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SCIENCE EXPLORERS

A unique professional development and science enrichment opportunity for teachers and students grades 5-8

2011-2012 Workshops

EARTH SYSTEMS SCIENCE:

EXPLORING CHANGE IN THE CRITICAL ZONE

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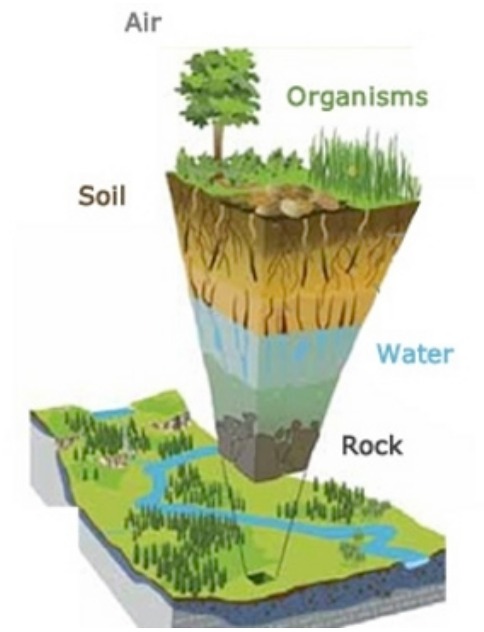
EARTH SYSTEMS SCIENCE:

EXPLORING CHANGE IN THE CRITICAL ZONE

The Critical Zone is Earth's porous near-surface layer, from the tops of the trees down to the deepest groundwater. It is a living, breathing, constantly evolving boundary layer where rock, soil, water, air, and living organisms interact. The Critical Zone is home to complex interactions that control the availability of life-sustaining resources like food and water.



Scientific research in the Critical Zone focuses on understanding how the system operates, how it evolves, and how it will respond to future changes in land-use and climate. Research in the Boulder Creek Watershed, part of the National Science Foundation's Critical Zone Observatory Program, strives to understand how the area's geology, hydrology, ecology and climate interact to provide and control the availability of water resource in three key areas represented by the learning modules described below.

Foundations for Flow:

In this module, learners and teachers will build a Colorado watershed from the bedrock up and wear it down with constructive and destructive forces over time. Using snow, ice, and summer rains they will create glaciers, streams and rivers to grind the mountains down to the landforms that we see today. They will see how events in our geological past, including the formation of sedimentary rock layers, mountain building, uplift and erosion, combine to form the foundations of the watershed.

Fire and Water:

Using computer mapping and hands-on experiments, participants will explore the relationships between ecosystems, wildfires, soils and water. They will predict fire intensity and see how wildfires impact soils, erosion and water quality. They will conduct experiments to help understand how different soils impact water flow and storage, how forest fires change soil and surface structures, and how these factors combine to impact both water quality and water availability in the watershed.

Ice, Snow and H_2O:

This chilly module focuses on how weather, climate, snow and ice impact the Earth System Interactions that supply year-round water to Colorado, with only the occasional flood or landslide. Participants will create and conduct experiments with glacial ice, and use snow, data, measurements and math to understand the relationship between glaciers, snowpack and our water supply.

For more information of the Boulder Creek Critical Zone Observatory Program visit the program website at: http://czo.colorado.edu

Fire and Water

Module Overview:
Wildfires have been an important part of the ecosystems, nutrient cycling, and natural history in Colorado for thousands of years. Though potentially devastating, wildfires play an important role in shaping the ecosystems and watershed structures we see today. Scientific research in the Boulder Creek Critical Zone Observatory focuses on the impacts of the 2010 Fourmile Fire and the Earth System interactions between fires, soils, erosion, and water quality in Boulder Creek.

This module, following the current research, explores the complex relationships that exist between wildfires and the environment. The introduction serves as a primer for understanding fire ecology, dominant land covers in the Boulder Creek Watershed, and the Earth System interactions that control fire intensity. In the first activity, learners will use Google Earth Historical Imagery to predict fire intensity in various locations and current land cover images and fire data to evaluate the accuracy of their predictions. The second activity focuses on an experiment designed to compare the impact of precipitation events on erosion in areas affected by varying fire intensity. The final activity introduces learners to soil structures, infiltration and groundwater retention potential in sample soils, while incorporating an inquiry focused on the relationships between fire intensity, changes to soil, surface materials, and runoff.

The module wrap-up uses a modeling process to help learners to organize, verbalize and evaluate the interactions between the Fourmile Fire and Earth System. The class will use the model to explore relationships impacting fire ecology, then fires impacts on hydrology and water quality. Finally, learners will use the model to discuss the potential impacts of climate change, Bark Beetles, and land use change on wildfires in the Boulder Creek Watershed.

Colorado Academic Standards:
Standard 2: Life Science

- Prepared Graduates: Explain and illustrate with examples how living systems interact with the biotic and abiotic environment
  - Grade 6-Concept 1: Changes in environmental conditions can affect the survival of individual organisms, populations, and entire species
  - Grade 6-Concept 2. Organisms interact with each other and their environment in various ways that create a flow of energy and cycling of matter in an ecosystem
  - Grade 8-Concept 1: Human activities can deliberately or inadvertently alter ecosystems and their resiliency

Standard 3: Earth Systems Science:

- Prepared Graduates: Evaluate evidence that Earth's geosphere, atmosphere, hydrosphere, and biosphere interact as a complex system
  - Grade 5-Concept 2: Earth's surface changes constantly through a variety of processes and forces
  - Grade 6-Concept 1: Complex interrelationships exist between Earth's structure and natural processes that over time are both constructive and destructive

Learning Goals:

Learners will be able to:

