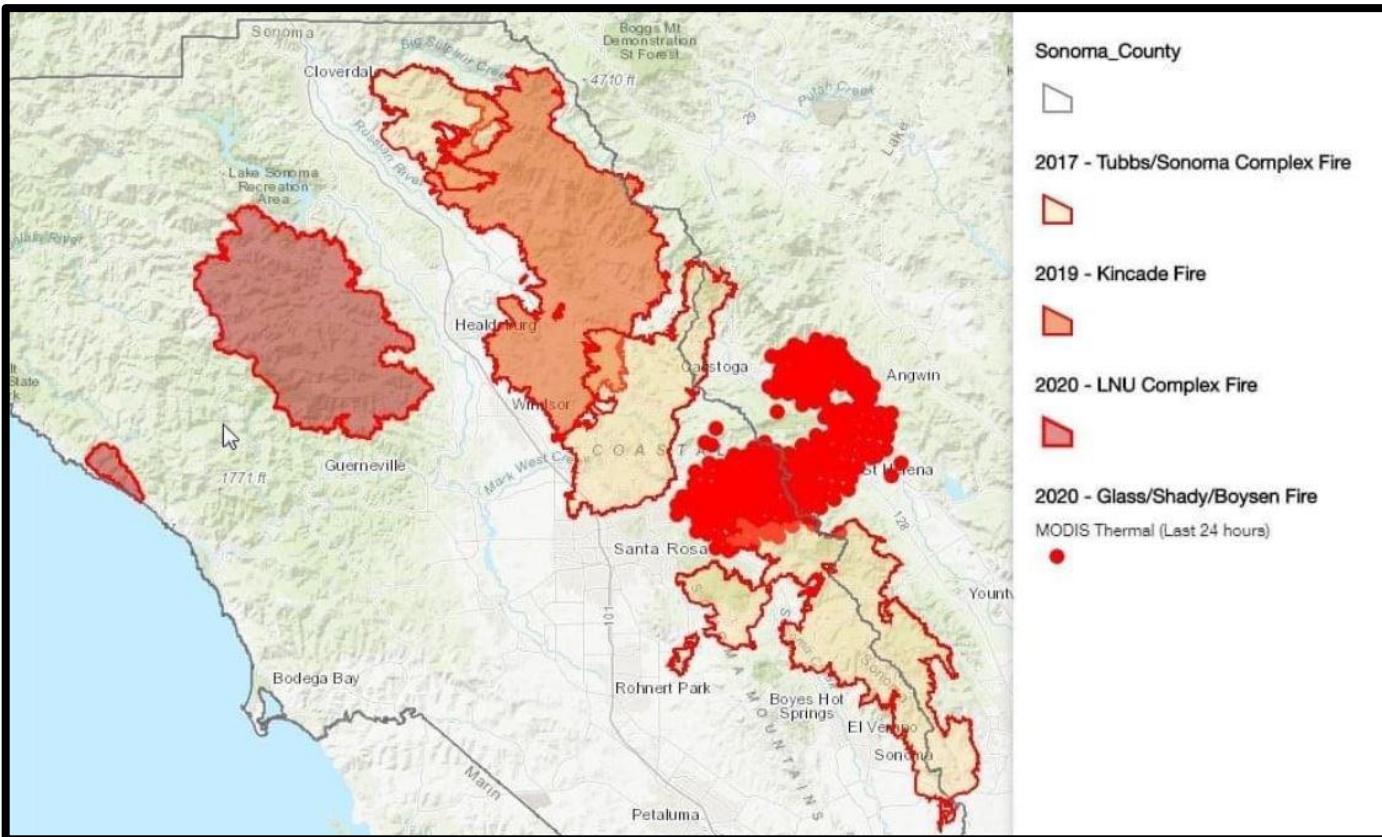




# Extinguishing Bottlenecks: Optimizing Fire Evacuation Routes

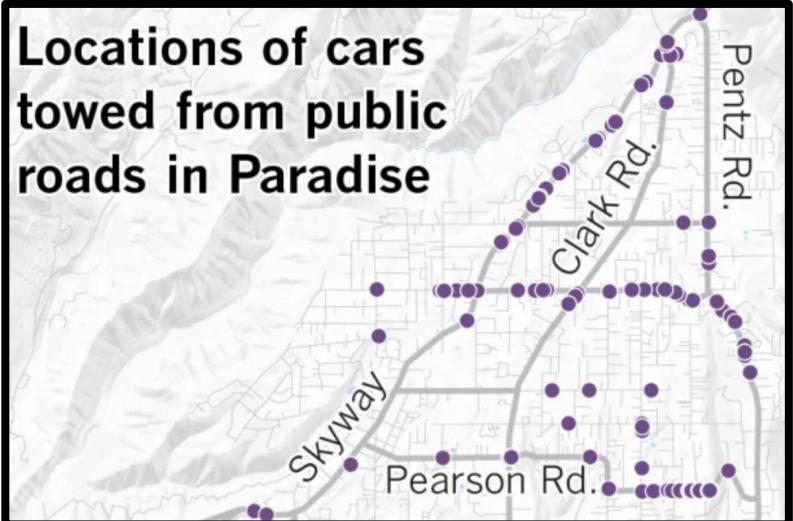
**Nick Crawford // Drew Horton**

# Personal Motivation



# The Camp Fire

- Paradise, CA
- Caused by downed power lines
- Deadliest Fire in California's History
  - 85 total deaths
  - 7 died in vehicles
- Fire spread 80 football fields a minute (at its peak).
- Only one way out of Paradise(Skyway, 4 lanes)
- Traffic jams caused people to abandon cars and flee by foot



# Colorado Fires

## Top 3 Fires in Colorado History:

- *Cameron Peak (2020)*: 208,913 acres
- *East Troublesome (2020)*: 193,812 acres
- *Pine Gulch (2020)*: 139,007 acres

20 of 20 largest wildfires have occurred in the last 20 years (since 2001)

16 of the top 20 largest wildfires have occurred in the last 13 years (since 2008)

15 of top 20 largest wildfires have occurred in the last 9 years (since 2012)

11 of top 20 largest wildfires have occurred in the last 5 years (since 2016)

9 of top 20 largest wildfires have occurred in the last 3 years (2018 and 2020)

4 of top 5 largest wildfires have occurred in the last 3 years (2018 and 2020)

## This Year:

- Marshall Fire
- NCAR Fire
- & more





# Colorado Fires

## This Year:

- Marshall Fire
- NCAR Fire
- & more



# Areas of Interest

- Limited entrances and exits
- Highly trafficked
- Dangerous Fire Conditions
- Lacking current evacuation plans

7 The Denver Channel

## 37E Fire burning north of Lyons, evacuations underway

As of Friday evening, the fire has burned 300 acres and is zero percent contained, according to the sheriff's office. Crews will continue to...

2 weeks ago



## Pueblo under 'extreme critical' fire conditions



**Justin Reutter**

The Pueblo Chieftain

Published 2:38 p.m. MT April 22, 2022

[View Comments](#)



# MAP YOUR PLAN

PREPARE AN EVACUATION ROUTE TODAY!

Learn more at [PreparePueblo.com](http://PreparePueblo.com)



