Predicting Wildland Fire Impacts on Public Drinking Water

William B. Samuels[1] Douglas Ryan[2], Kevin Hyde[3], William Elliott[4], David Calkin[5], Kelly Burnett[6], Dan Miller[7] and Deborah Martin[8]

[1]SAIC, McLean, VA
[2]USFS, Forestry Sciences Laboratory, Olympia, WA
[3]Collins Consulting, USFS, Forestry Science lab, Missoula, MT
[4]USFS, Rocky Mountain Research Station, Moscow, ID
[5]USFS, Forestry Science Lab, Missoula, MT
[6]USFS, Pacific Northwest Research Station, Corvallis, OR
[7]Earth Systems Institute, Seattle, WA
[8]USGS, Wildfire Group, Boulder, CO

ESRI Users Conference
San Diego, CA
July 16, 2009

Introduction

- A Government Report found that decision makers responding to and planning for wildland fires lack the ability to adequately consider a wider range of values-at-risk beyond current capabilities.

- Most existing decision support tools focus on buildings located within the projected fire boundary during the period while the fire is burning, while fire impacts on values such as public drinking water can occur outside of this space and time.

- This project seeks to fill this identified need for improved emergency response decision support.

Background

- The potentially long-lasting effects on drinking water (disruptive effects can last months to years after a large fire) make information about drinking water impacts a high priority need for decision makers.

- Depending on the contaminant source, fire-related risks to drinking water can occur as the fire is burning from fire-caused toxic spills and fire retardant application, or months to years after the fire is out, caused by rain-storm driven washoff of ash, and accelerated soil erosion or landslides from burned lands.

Sediment – Drinking Water Problem

CASE STUDY

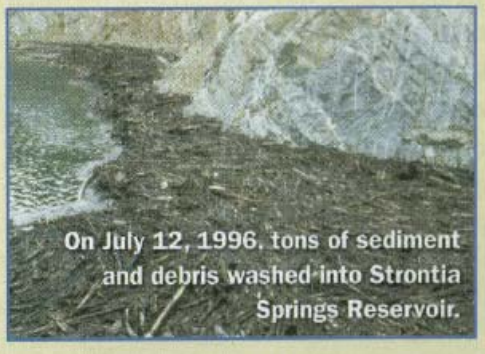
USING WILDFIRE EXPERIENCE TO ASSESS AND MITIGATE VULNERABILITIES

Several studies suggest that wildfires could become more frequent in many regions as climate change imposes new stresses on vegetation. Vegetation patterns will change through time in response to the changing climate, and fire will likely play a role in that evolution.

Denver Water has experienced substantial effects on its water quality attributable to wildfire. In 2002, in the midst of a severe drought, the largest wildfire in Colorado's history—known as the Hayman fire—literally surrounded Denver Water's Cheesman Reservoir, burning 97 percent of the 7,245 acres owned by the utility.

However, the devastation caused by the Hayman fire pales in comparison with the consequences of a much smaller fire that occurred six years earlier. The Buffalo Creek fire burned 11,900 acres on May 18, 1996. Although Buffalo Creek itself contributes only a small part of Denver's water supply, it is strategically located directly upstream of the critically important Strontia Springs Reservoir, which is the intake point for the utility's Foothills Treatment Plant. The Strontia Springs–Foothills facilities typically handle about 80 percent of Denver's water.

Two months after the Buffalo Creek fire, heavy thunderstorms directly over the denuded burn area resulted in a flash flood that killed two people and washed tons of sediment and debris down the creek and into Strontia Springs Reservoir. The debris flow necessitated emergency cleanup operations costing nearly $1 million. Elevated turbidity became a chronic problem in the reservoir, requiring an additional $250,000 in water treatment costs each year. In addition, dredging costs, necessitated by rapid sedimentation, may amount to $15 million to $20 million during the next 10 yr. Long-term effects of both fires include ongoing erosion, sedimentation, and transport of heavy metals and micronutrients into the reservoirs.



On July 12, 1996, tons of sediment and debris washed into Strontia Springs Reservoir.

