moisture, soil moisture, and weather and atmospheric conditions allow for the fire to be confined to a predetermined area and intensity to achieve the planned resource objectives” (AFLC 2003). The burning of piled limbs and debris left on the forest floor is needed after the thinning of small trees and brush to reduce future fire danger and improve forest health.

As with thinning, a reasonable first approximation of the acreage needed for these activities can be gleaned from AFR block prescriptions and progress reports. Using the same methodology we used for thinning, we determined that the stakeholders that developed AFR deem roughly 50 – 70% of the 5,510-acre treatment area in the Ashland Creek Watershed upstream of Reeder Reservoir suitable for prescribed fire or pile burning. The midpoint value (60%) translates into 3,306 acres for prescribed fire and pile burning, which we adopt for our analysis.

3.3 Road reclamation and mitigation

A third component of the green infrastructure scenario is a program to restore and upgrade road sections that are exacerbating the risk of landslides, debris flows, and sedimentation during severe storms and flood events. These risks will only increase during such events that occur within several years of a BAU fire. In such a situation, the road network will play a substantial role in the delivery of fine sediments into Reeder Reservoir.

Roads increase fire risk by increasing human access. As the Forest Service has noted “[i]ncreases in the level of human activities in the watershed (especially illegal or unauthorized uses) leads to an increase in fire risk associated with an increase in potential for human-caused fire ignitions” (ARD 2000). In the case of the Ashland Creek Watershed, the road network is closed to public vehicle access, so the degree to which they contribute to human-caused ignition is lower than in other forested watersheds. Roads also cause numerous problems with soil and watershed conditions. Existing roads often lack adequate drainage and do not dissipate energy at culverts. As a result, numerous gullies form and debris slides occur during peak flow events. Headcuts (continued erosion as the stream channel cuts through the sediment that had accumulated

upstream of the road crossing) have been observed at about 50-70% of culvert sites in the upper parts of the Ashland Creek Watershed (RVCOG 2001). Sediment delivery into streams comes from road surface, ditch line, cut slope, and fill slope erosion, which is routed directly into Ashland Creek and its tributaries (ODEQ 2007). For these reasons, a robust strategy for reducing risks to the City of Ashland's water supply could be enhanced by addressing these road-related problems.

There are two general strategies for reducing the impacts of roads: (1) road mitigation, and (2) road reclamation. Road mitigation involves a host of repairs, maintenance activities, storm proofing, and other mitigation activities along roads to reduce their watershed impacts. An example of these types of activities would be replacing defective or sub-standard culverts with those capable of safely passing water from large flood events without contributing to erosion above natural levels at the site. Road reclamation involves physically removing the road footprint from the landscape, including removing all culverts, restoring all stream crossings to their natural condition, recontouring the former roadbed, and planting the site.

The current AFR project does not include road reclamation or mitigation as a strategy. It is important to recognize that some portion of the existing road network is needed to facilitate AFR activities, to respond to wildfires, and to access existing City of Ashland water storage infrastructure. Roads necessary for such activities may be targets for mitigation to limit their effects on hydrology, erosion, and mass wasting while maintaining access. To develop a preliminary estimate of the scope for these interventions, we first calculated the difference between current and desired road density. There are a number of estimates for current road densities in the Ashland Creek Watershed. Using only official ("system") roads, road densities are approximately 2.1 miles per square mile for the East Fork and 1.7 miles for the West Fork (ODEQ 2007). An alternative assessment by the Rogue Valley Council of Governments found that "[r]oad density varies directly with elevation in the Mt. Ashland watershed. Below 3,500 feet elevation, road density is 7.35 miles/square mile, as compared to 2.27 miles/square mile above 3,500 feet." This figure, particularly below 3,500 feet in elevation, likely includes portions of the watershed below Reeder Reservoir, so road density is inflated due to urban uses. A third source is the 2003 Upper Bear Roads Analysis (RRSNF 2003). The analysis area included both the Ashland and Neil Creek Watersheds, and addressed density of just system roads. System road density was determined to average 1.79 miles per square mile. A fourth source from the Rouge River – Siskiyou National Forest Roads Analysis (RRSNF 2004) indicates that road densities vary considerably within the watershed, but with significant portions having a density of 3 miles per square mile or greater.

