



Rain-on-Mesh Modeling to Inform Post-Fire Restoration

**Russ Anderson, Michael Baker
Geoff Uhlemann, Michael Baker**

Sustaining Colorado Watersheds – 10/06/2021

About the Presenters (& Presentation)



Geoff Uhlemann - PE, CFM,
PMP
Michael Baker – Denver, CO



Russ Anderson- PE, CFM
Michael Baker – Denver, CO
Water Resources PM

- **Background**
- **RoM Basics**
- **Results**
- **Applications**

About the Contributors (& Presentation)

- Model Construction
- Post-Fire Factors
- Simulations



Kyle O'Neil

Michael Baker – Denver, CO

H&H Engineer



Kelly Watson
Boulder County

Project Purpose

- Identifying structures likely to overtop for possible storms
- OEM for advance warning (notifying residents) & closing roads
- Evaluated peak flows and elevations 0.25-3.75" 1-hr storms (>500 yr)
Building a library for event matching
- Completed between 3/18-5/25/21
- More Info at:
<https://www.bouldercounty.org/disasters/wildfires/calwood-lefthand-canyon/>

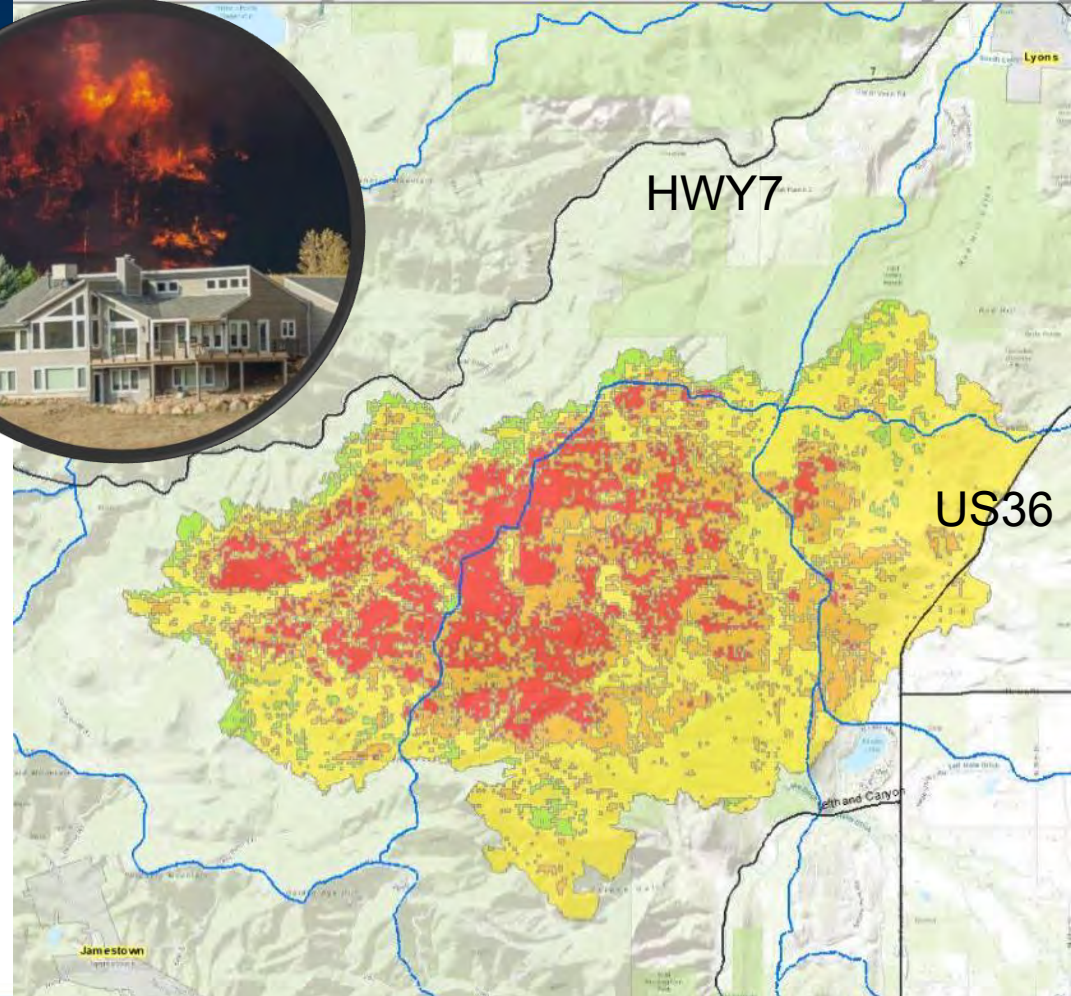


Project Purpose



The Fire

- Burned 10,113 acres between Oct 17-Nov 14 2020
- Covers portions of 4 HUC-12s
- All of Geer burnt & drains to LHC
- Lower Central Gulch burnt & drains to SSVC

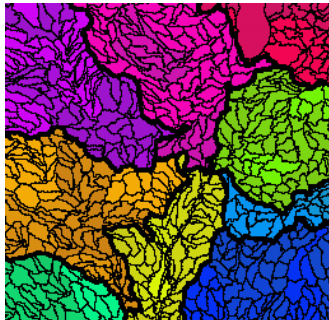


Rain-on-Mesh (RoM) Methodology (aka RoG, 2D BLE)

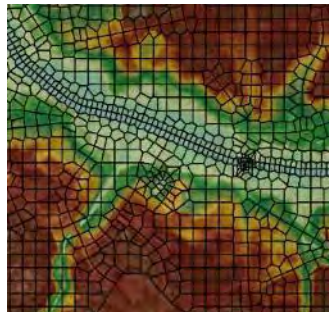
**Build Terrain
& DEMs**



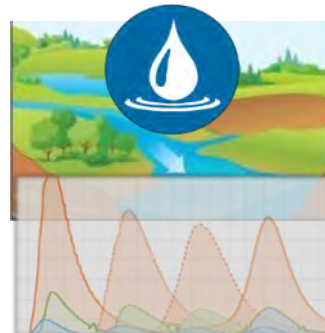
**Develop Domains
& Hydrology**



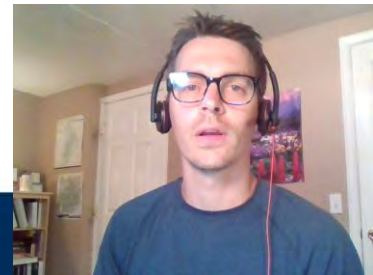
**Mesh Creation
& Refinements**



**Apply Rainfall
& Calibrate**

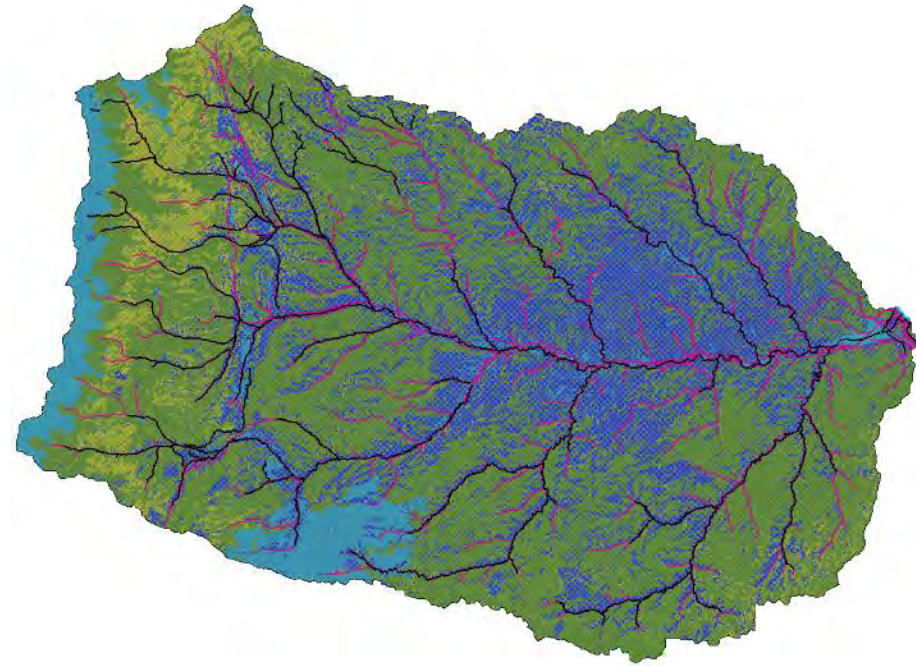


**Simulations &
Mapping**



Example RoM Layers

Manning's N (land use & calibration)

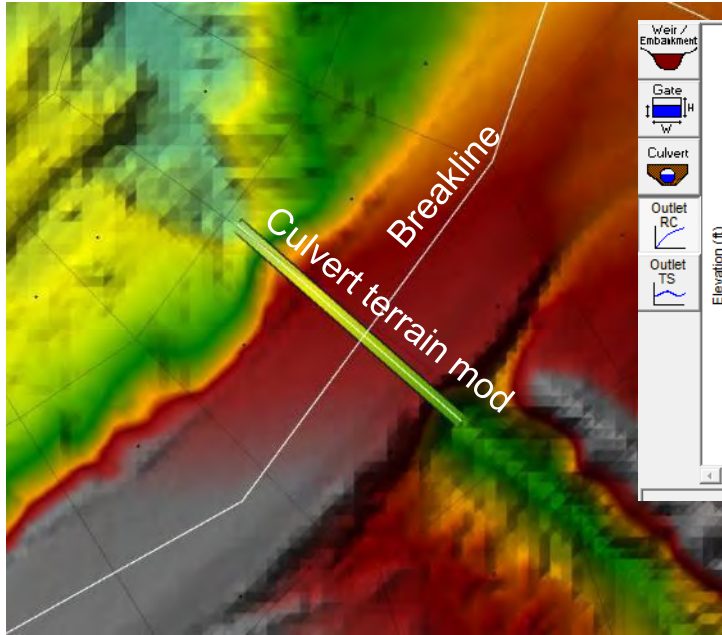


Infiltration (land use, soils, & calibration)

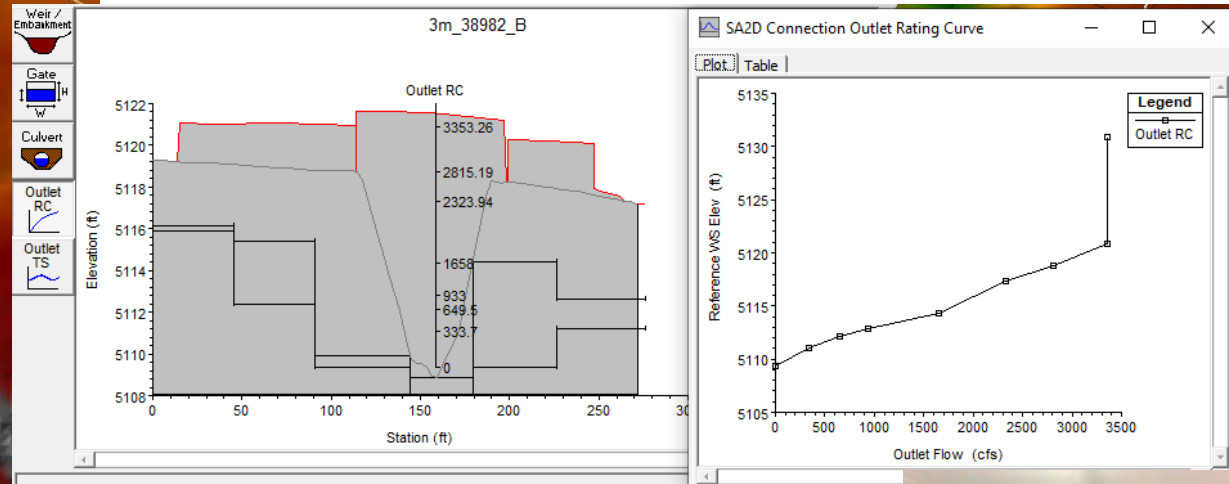


Example RoM Refinements

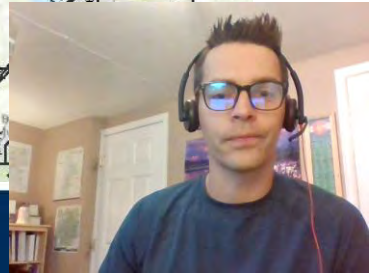
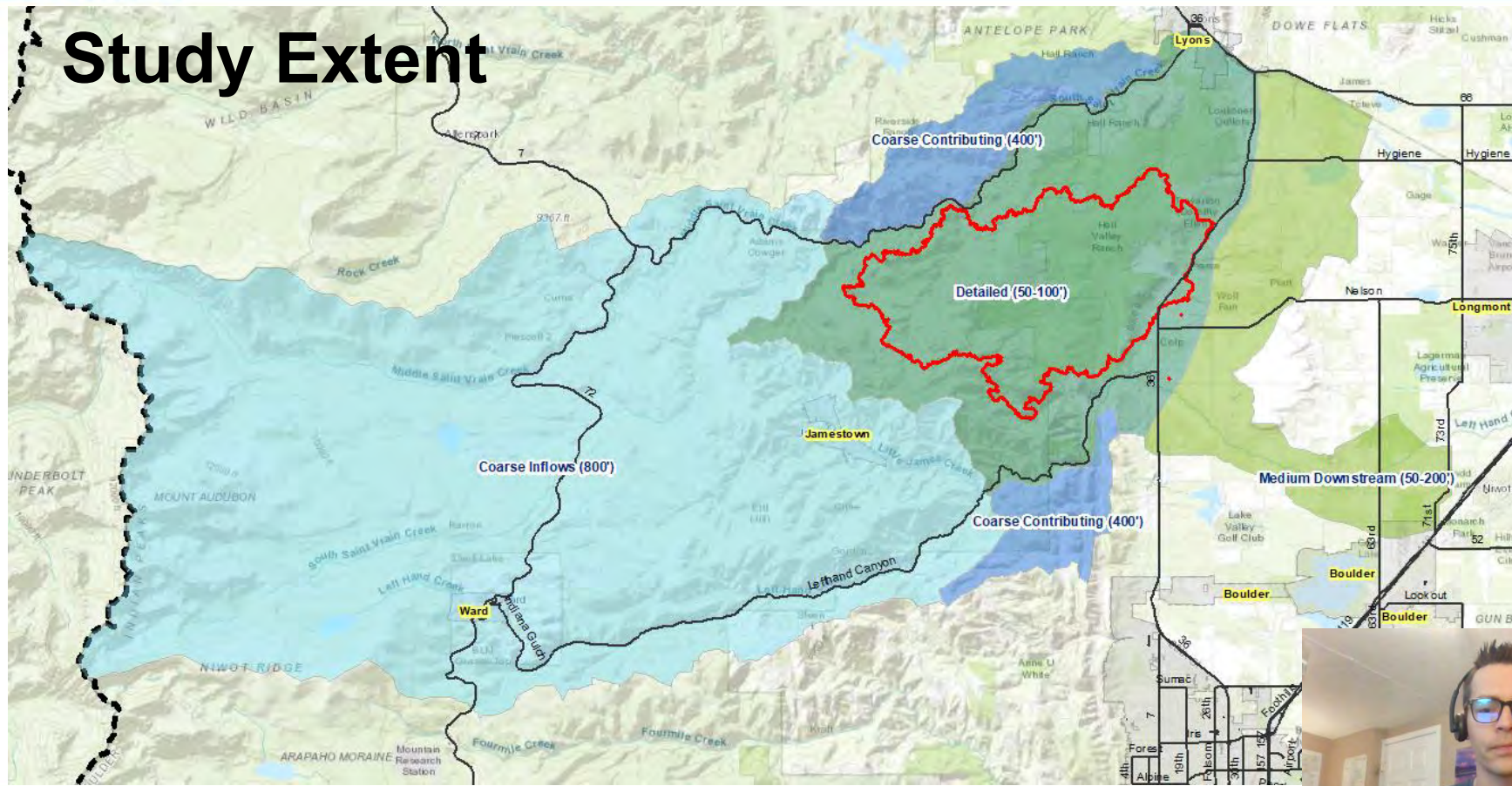
Typical Modification for Opening



