CASFM 2018 Annual Conference

Emergency Preparation Sessions:

Session1: Extreme Rainfall Events Along the Front Range of CO

Baxter Vieux (Vieux), Kevin Steward (UDFCD)

Session2: Structure-Level Risk Assessment Using 2D Modeling

Geoff Uhlemann (AECOM)

Mapping Fluvial Hazard Zones: Developing Guidance, Applications, Pilot

Stephanie DiBettito (CWCB), Joel Sholtes (USBR), Michael Blazewicz (Round River Design), Katie Jagt (Watershed Science)

Evacuation Planning for Extreme Events: Failure of Cherry Creek

Jeffrey Brislawn, Kyle Karsjen (Wood)

Innovation in Colorado: High Hazard Dam Release – Downstream Floodplain Impacts

Bill McCormick, Kallie Bauer (CO Division of Water Resources)

Showcasing the Pilot Boulder County FRIS

Madeline Kelley (DU), Thuy Patton (CWCB)

2018 CASFM Conference will be held September 25-28, 2018
Westin Snowmass Resort Snowmass, CO
Emergency Preparation EP1, Thursday, September 27, 2018 1:30pm Cathedral Peak

Extreme Rainfall Events along the Front Range of Colorado:

How much did we find, and How much did we miss?

Baxter E. Vieux P.E. Ph.D., CTO Vieux & Associates, Inc.
Kevin Stewart, P.E., UDFCD Program Manager
Flood Warning & Information Services

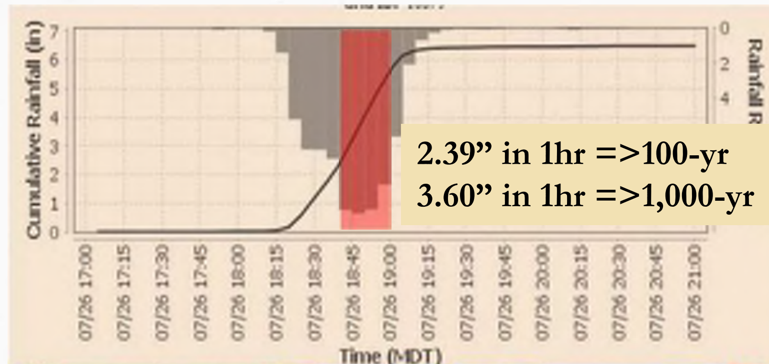
On July 26, 2017 news media reported street flooding in Greenwood Village…

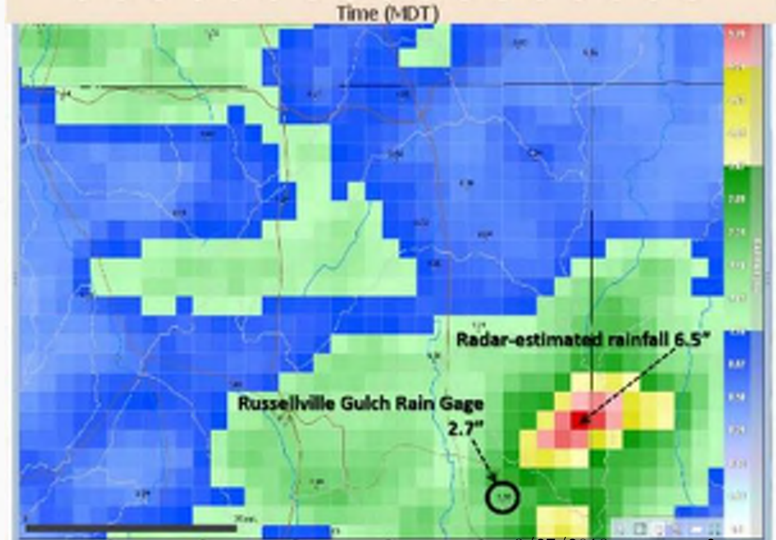
- A small stream out of its banks but no notable damages.
- Consistent with evening news reports about street flooding in Greenwood Village…
- **But where was the most extreme rainfall?**

  (Hint: Not Greenwood Village!)

Fox Hill Flood
July 26, 2017

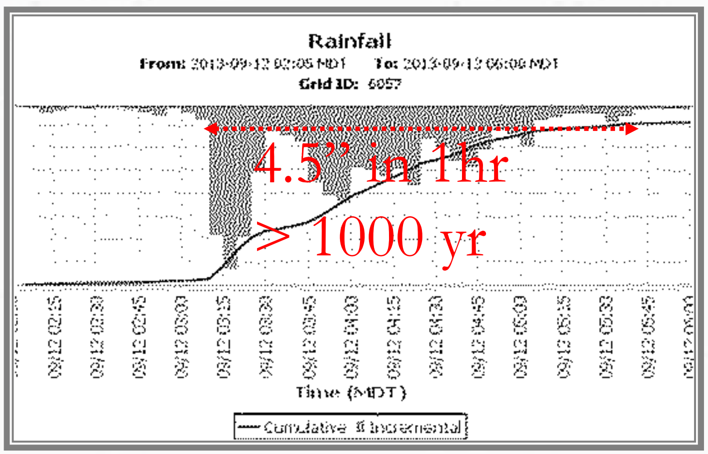
Flood damages from >1000 year rain event

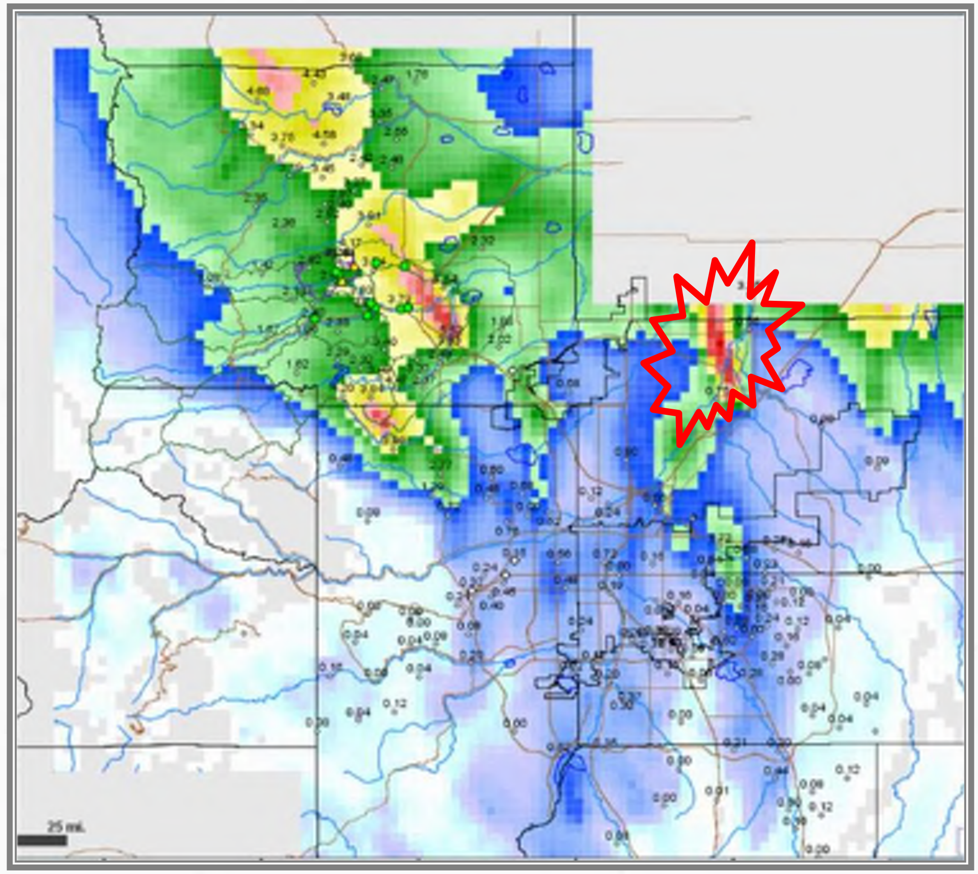




Todd Creek
Adams County

- A 8-hour period from
- 8PM (9/11/13) to 4AM (9/12/13)





Examining Extreme Event Detection

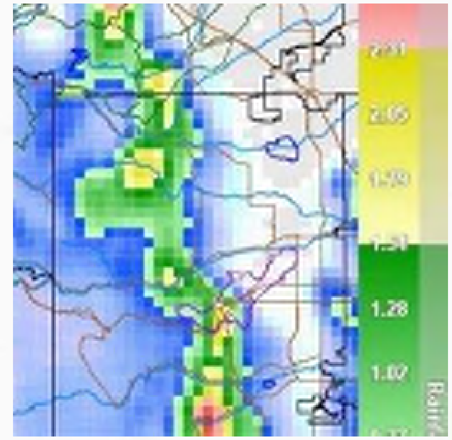
GARR and Gauges over the UDFCD Region

Detecting Extreme Rainfall

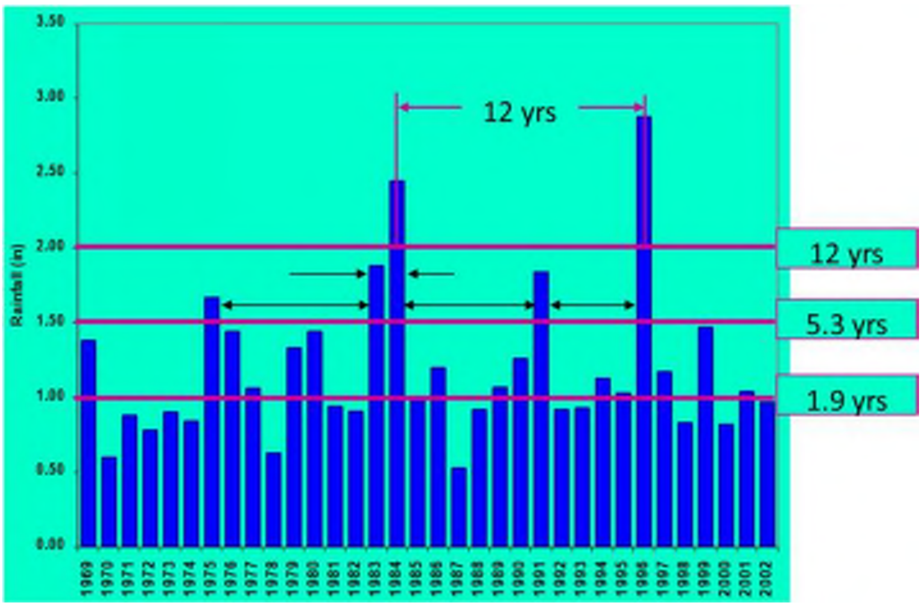
- Real-time rainfall is needed for flood alert decisions in support of the Urban Drainage and Flood Control District.
- UDFCD covers 1,608 mi^2 and parts of 6 counties along the Colorado Front Range
- FCD operates 202 ALERT rain gauges with a mean spacing of 2.6 mi.
- Gauge-adjusted radar rainfall (GARR) is a combination of weather radar and these gauges that fills in between the gauges.

Tools for today's analysis

- GARR
  - Radar spatial patterns at high resolution
  - Rain gauge point measurements
- Better than either system alone at producing accurate high resolution rainfall everywhere…'between the gauges'



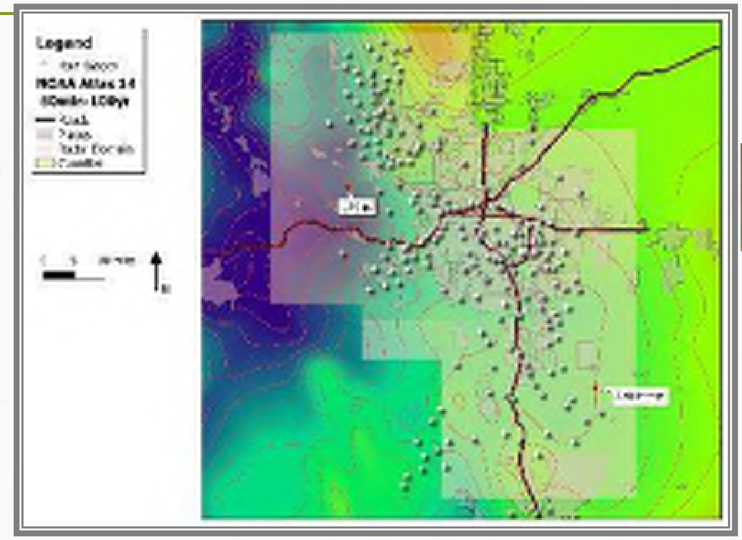
Return Period



- Defined as: “Average time between events larger than a given threshold”
- Used to categorize precipitation frequency.
- 100-yr event = 1 event in 100 years

NWS NOAA Atlas 14 Precipitation Probabilities

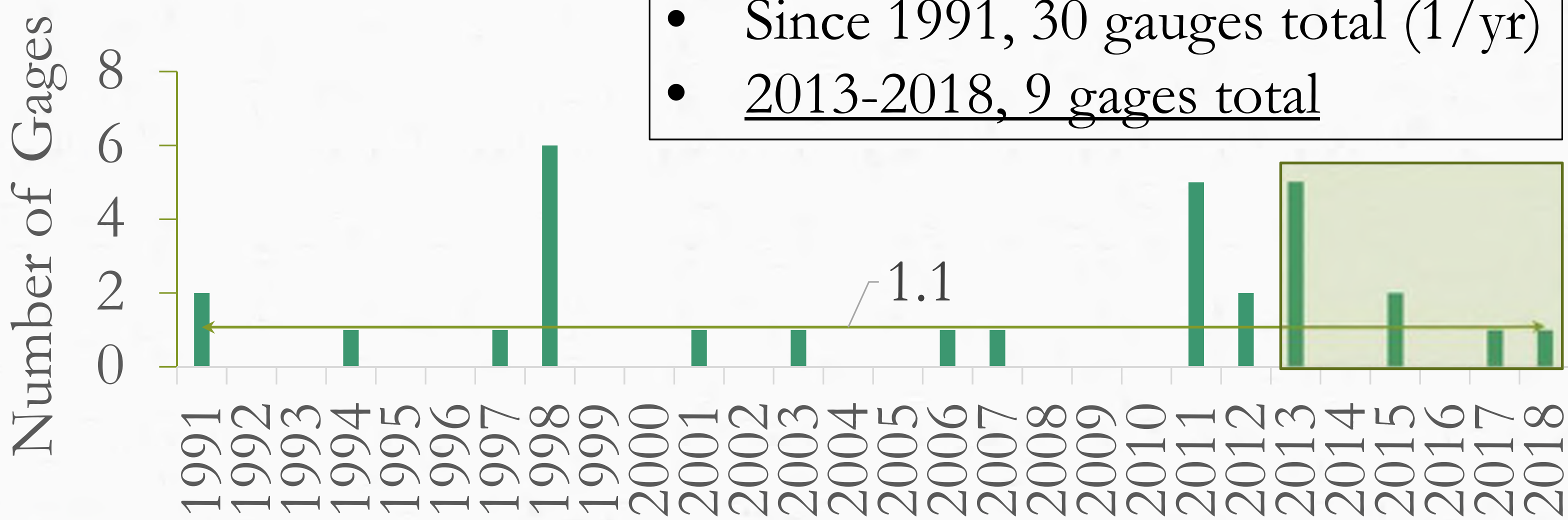
- Statistically at each of the 202 rain gauges there should be:
- One 100yr event occurs on average once every 100 years,
- Any one gauge has a 1% chance any given year
- Over 5 years, one gauge has 4.8% chance of a 100-yr event, Risk=$(1-1/T)^n$



Bedient, Huber, and Vieux (2018) Hydrology and Floodplain Analysis

100yr-60min Events Detected by Rain Gauges

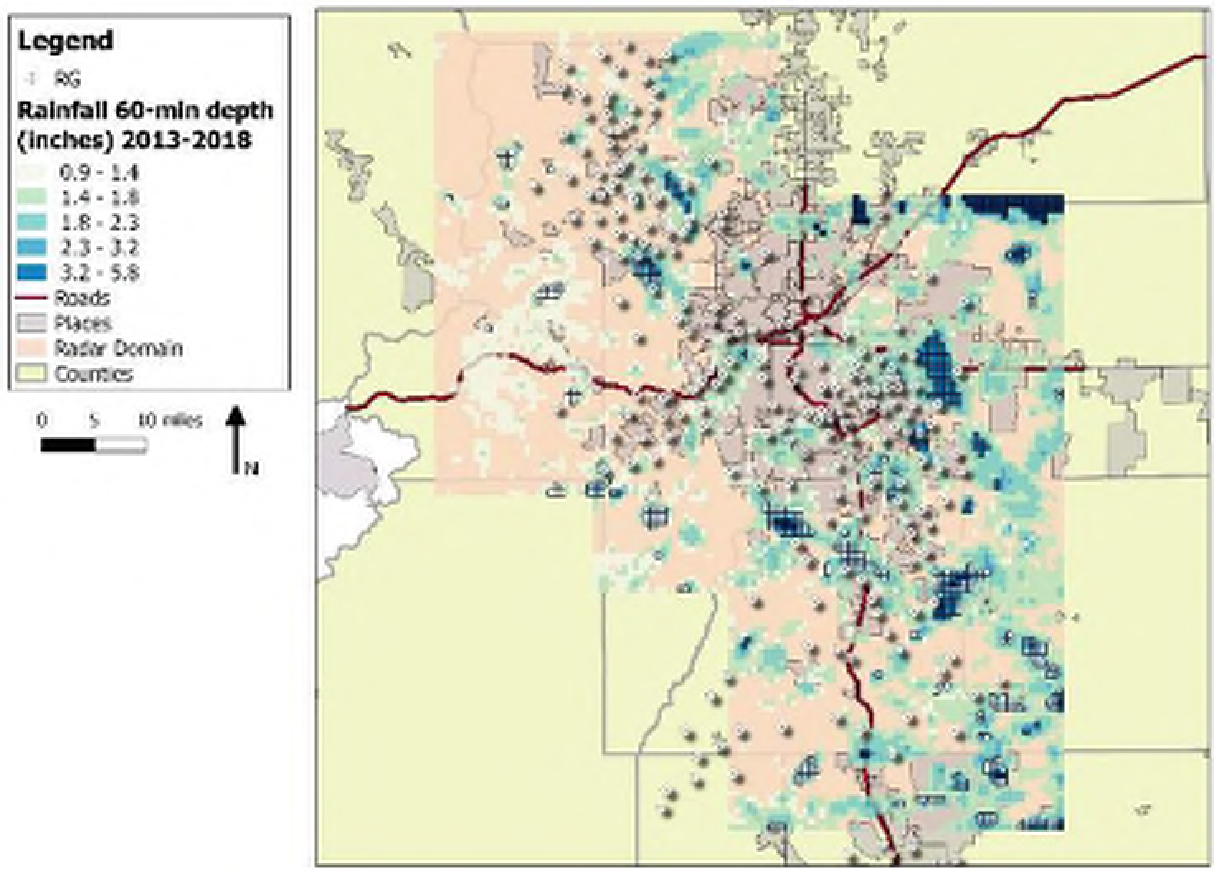
- Since 1991, 30 gauges total (1/yr)
- 2013-2018, 9 gages total

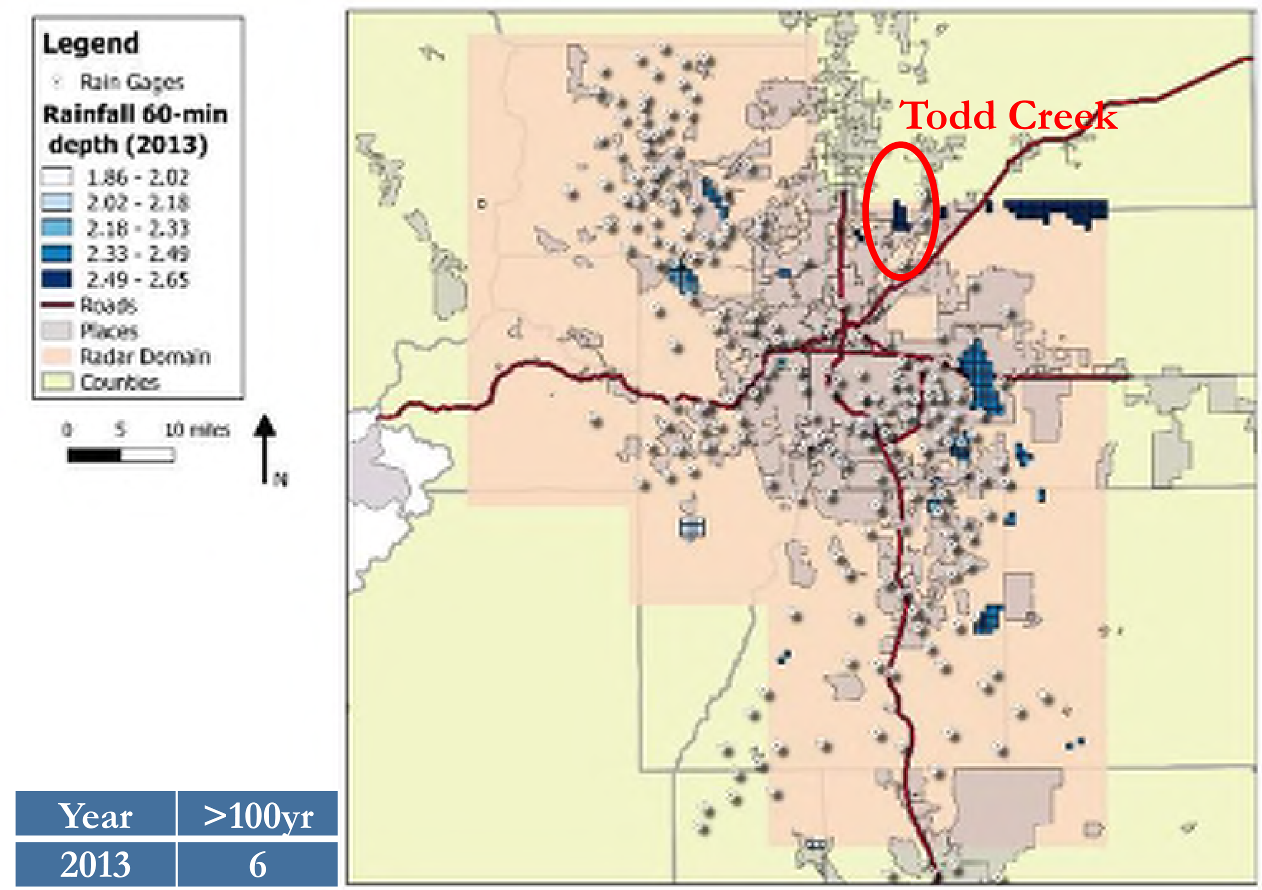


GARR Events

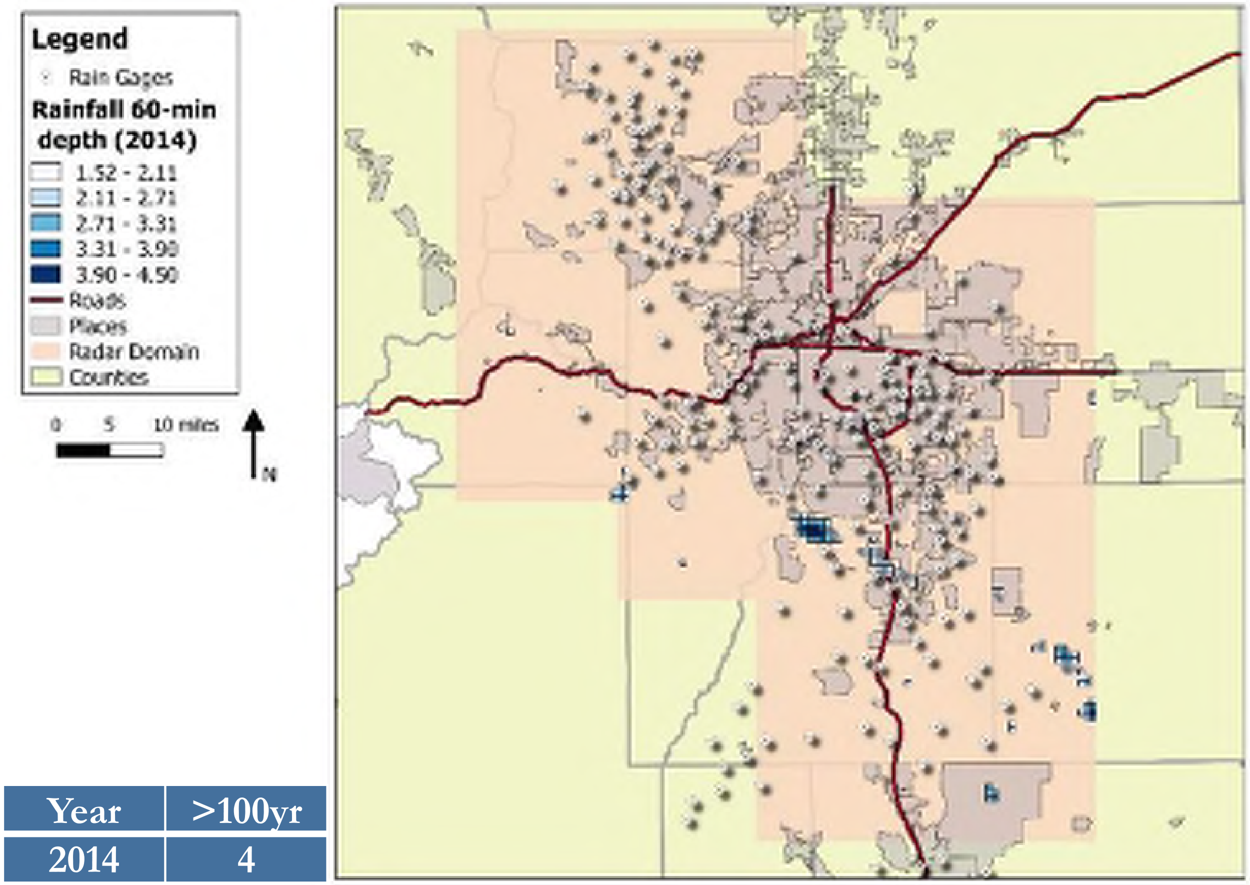
Year	>100yr
2013	6
2014	4
2015	3
2016	1
2017	12
2018	1
Total	26
Average	**5.2**

- **26 pixel events 5 per year**
- **9 gage events, 1 per year**

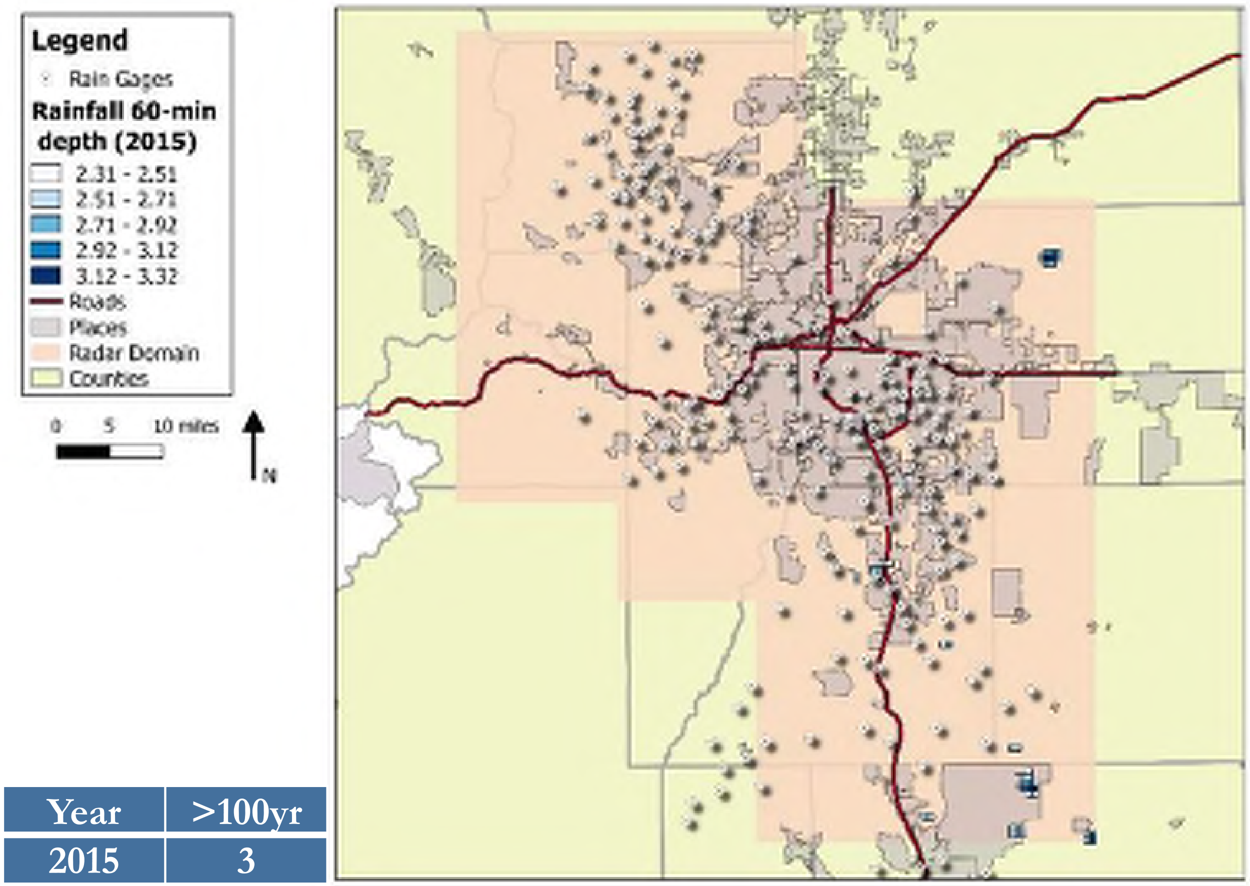




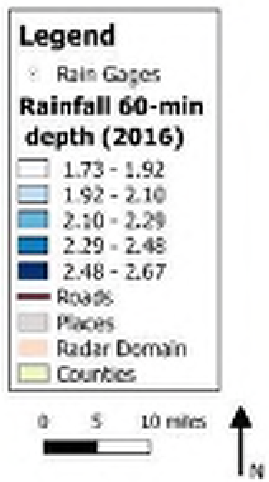
Year	>100yr
2013	6

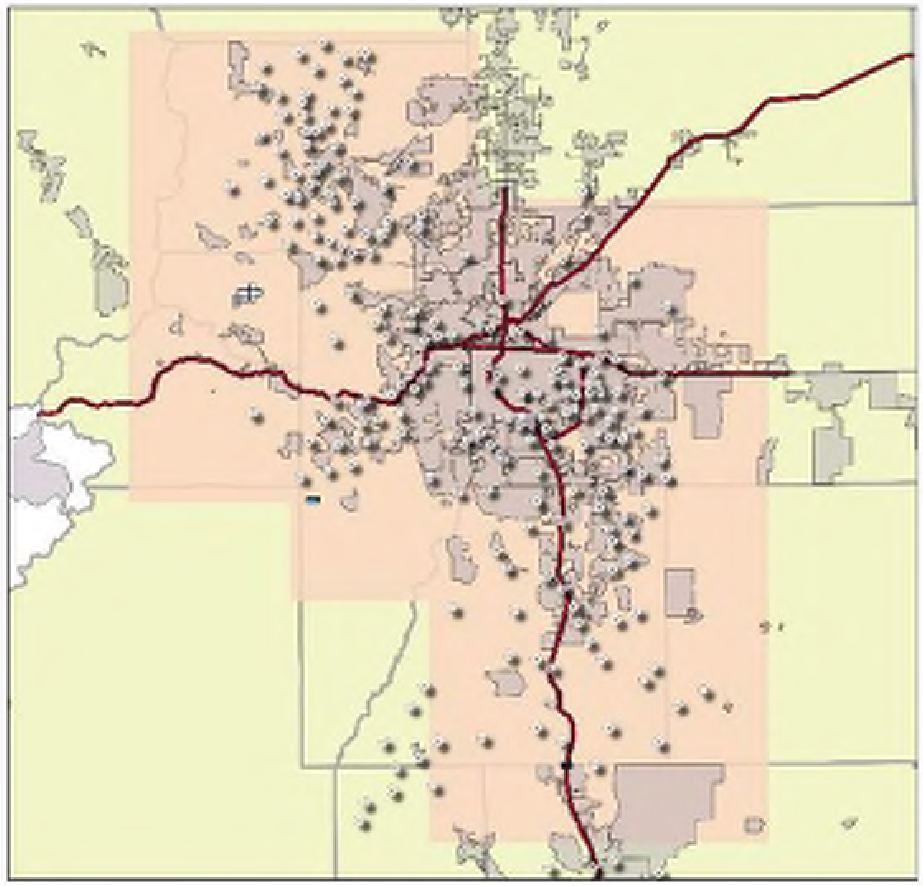


Year	>100yr
2014	4

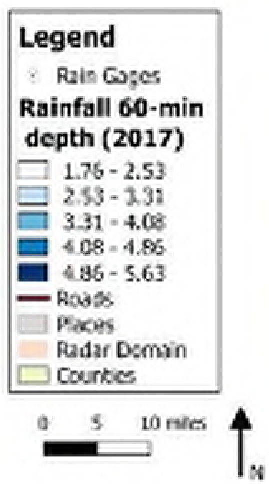


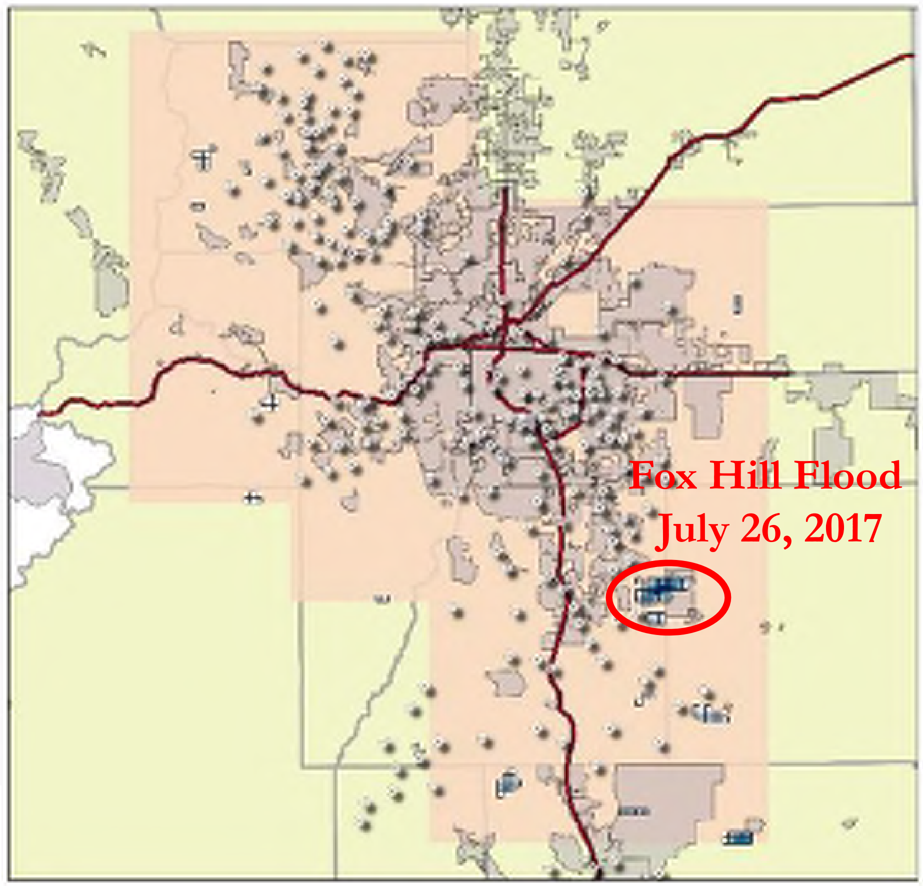
Year	>100yr
2015	3





Year	>100yr
2016	0





Year	>100yr
2017	12

Summary

- "Rare" events are not that rare when considering the UDFCD region
- 100-yr events happen frequently
- How much did we find and how much did we miss?