Differences among these analyses arise from the fact that some include only what the Forest Service calls "system" roads, others include roads that are unauthorized or "nonsystem". Nonsystem roads include abandoned travel ways, off-road vehicle tracks, or roads that were once under permit but not yet decommissioned (RRSNF 2004). According to Forest Service inventories, there are at least 6 miles of nonsystem roads in the Ashland Creek Watershed (RRSNF 2003).

For the purposes of this analysis, we assume the density of system and nonsystem roads is between 2.0 and 2.5 miles per square mile. This estimate may be high, but is adequate for this

initial economic analysis. However, it needs to be refined prior to conducting a more detailed Phase II analysis. The Ashland Creek Watershed upstream of Reeder Reservoir is about 20 square miles. Using these assumed road densities, we calculate between 40 and 50 miles of road in the Ashland Creek Watershed.

The Forest Service's target road densities are in the 1.5 to 2.0 miles per square mile range for municipal watersheds, riparian reserves, and late successional forest reserves. A strategy to achieve the low end of this target would include reclaiming 10 - 20 miles of roads. Projects completed since the roads analyses were conducted indicate that as many as 4 miles have already been decommissioned (i.e., ARD 2000). To be conservative we assume the need to decommission 15 miles for this analysis. This includes at least 6 miles of nonsystem roads. A more precise figure for reclamation – considering all types of roads – will be completed during Phase II.

With respect to mitigation opportunities, the total official number of road miles within the watershed is estimated to be 37.4 (ODEQ 2007). There are 31 stream crossings within the watershed, some of which may have problematic culverts that contribute to streambank instability and erosion. For example, according to ODEQ (2007), “[r]oad 2060 creates a large potential for intercepting subsurface flow along road cutbanks and routing it along ditches and through culverts to pre-existing and/or new channels.” Half the culverts failed in a 1997 storm event, over half of which now exhibit headcuts.

Road mitigation includes a wide range of activities such as replacing problem culverts, treating unstable sidecast, debris that has accumulated at culverts, converting culverts to bridges (or other approaches that restore the original stream bottom), recontouring, outsloping, resurfacing, and replanting roadsides. The benefits of these activities on water quality have been well established. For example, according to Weaver (2009) “approximately 40% of the typical forest road network on inventoried National Forest Lands in the Pacific Northwest has been found to be hydrologically connected to the streams. Upgrading roads to reduce this connection can result in significant reductions of fine sediment delivery to streams.” For purposes of this analysis, we assume that maintenance needs are roughly proportional to the proportion of problematic culverts (50%) in the watershed as noted by ODEQ. This leads to a target of 19 miles in our green infrastructure portfolio (half of the ODEQ road length estimate) for road mitigation activities to reduce sediment impacts to Ashland Creek and Reeder Reservoir.

Table 3, below, summarizes our assumptions regarding the extent of a green infrastructure investment portfolio needed to reduce the costs that would result from a large-scale fire with large proportions burning at high intensity. Since this is a preliminary analysis, these figures need to be placed in proper context. These figures are placeholders that do not reflect the actual acreages, road miles, or number of culverts that would be identified through a more rigorous scientific assessment and associated stakeholder processes. They represent rough extrapolations from existing, publicly available data. And they do not yet incorporate the specific recommendations from the Forest Service or AFR stakeholder teams, which have not yet refined their assessment of restoration needs above Reeder Reservoir. Nonetheless, they represent a reasonable basis for GGA modeling since one of the goals of that modeling is to test the sensitivity of the final analysis to ranges of green infrastructure investment.

Table 3:
Green Infrastructure Investment Portfolio for Ashland Creek Above Reeder Reservoir

Component	Scope
Thinning and follow up maintenance	2,204 acres
Prescribed and pile burning	3,306 acres
Road reclamation	15.0 miles
Road mitigation	19.0 miles

3.4 Potential green infrastructure cost savings

The most difficult aspect of GGA is to develop detailed scientific models that relate these green infrastructure investments to reductions in the probability, severity, and costs associated with fires that have large proportions burning at high severity and flood events. In the context of the AFR project, the Forest Service began some of this work, focused on modeling the effects of treatments on the probability of fire and fire behavior. In a future phase of this work, there would need to be additional modeling to estimate the impacts of green infrastructure investment activities reclamation on erosion and sediment delivery to Ashland Creek and Reeder Reservoir. These estimates would extend the analyses to predict the eventual effect on all of the cost elements identified in Table 2. For this analysis, we make the following assumptions, all of which can be altered in the interactive model used to conduct our GGA.