Structure Rating Curves (extracted from eff 1D)



Study Extent



Post-Wildfire Hydrology Guidance

USDA Natural Resources Conservation Service
United States Department of Agriculture

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 - Stream Restoration
- Water Quality
- Watersheds
- Wetlands

Fire and Post-Wildfire Hydrology

NRCS Technical Note:
Hydrologic Analyses of Post-Wildfire Conditions

***This Technical Note will be updated soon, and will include another case study, a draft of which may be downloaded here:
[NRCS case study 6](#)

hydrologic model downloads

[WinTR-20](#) [WinTR-55](#) [HeCHMS](#)

USFS fire hydrology spreadsheet:
[Wildcat5](#)

NRCS Fire Hydro spreadsheet:
[Fire Hydrology](#)

Info about Fire Hydro: [User Notes](#)

wildfire hydrology references

USFS BAER Tools:
[Post Fire Analysis Tools](#)

USFS Guide for pre and post wildfire modeling:
[Modeling Guide](#)

Reference list from the NRCS technical note
[Wildfire References](#)



United States Department of Agriculture

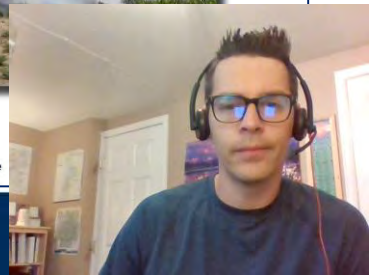
August 2016

Hydrology Technical Note No. 4

Hydrologic Analyses of Post-Wildfire Conditions



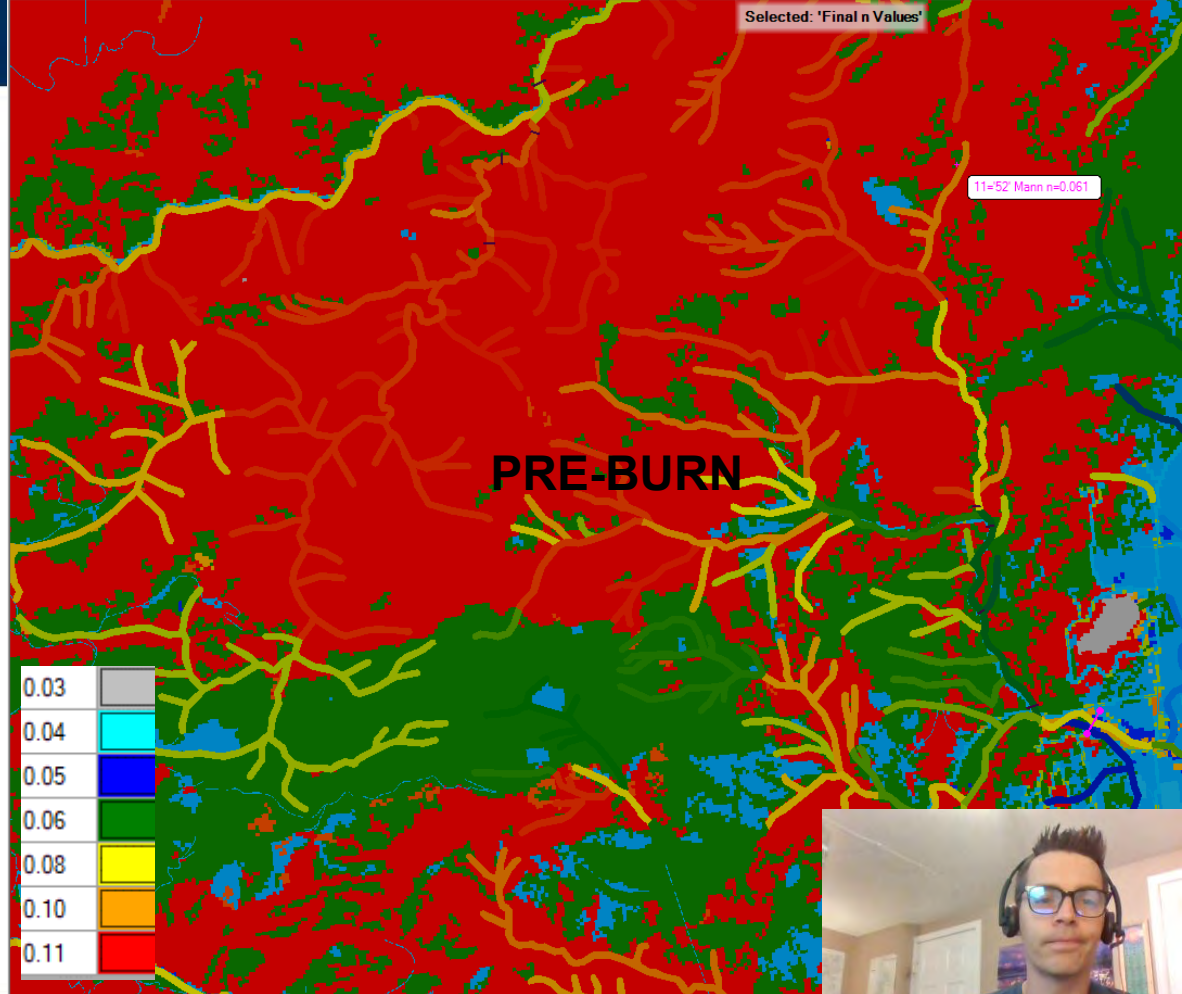
Natural Resources Conservation Service



Model Layers

Manning's n

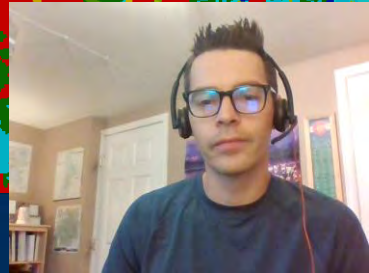
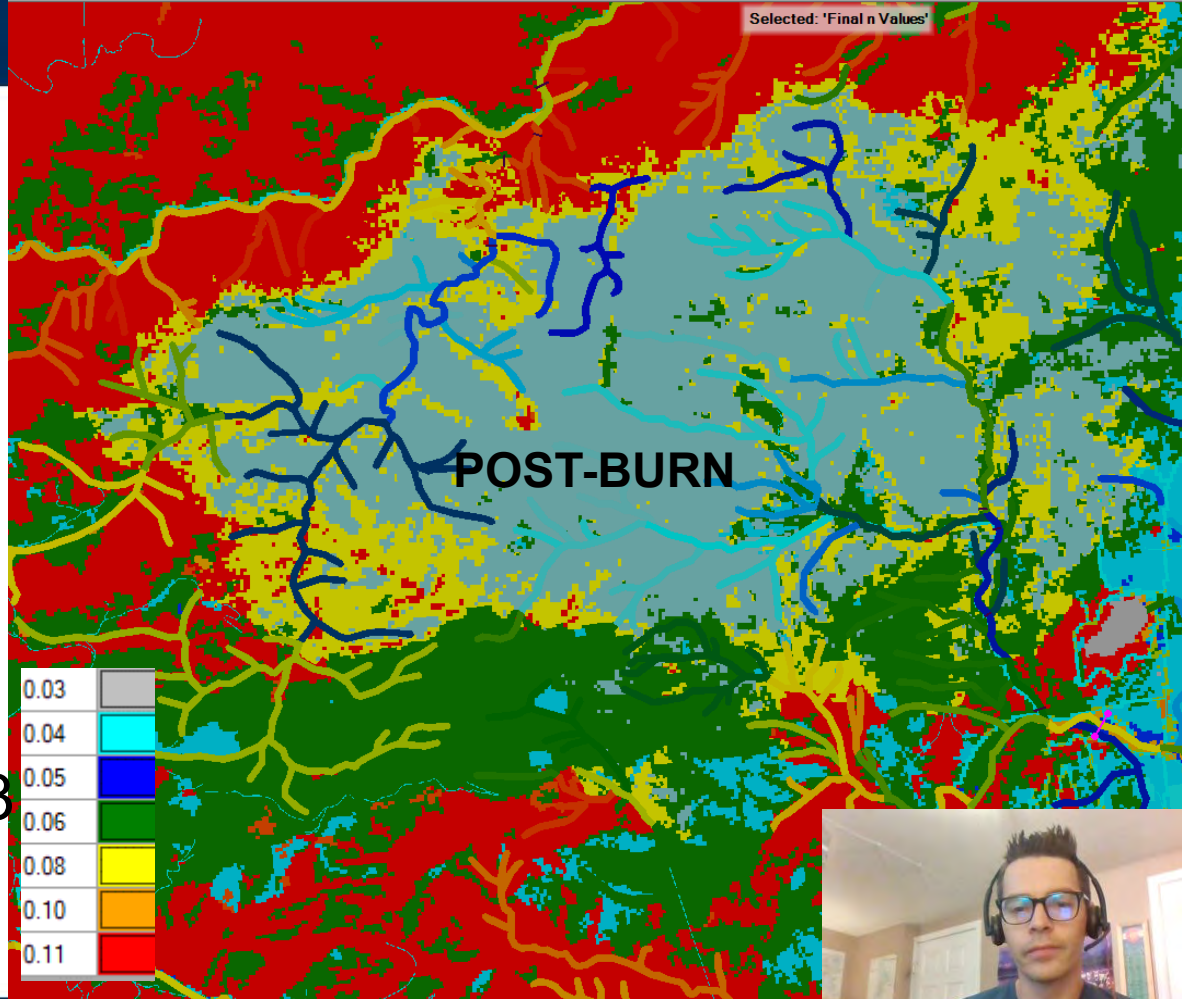
- Base layer from NLCD
- Sampled aerial
- 10' cell resolution



Model Layers

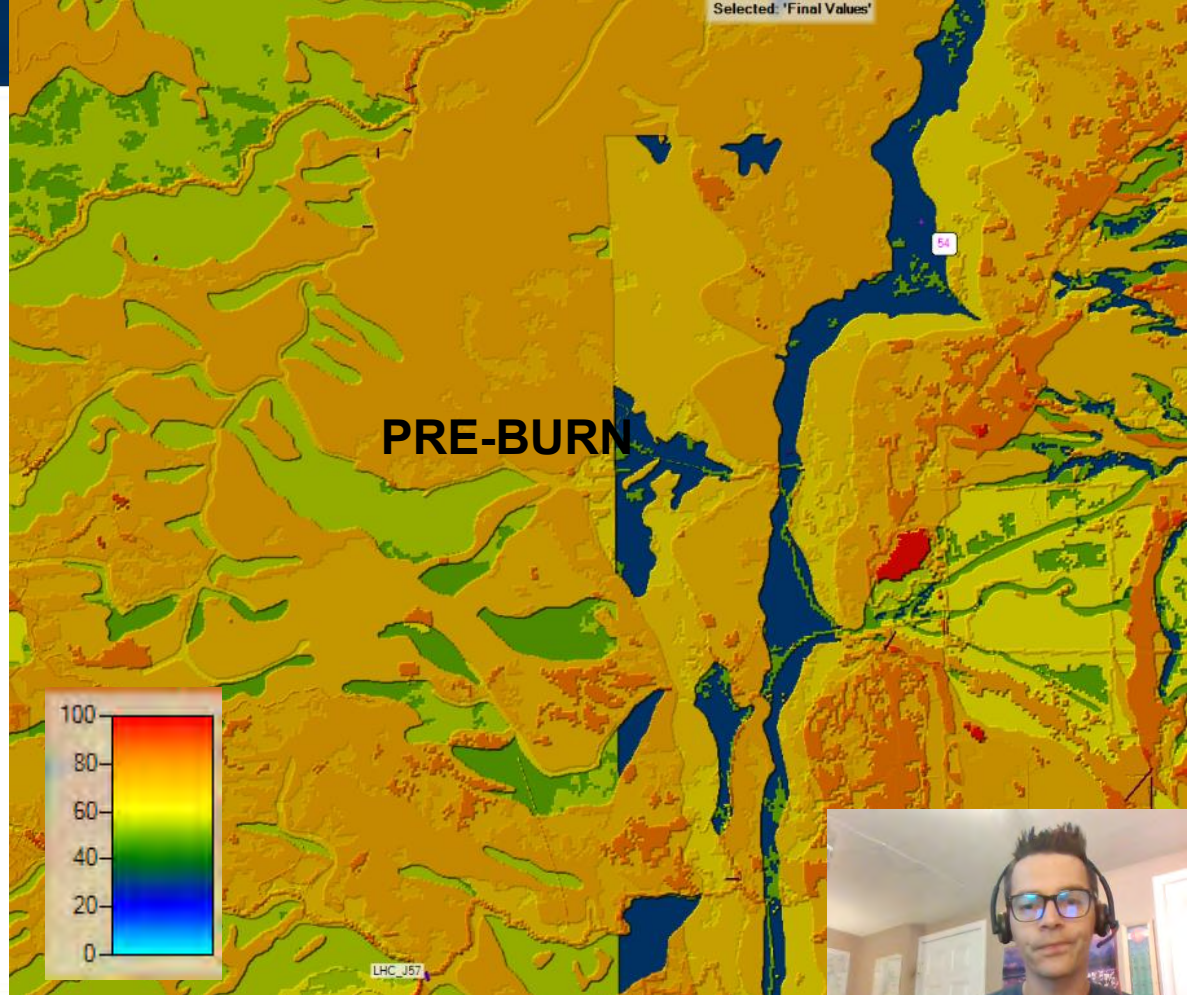
Manning's n

- Base layer from NLCD
- Sampled aerial
- 10' cell resolution
- Post-fire Adjustments
 - Low burn = 0.08
 - Mod/Severe = 0.033