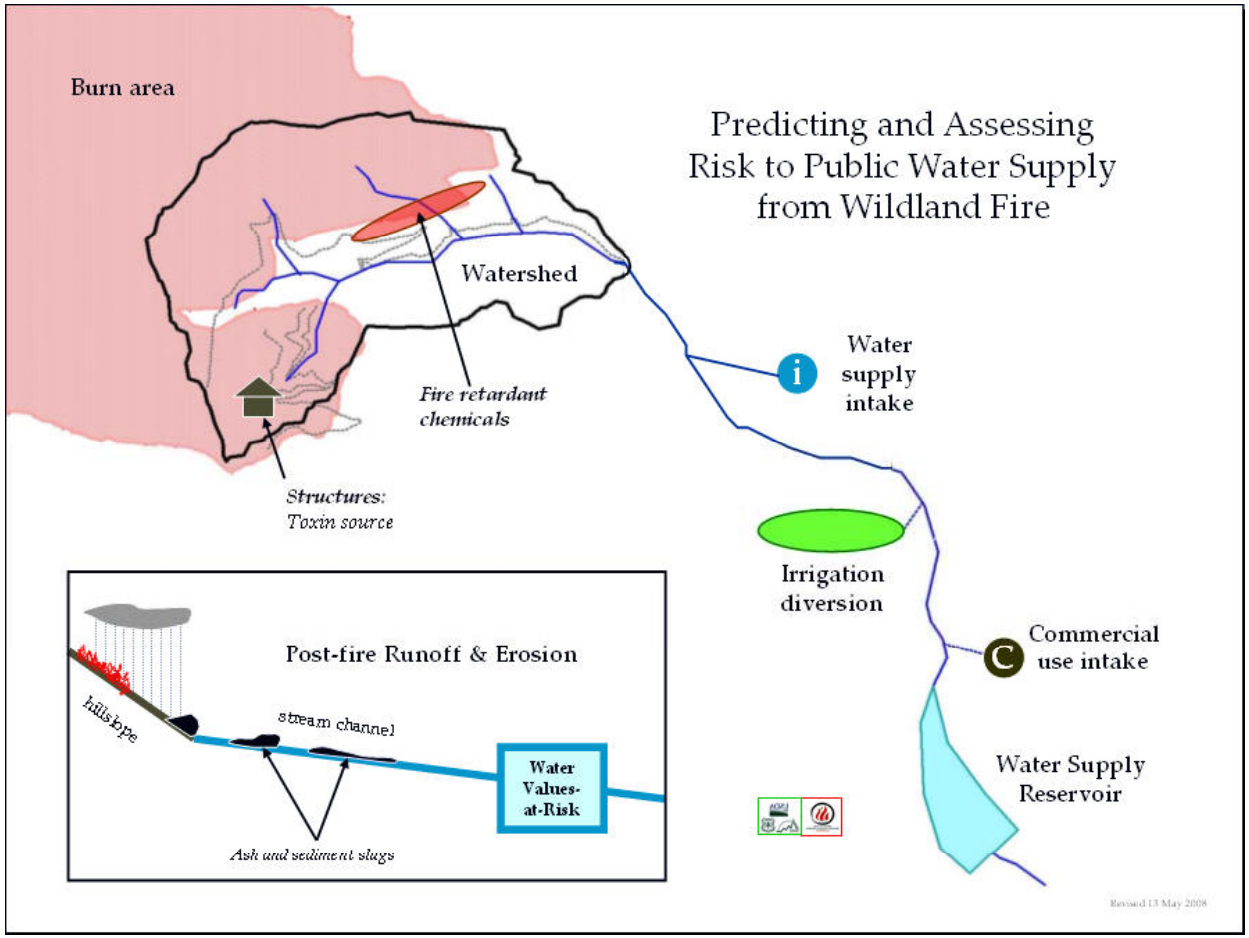
A lesson from Denver Water's experience is that water utilities should be proactive in assessing the potential consequences of wildfires, particularly with respect to sediment and debris flows, in determining appropriate rapid responses during actual crisis events.