<u>100yr-60min (2013-2018)</u>
9 gage events, 1 per year
26 pixel events, 5 per year

Structure-Level Risk Assessment Using 2D Probabilistic Modeling

CASFM 2018 – Snowmass, CO

Geoff Uhlemann - AECOM

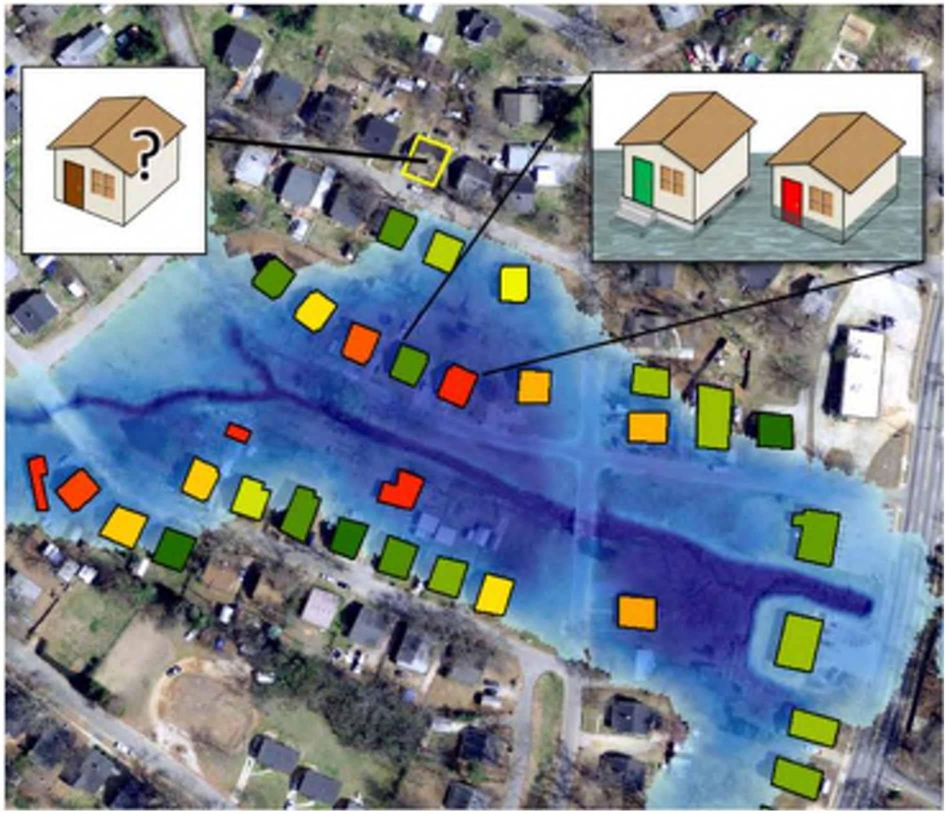
FEMA

compass
Identify, Interpret, Integrate

Reasons for a New Approach

Improved Accuracy & Resolution

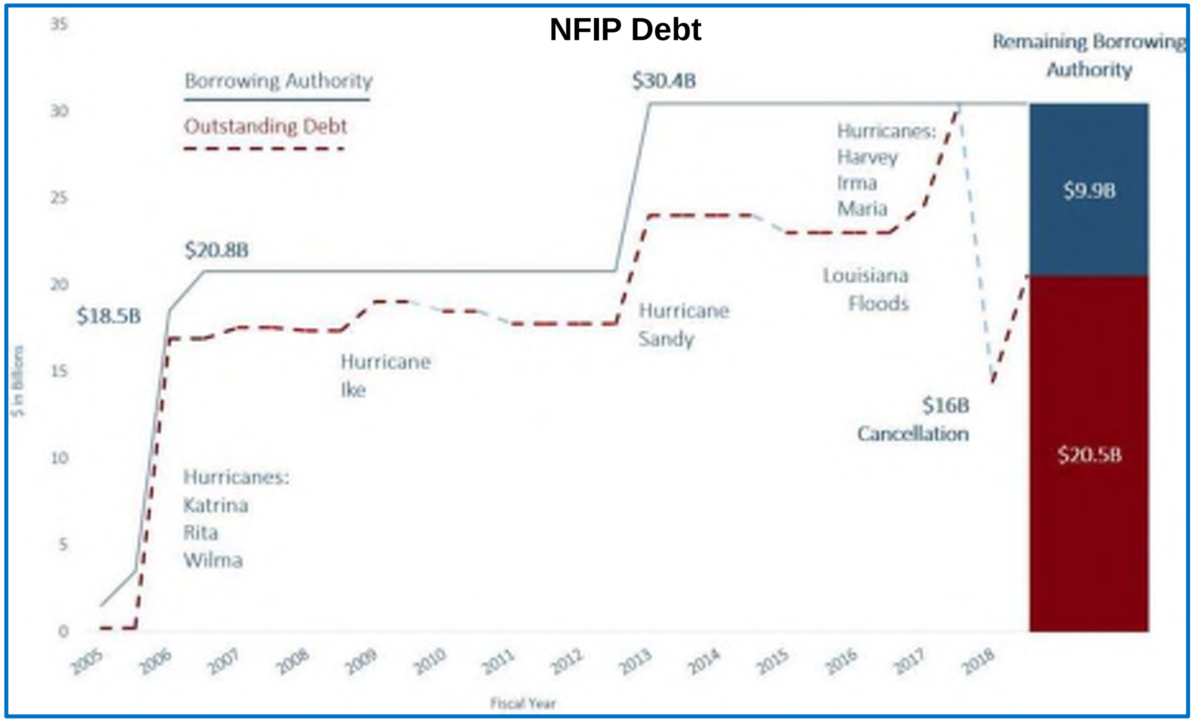
- To account for uncertainty
- Model future conditions
- >25% NFIP claims are structures outside SFHA (about 60% of losses)
- To capture more extreme events
- Show graduated risk within the 0.2% floodplain
- Include residual and pluvial risk
- Evaluate specific homes



Reasons for a New Approach

Enhanced End Products/Application

- To provide structure-level risk assessment
- To discretize flood insurance
- Communicate location-specific risk
- Evaluate risk behind levees
- CBA & performance-based levee analysis
- Risk-informed decision making process
- Depict total flood risk (fluvial + pluvial)
- Information on wide range of events, esp frequent (2 yr)
- Byproducts are grids for any recurrence interval

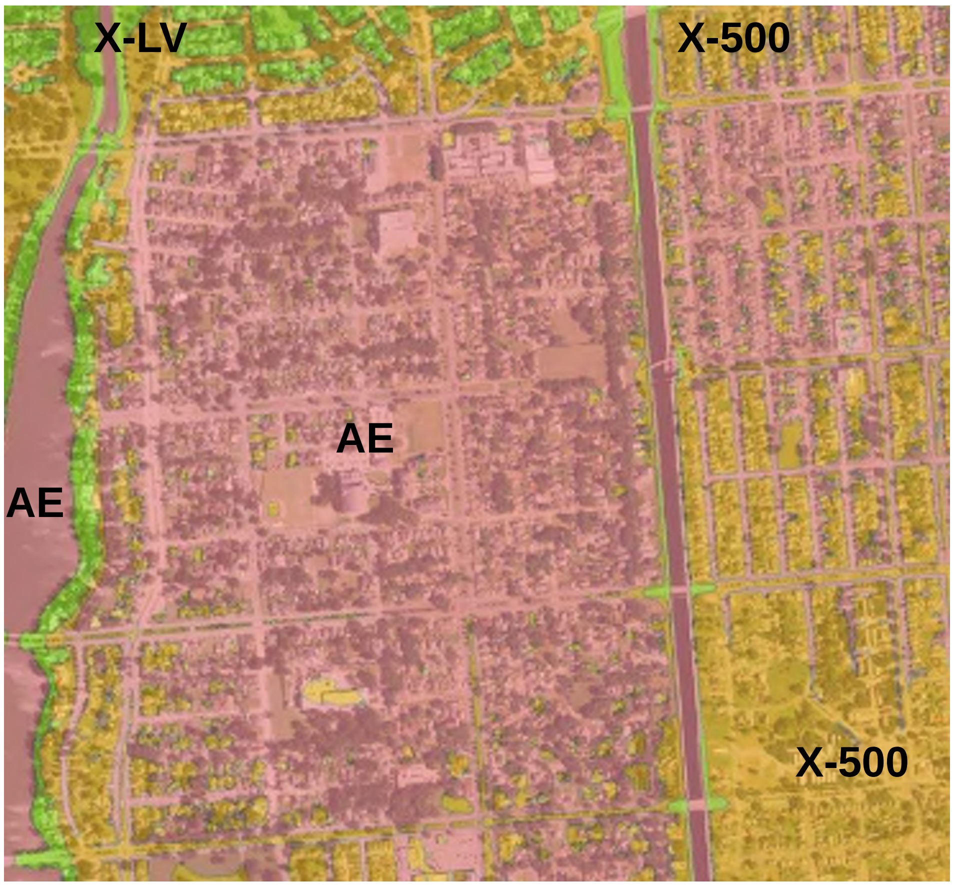


Potential NFIP Implications
From Zones to Graduated Risk

- Showing annual exceedance probability (AEP) rather than zones
- Especially useful behind levees

Potential NFIP Implications
Insurance Premiums

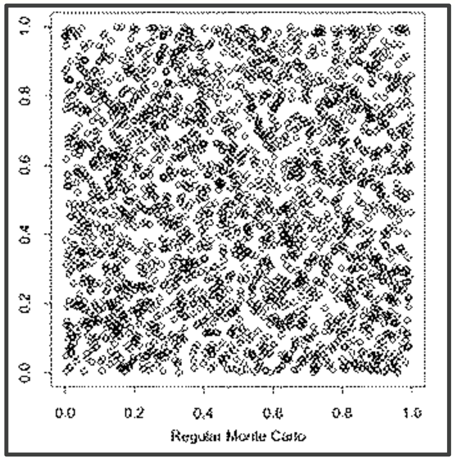
- Spatially varied insurance premiums (homes, neighborhoods, census blocks, zip codes) based on average annualized loss (AAL) relative to structure value/policy amount
- Can vary behind levees then & account for pluvial



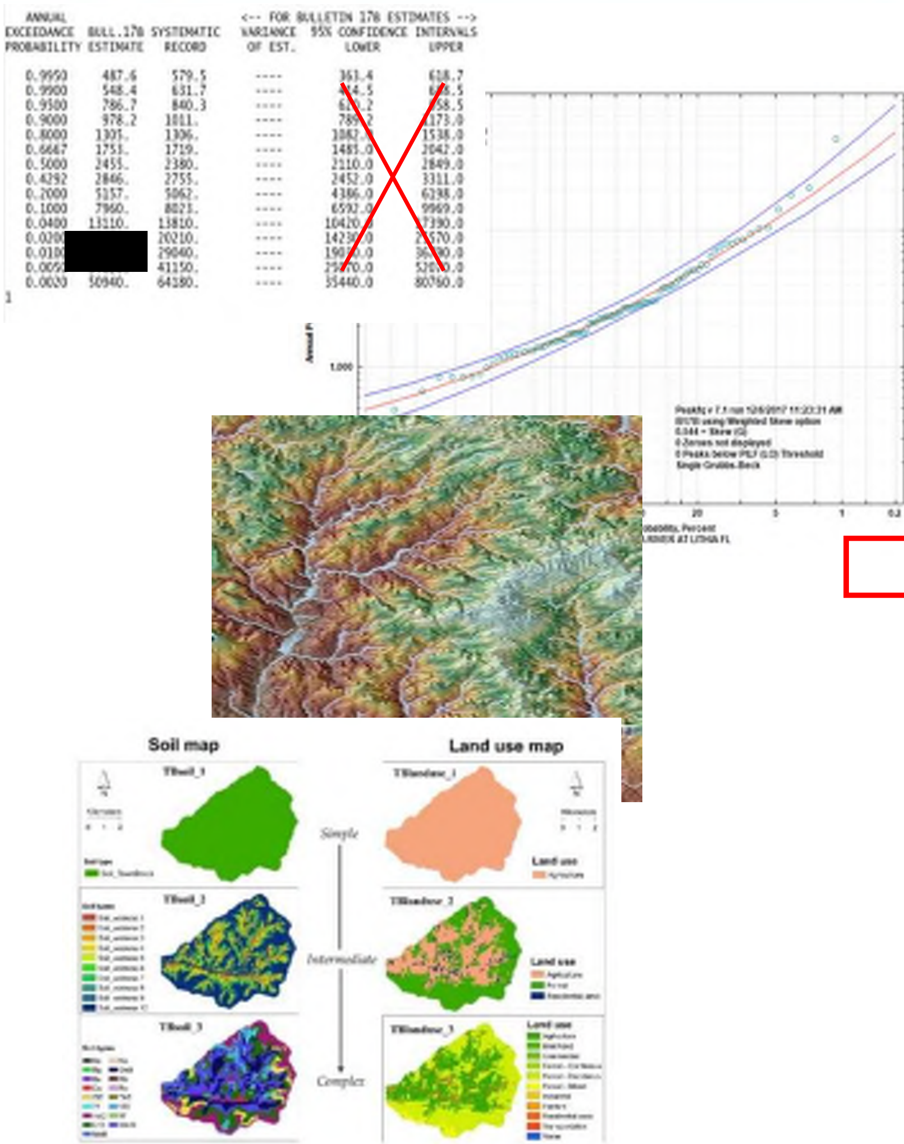
Fluv_AAL	Pluv_AAL	Lake_AAL	Total_AAL
1073.84	1366.1	25.59	2465.53
145.13	62.03	1093.38	1300.54

Concept of Probabilistic Modeling
Overview

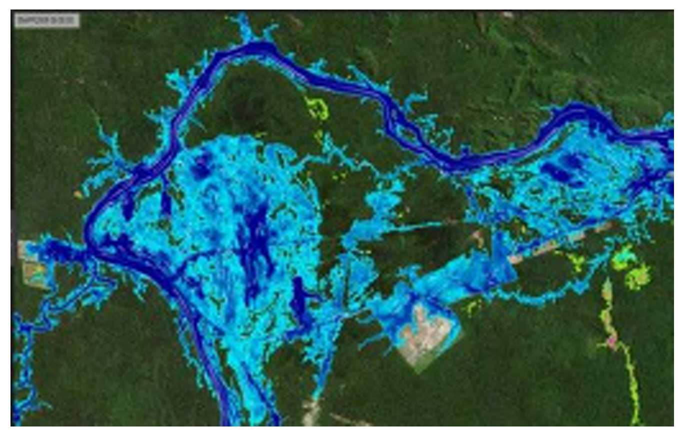
- Monte Carlo distribution & importance sampling
- Fluvial Hydrology
  - Differing flood durations, confidence limits, hydrographs
- Pluvial Hydrology
  - Differing durations, confidence limits, quartiles, hyetographs
- Batch Hydraulics - thousands of runs
  - Differing land cover, breach locations & dimensions
  - All 2D model based – exports max WSEL grids
  - Create AEP grids
- Risk Assessment (at structure level)
  - Extract WSELs from all runs at each structure
  - Damage calcs with varying FFEs
  - AALs



Concept of Probabilistic Modeling
Existing Approach Comparison

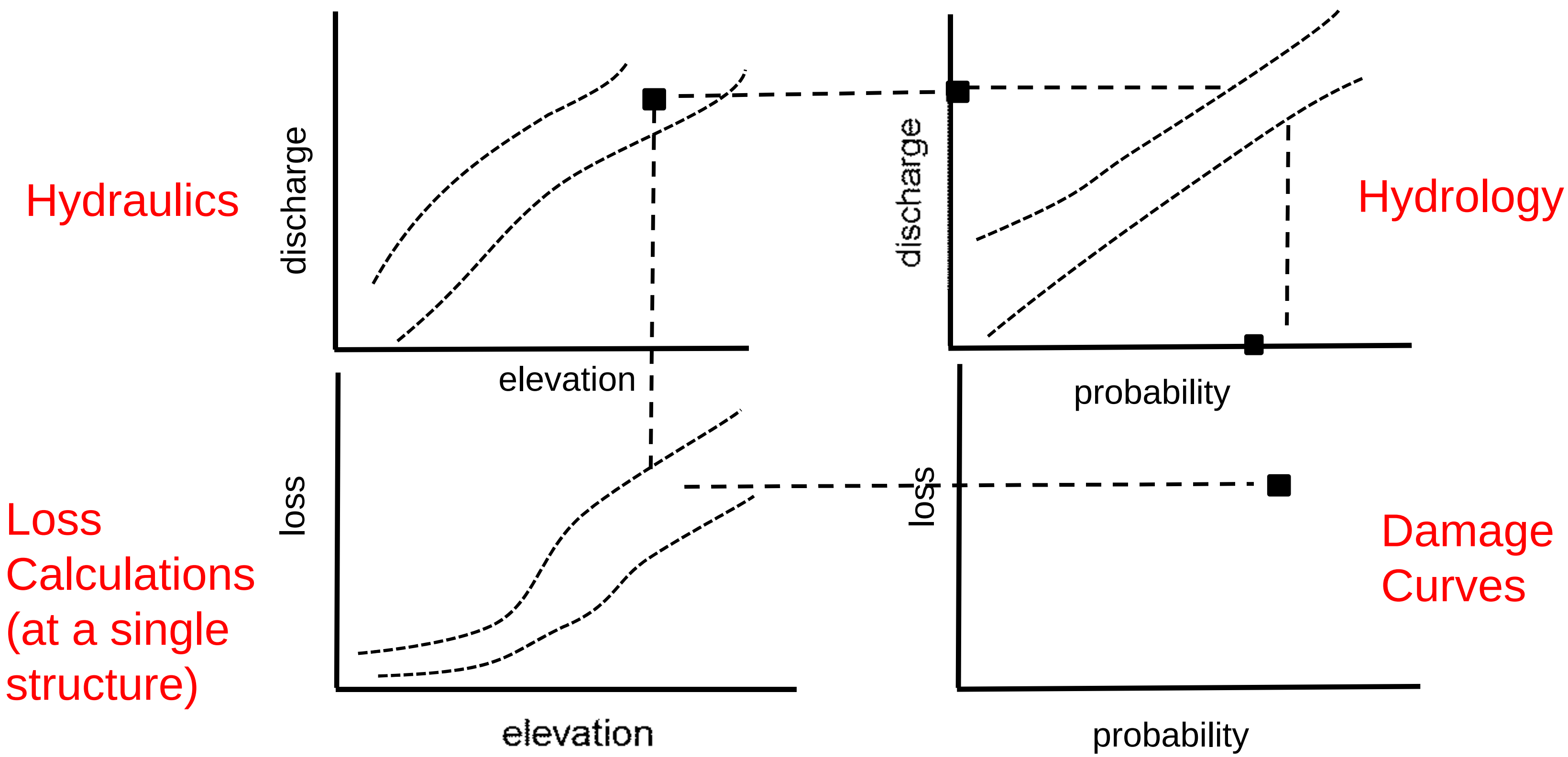


1D or 2D Hydraulic Modeling



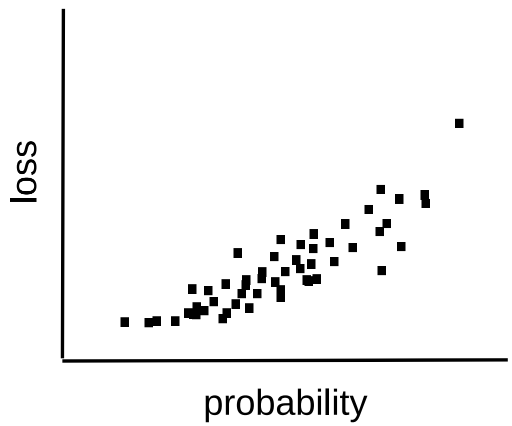
Concept of Probabilistic Modeling

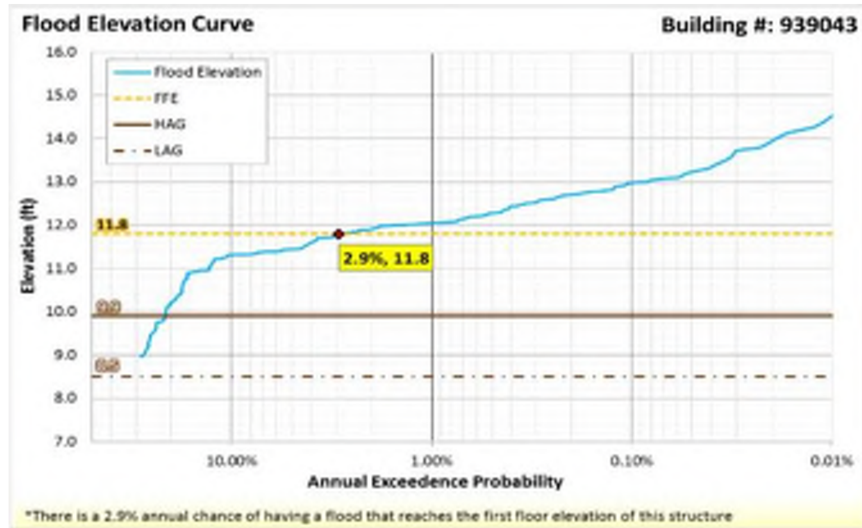
Random Sampling Methodology

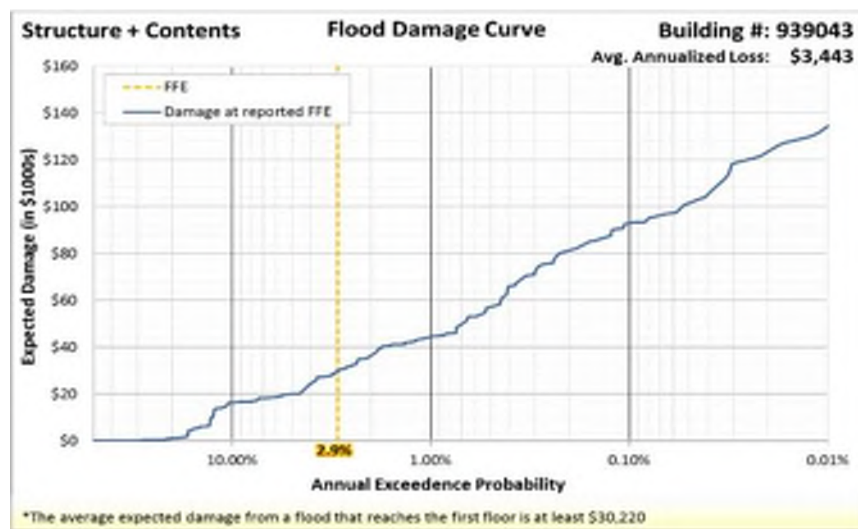


Concept of Probabilistic Modeling
Risk Assessment

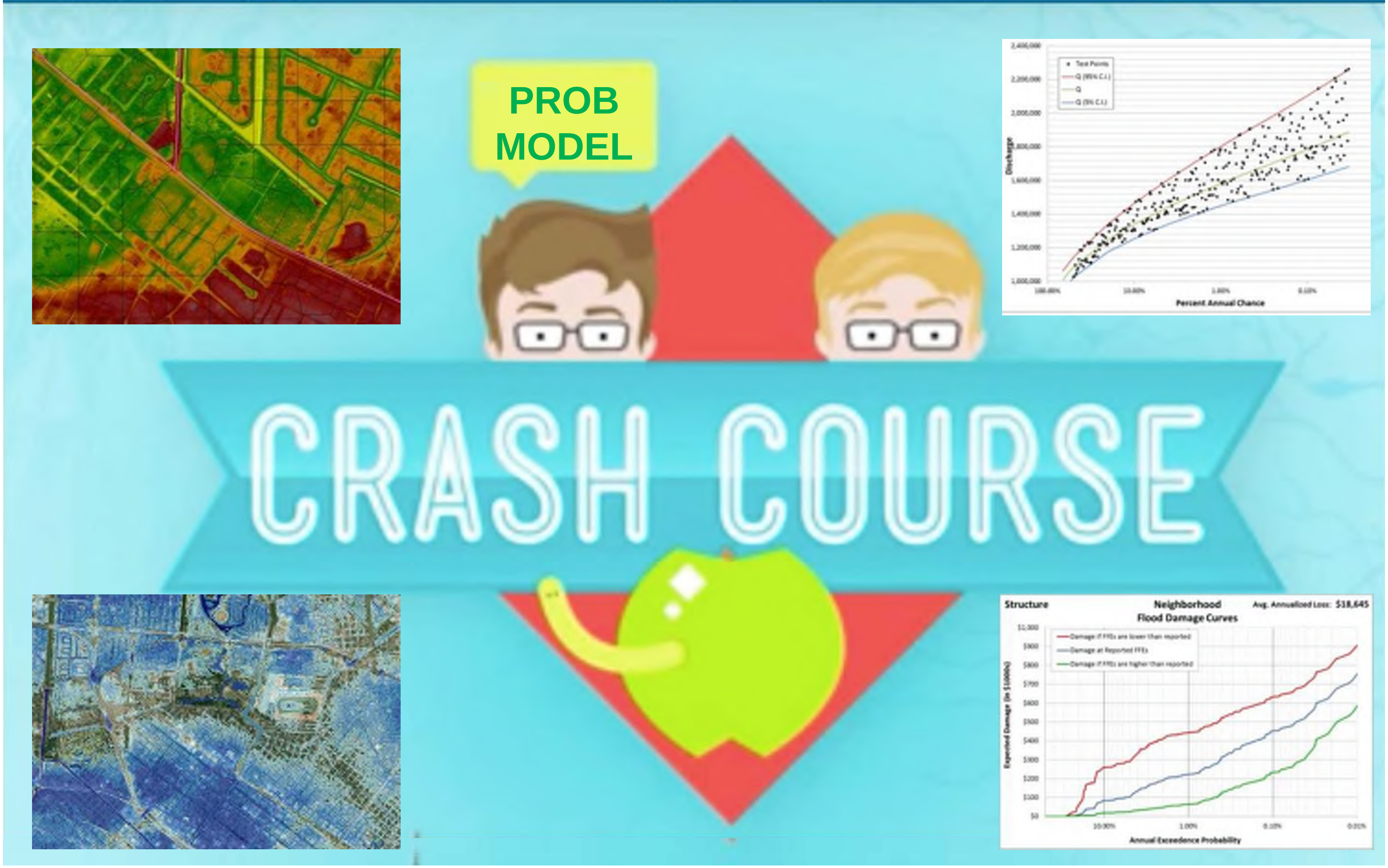
- **Individual model results plotted out to produce various curves**







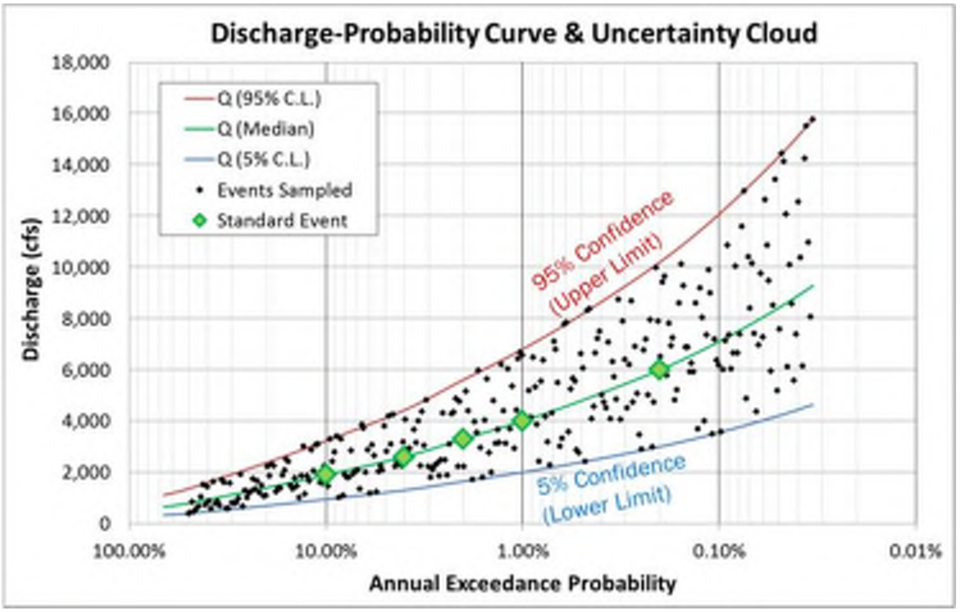
Crash Course of Probabilistic Approach



Crash Course of Probabilistic Approach

Fluvial Hydrology

- **Rather than selecting the 5 typical discharges along the median line, 300 discharges are randomly sampled between the 5% and 95% confidence limits for a large number of probabilities, from the 50% (2-yr) to the 0.033% (3000-yr) or beyond annual-chance probability**



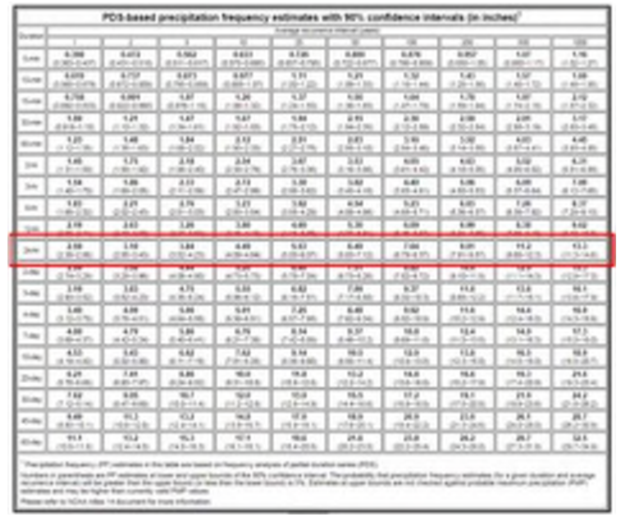
- **Applied as inflow hydrograph**
  - Vary flood durations & hydrographs

Crash Course of Probabilistic Approach
Pluvial Flooding

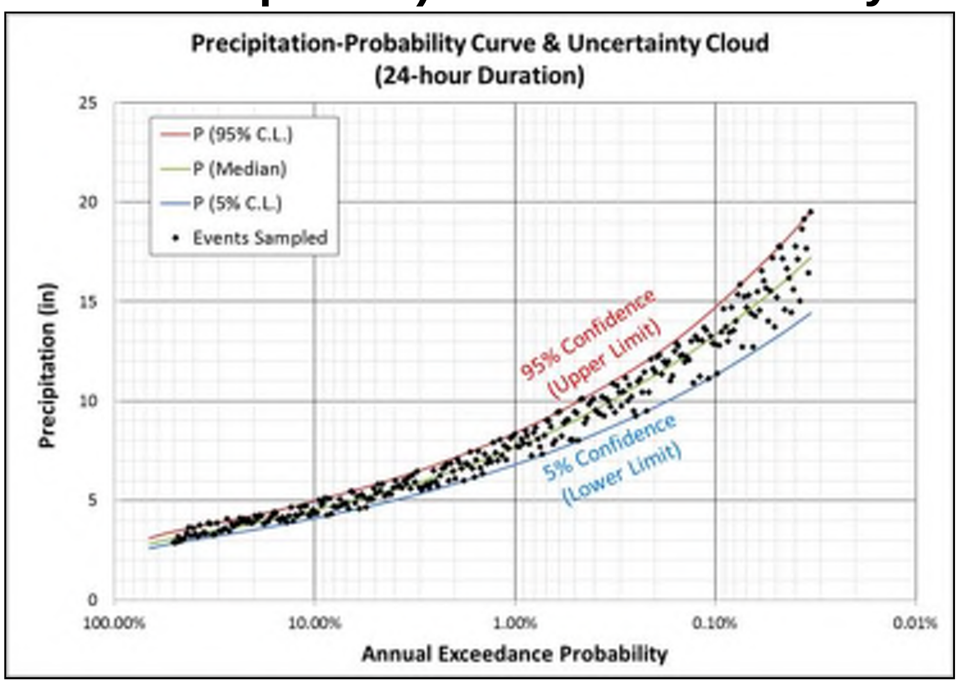
- **Evaluates runoff – applied as excess precip to 2D area**
- **Major contributor to the residual risk in leveed areas**
- **Currently not mapped on FIRMs or any of the existing flood products**
- **Catastrophic models used by private insurance companies capture pluvial hazard**
- **One reason structures outside the SFHA are flooded**
- **One cause of repetitive and significant repetitive loss**
- **Major contributing element in urban flooding**

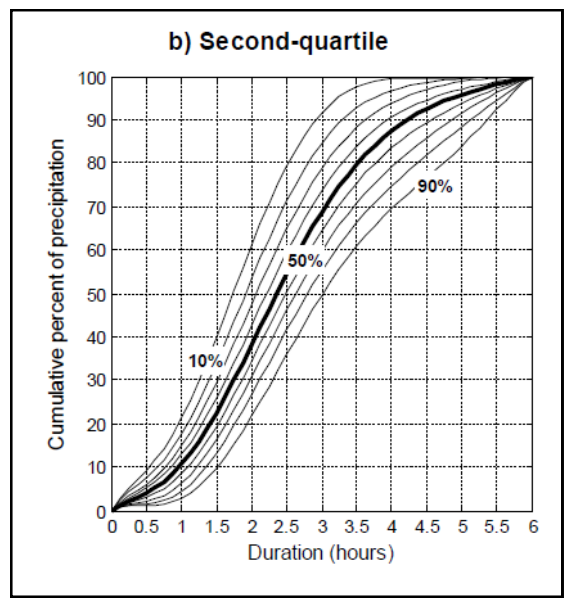
Crash Course of Probabilistic Approach
Pluvial Hydrology

- **Precipitation values sampled between the 5% and 95% confidence limits for probabilities from the 50% (2-yr) to the 0.033% (3000-yr) or beyond**
- **75 depths for 16 different unique storm duration (6-, 12-, 24-, and 96-hr) vs. temporal distribution (1st, 2nd, 3rd, or 4th quartile) scenarios are analyzed**



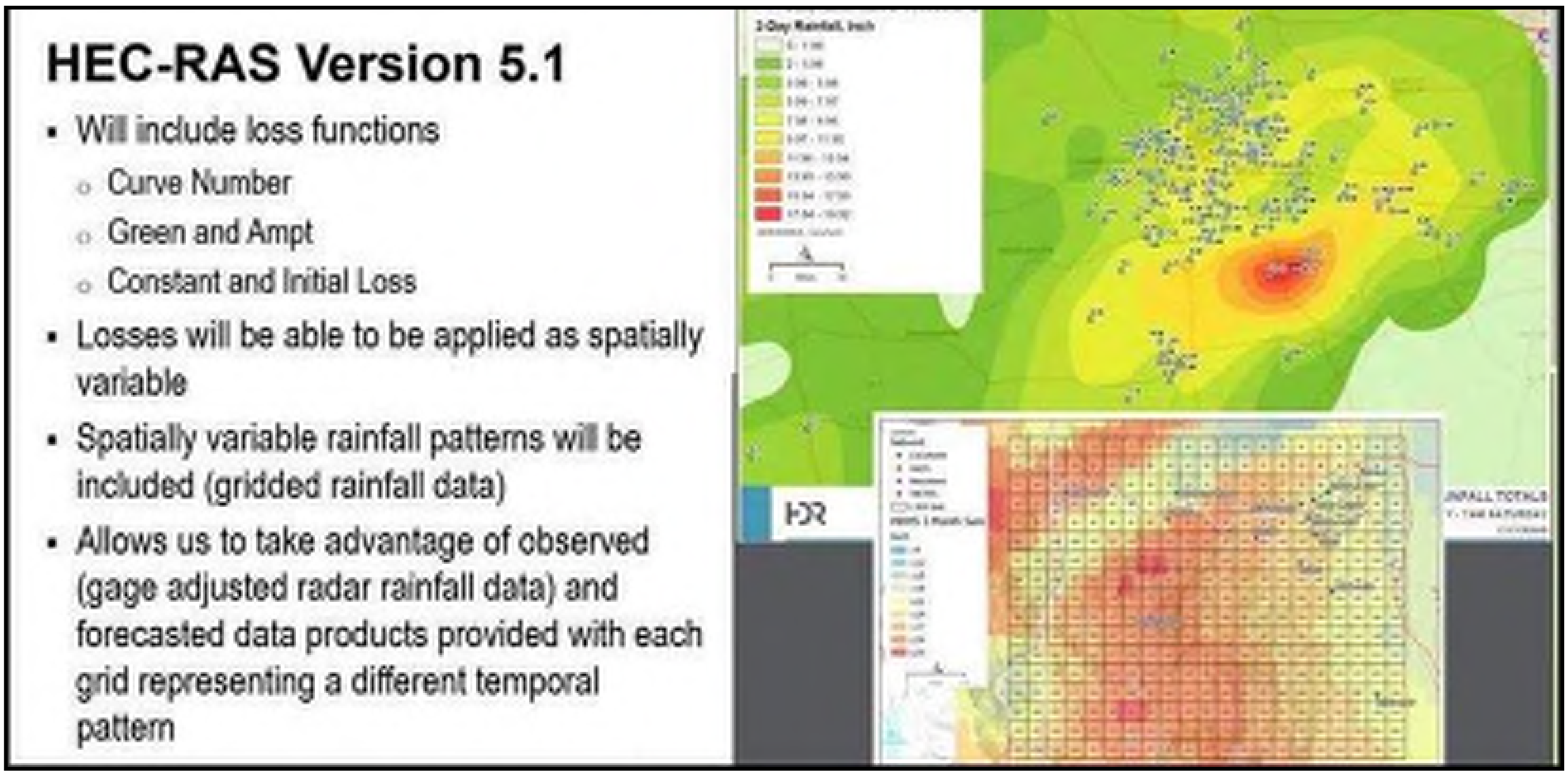
From NOAA Atlas 14 Precipitation Frequency Data Server





Crash Course of Probabilistic Approach
Pluvial Hydrology

- **Curve Number variation is considered and randomly selected in between +/- one standard deviation**
- **HEC-HMS generated 1,200 hyetographs that were then used in HEC-RAS to map the excess rainfall on the grid**
- **But going forward…**

