

TETRA TECH

complex world | **CLEAR SOLUTIONS™**

Debris Flow Modeling & Regulations in Aspen, Colorado

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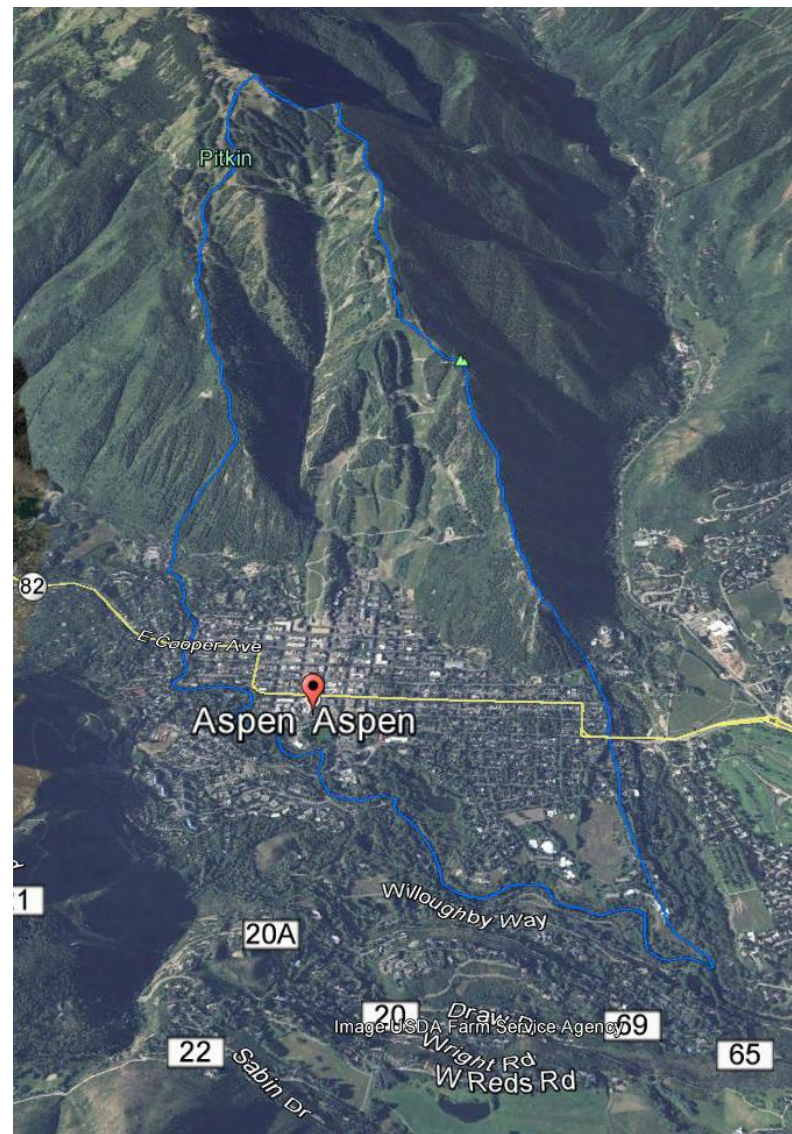
Jim O'Brien, PhD, PE - FLO-2D

April Long, P.E. – City of Aspen

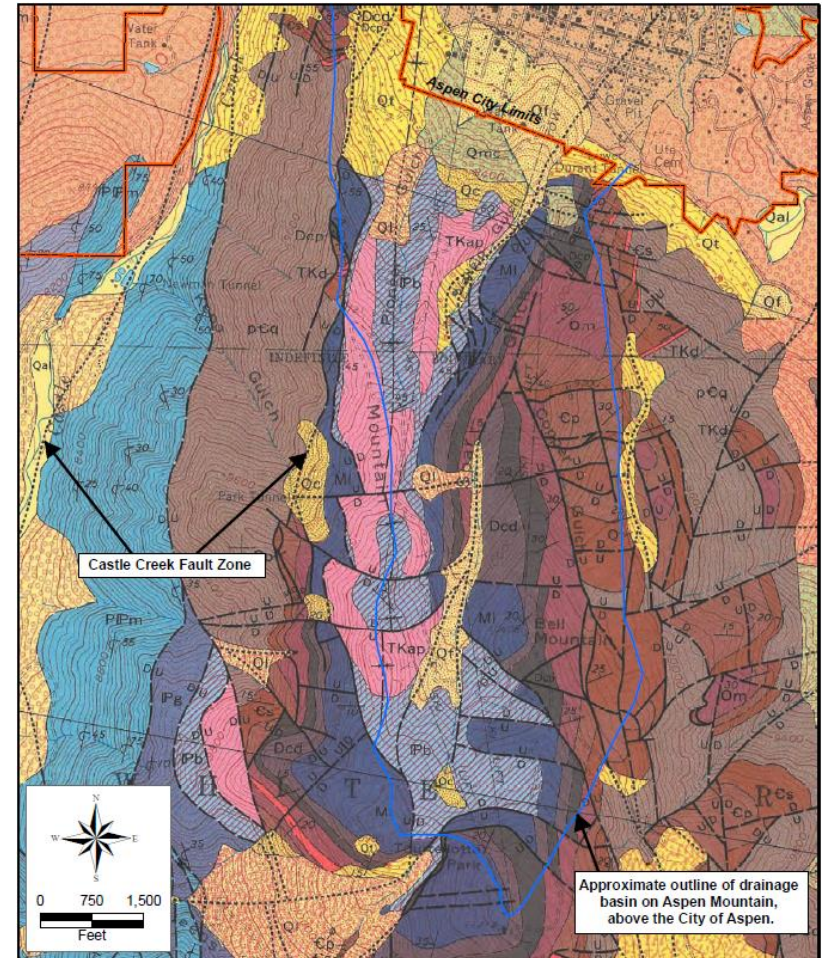
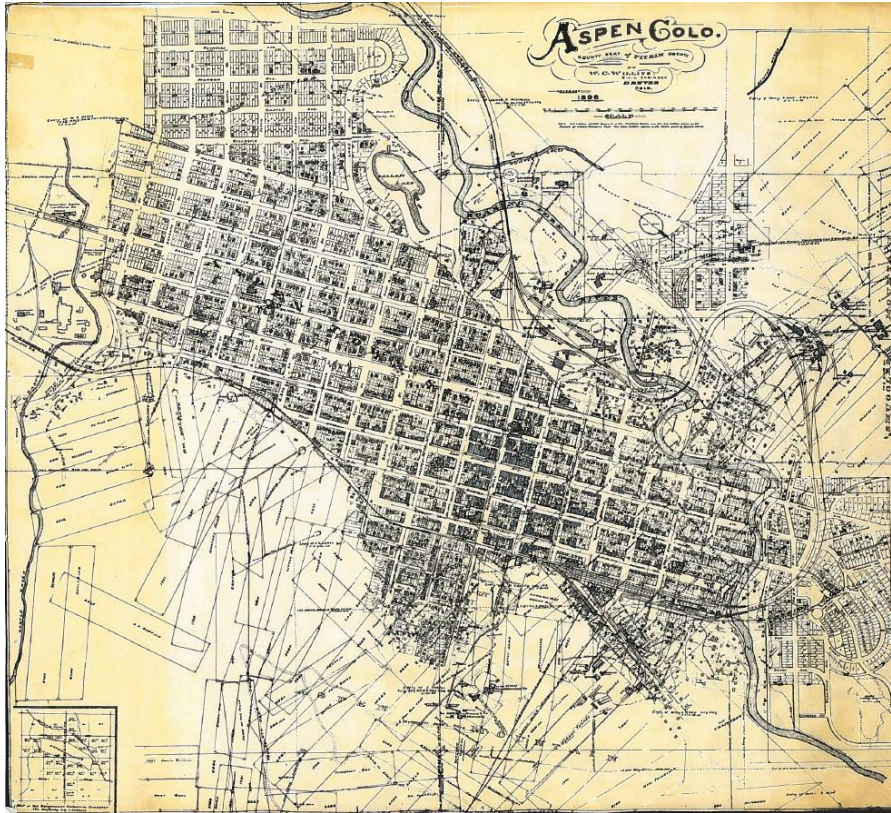
3rd May 2017