First, we assume that the treatments will reduce the probability of a large-scale wildfire, the number of acres within such a fire that burn at higher severities (increasing the number of acres that burn at lower severities), and the costs associated with that fire event, should it occur. In the context of the AFR analysis, the Forest Service estimated that the preferred alternative would reduce the probability of ignition from lightning by 16.8%, but would not alter the probability of a human-caused ignition. For the green infrastructure options modeled here, we include a component of road reclamation and mitigation work to decrease risk of sediment impacts and that might further reduce ignition opportunities. One recent analysis found that 95% of all human-caused fires ignited within .5 miles of a road, that “areas that are very close to roads have many times more wildfire occurrences than areas distant from roads,” and that there is “extremely strong evidence that road access is a significant contributing factor in the probability of occurrence of wildfires” (Morrison 2007). The effect of reclaiming roads in the Ashland Creek Watershed is not likely to limit human-caused fires to the same extent as in other forested settings because a large proportion of the road network is behind locked gates already (making access difficult). However, road reclamation is likely to have some positive influence on decreasing human-induced fire ignitions.

While this estimate would need refinement in future modeling exercises, we assume that the combined effects of thinning treatments and road reclamation could reduce the probability of an ignition by 50%. This range of fire risk reduction – from 16.8% to 8.4% percent is included in our GGA under different modeling scenarios, with 16.8% adopted as the baseline.

Second, we assume that in the event of a fire occurring post-treatment, the acreage expected to burn at higher severities would be reduced from the BAU estimates. In the AFR FEIS, the Forest Service concludes that the acreage affected by moderate to high intensities could be reduced to 25% (from as high as 50%).¹⁷ We adopt the 25% for purposes of our baseline scenario, and distribute the acreage as shown in Table 4, with 10% falling into the high, 15% in moderate, and 75% in unburned to low severity categories.

Third, with a reduction of higher severity burn categories and an increase in overall forest resilience to both fire and high intensity rainfall events, we can expect most of the cost elements in Table 2 to decrease. Again, this would need to be modeled carefully in the future, but for now we assume that fire suppression and rehabilitation costs would drop because fewer acres would require fire suppression (i.e. more acreage would be allowed to burn naturally) and the acreage of lands needing rehabilitation post-fire would decrease. For both these cost elements, we assume that only those acres that fall into the moderate and high burn severity class would be subject to suppression and rehabilitation activities. We also assume that the costs of carbon emissions and lost passive uses would decline proportionally with the amount of acreage that burns at higher severities. We did not include the carbon costs associated with thinning, pile burning, or prescribed fire in this analysis. These costs will be an essential element of a more refined GGA on the green infrastructure portfolio in the Ashland Creek Watershed.

In terms of water quality costs, we assume that there would be no need for alternate water sources, and that sedimentation would drop by 75% over the BAU scenario due to the combined effects of a lower proportion of acres burning in the higher severity burn categories and substantial decreases in sediment delivered to streams from the road system. Again, this is an estimate that requires refinement through site-specific data and hydrologic and geologic modeling.

Table 4:
Green Infrastructure Fire Event Scenario for the
Ashland Creek Watershed Above Reeder Reservoir
(P=0.832 over 20 years)

Burn severity	Burned acreage
Unburned or low severity	9,524
Moderate severity	1,905
High severity	1,270
<i>Total:</i>	12,698

All these assumptions are summarized in Table 5, which shows a net reduction in costs associated with wildfire and sedimentation impacts from over \$36 million in the BAU case to roughly \$11 million after green infrastructure investments have been made (note that some carbon emission costs and benefits of the green infrastructure activities are not included in this analysis). These include costs and benefits associated with thinning, prescribed burn, and road reclamation and mitigation activities. The magnitude of this potential benefit (without the more

¹⁷ FEIS at III-48.

complete carbon accounting) - \$25 million – needs to be compared with implementation costs over time (e.g., brush control, road maintenance, and etc.) and incorporated into a probabilistic green versus gray (GGA) model over the 20-year analysis period selected for this Phase I study. We present this in Section 4.