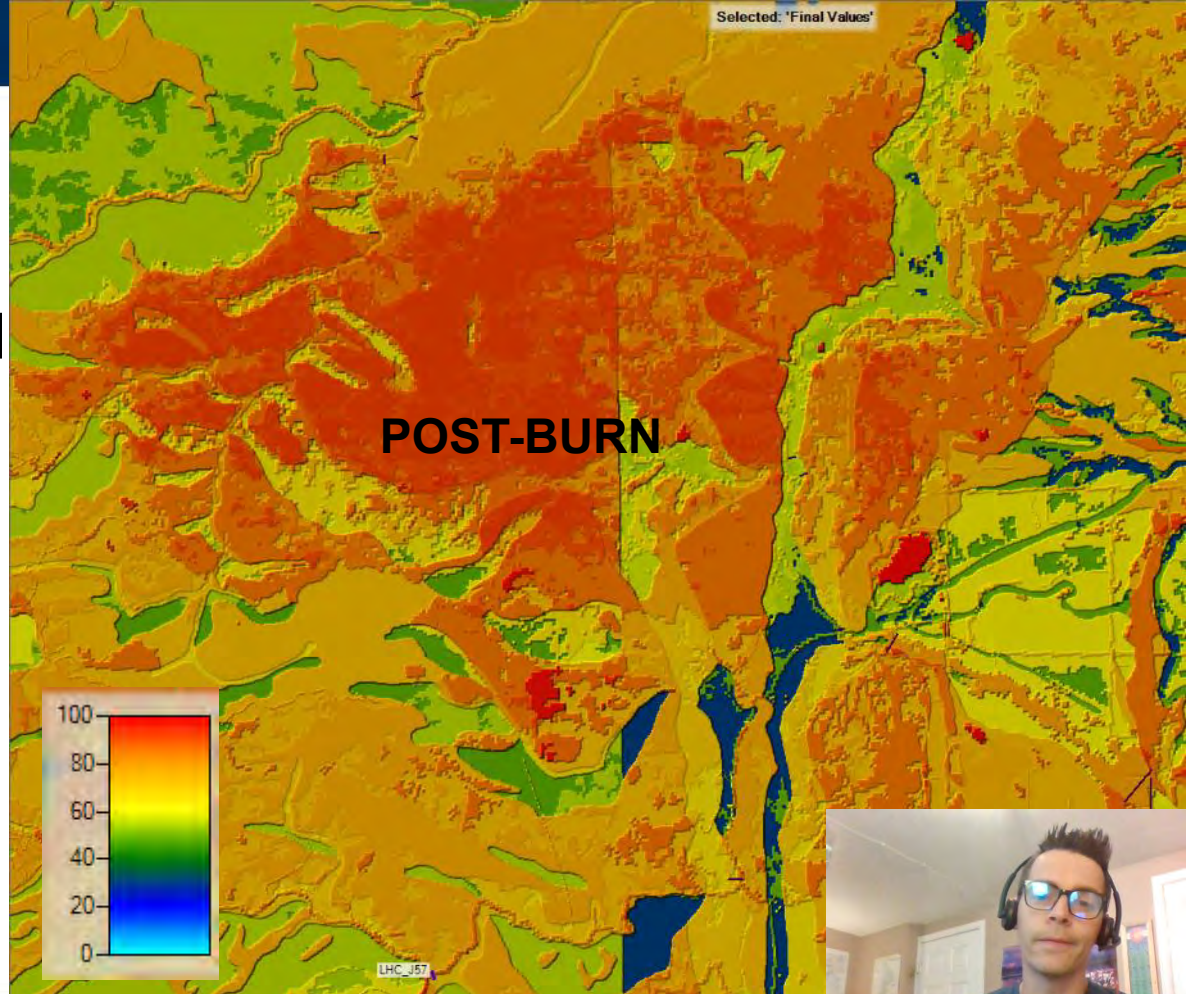
Model Layers Infiltration/CN

- Combo of land cover and soils from SSURGO
- 10' cell resolution
Losses at cell level
- $I_a=0.2$ pre-burn

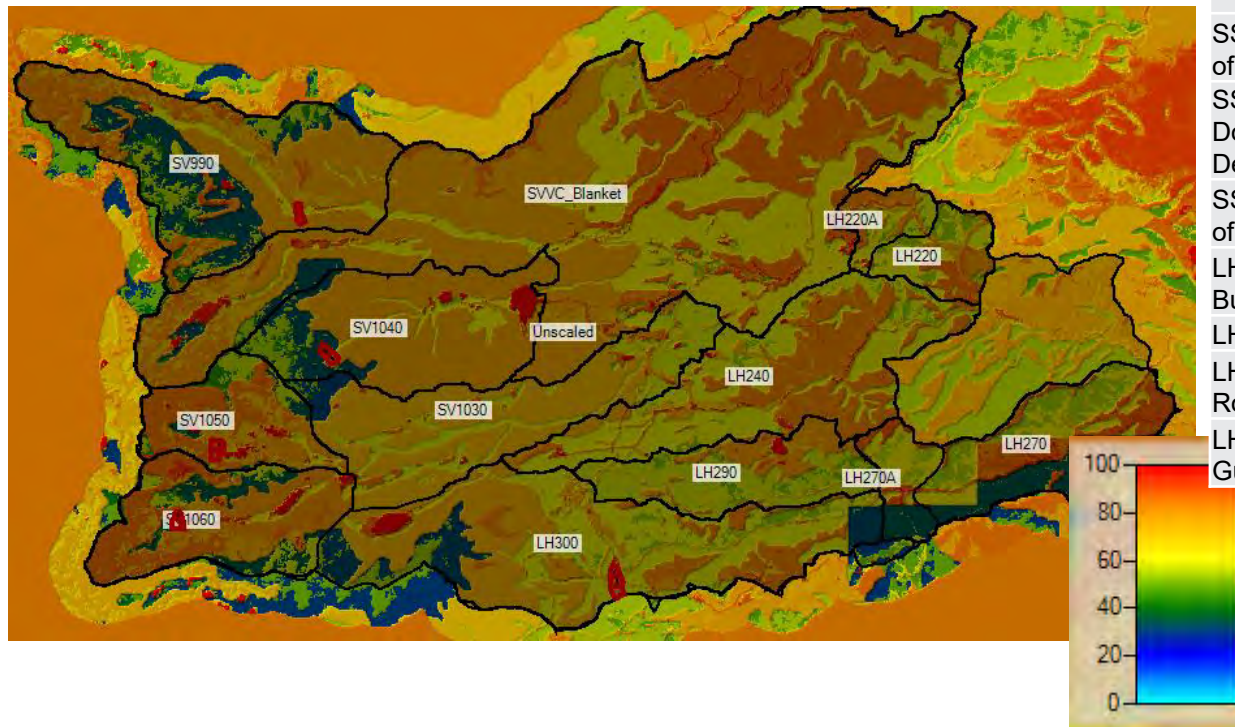


Model Layers Infiltration/CN

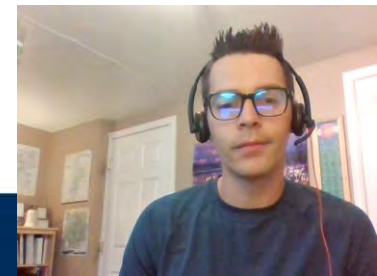
- Combo of land use and soils from SSURGO
- 10' cell resolution
Losses at cell level
- $I_a=0.20$ unburned
 $=0.15$ low burn
 $=0.10$ severe &
moderate burn



Calibration Regions



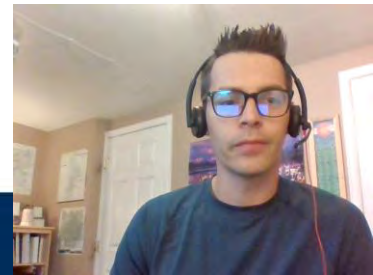
Location	Target Peak Flow (cfs)	Calibrated Peak Flow (cfs)	Percent Difference
SSVC Upstream of Burn	5267.1	5220	-0.9
SSVC Downstream of Deadman Gulch	6605.5	7211	9.2
SSVC Upstream of Lyons	7036.4	7917	12.5
LHC Upstream of Burn	3987.6	3873	-2.9
LHC at US-36	4985.2	5832	17
LHC at Old Stage Road	4804	4615	-3.9
LHC at Licksillet Gulch	1371	1287	-6.1



Simulations

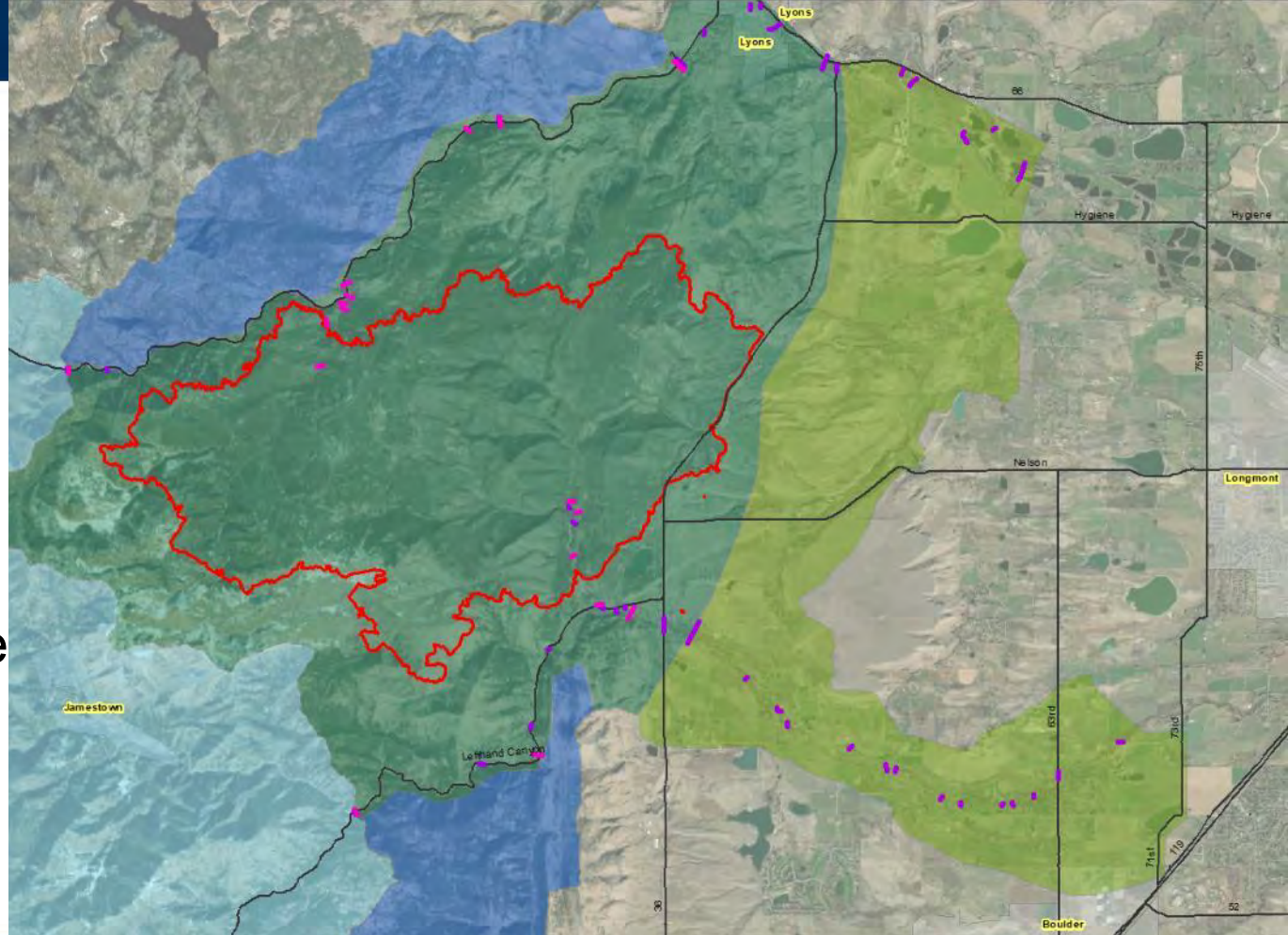
Rainfall Event (in)	Pre-Burn		Post-Burn	
	Run-Time (hrs)	Simulation Time (hrs)	Run-Time (hrs)	Simulation Time (hrs)
0.25	0.68	12	0.49	8
0.5	0.69	12	0.51	8
0.75	0.70	12	0.75	8
1	0.76	12	0.72	5
1.25	0.78	12	0.78	4
1.5	1.05	10	0.61	4
1.75	0.76	7	0.76	4
2	0.56	5	0.77	4
2.25	0.65	5	0.86	4
2.5	0.63	5	0.83	4
2.75	0.66	5	0.82	4
3	0.89	5	0.95	4
3.25	0.81	4	1.05	4
3.5	0.87	4	1.06	4
3.75	0.82	4	1.07	4

- 30 simulations for 15 rainfall events
- Simulation time based on peak flow timing
- Manageable run-times