Aspen Mountain



Geology and Mining



It's complicated!

Tourtelotte Park c1890-1893








Historic

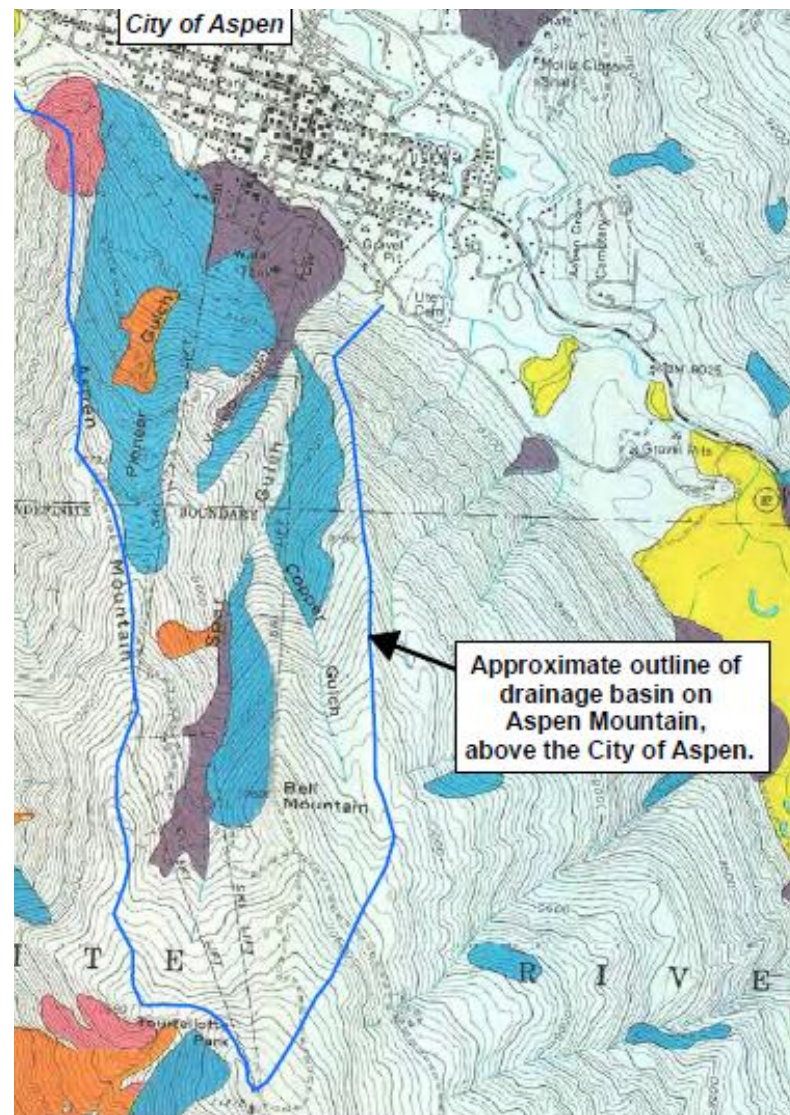
- September 1919
 - Cloudburst
 - “yellow clay mud from the mountain”
- August 1964
 - 1.13 inches in 1 hour
 - Pioneer Gulch up to 5’ of mud
- June 1984
 - Strawpile Landslide