# Data

## OSM (Open Street Maps)

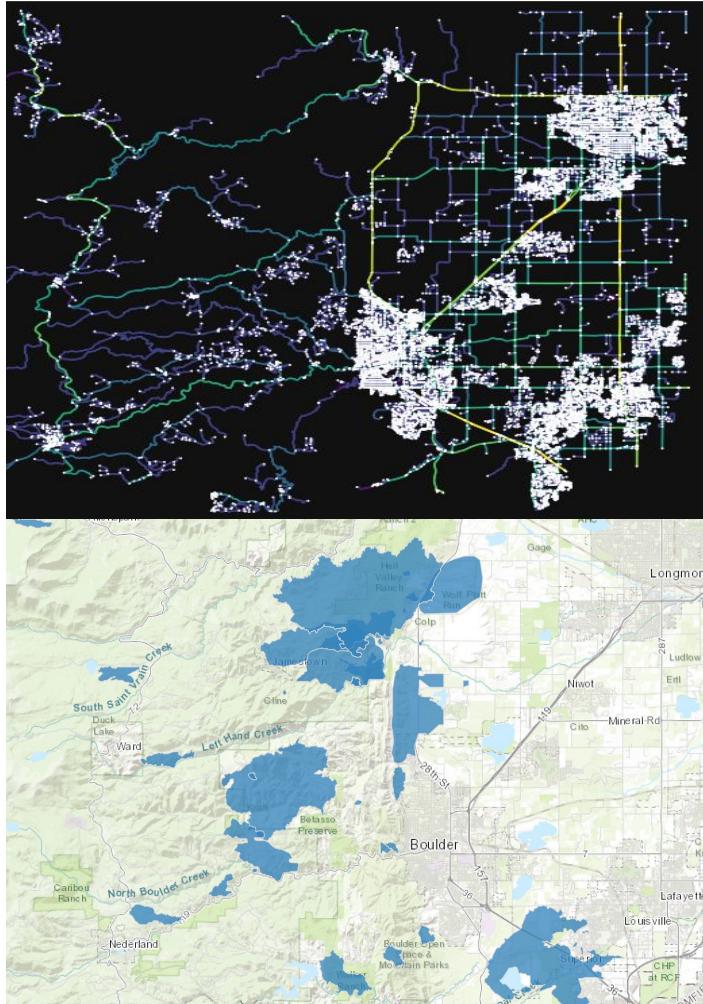
- All driving routes of any neighborhood, city, state, or area
  - Speed limits of roads
  - Approximate travel times

## StreetLight Data

- Communities with limited evacuation routes

## Focus on Colorado

- Boulder County
  - Lyons
  - Superior
- Pueblo County
  - West Pueblo

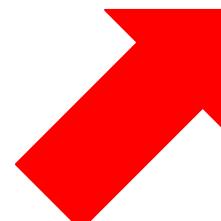
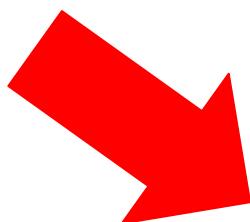


# Methods

Determine  
Source and  
Sink Nodes

Determine  
Bottlenecks

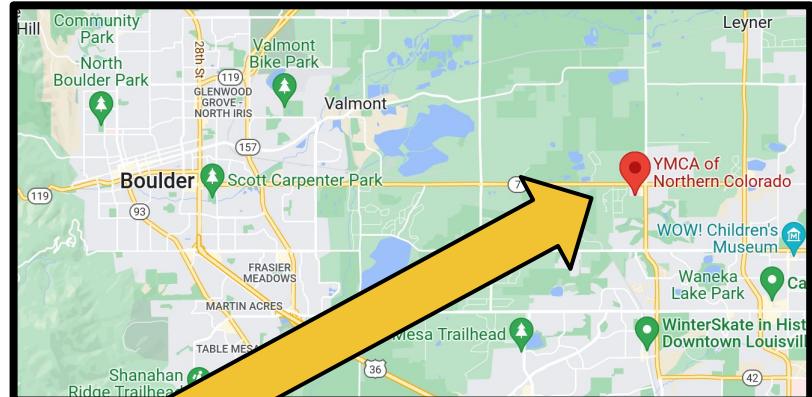
Solve  
Maximum Flow  
Problem



# Source and Sink Nodes

## Source

- Areas where fires have occurred
- Places close wilderness
- Neighborhoods with minimal entrances and exits
- Densely populated/visited areas



## Sink

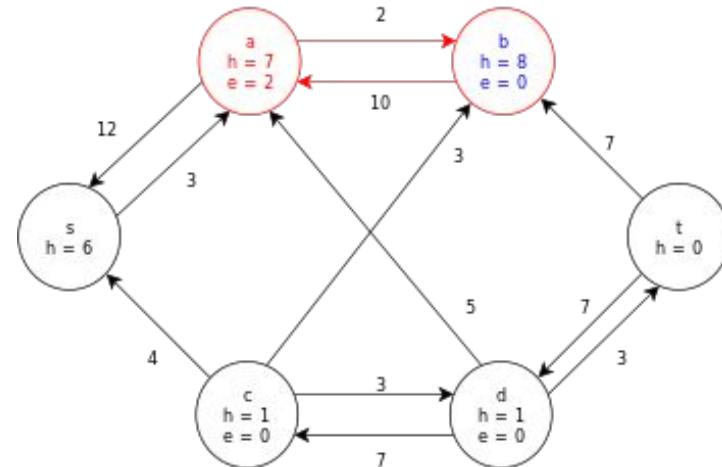
- Current evacuation shelters
- Nodes outside fire perimeter
- Larger cities
- Eastern cities (Colorado Specific)