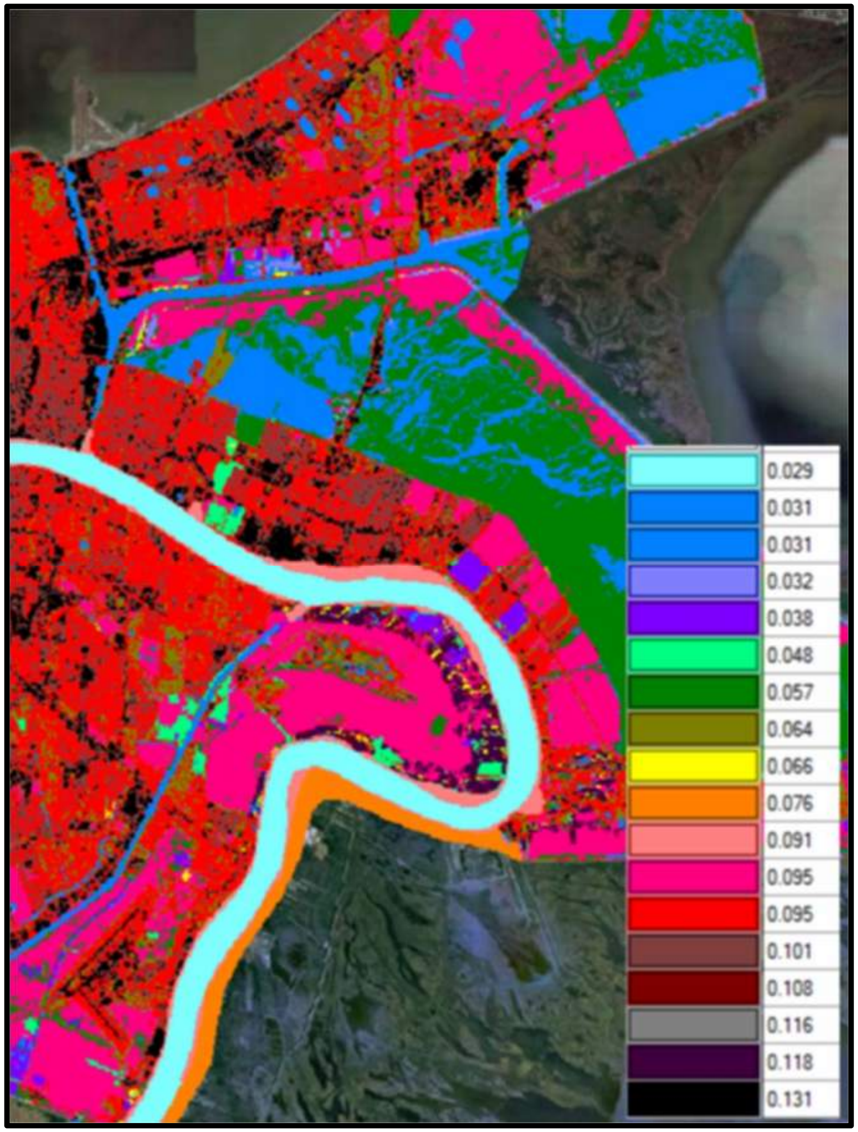


Crash Course of Probabilistic Approach

Hydraulics – Land Cover

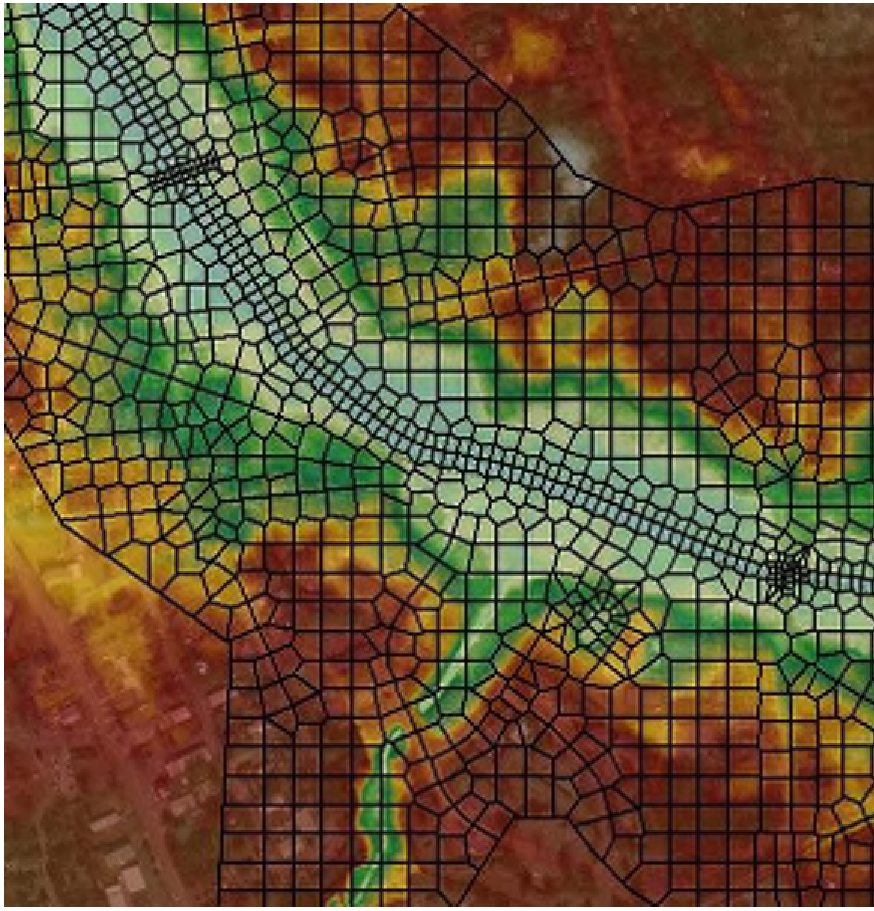
Uncertainty in Manning's n-values are factored into models – 10 land use layers

NLCD Classification	Assigned Manning's Roughness		
	Minimum	Normal	Maximum
Open Water	0.025	0.03	0.033
Developed, Open Space	0.035	0.055	0.095
Developed, Low Intensity	0.085	0.095	0.11
Developed, Medium Intensity	0.09	0.115	0.13
Developed, High Intensity	0.1	0.13	0.16
Barren Land	0.03	0.033	0.036
Deciduous Forest	0.1	0.12	0.16
Evergreen Forest	0.085	0.115	0.14
Mixed Forest	0.09	0.115	0.15
Scrub/Shrub	0.05	0.075	0.09
Grassland Herbaceous	0.028	0.03	0.035
Pasture/Hay	0.038	0.045	0.055
Cultivated Crops	0.035	0.042	0.048
Woody Wetlands	0.08	0.095	0.12
Emergent Wetland	0.04	0.065	0.1
River Channel	0.026	0.028	0.03

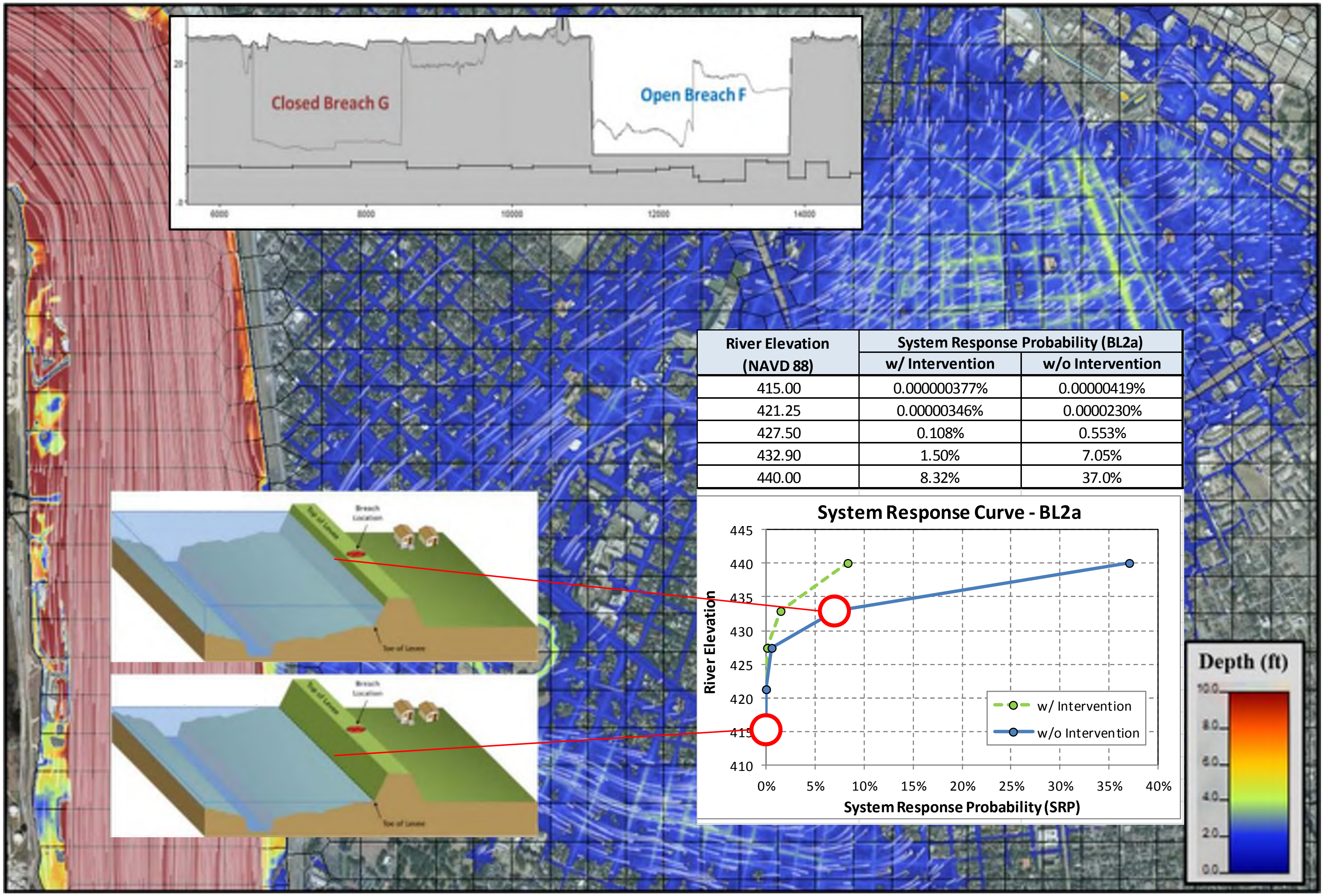


Crash Course of Probabilistic Approach
Hydraulics – Simulations

- **2D model scenarios are run in a batch, automated process**
- **30 fluvial/land set; 120 pluvial/land set**



Probabilistic Approach (Levees)



River Elevation (NAVD 88)	System Response Probability (BL2a)	
	w/ Intervention	w/o Intervention
415.00	0.000000377%	0.00000419%
421.25	0.00000346%	0.0000230%
427.50	0.108%	0.553%
432.90	1.50%	7.05%
440.00	8.32%	37.0%

Results

WSEL, depth, depth * velocity grids

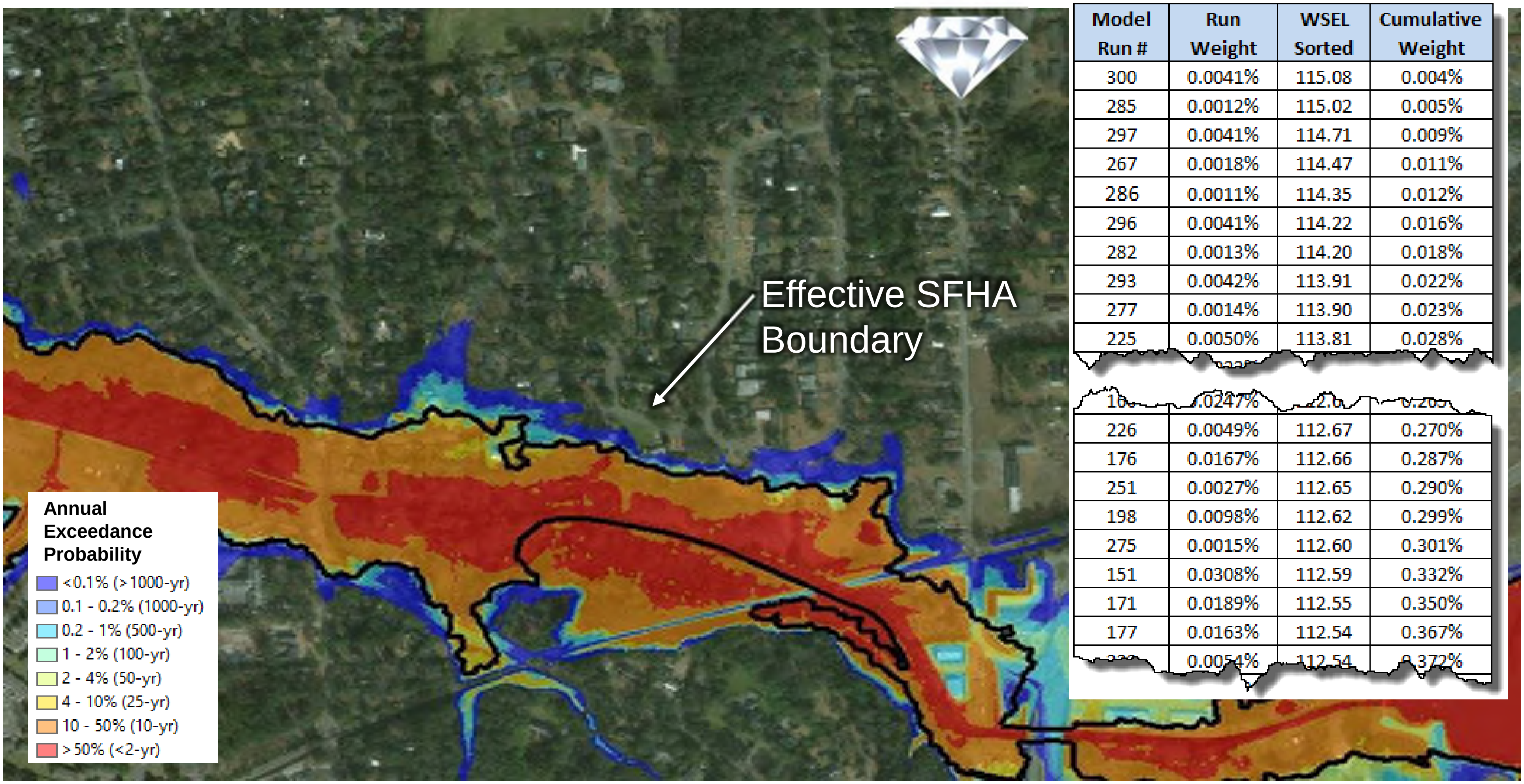
Annual Exceedance Probability (AEP) grids

Damage curves at any structure

Average Annualized Loss (AAL) for any structure or area

Annual Exceedance Probability Grid

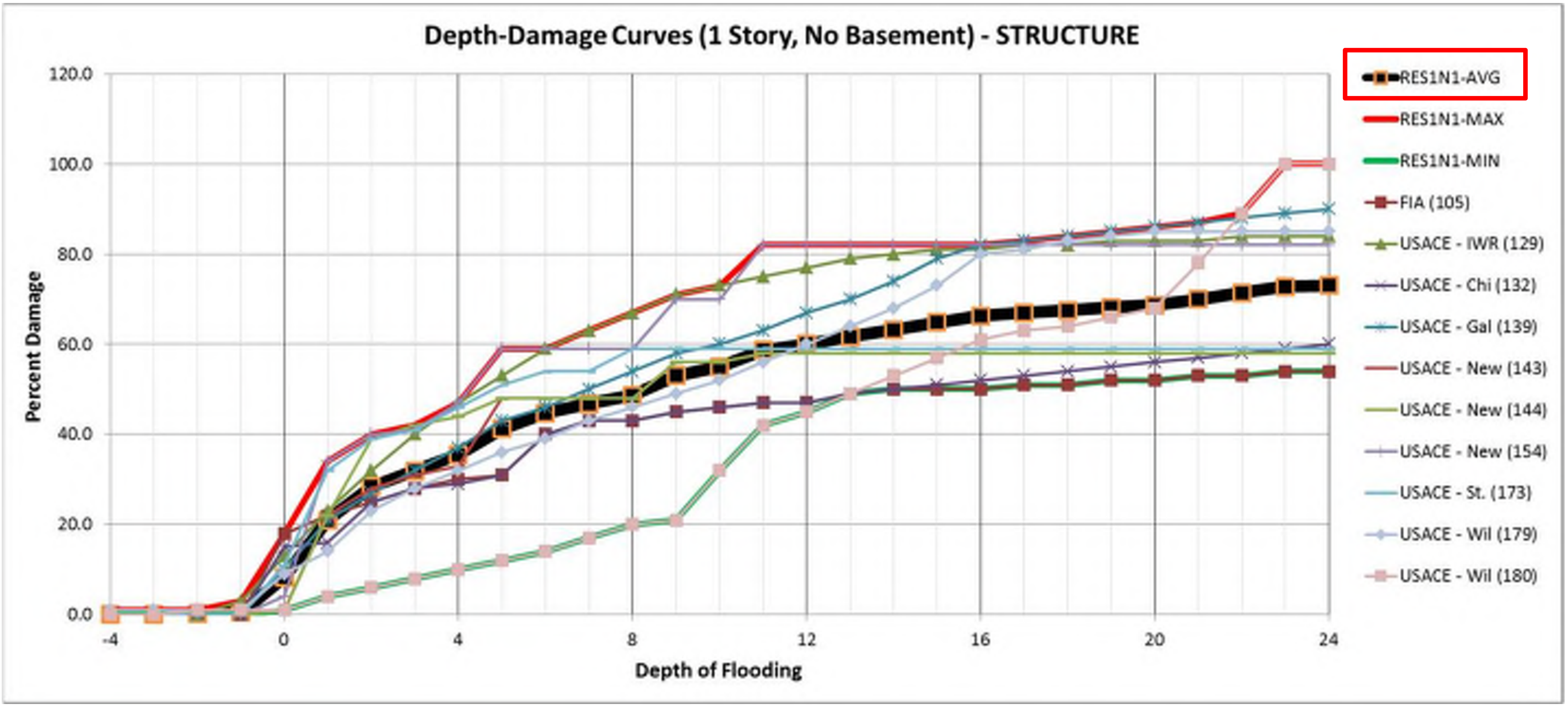
- **Using the results and probabilities from each model run, a probability grid is generated**



Model Run #	Run Weight	WSEL Sorted	Cumulative Weight
300	0.0041%	115.08	0.004%
285	0.0012%	115.02	0.005%
297	0.0041%	114.71	0.009%
267	0.0018%	114.47	0.011%
286	0.0011%	114.35	0.012%
296	0.0041%	114.22	0.016%
282	0.0013%	114.20	0.018%
293	0.0042%	113.91	0.022%
277	0.0014%	113.90	0.023%
225	0.0050%	113.81	0.028%
[illegible]	[illegible]0247%	[illegible]	[illegible]
226	0.0049%	112.67	0.270%
176	0.0167%	112.66	0.287%
251	0.0027%	112.65	0.290%
198	0.0098%	112.62	0.299%
275	0.0015%	112.60	0.301%
151	0.0308%	112.59	0.332%
171	0.0189%	112.55	0.350%
177	0.0163%	112.54	0.367%
[illegible]	0.0054%	112.54	0.372%

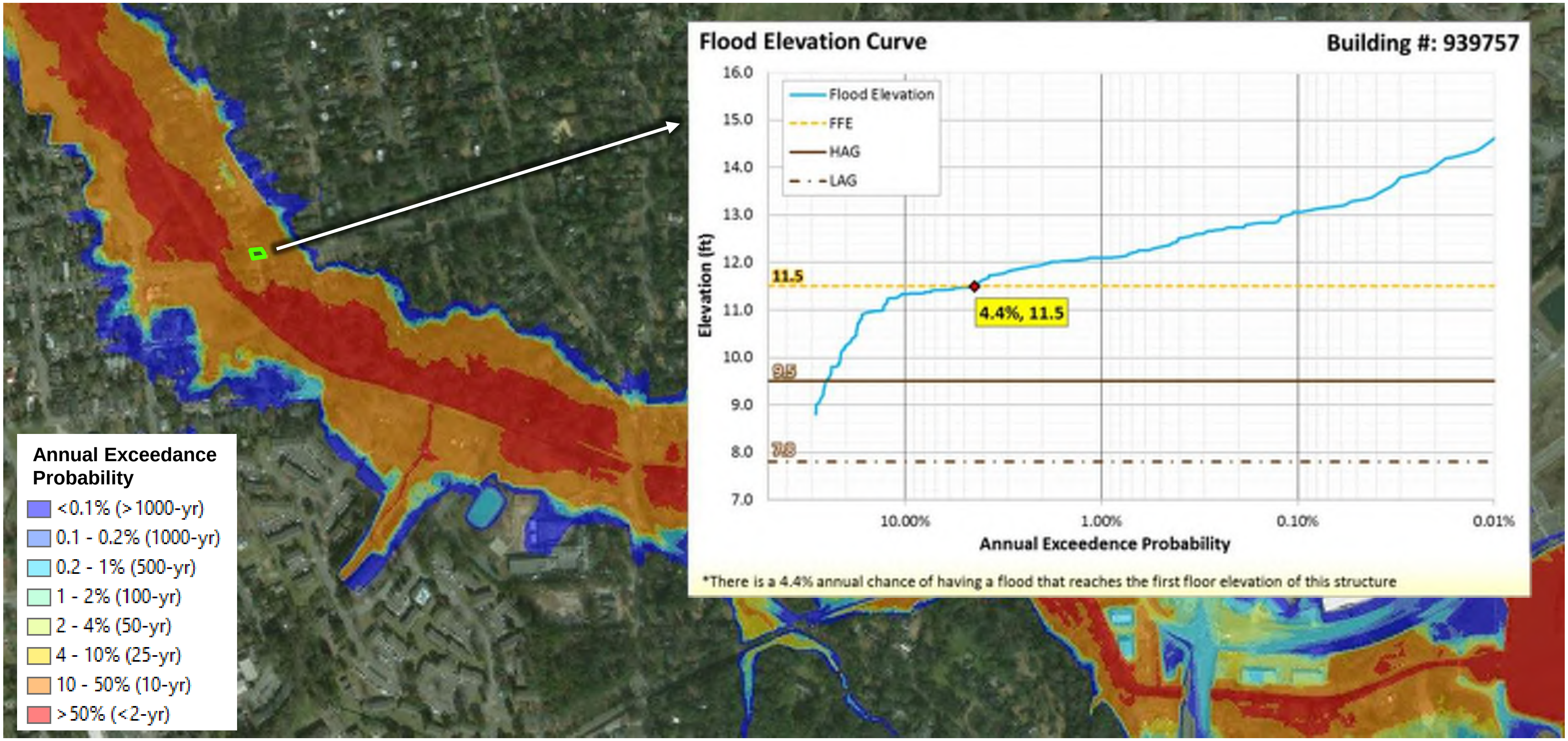
Depth-Damage Functions used in Risk Assessments

- **Composite Depth-Damage curves for each structure type were used based on available curves from Hazus**



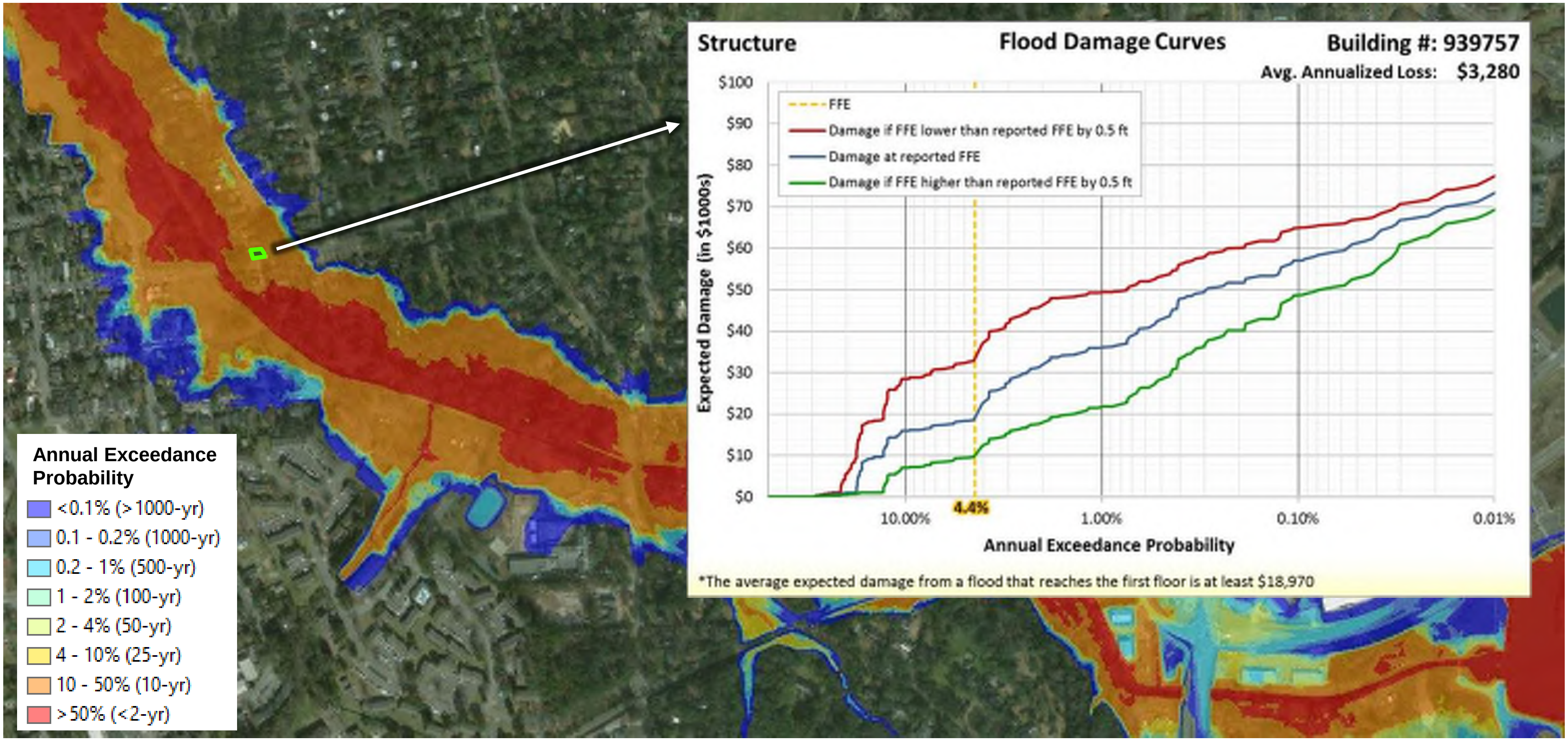
Structure-Level Risk

- **Detailed Flood Elevation-Probability Curves can be extracted for any structure of interest based on the underlying model results**



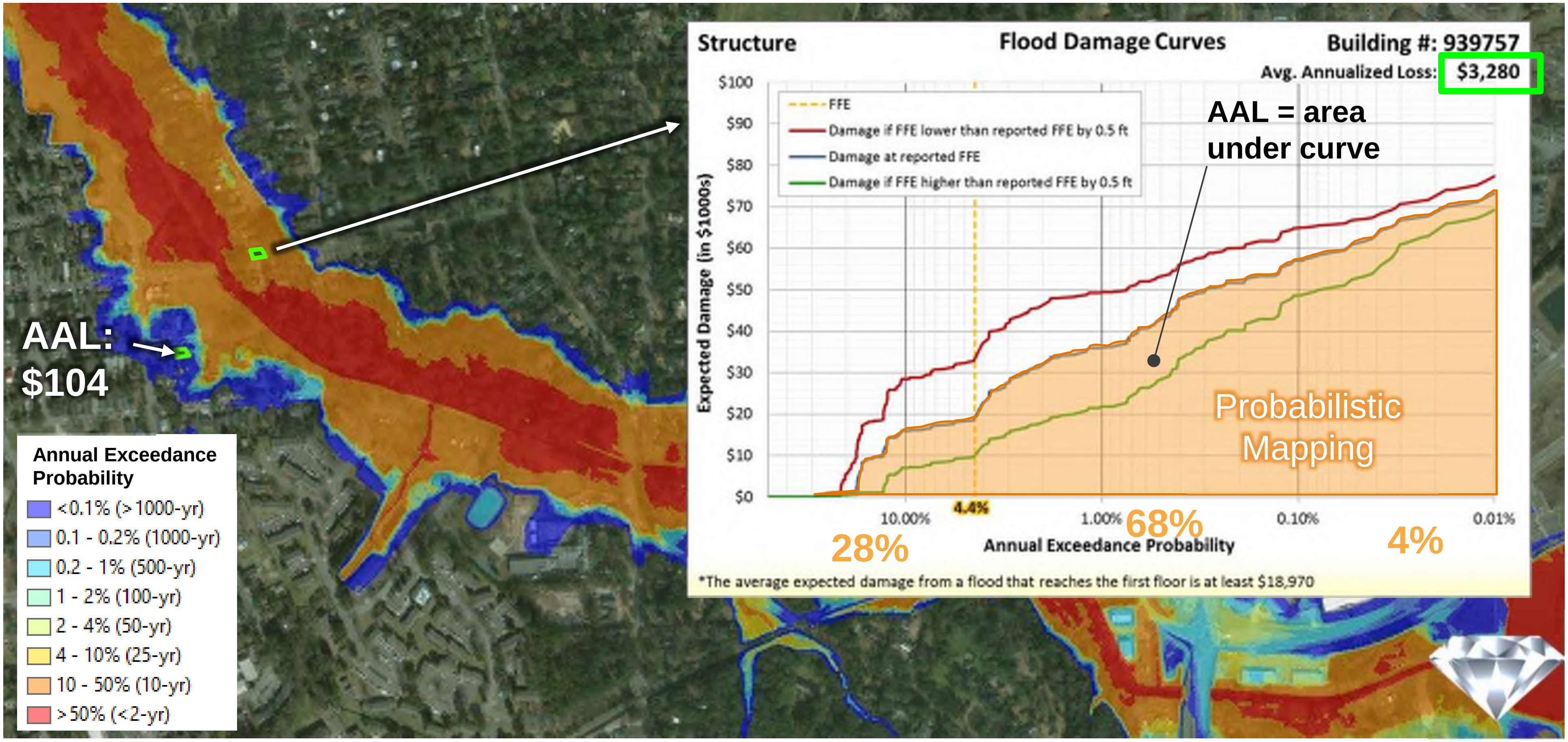
Structure-Level Risk

- **Flood Damage Curves can be generated, taking into account uncertainties in structure occupancy and first floor elevations (FFE)**



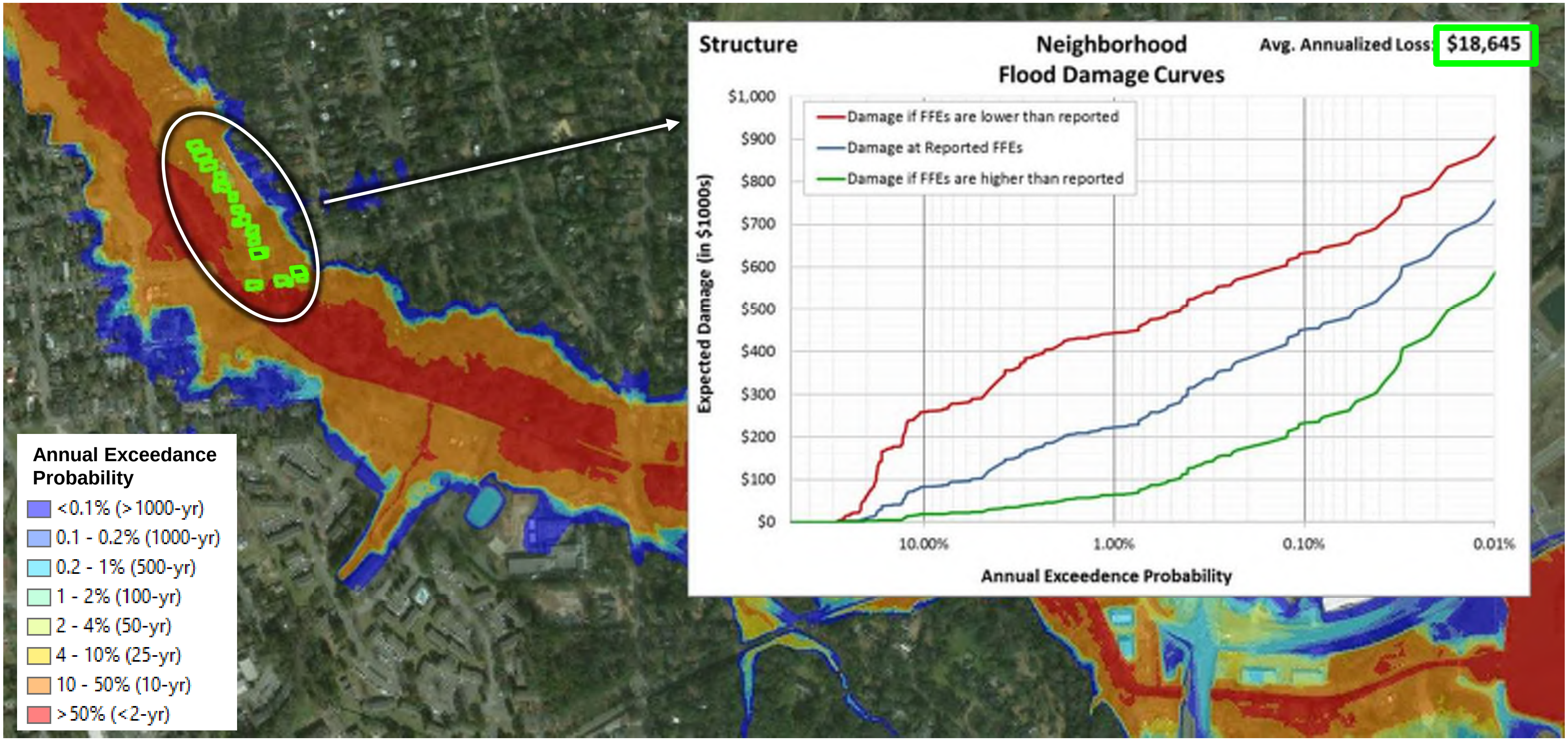
Structure-Level Risk

- **Average Annualized Losses (AAL) much more accurate – little to no extrapolation required, unlike with typical studies**



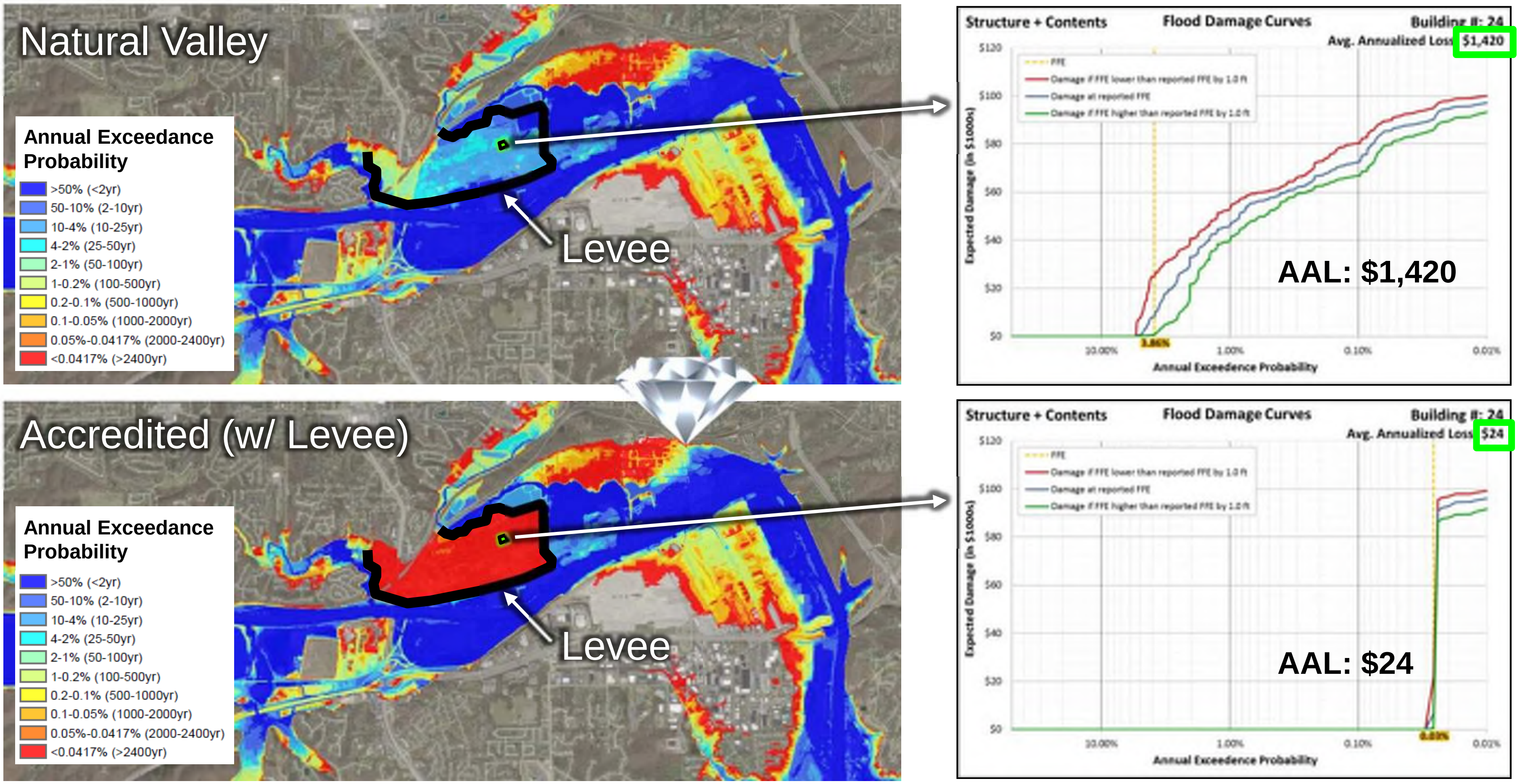
Structure-Level Risk

- **"Neighborhood" Damage Curves aggregated from structure data can provide insight into expected damages for multiple properties**

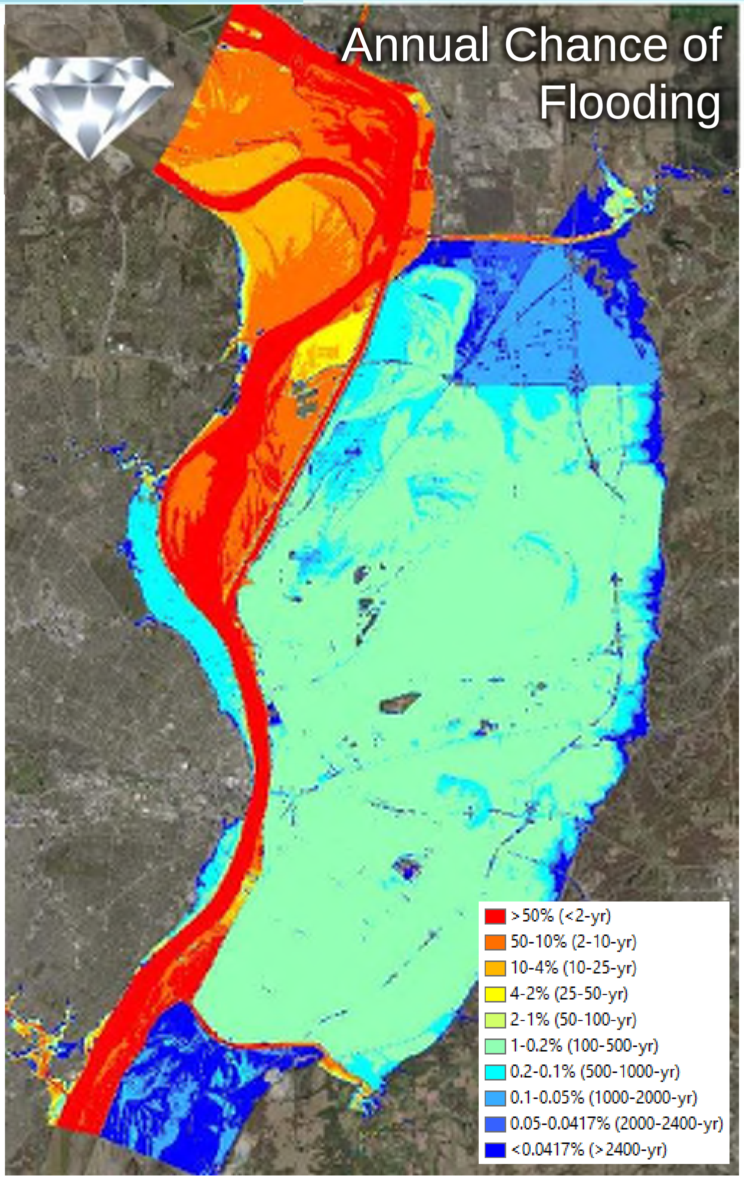


Cost Benefit Analysis for Levees

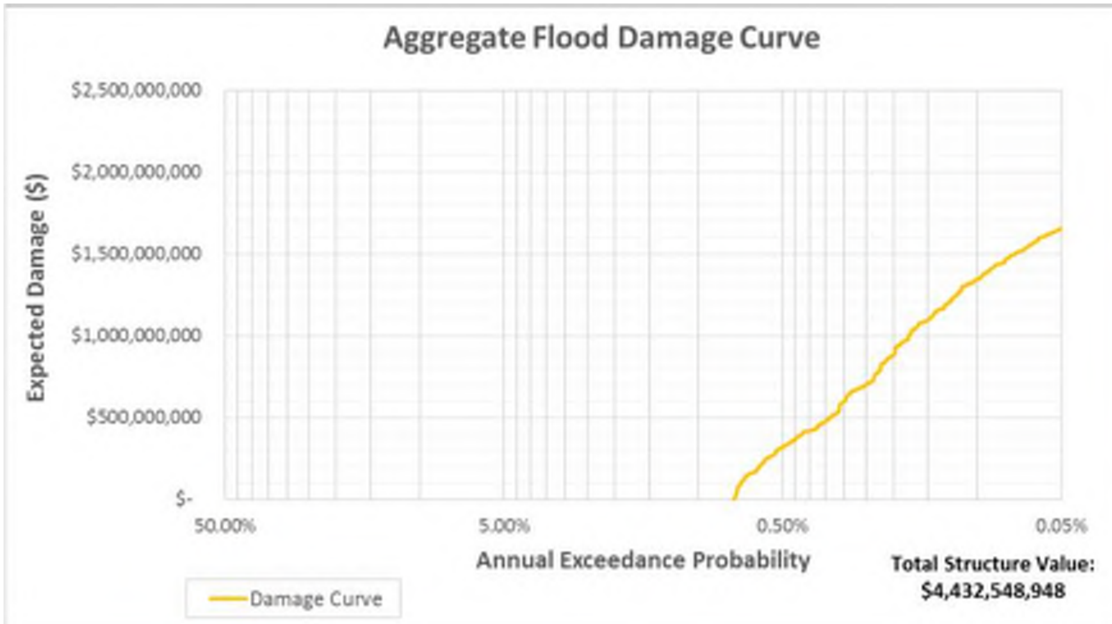
- **Probabilistic approach can consider accredited, breaching, and natural valley levee scenarios (each w/ associated probabilities)**