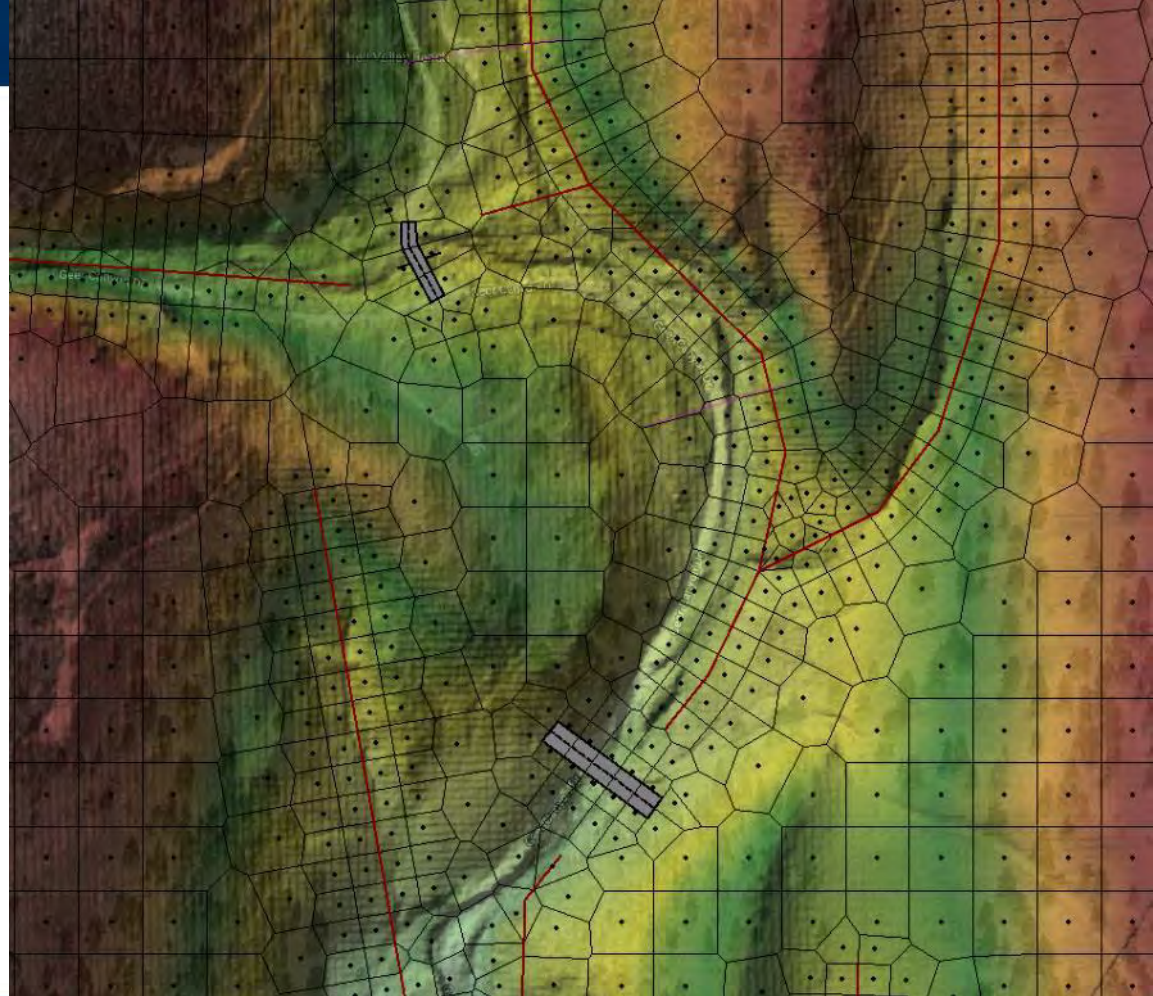
Observation Points

- 42 connections (structures & cal)
- 45 Profile Lines (add anywhere)
- Time series of:
 - Flow & volume
 - Stage/WSEL
 - Depth
 - Velocity

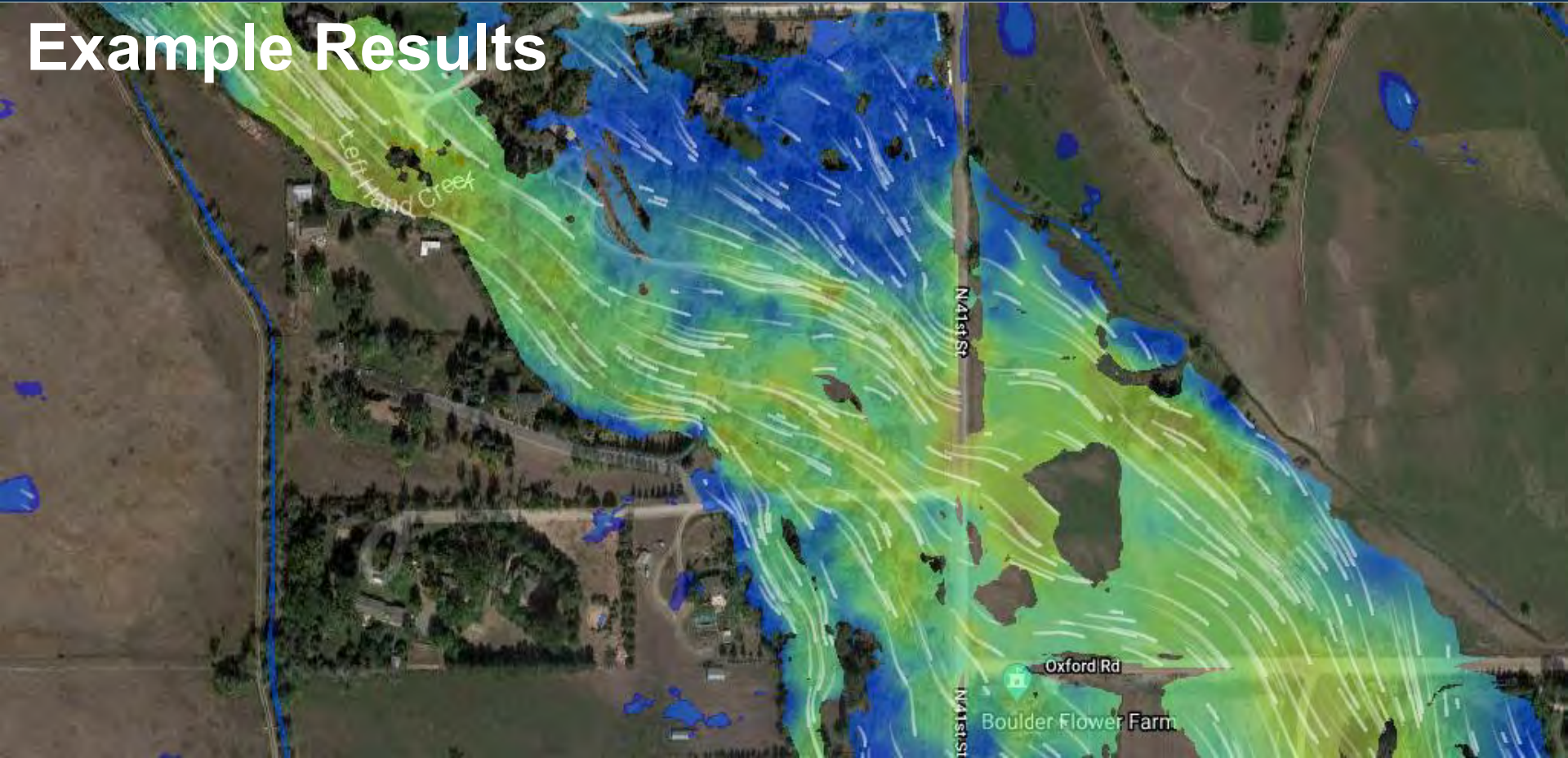


Model Construction

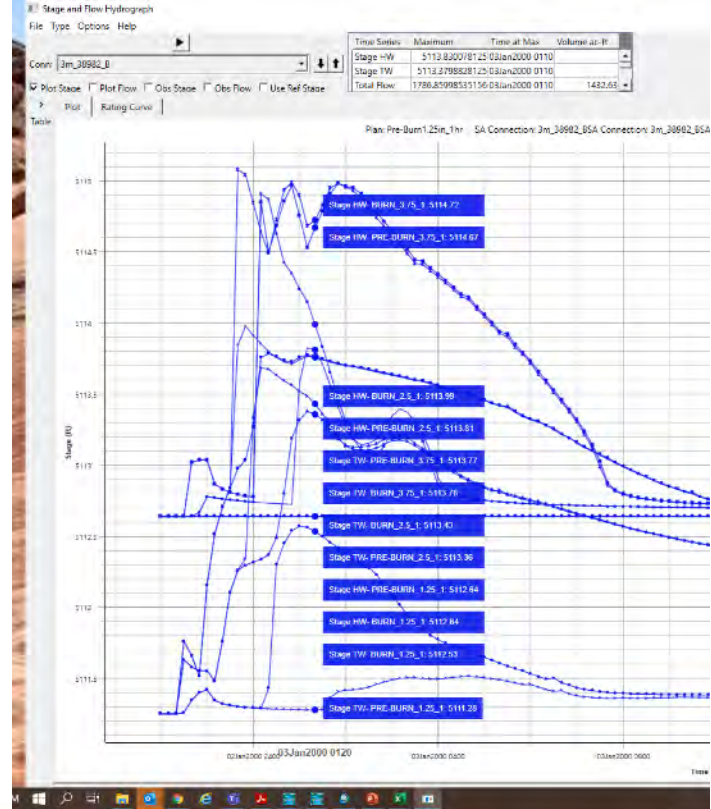
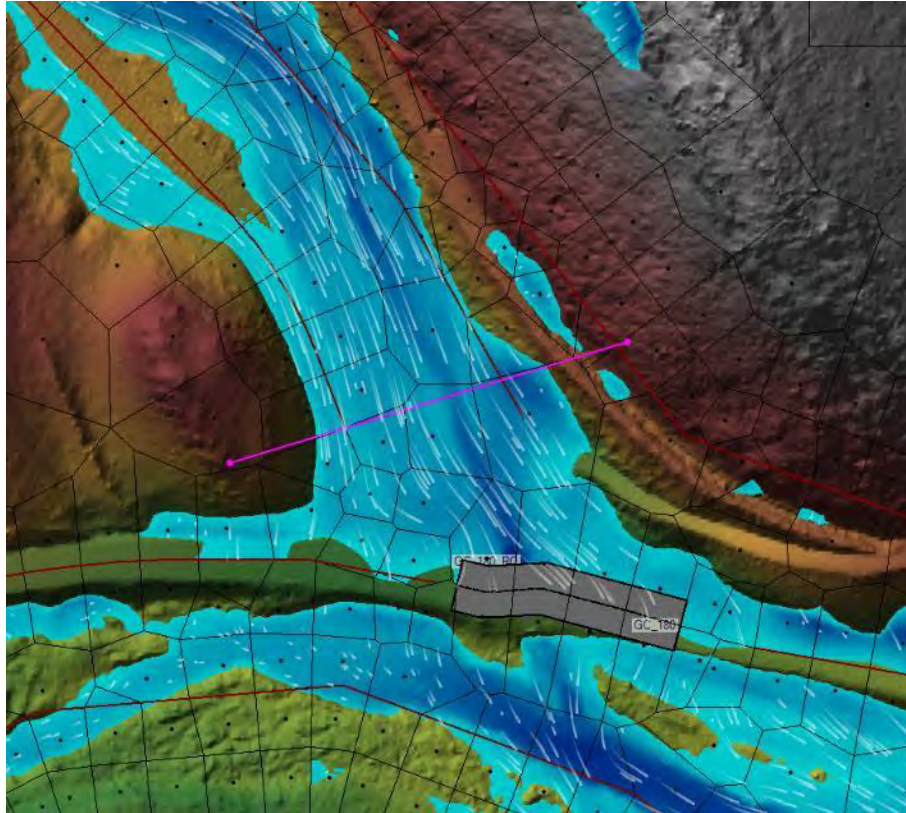
- Varied nominal mesh (100-800')
- 50' refinements at structures and detailed streams
- Breaklines along streams, ridges, and controlling features



Example Results

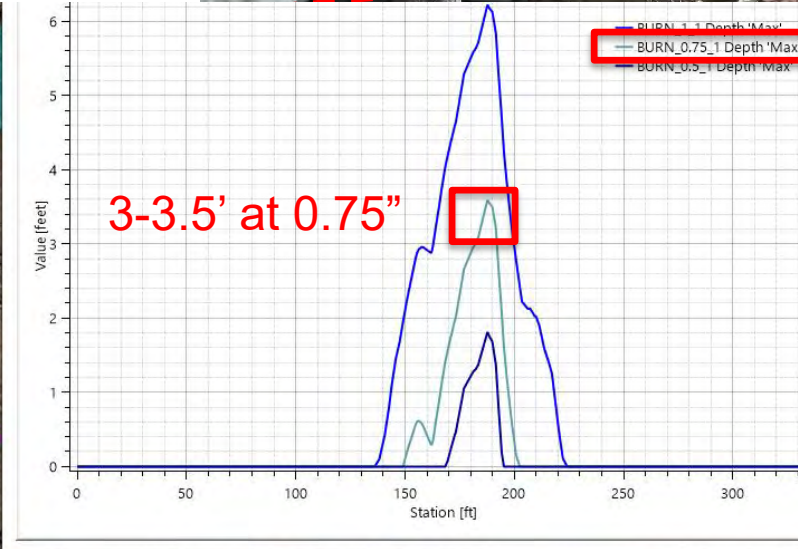


Data Extraction



Model Verification

Memorial Day
(days after delivery)



Project Deliverables

■ Peak Flows

- Total
- Through Structure opening
- % Change (burn vs pre)