- Develop, communicate, and justify an evidence-based explanation about how ecosystems interact with and impact the global environment
- Compare and contrast the flow of energy with the cycling of matter in ecosystems
- Gather, analyze, and communicate an evidence-based explanation for the complex interaction between Earth's constructive and destructive forces
- Develop and communicate an evidence based scientific explanation around one or more factors that change the Earth's surface
- Identify problems, and propose solutions related to water quality, circulation, and distribution - both locally and worldwide
- Develop, communicate, and justify an evidence-based scientific example of how humans can alter ecosystems

Key Concepts:

- Wildfires and fire intensity involve complex relationships in the Earth System
- Wildfires play an important role in the transfer of nutrients, materials, and energy
- Wildfires are a deconstructive force in the Earth System
- Wildfires have significant impacts on the structure and function of watersheds and change the Earth's surface
- Fuels and fire management, as well as post-fire erosion control, are an important part of protecting communities and limiting changes to water quality and flow regimes
- Changes to the environment associated with climate, land use change, management, and Pine Bark Beetles will have a significant impact on fire ecology in the Boulder Creek Watershed

Guiding Questions:

- What Earth System interactions influence the development and intensity of wildfires?
- What Earth System interactions do wildfires influence?
- What role do wildfires play in the transfer of nutrients, materials, and energy?
- How are wildfires deconstructive forces in the Earth System?
- What role do wildfires play in changes to the Earth's surfaces?
- How do wildfires, topography, soil structures, and precipitation regimes combine to impact how water is transferred throughout the Earth's systems?
- How do fuels and fire management, as well as post-fire erosion control efforts, impact the landscape, water quality, and flow regimes?
- How will changes to the environment associated with climate, land use change, management, and Pine Bark Beetles impact fire ecology in the Boulder Creek Watershed?

Activity 1: Fire Ecology, Soils and Earth Systems Science

Overview:
The introduction to this module uses PowerPoint slides, Google Maps and soil/land cover samples to familiarize learners with land cover patterns and forest types in the Boulder Creek Watershed, common soils and soil structures, as well as introduce or reinforce concepts related to fire ecology and fire intensity. Learners will then use the Google Earth's Historical Imagery Tool to predict patterns in fire intensity across the Fourmile Fire impact area and use current images, along with fire data, to test the accuracy of their predictions. The class will hypothesize about the impacts of changes to surface structures and soils on water quality and flow regimes in the Boulder Creek Watershed. These activities are easily adapted to any location or fires, recent or historical.

Time Needed: 10-15 Minutes

Learning Objectives:
Learners will:
- Develop an evidence-based explanation about how wildfires interact with and impact the environment
- Use fire as an example to compare and contrast the flow of energy and the cycling of nutrients and materials
- Describe fires role as a destructive force in the Earth system.
- Develop and communicate an evidence based scientific explanation of the role fires play in changing the Earth's surface
- Communicate the impacts and interactions linked to differences in fire intensity

Guiding Questions:
- What Earth System interactions influence the development and intensity of wildfires?
- What Earth System interactions do wildfires influence?
- What role do wildfires play in the transfer of nutrients, materials and energy?
- How are wildfires deconstructive forces in the Earth System?

Common Misconceptions:
- The effects of wildfires are spread evenly throughout the impacted landscape
- Historically, only low and medium intensity fires were dominant in the Boulder Creek Watershed, and throughout Colorado

Prerequisite Knowledge and Skills:
- A basic understanding of ecosystem structures and Earth System processes

Learner Engagement:
- Have learners share their experiences and knowledge related to wildfires

Materials for the Teacher:
- PowerPoint presentation, notes, and background materials
- Computer with Google Earth software, screen, projector or smart board

Materials for the Class:
- A set of soil samples and land cover

Safety and Logistics:
A large number of Coloradans were directly or indirectly impacted by the Fourmile Fire and other fires across the State. Therefore, care should be taken when addressing wildfire related content.

Set Up:
1. Prepare boxes, 3-liter bottles, or other clear containers with layers of materials representing local soils and land cover structures
2. Check the computers, projector, internet connection and map files
3. Test and preview the PowerPoint presentation and presentation materials
4. Open Google Earth, appropriate layers (kml's) and adjust the locations and perspective

Procedures
1. Introduce the module by relating learner's experiences with wildfires, their understandings of fire ecology, as well as the local and global impacts.
2. Use the PowerPoint presentation to discuss the dominant land cover types in the Boulder Creek Watershed, as well as fire ecology and fire intensity.
3. Using Google Earth, show learners the extent of the Boulder Creek Watershed and, combined with the soil and land cover samples, refine their understandings of the distribution of soils, slopes, and land covers.
4. Next, using Google Earth's Historical Imagery Tool, add the Fourmile Fire Boundary layer (kml) to a pre-fire land cover image.
5. Explore the Fourmile area, focusing on the slopes, streams, and land covers. Carefully address the presence of houses, roads and developed areas, as well as the fire's impacts.
6. Navigate to an appropriate part of the impact area and have learners describe the varying land covers and slopes.
7. Applying their understandings of fire intensity, have learners predict, mark or outline areas they believe will have low, medium, and high intensity fires.
8. Using the Fourmile Fire Intensity layer (kml), show the learners the estimated fire intensity for each area, compare it to their predictions, and turning off the Historic Imagery Tool, explore the post-fire images, fire variations, and impacts.
9. Focusing on Fourmile Creek, explore the fire intensities, slopes, and evidence of erosion to prepare the learners for the next activities in the module.
10. If time allows, explore the layers and land covers from historical fires in the watershed and across the state.

Assessment:
Using the PowerPoint Presentation, Introduce the Earth Systems Science model and help learners apply it to the relationships controlling wildfires, fire intensity and their impacts. Conclude by posing the guiding questions to the class in a verbal or written format.