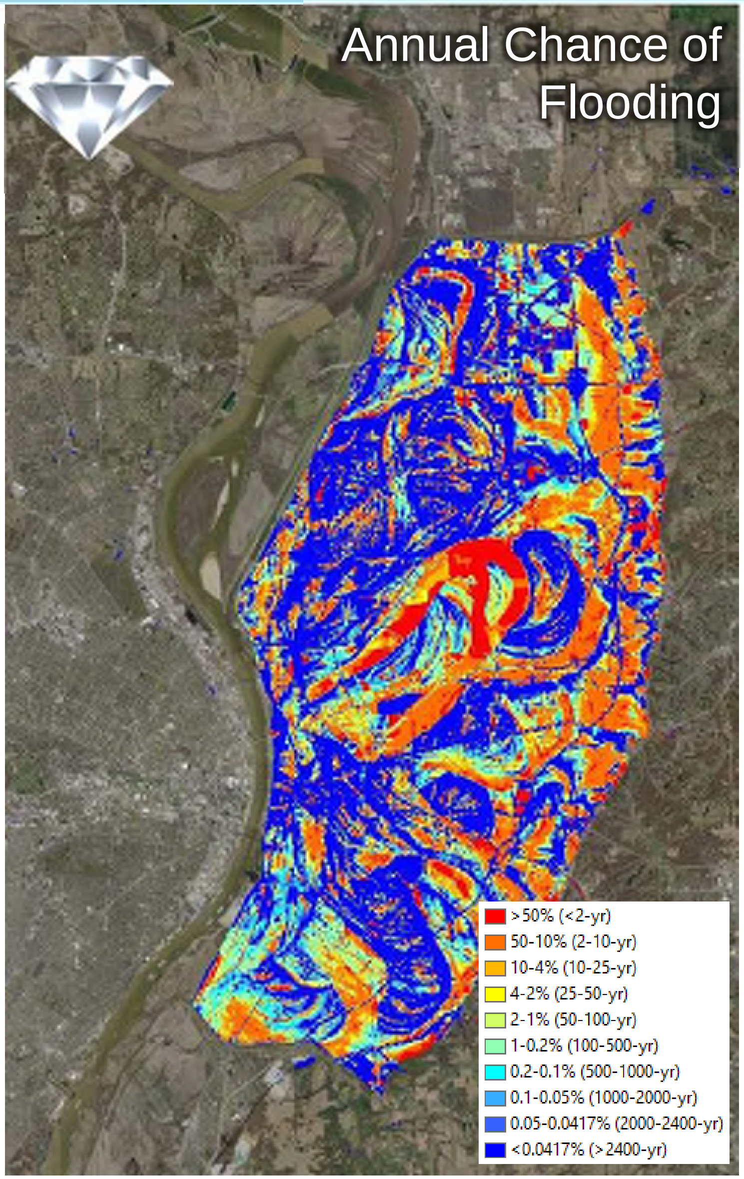
Fluvial (Riverine) Results: Aggregate



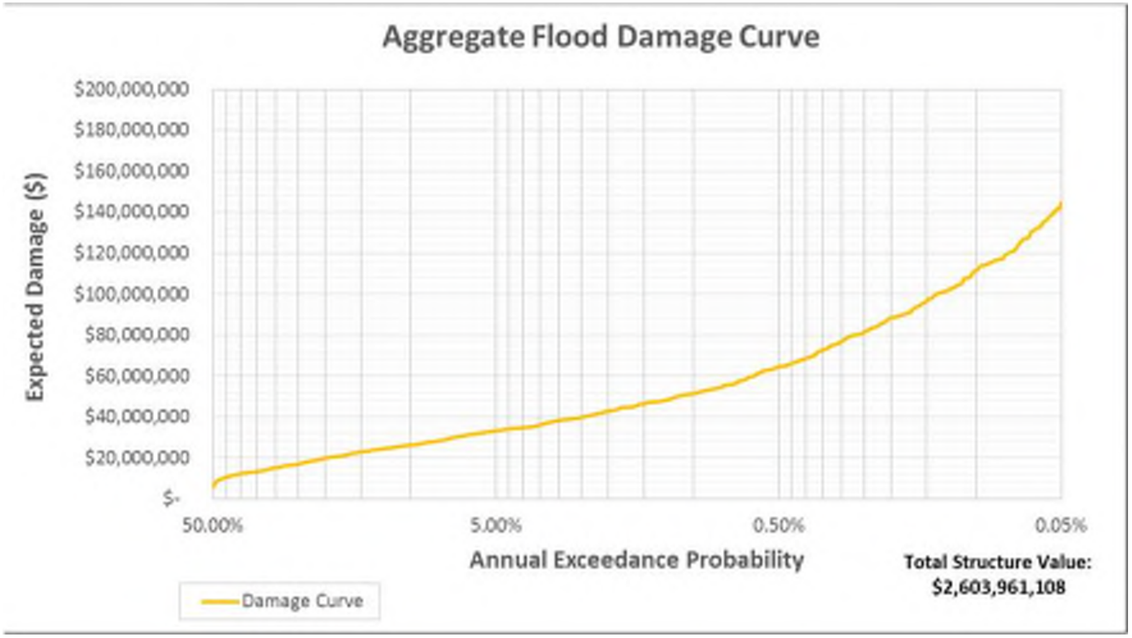
# Structures with Damage	35,197 of 35,236 (99.9%)
Avg. Annualized Loss (AAL)	$4,848,716



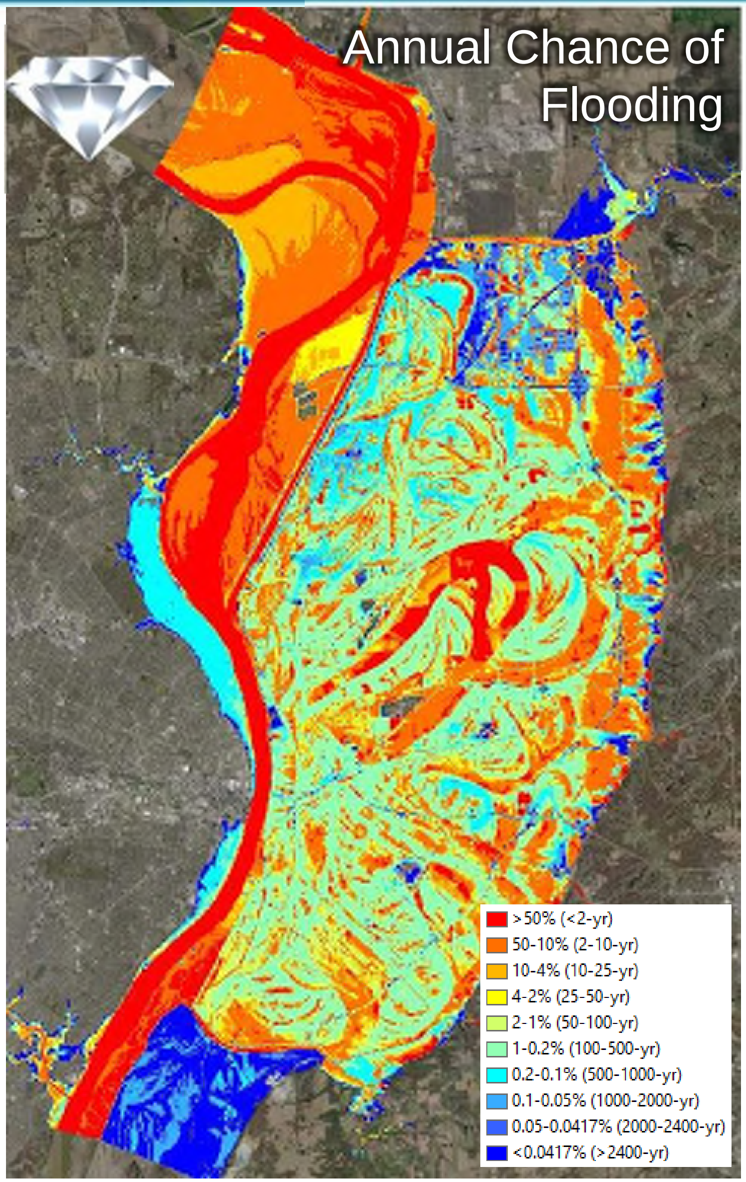
Pluvial (Rainfall) Results: Aggregate



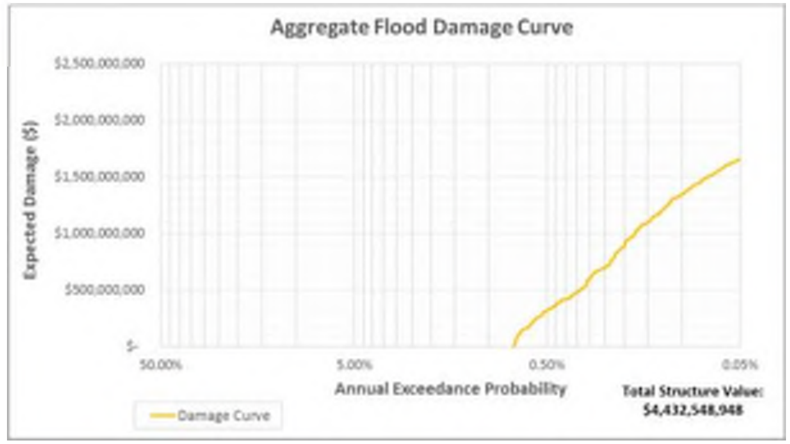
# Structures with Damage	21,491 of 35,236 (61%)
Avg. Annualized Loss (AAL)	$10,179,415



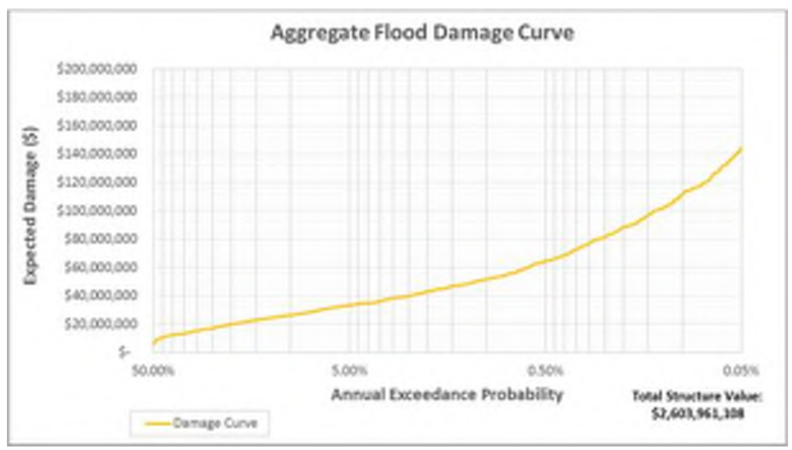
Combined Fluvial & Pluvial: Aggregate



AAL (Fluvial): $4,848,716



AAL (Pluvial): $10,179,415

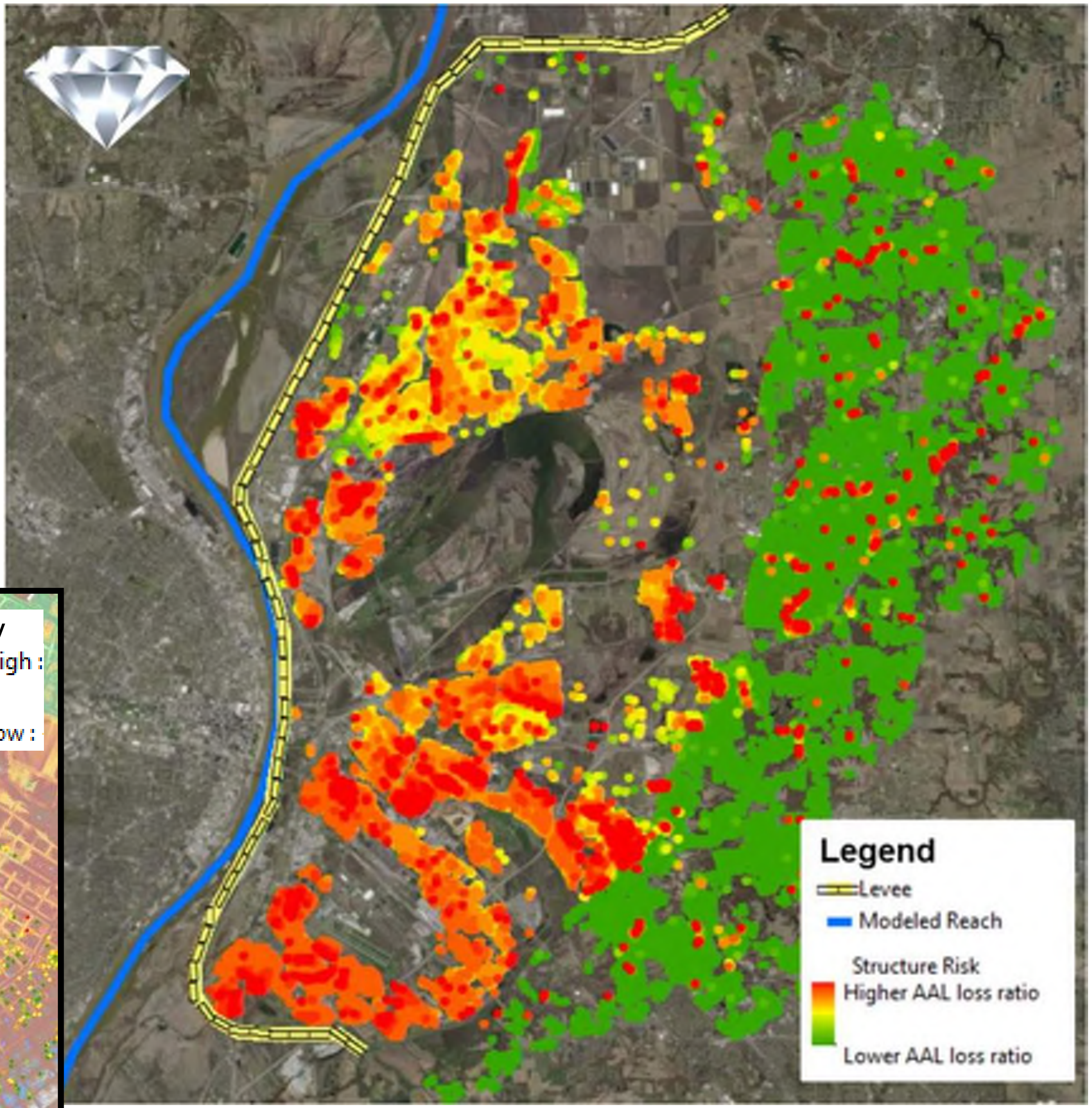


Total AAL
$15,028,131

Hot Spot Map of AAL Loss Ratio (Combined Fluvial and Pluvial)

AAL Loss Ratio = $\frac{AAL}{Structure\ Value}$

High AALs were primarily due to pluvial flooding within low-lying topographic areas

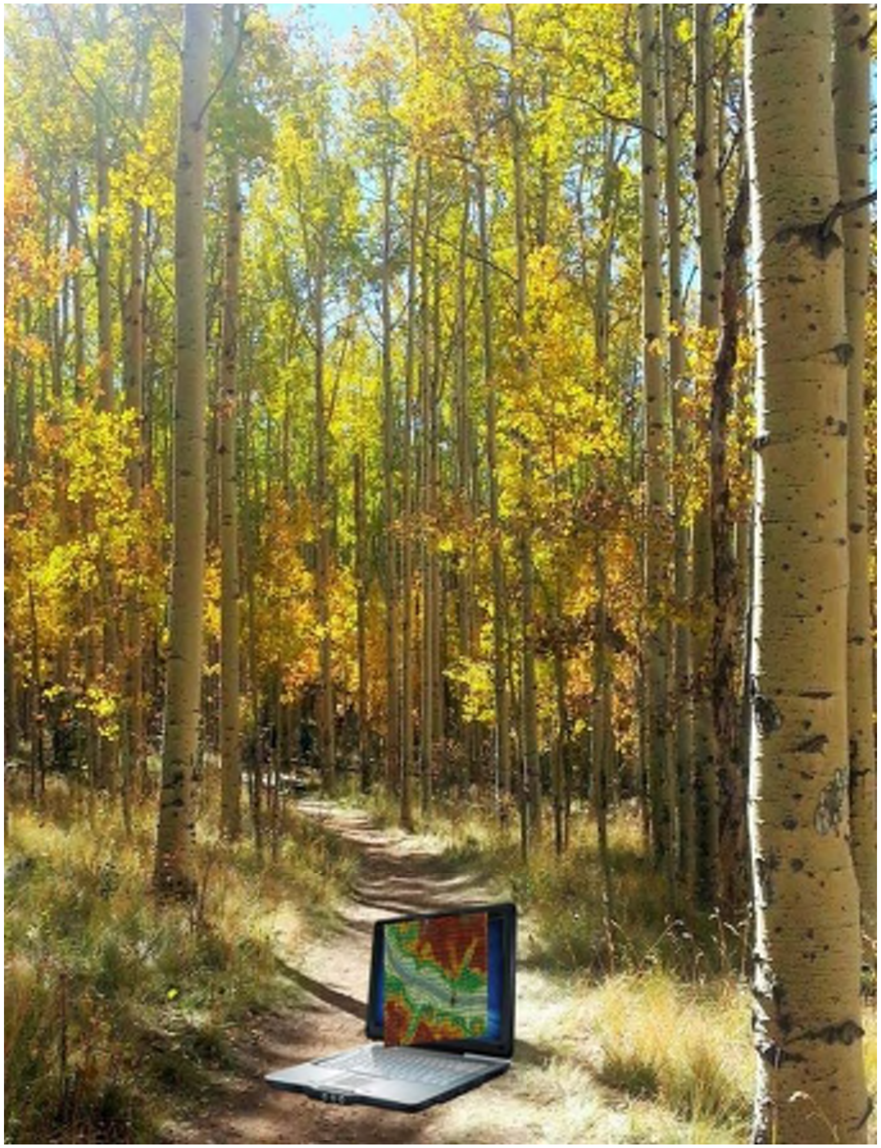


Probabilistic Mapping – Benefits

- **More comprehensive analysis of the flood hazard – from the 50% (2-yr) to the 0.033% (3000-yr) annual chance**
- **More credible analysis of the flood hazard – modeled scenarios consider multiple uncertainties**
- **Increased confidence in the probability at which a flood would reach a structure's first floor elevation**
- **More accurate flood risk and annualized loss estimates**
- **Improved way to look at risk behind levees**
- **True multi-frequency grid outputs (WSEL, depth, velocity, and depth * velocity) applications in both pre- and post-disaster environments**
- **Enhanced outreach and awareness**

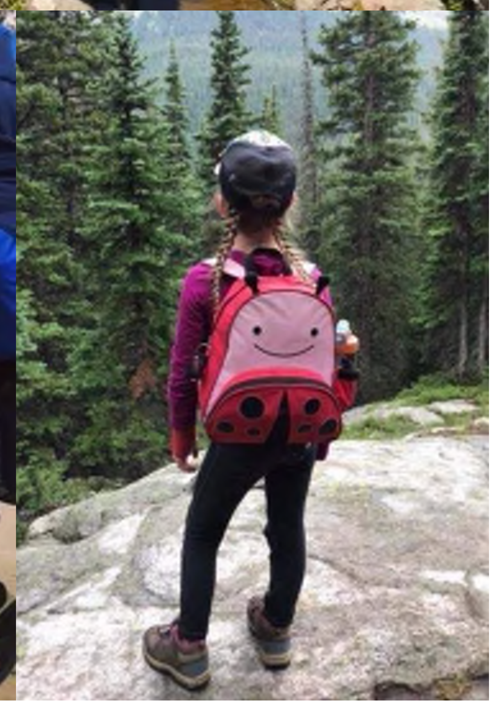
Next Steps

- **Performing additional pilots now**
- **Methodology and approach being refined based on continued lessons learned**
- **Development of guidelines and/or best practices (App C)**
- **Results to inform insurance premium adjustments in areas, particularly behind levees**
- **Time will tell…**



If you have any questions, please visit below!
https://aecom.jobs/

Geoff Uhlemann
geoffrey.uhlemann@aecom.com
303.796.4783



COLORADO
Colorado Water Conservation Board
Department of Natural Resources

Mapping Fluvial Hazard Zones: Developing Guidance, Applications & the Pilot Mapping Program

Stephanie DiBettito, CFM
Colorado Water Conservation Board

Joel Sholtes, PhD, PE
USBR Sedimentation and River Hydraulics

Michael Blazewicz
Round River Design

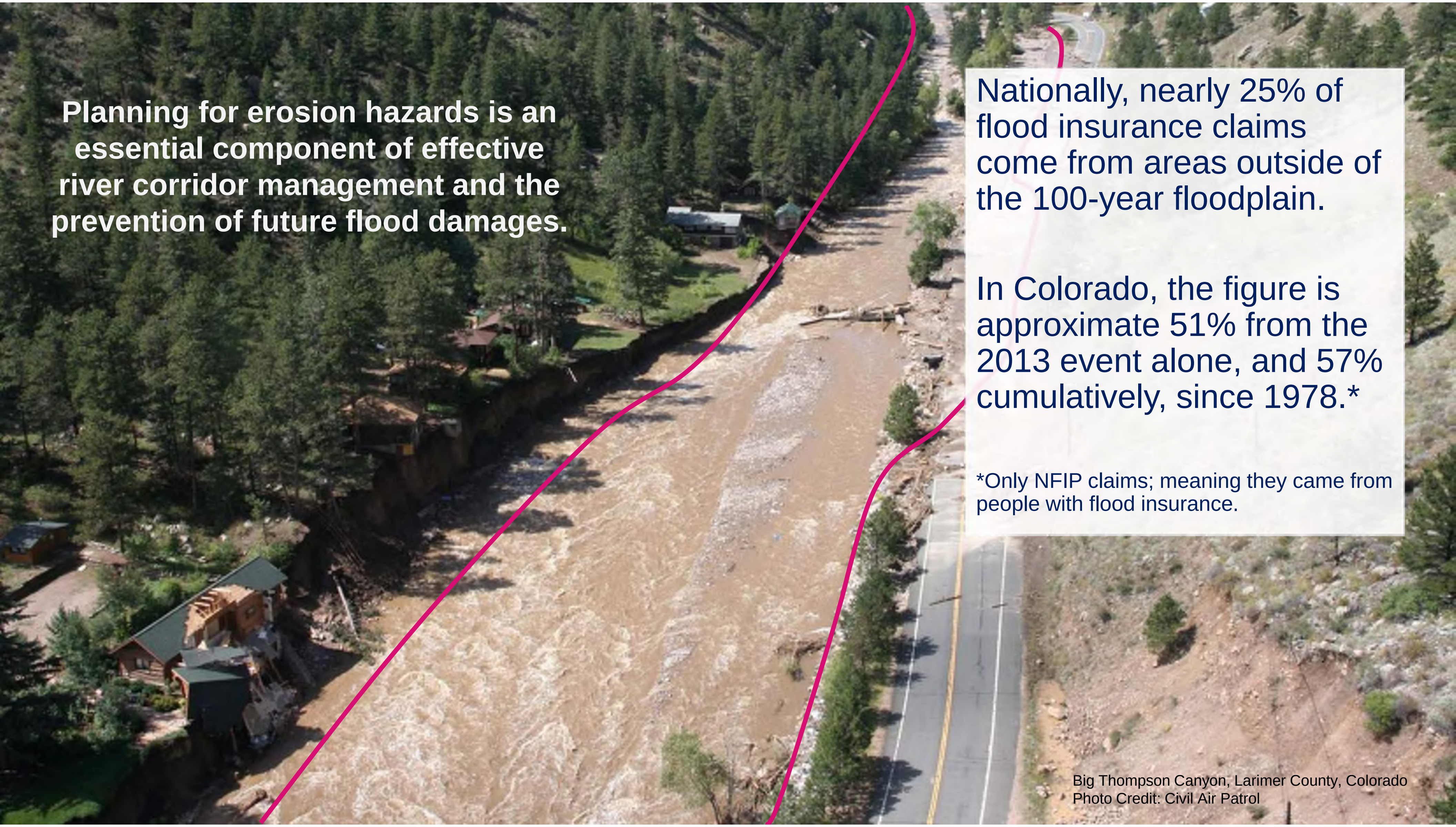
Katie Jagt, PE, CFM
Watershed Science + Design, PLLC

September 27, 2018 2:30pm
CASFM Snowmass
Emergency Preparedness

FLUVIAL HAZARD ZONE DEFINITION

"The Fluvial Hazard Zone (FHZ) is the area a stream has occupied in recent history, could occupy, or could physically influence as it stores and transports sediment and debris. The objective of a mapped FHZ is to identify lands most vulnerable to fluvial hazards in the near term."

Estes Park, Larimer County, Colorado
Photo Credit: Town of Estes Park


Planning for erosion hazards is an essential component of effective river corridor management and the prevention of future flood damages.
Nationally, nearly 25% of flood insurance claims come from areas outside of the 100-year floodplain.
In Colorado, the figure is approximate 51% from the 2013 event alone, and 57% cumulatively, since 1978.*
*Only NFIP claims; meaning they came from people with flood insurance.
Big Thompson Canyon, Larimer County, Colorado
Photo Credit: Civil Air Patrol

State of Colorado’s Perspective

The Colorado Water Conservation Board (CWCB) is the state coordinating agency for the National Flood Insurance Program (NFIP). **Floodplains are a matter of statewide importance** and the CWCB has been given the authority to prevent flood damages, regulate and designate floodplains, and ensure proper regulation of floodplains. The CWCB has Rules and Regulations for regulatory floodplains that set higher standards for floodplain management for communities in the state.

The Fluvial Hazard Mapping Program will develop and implement a program for mapping fluvial hazard areas, which will help strengthen the CWCB’s role in **preventing flood damages**, regulate and designate floodplains, and ensure proper regulation of floodplains. The CWCB will **provide technical standards,** conduct studies for communities requesting mapping, and provide **regulatory guidance** for communities interested in **voluntarily** adopting map products.

FHZ PROGRAM GOALS

Goal 1. Develop a scientifically defensible set of standards for Colorado.

Goal 2. Implement fluvial hazard mapping throughout Colorado.

Goal 3: Reduce damage from future flood events by increasing awareness of fluvial (river-related) hazards thereby leading to better land use decisions.

Glen Haven, Larimer County, Colorado
Photo Credit: Town of Estes Park

STATE PROGRAMS AND TAC

- Vermont River Corridor Planning and Protection Program
  - Mike Kline
- Washington State Channel Migration Zone Program
  - Patricia Olson
  - Tim Abbe
- Montana Channel Migration Easement Program
  - Karin Boyd
  - Tony Thatcher

FLUVIAL HAZARD ZONE MAPPING TIMELINE

- 2013: Front Range Flood
- 2014: CWCB's Flood Recovery Master Planning delineates preliminary Channel Migration Zones for Estes Valley and St. Vrain Creek
- 2015: CWCB Executes Erosion Hazard Mapping Preliminary Study/Proof of Concept
- 2017: CWCB Executes Fluvial Hazard Zone Pilot Mapping Program
- 2019: CWCB Completes Fluvial Hazard Zone Pilot Mapping Program

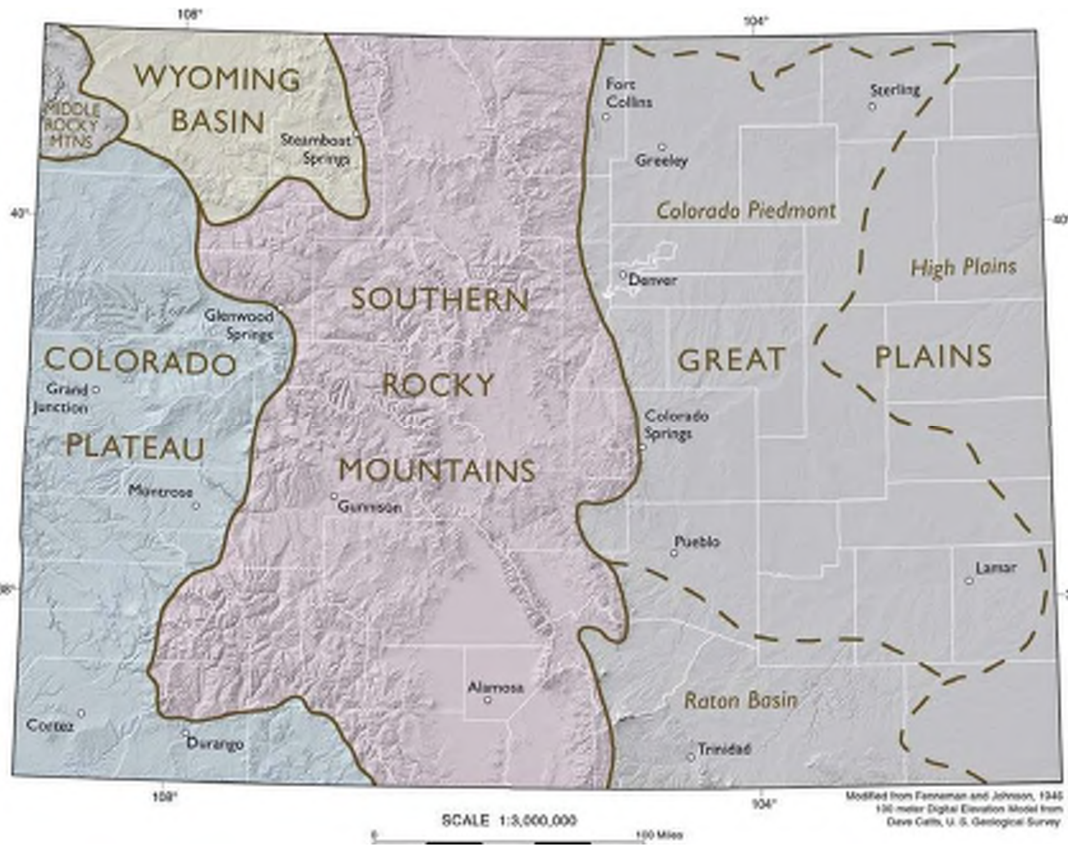
WHY NOT "EROSION" HAZARD MAPPING

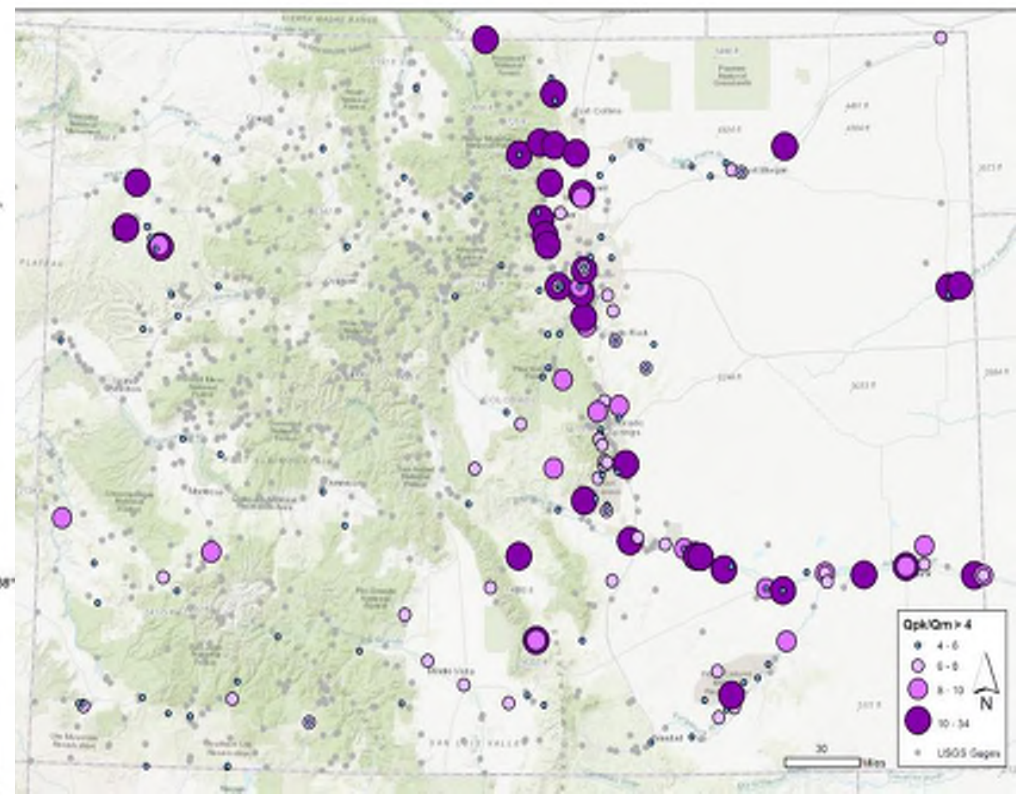
Erosion is just one of the geomorphic hazards associated with rivers. Simply measuring, modeling, or calculating erosion or bank retreat is insufficient to capture all hazards in a river corridor. Other geomorphic hazards include deposition, avulsion, and fan processes. This program identifies areas susceptible to erosion but also includes areas where these other geomorphic hazards present risk.

GOAL 1. DEVELOP A SCIENTIFICALLY DEFENSIBLE SET OF STANDARDS FOR COLORADO

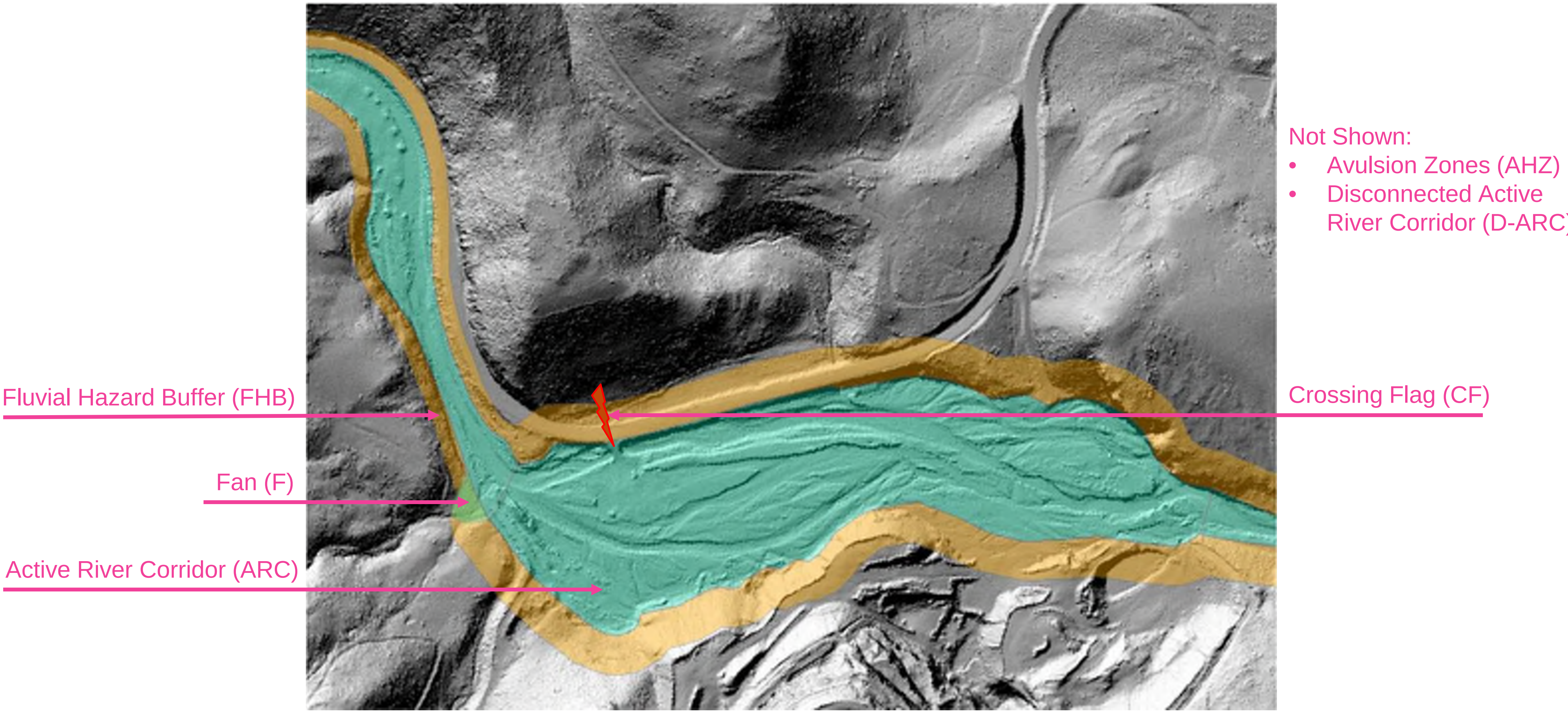
FHZ PROTOCOL DEVELOPMENT

PHYSIOGRAPHIC, GEOLOGIC, AND HYDROLOGIC CONTEXT

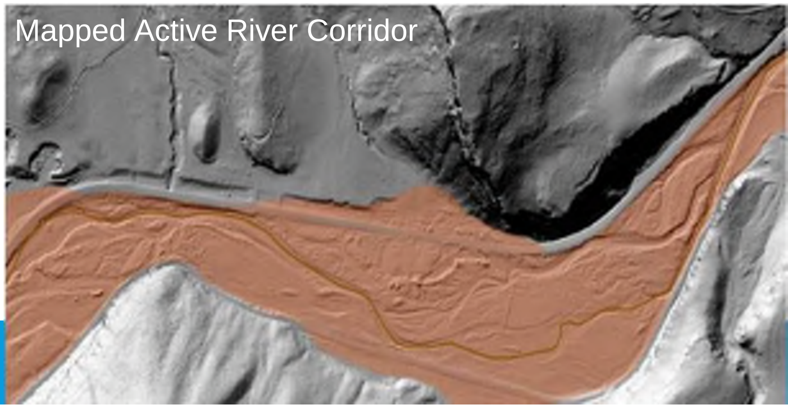




FLUVIAL HAZARD ZONE MAP COMPONENTS



Active River Corridor (ARC):
Where the river has occupied in the past or is likely to occupy in the future.