■ Max Depths

- On structure deck
- Along road/approach
- In channel

■ Timing

- Time to Peak
- Time to Overtop
- Overtopping Duration

■ Spatial Files

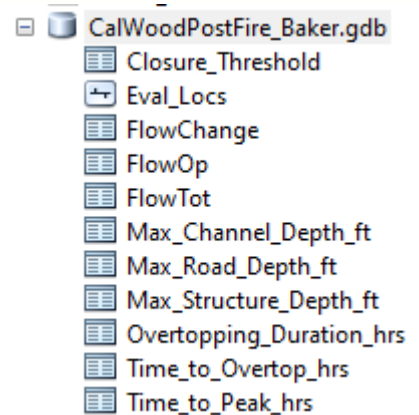
■ Model


■ Excel Tables

■ Graphs & Rating Curves

■ Inundation Maps

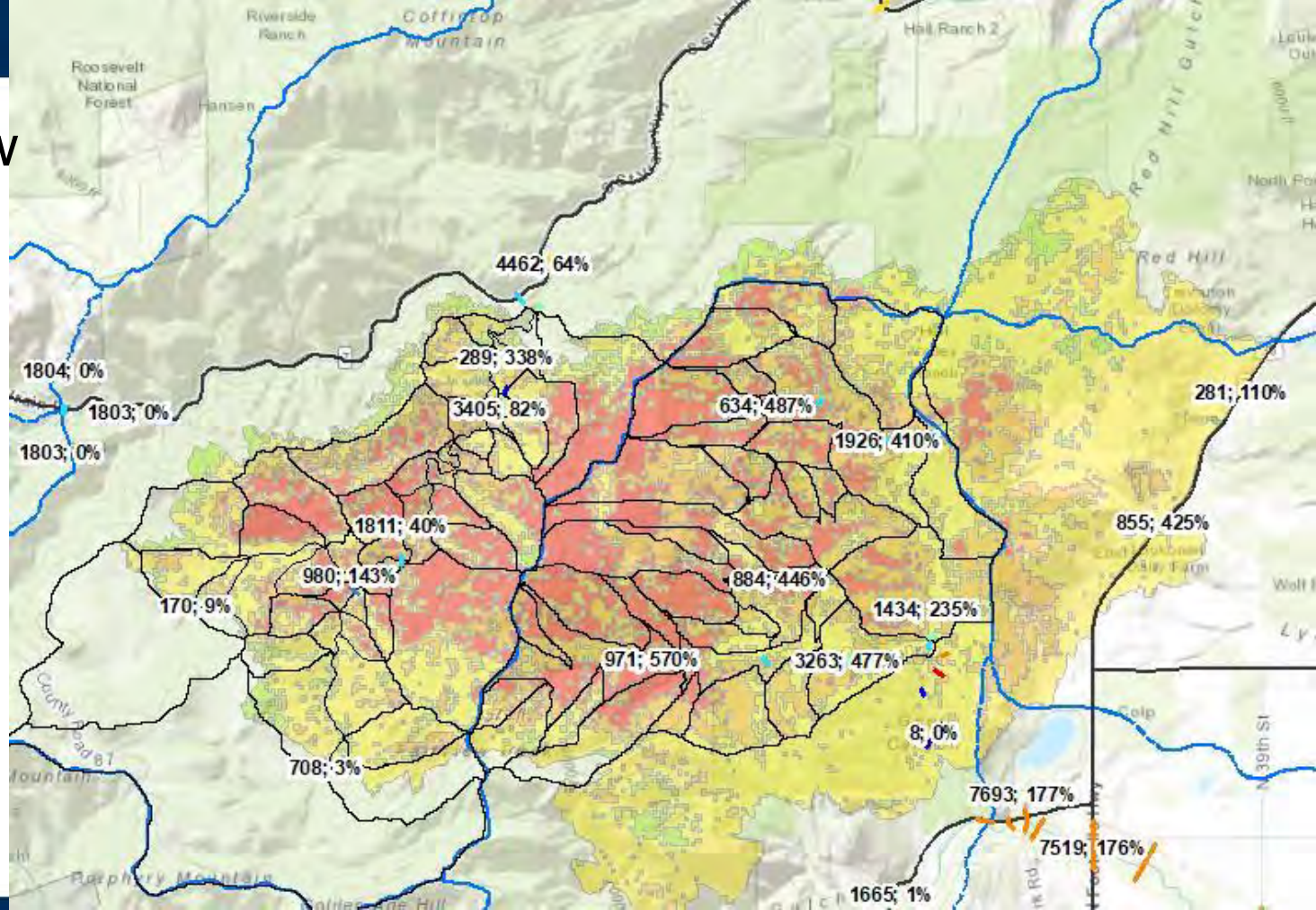
■ Interactive WebMap



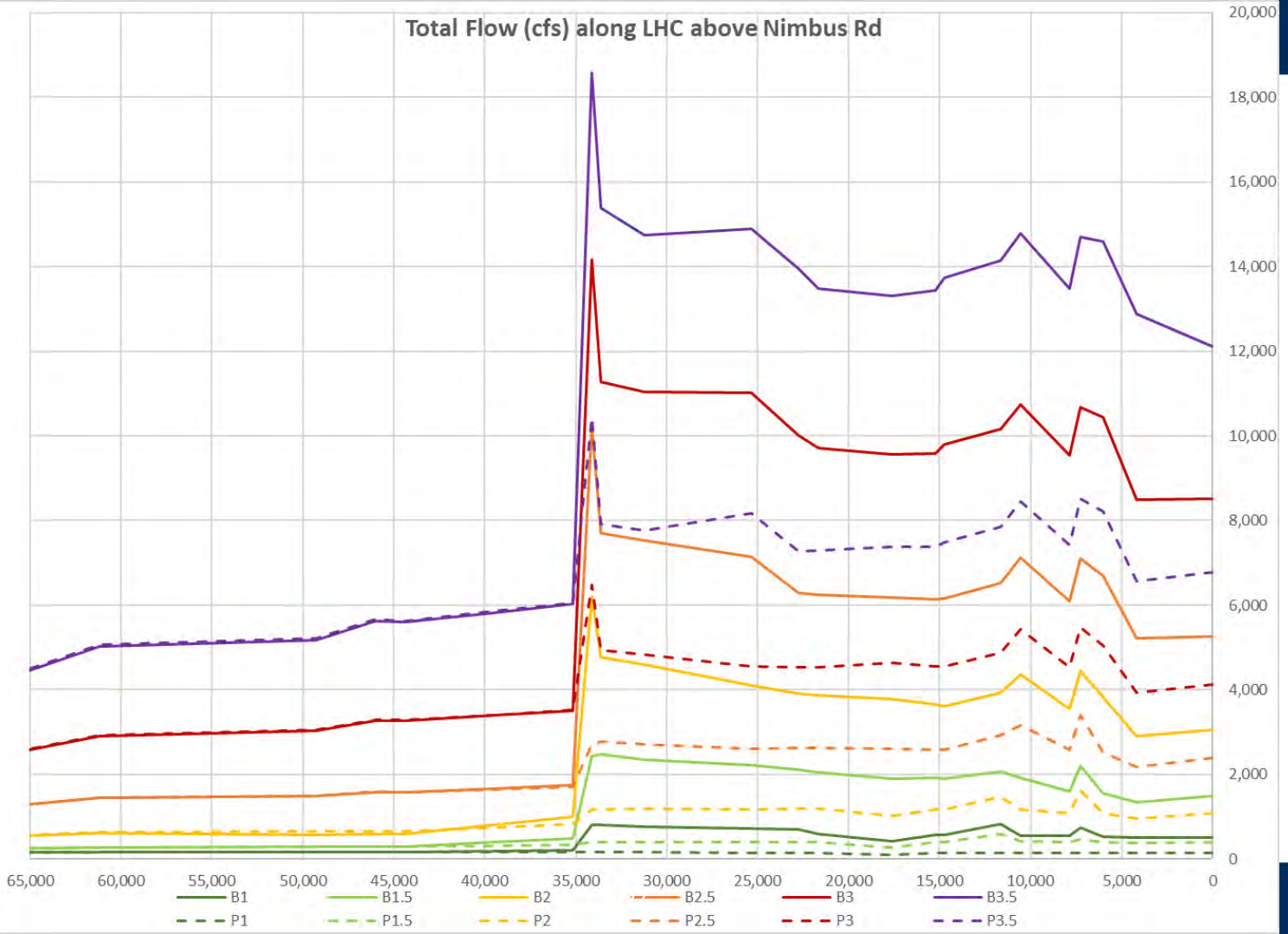
	SSVC_R2 US-7 downstream of Deadman Gulch	NA	1.75
	SSVC_R3 US-7 downstream of Central Gulch	NA	1.75
LHC09	N 49th St	2 Close Structure (0.5 ft freeboard)	2.5 Close Road (1ft depth)
LHC01	LHC Dr downstream of Buckingham lot	NA	2
LHC01	Nimbus Rd bridge	NA	2
GC_M1	GC at confluence with LHC	NA	0.75
SSVC_R1	US-7 upstream of Lyons Valley Ranch	NA	NA
EMC04	NHC Str Brigadoon Dr	NA	1.75
EMC08	Small bridge upstream of Boulder Feeder Canal on LHC	NA	NA
LHC14	PH Gate Canal Split of 41st St - 1	2.25	NA
SSVCR4	Old St Yrco Rd	NA	2.25
LHC_WR3	Ogala Rd Valley Ranch	NA	2.25
LHC R2	Private driveway off of 41st St - 2	NA	NA
EMC05	McCannell Dr (changed since CHAMP)	NA	2.75
LHC08	Small bridge down off of LHC Boulder Feeder of USA 36 on LHC	1.35	NA
LHC08	Small bridge downstream of 49th St on LHC	3.25	NA
EMC14	Private driveway off of LHC Dr downstream of GC confluence	3.25	NA
LHC00	Private driveway off of LHC Dr downstream of Spruce Gulch	3.75	NA
SSVC_R2	US-76 on LHC team of Deadman Gulch	NA	NA
SSVC_R3	US-76 downstream of Central Gulch	NA	NA
SSVC09	Private driveway off of US-7 upstream Long Gulch	3.25	NA
EMC22	RHC Dr bridge at N 51st Buckingham lot	NA	NA
EMC07	RHC bridge on raft takeout	NA	NA
LHC11	41st St	NA	2
We Make a Difference	SSVC_R1 US-7 upstream of Lyons SVC13 N 51st St	NA NA	2 2

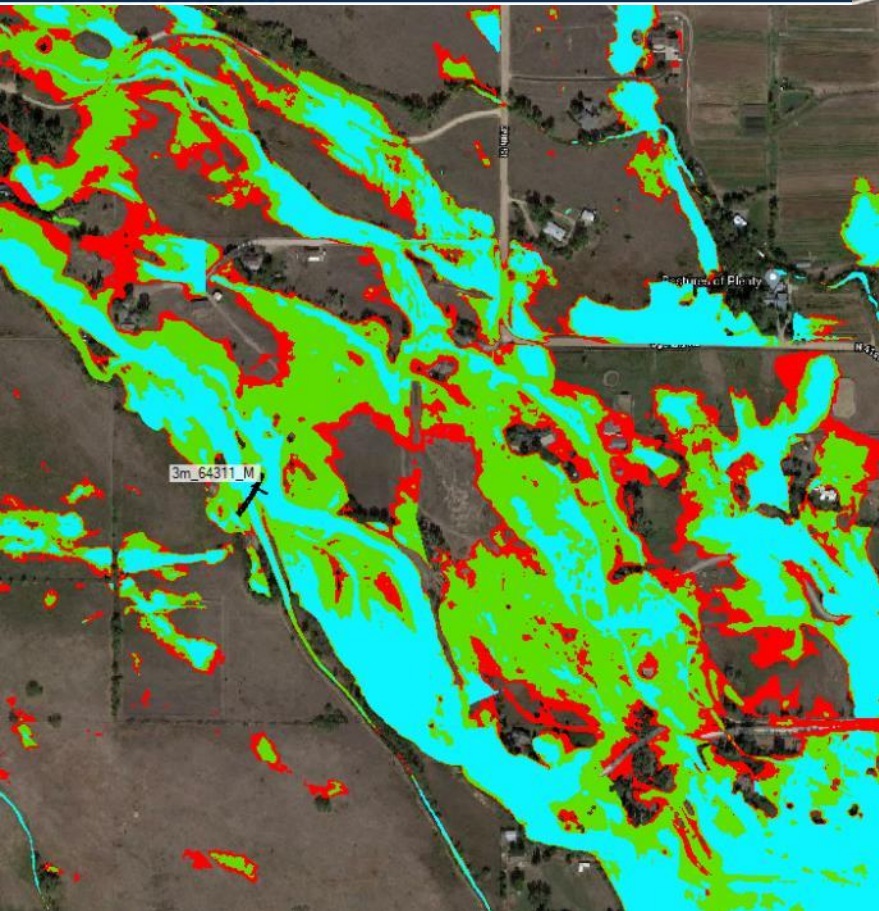
1	Structure Freeboard (negatives) or Overtopping Depth (positives) -																
-0.5	Post-Burn Scenarios (inches)																
Loc_ID	0.25	0.5	0.75	1	1.25	1.5	1.75	2	2.25	2.5	2.75	3	3.25	3.5	3.75	0.25	0.5
GC_M1	-6.5	-6	-2.7	1.6	2.4	3.1	3.7	4.2	4.7	5.2	5.7	6.1	6.5	6.8	7.2	-6.6	-6.6
GC_M3	-8.6	-6.1	-2.6	0.1	1.6	2.9	3.9	4.8	5.8	6.8	7.7	8.7	9.6	10.5	11.3	-8.6	-8.6
GC_W1	-1.6	-1.6	-0.9	-0.9	0.9	2	2.6	3.3	3.8	4.4	4.8	5.3	5.6	5.9	6.2	-1.6	-1.6
LHC01	-8.3	-8.1	-7.4	-6.6	-5.8	-4.9	-4	-2.9	-2.2	-1.8	-1.5	-1.2	-0.9	-0.8	-0.6	-8.3	-8.3
LHC02	-12.4	-12.3	-12.1	-11.5	-10.8	-9.9	-8.7	-7.2	-6.1	-5.1	-4.3	-2.5	-0.8	-0.3	0	-12.4	-12.4
LHC03	-6.9	-6.8	-6.3	-5.4	-3.9	-1.7	-0.4	0.9	1.3	1.7	2.1	2.4	2.8	3	3.3	-6.9	-6.9
LHC04	-2.7	-2.3	-0.7	0.6	1.7	3.3	4.6	5.6	6.7	7.6	8.4	9	9.6	10	10.4	-2.7	-2.6
LHC05	-6.7	-6.4	-5.4	-4.1	-2.3	0.4	2.6	3.5	3.9	4.3	4.7	5.1	5.4	5.6	5.9	-6.7	-6.6
LHC06	-4.7	-4.3	-2.6	-1.6	-0.5	0.1	0.8	1.1	1.4	1.6	1.8	2	2.3	2.4	2.6	-4.7	-4.6
LHC07	-3.9	-3.5	-1.8	1	1.7	2.3	2.7	3	3.3	3.6	3.8	4.1	4.4	4.6	4.8	-3.9	-3.8
LHC08	-9.8	-9.5	-7.9	-6.8	-3.1	-2.3	-2	-1.7	-1.4	-1.1	-0.9	-0.6	-0.3	-0.1	0.1	-9.8	-9.7
LHC09	-7.4	-7.2	-6	-5.1	-3.7	-2.2	-1.1	-0.3	0.8	1.6	2.2	2.7	3.2	3.5	4	-7.4	-7.4
LHC10	0.6	0.8	1.3	1.9	2.8	3.5	4.1	4.5	4.8	5.2	5.6	6	6.4	6.7	7.1	0.6	0.7
LHC11	-10.1	-9.6	-7	-5.9	-5	-4.4	-3.9	-3.6	-3.2	-2.9	-2.4	-1.8	-1.4	-1.1	-0.8	-10.1	-10
LHC12	-3.6	-3.3	-2.2	-0.3	0.5	1	1.2	1.3	1.4	1.6	1.7	1.8	1.9	2	2.1	-3.5	-3.5
LHC13	-7	-6.7	-4.6	-3.6	-2.6	-2.3	-1.6	-1	-0.5	-0.1	0.3	0.6	0.8	1	1.2	-7	-7
LHC14	-7.2	-6.9	-5.3	-4.3	-3.5	-2.7	-1.6	-0.6	-0.1	0.6	1	1.3	1.6	1.8	2	-7.2	-7.2
LHC16	-19.7	-19.6	-18.7	-18.5	-18.3	-17.3	-15.8	-14.2	-13.3	-12.4	-11.5	-10.6	-2.9	-0.6	0.2	-19.6	-19.6