Grade Level Adaptations and Local Variations:
This activity can be easily adapted to include content related to ecology, general fire ecology, land cover, and soils. Using Google Earth, learners can compare the areas impacted by different types of fires, fire intensities, or compare land cover and soil types across the watershed. This activity is easily adapted to other locations, fires and events, as well as other mapping technologies.

Activity 2: Fire Intensity, Erosion and Water Quality

Overview:
In this activity, learners will explore the impacts of different intensity fires on erosion and water quality by simulating precipitation events on recently burned slopes. In order to facilitate this inquiry learners will be introduced to the concept of flow, its measurement in volume over time, and practice their pouring and science process skills. Next, learners will be introduced to the concepts of pH and electrical conductivity as indicators of water quality and practice using the meters while collecting baseline data on the water used in the inquiry. Learners will then pour a fixed amount of water, over a fixed amount of time, on similar locations in four prepared models simulating unburned, low, medium, and high intensity fires in the Gordon Gulch area. Next, learners will compare the results of the erosion and runoff collection, or lack thereof, noting the visual differences in the movement of materials and water quality. Finally, learners will measure, compare and contrast differences in pH and electrical conductivity in the available samples. The wrap up will focus on using the Earth Systems Science model to explore wildfire impacts on erosion, water quality, and hydrology.

Time Needed: 15-20 Minutes

Learning Objectives:

Learners will:

- Practice inquiry and science process skills related to the experiment
- Develop an evidence-based explanation about how wildfires interact with and impact the environment
- Use fire as an example to compare and contrast the flow of energy and the cycling of nutrients and materials
- Describe fires role as a destructive force in the Earth system
- Develop and communicate an evidence-based scientific explanation of the role fires play in changing the Earth's surface
- Communicate the impacts and interactions linked to differences in fire intensity

Guiding Questions:

- What Earth System interactions do wildfires influence?
- What role do wildfires play in the transfer of nutrients, materials, and energy?
- How are wildfires deconstructive forces in the Earth System?
- What role do wildfires play in changes to the Earth’s surfaces?
- How do wildfires, topography, soil structures and precipitation regimes combine to impact how water is transferred throughout the Earth’s systems?

Learner Engagement:

- Having learners describe what they have heard or their experiences related to fire, water quality and erosion events.

Common Misconceptions:

- Ecosystems and land cover remain stable for long periods of time
- Wildfires cause permanent water quality issues in streams and rivers

Prerequisite Knowledge and Skills:

- Basic inquiry and science process skills
- The ability to use a stopwatch and measure volume

Materials for the Teacher:

- PowerPoint presentation, notes and background materials
- Computer with Google Earth software, projector and screen, or smart board
- Paper or hand towels, mops and other cleaning supplies
- A set of materials to repair the models between groups

Materials for the Class:

- Plastic bins, containers or outside space to build slopes
- Surface soils, sand, grass, pine needles, burned pine needles and ash
- Small containers and funnels to collect runoff from slopes
- Eight small beakers or other volumetric containers for each group
- Two stop watches per group
- pH paper and/or electrical conductivity meters
- Access to tap water and a small amount of distilled or deionized water
- Blank paper for recording results
- Buckets for water and waste products
- Paper or hand towels, mops and other cleaning supplies

Safety and Logistics:
Sharing roles, data, and opportunities are central to the success of this activity. Close monitoring and clean-up of spilled water and materials will limit slip and fall hazards.

Set Up:

1. Prepare containers, tables or outdoor spaces by creating slopes with sand, removing valuable materials, and adding drainage systems if needed.
2. Cover the slopes with an equal amount of base materials from local soils.
3. Add materials to create the models described below:
    - A section of the model with a thin layer of living grass and soil, soil base materials, and pine needles representing an unburned area.
    - A section with a thin layer of non-living grass, or one with the green stalks removed, soil base materials, and a mix of unburned and burned pine needles representing a low intensity burn area.
    - A section of the models without the grass layer and covered by a mix of well burned pine needles. This layer, representing a medium intensity burn, should not be as thick or tall as the first two layers.
    - A section of base materials covered by a 1 cm thick layer of ash mixed with mineral soil materials (preferably orange, red or another light color) and topped with a 1 cm thick layer of ash. This section, representing an area after a high intensity burn, will need significant maintenance and clean-up between groups.
    - Add small funnels and containers to the bottom of the slopes to collect runoff.
4. Prepare trays with paper, pencils, 8-10 beakers, two stopwatches, an electrical conductivity meter, and pH paper or meters.

Procedures

1. Introduce the activity using the slopes and soil boxes to describe the impacts of different fire intensities on soils and surface structures.
2. Prepare the class for the inquiry by reviewing the steps and considerations for a scientific investigation and explaining the use of the models.
3. Define and explain the role of consistent pouring location and flow for validity and variable control.
4. Have the teams practice pouring 250 ml of water, over 5 seconds, between the beakers until they have a consistent pour and flow rate.
5. Introduce the concepts associated with electrical conductivity, pH, nutrient cycling, and water quality.
6. Have the learners collect and record baseline data on the water used for the experiment.
7. Have the learners hypothesize about the potential differences in runoff and erosion in each section of the model
8. Conduct the experiment, compare observed results, and measure pH and electrical conductivity.
9. Have each team share the results of the inquiry and as a group, explain how this experiment can inform us about changes in the real world.
10. Have the teams replace as much of the eroded material as possible, empty the water collection containers, and return the models to their original state as best they can.
11. Finally, have the learners clean the tables, floors, and refill the beakers with water.

Assessment:

Using the PowerPoint presentation, help learners apply the Earth Systems Science model to the relationships between wildfires, erosion, runoff, and water quality. If time allows have the learners elaborate on the roles of fire in other ecosystems. Conclude by posing the guiding question to the class in a written or verbal format.