Strawpile Landslide

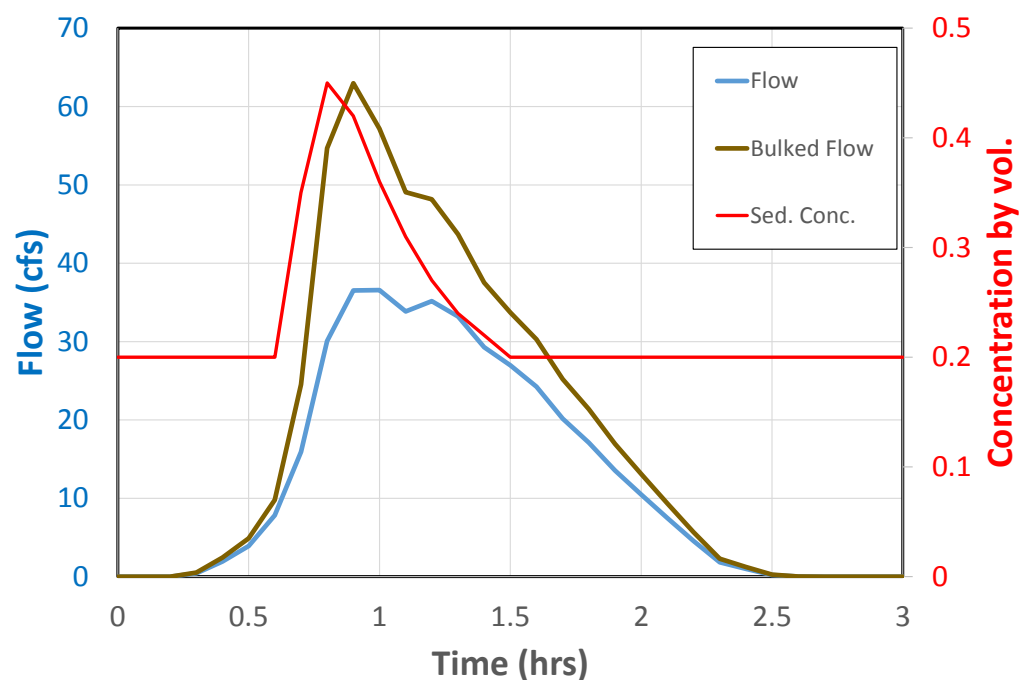
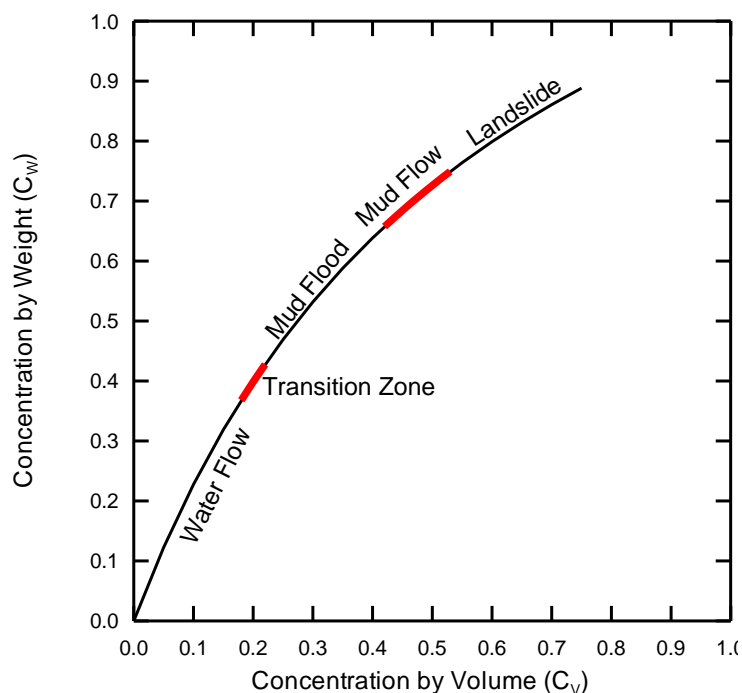
- June 1984
- Downtown Evacuated
- 28 to 62 feet deep
- ~15 acres

Legend

-  Flood Plains; subject to flooding.
-  Alluvial Fans; subject to sediment deposition during mud floods, mudflows, and debris flows.
-  Landslides; areas that slid in the past and may be prone to future movement.
-  Rockfall Areas; areas on or below cliffs that are prone to future rockfall.
-  Potentially Unstable Slopes; areas potentially prone to future land sliding.



Mudflow Characteristics



Mudflow Characteristics

- Saturated Soil Conditions
- Sediment
- Rainfall (10 to 25-Year Event)