# Solving Maximum Flow Instance

- Dijkstra's algorithm
  - find shortest paths routes using travel time

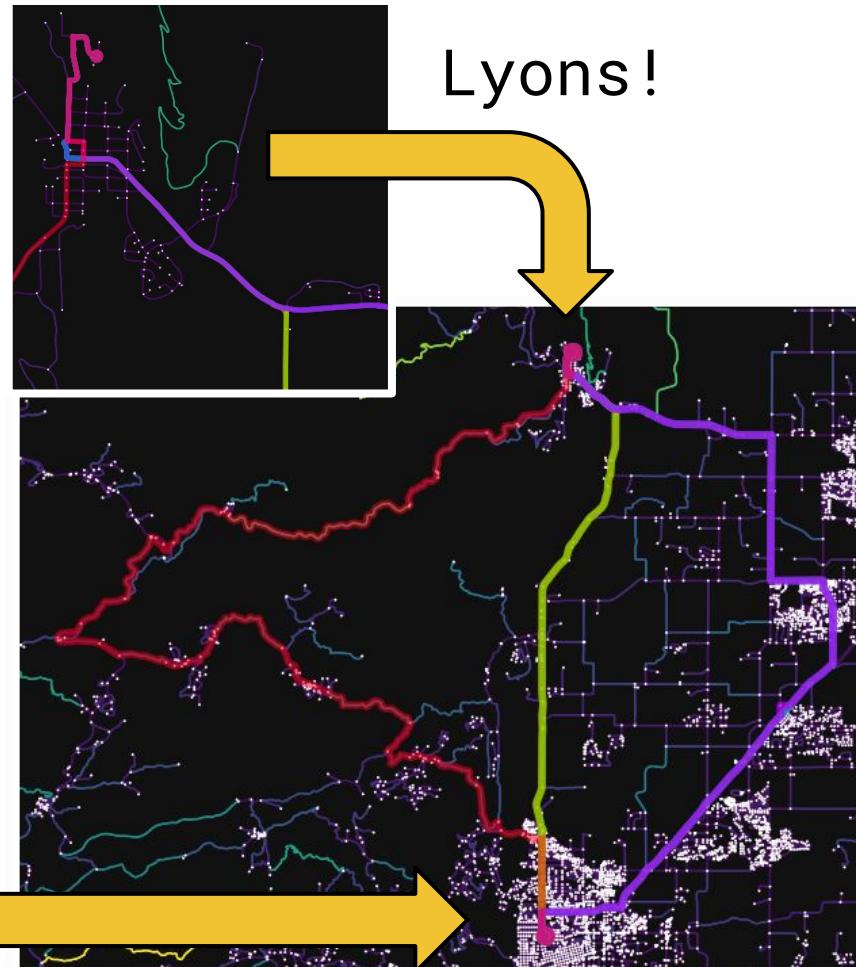


- Augmenting Path Labeling Algorithm
  - find maximum flow along shortest paths



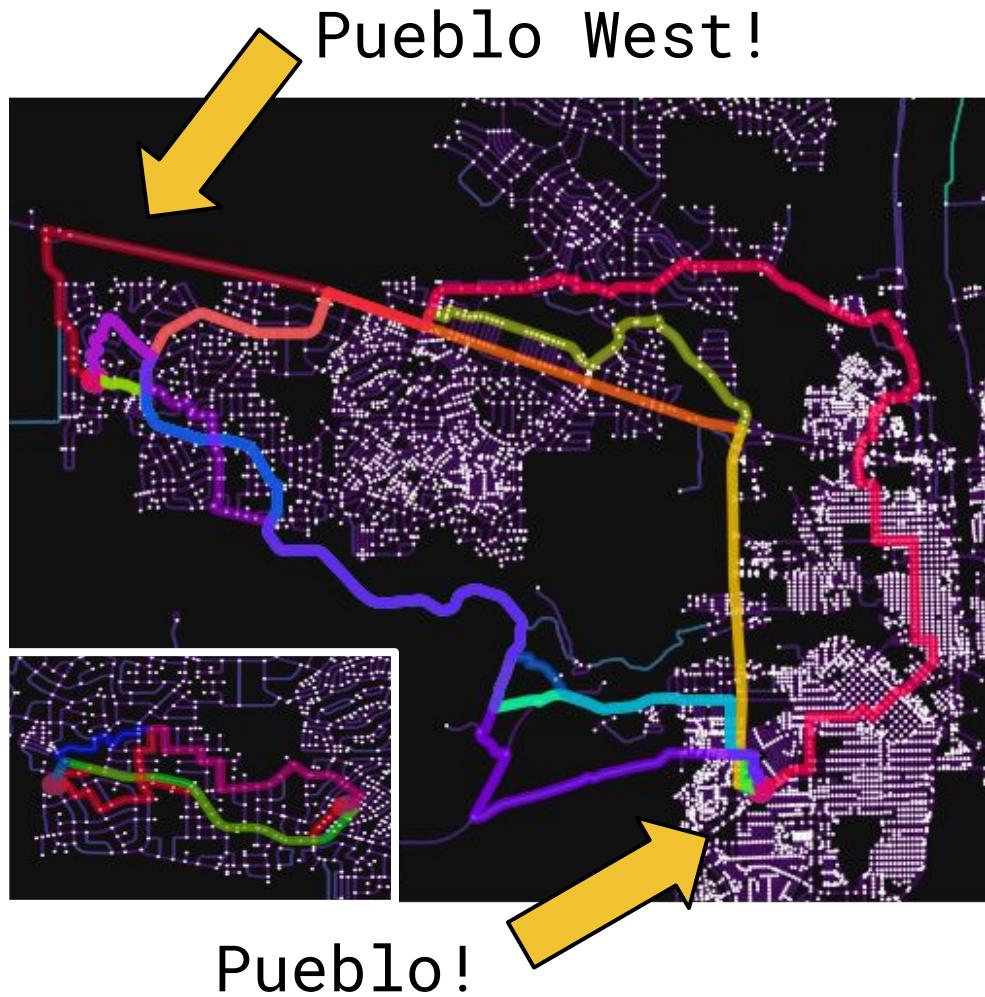
## Lyons, Colorado

- **Population:** 2,228 (2019)
- **4 total exits**
- 59% of daily traffic uses the main exit route (Streetlight Data)
- **Maximum Flow** from Lyons Colorado to Evacuation Center in Boulder: 1958 vehicles per hour