Burnt Total Flow & % increase 2.5", 1-hr (~1% depth)



Total Flow (cfs) along LHC above Nimbus Rd

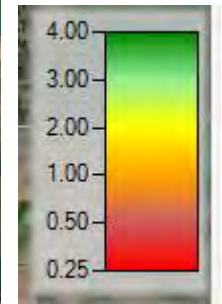




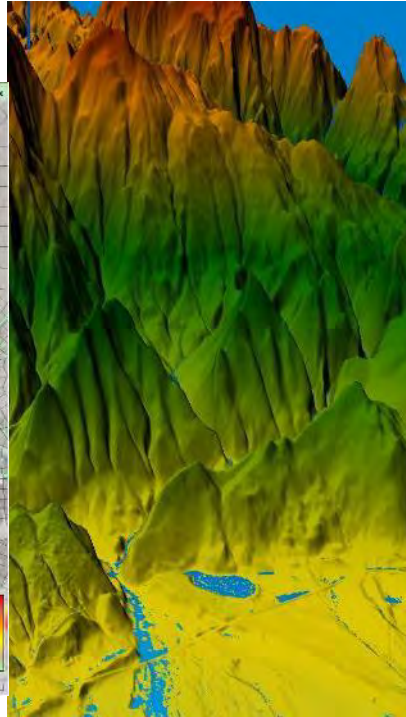
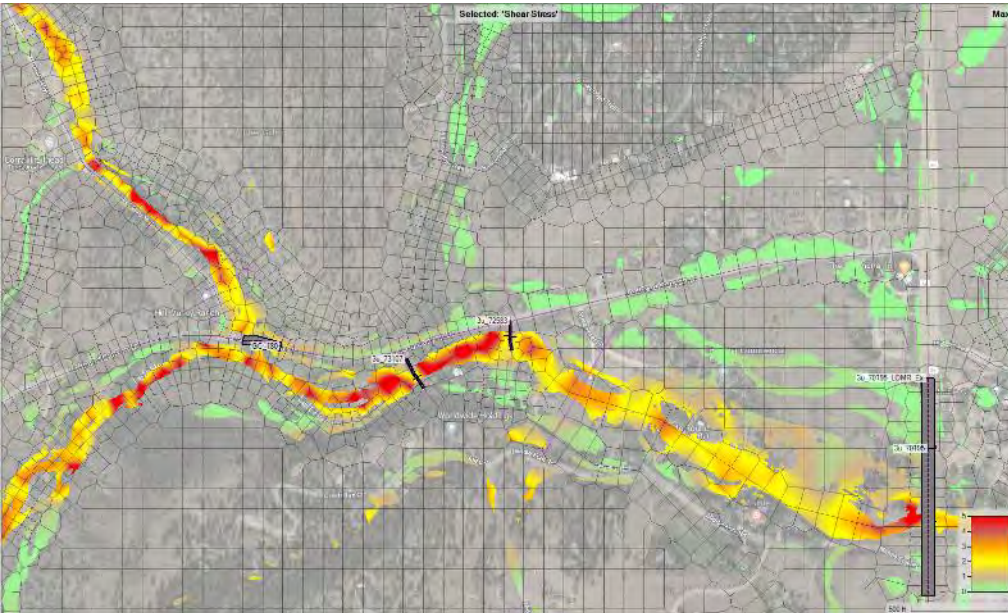
Expanding Inundation Extents

Other Capabilities

Arrival Time to 2.5 ft deep



Informing Restoration Design / Watershed Recovery



Results Map Parameters

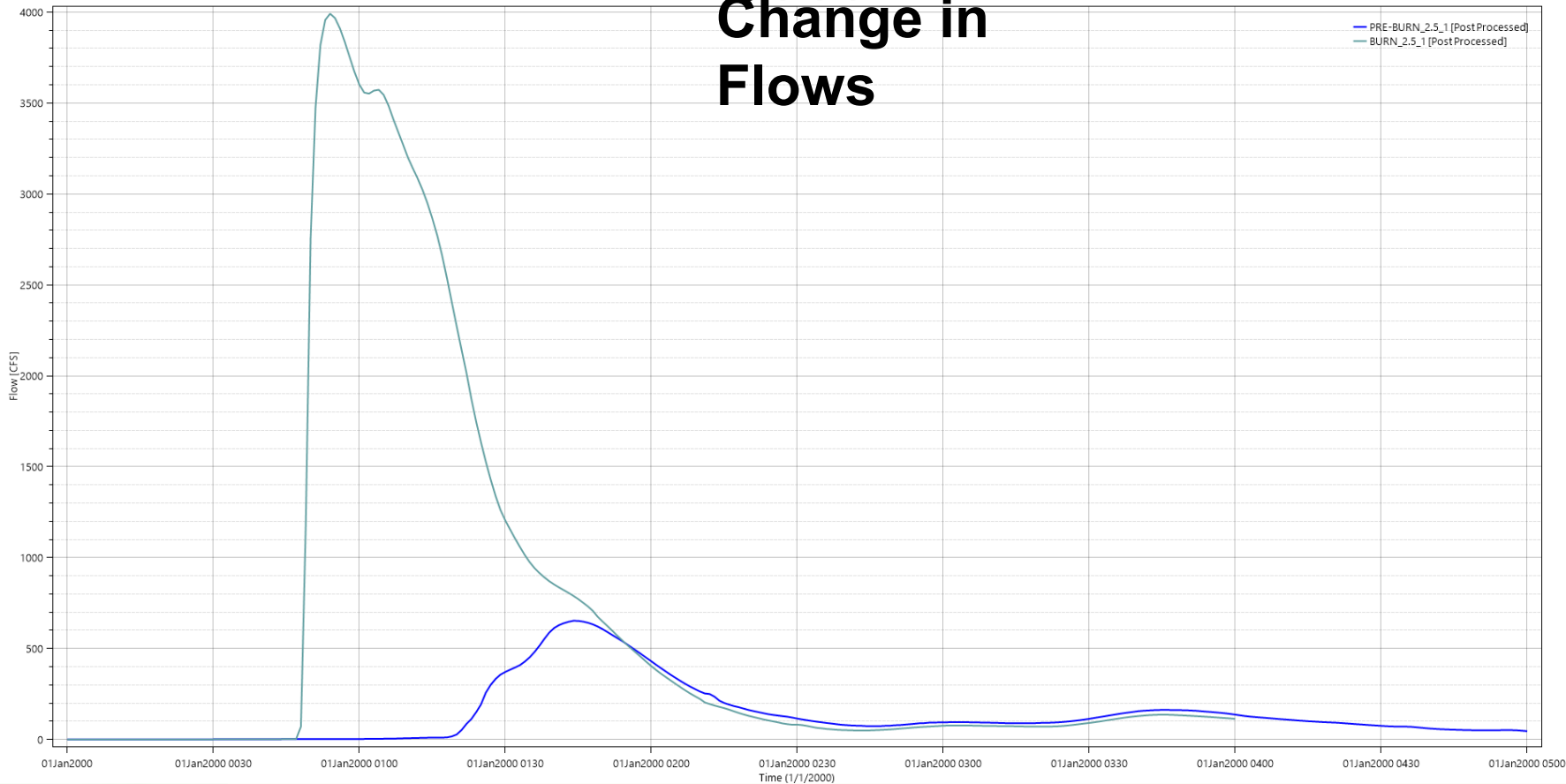
Map Type

Hydraulics

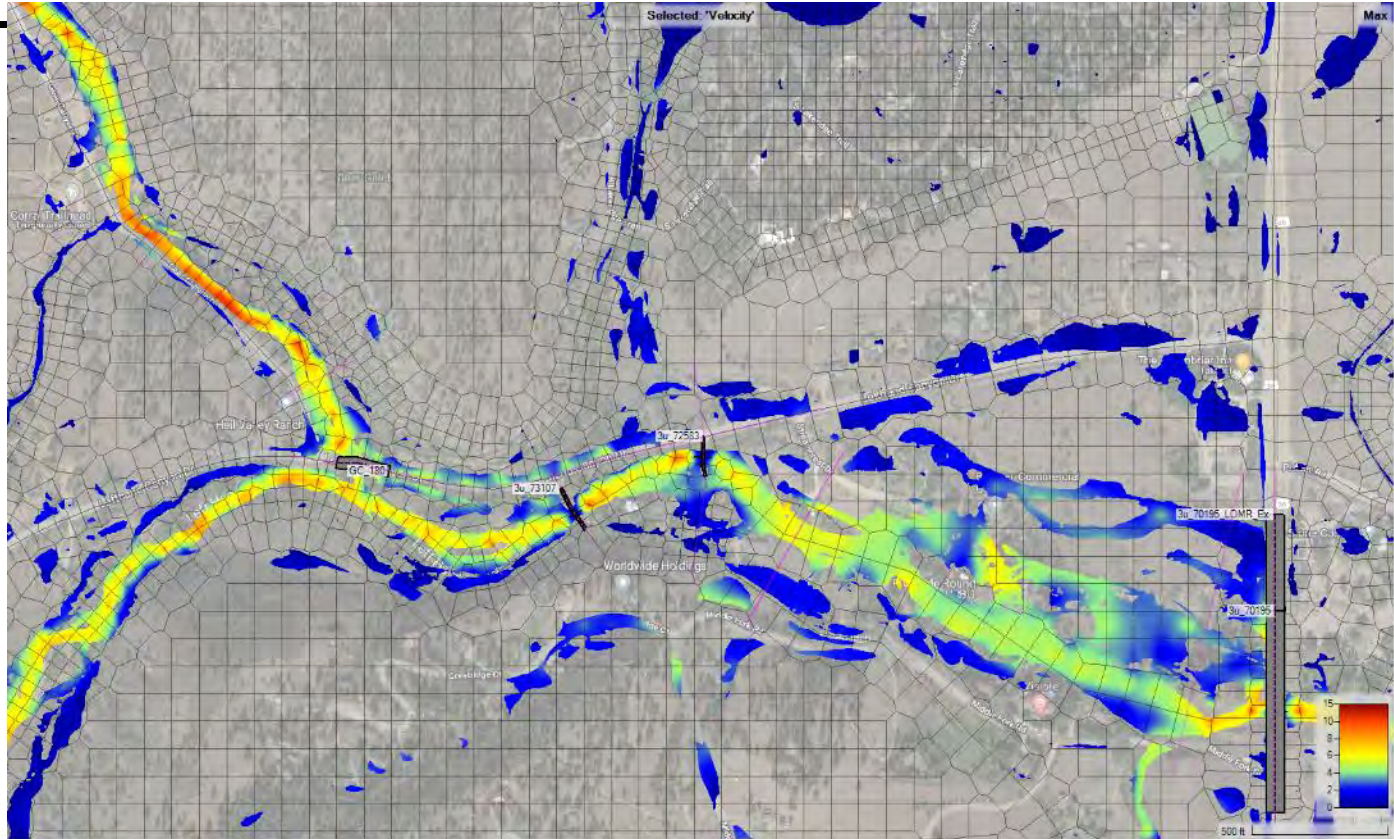
- Water Surface Elevation
 - Velocity
 - Flow (1D Only)
 - Inundation Boundary
 - Depth
 - Courant (Velocity/Length)
 - Courant (Residence Time, 2D Only)
 - Froude
 - Shear Stress
 - Depth * Velocity
 - Depth * Velocity²
 - Energy (Depth)
 - Energy (Elevation)
 - Arrival Time
 - Arrival Time (Max)
 - Recession
 - Duration
 - Percent Time Inundated
 - Stream Power
 - Wet Cells
- #### Additional 2D Variables
- Cumulative Excess Depth
 - Cumulative Infiltration Depth
 - Cumulative Precipitation Depth

Flow along 'HC_Above_US-36_BRIDGE'