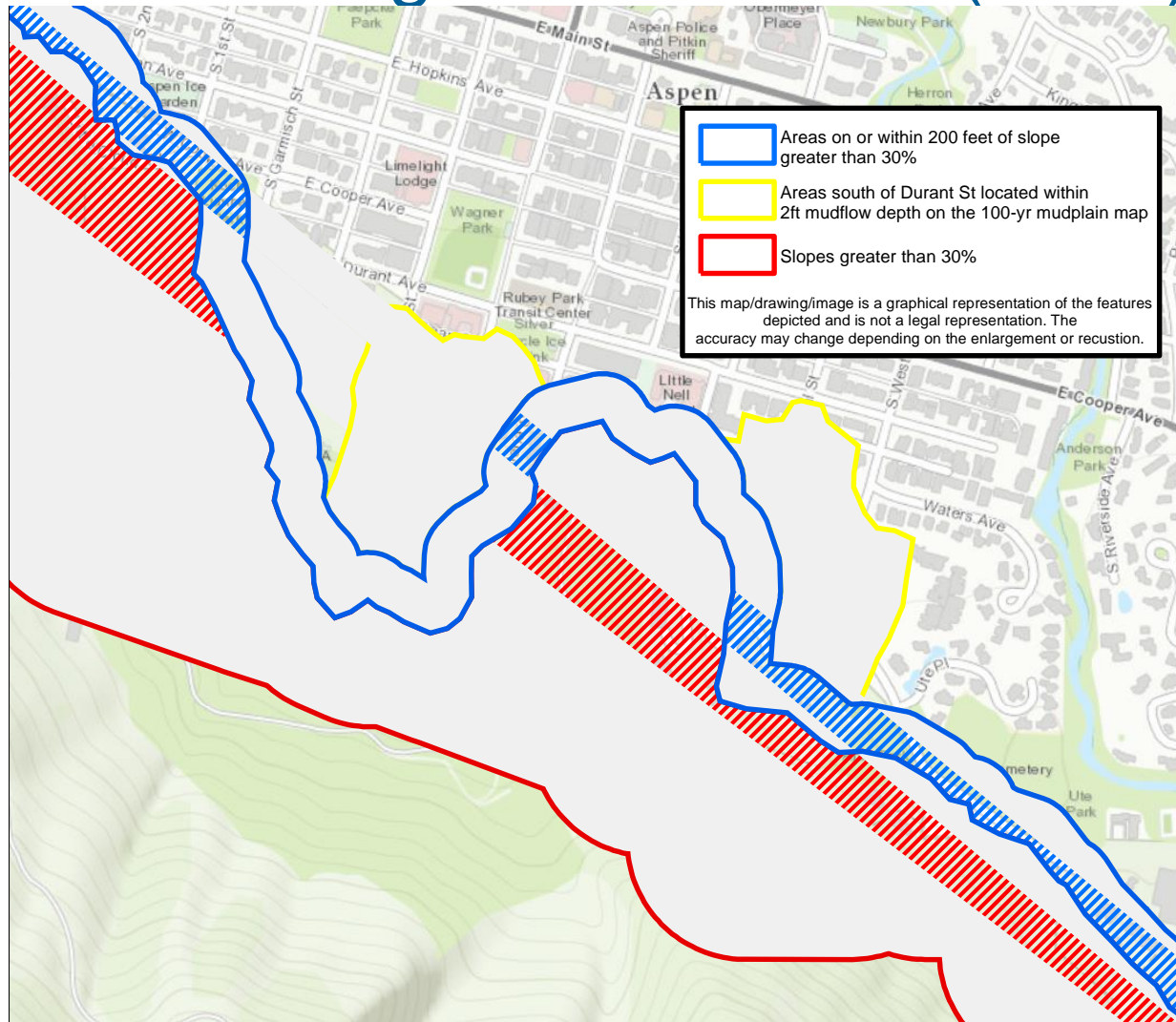
Mudflood





Existing Regulations

- WRC – Drainage Master Plan (2001)



Existing Regulations

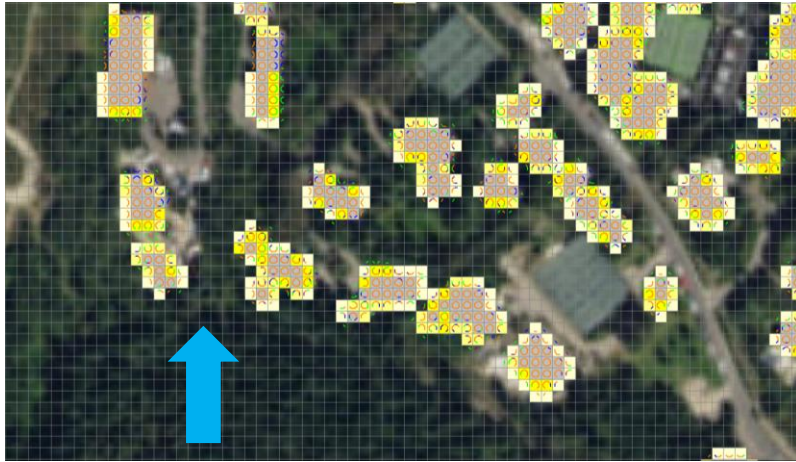
- Similar to FEMA procedure
 - Duplicate Effective
 - 100-Year Peak Flow Event
 - Sediment Concentration 45%
 - Existing Conditions
 - Project Conditions

Existing Regulations

- Evaluate downfan impacts
 - No increase in mudflow depths on neighboring properties
- Evaluate static and dynamic forces on structures
- Identify potential mitigation measures
 - Store mudflow
 - Convey mudflow to streets