Table 5: Midpoint Cost Estimates for Post-Green Infrastructure Fire Event

Cost element	Units	Impact/ extent	Duration	Cost
Fire suppression	acres	3,175	event	\$2,380,875
Burned area rehabilitation	acres	3,175	3 years	\$1,428,525
Costs of sediment removal	y3	48,750	1 year	\$4,875,000
Alternate water sources	gpd	none	-	\$0
Lost passive use values	acres	-1,845 roadless acres	50 years	\$432,465
Carbon emissions	tons	52,908 mtons released	event	\$1,904,700
<i>Total:</i>				\$11,021,565

4.0 Green Gray Analysis

In this section we take the data presented for each scenario and complete a Phase I GGA using standard modeling techniques synthesized by Talberth et al. (2013a), but based on standard public infrastructure investment analysis. The general approach involves using a spreadsheet-based model to compare the present value costs of both green and gray options taking into consideration capital, or upfront costs of green and gray infrastructure options, annual operations and maintenance costs, the opportunity costs of capital, a discount rate, and an analysis period.

GGA analysis is intended to serve one or more of three purposes: (1) identify the least-cost manner for meeting regulatory requirements; (2) identify the least cost approach for achieving target levels of public good provision, or (3) determine the cost effectiveness of green infrastructure solutions in minimizing the costs of natural disasters (Talberth et al. 2013a). For this analysis, our GGA is intended to serve the third purpose. The general steps include estimating costs of a specific natural disaster with and without the green infrastructure investments, estimating the present value costs of green infrastructure investments, converting the total costs of each scenario into an annual “expected value,” and taking the present value of this resulting cost stream over the analysis period (Talberth et al. 2013b). Section 3.0 of this report discusses the expected cost differential between the BAU and green infrastructure fire scenarios. Section 4.1 provides details of our green infrastructure cost assumptions. The final modeling and results are provided in Section 4.2.

4.1 Green infrastructure costs

There is a fairly well developed body of data on which to develop unit cost estimates of the green infrastructure options contained in this analysis. For the AFR, the Forest Service estimates a unit cost range of \$1,000 to \$1,200 per acre for thinning and follow up activities,¹⁸ and \$80 to \$350

¹⁸ Many green infrastructure activities require follow-up maintenance. To incorporate those costs, we considered both initial cost and subsequent (annual) maintenance cost figures, annualized them, and then translated those annual figures into a single present value unit cost estimate per acre or per mile.

per acre for prescribed burning based on an analysis of past contract work (SMRD 2008b). Further refinements were offered by Forest Service staff, and indicate that thinning related treatments fall into the \$1,000 to \$2,290 range, with the higher costs associated with helicopter based activities. Various burning operations range in costs from \$120 to \$300 per acre.¹⁹

Road reclamation costs are also fairly well documented. A 2003 analysis published by Wildlands CPR (Shaffer 2003) found that in the Pacific Northwest, the average cost-per-mile for road reclamation was \$11,343 – which translates into a cost of \$14,394 per mile in current dollars. In 2004, the Forest Service found that road reclamation costs in the Rogue River – Siskiyou National Forest varied widely, and was highly dependent on a number of site specific factors such as whether the road was system or nonsystem. Costs ranged from \$500 to \$10,000 per mile, or \$618 to \$12,360 per mile in current dollars. In recent conversations with Forest Service staff, costs reported by Shaffer (2003) were again cited.²⁰ For now, and to be conservative, we adopt the higher cost range of \$12,360 - \$14,394 per mile for this analysis.

With respect to road mitigation, we incorporate estimates prepared for the Forest Service roads analysis (RRSNF 2004). In the context of this analysis, road maintenance costs for the Siskiyou Mountains area were stratified into four maintenance levels of increasing cost and complexity. Maintenance levels 3 and 4 include a number of activities designed to reduce road impacts on water quality including grading of roadway, brushing, slide removal, ditch maintenance, culvert maintenance, and structure maintenance. These categories capture the activities and goals most closely aligned with the restoration needs identified for the green infrastructure option, especially with respect to repair of problem culverts. The cost range for levels 3 and 4 were reported to be \$2,580 to \$2,935, or \$3,189 to \$3,628 per mile in current dollars.

