Task 1. Request for Proposals:
Mitigating the Effects of Wildfires on Watersheds

Task sponsored, proposed, and developed by:

- Souder, Miller, & Associates
- EPA Office of Research and Development

See the Appendix for a list of changes made to the task since the Task Overview was published.

Task

Develop an innovative solution to protect communities from the severe flooding and sediment loads that often follow a wildfire. Your team is invited to select an area that could most benefit from your solution. This may either be in your local area or an area of your choice that would be greatly impacted if it were compromised by wildfires. Solutions should be innovative, low-cost, easily implemented, and sustainable. Nature-based solutions and passive treatments are encouraged. Teams will be provided with actual fire-scar and washdown sediments to use in their bench-scale demonstrations.

Background

Wildfires are natural components of a healthy watershed and ecosystem, but increasing average fuel loads (caused by rising climatic temperatures, prolonged droughts, past fire-suppression practices, and pest infestations) are resulting in more severe wildfires.

Wildfires damage watersheds, leaving behind burn-scarred areas that open the opportunity for severe flooding during storms. Flooding can compromise water supplies, threaten downstream communities, and damage ecological habitats [1].

A watershed is the area of land that supplies runoff to bodies of water, including lakes, rivers, streams, wetlands, estuaries, and bays. Watersheds support wildlife and vegetation and serve as drinking water sources to local communities. The damaging effects of wildfires on watershed systems are twofold [1]:

1) They increase the incidence of flooding and debris flows during post-fire storms or snowmelt because they reduce water infiltration and increase surface runoff and soil erosion.
2) They compromise water supplies by increasing the sediment load and introducing additional dissolved organic matter, nutrients, and sometimes metals, into streams and rivers.

<u>Post-fire Flooding and Debris Flows</u>

In a healthy forest, the canopy, loose tree litter, and duff ordinarily absorb enough rainfall to minimize runoff during an average storm. However, severe wildfires destroy most of this vegetation and the organic surface layer, leaving behind burn scars – mostly barren land with altered soils and patches of vegetation that can only minimally absorb storm waters.

The result is greatly increased runoff during a storm. Further contributing to runoff issues, when plants burn, they often release waxy substances that seep through the upper mineral layer of soil and create a patchy hydrophobic layer about 1 inch below the top of the soil. This waxy layer can be ½” – 3” thick. It resists water infiltration, increasing the potential for even low levels of rainfall to result in severe flooding and debris flows. Over time, the hydrophobic layer will dissipate and originalx soil properties will be restored [2, 3].

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Efforts to mitigate severe flooding events are most important within the first year after a wildfire and often decline to baseline conditions within three years, but the timeframe can be much longer, depending on the rate of vegetation regrowth and the restoration of soil hydraulic properties. In areas affected by significant snowmelt, suspended sediment concentrations typically reach a maximum two years after a wildfire, then decline to baseline conditions in year three [4, 5].

The timeframe for burn scars to create serious flooding issues is short, but during this time, the damage can be devastating. Thus, rapid intervention is important for mitigating post-fire flooding and debris flows [6]. With recent evidence that thunderstorms are increasing in frequency and intensity, the need for rapid response is becoming more critical [7]. Traditional solutions, such as hay bales have been used previously for erosion and sediment control, but new, innovative approaches are needed for more effective flow and contaminant management.

Effect of Wildfires on Drinking Water Supplies and Fish Habitats

In addition to stormwater hazards, when the ash and soil entrained in the surface-runoff waters enters drinking water supplies, they create challenges for drinking water treatment, sometimes resulting in water treatment facility shutdowns. Post-fire water treatment is challenged by elevated turbidity, dissolved organic matter (DOM), excess nutrients (including phosphorous and nitrogen), and sometimes increased metal concentrations. The influx of these materials may require greater coagulant dosing, higher solids processing, shorter filter run times, and guarding against toxic disinfection byproducts during water treatment. These issues are particularly challenging for small public water systems.

Additional post-fire effects include rising stream temperatures, changes in water chemistry, turbidity, and runoff that can cause fish die-offs. Downstream reservoirs can also be affected by elevated nutrient levels, which, along with increased light exposure and elevated stream temperatures, can result in harmful algal blooms. Algal-associated issues also challenge drinking water treatment due to taste and odor issues, algal DOM, and the potential for cyanotoxins.