Example

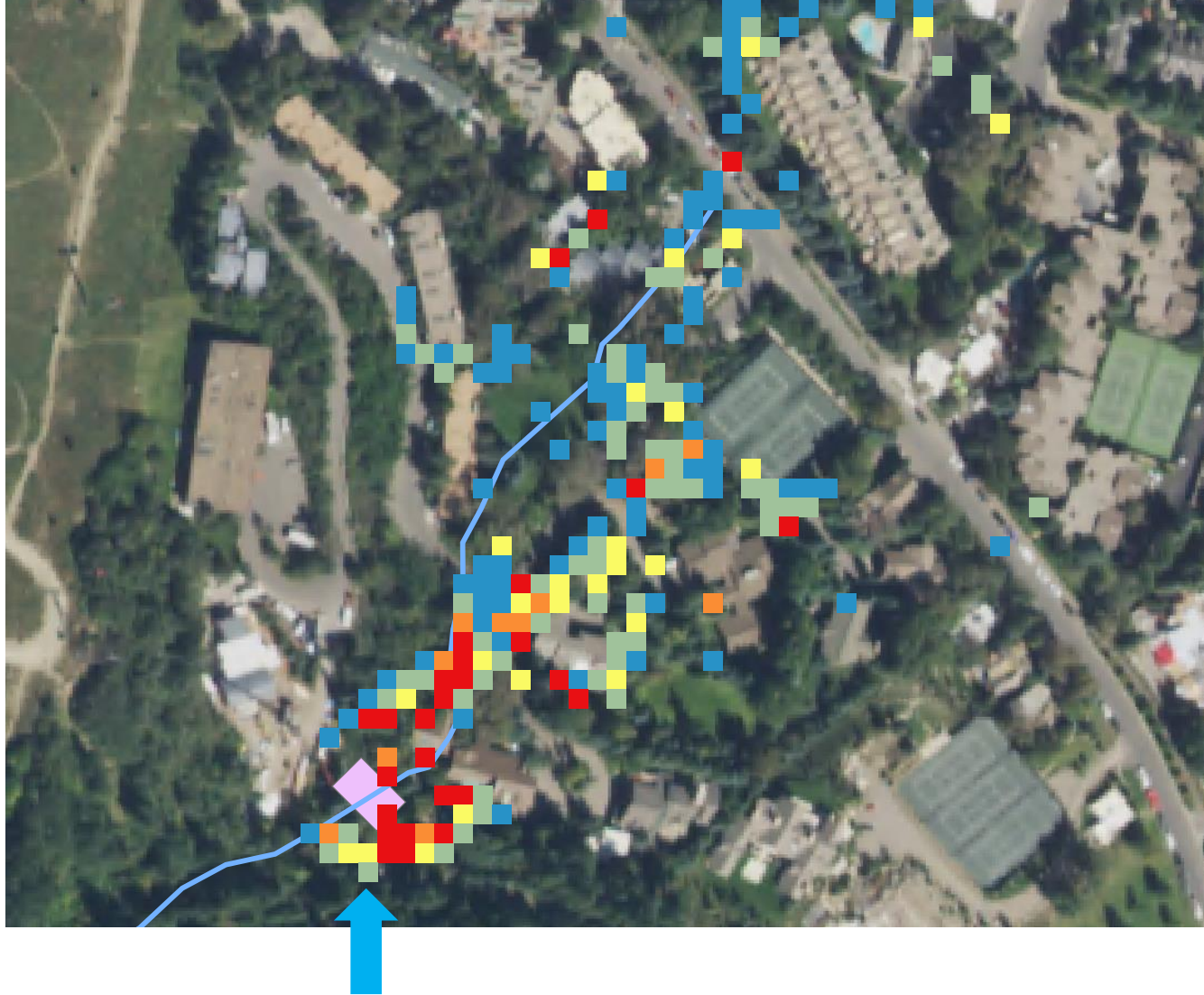
Existing



Project



Increase in Depth

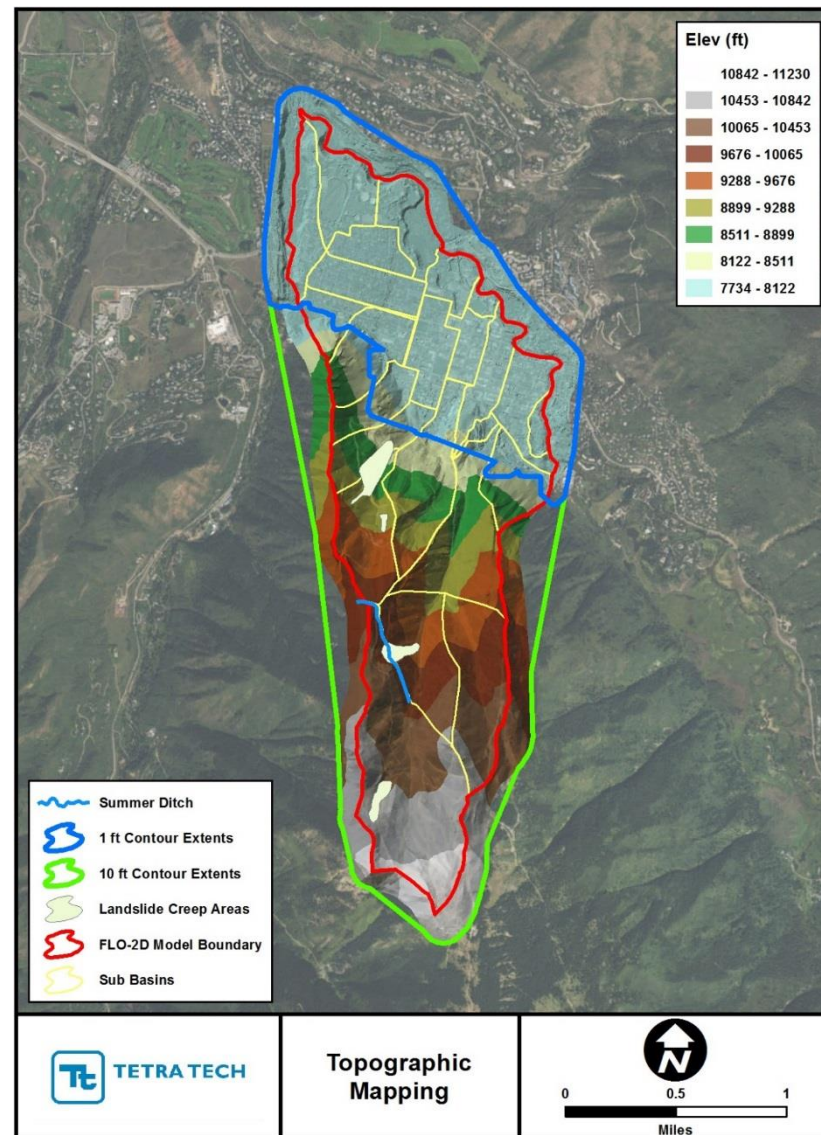


Current Study

- Evaluate potential impact to City
- Historical Review
- Geologic Investigation
- Develop new mudflow flow (FLO-2D) model
 - 2-Hour, 2-, 25-, and 100-Year Rainfall Events
 - Depth and Extent of Flooding
 - Hazard Mapping
 - Wildfire Analysis
 - Mitigation
 - Economic Analysis
 - Develop New Guidelines

New FLO-2D Model

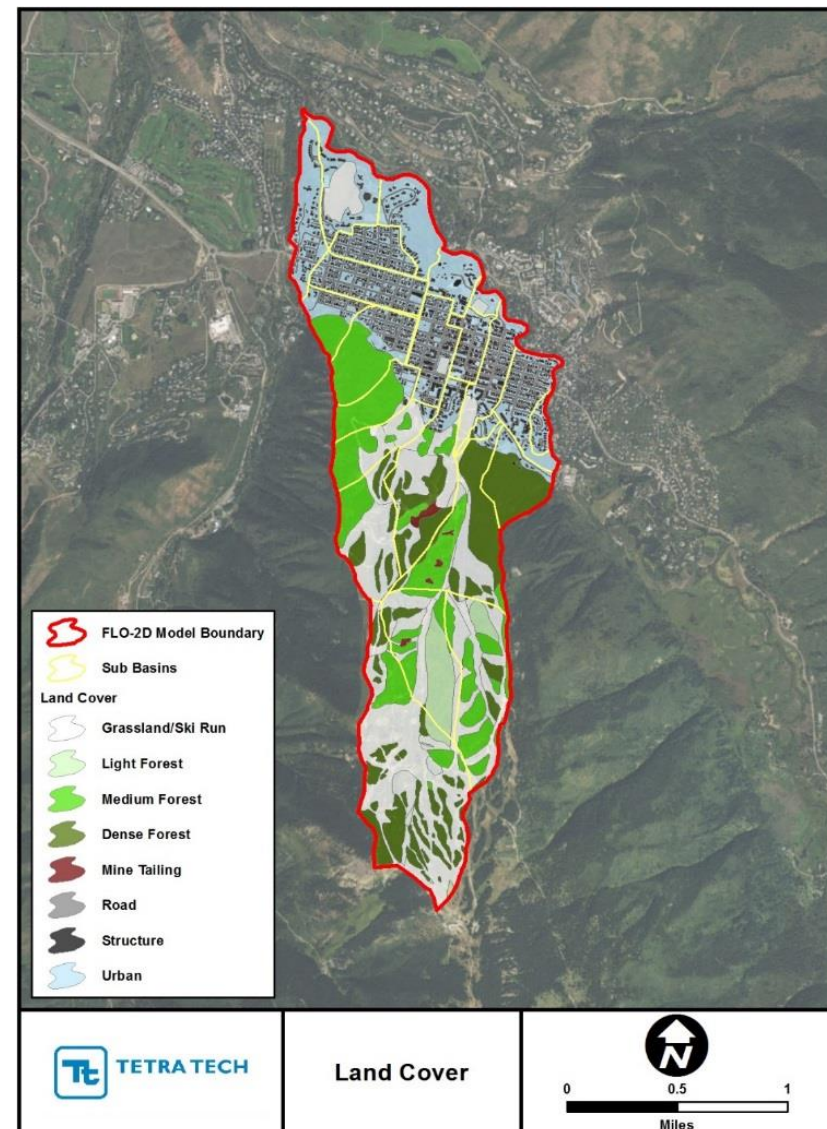
- 20-foot Grid Size
- 165,214 Elements
- Based on LiDAR mapping from City