Taking each range at its mean value, multiplying by the number of acres or miles included in the green infrastructure portfolio, and then discounting over a 5-year implementation period yields the mean total cost figures reported in Table 6, which are reflected in our baseline GGA. Under this baseline, the present value cost of implementing the green portfolio is roughly \$5.1 million.

Table 6:
Green Infrastructure Investment Cost Assumptions

Component	Scope	Unit cost range	Mean Present Value cost
Thinning and follow up maintenance	2,204 acres	\$1,000-\$2,290	\$3,320,819
Prescribed and pile burning	3,306 acres	\$80-\$350	\$651,042
Road reclamation	15.0 miles	\$12,360-\$14,394	\$183,788
Road mitigation	19.0 miles	\$3,189-\$3,628	\$963,488
			\$5,119,137

¹⁹ Boucher, D. Personal communication with Bryan Bird, October 21, 2013.

²⁰Id.

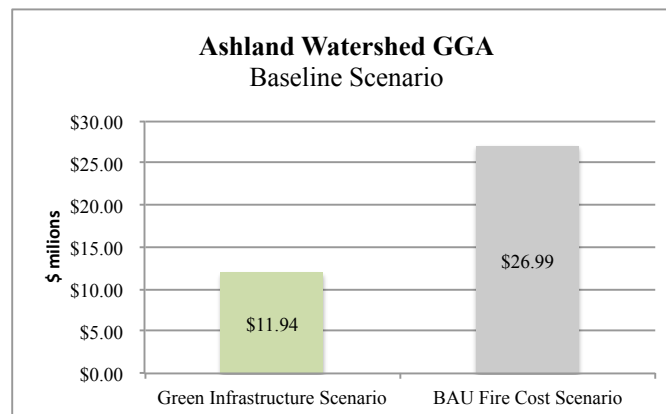
4.2 Modeling and results

The final step was to complete the GGA using the interactive spreadsheet model developed for this analysis. While the model is capable of testing a wide range of assumptions for each parameter, to make the analysis tractable we focused on three GGA modeling cases to compare green versus gray and demonstrate how the results change when a few key assumptions are altered. In case 1 (Baseline) we assume a 20-year analysis period, a 3% discount rate, the 20-year probability of fire as 100% for the BAU scenario, and unit costs for green infrastructure options as the mean values for the cost ranges shown in Table 6. For the green infrastructure scenario fire probability, we used 83.2% based on the Forest Service AFR assumption that AFR activities would reduce the risk of large-scale fire burning large proportions of the watershed at high severities by 16.8%.

In case 2 (Low Gray) we modeled a less optimistic scenario for green infrastructure by reducing the likelihood of fire over a 20-year period to 25% for BAU and 8.2% (i.e. 16.8% less than 25%) for green infrastructure and increasing unit costs to the high end of the ranges reported in Table 6. In case 3 (Low Green) we modeled a more optimistic scenario for green infrastructure by assuming that the BAU fire probability was 100% over 20 years, that green infrastructure investments would reduce this probability by 50% (as discussed in Section 3.5) and by using unit costs on the low end of the ranges reported in Table 6.

The results for each case are reported in Table 7. All values are reported in current (\$2013) dollars. Figure 1 depicts the results for the Baseline case. As shown in Table 7, under Baseline, investing in an ambitious package of green infrastructure solutions to reduce fire risk and protect municipal water supplies would result in a present value cost savings of over \$15 million, or roughly 56% less than BAU. Under more optimistic assumptions for green infrastructure (Low Green), those cost savings increase to nearly \$20 million, representing a 72% reduction with respect to BAU.

Figure 1



On the other hand, under the Low Gray case, the level of investment in green infrastructure we modeled would not be cost effective. In this case, the green infrastructure scenario represents an \$830,000 (12%) increase over BAU. The most important factor driving the different outcomes is

the probability of the BAU fire over a twenty-year period. Through iterative runs of the spreadsheet-based model varying the probability of a watershed-wide fire and nothing else, it appears that if that probability of such a fire is roughly 30% or less, the level of investment in green infrastructure would have to drop – but be just as effective in reducing fire risk – to be economically justifiable.