— AWWA Research Foundation, © 2006, reprinted with permission

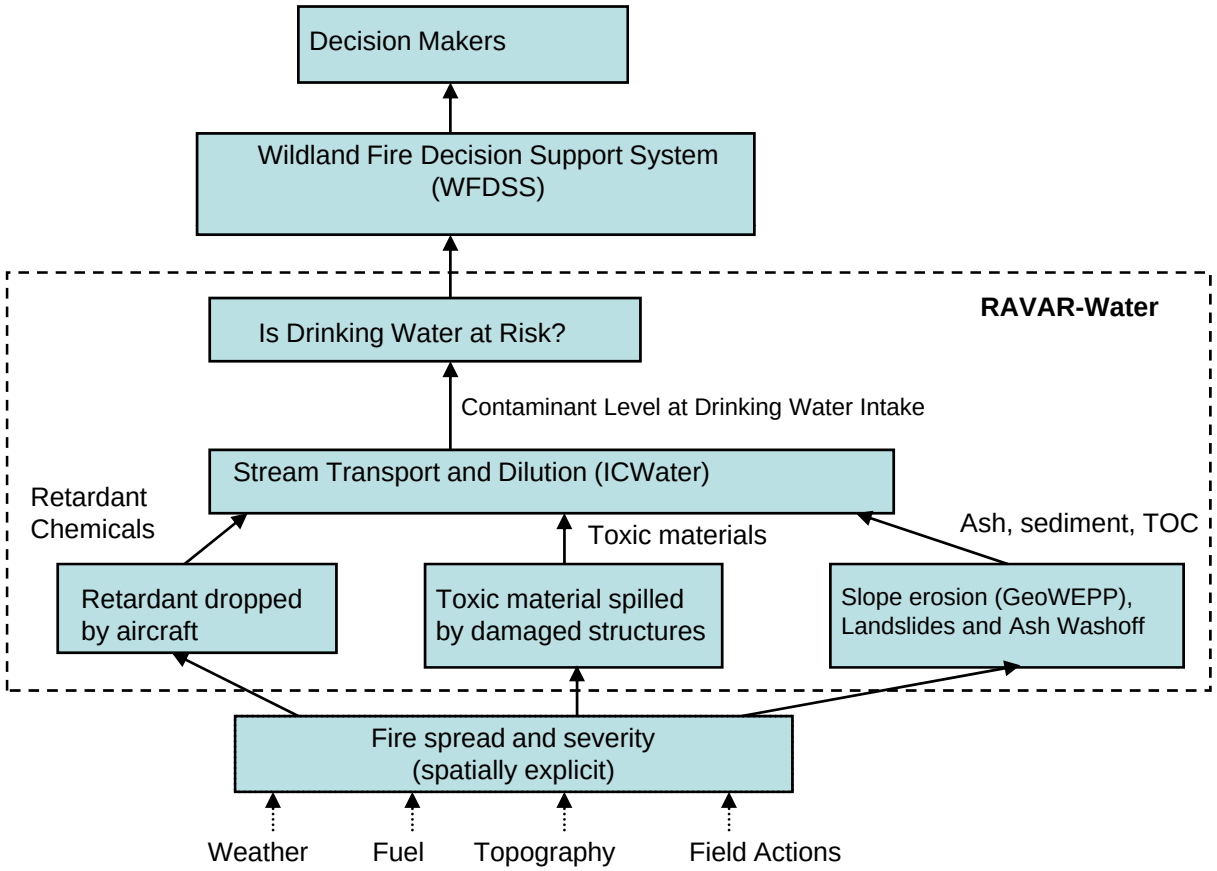
Technical Challenges

- Developing automated links between the proposed tool and FSPro (Fire Spread and Intensity Model), and WFDSS.
- Linking contaminant generation models to ICWater. Proof of principle work using the ICWater has already demonstrated this capability by simulating the impact on drinking water of a high sediment event (using WEPP), fire retardant drops and toxic spills. Proof of principle still needs to be demonstrated for sediment generated by landslides, and ash and dissolved organic matter washoff during rain events.
- Incorporating probability of future events into risk estimations. This capability has already been demonstrated by the proof of principle work simulating high sediment and erosion events (using WEPP), but still needs to be accomplished for landslides, ash and dissolved organic matter.
- Many models exist of complex processes sediment transport. But because fine sediment (clay and silt particles) pose the greatest risk to drinking water, we can simplify our modeling to only these fine-particle fractions which, in turbulent rivers, have behavior similar to dissolved constituents already modeled in ICWater.