Manning's n roughness

Overbank Manning's n -values.

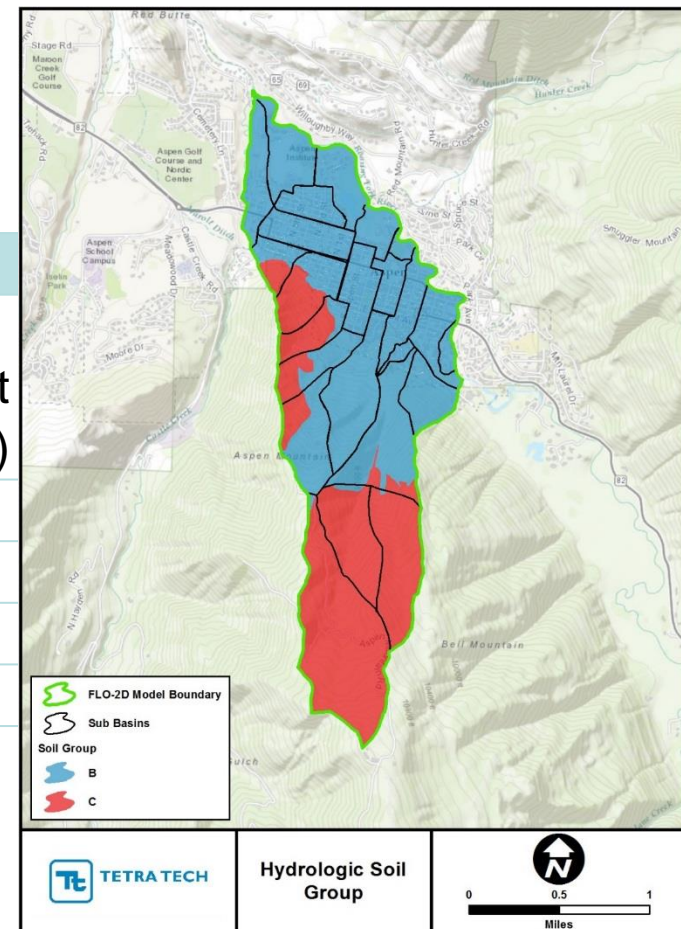
Land Use	n -value
Urban/Structures	0.04
Roads/Streets	0.02
Mine Tailing	0.40
Grassland/Ski Runs	0.20
Light Forest	0.30
Medium Forest	0.35
Dense Forest	0.40



Infiltration

Horton's infiltration parameters.

Hydrologic Soil Group	Initial Rate (in./hour)	Final Rate (in./hour)	Decay Coefficient (1/second)
A	5	1	0.0007
B	4.5	0.6	0.0018
C	3	0.5	0.0018
D	3	0.5	0.0018