Grade Level Adaptations and Local Variations:

The structure of this inquiry can be adapted to accommodate different levels of facilitation and abilities. The science process skills and water quality sections can be extended for higher level learners and the materials can be easily adapted to match those found in any location.

Activity 3: Just Passing Through, or Not

Overview:
This inquiry is an adaptation of a GLOBE Program activity originally titled "Just Passing Through" that is available for download at http://www.globe.gov/tctg/passthrough_beg.pdf?sectionId=101.
The activity centers on upside down soda bottles, with the tops removed and caps replaced with screens, filled with a variety of soil mixtures and placed in a beaker. Deviating from the original lesson, the containers used in this activity have a notch and pour spout cut into the top edge just above the soil level, and three of the six containers demonstrate the impacts of low, medium and high intensity fires on valley soils, while one serves as a control for the experiment. The high intensity fire sample will have been treated to simulate the effects of hydrophobic soils on runoff, infiltration rates, and water quality.

Time Needed: 15-20 Minutes

Learning Objectives:
Learners will:
- Practice inquiry and science process skills related to the experiment
- Develop an evidence-based explanation about how wildfires interact with and impact the ground and surface water
- Communicate the impacts and interactions linked to differences in fire intensity

Guiding Questions:
- How do soil structures and land cover differ over a variety of landscapes?
- How do differences in soil structures impact groundwater flow and storage?
- How do varying fire intensities impact surface and groundwater?
- How do wildfires, topography, soil structures, and precipitation regimes combine to impact how water is transferred throughout the Earth's systems?

Learner Engagement:
- Having a sample of the class describe their understandings of groundwater and the importance of groundwater resources

Common Misconceptions:
- Wildfires impact on local hydrology are limited to surface water and erosion

Prerequisite Knowledge and Skills:
- Basic inquiry and science process skills
- The ability to use a stopwatch and measure volume

Materials for the Teacher:
- PowerPoint presentation, notes, and background materials
- Computer with Google Earth software, screen, projector or smart board
- Paper or hand towels, mops and other cleaning supplies
- A set of materials to repair the models between groups

Materials for the Class:

- Containers to hold soil samples and beakers to prevent spilling
- Six soda bottles of any size
- Scissors or a sharp knife
- A small amount of window screen or cloth
- Soil base materials from a variety of locations
- Pine needles and other land cover materials
- 18 graduated beakers or other containers and tools for measuring volume
- Access to water and buckets for water and waste materials
- Two stopwatches for each group
- Pencil and paper
- Optional pH and electrical conductivity meters

Safety and Logistics:

Sharing roles, data and opportunities are central to the success of this activity. Close monitoring and clean-up of spilled water and materials will limit slip and fall hazards. Extra care should be applied to prevent the 'top heavy' containers from spilling.

Set Up:

1. Prepare the six soda bottles per team by removing the bottoms with a sharp knife and removing the center section of the caps
2. Cut a notch and pour spout into the bottom of the bottle, the top when it is upside down, approximately 3 cm from the edge.
3. Place a small amount of screen or cloth in the cap and put it back on the bottles
4. To create the soil models, dig soil pits in a variety of locations, collect the materials, and note the relationships between the layers so the ratios can be simulated in the bottles.
5. To create soils common to the Boulder Creek watershed in 20 ounce bottles follow the directions below:
    - High Elevation or Mountain Soils: The shallow nature of these soils is simulated by adding large quantity of gravel and small amounts of surface soils. Add 750 ml of gravel or saprolite, 50 ml each of C, B and A horizon soils, topped with less than 1 cm each of organic soils and pine needles.
    - Soils found in the canyon bottoms and along streams can be simulated by adding repeating 75 ml layers of gravel or saprolite, play sand, small rounded rocks, white sand, then small amounts (50 ml) of C, B, and A horizons topped with 2 cm each of organic soils and pine needles.
    - Fourmile Valley Soils can be created using 500 ml of saprolite or gravel, 150 ml of C and B horizon soils, and 75 ml of A horizon soil topped with 2 cm layers of organic soils and pine needles. The label for this container should also describe it as the control for the experiment.
    - The low intensity fire sample mimics the soils above but the pine needles should be replaced with a mix of burned and unburned needles.
    - The medium intensity fire sample mimics the valley soil sample but the top layers should be replaced with 0.25 ml of organic soils and 0.25 cm of burned pine needles.
    - The high intensity fire sample mimics the valley soil sample but the top layers are replaced with a 0.25 ml mixture of ash and light colored soils, topped with a 0.25 cm of fireplace ash. Spray a small amount of Scotch guard, or its natural alternative, on the mixture, heat if needed, and cover with another layer of fireplace ash.

6. If following the previous activity, refill the water containers, add the extra beakers, and towels for clean-up.

Procedures

1. Introduce the activity using the bottles and soil boxes to describe the differences in soil structures and fire impacts.
2. Prepare the class for the inquiry by reviewing the steps and considerations for a scientific investigation, explaining the use of the models, introducing infiltration and the relationships between soil structures and water holding capacity.
3. Remind the class of the importance of consistent pouring and flow for variable control.
4. Have the teams remove high mountain and valley sets from the containers and prepare the beakers for catching the runoff.
5. Pour 250 ml of water into the models, and simultaneously start the stopwatch.
6. Compare the differences in runoff while waiting one minute for the water to drain.
7. Record, compare, and contrast the quality and volume in the lower beakers and relate to differences in soil structures.
8. Have the learners create a set of hypotheses describing the differences in runoff, infiltration and water holding capacities for the inquiry section of the activity.
9. Remove the valley and low intensity soils and explain the valley soils' role as the control for the experiment, before repeating the steps above for them and the remaining sets.
10. Introduce the concept of hydrophobicity, explain how it was simulated, and its role in the relationships between wildfires, soils, and hydrology.
11. Finally, have the learners organize their data, compare the results and create evidence-based generalizations about the relationships between soil structures, wildfires, changes to soils, groundwater, and surface water.
12. At the end of the activity, have the teams empty and rinse the beakers, clean up any water and materials, and reset the materials for the next team.