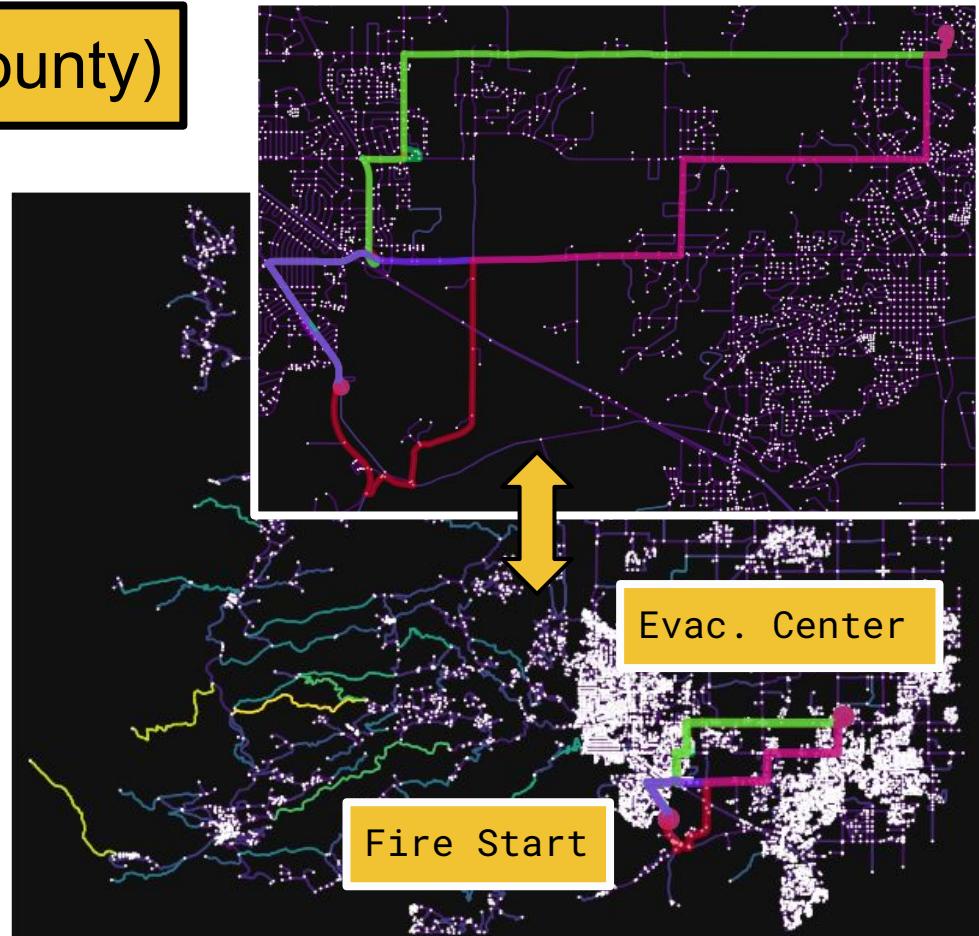
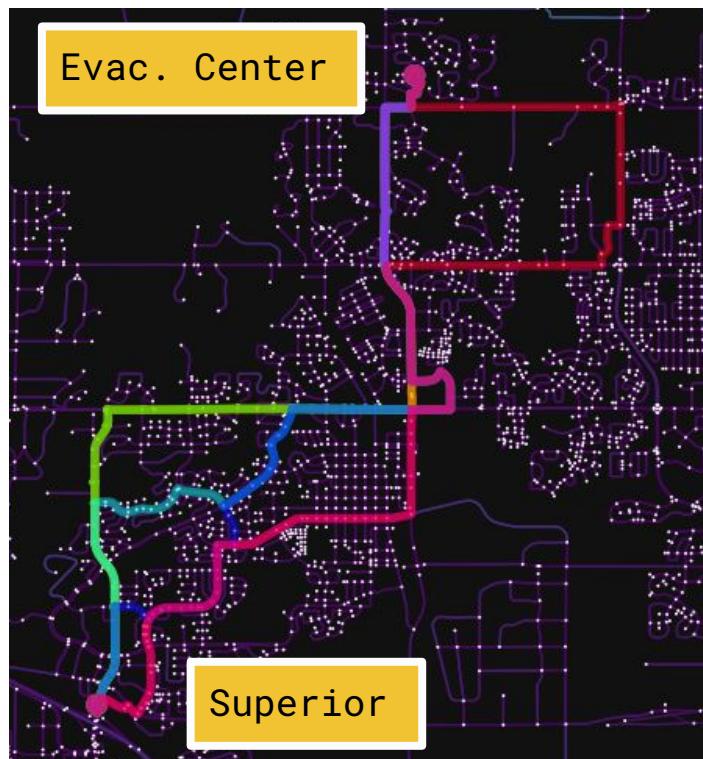