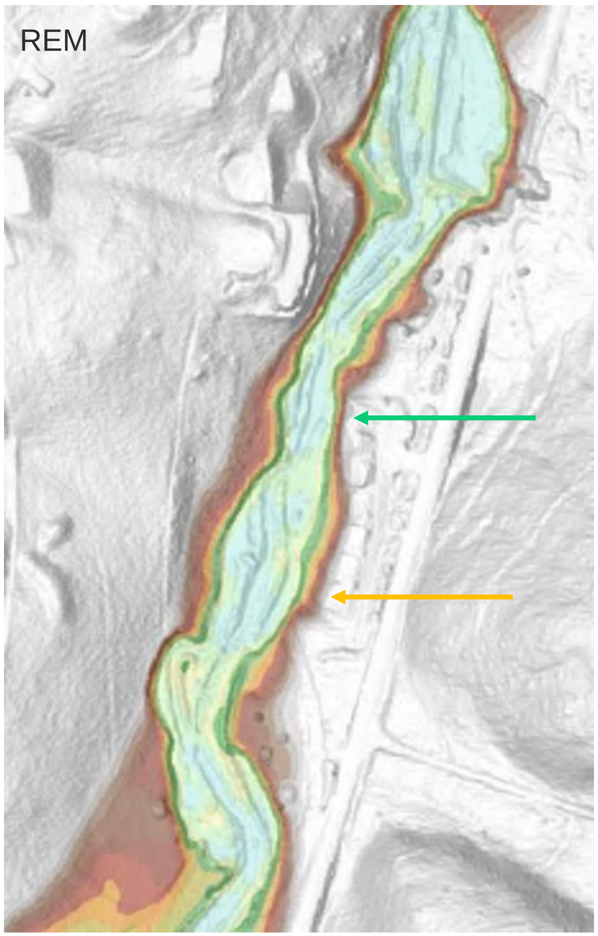
Four Methods to Delineate an ARC:

- **Headwater**: In steep headwater reaches
- **Fluvial Signature**: In streams with steeper slope or streams that are confined and partially confined by their valley walls or terraces
- **Meander Belt-Width**: In low-sloped streams that are unconfined by the valley margin or terraces
- **Urban**: In urbanized and heavily modified stream corridors also assesses the Disconnected-ARC.

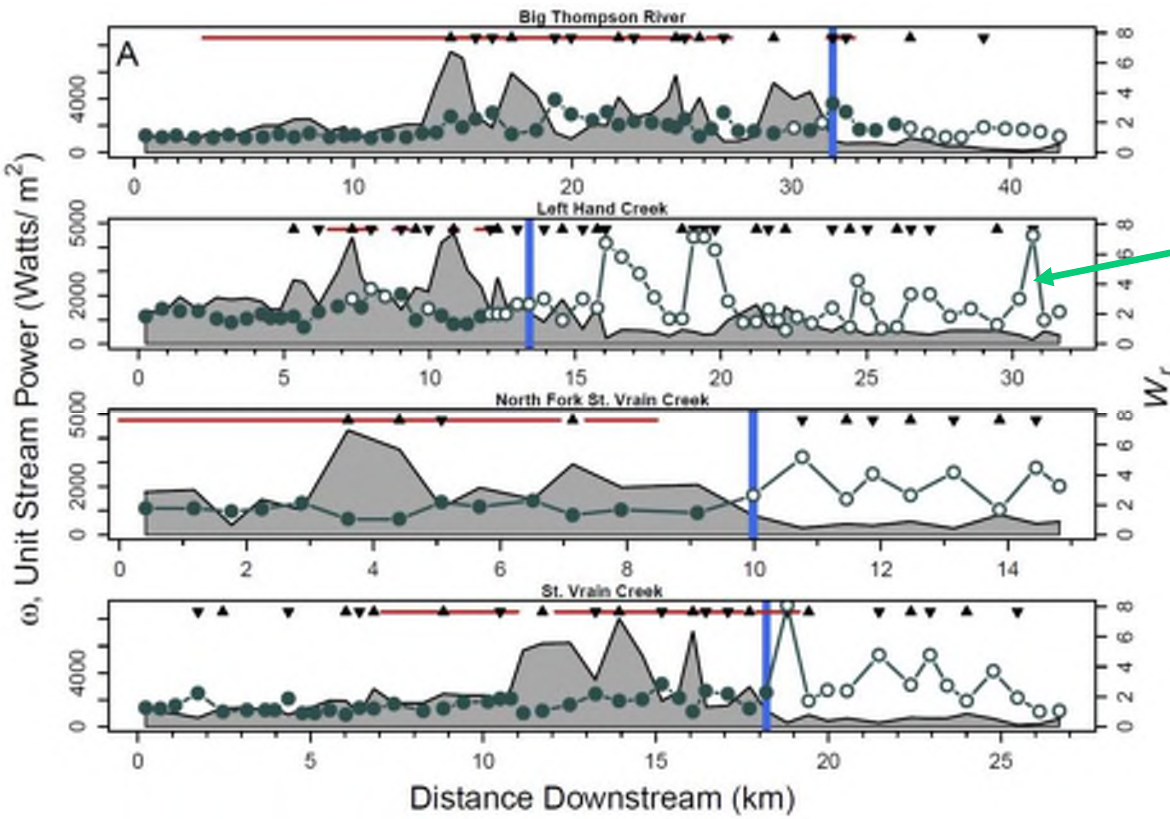
FLUVIAL SIGNATURE METHOD: ARC DELINEATIONS USING AN REM

- The ARC is mapped based on expert identification of the features that compose an active, geomorphic floodplain.
- We refer to these features as “fluvial signatures” and define them as landforms that are created by the deposition of sediment or erosion of sediment or bedrock. More than 17 of these out-of-channel geomorphic features have been described by Wheaton et al. 2015, and Brierley and Fryirs 2012.

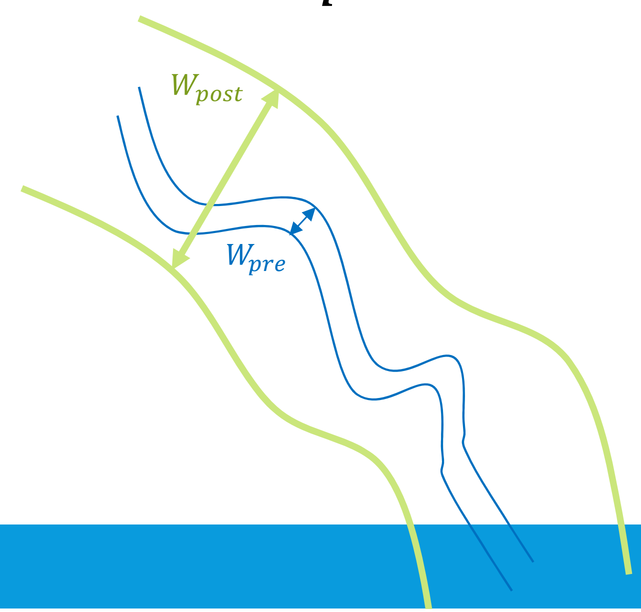
FLUVIAL SIGNATURE METHOD: ARC DELINEATIONS USING AN REM



FLUVIAL SIGNATURE METHOD: FLUVIAL SIGNATURE DATA AND OBSERVATIONS

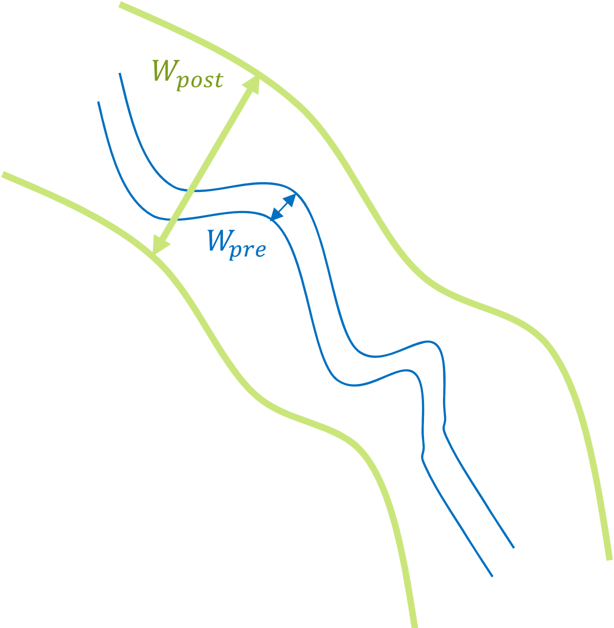


$$W_r = \frac{W_{post}}{W_{pre}}$$



FLUVIAL SIGNATURE METHOD: FLUVIAL SIGNATURE DATA AND OBSERVATIONS

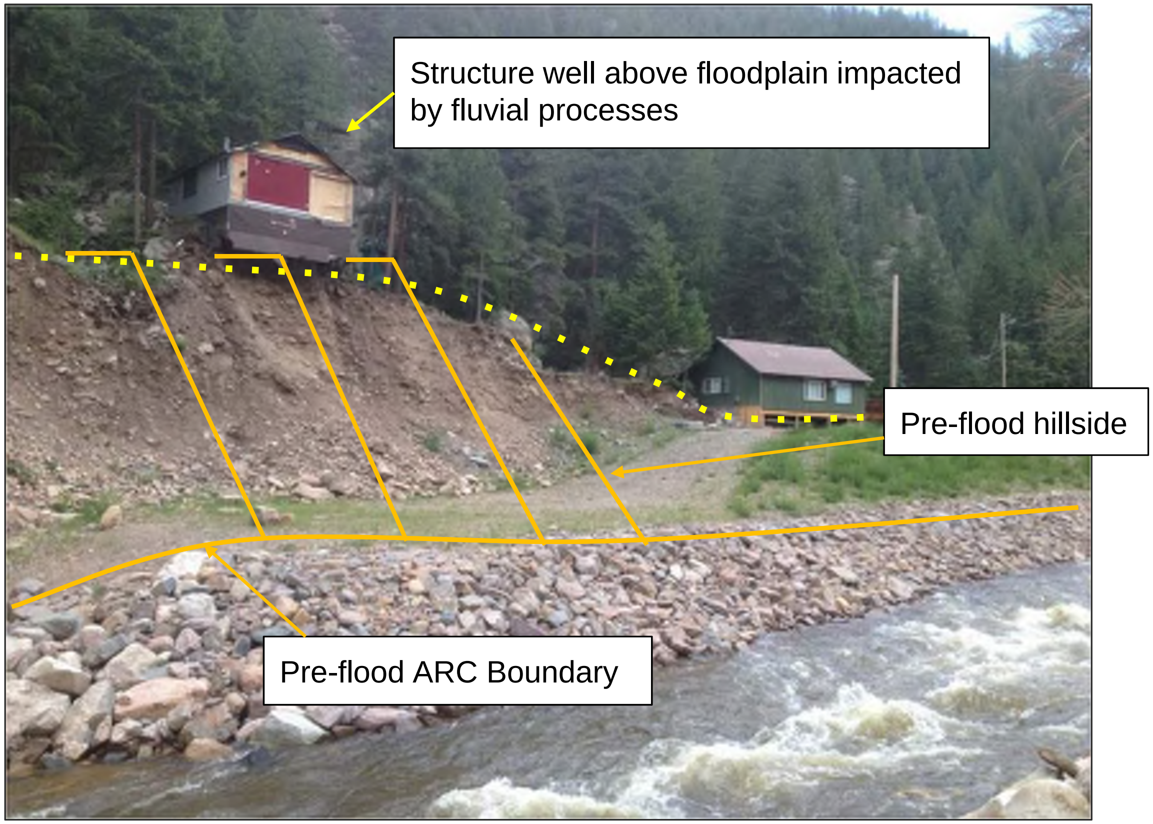
$$W_r = \frac{W_{post}}{W_{pre}}$$

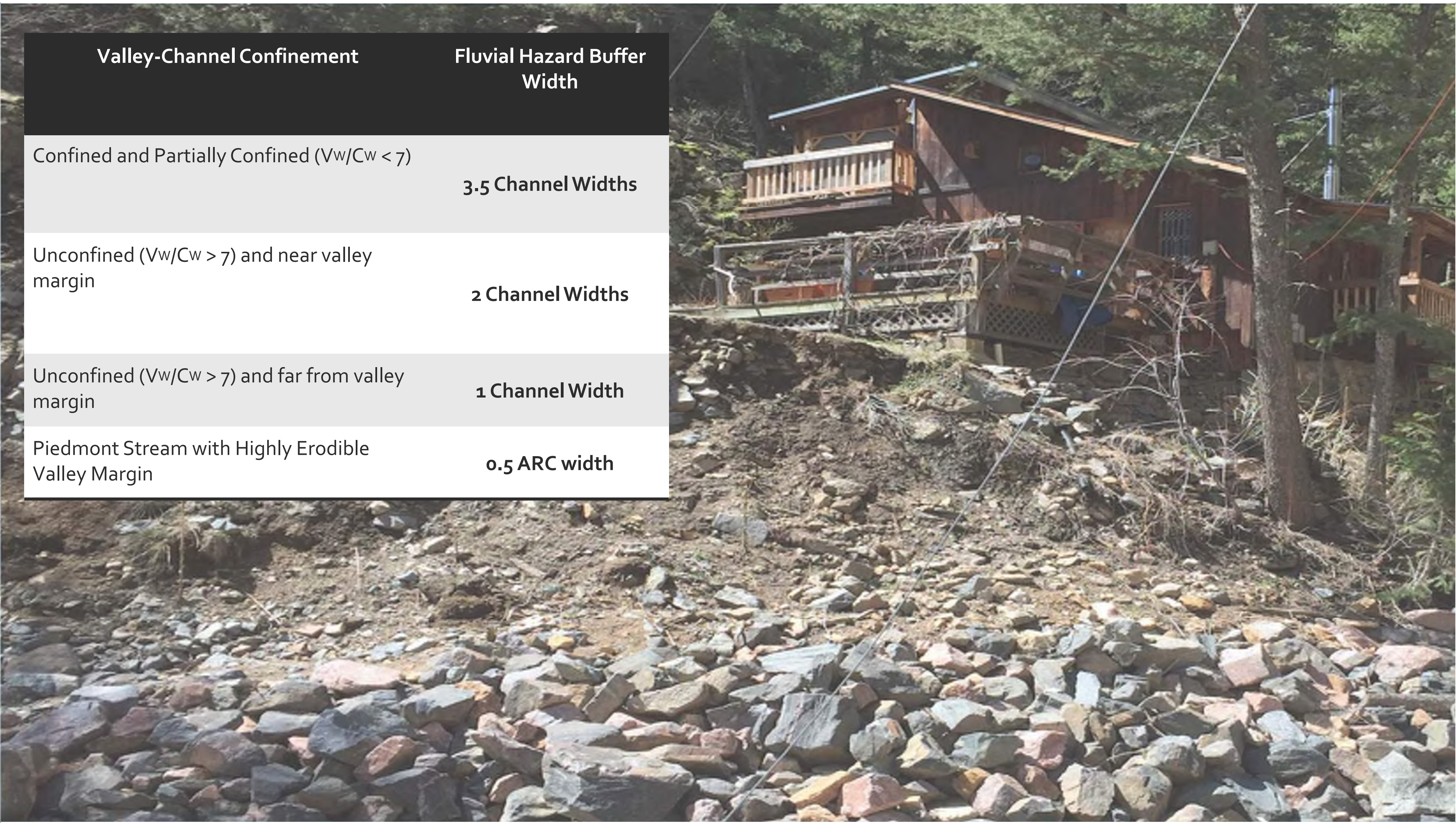


Big Thompson Canyon, Larimer County, Colorado
Photo Credit: Civil Air Patrol

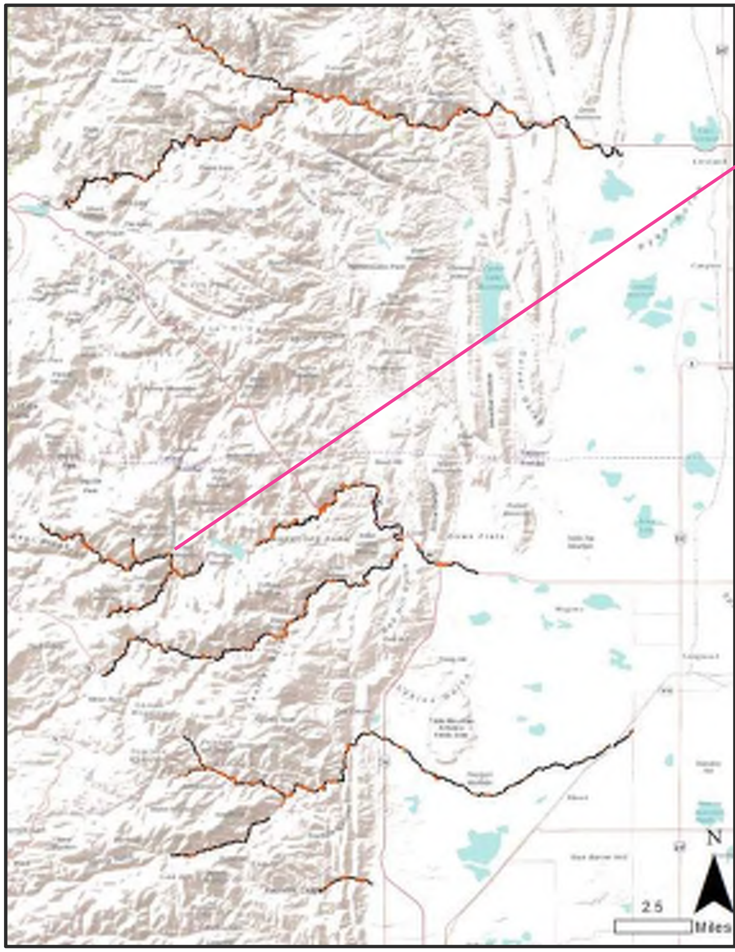
Fluvial Hazard Buffer (FHB):

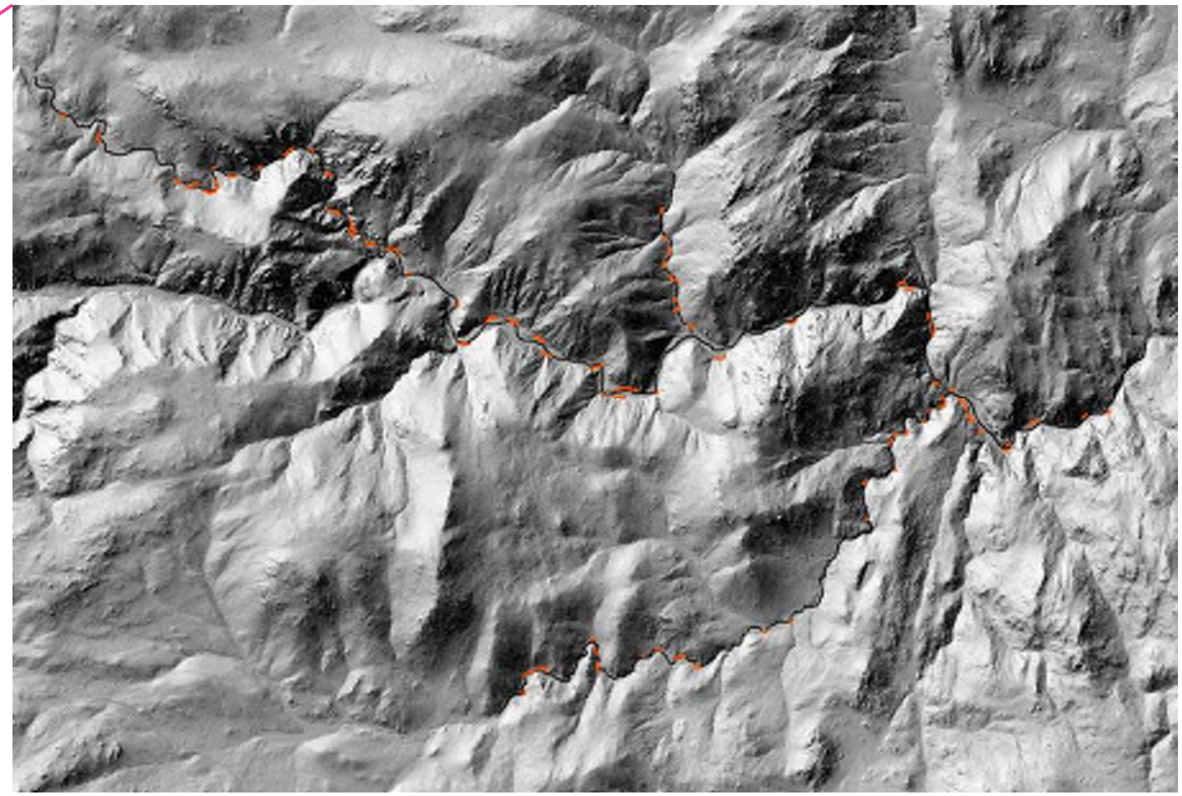
Regions, such as terraces or hillsides, that extend outward beyond the ARC and may be susceptible to erosion and mass wasting induced by lateral migration, widening, and incision of the river channel.



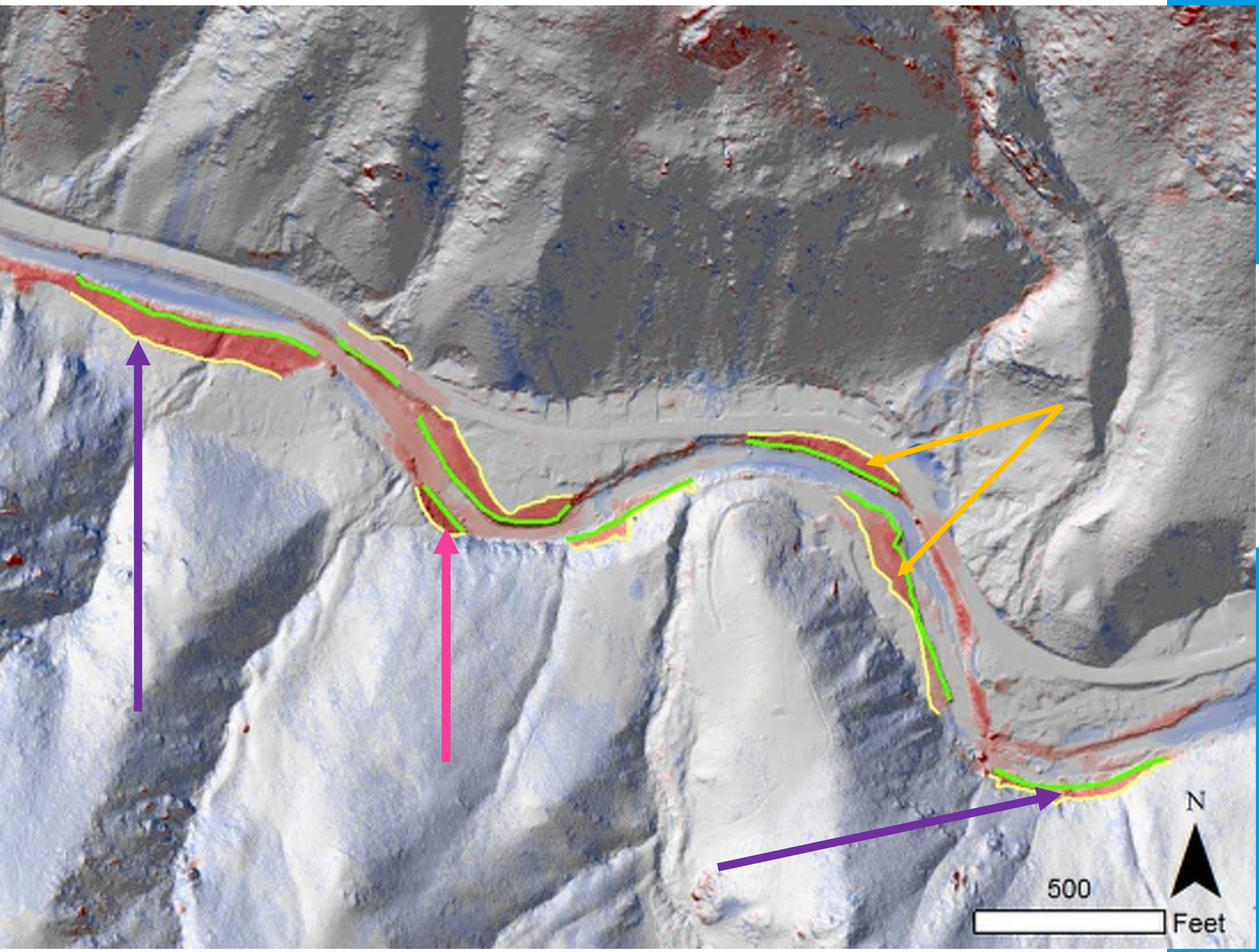


Valley-Channel Confinement	Fluvial Hazard Buffer Width
Confined and Partially Confined ($V_W/C_W < 7$)	**3.5 Channel Widths**
Unconfined ($V_W/C_W > 7$) and near valley margin	**2 Channel Widths**
Unconfined ($V_W/C_W > 7$) and far from valley margin	**1 Channel Width**
Piedmont Stream with Highly Erodible Valley Margin	**0.5 ARC width**





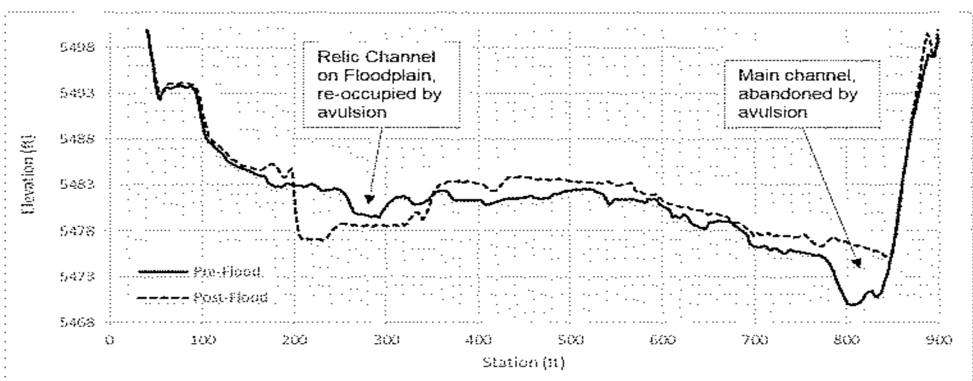
HILLSLOPE EROSION – 2013 FRONT RANGE FLOOD

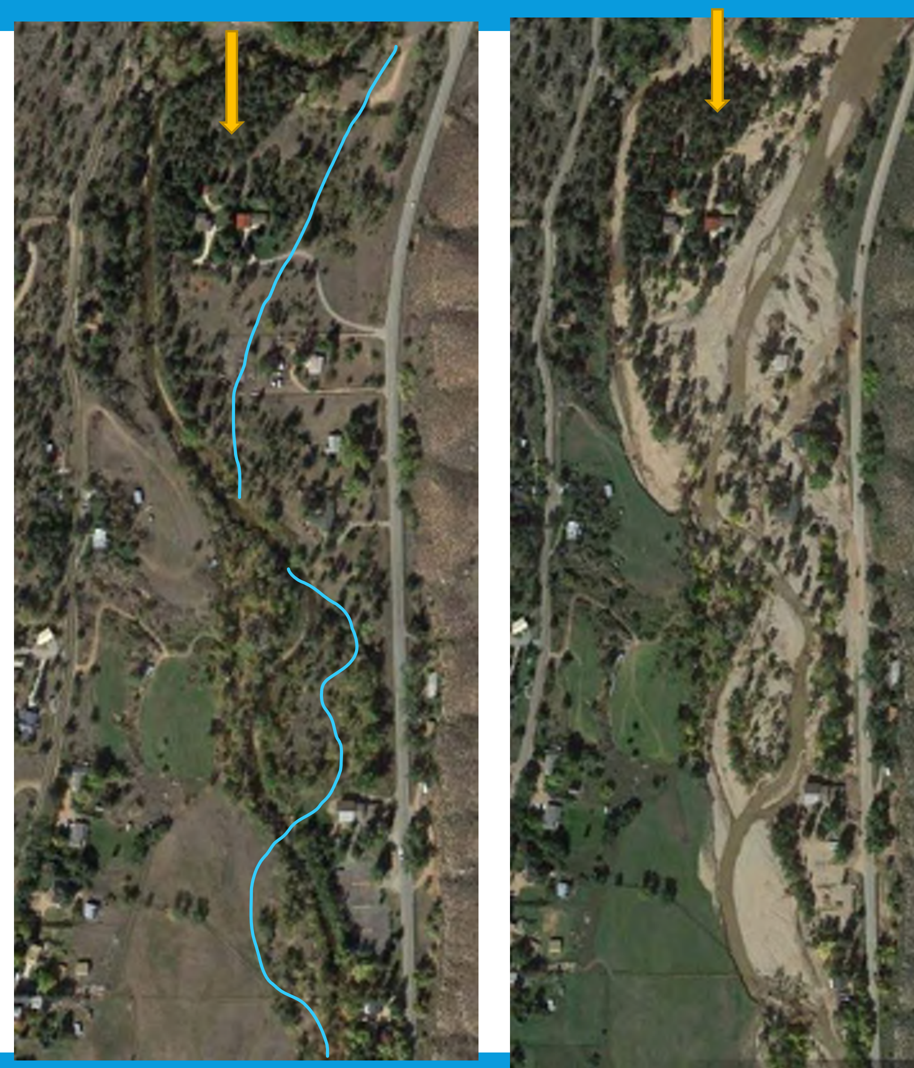


MEASURING HILLSLOPE FAILURE

Avulsion Hazard Zone:

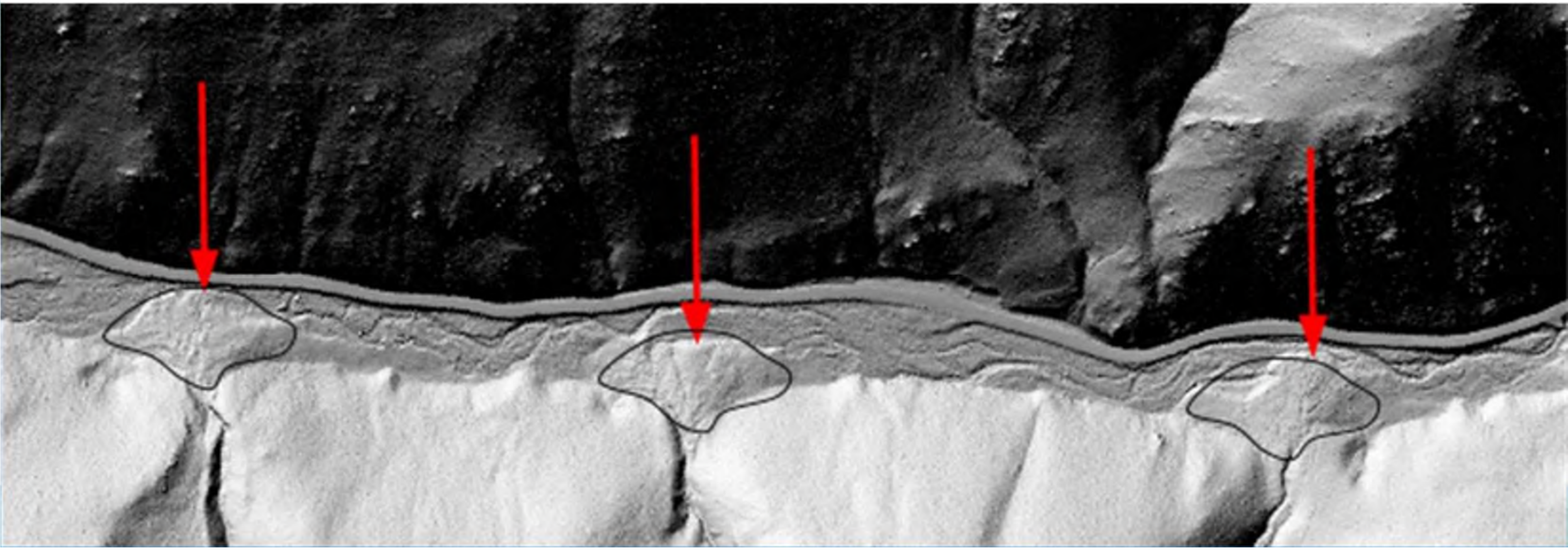
Areas a channel might occupy during a flood event due to a wholesale shift in channel position on the valley floor.





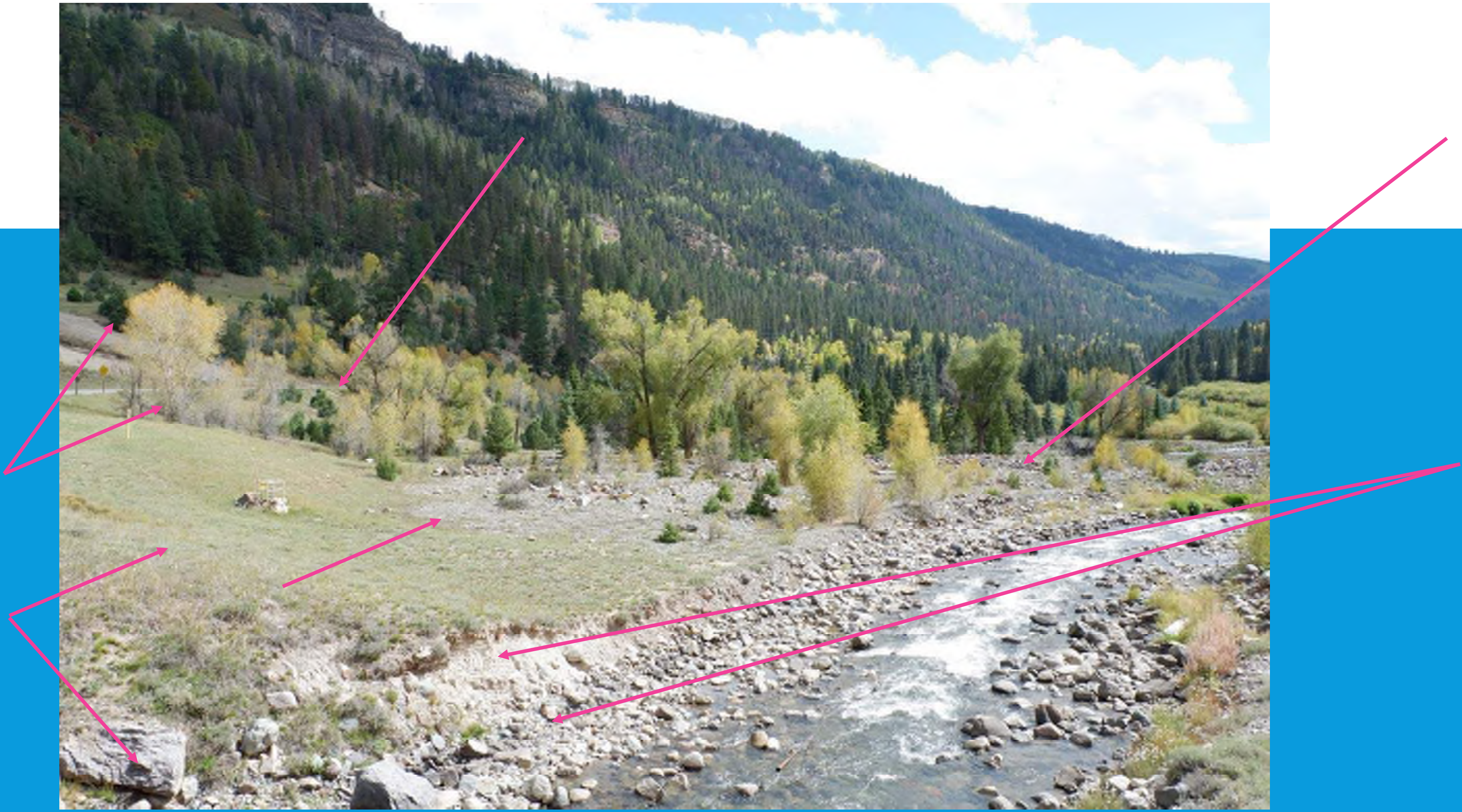
Fans:

Fans are triangular-shaped depositional features that generally form where steep transport reaches meet an unconfined, relatively flat river valley and a reduction in sediment and debris transport capacity causes material to deposit.