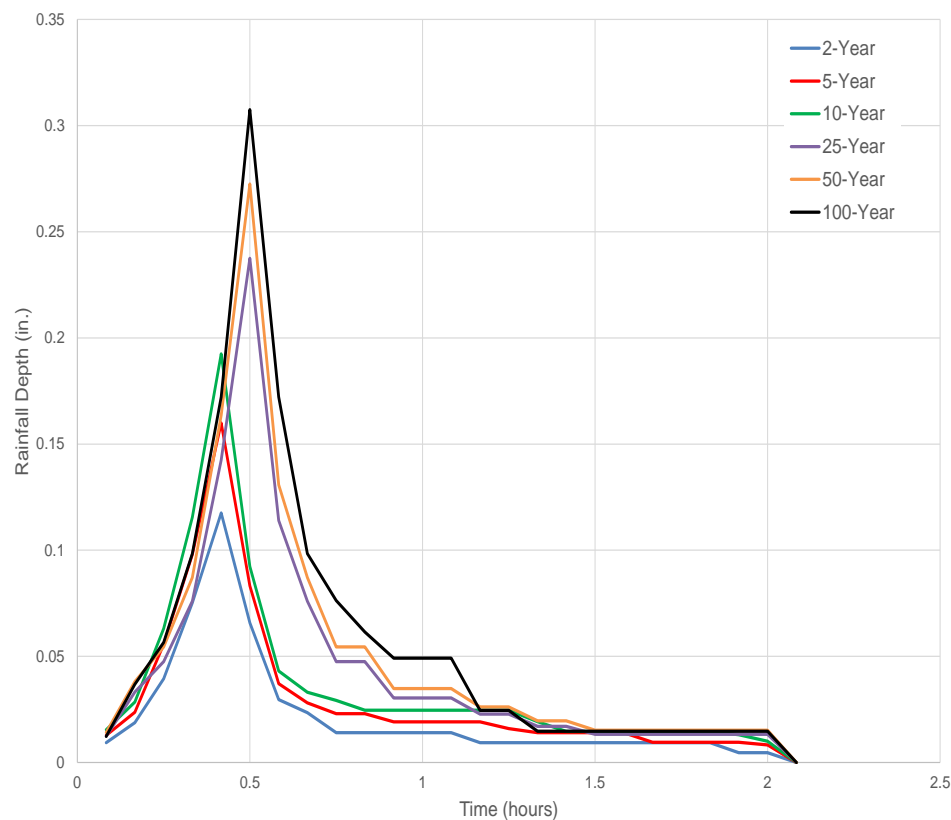


Rainfall

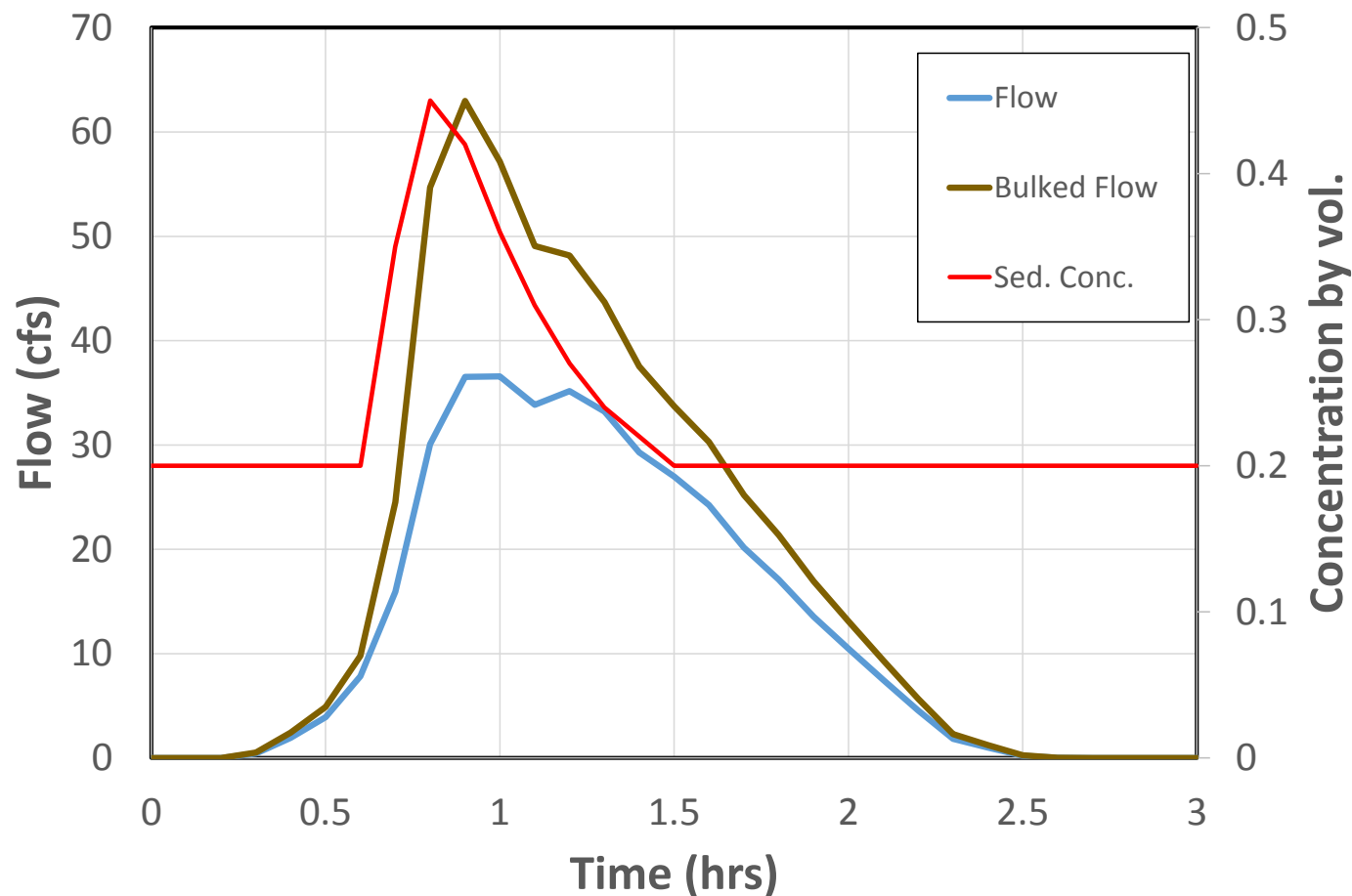
Colorado Unit Hydrograph Procedure (CHUP)

NOAA Atlas 14

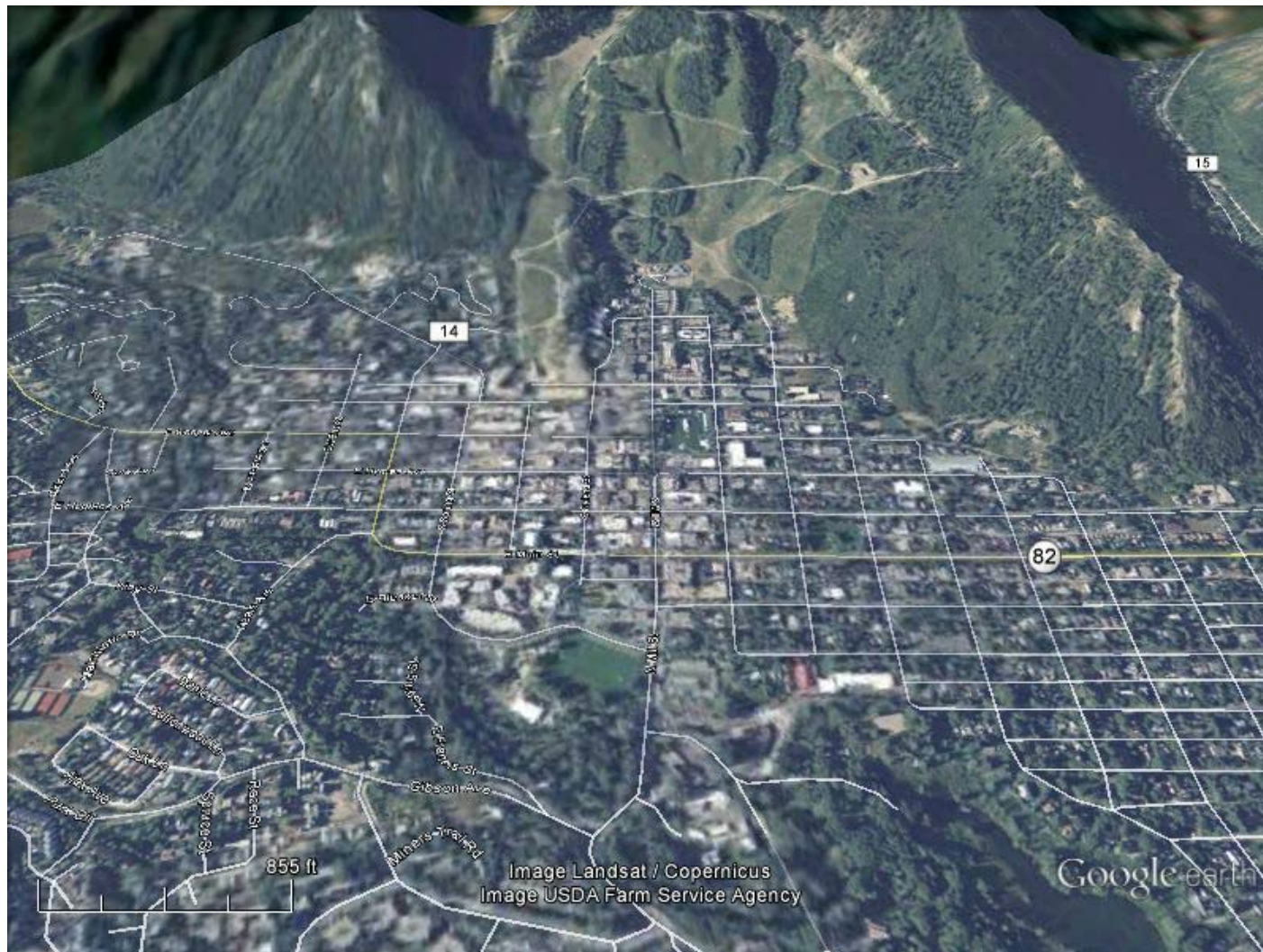
Recurrence Interval (years)	Rainfall (in.)
2	0.47
5	0.64
10	0.77
25	0.95
50	1.09
100	1.23