Two Case Studies in New Mexico

The issues listed above can be studied for two small communities in New Mexico: Las Vegas, served by the Gallinas watershed, and watersheds that supply Ruidoso and outlying regions. Each region faces unique issues.

Las Vegas, NM

The Las Vegas water treatment facility, capable of treating reservoir water at turbidity levels up to 20 NTU, served the community from the 1970s until the 2022 Hermits Peak/Calf Canyon Fire. Over the past two years, post-fire storms have sporadically raised the turbidity in the reservoir to over 200 NTU, rendering water treatment useless when storm waters rage. Experts predict that fire debris and increased turbidity may continue to flow toward the town for at least 10 years. The federal government has granted the town $98 million for a new treatment facility that can alleviate most of the issues with high turbidities and debris, but it will be years before the system will be built and fully functional [9, 10]. Communities such as these need low-cost interim solutions to reduce the effect of high sediment loads on their water supplies.

Ruidoso, NM

In 2012. Ruidoso experienced the Little Bear fire that burned 44,000 acres. Subsequent severe flooding events in 2012 and 2013 filled Bonito Lake with hundreds of thousands of cubic yards of debris and sediments. Restoration of Bonito Lake began in 2017 and was completed in 2024, but the lake’s re-opening was halted due to the 7,500-acre Blue 2 Fire (started May 16, 2024) followed by the 17,000-acre South Fork Fire and the 7,900-acre Salt Fire [11]. The three Ruidoso fires occurred within two months of each other, leaving large burn-scarred areas at the start of monsoon season. Subsequent flash floods that began on June 30, 2024 forced the evacuation of hundreds of people, destroyed over 850 homes, and carried with it volumes of sediment and debris that further challenged the community [11, 12, 13, 14].

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Figures 1 and 2 illustrate how quickly post-fire storms can cause severe damage to infrastructure due to high sediment loads carried in streams and rivers. The sediment/cobbles/debris shown in the photos were carried by high-velocity sheet flow. The debris was deposited when water velocities declined after the storm had passed. During the height of storms, similar loads of sediment and debris make their way further downstream to challenge local water supplies.

Figure 1. Cedar Creek, Ruidoso, one week after the Blue 2 fire. Heavy sediment loads partially buried a wellhead with debris. The backhoe is maneuverable on the road. *(Photo courtesy of SMA Engineering)*

Fig. 2. Cedar Creek, Ruidoso, two weeks after the Blue 2 Fire. High flow velocities during a post-fire storm carried large cobbles, sediment, and debris, then dropped them in place when water velocities decreased, burying the wellhead and backhoe. *(Photo courtesy of SMA Engineering)*

Mitigating the Effects of Wildfires on Water Supplies

Two primary approaches can be used to address the effects of wildfires on water supplies. The first is to install preventive measures while the watershed is robust. However, smaller communities struggle with this approach because they would need to invest significant funds to guard against a disaster that may never occur. To better serve these smaller communities, this task will focus on a second option: planning for mitigation measures that could be implemented immediately after a severe fire to reduce the effects of storms that may follow. Rapid deployment would best be initiated within days of containment of the fire, but may take weeks or months to fully implement.

Because no two fires are alike, rapid-deployment mitigation requires planning that considers a variety of scenarios and proposes specific actions according to each scenario. This calls for developing a decision tree that would guide city officials and engineers through specific actionable mitigation steps within the first weeks after a fire. The decision tree could include actions to be taken depending on the size and severity of the fire, the nature of the resulting burn scar, potential storm severity, and downstream features that need to be protected (such as their distance from the burn scar, elevation, area, proximity to floodplains, etc.)

A decision tree makes it easier to implement mitigation measures almost immediately after a fire. Another benefit of developing a rapid-deployment plan for a community is that it could be quickly modified to help similar regions.

All watershed mitigation plans should consider how to best support the local community. This may include protecting water supplies, infrastructure, wildlife, economically significant species, and/or recreational features that may be a major source of income for the area. Mitigation plans will also be shaped by community resources, such as available funding, personnel, volunteers, technical capabilities, storage, etc.

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Watershed Restoration

The primary post-fire mitigation measure to protect water resources is watershed restoration. Although watershed restoration projects may also include reducing pollutants and nutrients in the water, this task will focus on the immediate issues of reducing flow velocities and volumes during storm or snowmelt events and reducing turbidity and total suspended solids (TSS) in those flows [5]. These measures restore balance to the area by capturing sediment and debris before they reach a lake or river that may be used for municipal water supplies, or to provide ecosystem services and habitats [6].

