Valuation of Sediment Loads and Water Quality in Reeder Reservoir Following a High-Intensity Fire: A Market Analysis of Ecosystem Goods provided by the Ashland Watershed

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Abstract

In the event of a large intensity, stand-replacing fire, surface erosion such as raveling occurs immediately after the fire for a period of 24 hours, followed by a minimum 5 year period of insufficient soil cohesion. This leads to an increase in mass-wasting events and sedimentation into Reeder Reservoir. To remove an unprecedented amount of sediment, a low-bound cost of \$100/yd^3 is appointed to estimate the total cost. A minimum monitoring cost of turbidity and algal blooms of \$133,000 has been assessed, and furthermore, TID water usage would cause the price of water to nearly double for Ashland's residents, as well as industrial and commercial sectors.

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Introduction:

The Ashland Forest Resiliency Project (AFR) is a proposed action designed to reduce the probability of a high intensity stand replacing fire in the Ashland watershed by means of implementing forest treatment at strategic locations throughout the watershed to contain a potentially large fire. The purpose and need for this action is driven by a multitude of factors, but perhaps the most pertinent are the damage costs avoided in relation to water quality degradation in Reeder Reservoir. This study attempts to analyze the ecological ramifications of a high intensity fire in the Ashland watershed by providing an outline of the market costs incurred with an increase in water quality degradation. As the City of Ashland is largely dependent on drinking water derived from Reeder Reservoir, which is treated locally, these quantified damage costs avoided are extremely relevant in demonstrating the need for action, as this study predicts the costs of no action may be detrimental.

This study will first provide a thorough outline of the expected ecological ramifications in the order of their occurrence following a stand replacing fire. The environmental consequences examined in this paper relate exclusively to water quality. These consequences include the loss of soil structure and soil cohesion following a high intensity fire, the types of surface erosion we expect to occur, rates at which mass wasting events increase, the accumulation of nutrients in the Reeder Reservoir transported through sedimentation, as well as the expected duration of insufficient soil cohesion. This study also demonstrates the expected ecological consequences associated with treating the excessive sediment loads. These outcomes are primarily related to dredging and include an increase in stream turbidity, and the associated effects of turbid conditions on the availability of clean water.

With the above listed ecological effects in consideration, this study will also attempt to quantify the market costs correlated with ecological degradation in the watershed, with a direct focus on the subsequent treatment costs. These market costs include the operation of multiple dredging procedures in Reeder Reservoir, temporarily externalizing our domestic water source to the Talent Irrigation District (TID), monitoring the turbidity of Ashland Creek, and monitoring the nutrient levels in Ashland Creek and Reeder Reservoir. This study also acknowledges the need for future studies in regards to non-market values likely to be adversely affected in the event of a catastrophic fire.

The Ecological Effects of High Intensity Fire on Water Quality and Availability:

Surface Erosion and Sediment Transportation

Following a high intensity stand-replacing fire, geomorphic changes occur instantly on the soil surface. Soil raveling is the most immediate post-fire erosive process and can significantly contribute to an increase in sediment loads in Reeder Reservoir (King). Unlike mass wasting events such as debris slides or debris flows, raveling occurs independently of driving mechanisms such as wind or water (King). Instead raveling occurs in the extreme absence of moisture and at accelerated rates in steep topography (Brown and Caldwell 2008). In the event of catastrophic fire in the Ashland watershed, the majority of surface raveling would occur during the 24-hour period immediately following the disturbance (King). According to John King and Steven Wondzell, the raveling process is estimated to continue over a period of one year or more following a disturbance. It should be noted that the amount of surface raveling that occurs during this period is relatively insignificant in comparison with the amount transported immediately after a fire (King). This is primarily because moisture quickly returns to the soil and reduces the rate of soil raveling (Brêda 1994). However, the presence of moisture drives different types of soil erosion, which are arguably more detrimental in terms of erosion rates and sediment loads (Brêda 1994).

The loss of canopy cover in a stand replacing fire significantly decreases the rate of evapotranspritaion, which in turn leaves the soil saturated for extended periods of time (Brêda 1994). In addition to altering the natural process of evapotranspiration, the removal of surface litter and duff, which regulate the rate of water infiltration and soil saturation, provokes surface erosion in the form of debris slides (King). Furthermore, the process of soil raveling exposes the pores of the soil, which combined with the loss of the regulating protection of surface litter, drastically increases the rate of soil transportation in a potential post fire scenario (King).