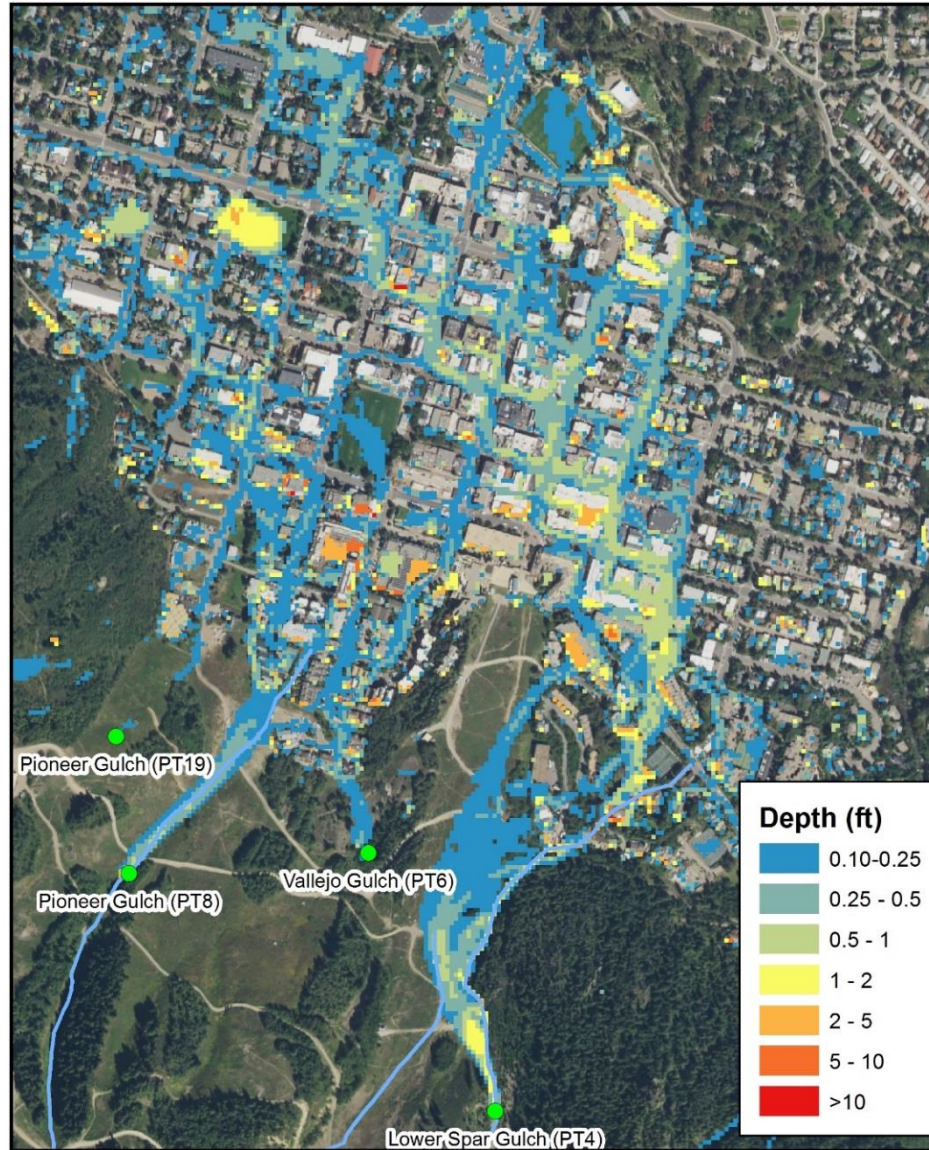
Water and Sediment Hydrograph



Model Output



Mapping



Economic Costs

Location	Mud Depth	Days of cleanup	Cost
Streets			>\$300,000
Sewer Lines			>\$380,000
Residential	6'	11	>\$800,000
Hotel	3'	50	>\$4.5M
Commercial	3'	3	\$165,000

Possible Changes to Regulations

- Adjust zoning areas
- 25-year (45% concentration)
- 100-year (20% concentration)
- Depth increase up to 0.5 feet
 - On ground previously inundated
 - Make reasonable effort to not increase.
- No depth increase on land not inundated under existing conditions

Current Study

- Model will be available to:
 - Developers
 - Engineers
- Substantial decrease in analysis cost
- Easier for City to review
- City to keep track of model changes