Rapid-deployment Watershed Restoration Measures

Rapid-deployment measures should begin within days of the wildfire, but may take weeks or even months to fully implement. Such measures require pre-planning that may include:

- Identifying an area that could be scarred by severe wildfires in the future and that does not currently have significant preventative flooding measures in place.
- Determining the expected flow rate, $Q = V/t$ for a healthy watershed during a potential storm event for that area, basing Q on slope angles and historical infiltration rates in the area under normal soil and vegetation conditions.
- Predicting the expected flow rate, Q_{flood}, for the same locale and same storm severity as above, after fires have scarred the watershed. Assumptions must be made about vegetation and groundcover loss and hydrophobicity of the soils due to wildfire.
- Developing a watershed restoration plan to protect downstream features based on Q_{flood}, and determining how to protect those features, recalling that even an average storm for the selected area can result in severe flooding after a wildfire.
- Minimizing upfront costs and equipment/supply storage.
- Building a pilot-scale solution.
- Preparing a decision tree that can be used immediately after a fire to help the deployment team quickly identify appropriate rapid-deployment mitigation strategies.

Task-Specific Parameters and Site Selection

Your team's plans for rapid deployment will assume an initially healthy watershed that might become burn-scarred in the future by a wildfire. Plan your design to address a 2000-acre (minimum) burn-scarred area that experiences an average, routine storm event. Assume that the fire caused 80% loss of vegetation and organic surface layers.

Based on this information, estimate the expected soil hydrophobicity and the nature of a routine storm event for this locale (use average storm data collected over the previous 10 years). Not only should your technical report address an average storm, it should also evaluate the effectiveness of your design in the event of a larger (10-year) storm. This analysis for a 10-year storm is requested in the technical report but it is not required for the bench-scale demonstration.

Select a site that might be at risk for post-fire flooding and would be economically and/or ecologically challenged by such flooding. If you cannot identify a local site of interest for this study, consider other locations that have been previously struck by wildfires and flooding.

Although this task addresses a burn-scarred area that covers approximately 2000 acres, previous wildfires in your selected locale may have destroyed tens of thousands of acres. Since that is an intractably large acreage to model in the bench-scale demonstration, scale down the wildfire scenario to meet the task requirements.

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Problem statement

Your team will research, evaluate, and design an innovative, rapid-deployment, post-fire watershed restoration project for a site of your choice. The design will mitigate watershed issues in a 2000-acre (minimum) burn-scarred area in the event of a storm of average intensity for that area. Using actual fire-scar flooding and washdown sediments from Ruidoso, NM, your team will design and test a system that promotes infiltration, and reduces by 50%: runoff volumes and velocities, turbidity, and TSS in the flood waters.

Consider the needs of the targeted community. Solutions shall be innovative, low-cost, high impact, quickly implemented, require little routine maintenance once installed, and withstand storm-related flows during routine precipitation events for a minimum of three years.

Design Considerations

Your proposed design should provide specific details and outcomes as follows.

- Research the vegetation, soils, landscape, hydrology, and climate of the area and consider potential post-fire risks to the watershed, the community, and/or other downstream features of concern.
- Evaluate potential fire characteristics and burn severity, including the nature of the hydrophobicity of the soil, based on 80% of the vegetation and organic surface layers being destroyed by the fire.
- Assess the historical nature, scale, and frequency of storms in the locale, based on the last 10 years, and design the solution to address an average storm event for the area.
- In the technical report only, using supporting documentation, evaluate the potential effectiveness of your rapid-deployment plans in the event of a 10-year storm.
- Estimate the expected post-wildfire flow rates, erosion, and debris flows downstream of the watershed, assuming that 80% of the vegetation and organic surface layers will be burned across a 2000-acre area.
- Support all assumptions with appropriate data.
- Provide appropriate diagrams describing the processes involved in your solution. These may include a Process Flow Diagram (PFD) that includes mass and energy balances of all processes, water flows, waste streams, etc., and/or additional diagrams, such as site maps with dimensions that illustrate the features of the mitigation system.
- Plan a logistically feasible rapid-response watershed mitigation system that will scale to an average storm event. Plans should include a detailed implementation schedule and should optimize time to deployment vs. benefits vs. costs.
- Plan and demonstrate a bench-scale rapid-response watershed mitigation system that will scale to an average storm event. The bench-scale solution will:
    - Demonstrate that the rapid-deployment plans are feasible.
    - Set forth a timeline for achieving full deployment once the fire has been contained.
    - Produce the expected flow velocities due to an average storm and demonstrate flow reduction due to the team's mitigation solution, with the goal of reducing flow velocities by 50%.
    - Reduce turbidity and TSS by 50%.
    - Minimize the need for long-term storage of equipment or materials while awaiting a storm.
- Develop a community engagement plan, as appropriate.
- Present a solution that results in minimal disturbance to the infrastructure or existing land uses and minimizes aesthetic and environmental impact, cost, and waste generation.
- Quantify the local benefits and demonstrate that the needs of the targeted community are met and its local waterways are preserved.