GO IN THE FIELD!

Estes Park and Telluride, Colorado
Photo Credit: Katie Jagt and Steph DiBettito



FIELD VERIFY—WHY?

Telluride, Colorado
Photo Credit: Katie Jagt

GOAL 2. IMPLEMENT FLUVIAL HAZARD MAPPING THROUGHOUT COLORADO

FHZ PILOT MAPPING PROGRAM

FHZ PILOT PROGRAM

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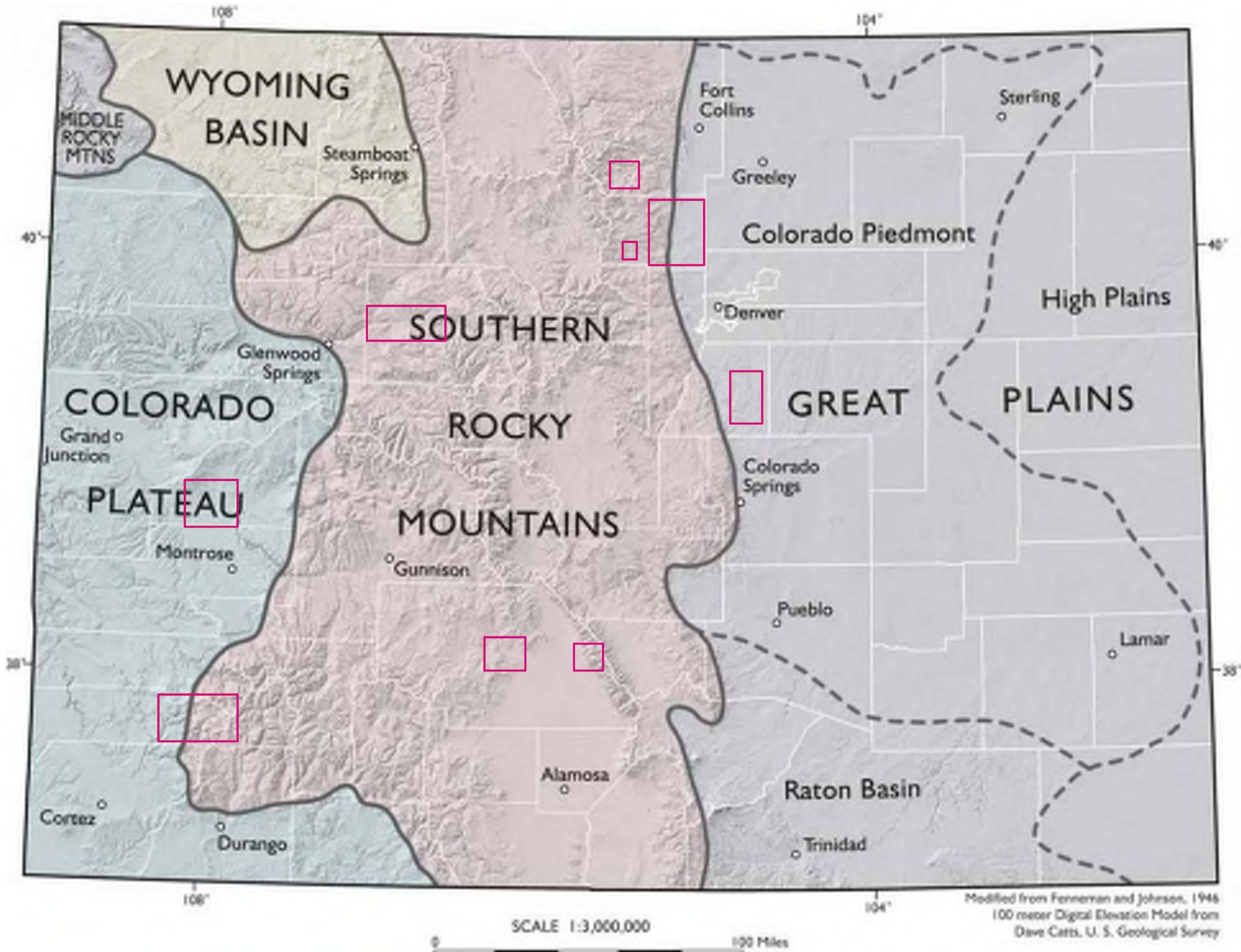

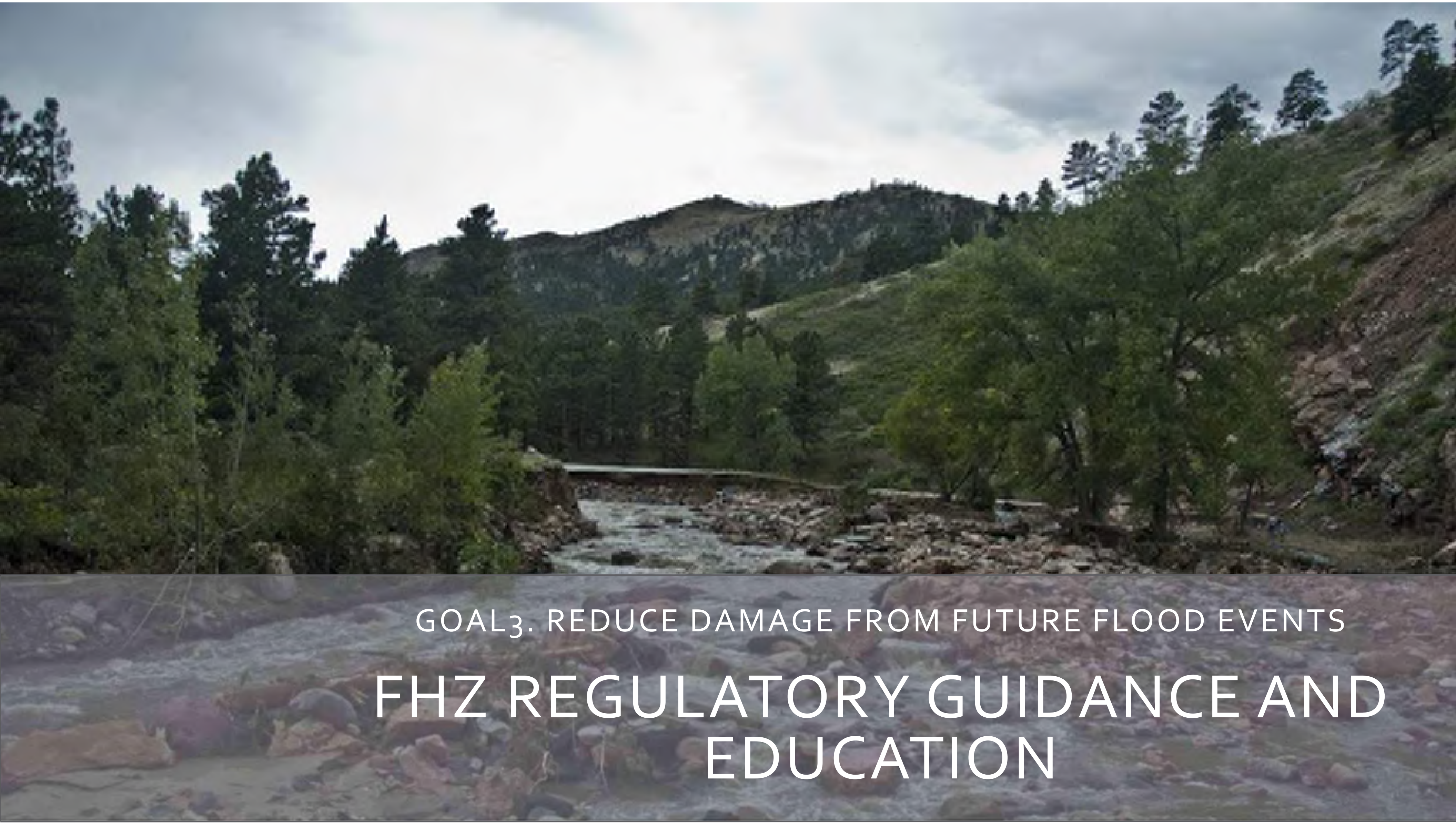

GOAL3. REDUCE DAMAGE FROM FUTURE FLOOD EVENTS

FHZ REGULATORY GUIDANCE AND EDUCATION

Krz#Pdsv#Pljkw#eh#Xvhg

- Suhyhqw#frppxqlw|#iurp#lqyhvwlqj#vhuylfhv# +h1j1/#vfkrrov/#iluh2uhvfxh#vwdwlrqv/#zdwhu# vdqlwdwlrq/#hwf1,#lq#fulwlfdo#yxoqhudeoh#duhdv1##
- Surylgh#lqirupdwlrq#wr#odqgrzqhuv#derxw# h{lvwlqj#ulvn
- Dvvlvw#lq#wudqvsruwdwlrq#ghflvlrqv#zkhuh# urdgv2ulyhuv#lqwhudfw
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- Ryhuod|#lq#odqgxvh#ru#}rqlqj#

Jamestown, Colorado
Top: 2013 Flood, Civil Air Patrol
Bottom: 1969 Flood, Carnegie Branch Library/Boulder Historical Society


Drake, Colorado
Left: 2013 Flood, Civil Air Patrol
Right: 1976 Flood
Bill Sptiz

LIMITATIONS

Wkrxjk#wklv#surfhvv#
frqvwlwxwhv#d#vljqlilfdqw#
lpsuryhphqw#wr#
xqghuvwdqglqj#iox|yldo#
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iorrg/#jhrprusklf/#dqg#
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Fourmile Canyon, Boulder, Colorado
Photo Credit: FMFPD

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

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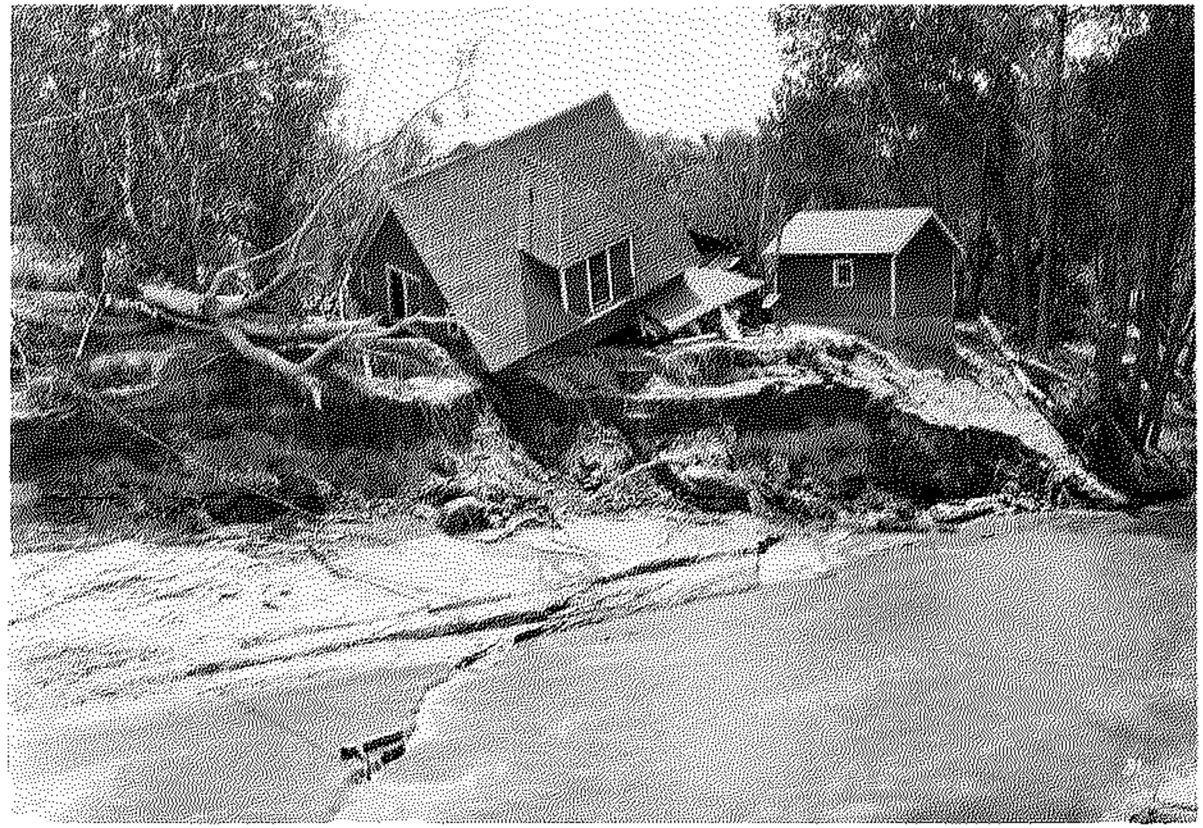
WATERSHED
SCIENCE + DESIGN



1935 Memorial Day Flood Fountain and Monument Creeks
Image Source: Pikes Peak Library Digital Collection

Evacuation Planning for Extreme Events: Failure of the Cherry Creek Dam

Presented by:
Jeffrey Brislawn, CFM / Wood
Kyle Karsjen, Wood

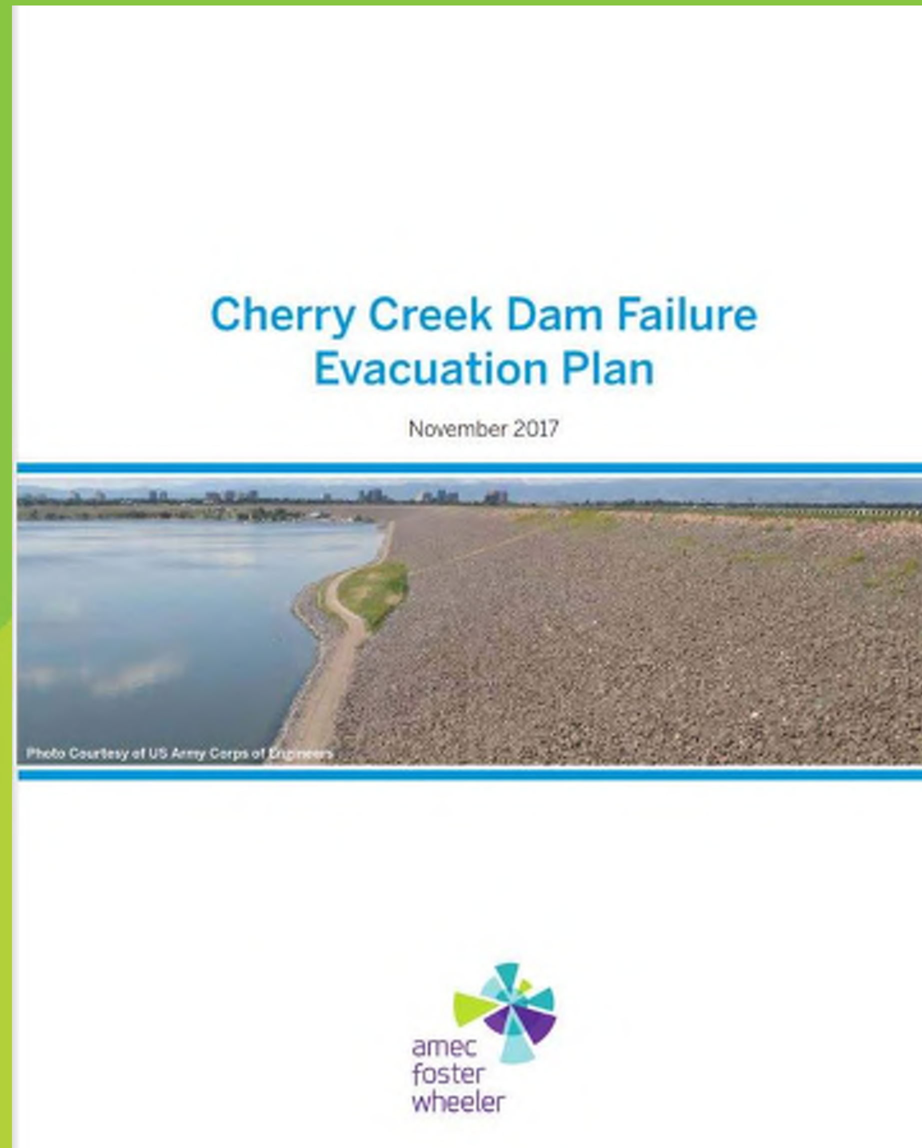
2018 Annual CASFM Conference
Snowmass, CO: "*Tackling the Impossible*"

woodplc.com

Presentation overview

- Project background
- Planning Situation and Probable Maximum Flood Risk
- Planning Process
- Multi-jurisdictional considerations
- Plan Elements
- Summary/Lessons Learned

Project Background


Cherry Creek Dam Failure Evacuation Plan

November 2017

Photo Courtesy of US Army Corps of Engineers

amec foster wheeler

Purpose

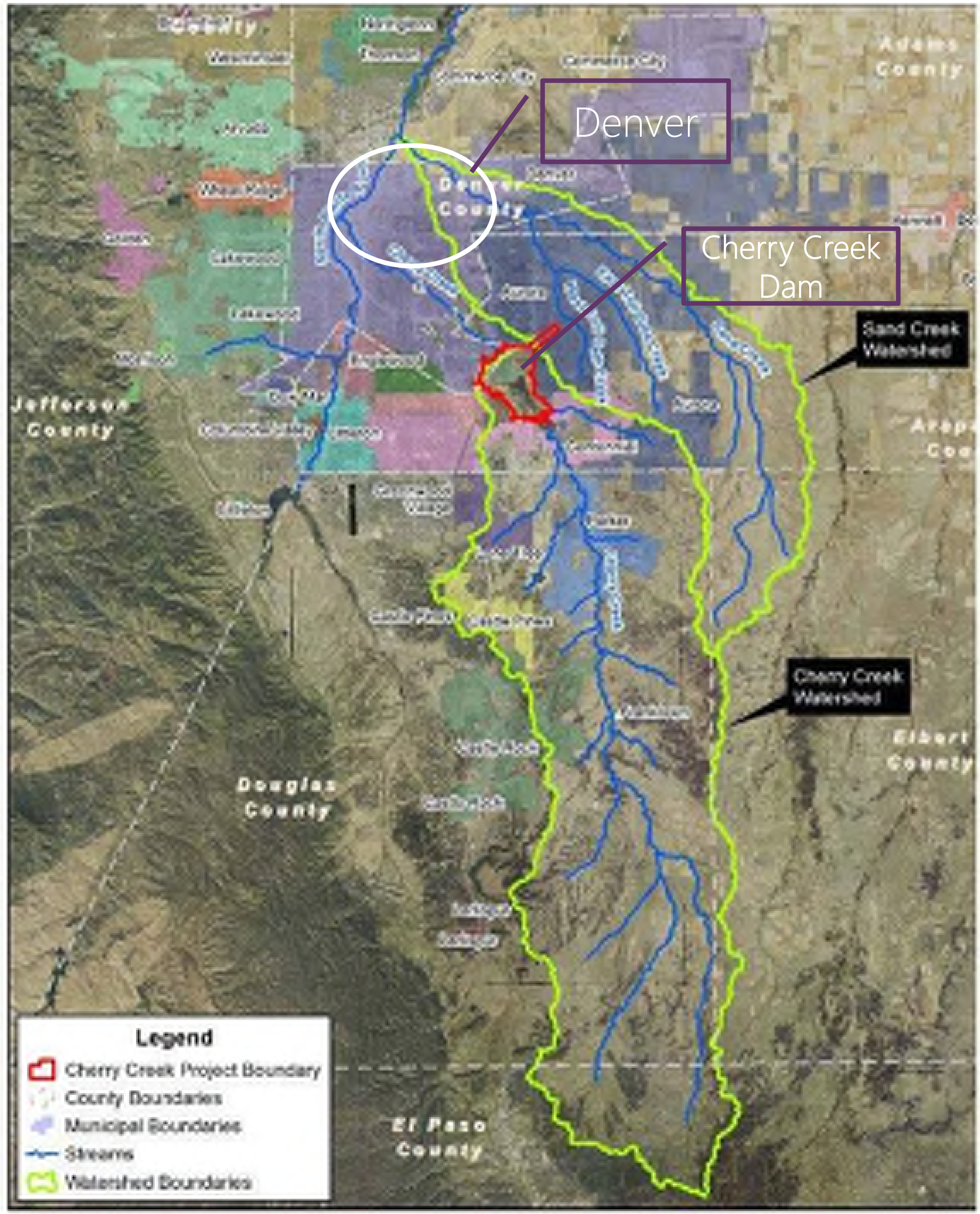
- *The goal of the Evacuation Plan is to provide a coordinated strategy to evacuate large numbers of persons from an area of high flood risk within the Cherry Creek Dam protected region to an adjoining area of reduced risk prior to, during and after a dam incident or failure.*

In other words:

1. There are a lot of people in the inundation area
2. There is a lot of water coming
3. How do our communities work together to get people out efficiently and effectively?

Watershed and Planning Area

- Cherry Creek Dam completed in 1950
- Managed in conjunction with Chatfield and Bear Creek dams to mitigate flood risk in the Denver area.
- 2017 Army Corps of Engineers Water Control Plan Modification and Dam Safety Modification study identified concerns and mitigation options

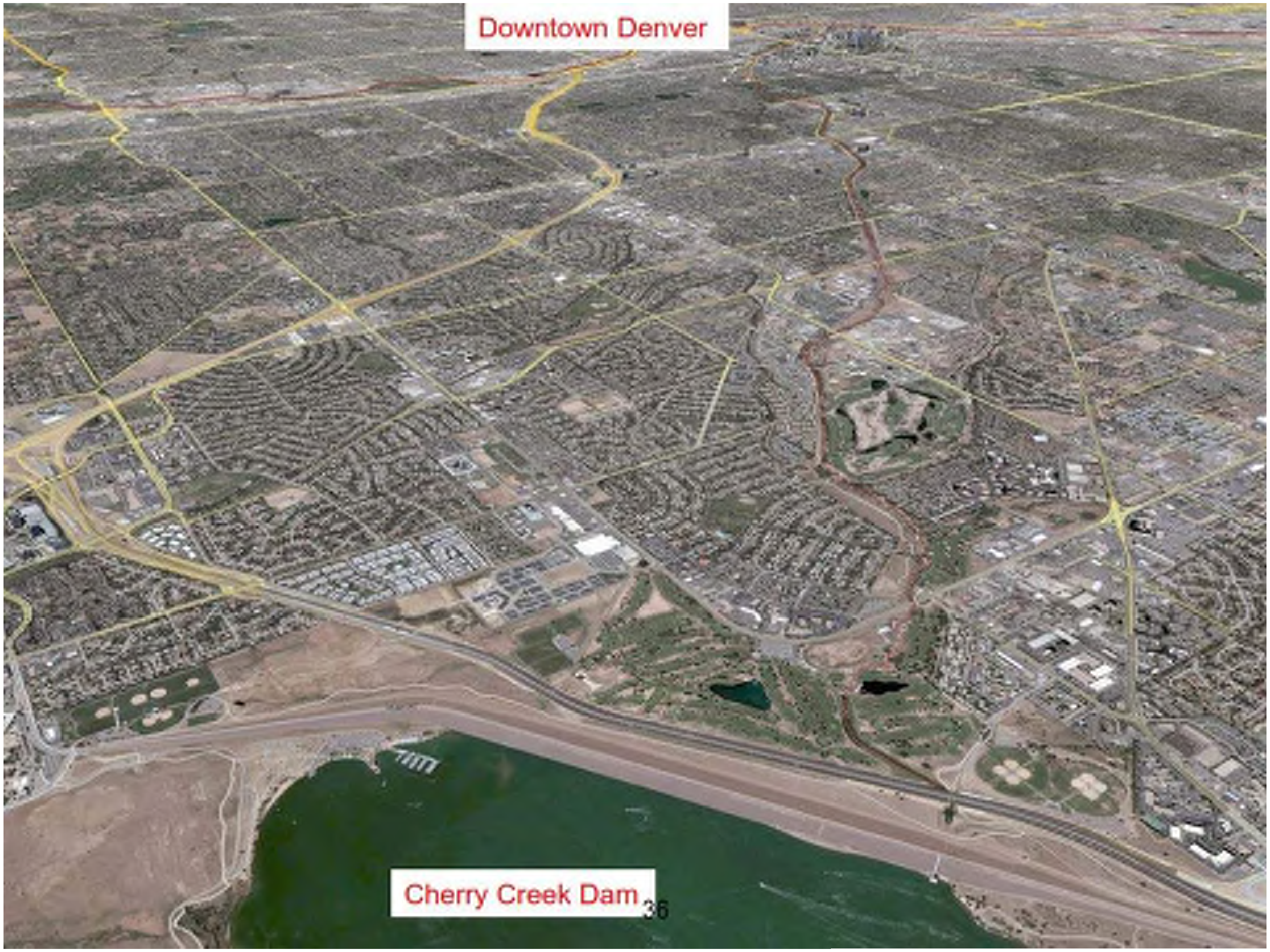


Cherry Creek Dam and Reservoir

Source: Army Corps of Engineers

Cherry Creek Dam and Reservoir – Perspective View

Perspective View Towards Denver

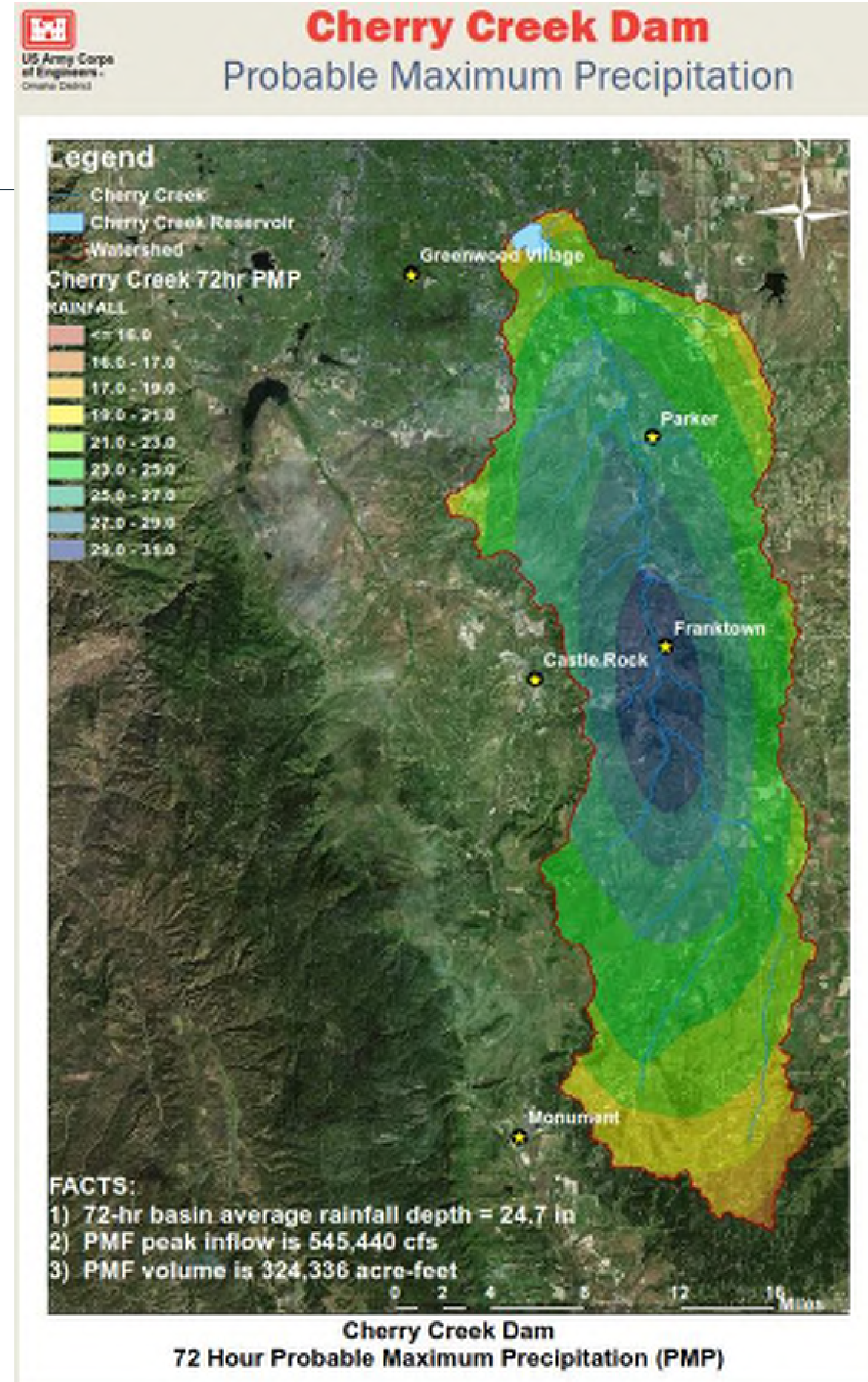


Source: Army Corps of Engineers

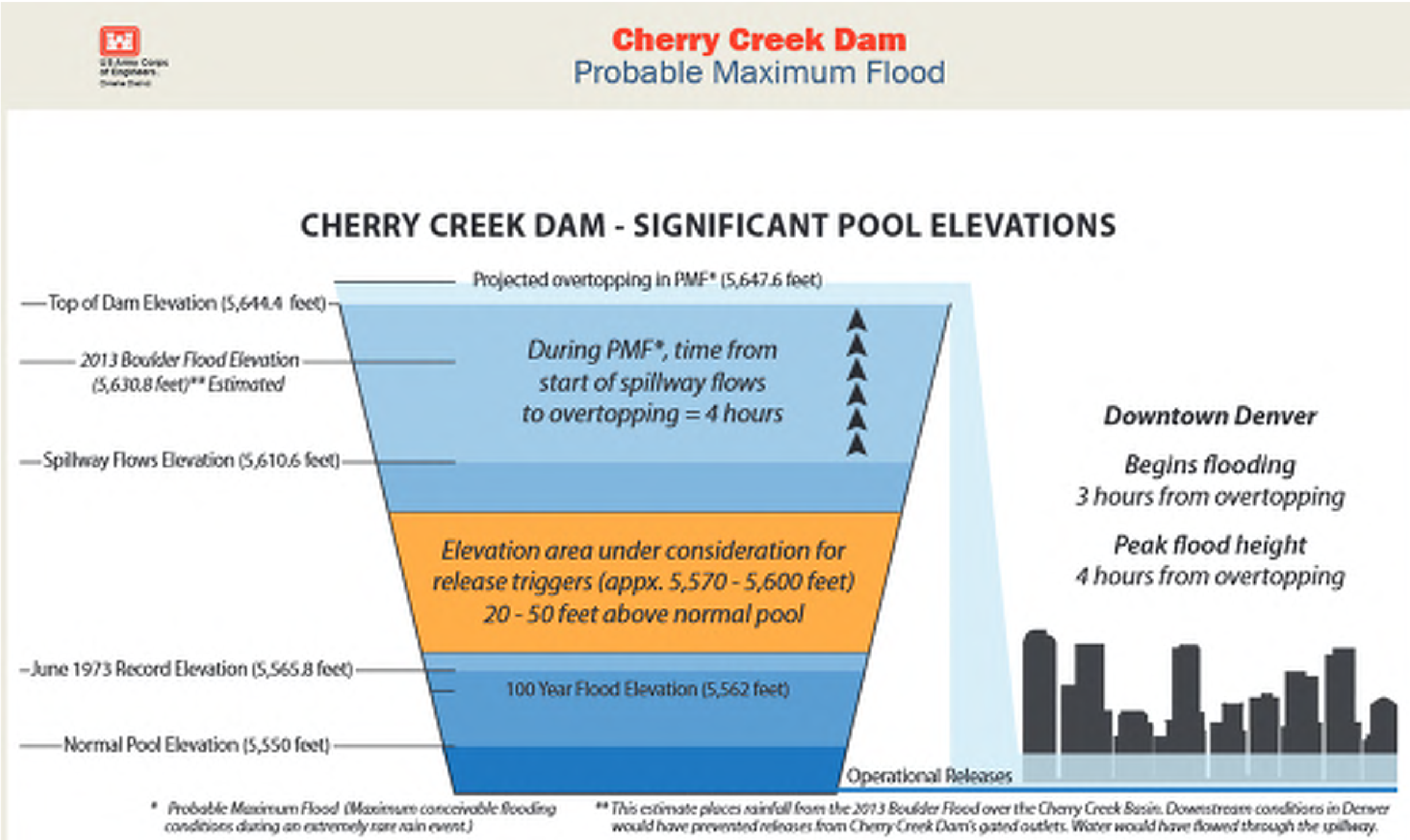
Planning Situation and Probable Maximum Flood Risk

Probable Maximum Precipitation and Flood

- 24.7" in 72 hrs in watershed upstream of Dam
- The PMF produces uncontrolled drainage flooding peak flows of 27,000 cfs at the Cherry Creek gage and 109,000 cfs at the South Platte River at Denver stream gage.
- It would take 40 days to empty the flood water stored in the reservoir and the spillway would flow for about 8 days.
- Assumed that the weather forecast would allow a warning and planning time of approximately 24-72 hours.