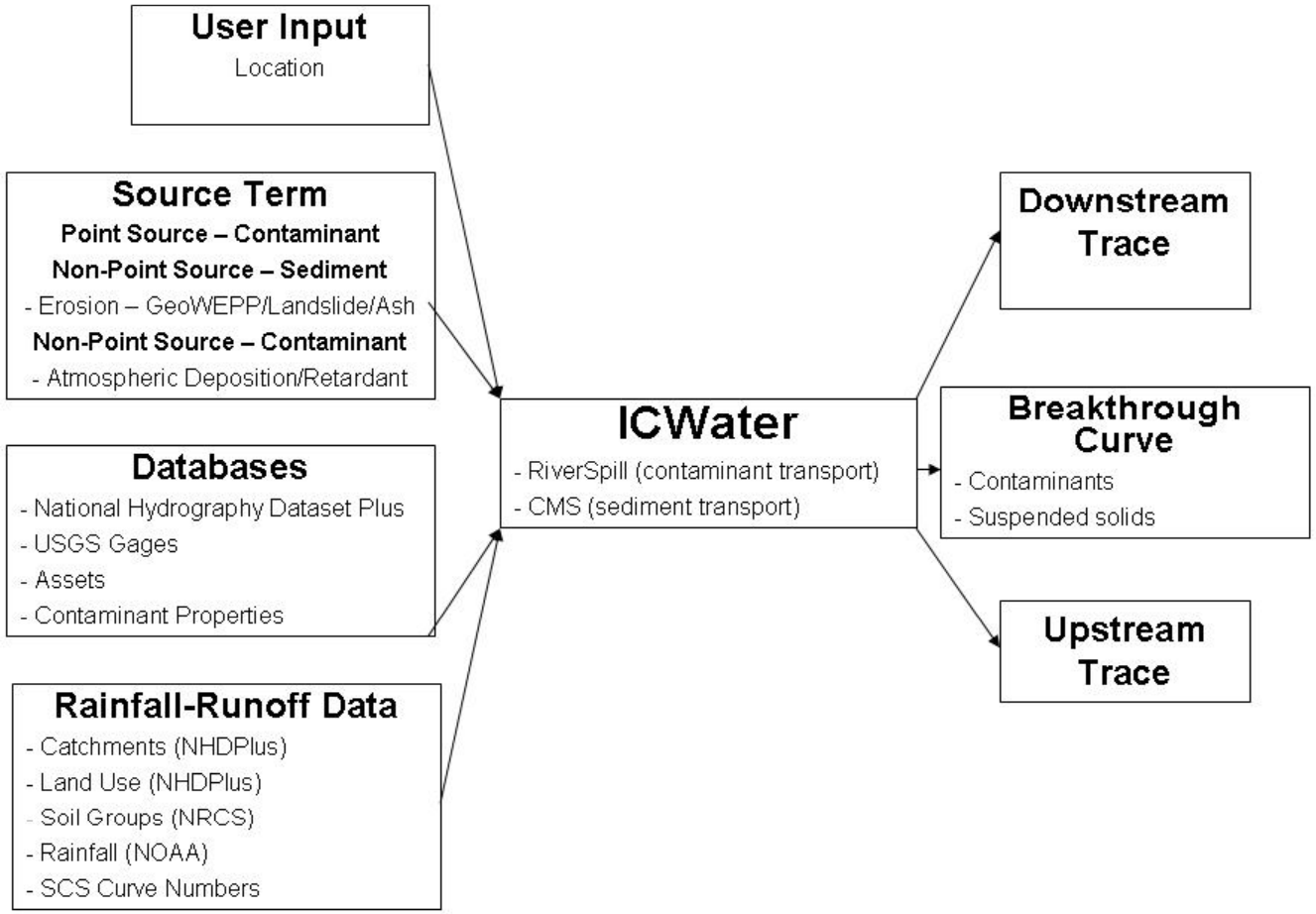
Conceptual Design



Schematic Diagram

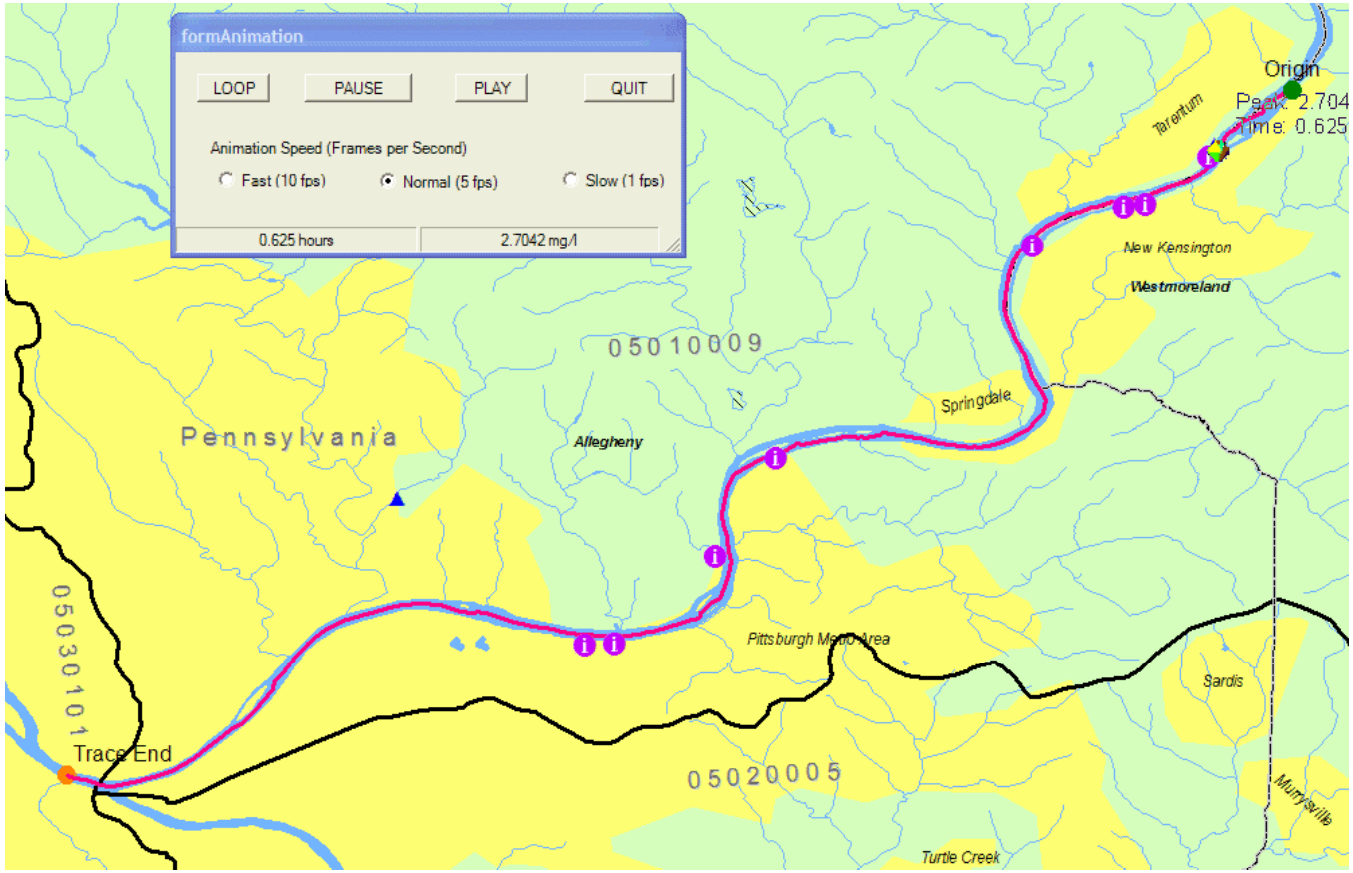


System Architecture



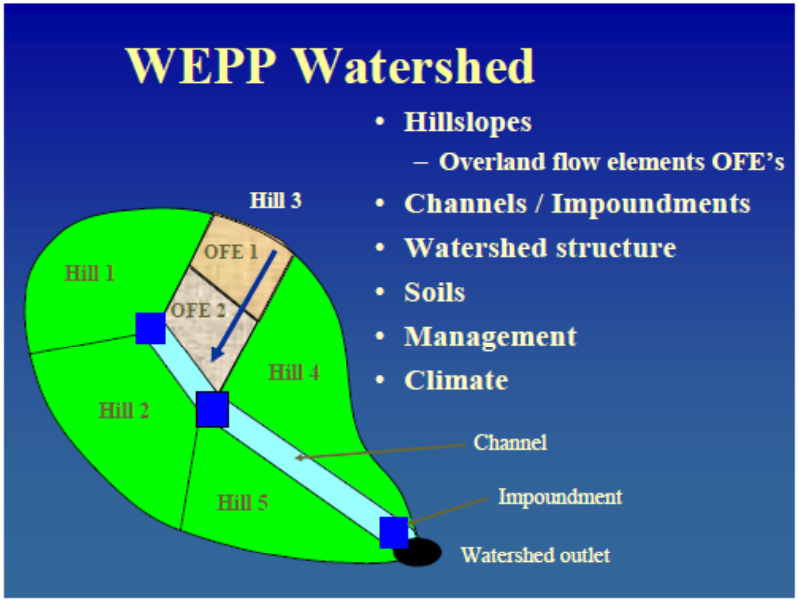
SAIC
From Science to Solutions

ICWater Architecture



Erosion

- The **Water Erosion Prediction Project (WEPP)** model is a continuous simulation, process-based model that allows simulation of small watersheds and hillslope profiles within those watersheds for assessing various soil and water conservation management options for agricultural, rangeland, and forest sites.