Assessment:

The activity and module wrap-up uses the modeling process to help learners to organize, verbalize, and evaluate the interactions between the Fourmile Fire and Earth Systems. As a class, have learners use the model to explore relationships impacting fire ecology, then fires impacts on hydrology and water quality. Finally, guide the learners in the use of the model to discuss the potential impacts of climate change, Bark Beetles, and land use change on the Boulder Creek Watershed. Conclude by posing the guiding questions to the class in a written or verbal format.

Grade Level Adaptations and Local Variations:

The structure of this inquiry can be adapted to accommodate different facilitation types for different ability levels and experiences. The science process skills, soil structure, geography and water quality sections can be extended for higher level learners and the materials can be easily adapted to match local land cover and soils.

Background Information, Resources and Extensions

Wildfires have been an important part of Colorado's natural and built communities for thousands of years. They are one of the many dynamic processes that shape the Earth System and impact the Critical Zone. Understanding the complex relationships between wildfires and water involves not only fire ecology, but soils, topography, ecosystems, erosion, deposition and finally, hydrology and water quality. The Boulder Creek Critical Zone Observatory, with its wide range of landscapes, ecosystems, and hydrologic features, serves as an ideal platform for understanding these relationships, as well as representing landscapes and ecosystems across Colorado and the Western United States.

Wildfires reflect the Earth System relationships between the geosphere, hydrosphere, atmosphere, and biosphere with the interactions between slopes, aspect, and soils; precipitation and humidity; wind and the seasons; as well as the forest and ecosystem structures that provide the fuels. The connections between fire and water are not limited to the interactions involving soils, erosion, and streams. The deposition of ash directly into streams and lakes, the role of particulates in cloud formation and precipitation, as well as fire's role in releasing carbon dioxide and impacting climate, all add to the complicated web that connects fire and water.

Topography and Soils Background Information:
To begin understanding fire and water, the best place to start is with the landscape itself and the base materials that form its foundations. Each of the communities in the watershed, from the mountains to the plains, have topographical and soil features that impact the relationships between fire and water. In fact, we usually think of wildfires burning in the forested foothills, but before development, wildfires burned regularly across the plains, deserts, riparian areas and high mountain valleys now managed and changed by logging, farms, roads, and communities.

Soils are formed from the base or parent material below them and organic and inorganic materials washed down the slopes or leached from the decomposing duff, or leaf litter, above them. The process, which can take thousands of years in some cases, begins with the chemical and physical weathering of the parent materials by water, ice, plants, wind and other forces, as well as the deposition of materials. In some stable soils these processes can form a distinct layer of chemically weathered, yet undisturbed, material just above the solid bedrock called saprolite. Soil scientists use a term called 'horizons' to describe the layers found in stable soils, and the bedrock and saprolite form the lowest or 'C' horizon. Above the bedrock and saprolite is a layer of inorganic material, the results of the weathering process, stained yellow, orange or red, by minerals leached from the layers above it. These 'B' horizons usually form the bottom of 'root zone' where plants are active, and contain concentrated minerals and 'pore spaces' that hold water. The richest and most active layer in the soil, other than the organic layers on top, or 'O' horizons, is the 'A' horizon. This layer is a mixture of the decomposed plant materials from above and the inorganic materials below them. Depending on the location and processes that form them, these layers can be just millimeters thick, or in some cases meters thick. Soil structures, materials, and the nutrients they contain directly impact the plant communities they support, as well as the way water moves over and through them. Each of the communities in the Boulder Creek Watershed has distinct features and soils that impact the relationships between fire, plant communities, and water.

In the high-mountain or alpine communities, characterized by low growing plants and grasses, the topography and soils have been shaped over time by the glaciers and erosion that formed them. There are areas of exposed basement rock, the remains of sedimentary layers, and steep walled, U-shaped valleys with large deposits of unsorted sand and gravel left by the glaciers known as glacial till. On the exposed areas and slopes, the soils may be only a few centimeters deep. In the valleys, a thin layer of topsoil may cover tens of meters of glacial till in snaking banks called moraines left along the sides and bottoms of the areas where glaciers once scoured the landscape.

Glacial deposits, till, and valley features also dominate the subalpine and montane ecosystems just below the headwaters. These areas, characterized by spruce/fir, aspen, and more importantly Lodgepole Pine forests, lie on eroded sedimentary layers, cover vast deposits of glacial till, and exposed basement rock. The glacial features in this area can also include small to medium sized lakes, which in some cases have been 'improved' for water management with dams and would be classified as reservoirs. The deep deposits of glacial till and gentler slopes can hold vast amounts of water and in some cases serve as important groundwater recharge zones.

The foothills ecosystems, dominated by Ponderosa Pines, sage meadows and valleys filled with willow and aspen stands, lies on top of the eroded and up-ended sedimentary layers left by tectonic uplift. Over time, streams and rivers have cut deep V-shaped valleys, in some cases down to the underlying basement rock, and left steep slopes, layered valley deposits, and soils as diverse as the terrain itself.

The plains, dominated by stream and river deposits, as well as changes to these deposits over time including meandering valleys, terracing, and layered deposits, lie on top of soft shales and the remains of sedimentary layers. These deep soils, often dominated by clays left from the eroding shales, can hold a vast amount of water, are highly susceptible to erosion, and are nutrient rich, thereby supporting a large number of farms in the lower reaches of the watershed.