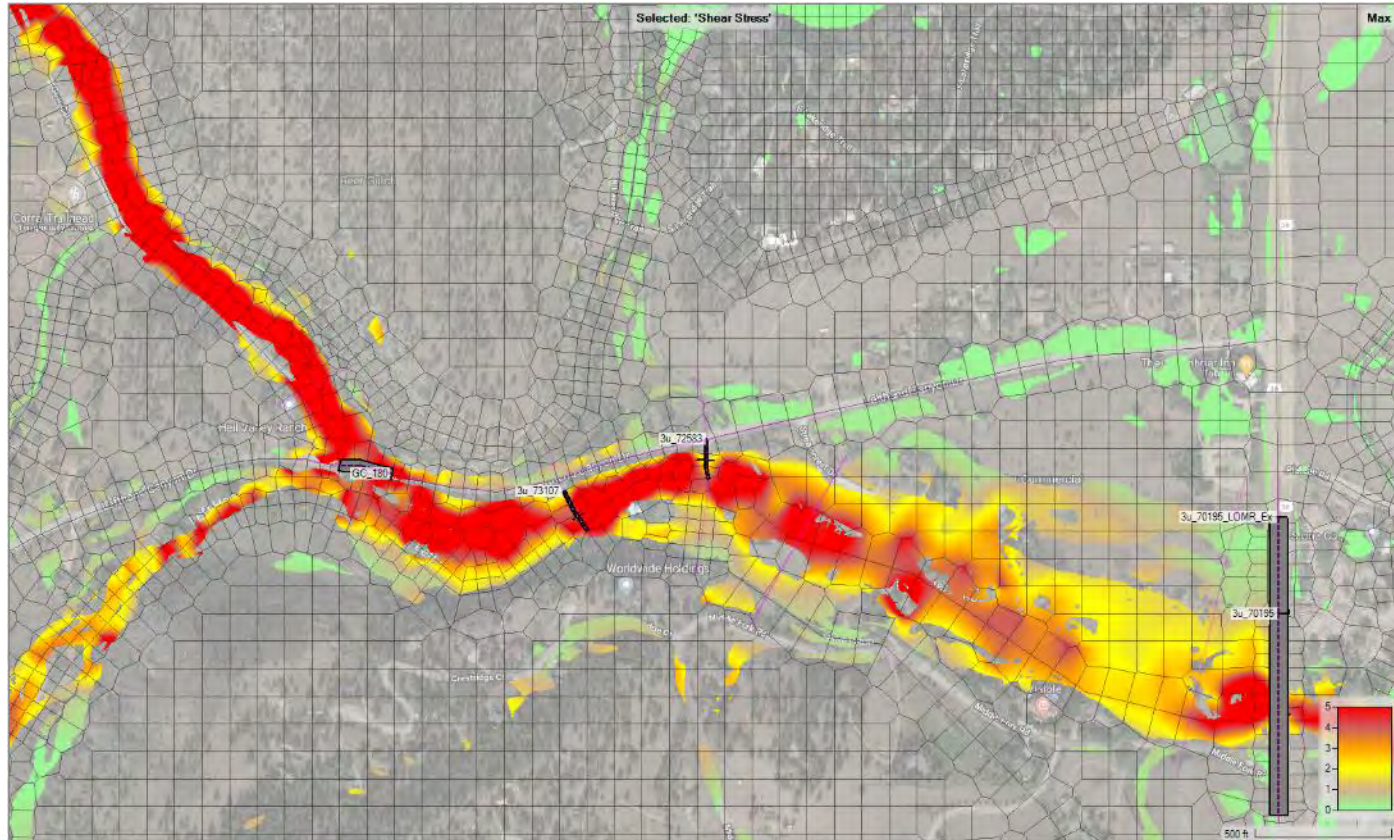
Change in Flows



Pre-Burn 2.5" – Velocity

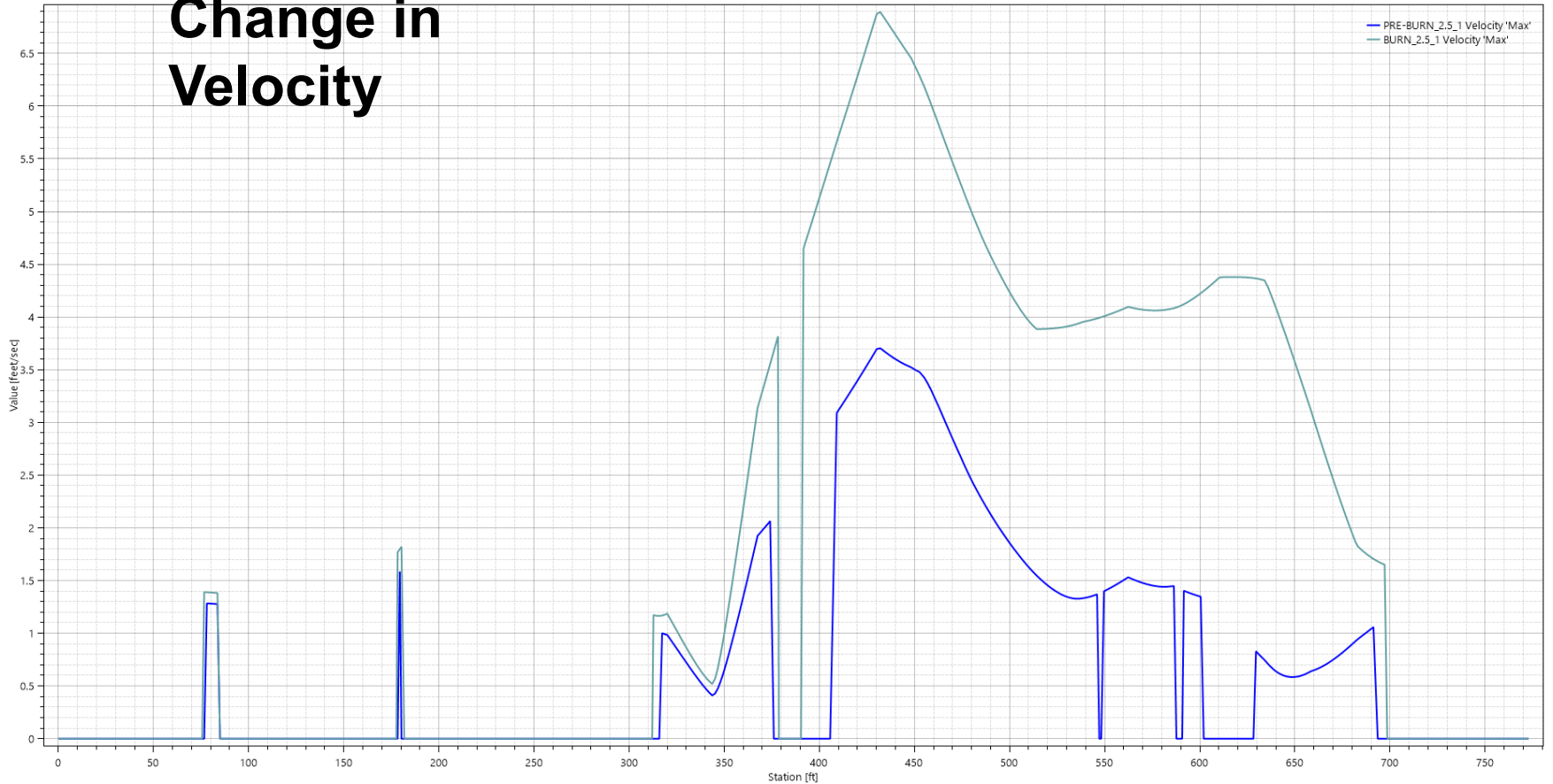


Post-Burn 2.5” – Velocity

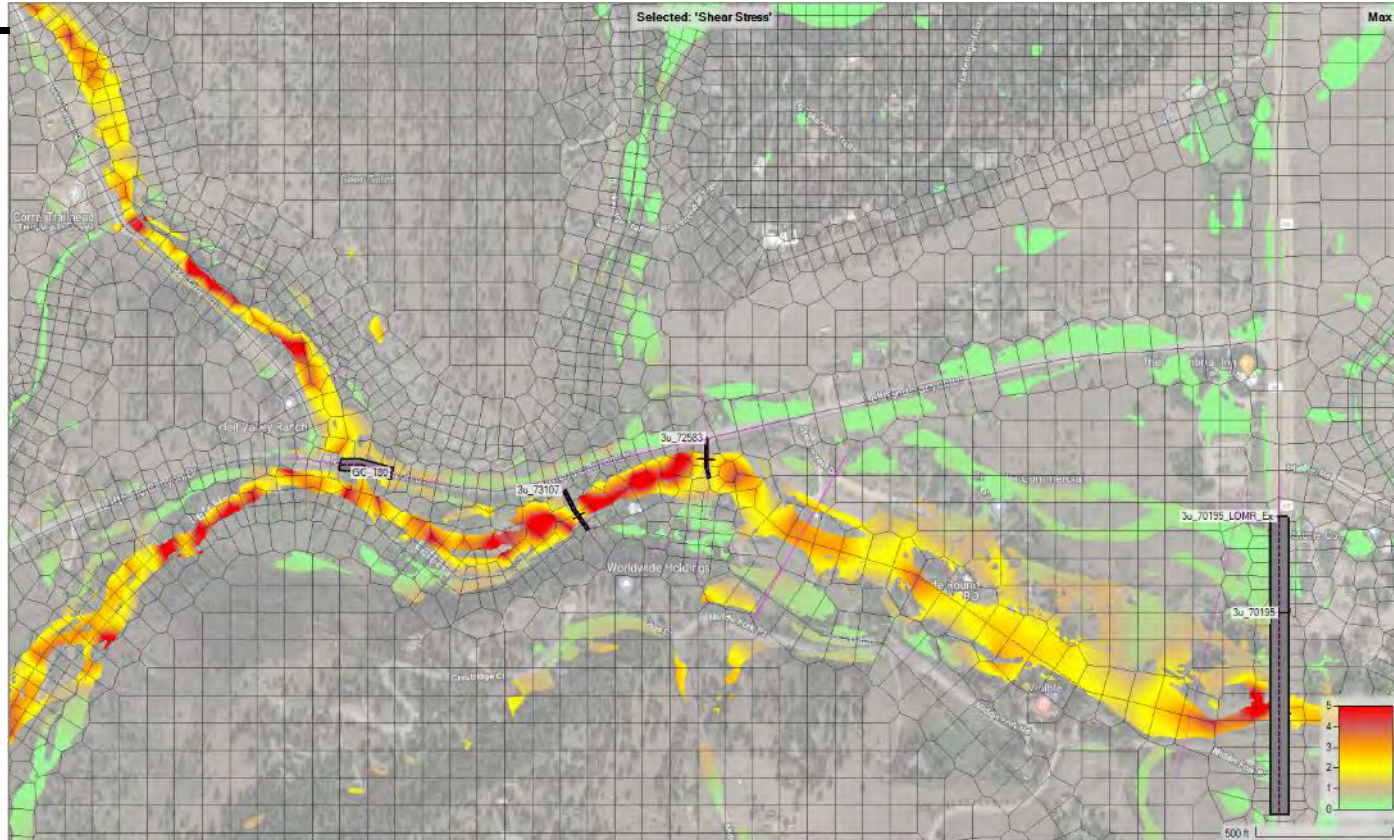


Change in Velocity

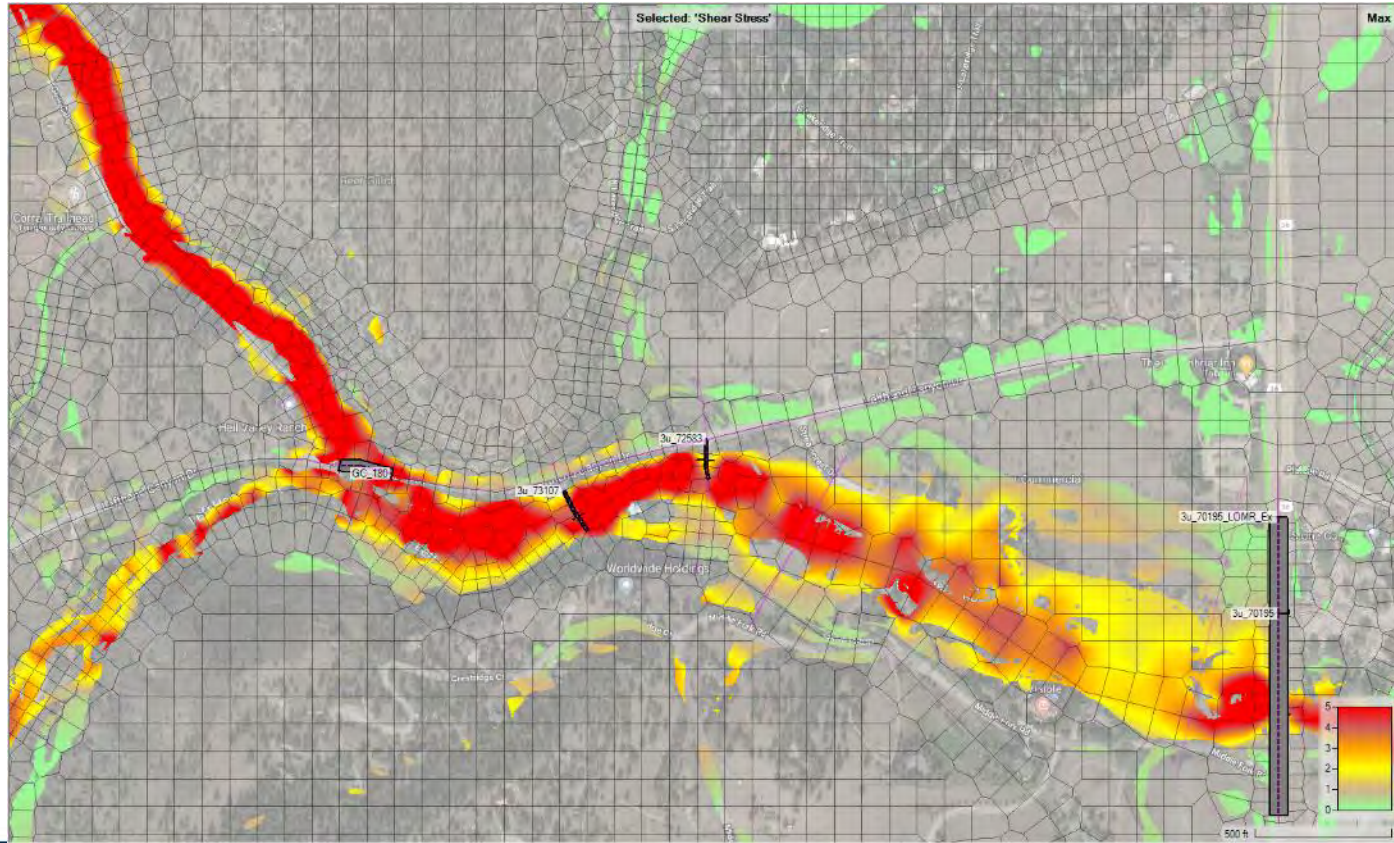
Velocity on 'LHC_Above_US_36_BRIDGE'