WEPP Output

1 event produced 7.00 mm. of runoff
passing through the watershed outlet on an AVERAGE ANNUAL basis

Average Annual Delivery From Channel Outlet:

Total contributing area to outlet	=	1776.98	ha
Avg. Ann. Precipitation volume in contributing area	=	0.	m^3/yr
Avg. Ann. irrigation volume in contributing area	=	0.	m^3/yr
Avg. Ann. water discharge from outlet	=	124407.	m^3/yr
Avg. Ann. sediment discharge from outlet	=	5601.6	tonnes/yr
Avg. Ann. Sed. delivery per unit area of watershed	=	3.2	T/ha/yr
Sediment Delivery Ratio for Watershed	=	0.84	

ASH

[redacted]

Transport to surface water body by overland flow: GeoWEPP
Ash is moved under same intensity thresholds as hillslope sediment

Dissolved Phase

Chemical load

1. Soluble components readily released
2. Use data from 5-minute leach tests

Units: mg/kg of ash

ICWater: 1.Transformation is by DILUTION
2. SDA: no chemical transformations
3. Conc. at intake triggers ALERT

Particulate Phase

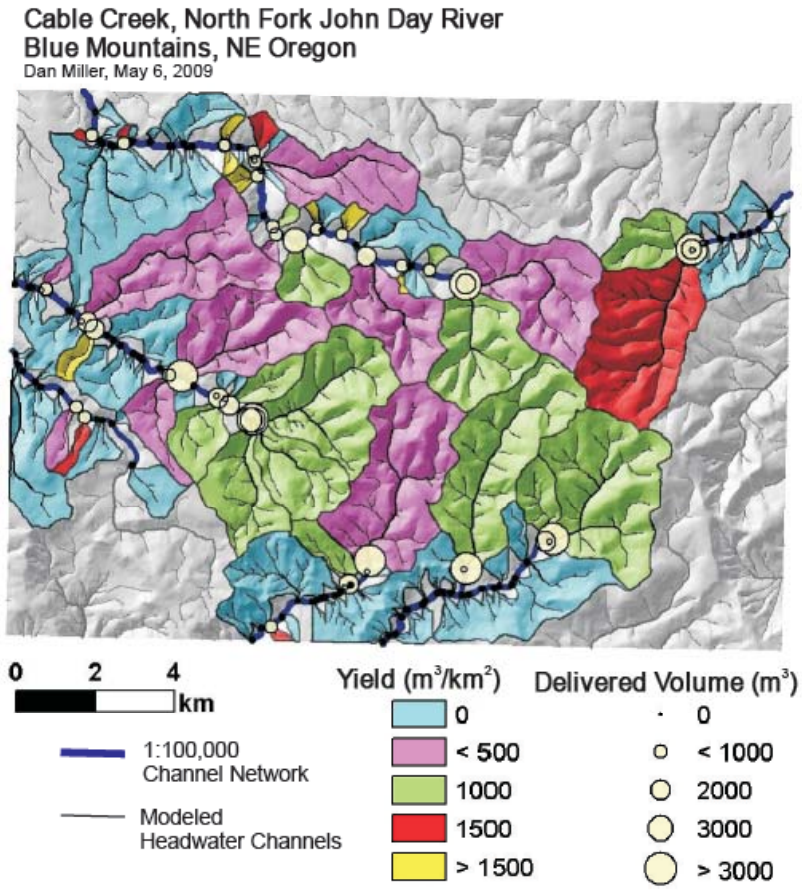
Suspended sediment load (ash only, need to add to SS load from hillslope erosion)

Data gap: 1. Will mass of particulate phase continue to change as it is transported downstream?

Units: mg/kg of ash

ICWater: 1.Transformation is by DISSOLUTION
2. Conc. at intake triggers ALERT

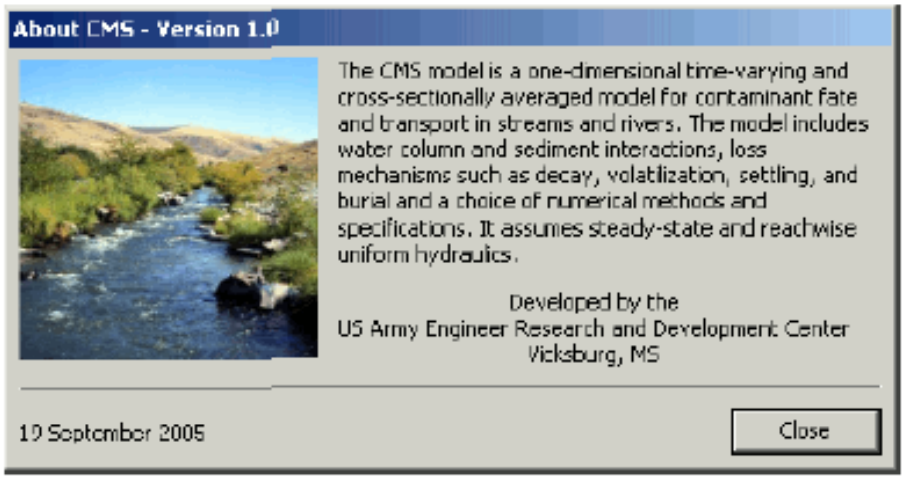
Landslide – Debris Flow



Example outputs from debris-flow models. This map shows modeled sediment from headwater basins delivering to the 1:100,000-scale network in terms of both yield over each basin (colored polygons) and volume delivered (variably sized circles). This map shows the result for a single post-fire storm; model calibration to this storm from data collected by Will Russell.