Fire and Ecosystems Background Information:

Wildfires, as well as their impacts, vary across a landscape based on the amount of fuels available in each location and the impacts of topography, soil moisture, humidity, wind, precipitation, and the structure of the ecosystems themselves. In areas with a small amount of fuels, like open meadows, the fire can move through fast, barely scorching the groundcover and plants. In these low intensity fires, common also to steep, low-fuel slopes, the resulting changes to ecosystems and soils are limited to charred base materials and groundcover, with little to no impact on the underlying soils or canopy cover. In areas with more fuels medium intensity fires are common. These longer duration fires, which can reach the canopy in some locations, result in the burning of ground cover, the loss of organic layers in the soil and some root damage, as well as physical and chemical changes to the upper layers of the soils. When the organic layers burn, hydrocarbons are released and may penetrate underlying soils. As the hydrocarbons cool, it creates a waxy surface layer coating the soil surfaces. This waxy coating makes the soils resistant to water, or hydrophobic.

In areas with large amounts of fuels, and therefore longer fire durations, fire's impact can be severe. Fuel ladders, or smaller trees and branches under the canopy, can help the fires reach the tops of the trees, resulting in crown or stand replacement fires. In these high intensity fires, the surface soils and organic layers can be completely burned, leaving only ash. Extensive root damage can occur, and the soils can become severely hydrophobic. These high intensity fires often leave sterilized, mineral soils, which can take many years to recover, and are highly susceptible to surface erosion as the activities in the module show. The varying nature of fire intensity means that sections of the landscape only meters apart can be impacted quite differently.

Wildfires are an important part of many ecological processes in Colorado, and across the Western U.S. including nutrient cycling, ecological succession, ecosystem distribution, and hydrology. The relatively dry conditions limit the decomposition of organic matter by microorganisms and therefore the redistribution of nutrients in the ecosystem. Wildfires, though destructive, free the nutrients in the organic material so they can be recycled and distributed across the watershed by water and wind. Each of the ecosystems described above have different relationships with wildfires, including different fire-types and fire frequencies, or the average time between fires.

While the alpine ecosystems rarely burn due to cold, wet weather and snow, fires are more common in the subalpine and montane zones. In fact, Lodgepole Pine forests are specifically adapted to fire. These forests tend to burn with a high intensity, completely burning the stands of trees, and then re-seeding again with close growing stands of pines. Fires also burn frequently in the foothills, but with more diversity in fire intensity. The open meadows trend towards low and medium intensity fires between the stands of Ponderosa Pines, whose thick bark protects them from fire damage. Regular fires in the more forested areas, often on North-facing slopes, keeps the amount of fuel, or fuel load, low resulting in, again, low and medium intensity fires under the canopy. When fuels build up, either through fire suppression or natural process like a series of wetter years, high intensity stand replacing fires can result. Historically, all three types of fires were common across the foothills. On the plains, grass or range fires were a common sight before development in the dry summer months, and like higher elevation fires, were an important part of nutrient cycling and ecological succession.

Fire and Water Background Materials:
Across Colorado, we find evidence of past fires and their impacts on landscapes, ecosystem distributions, and hydrology. Some impacts, like changes in forest structures and water quality, are short term, while others, like the impacts on soils, slopes, erosion, and the deposition of sediments in stream channels can have lasting impacts. In general, fires impact the flow of water, changing both surface and groundwater flow regimes, and water quality. These changes are primarily the result of the release and mobilization of materials from burned plants, increases in surface erosion caused by the removal of the groundcover and canopy features, and changes to soil structures including the formation of hydrophobic soils. These changes, when compounded by steep slopes, shallow soils, and precipitation or melting events, can have significant impacts on streams, rivers, lakes, and reservoirs.

Fire's impacts on water flow regimes, both above and below ground, begin with changes to the groundcover and canopy structures. By removing the protective plants and forest canopy, more precipitation falls directly on the surface, resulting in increased overland flow and the mobilization of materials. When the duff or organic layers are completely burned in higher intensity fires, precipitation and overland flow have direct access to the underlying soils. The removal of the duff layer also allows surface water to flow unimpeded by the pine needles and leaves which slow it, collect the larger particles, and allow time for the water to soak into the ground. Finally, by burning the root structures that hold the soils together, medium and high intensity fires can weaken the soil structure itself. These changes, which can be compounded by the creation of hydrophobic soils, result in more water flowing downslope, faster, and carrying more materials in flooding events. In some cases, the weakening of soil structures and increased infiltration of groundwater can result in landslides on slopes, further adding to the materials available for mobilization. On the other hand, hydrophobic soils can decrease groundwater infiltration in some areas and actually reduce the likelihood of landslides. To say the very least, wildfires impacts on soils, erosion, and water flow are a great example of the complex interactions in the Earth System.

The next consideration in the relationships between fire and water are the mobilized materials themselves. Fires produce vast amounts of easily dissolvable, nutrient rich ash and combustion products, as well as mobilize large amounts of organic material, soil particles, and in some cases entire slopes. When these materials reach the stream and rivers their impacts can be profound.

Ash and other dissolved materials, including fire products and minerals from the exposed soils, have a duel role. While they add valuable nutrients to the hydrologic system, which can encourage plant growth and can be deposited downstream in flooding events, they can greatly impact other living things in the short term. Ash and fire products, which contain a large amount of lye, can almost instantly increase the pH of water beyond the tolerances of living things like fish and macroinvertebrates. Though the nutrients in the water are very valuable to agriculture and other uses, the increased pH can burn plants and their roots, as well as make the water unusable for drinking water or commercial uses.