Table 7: Green versus Gray Results for the Ashland Municipal Watershed

Cost element	Scope	Present value
Baseline		
<i>BAU “gray” costs of fire</i>	12,698 acres	\$26,991,042
<i>Green infrastructure fire costs</i>	12,698 acres	\$6,821,279
<i>Thinning and follow up maintenance</i>	2,204 acres	\$3,320,819
<i>Prescribed and pile burning</i>	3,306 acres	\$651,042
<i>Road reclamation</i>	15.0 miles	\$183,788
<i>Road restoration</i>	19.0 miles	\$963,488
<i>Total green</i>		\$11,940,415
Green minus gray		\$15,050,627
% cost savings		55.76%
Low Gray		
<i>BAU “gray” costs of fire</i>	12,698 acres	\$6,747,761
<i>Green infrastructure fire costs</i>	12,698 acres	\$672,290
<i>Thinning and follow up maintenance</i>	2,204 acres	\$4,622,903
<i>Prescribed and pile burning</i>	3,306 acres	\$1,059,836
<i>Road reclamation</i>	15.0 miles	\$197,761
<i>Road restoration</i>	19.0 miles	\$1,025,534
<i>Total green</i>		\$7,578,323
Green minus gray		-\$830,562
% cost savings		-12.31%
Low Green		
<i>BAU “gray” costs of fire</i>	12,698 acres	\$26,991,042
<i>Green infrastructure fire costs</i>	12,698 acres	\$4,099,326
<i>Thinning and follow up maintenance</i>	2,204 acres	\$2,018,735
<i>Prescribed and pile burning</i>	3,306 acres	\$242,248
<i>Road reclamation</i>	15.0 miles	\$169,816
<i>Road restoration</i>	19.0 miles	\$901,441
<i>Total green</i>		\$7,431,566
Green minus gray		\$19,559,476
% cost savings		72.47%

5.0 Concluding Thoughts and Suggested Refinements

Although this analysis is preliminary, and based on assumptions that need to be revisited to provide more accurate comparisons, we can draw four general conclusions from our GGA results for the Ashland Creek Watershed.

First, the results indicate that investments in ecologically sound fuels reduction and watershed restoration activities in high-risk municipal watersheds similar to Ashland are likely to pay for themselves several times over if the underlying models of fire risk and subsequent watershed damages from high intensity rainfall events are reasonably accurate. Under the baseline scenario investments in green infrastructure are preliminarily estimated to generate costs savings of over \$15 million dollars over the “business as usual” scenario where there are no additional investments by public agencies in fuels reduction or watershed restoration.

Second, the analysis demonstrates the sensitivity of the results to variation in key parameters. For example, as demonstrated in the Low Gray case, if the risk of watershed-wide fire over 20-years falls below about 30% and green infrastructure costs tend toward the high end of their ranges, then a green infrastructure portfolio as large in scope as the one modeled here does not appear to be economically justified. A further reduction in economic feasibility would occur if assumptions about the efficacy of proposed treatments are less than what is assumed in this analysis.

Third, it establishes the broad applicability of GGA in situations that are similar to Ashland, where the risks of large-scale, high severity wildfire and the impacts from high levels of erosion and sedimentation during intense rain events on municipal water system infrastructure warrant a careful analysis of costs and benefits of options to reduce that risk. In particular, the GGA methodology completed here is based on a large but replicable set of data that is fairly standard, at least throughout the fire-prone regions of the Western United States.

Lastly, the potential magnitude of the cost savings warrants a more detailed analysis in Phase II. In such an analysis, one of the most important initial tasks would be to create and run scientific models capable of projecting carbon emissions from green infrastructure measures with an accurate estimate of the benefit that they would be expected to produce and the effect of these measures on carbon emissions / storage (which are not included in this Phase I GGA). Additionally, modeling the effectiveness of thinning, prescribed fire, road reclamation, and road mitigation as a package on reducing the probability of a severe large-scale fire and ensuing sedimentation and the effects of severe storm events on erosion and sedimentation damages to Ashland’s municipal watershed.

With scientific modeling as a basis, a more detailed analysis will be a much better tool for evaluating the costs and benefits of a wide range of treatment options to protect and restore the ecological integrity of Ashland’s municipal watershed. The results presented in this preliminary analysis suggest that there is great potential for a green infrastructure investment to help the City of Ashland manage a high risk to the quality of their water supply. Investing in more detailed modeling could help refine the value and not only benefit the City of Ashland, but other cities

and towns throughout the West facing similar municipal watershed risks and the challenge of evaluating alternatives to reduce those risks.

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