Though the full effects may not be experienced for some time after a high intensity fire, the loss of soil cohesion due to advanced root decay, is a process notable for accelerating the rate of debris slides as well as setting the stage for a catastrophic event such as a debris flow (King). Debris flows, normally prohibited by immense and intricate root structures, generally depend upon extreme weather events such as thunderstorms or periods of high precipitation to transport deep pockets of soil and woody debris (King). This process of movement will perpetually occur at a slow pace as water saturates deeper into the soil horizons (King). With the introduction of a triggering mechanism such as an intense storm, the momentum and speed of the movement increases, rendering the process capable of dragging with it any existing saplings or standing trees (King). This unfortunate aspect of a debris flow presents an increased likelihood of high volumes of woody debris and sediment accumulation at the bottom of Reeder Reservoir following a severe fire (Brown and Caldwell 2008).

The accelerated rate at which debris flows unfold dictate the eventual necessity to implement dredging or sluicing operations in Reeder Reservoir as a means of removing the accumulating sediment (Reeder 2008). These actions alone, though likely the only available solutions, remove large amounts of sediment and woody debris but in doing so, increase the levels of turbidity in Ashland Creek (Brown and Caldwell 2008). During past dredging and sluicing efforts, which were the result of years of accumulated debris and seasonal floods, stream turbidity exceeded levels fit for safe human consumption as regulated by DEQ standards (Weaver 1974). These turbid conditions, which were measured to exceed DEQ standards for up to two weeks following the disturbance, were also likely to have adverse affects on salmonid spawning in Ashland Creek, Bear Creek, and the Rogue River (Weaver 1974). Although further studies are needed to fully quantify the ecological ramifications on their populations, salmonids fill a vital niche in their ecosystem, which alone warrants the need for more extensive studies (Weaver 1974).

Following a high intensity fire and the decay of intricate forest root systems in the disturbed location, it is expected that soil cohesion will reach a minimum threshold of stability after 5 years of regeneration (King). At this point in time enough saplings and vegetative cover will have regenerated to decrease the rate of soil erosion and the subsequent effects on stream turbidity following removal of sediment from Reeder Reservoir (King). However, during this 5-year period the disturbed location will be susceptible to continual catastrophic mass wasting events as well as an increased rate in sediment loading (King). It is during this critical time period that follow-up dredging and/or sluicing operations will likely be needed, which will therefore raise the levels of turbidity in Ashland Creek once again (Brown and Caldwell 2008).

Damage Costs Avoided and Valuation Techniques Utilized

In the event of a large stand-replacing fire above Reeder Reservoir, one of the more immediate costs will be reflected in the necessary removal of sediment deposited into Reeder

Reservoir. Algal bloom and turbidity monitoring will also be required, as water quality will be greatly compromised in this situation. The cost of utilizing the TID to meet the city's water demand will also increase significantly.

The 2008 Reeder Reservoir study conducted by Brown and Caldwell for the City of Ashland provided some important insight to the costs of sediment removal. The study involved removing 6,000 yd^3 of sediment and woody debris (5,500yd^3 and 500 yd^3 respectively), utilizing a method that would place the material directly below the dam to be dewatered and later removed (Brown and Caldwell 2008). The assumption was that "in the current regulatory environment, it was not feasible to simply open the sluice gates, drain the dam, and remove the remaining material that did not exit out the sluicing tunnels" (Brown and Caldwell 2008). Utilizing a suction dredge to remove 5,500 yd^3 of sediment generated an estimated cost of \$100/yd^3; removal of the woody debris using a small clam shell was estimated to cost \$200/yd^3; and re-handling of the material after it was dewatered was estimated to cost \$50/yd^3 (Brown and Caldwell 2008). Combined with costs to monitor, permit and control the work, the approximate cost came to \$1.2 million dollars. As this study was not able to incorporate any actual city receipts for previous sediment removal (such as the 40,000-50,000 yd^3 of sediment removed after the 1997 flood that employed a similar process) to adequately verify these costs, we decided that these numbers were the best available information and could be used to generate an approximate cost for sediment deposition into Reeder Reservoir. To appreciate the magnitude of this cost, some historical insight is necessary: According to the <u>Bear Creek Total Maximum Daily Load</u> (TMDL) report done by the Oregon Department of Environmental Quality (ODEQ), Reeder Reservoir experienced a "historically unprecedented" 130,000 yd^3 of sediment deposition in 1974 (Bear Creek TMDL 2007). Since we do not know the percentage of sediment and woody debris removed at the time, it is difficult to estimate total cost for total material removal. The low-bound rate of $\$100/yd^3$ of only removing sediment (suction dredge) would come to approximately $130 million.