While pH is commonly understood, and incorporated in many learning environments, measurements of the valuable dissolved minerals are less common, including the measurement of electrical conductivity included in these activities. In brief, water in its pure form is a relatively poor conductor of electricity. As more material is dissolved into it, particularly solids like salts, minerals and nutrients, its ability to conduct electricity is increased, or in other terms, the amount of electrical resistance is reduced. Therefore, conductivity meters use electrical resistance between the meter's poles as a way to measure the total amount of dissolved solids in a water sample. While most water bodies register between 20-300, electrical conductivity in impacted streams can go over 2000 Um/cm^3! We include the measurement of electrical conductivity in the module to help reinforce learner understanding of fire's role in nutrient cycling. For more information on electrical conductivity visit: http://www.waterontheweb.org/under/waterquality/conductivity.html.

Finally, the impacts of increased flow and flooding on communities are easy to understand, while the impacts of increasing particle or sediment loads can be hard to comprehend. Clays, sand, and gravel released from the soils can bury living things, their eggs, and cover biologically active organic materials with sediments. Flooding events add even more materials by further mobilizing existing sediments from the stream channels. These materials can further impact stream structures and hydrology by filling in pools, decreasing stream flow, and creating blockages, as well as shorten the lifespan of reservoirs and lakes by adding large mounts of materials. Floating or suspended organic materials can block the sun, increasing turbidity and decreasing the potential for photosynthesis and available oxygen. Additional organic material provides food for decomposers, increasing the biologic oxygen demand in the system, and further limiting the amount of oxygen available for living things. For more information on stream chemistry and water quality, as well as citizen science opportunities visit: http://www.waterontheweb.org/index.html.

Additional Resources:

- The Science Education Resource Center at Carleton College has an excellent overview of Earth Systems Science available at: http://serc.carleton.edu/introgeo/earthsystem/nutshell/.
- A brief overview of the Earth Systems Science modeling process model is available at: http://www.cotf.edu/ete/ESS/ESSmain.html.
- Colorado State Forest Service's Wildfire website: http://csfs.colostate.edu/pages/wildfire.html
- U.S. Forest Service Fire Prevention and Education website: http://www.fs.fed.us/fire/prev_ed/index.html
- Colorado State University, Fire Ecology Institute for Educators: http://csfs.colostate.edu/pages/fire-ecology.html
- Fires Effects on Water Quality from ForestEncyclopedia.net: http://www.forestencyclopedia.net/p/p621
- Fourmile Fire information from Boulder County, CO: http://www.bouldercounty.org/live/environment/land/pages/fourmilefire.aspx

- USDA-Natural Resource Conservation Service's Soil Information website: http://soils.usda.gov/education/facts/
- USDA-Natural Resource Conservation Service's Soil Formation and Glossary: http://soils.usda.gov/education/facts/formation.html
- Boulder Creek Critical Zone Observatory's Soil Research website: http://czo.colorado.edu/inter/soil_weather.shtml
- The University of Colorado's Institute for Alpine and Arctic Research homepage: http://instaar.colorado.edu/
- The Colorado Department of Natural Resources, Colorado Water Resources Division webpage: http://water.state.co.us/Home/Pages/default.aspx
- Boulder Creek stream flow data and other resources from B.A.S.I.N.: http://bcn.boulder.co.us/basin/data/STREAMFLOW/STREAMFLOW.html

Extension Activities and Opportunities:
A variety of learner-directed research and science fair projects can center on wildfires, soils, and the hydrological concepts from this module. Some of these opportunities include:

- Contacting your local or regional fire information officers to find locations for upcoming prescribed burns and collecting and comparing pre and post-fire soils, hydrology or fire intensity research projects.
- Collecting and comparing soil, water, and potentially fire data from your area for analysis and learner research.

The Boulder Creek Critical Zone Observatory Program offers a wide variety of data, map layers, and other resources related to their research that can form the foundation for extension activities and are available at: http://czo.colorado.edu

The USDA "FireWorks" Curriculum featuring Ponderosa, Lodgepole, and Whitebark Pine Ecosystems: **www.fs.fed.us/rm/pubs/rmrs_gtr065.pdf**

NOVA-Online's Wildfire Simulator: http://www.pbs.org/wgbh/nova/fire/simulation.html

Glossary

A Horizon: The top layer of soil, just below the duff and characterized by the presence of humus.

Alluvial Plain: An area of the floodplain characterized by the deposition of sediments linked to decreasing stream velocity.

Alluvium: Deposits of clay, silt, sand, gravel, or other particulate material that has been deposited by a stream or other body of running water.

Aquifer: A geologic formation(s) that is water bearing.

Aspect: The direction the majority of a slope faces. Usually expressed in cardinal directions.

B Horizon: The second layer of soil characterized by the deposition of materials leached from the organic layer above it.

Bedrock: A general term for solid rock that lies beneath soil, loose sediments, or other unconsolidated material.

C horizon: A layer in soil taxonomy often used to refer to the bedrock or saprolite.

Canopy: The covering formed by interlocking tree branches or the dominant land cover.

Condensation: The process of water vapor changing to the liquid phase.

Conductivity or Electrical Conductivity: A common water quality measurement quantifying the concentration of salts, minerals or dissolved solids in a water sample using electrical resistance.

Crevasse: An open fissure or deep crack on the surface of a glacier created due to shear stress from the movement of the glacier.

Defensible Space: Natural or man made areas around a building or structure where vegetation is cleared to limit the spread of fires.

Discharge: The volume of water that passes a given location within a given period of time. Usually expressed in cubic feet or meters per second.

Drainage basin: The land area where precipitation runs off into streams, rivers, lakes, and reservoirs. Also called a watershed.

Duff: A layer of decomposing organic matter on the surface of soils (pine needles, leaves, etc).

Entrainment: The process by which rocks from the landscape are incorporated inside a glacier.