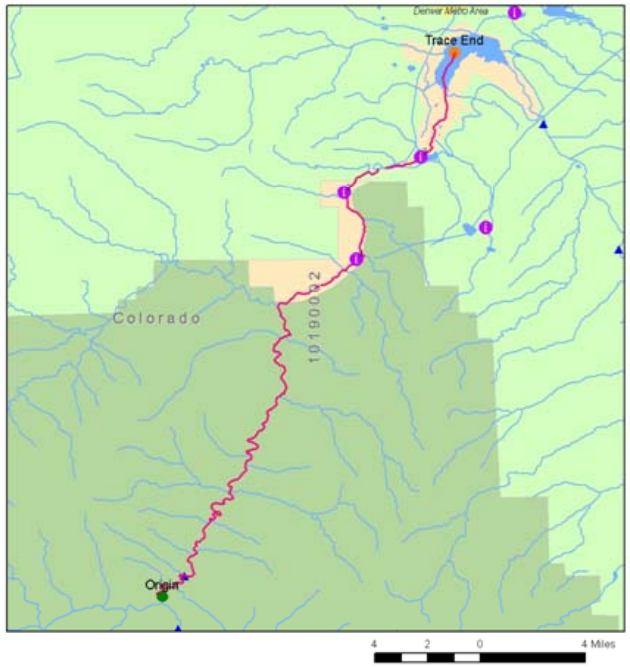
Sediment Transport

- Integration of ICWater with CMS
  - The Contaminant Model for Streams (CMS) was developed for studies where data and resources for model application are limited.
  - predicts short- and long-term concentrations of contaminants in the water column and bottom sediments.