- Discuss project implementation, including permitting, safety, and regulatory compliance.
- Develop a decision tree to help the deployment team quickly implement the solution.
- Present a Techno-Economic Assessment and Analysis (TEA) to construct your proposed solution. Target the TEA towards community needs, with the community or local government being the customer.
    - Consider capital expenses (CAPEX) to establish a full-scale rapid-deployment mitigation system and put in place any needed up-front infrastructure, materials, etc.
    - Include operating expenses (OPEX), according to typical costs in the community you are addressing. Include maintenance and storage of equipment, structures, or materials while awaiting a prospective fire.
    - Evaluate the balance between time-to-deployment, cost, and benefits.
    - Invite a business/economics major as part of a multi-disciplinary team (recommended) to help you draw up economic plans for full-scale implementation.
- Address safety aspects of implementing the rapid-deployment solution as well as potential issues with handling post-fire stormwater and any waste products. Safety issues for the full-scale design should be addressed in the written report. Safety issues for the bench-scale demonstration should be addressed in both the written report and the Experimental Safety Plan (ESP).

Bench Scale Demonstration

Bench-scale demonstrations will serve to illustrate the design considerations listed above. The bench-scale demonstration need not physically replicate the entire watershed area. It should illustrate the primary requirements: improving infiltration and achieving 50% flow reduction, and reducing both turbidity and TSS by 50%.

Teams that are interested in exploring the effectiveness of their model in reducing other contaminants such as nutrients, DOM, or metals, are welcome to indicate this in their ESP. If your plans are approved by our Safety Officer, you will receive instructions for moving forward and having WERC arrange to have your pre- and post-mitigation samples tested for the contaminant. This is not considered an official part of judging, but is an opportunity to explore the effect of your designs on other contaminants that affect water supplies.

For use at the bench-scale demonstration in Las Cruces, all teams will be provided with up to 18 L of potable water and approximately two gallons of dried post-wildfire sediments. The sediments were collected from Cedar Creek Trail and Lynx Trail in Ruidoso, NM on September 14, 2024.

As a part of your engineering design, your team will design the bench-scale testing parameters. These include developing a means of producing appropriate flow velocities and ensuring storm-level sediment loads as well as gathering data from the bench-scale model. In particular, your team will:

1. Provide a bench-scale apparatus that will:
    a. Produce water-flow velocities and sediment loads that scale appropriately to the flow rates and sediment loads expected during an average post-fire storm in your selected locale.
    b. Set up a system that will allow you and the WERC staff to easily:
        i. Measure pre- and post-mitigation water velocities.
        ii. Collect pre- and post-mitigation samples of water for turbidity and TSS analysis. The design should provide a means of collecting water samples in 125-mL bottles with and without your mitigation system being implemented. (Upon request, WERC can ship you a sample of the type of bottle that we will use for collection.)
2. Demonstrate rapid deployment of a watershed mitigation project that will increase infiltration and reduce flow velocities, turbidity, and TSS by 50%.

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Teams will provide at the contest:

The bench-scale demonstration that consists of two parts:

1. A working bench-scale model that is functional, with demonstrated ability to be rapidly deployed and reduce turbidity, TSS, and flow velocities during a simulated storm event, as described in #2, above.
2. A digital scale model to illustrate the application of your design across the watershed. The model should illustrate how flow velocities will change across the watershed due to your rapid-deployment plans. In lieu of a digital model, a scale model may be considered if it can demonstrate the effectiveness of the system.