Pre-Burn 2.5" Shear Stress

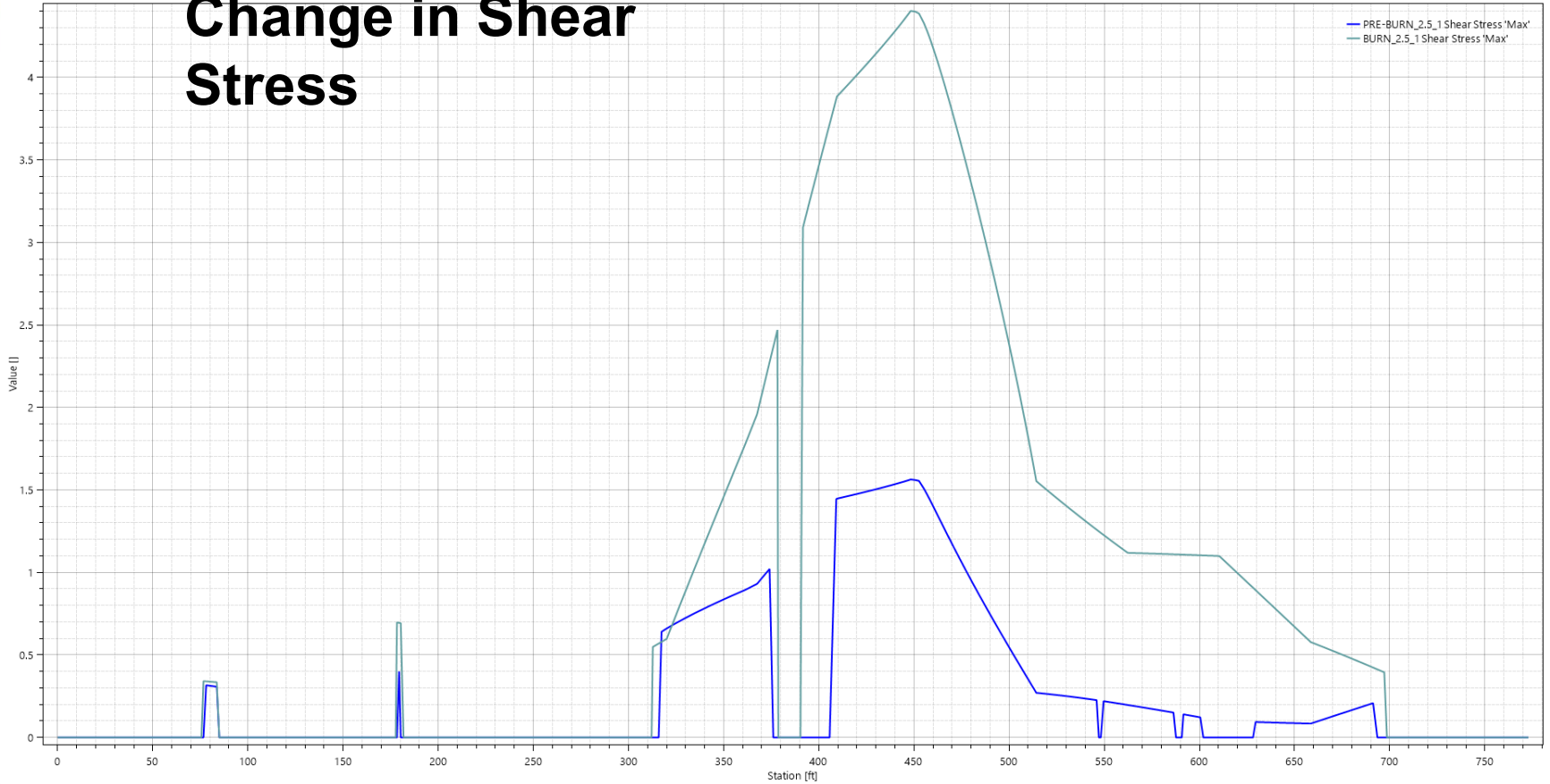


Post-Burn 2.5” – Shear Stress



Change in Shear Stress

Shear Stress on 'LHC_Above_US-36_BRIDGE'



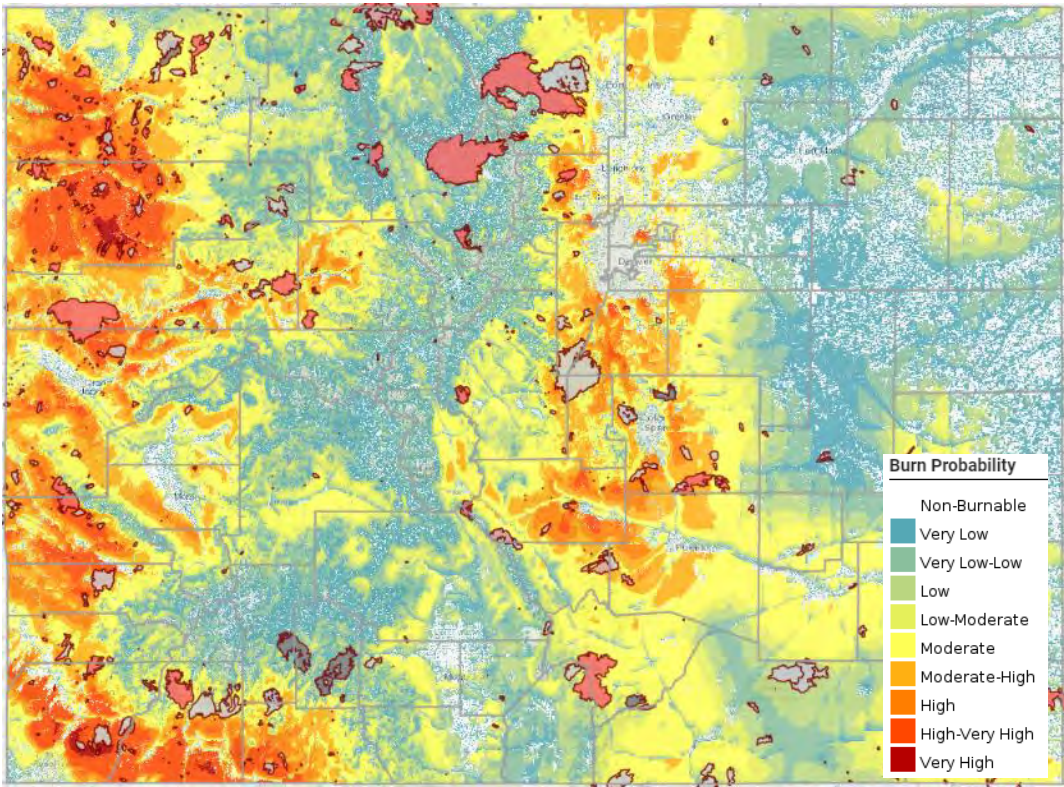
Predictive Post-Fire Resources

COLORADO WILDFIRE RISK

Understanding the wildland-urban interface risk index



LA PLATA COUNTY



Adapt, Prepare by Knowing Fire Risk

Each county in Colorado is unique, with a character shaped by individual history, land, climate, people and resources. However, something every county in the state shares is the potential to be negatively affected by wildfires.

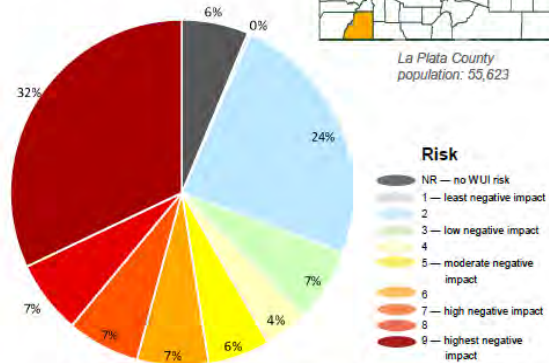
In order to effectively prepare for the impact of wildfires, residents, leaders and community planners must be aware of the wildfire risk associated with living in the wildland-urban interface and recognize actions that can be taken to reduce this risk. Connecting with wildfire resources — like those listed below — can help guide wildfire adaptation efforts from a personal to a community-wide level.

WUI Risk

This chart shows the portion of La Plata County's residents who live within the wildland-urban interface classified by level of wildfire impact on lives and property.



La Plata County population: 55,623



Select a map theme:

- Wildfire Risk
- Burn Probability
- Fire Intensity Scale

VIEW LEGEND

- Wildfire Effects Themes
- Landscape Characteristics
- Historical Wildfire Occurrence
- 2020 Forest Action Plan

DEMO

Post-Fire Recovery Resources



<https://aftertheflames.com/resources/>



Colorado Springs Utilities
It's how we're all connected



SWCA



City of Golden



wildfirerisk.org

Colorado Post-Fire Recovery Playbook

Guidance for Counties, Tribes, Municipalities, and Water Providers

February 2021



HOMEOWNERS & RESIDENTS	COMMUNITY & SMALL BUSINESS	HYDROLOGY & HYDRAULICS
<p>Recovery Guides</p> <ul style="list-style-type: none"> Disaster Recovery Guide Post-fire Flooding Checklists <p>Clean Up & Recovery</p> <ul style="list-style-type: none"> Asbestos & Natural Disasters Guide Flood After Fire Fact Sheet Hazardous Materials and Floodwater NWS Flash Flood Facts Safe Cleanup of Fire Ash Staying Safe from Asbestos Understanding Burn Severity <p>Health & Well Being</p> <ul style="list-style-type: none"> After the Fire CDC Prepare, During & After Wildfire Help Kids Prepare Red Cross: Disaster Relief and Recovery Services Red Cross Before, During & After Wildfire USDA Food Safety Tips <p>Important Documents</p> <ul style="list-style-type: none"> Important Documents Checklist Replacing Vital Documents <p>Insurance & Finances</p> <ul style="list-style-type: none"> Insurance for Wildfires How to Protect Your Home from Wildfire Disasters National Flood Insurance Program Recovering Financially Wildfire Insurance 101 	<p>Floods Follow Fire</p> <ul style="list-style-type: none"> Manitou Springs Flooding NOAA Flash Flood Threat <p>Prepare Your Business</p> <ul style="list-style-type: none"> Backflow Prevention Required Disaster Recovery Plan for Business Flood Insurance Flood Preparation Prepare Your Business for Flood Wildfire Insurance 101 <p>Clean Up & Recovery</p> <ul style="list-style-type: none"> Safe Clean Up of Fire Ash Understand Burn Severity Wildland Fire Chemical Clean Up <p>Finances</p> <ul style="list-style-type: none"> DisasterAssistance.gov Small Business Disaster Loan <p>Long Term Recovery</p> <ul style="list-style-type: none"> Disaster Recovery Programs Long Term Recovery Overview Planning for Post Disaster Recovery Support Through COCO Affiliation <p>Post-Fire Guides & Toolkits</p> <ul style="list-style-type: none"> After Fire Toolkit for the Southwest CUSP Phoenix Guide Mitigating Post-fire Runoff and Erosion 	<p>Colorado State</p> <ul style="list-style-type: none"> Colorado Decision Support System Colorado Hazard and Lidar Mapping <p>USGS</p> <ul style="list-style-type: none"> Burn Severity Portal Landslide Hazards Program National Geospatial Program Map National Land Cover Database Stream Statistics National Lidar National Weather Dashboard National Weather Information System <p>Additional Sources</p> <ul style="list-style-type: none"> NRCS Web Soil Survey USACE HEC-HMS USDA Hydrologic Analysis of Post-Wildfire NOAA Precipitation Data Frequency Server <p>LAND MANAGEMENT RESTORATION</p> <p>Recovery Structures</p> <ul style="list-style-type: none"> EALN Structures Concrete Barrier Wall Contour Walls Erosion Control Mat Hand Raking Hesco Flood Barrier Log Erosion Barriers Mechanical Scarification

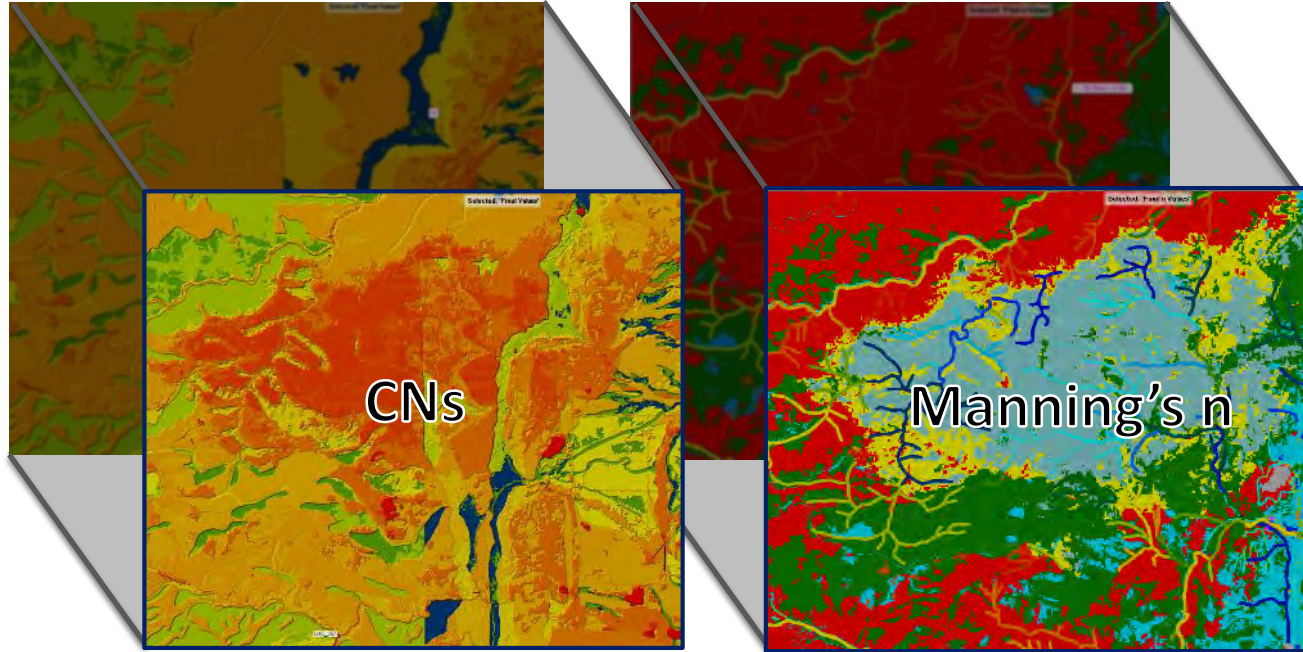
Predictive Post-Fire H&H

Probability

where to modify (deterministic)
PDFs & graduated (probabilistic)

Intensity

how much to modify



Increased CNs and decreased manning's n
based on burn probability and intensity

VOTE YES
ON
RoM 2D



Russell.Anderson@mbakerintl.com or Geoff.Uhlemann@mbakerintl.com