Erosion: The process in which a material is worn away by a stream of liquid (water) or air, often due to the presence of abrasive particles.

Estuary: A place where fresh and salt water mix, such as a bay, salt marsh, or where a river enters an ocean.

Evaporation: The process of liquid water becoming water vapor, including vaporization from water surfaces, land surfaces, and snow fields, but not from leaf surfaces. See transpiration.

Evapotranspiration: The sum of evaporation and transpiration.

Fire intensity: A term used to describe the severity, types of fires, or their impact on soils.

Flood plain: A strip of relatively flat and normally dry land alongside a stream, river, or lake that is covered by water during a flood.

Frost cracking: The process in which rocks are broken up by water trapped in crevices freezing and expanding, further cracking the rock or breaking pieces off.

Fuel Load: The dry weight of fuels in a given area.

Fuel: Biological or man made materials that combust during fires. Like fire intensity, they can be classified as light, medium or high levels of fuel.

Glacial Striations: Long grooves in the bedrock cut by glacial abrasion as the glaciers move across the surface.

Glacial Till: A random, non-homogenous mixture of rocks, gravel, boulders, and rock flour left behind in clumps as glaciers leave an area.

Glacial Valley: Broad, often smooth, U-shaped valleys cut into mountains by glaciers.

Glacier: A mass of ice formed on land by the compaction and recrystallization of snow that moves very slowly down slope or outward due to its own weight.

Ground Fire: A fire that occurs underground in the soils, roots, and duff.

Ground water: Water that flows into and saturates soil or rock layers

Headwater(s): The source and upper reaches of a stream or river system.

Horizons: A term used to describe the layers formed in stable soils and differentiated by color, texture or other characteristics.

Humus: The organic component of soil, formed by the decomposition of leaves and other plant material by soil organisms.

Hydrocarbons: Any compound made of the elements carbon and hydrogen. Often used to define fossil fuels such as petroleum or natural gas.

Hydrologic cycle: The cyclic transfer of water vapor from the Earth's surface into the atmosphere, and back to Earth.

Hydrology: A branch of geology focused on the Earth’s water and water systems.

Hydrophobic: A term used to describe materials that, due to polarity, repel water.

Impermeable layer: A layer of solid material, such as rock or clay, which does not allow water to pass through.

Infiltration: Flow of water from the land surface into the subsurface.

Irrigation: The controlled application of water for agricultural purposes through manmade systems to supply water requirements not satisfied by rainfall.

Ladder Fuels: Materials or ecosystem structures that allow fuels to spread vertically through the forest canopy.

Leaching: The process by which soluble materials in the soil, such as salts, nutrients, pesticide chemicals or contaminants, are washed into a lower layer of soil or are dissolved and carried away by water.

Meander: A term used to describe the shape of a stream that naturally twists and curves across the land surface.

Meltwater: A term referring to the water released from a glacier or snowpack due to melting.

Moraine: An accumulation of unconsolidated debris such as soil or rocks which are collected by a moving glacier and deposited in a location as the glacier moves or melts.

Morphology: A term used to describe the shape and physical form of something.

Non-point source (NPS) pollution: Pollution discharged over a wide land area, not from one specific location.

O horizon: The top layer of soil composed of dead and decaying plant matter.

Parent Material: The base material from which soils are formed, usually bedrock.

Permeability: The ability of a material to allow the passage of a liquid, such as water.

pH: A term used to describe the amount of free hydrogen ions in a solution and used to describe the strength of acids, bases, and solutions.

Point-source pollution: Water pollution coming from a single area or source.

Pool: An area of a stream where the water is slow and the stream area widens, often interspersed with riffles and runs.

Porosity: A measure of the water-bearing capacity of subsurface rock.

Reservoir: A pond, lake, or basin, either natural or artificial, for the storage, regulation, and control of water.

Riparian Zone: The portion of the land located next to a stream or river, often wetter than the surrounding landscape.

Runoff: That part of the precipitation, snow melt, or irrigation water that appears in uncontrolled surface streams, rivers, drains or sewers.

Saprolite: Chemically weathered bedrock that has not mobilized.

Sediment: Usually applied to material in suspension or recently deposited from suspension. In the plural the word is applied to all kinds of deposits from the waters of streams, lakes, or seas.

Sedimentary rock: Rock formed of sediment, and specifically: (1) sandstone and shale, formed of fragments of other rock transported from their sources and deposited in water; and (2) rocks formed by or from secretions of organisms, such as most limestone.

Shale: A type sedimentary rock formed by layers of mud and clay that is soft and highly stratified.

Snowpack: An accumulation of snow throughout the year that has not yet turned into ice.

Surface Fire: A fire that occurs in surface fuels.

Surface water: Water that is on the Earth's surface, such as in a stream, river, lake, or reservoir.

Thinning: The removal of understory and canopy trees to reduce fire fuels.

Transpiration: The process by which water that is absorbed by plants, usually through the roots, is evaporated into the atmosphere from the plant surface. See evapotranspiration.

Tributary: A smaller river or stream that flows into a larger river or stream. Usually, a number of smaller tributaries merge to form a river.

Turbidity: The amount of solid particles that are suspended in water and that cause light rays shining through the water to scatter.

Understory: Vegetation that grows underneath the tree canopy or dominant land cover.

Water cycle: The circuit of water movement from the oceans to the atmosphere and to the Earth and return to the atmosphere through various stages or processes such as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transportation.

Water quality: A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

Water table: The top of the water surface in the saturated part of an aquifer.

Watershed: The land area that drains water to a particular stream, river, or lake.

Weathering: The breakdown, or decomposition, of surface materials by mechanical, chemical, or biological processes.

Wildland Urban Interface: The point where natural and built communities meet.