## Pueblo West, CO

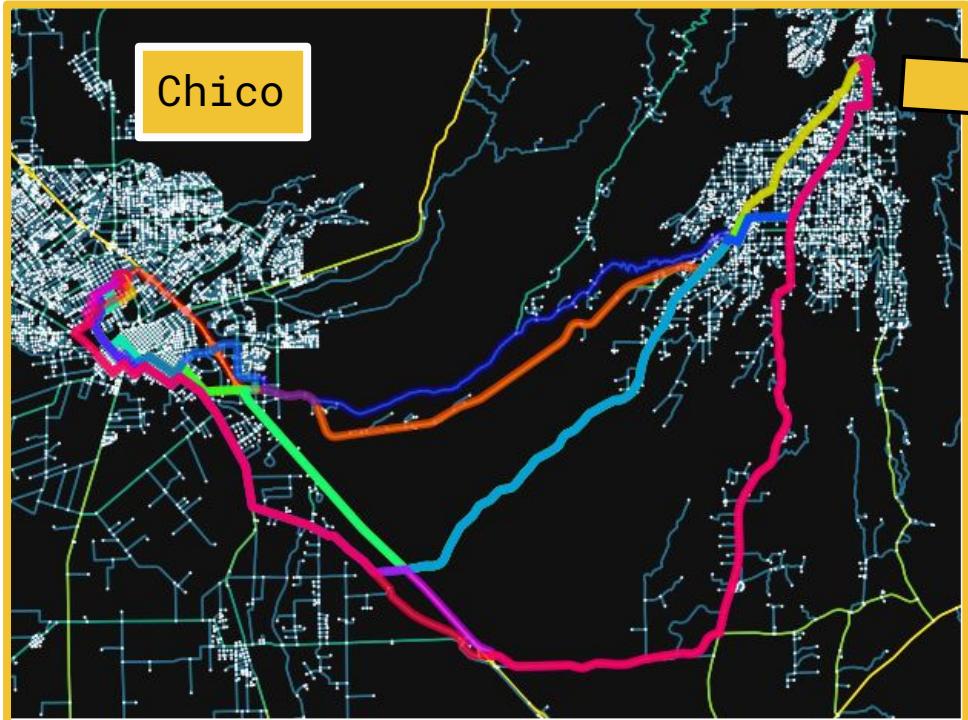
- **Population:** 31,849 (2019)
- **12 total exits**
- 51% of daily traffic uses the main exit route (Streetlight Data)
- **Max Flow** from Pueblo West to Evacuation Center in Pueblo: 1841 vehicles per hour



# Marshall Fire (Boulder County)

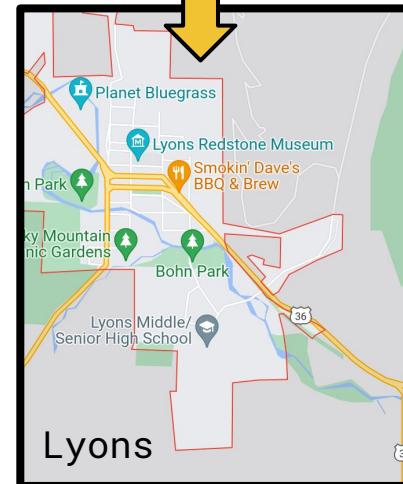
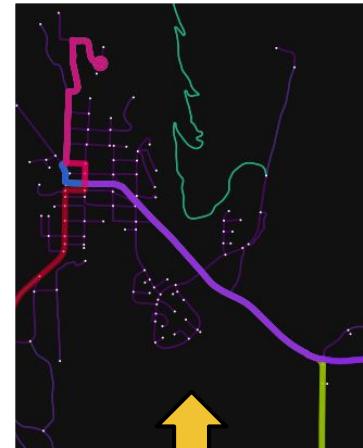


# Camp Fire (Butte County)



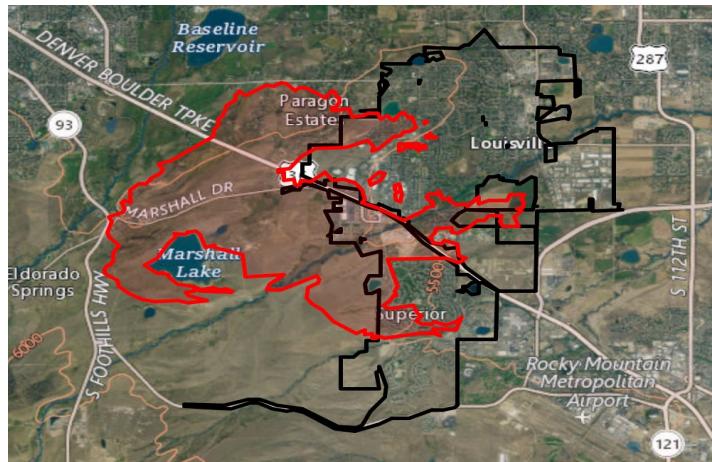
# Policy Recommendations

- Shortest path and maximum flow algorithms can be used to assess current evacuation strategies.
- As populations grow, re-asses whether current road infrastructure is suitable for evacuating residents.
- Consider expanding roads that are 'bottlenecks' in evacuation routes.
- Maximum flow can inform fire officials who make decisions on when to send evacuation notices