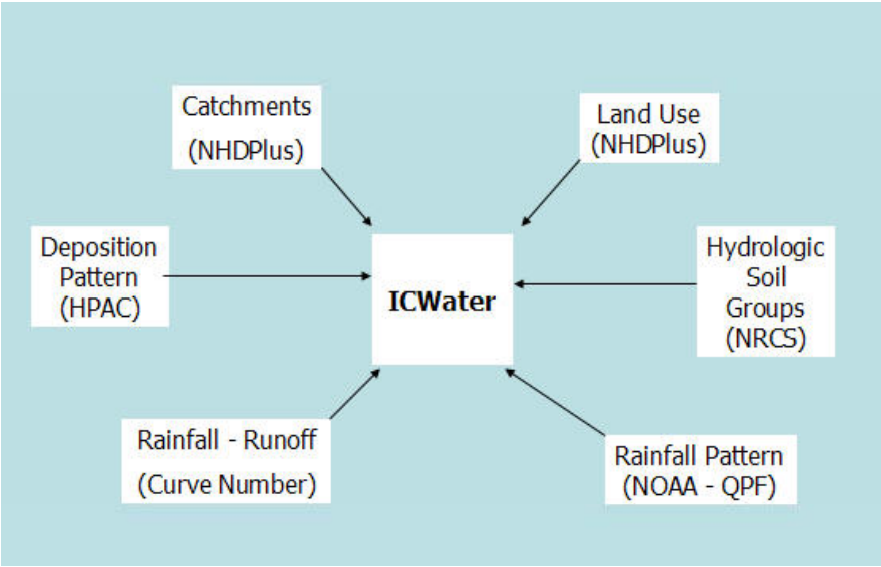


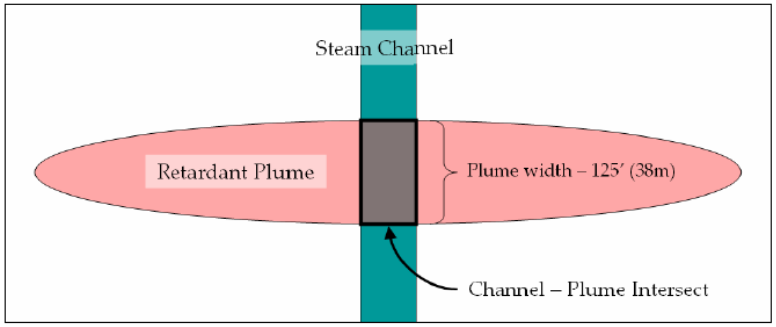
ICWater Output Report

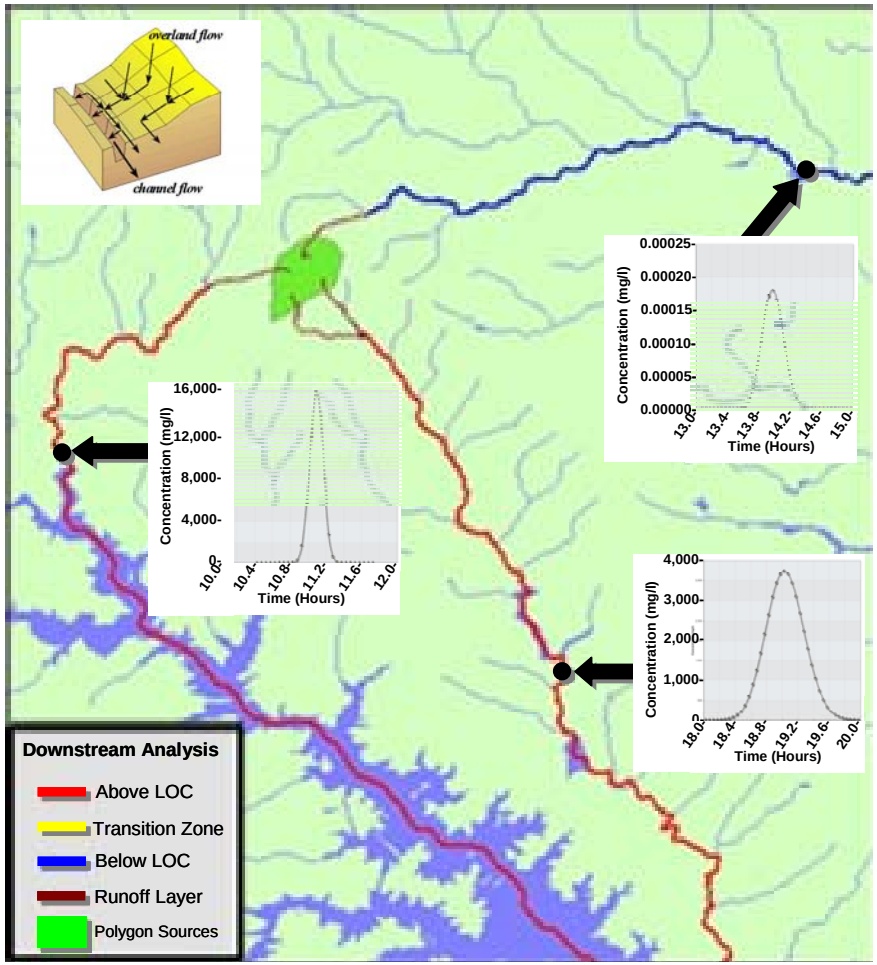
Index	Facility	City	State	Population Served	Phone	Downstream Distance (miles)	Peak Conc. (mg/l)	Peak Time (Hours)	Leading Edge (Hours)	Trailing Edge (Hours)	Duration LOC (Hours)
1	AURORA - CITY OF	AURORA	CO	160000	303 695 7370	19.86	12645.250	16.38	15.38	17.63	2.25
2	DENVER BOARD OF WATE	DENVER	CO	766000	--	22.90	12617.407	18.63	17.38	19.88	2.50
3	DENVER BOARD OF WATE	DENVER	CO	766000	--	26.39	12336.752	21.13	19.88	22.38	2.50



ICWater – Atmospheric Deposition







Energy | Environment | National Security | Health | Critical Infrastructure

Summary and Conclusions

- Provide incident command teams with informative, succinct and timely reports of wildland fire risk to drinking water via WFDSS.
- Use wildland fire spread and severity predictions from models and, when available, from remotely-sensed or field-measured data to estimate water contaminant sources.
- Identify all public drinking water surface intakes and structures that contain toxic materials that will be impacted by wildland fire effects.
- Assess potential risk to drinking water caused by:
  - » toxic spills from fire damage to structures containing toxic materials.
  - » fire retardant chemical drops from aircraft
  - » ash, sediment and dissolved organic matter transported to streams by rain events
- Predict time of arrival and concentration of fire-related contaminants in source water at downstream public drinking water intakes and other points along their path of travel.
- Make estimates of risk based on probability for future timing and magnitude of rainfall (e.g. size of contaminant event depends on return frequency of rainfall events)
- Predict impacts to drinking water from a wildland fire occurring in any of the 50 states.