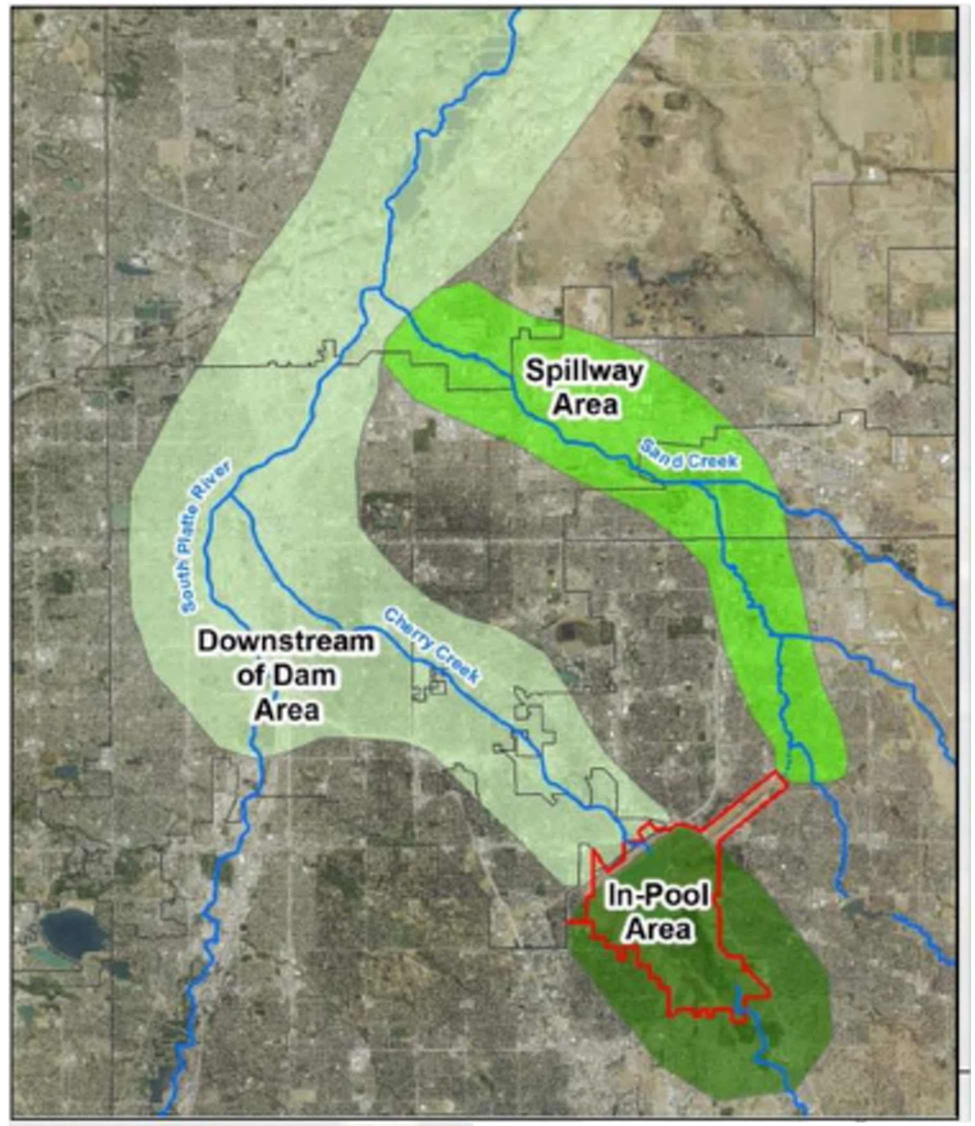


Probable Maximum Flood Risk



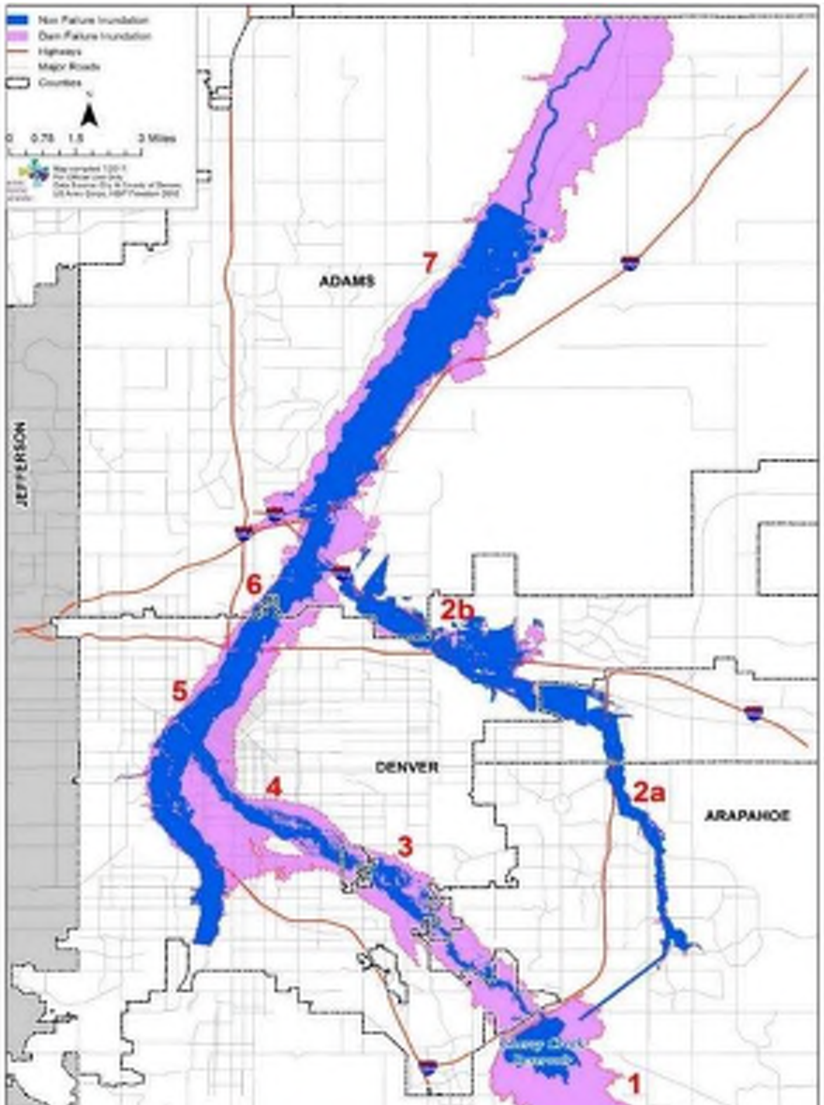
Consequence Impact Areas

- In- Pool Area
- Downstream of Spillway
- Downstream of Dam

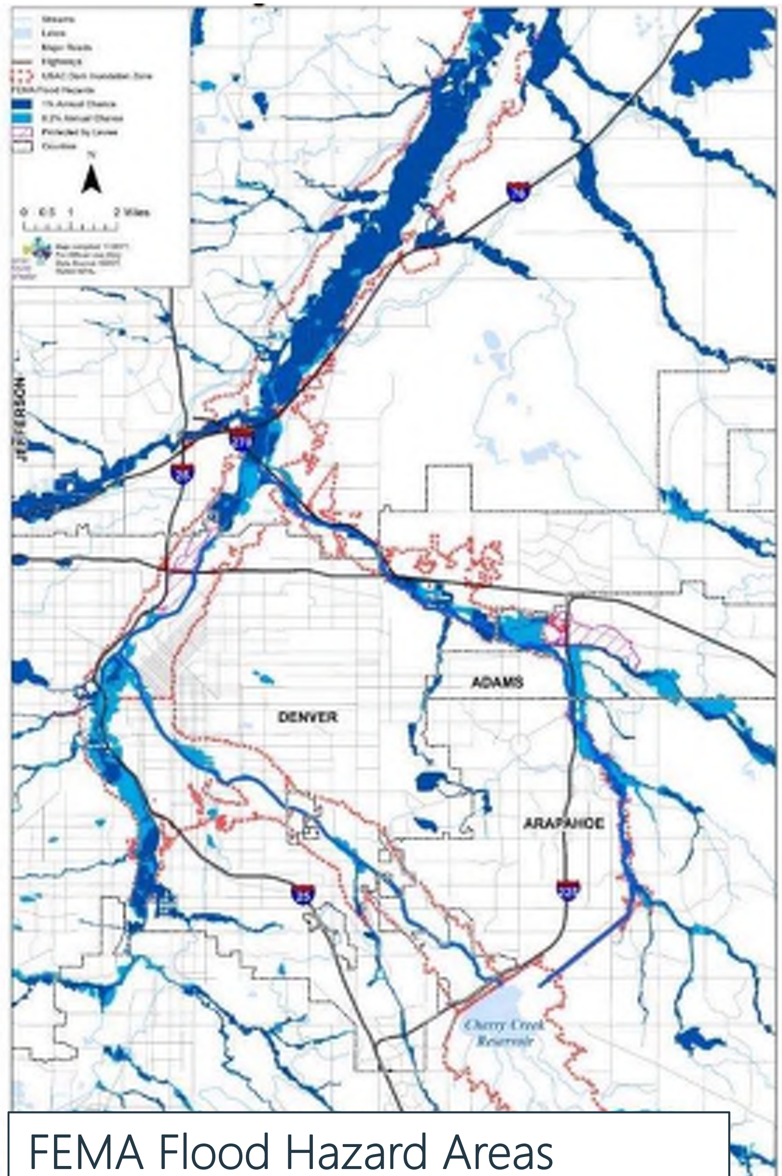


Source: Army Corps of Engineers

Regional Inundation



Controlled Release (Blue) and Failure (Pink)



FEMA Flood Hazard Areas

Consequences/Planning Situation

- Population at Risk: approximately 300,000 in the inundation area
- Critical facilities, bridges and other infrastructure
- 25,000 buildings impacted
- Hospitals, nursing homes, schools

Planning Process

Evacuation Planning Committee and Working Groups

Developed with input from subject matter experts, stakeholders and local emergency managers

- Steering Committee
  - Arapahoe County Emergency Management
  - City and County of Denver Emergency Management
  - City of Aurora Emergency Management
  - Adams County Emergency Management
- Evacuation Planning Team (EPT)
  - Regional stakeholders and subject matter experts
    - Army Corps of Engineers
    - Urban Drainage and Flood Control District
    - CO Division of Homeland Security and Emergency Management
    - Regional Transportation District
    - CDOT
    - Colorado State Patrol

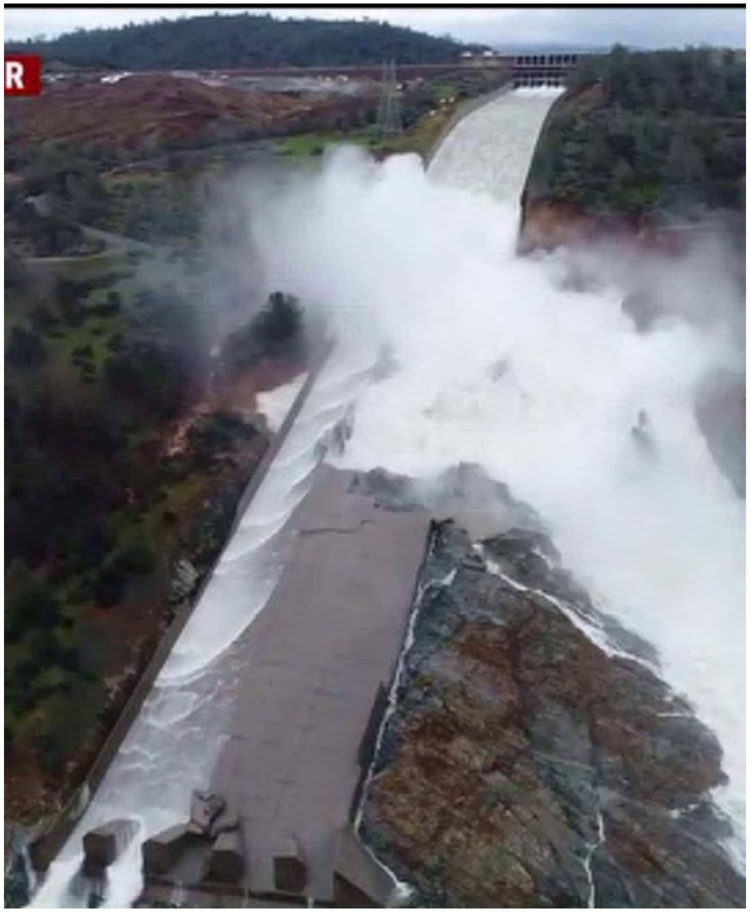
Planning Process and Timeline

- Working groups for functional areas: Transportation, Communications and Warning, Access and Functional Needs, Animal Protection, Reunification and Re-entry
- Two large group Evacuation Planning Team meetings
  - Kickoff (April 12, 2017)
  - Plan Rollout (October 2017)
- Two working group sessions
  - 2 half-day sessions for each working group in May/June and August
- Monthly coordination calls and additional meetings with Steering Committee
- Initial Draft provided to Steering Committee October 10th, 2017

Planning Process

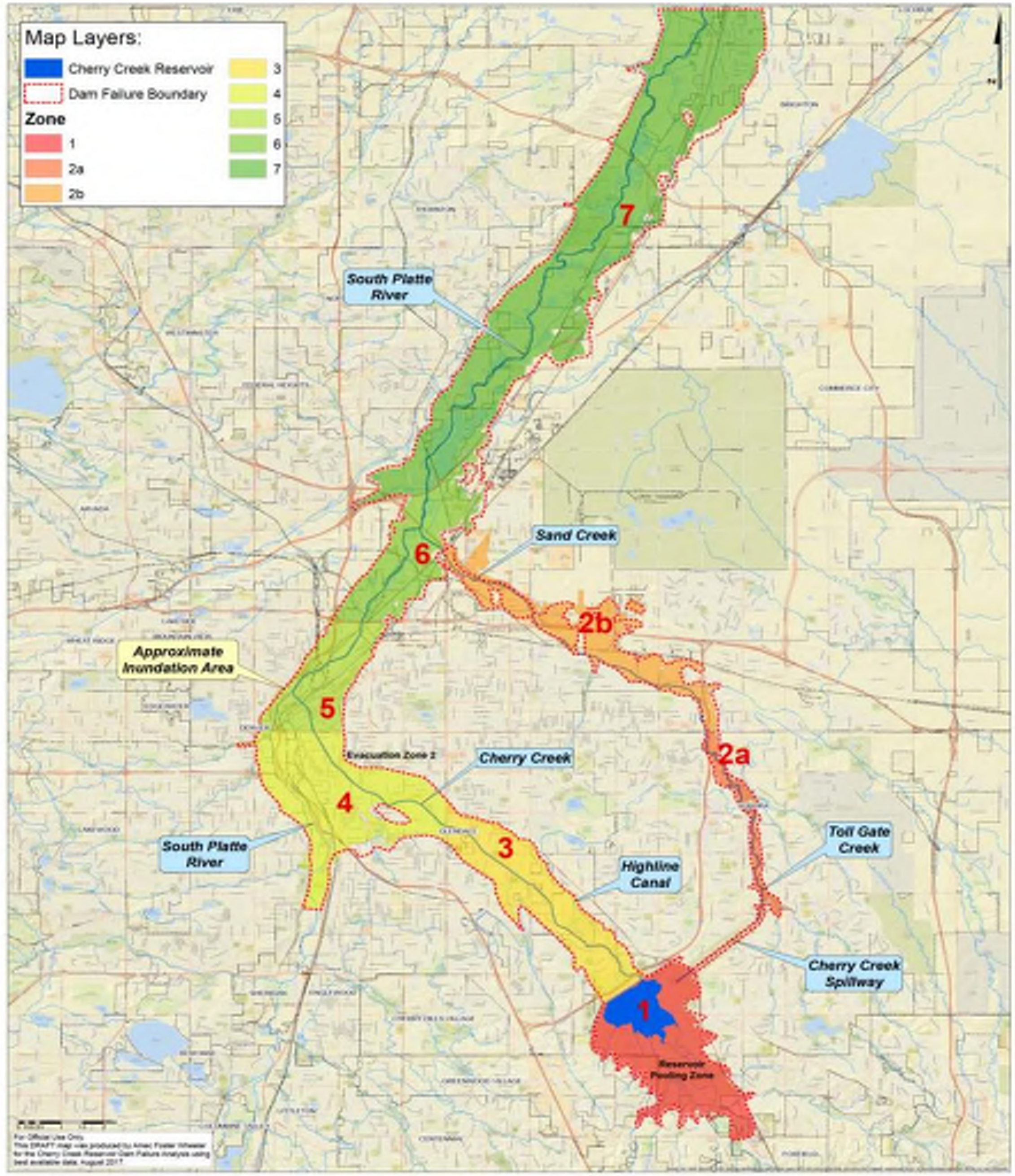
Planning Considerations from the 2017 Oroville Dam Incident Used to Inform Plan

- Notifications, evacuation warnings and orders
- Transportation of Evacuees
- Shelters and Shelter Operations
- Security of the Evacuated Area
- Diversion, Inundation, and Debris
- Decision support and decision-making
- Intergovernmental Relations and Coordination



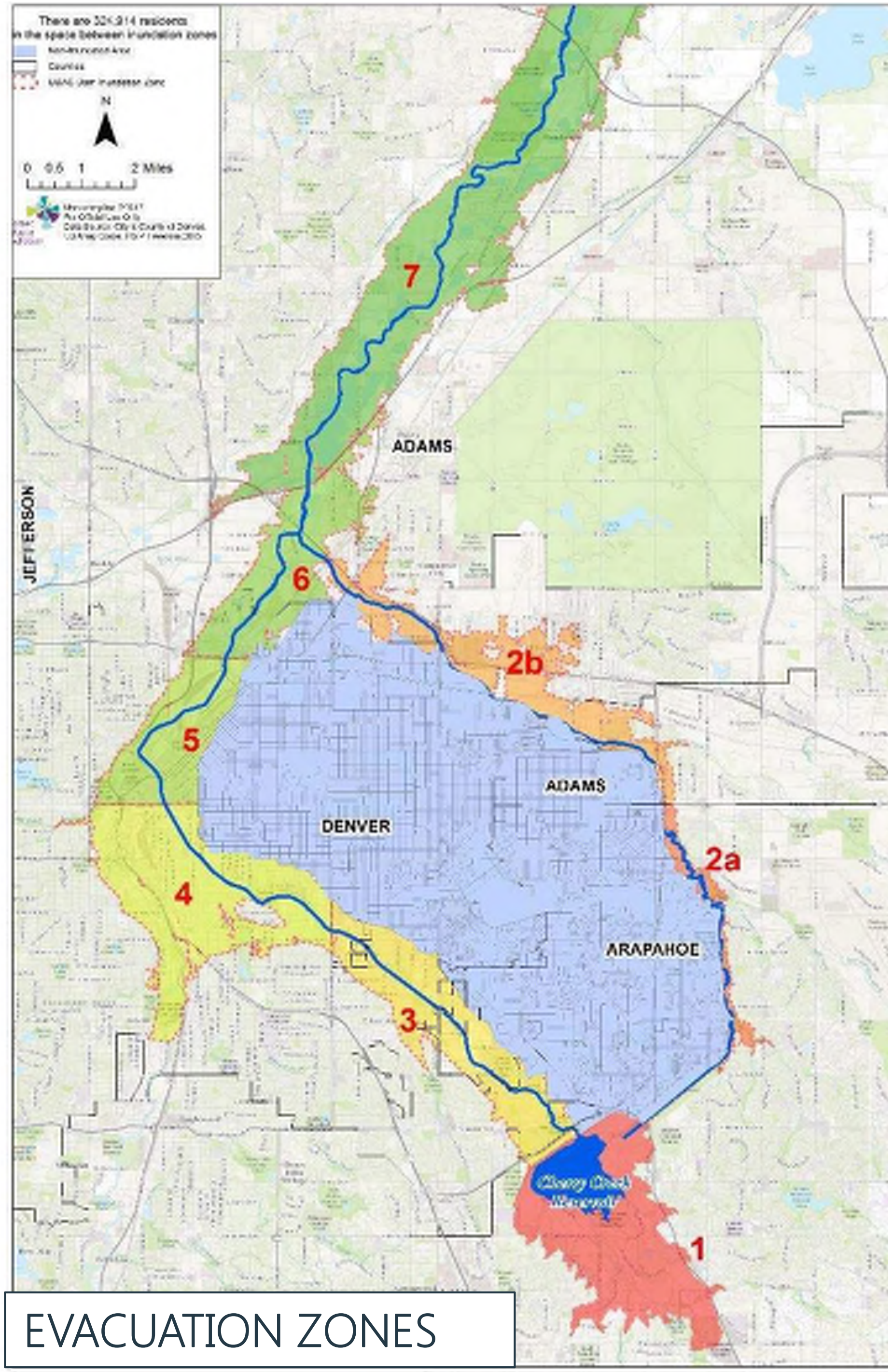
Evacuation Zones

- Zones for internal management of incident
- Determined Early on for planning purposes
- In- Pool Area (1)
- Downstream of Spillway (2)
- Downstream of Dam (3-7)



Dam Failure Flood Evacuation Zones and "Island"

- "Island" blue area on map between spillway and Cherry Creek/S Platte may need to be evacuated
  - 324,914 residents
  - Reduced flood risk, but potentially isolated from services should a failure occur



EVACUATION ZONES

Multi-Jurisdictional Considerations

Multi-Jurisdictional Considerations

Multi-Agency Coordination

Evacuation Plan Crosswalk with Local Emergency Operations Plans

Coordination with existing planning mechanisms and emergency procedures

Evacuation Components/Annexes	Relevant Emergency Support Function	Relevant Function
Base Plan	• Emergency Management	• Direction and Control • Evacuation
Communications and Warning	• Communications • External Affairs	• Communications and Warning • Emergency Public Information • Evacuation
Transportation	• Transportation • Public Works and Engineering • Public Safety and Security	• Transportation and Resources • Evacuation
Access and Functional Needs	• Mass Care	• Sheltering and Mass Care • Evacuation
Animal Protection	• Agriculture and Natural Resources	• Sheltering and Mass Care • Evacuation
Reunion and Reunification	• Mass Care	• Sheltering and Mass Care

Plan Elements

Base Plan - Overview

- Situation/overview of hazard
- Relationship to existing plans
- Concept of operations
- Direction, Control and Coordination
- Multi-Agency Coordination System
- Evacuation Decision Making and Authorities
- Roles and Responsibilities
- Plan maintenance and exercising recommendations

Tiered Activation Stages

Evacuation Plan – Stages and Phases
Stage 1 Evacuation – Controlled release flooding on Cherry Creek, spillway flooding and uncontrolled drainage flooding; the dam is still structurally sound and functioning
Evacuation Area: Evacuation zones should be evacuated depending on projected release flows with priority on Zones 3, 4, 5, 6 and 7; Spillway flows will necessitate evacuation of Zones 1 and 2 **Phase 1: Evacuation Watch**: immediate preparation for a full-scale evacuation. **Phase 2: Evacuation Warning:** evacuate
Stage 2 Evacuation – Potential Dam Failure Situation
Evacuation Area: All evacuation zones should be evacuated with priority on Zones 1, 2, 3, 4, and 5; Evacuation of Denver in areas ringed by I-25, I-225 and I-270 as second priority. **Phase 1: Evacuation Watch** **Phase 2: Evacuation Warning**
Stage 3 – Dam Failure
Evacuation Area: Continued evacuation of all inundation zones excluding the Interstate Ring
Preparedness/Blue Sky Activities: Building partnerships, exercise, training, personal perparednes

Functional Annexes

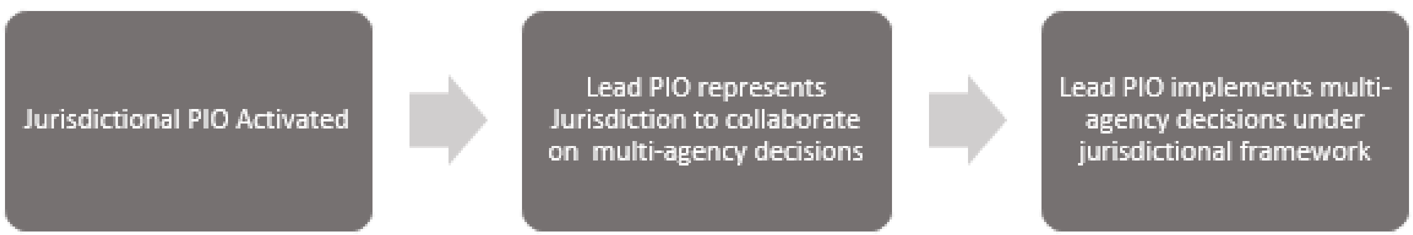
- Focused on specific areas of the response requiring jurisdictional coordination
  - Transportation
  - Communications and Warning
  - Access and Functional Needs
  - Family Reunification and Re-entry
  - Animal Protection
- Developed with input from working groups
- Functional considerations as communities execute the response based on jurisdictional response plans
  - Watch vs. Warning phase considerations
- Annexes do not supersede jurisdictional operations

Communications and Warning

Key Elements

- Joint Information Centers (JICs) – Local jurisdictions
- Multi-jurisdictional/multi-agency coordination on communication through Joint Information System (JIS)
  - Unified decisions regarding:
    - What messages will be released – Watch vs Warning
    - When the messages will be released
    - Sample message text edits
    - Coordinated messaging

Lead PIO/Multi-Agency Coordination Flow Chart

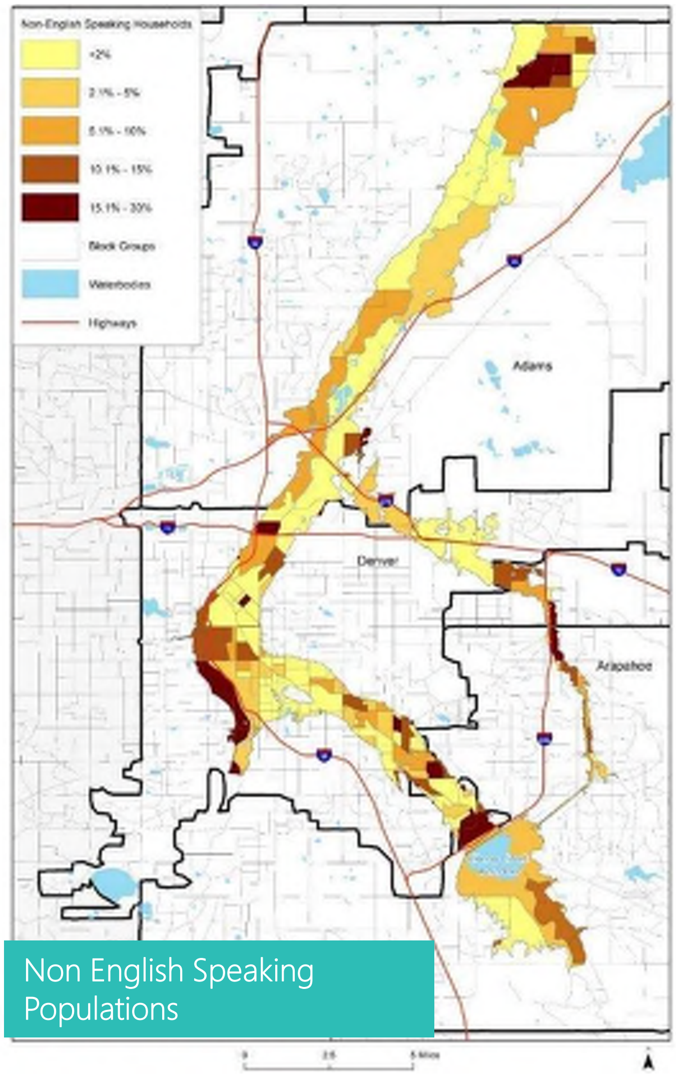


Communications and Warning

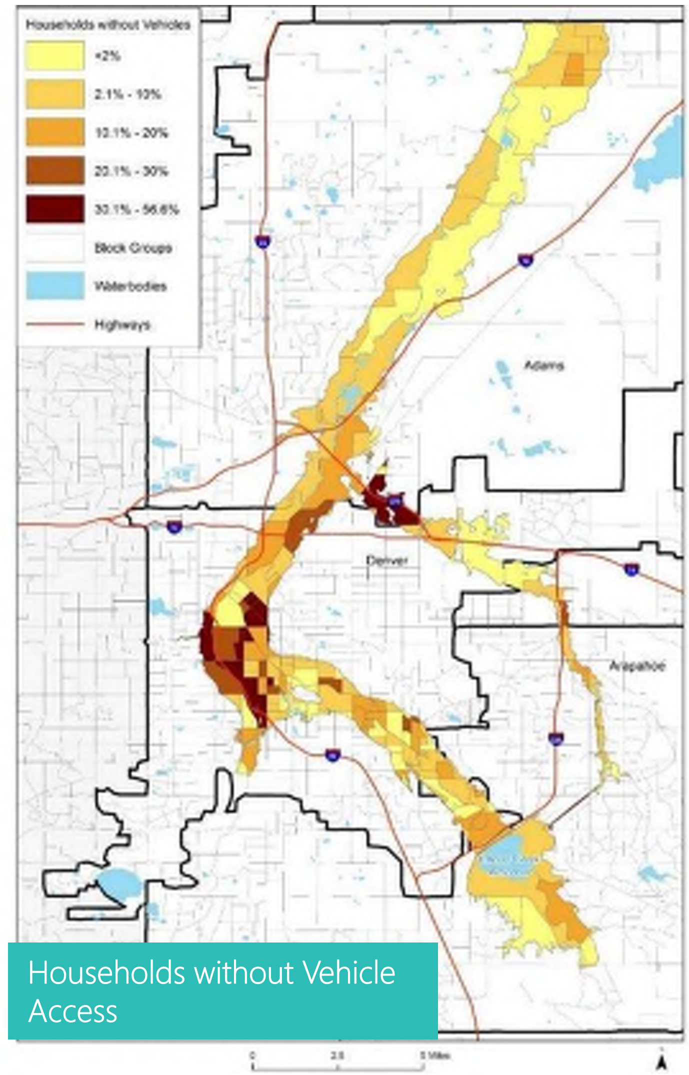
Messaging Dissemination Channels and Tools

- IPAWS
- Wireless Emergency Alerts (WEA)
- Wireless Communications
- Radio
- Variable Message Signs
- Television broadcast and message scrolls
- NOAA WX radio
- UDFCD Alert
- Social Media
- Sample Message Templates
- Sample Evacuation Order

Social Vulnerability Considerations



Non English Speaking Populations



Households without Vehicle Access

Transportation Annex

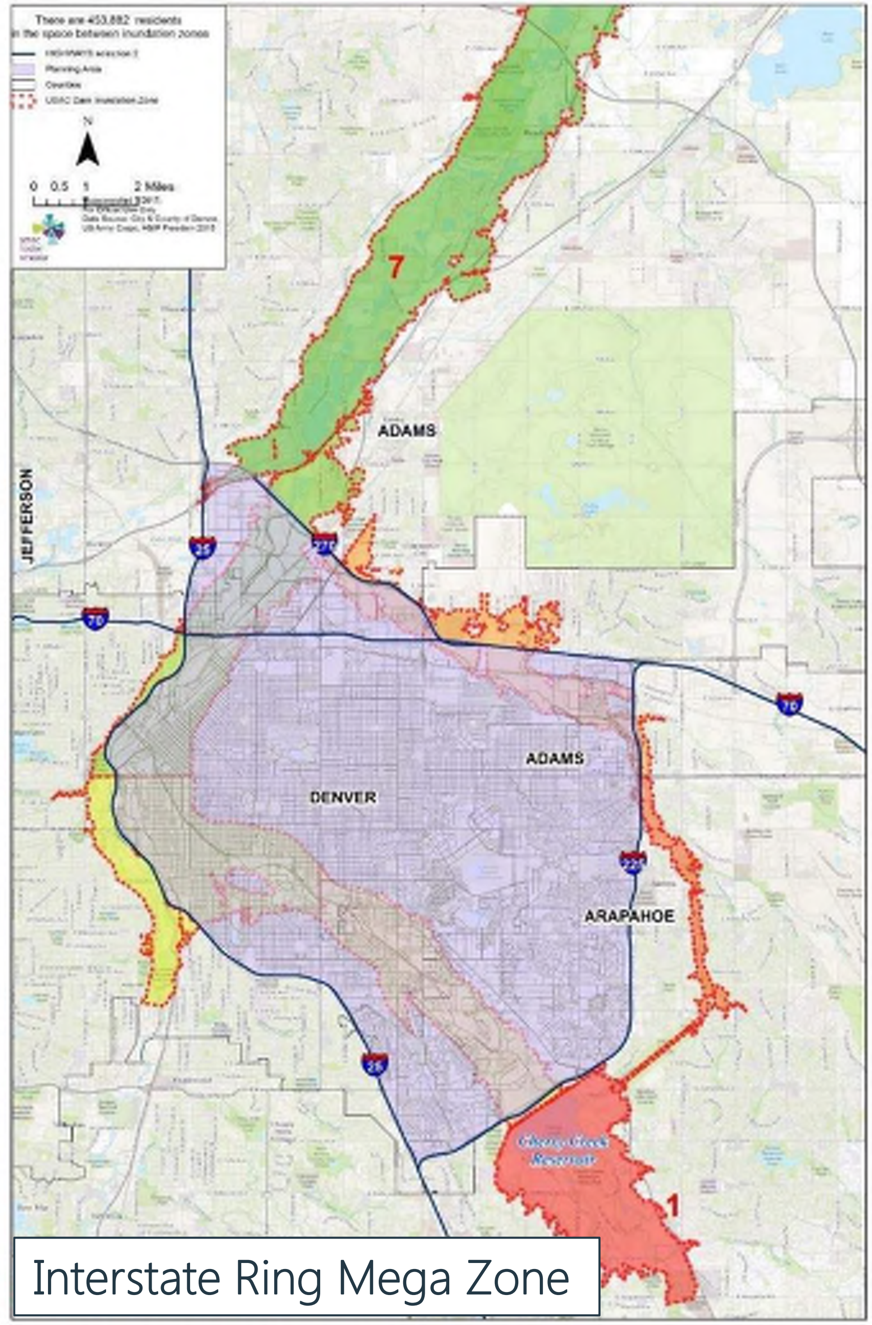
- Table 3: Evacuation Zones, Jurisdictions and Primary Transportation Options

Table 3: Evacuation Zones, Jurisdictions and Primary Transportation Options

Zone number and name	Boundaries/Description	Primary Jurisdictions Involved	Primary Transportation Options	Flood Arrival Time (hrs)
Zone 1 Reservoir pool	Reservoir pool area- areas adjacent to reservoir and State Park	Arapahoe, Aurora, Greenwood Village, Cherry Creek State Park	Motor vehicle	0-1
Zone 2a Spillway South	West Tollgate Creek to Colfax Blvd	Arapahoe, Aurora	Motor vehicle RTD - bus	0-1
Zone 2b Spillway North	West Tollgate Creek from Colfax Blvd, junction with Sand Creek to confluence of South Platte River	Aurora, Adams, Denver, Commerce City	Motor vehicle RTD - bus	1-2
Zone 3 Arapahoe-Glendale	Cherry Creek Dam to South Colorado Boulevard	Arapahoe, Denver, Glendale	Motor vehicle Foot RTD - bus	1-2
Zone 4 Denver South	South Colorado Boulevard to W Colfax Ave	Denver	Motor vehicle Foot RTD – bus and light rail	2-3
Zone 5 Denver Downtown	W Colfax Ave to I-70	Denver	Motor vehicle Foot RTD – bus and light rail, Amtrak	3-4
Zone 6 Commerce City	I-70 to I-76	Denver, Adams, Commerce City	Motor vehicle RTD - bus	4-5
Zone 7 Adams County	I-76 to the E 168th Avenue (Adams-Weld County line)	Adams, Brighton	Motor vehicle RTD - bus	5.5

Transportation Appendix

- Supporting maps and statistics
- Interstate Ring 'Mega Zone'
  - I 25
  - I 225
  - I 270



Interstate Ring Mega Zone

Evacuation Routes

- Regional Routes and Barricades
  - I 25
  - I 225
  - I 270
- Detailed maps with critical facilities for each zone for emergency managers
- Simple messages for the public that vary based on watch vs warning

Regional Evacuation Routes

Summary / Lessons Learned

Summary / Lessons Learned

- Consequence analysis spurred action and informed planning process
- Emergency managers want to plan for controlled release scenarios, not just dam failure
- Communities want autonomy but recognize the value of working together in a common framework
- Coordination and cross referencing existing jurisdictional plans and procedures key in a multi-jurisdictional effort.
- Drawing the line between evacuation of dangerous areas versus isolated areas
- Overall scope of regional mass evacuation would require additional planning e.g. regional mass care, regional mass evacuation
- Continuity of operations would be challenging due to widespread impacts

Acknowledgements

Acknowledgements

Thanks to everyone that contributed to this effort!

- Arapahoe County
- Denver City and County
- Aurora
- Adams County
- US Army Corps of Engineers
- Working group and Evacuation Planning Team members
- Wood project team

Questions?

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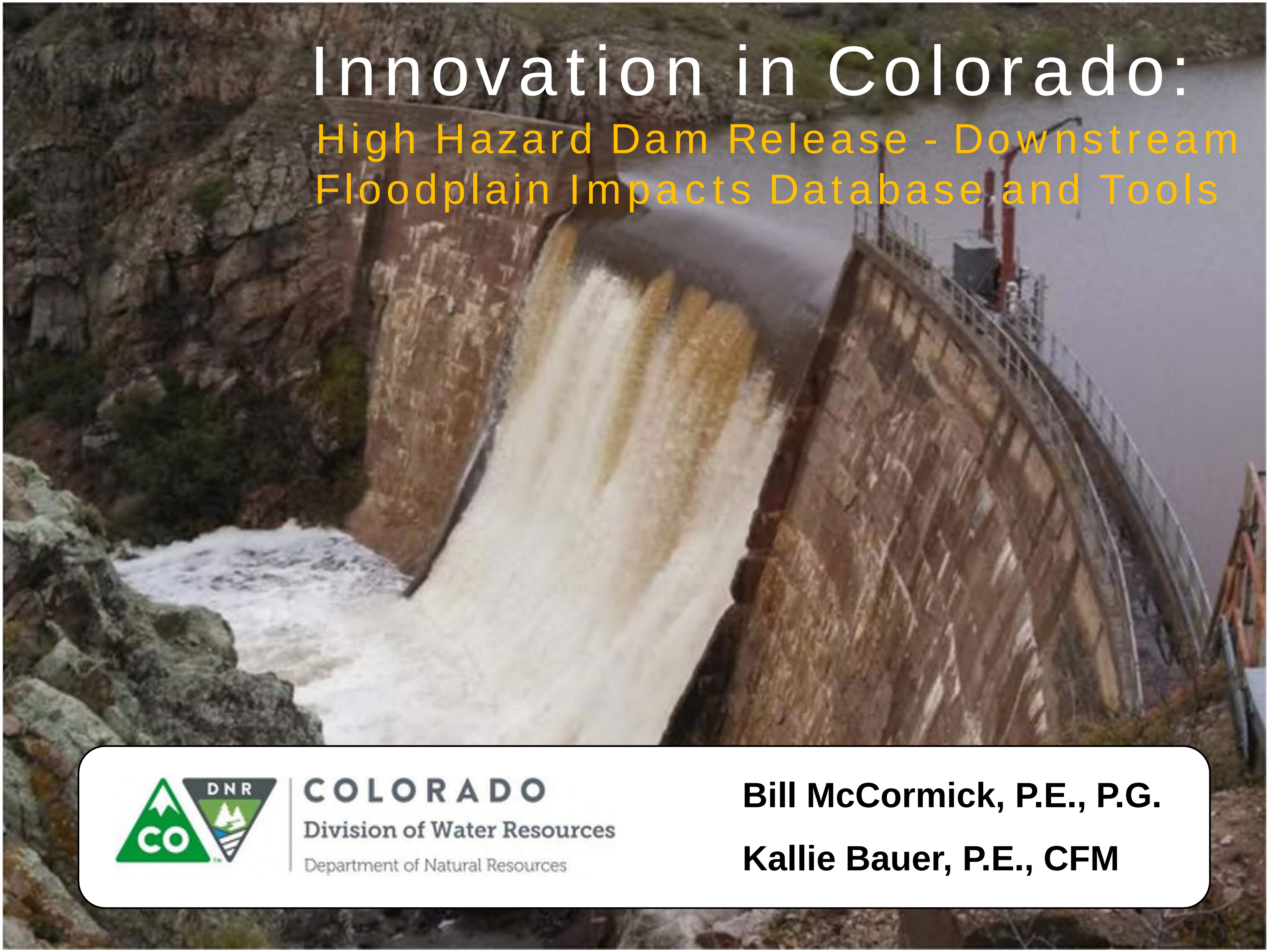
Innovation in Colorado:

High Hazard Dam Release - Downstream Floodplain Impacts Database and Tools



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Bill McCormick, P.E., P.G.