WERC will provide at the contest:

WERC will provide each team with a minimum of two gallons of post-wildfire-flooding sediments collected from Ruidoso, NM, up to 18 liters (5-gallon container) of potable water, six 125-mL sample bottles for sample collection, and a kiddie wading pool and/or tarps as secondary containment in case of spills.

The volumes stated above are starting points, but your needs may be different. In your team's ESP, note the amount of water and sediment you will require to run the bench-scale demonstration and note any specific water-containment needs you will have. If your team would like to request additional bulky items, submit this request in the ESP by February 26, 2025. (See Team Manual).

Analytical Testing of the Bench-scale Demonstration

After treatment, your team shall submit six 125-mL samples for analysis: three samples of pre-mitigation waters and three samples of post-mitigation waters. Collection of samples will be witnessed by a WERC staff member and sent to NMSU labs for analytical testing.

At the contest, each team's bench-scale demonstration will be analyzed by:

TSS – Glass-fiber filtration, drying, and weighing.

Turbidity – Light transmittance probe measuring NTU (nephelometric turbidity units).

Water velocities – measured pre- and post-mitigation. Teams will provide a means for testing these velocities in real time.

Evaluation Criteria

Each team is advised to read "Evaluation Criteria" and "Contest Scoring" in the 2025 Team Manual for a comprehensive understanding of the contest evaluation criteria. For a copy of the Team Manual, Public Involvement Plan, and other important resources, visit the WERC website: Guidelines | werc.nmsu.edu

In addition to evaluation criteria that applies to every task, judges will evaluate your team's response to the problem statement and design considerations, with consideration of:

- The innovative aspects of your design.
- The effectiveness of your bench-scale apparatus in increasing infiltration rates and reducing flow velocities, turbidity, and TSS.
- The effectiveness of your digital or scale model in demonstrating practical implementation within your chosen watershed and appropriate integration into the chosen landscape and community.
- The feasibility of the rapid-deployment plan and an appropriate balance between time-to-deployment, cost, and benefits.
- The decision tree to facilitate rapid deployment.
- Other specific evaluation criteria that may be provided at a later date (watch the FAQs online).

Experimental Safety Plan (ESP) and Required Short Course.
All members of your team are required to attend the ESP preparation short course. Due dates are listed below. See team manual for details.

Specific to this task, include in the ESP the amount of water and sediments your team will need for the bench-scale demonstration, along with special water containment needs, if any.

Dates, Deadlines, FAQs (*dates subject to change—watch website FAQs*)

- Today: Email us to let us know you are interested in this task, and we will:
    - Reserve a registration slot for your team that will enable you to register (~early October).
    - Keep you posted on breaking news about the task and the contest.
    - Ship a sample of post-wildfire-flood sediments and a sample-collection bottle, if needed. (Be sure to include your shipping address – preferably the address of your Team Leader or Faculty Advisor.)
- October 15, 2024 - December 31, 2024 – Early Bird Registration (discount applies).
- December 1, 2024 - February 20, 2025: Mandatory On-demand Course: Preparing the ESP.
- February 17 - 26, 2025: ESP due.
- March 8, 2025: Final date to register a team.
- March 31, 2025: Technical Report due
- Weekly: Check FAQs weekly for updates:
    - Task-specific FAQs: 2025 Tasks/Task FAQs
    - General FAQs: 2025 General FAQs

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Appendix – Updates since publication of the Task Overview

Since the Task Overview was published in July, 2024, the following changes were made to this design challenge.

1. The bench-scale demonstration will use actual post-fire flood sediments instead of a synthetic solution. We have been working with the US Forest Service to obtain these sediments from Ruidoso, NM. We will ship a sample to your team upon request.
2. The task has been simplified. Our engineers determined that the greatest immediate threat to downstream communities are elevated flow velocities and associated sediment loads. Therefore, teams will be asked to build a bench-scale model to reduce flow velocities, turbidity, TSS only. You will no longer be expected to reduce metals, DOC, or nutrients, however, as noted under "Bench-Scale Demonstration," teams may test their system's ability to reduce additional contaminants.
3. The severe storm event (25-yr storm) previously cited was reduced to an average storm event to model the task after a real-world-scenario. Two reasons support this change:
   1) it is unlikely that both a severe fire and a severe storm will hit within weeks of each other, and
   2) average storm events are easily capable of causing severe flooding.
4. The text has been changed in minor ways throughout the document.