Table 2. Costs of Sedimentation and Monitoring

Sediment Removal	$\$100/yd^3$
Woody Debris Removal	$\$200/yd^3$
Re-Handling	$\$50/yd^3$
Monitoring Costs	$133,000

This is only estimated as a one-time cost. A major concern is that the amount of sediment deposited by a stand-replacing fire (worst-case scenario) will call for multiple removal efforts caused by the above mentioned soil stability issues and erosion rate increases. These total costs will multiply in pursuit of being able to regain use of Reeder Reservoir. Also worth mentioning is that the Brown and Caldwell study estimated a cost of current (ambient) stream turbidity monitoring, as well as algal blooms caused by nutrient (N and P) loads at around $133,000 (Brown and Caldwell). These costs are likely to increase, as the water quality must meet a safe recreational and consumptive quality. External costs are also possible to other communities that rely on the same source of TID's water supply.

In the event of an emergency, such as massive sediment loads to Reeder Reservoir, TID has been convened to meet Ashland's water demands. According to the Ashland City Engineer Pieter Smeenk, Ashland currently pays $50 per acre-foot to obtain water from TID. Under normal conditions, water from Reeder Reservoir costs $160 per million gallons to treat (Smeenk). Taking the weekly average from the City of Ashland's online Water Production/Use Report of 2.14 million gallons used from June 2 through June 8 (household use—includes residential, business and commercial accounts), we would need to acquire 6.57 acre-feet of water from TID

(1 acre foot = 325,851 gallons) to meet this demand. To treat 2.14 million gallons of water from TID, the cost is $342 per day added to the $328 per acre-foot charge (for daily average of 2.14 million gallons at $50/acre-foot) to obtain the water and results in almost doubling the treatment costs of Ashland's water supply. This is also a relatively low-bound estimate, as Smeenk suggests that the commercial industry could experience rates increasing several times over.

While the probability of a stand-replacing fire above Reeder Reservoir is not certain in any sense, the possibility is still there. These figures are only meant to show that in monetary terms, the Ashland Creek watershed is more than worth the initial abatement costs of the AFR project to keep the probability of a severe fire to a minimum.

Table 1. Rates Applied to TID Backup Water Supply

Current Cost of Treatment (H_20 from Reeder Reservoir)	$160/million gallons
Weekly Average Household Use (June 2, 2010)	2.14 million gallons
Cost to Obtain TID Water	$50/acre-foot
Subsequent Cost of TID Treatment	$160/million gallons

Recommendations for Future Studies

The collaborative efforts of the AFR project are designed not only to protect water quality, but also to incorporate the protection of all the ecosystem goods and services provided by the watershed. To quantify the total value of the goods and services provided by the Ashland watershed, there are many market and non-market valuations to consider that fall beyond the scope of this study. A study to determine the passive-use value of recreation in the watershed is an important non-market asset to address. The travel cost method could be utilized to calculate the costs incurred by people traveling to experience the recreational attributes of the Ashland watershed. The costs of traveling to the location as well as an assessment of the recreational or passive-use values such as mountain biking, hiking and photography, could be considered and quantified in monetary terms either by utilizing existing studies or by conducting new surveys to demonstrate the willingness to pay for such values.

Soil stability for example, is an ecosystem service that could potentially be valued in a non-market study. Furthermore, soil anchoring is an ecosystem service that could be used to analyze the degree of change in soil cohesion. Measuring the non-market values of standing forests for the service of carbon sequestration would also be a worthwhile value to monitor. There are local, regional and global benefits to maintaining carbon structure. Valuing carbon would have a focus on replacement costs and damage costs avoided and could be assessed by damages incurred through hydro-geological storms, as they contribute to climate change, as well as risk aversion techniques such as health costs.

The ecological effects caused by sediment loading and stream turbidity on salmonid populations and their spawning habitat, as well the cumulative economic benefits derived from the watershed as non-timber goods including morels, nuts, etc., are a few more non market valuations to be considered. An important market valuation to be acknowledged is the potential for algal blooms in Reeder Reservoir. When water quality is degraded, blooms of algae that can have ecological, aesthetic, and human health impacts can occur. In water bodies used for water supply, algal blooms can cause physical problems, such as clogging screens, or can cause taste and odor problems in waters used for drinking. Blooms involving toxin-producing species can pose serious threats to animals and humans. Quantifying the full health effects is difficult with the absence of a specific and extensive study, as health effects are generally a result of non-point source pollution and difficult to quantify.

Conclusion

This paper has addressed the ecological processes involved with increased sediment and nutrient loads, as well as the corresponding economic consequences resulting from a severe fire. In doing so, the costs of treatment, sediment removal, and nutrient monitoring have all been quantified as low-bound estimates concerning a worst-case scenario. These damage costs avoided represent the benefits from reducing the probability of a stand-replacing fire. Furthermore, they are not meant to offer validity to the AFR project but rather to demonstrate the vast ecological and economic connections between the wild land-urban interfaces.

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