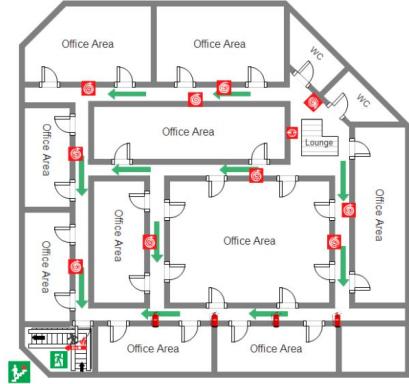
# Limitations

- Road capacities are theoretical
  - based on safe/calm drivers
- Need to determine method to assign neighborhoods to specific paths
- Evacuation route goes to one specific location
  - Need to consider any safe area as a sink node
- Need to consult experts on what other things should be considered



# Other Applications

- **Festivals/Densely Populated gatherings**
  - Love Parade
  - AstroWorld
- **Natural disasters**
  - Flood
  - Tsunami
  - Hurricane
  - Volcano
- **Building Evacuations**
  - Large Venues
  - Schools
  - Apartments



# Future Work

- Partition areas into different zones and asses evacuation routes for each zone
- Incorporate ways to close streets that are affected by fire
- Adjust the capacities to “realistic” driving conditions during evacuation
- Consider implications of adding flow to certain arcs

## Paradise

### Emergency Fire Zones and Assembly Points

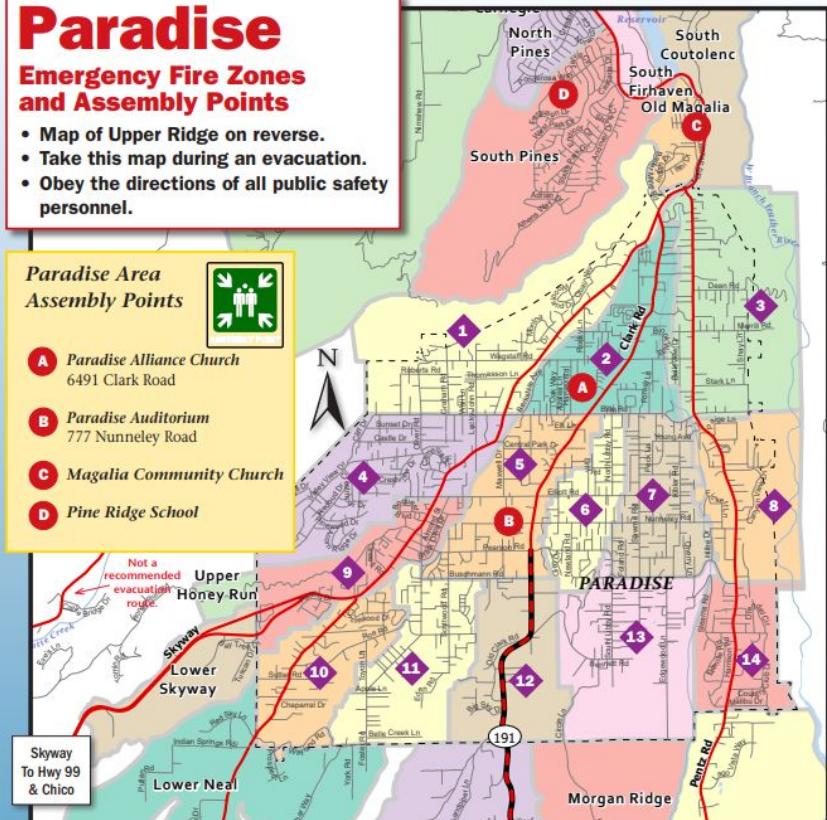
- Map of Upper Ridge on reverse.
- Take this map during an evacuation.
- Obey the directions of all public safety personnel.

#### Paradise Area Assembly Points



- A Paradise Alliance Church  
6491 Clark Road
- B Paradise Auditorium  
777 Nunneley Road
- C Magalia Community Church
- D Pine Ridge School

Skyway To Hwy 99 & Chico



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