Kallie Bauer, P.E., CFM

Outline

- Why we did this project
- How we did this project
- How the project turned out
- What we Learned
- Where we go from here

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Colorado Dam Safety Mission

- Prevent loss of life and property damage from dam failures
- Maximize *Safe* storage of water
- Technical liaison between dam owners and emergency and floodplain managers

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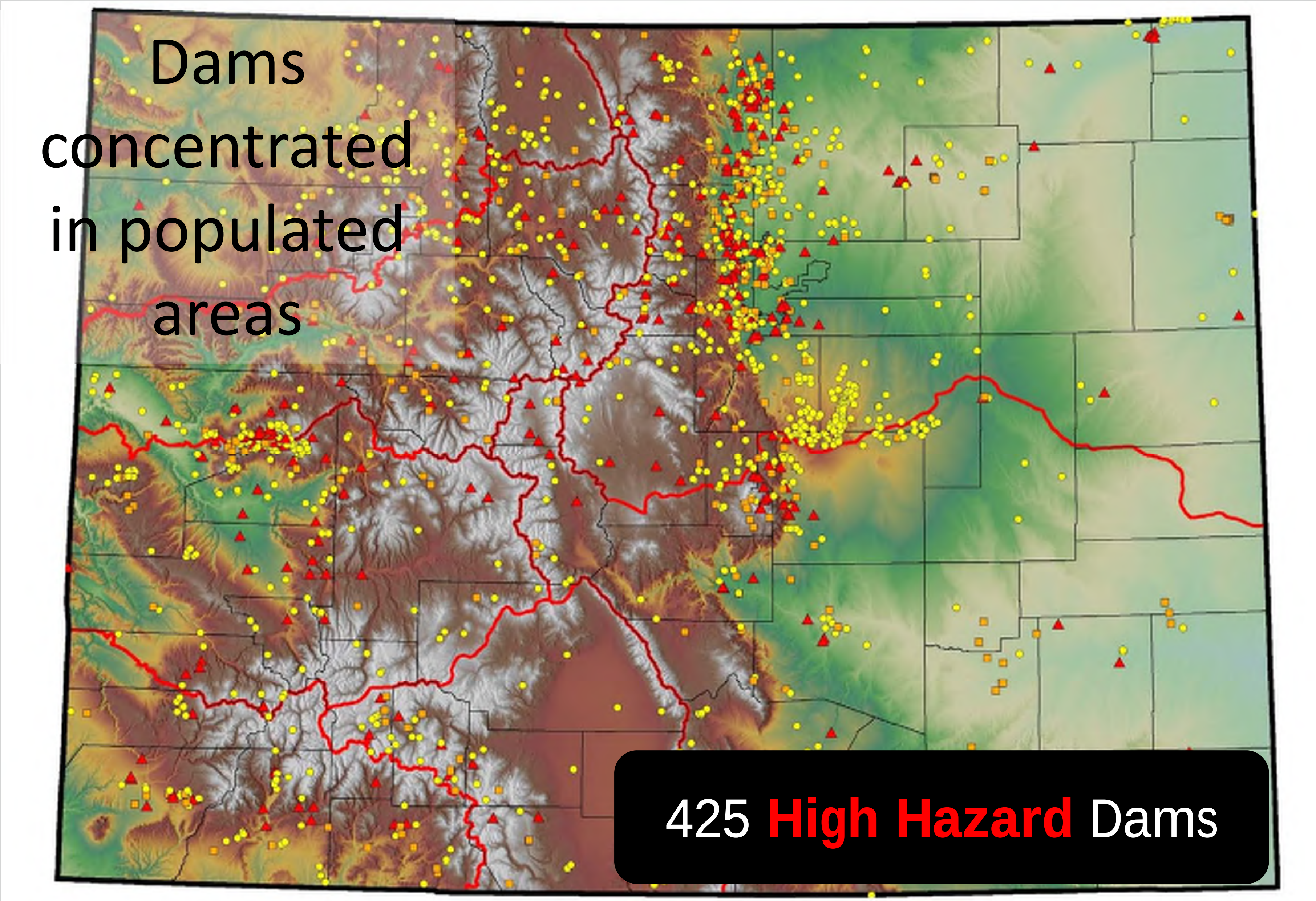
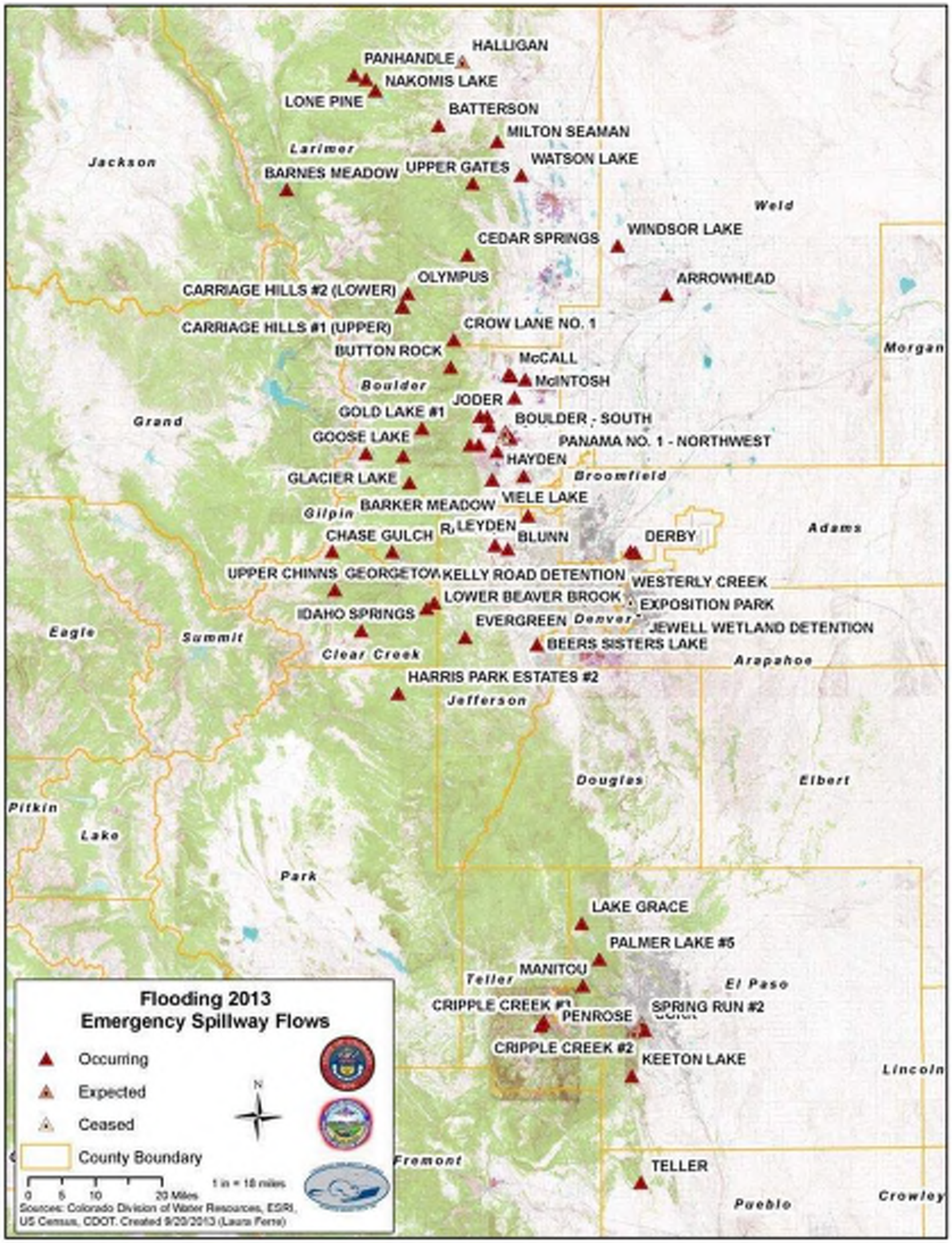
1750ish Program Dams





Spillway Flows 9/20/13

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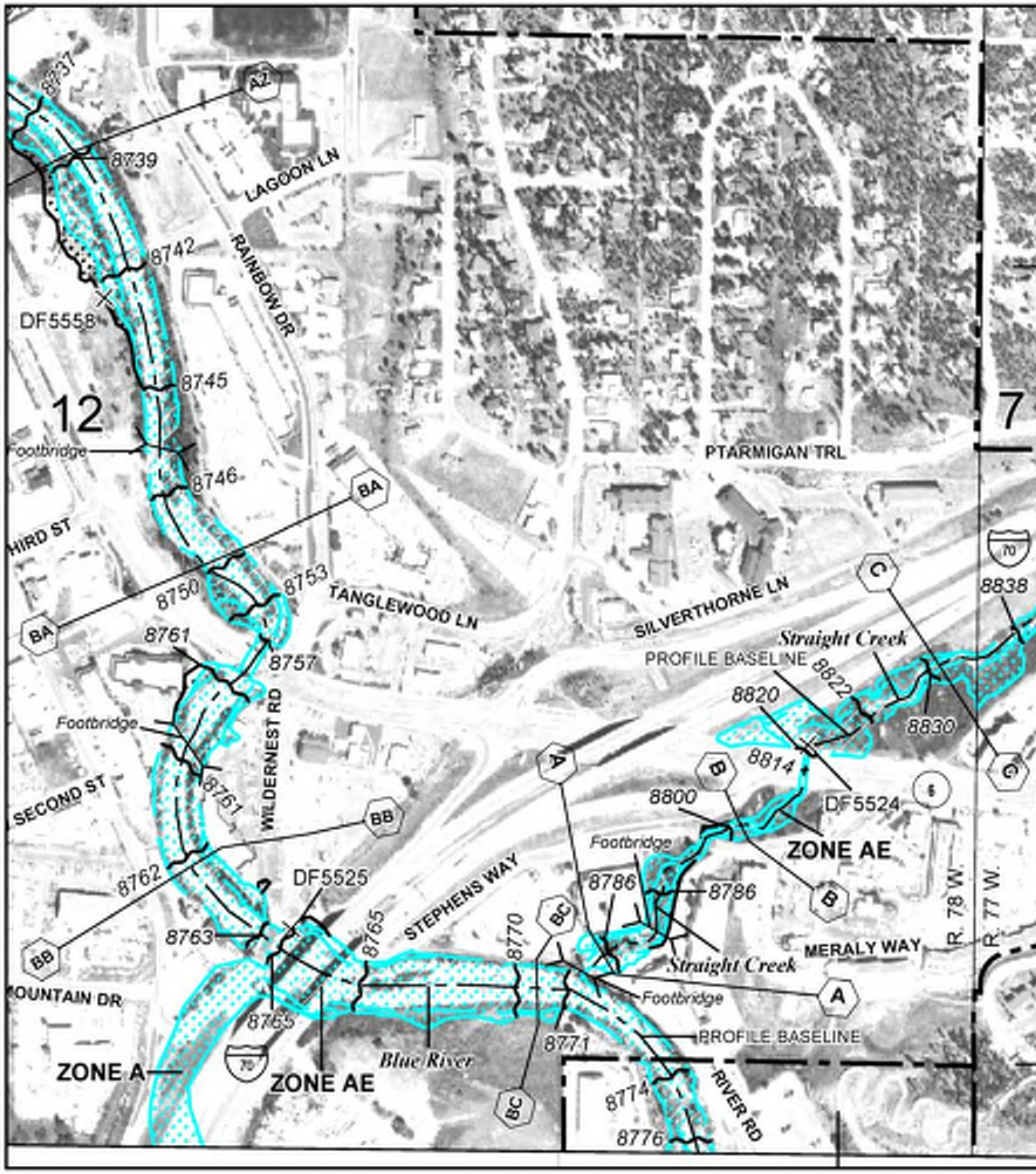
Outlet Releases - Dillon Dam



MAP SCALE 1" = 500'

250 0 500 1000 FEET

METERS

NFIP

PANEL 0239E

FIRM

FLOOD INSURANCE RATE MAP

SUMMIT COUNTY, COLORADO AND INCORPORATED AREAS

PANEL 239 OF 575

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
DILLON, TOWN OF	080237	0239	E
SILVERTHORNE, TOWN OF	080201	0239	E
SUMMIT COUNTY, Unincorporated Areas	080290	0239	E

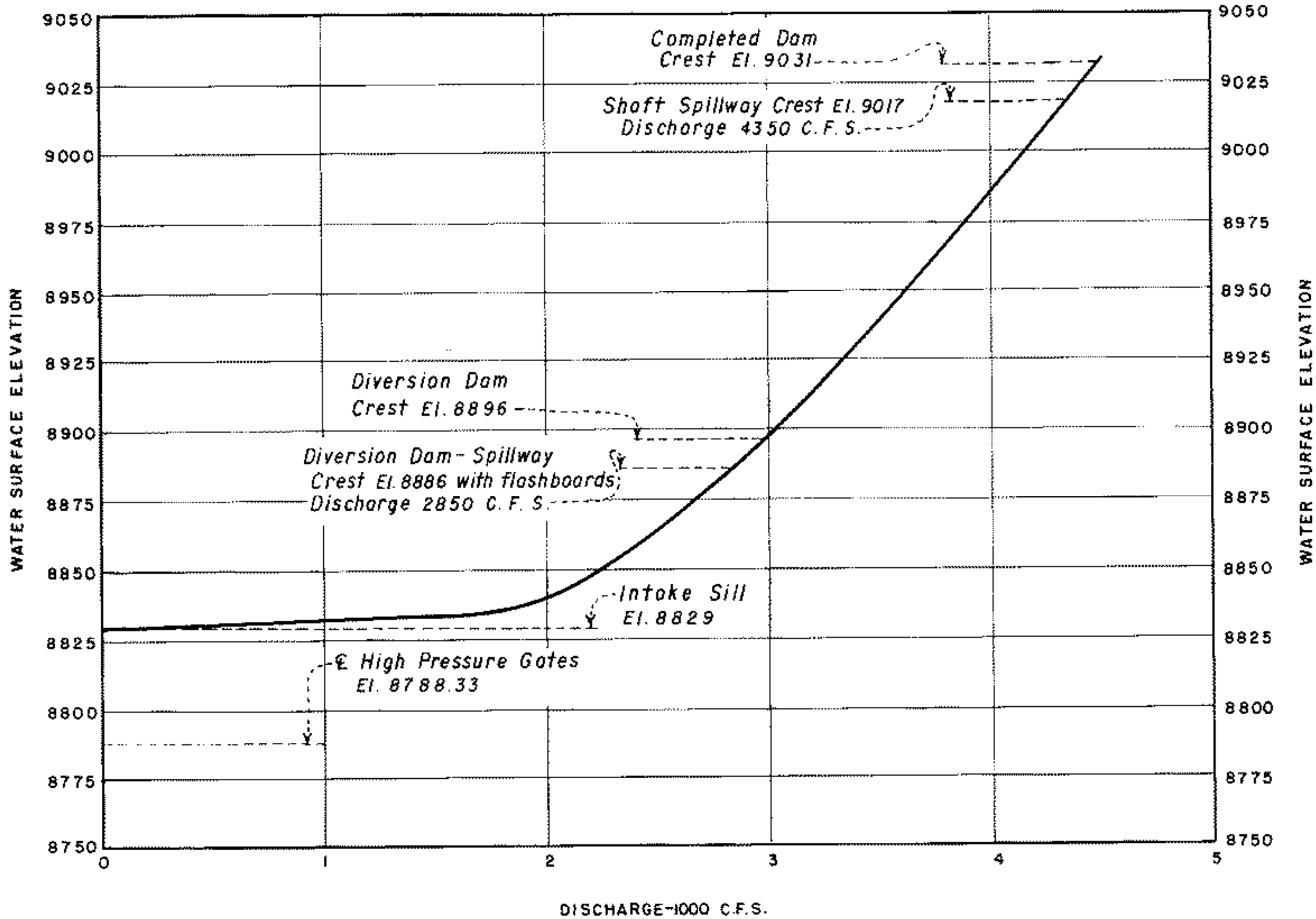
NATIONAL FLOOD INSURANCE PROGRAM

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER 08117C0239E

EFFECTIVE DATE NOVEMBER 16, 2011

Federal Emergency Management Agency



DISCHARGE CURVE-OUTLET WORKS

2 - 4'-0" x 5'-0" HIGH PRESSURE GATES

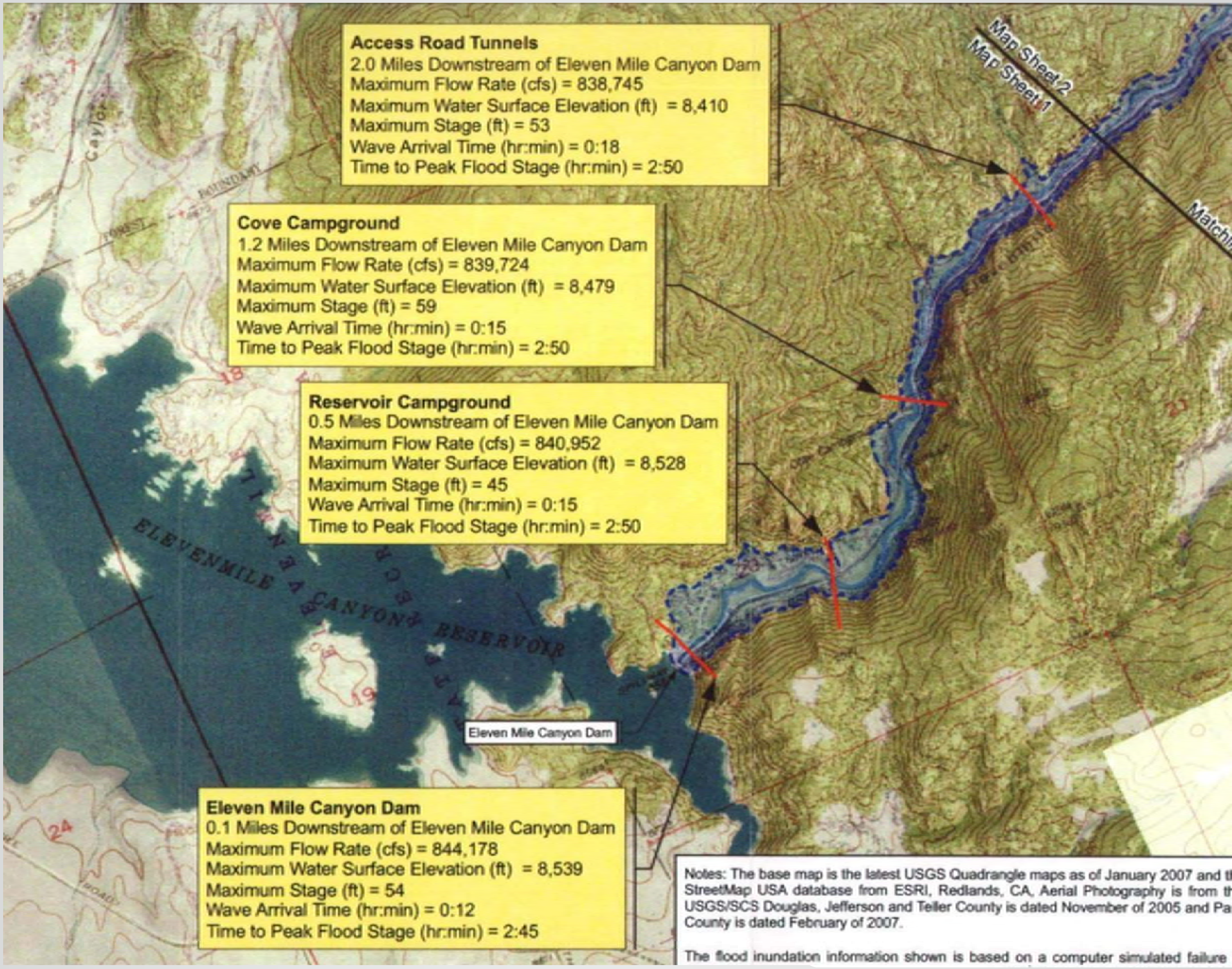
1 - 2'-3" x 2'-3" HIGH PRESSURE GATE

Outlet Releases – EAP Activations 2015 - Eleven Mile Canyon Dam

Outlet channel

Spillway channel

Eleven Mile Inundation Map



esources
urces

Project to highlight the Gap?

- $95,000 project, Funded by NDSP States Grants ($45K) and Colorado Water Conservation Board grant ($50k)
- Created a High Hazard Dam Release - Downstream Floodplain Impacts Database and Ranking Tool
- "Controlled Releases" only
- Safe Channel Capacity Comparisons
- Promote and share information, database and tools with floodplain and emergency managers

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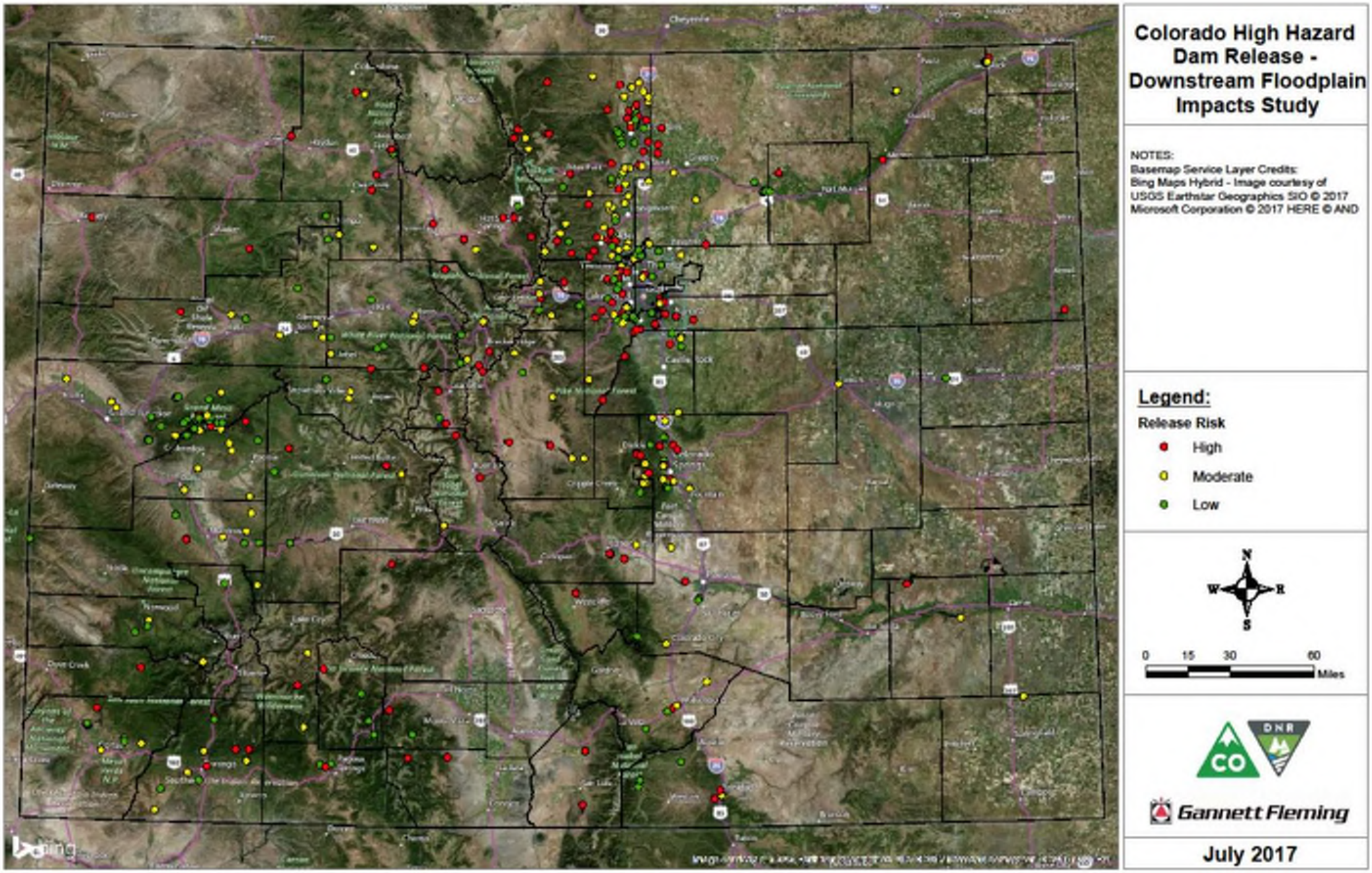
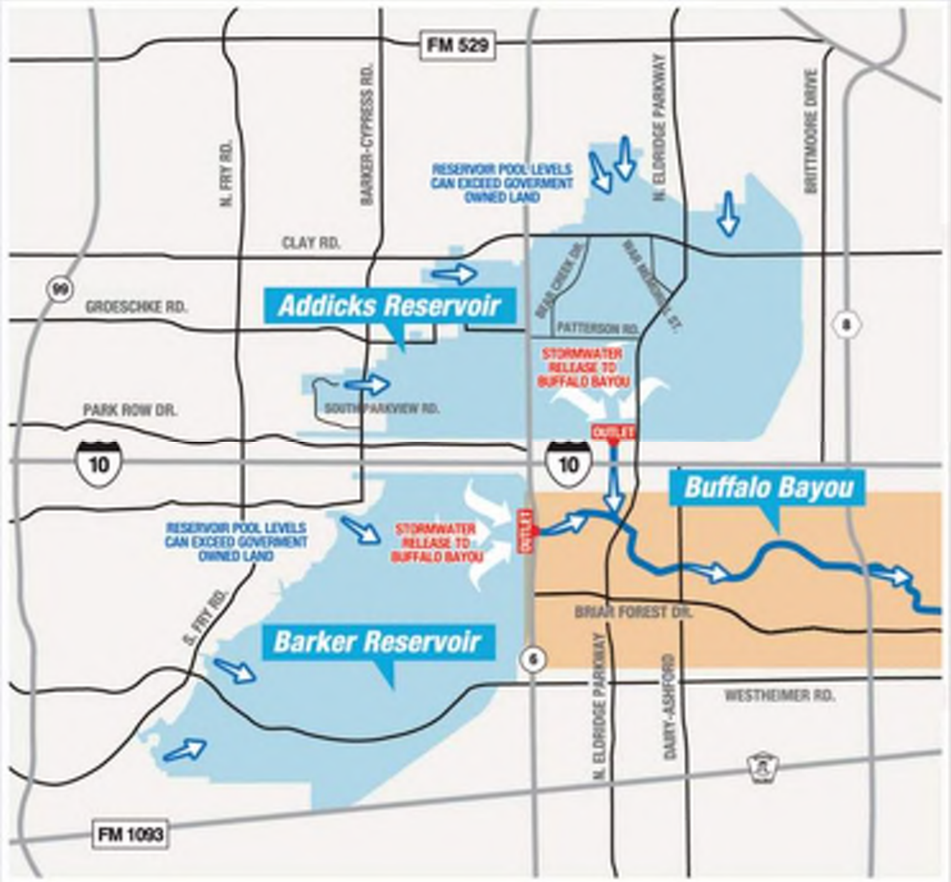
Ranked Dams - Statewide



Aug 2017 - Barker and Addicks Dams

- Flood control dams built in 1940
- Water surface in reservoir rising at ½ ft per hour
- Record high elevation
- Outlets opened, releasing 4,000 cfs each



Neighborhoods around Barker and Addicks Reservoir

What Did We Learn?

- Colorado in 2013 and 2015, Texas 2017 show dams operating as designed but still cause dangerous flooding downstream

- Dam Emergency Action Plans have maps for dam failure inundation – of no use in operational release flooding scenarios

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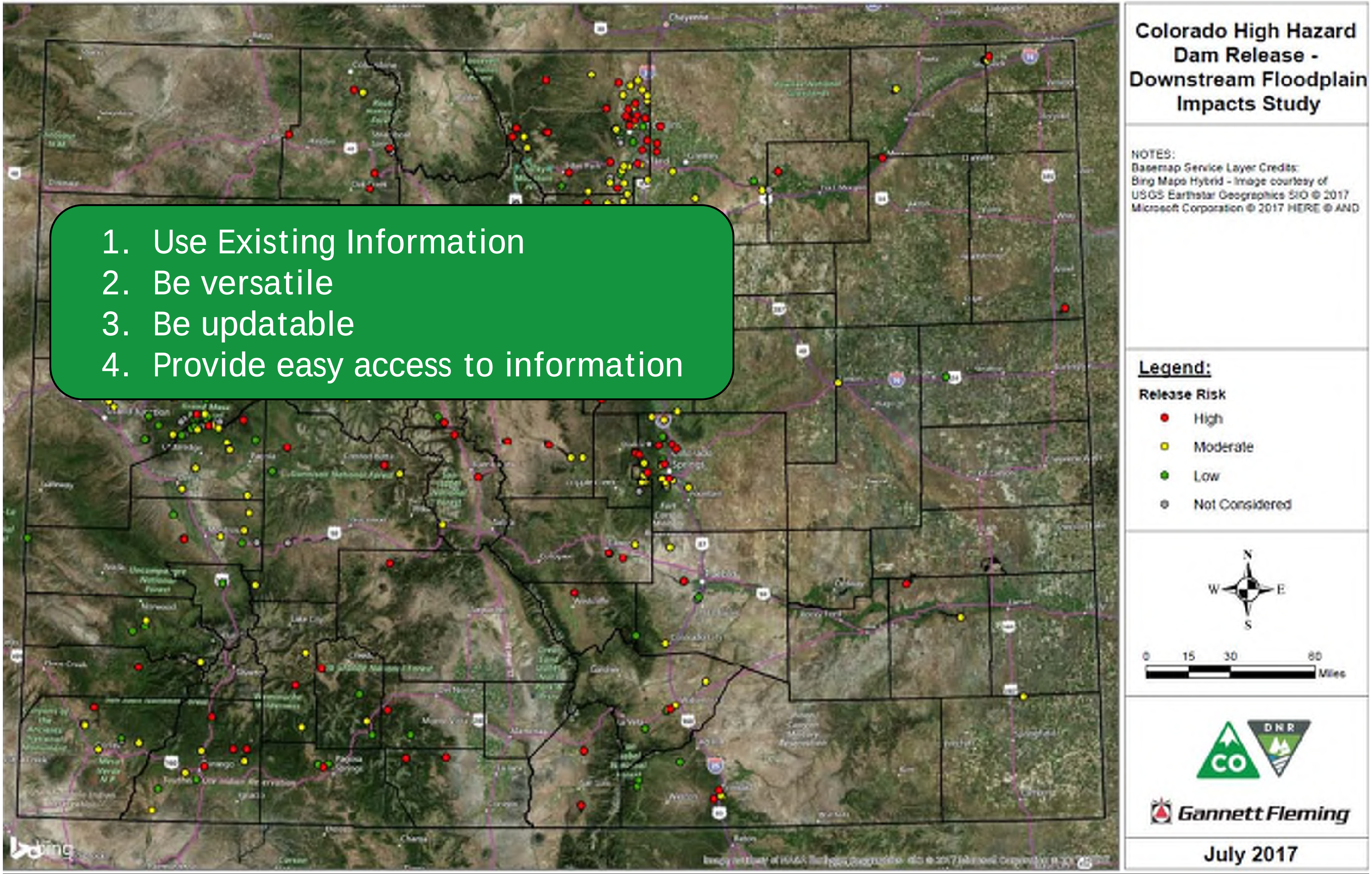
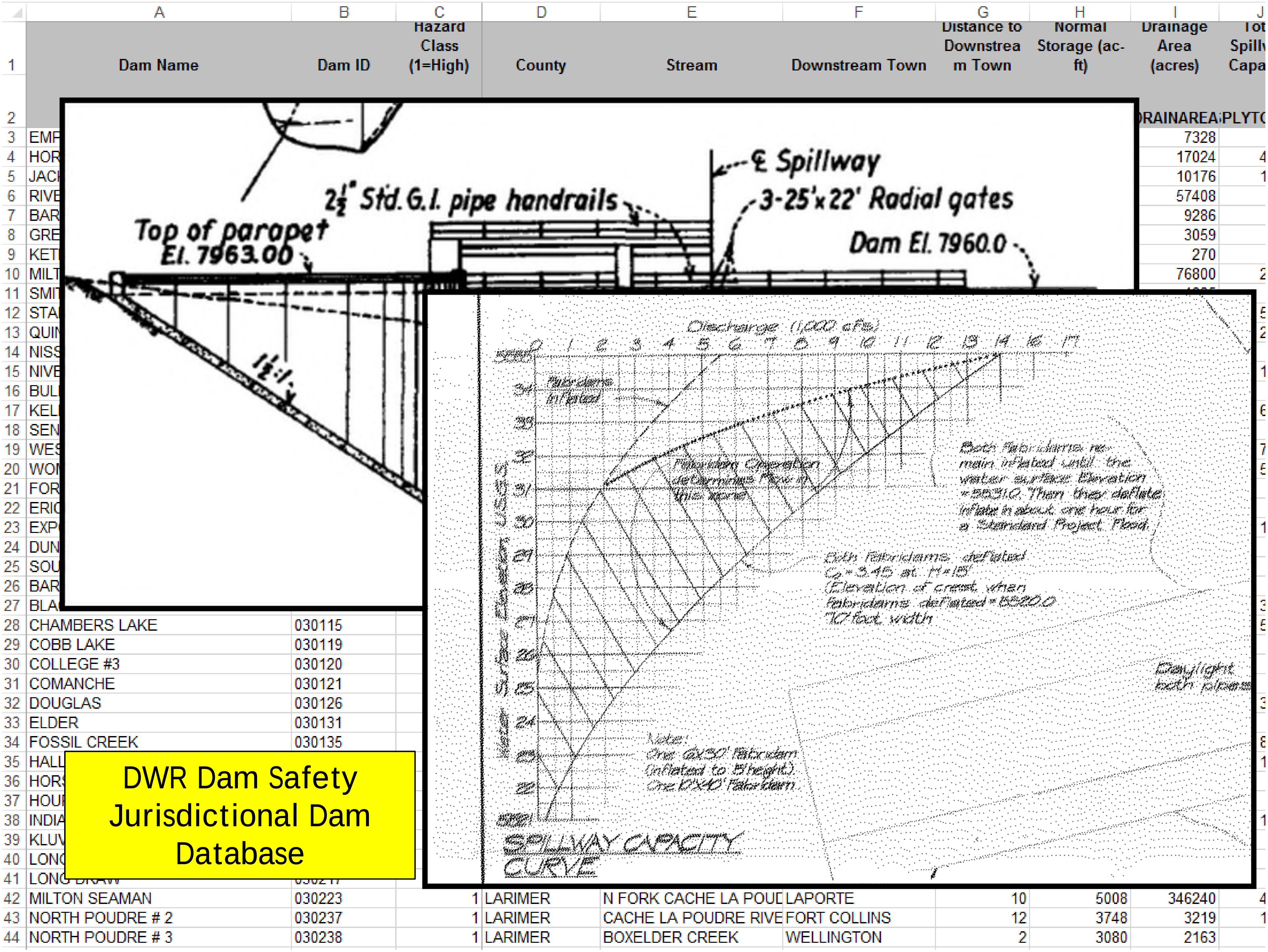
Why should Floodplain Managers care about Dams

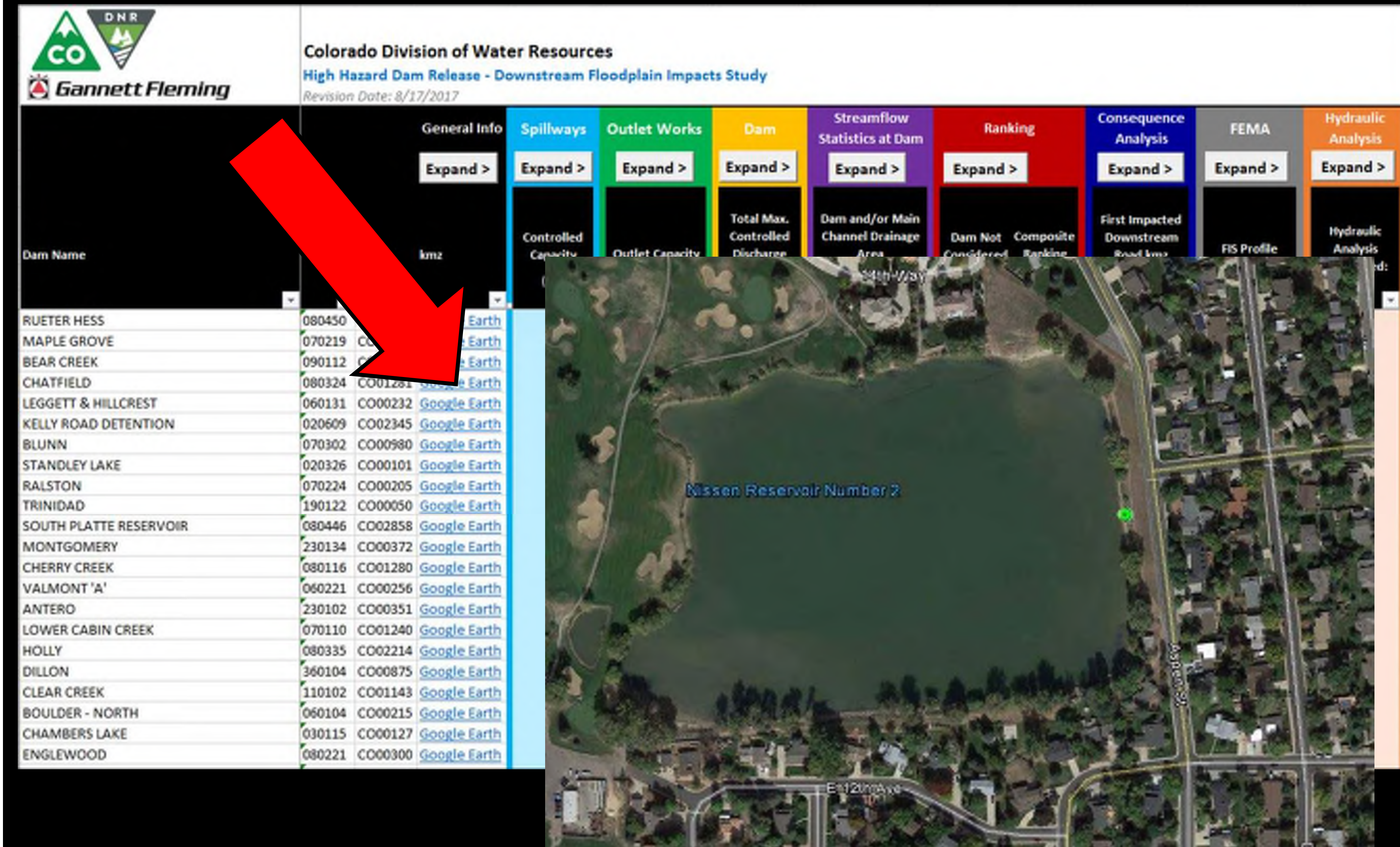
- Not all dams provide flood control
- FEMA maps don’t show spillway flows or outlet releases
- Dam releases impact floodplain management

1. Use Existing Information
2. Be versatile
3. Be updatable
4. Provide easy access to information




DWR Dam Safety Jurisdictional Dam Database
Dam Name
Dam ID
Hazard Class (1=High)
County
Stream
Downstream Town
Distance to Downstream Town
Normal Storage (ac-ft)
Drainage Area (acres)
CHAMBERS LAKE 030115
COBB LAKE 030119
COLLEGE #3 030120
COMANCHE 030121
DOUGLAS 030126
ELDER 030131
FOSSIL CREEK 030135
MILTON SEAMAN 030223 1 LARIMER N FORK CACHE LA POUD LAPORTE 10 5008 346240
NORTH POUDRE # 2 030237 1 LARIMER CACHE LA POUDRE RIVE FORT COLLINS 12 3748 3219
NORTH POUDRE # 3 030238 1 LARIMER BOXELDER CREEK WELLINGTON 2 3080 2163
℄ Spillway
2½" Std. G.I. pipe handrails
3-25'x22' Radial gates
Top of parapet El. 7963.00
Dam El. 7960.0
1½:1
Discharge (1,000 cfs)
SPILLWAY CAPACITY CURVE
Both Fabridams deflated
Fabridam Operation determines Flow in this zone

Colorado High Hazard Dams Release Database



CO High Hazard Dams Release Database – General Information

General Information

- Dam Name
- Dam ID
- NID ID
- Latitude
- Longitude
- County
- Stream
- CO Database Drainage Area

Spillways

- Controlled Capacity
- Total Capacity

Outlet Works

- Outlet Capacity
- Outlet Description

Dam

- Total Maximum Controlled Discharge
- Type
- Off Channel
- PAR
- Social Vulnerability
- Distance to Downstream Town
- Height
- Length
- Dam Safety Engineer
- Owner Type
- Owner

Streamflow Statistics at Dam

- Drainage Area
- Elevation
- Basin Slope
- EL7500
- Precip
- 16HR100YR
- PK2
- PK5
- PK10
- PK25
- PK50
- PK100
- PK200
- PK500

Links!
Sorting!
Views!

CO High Hazard Dams Release Database – Initial Ranking

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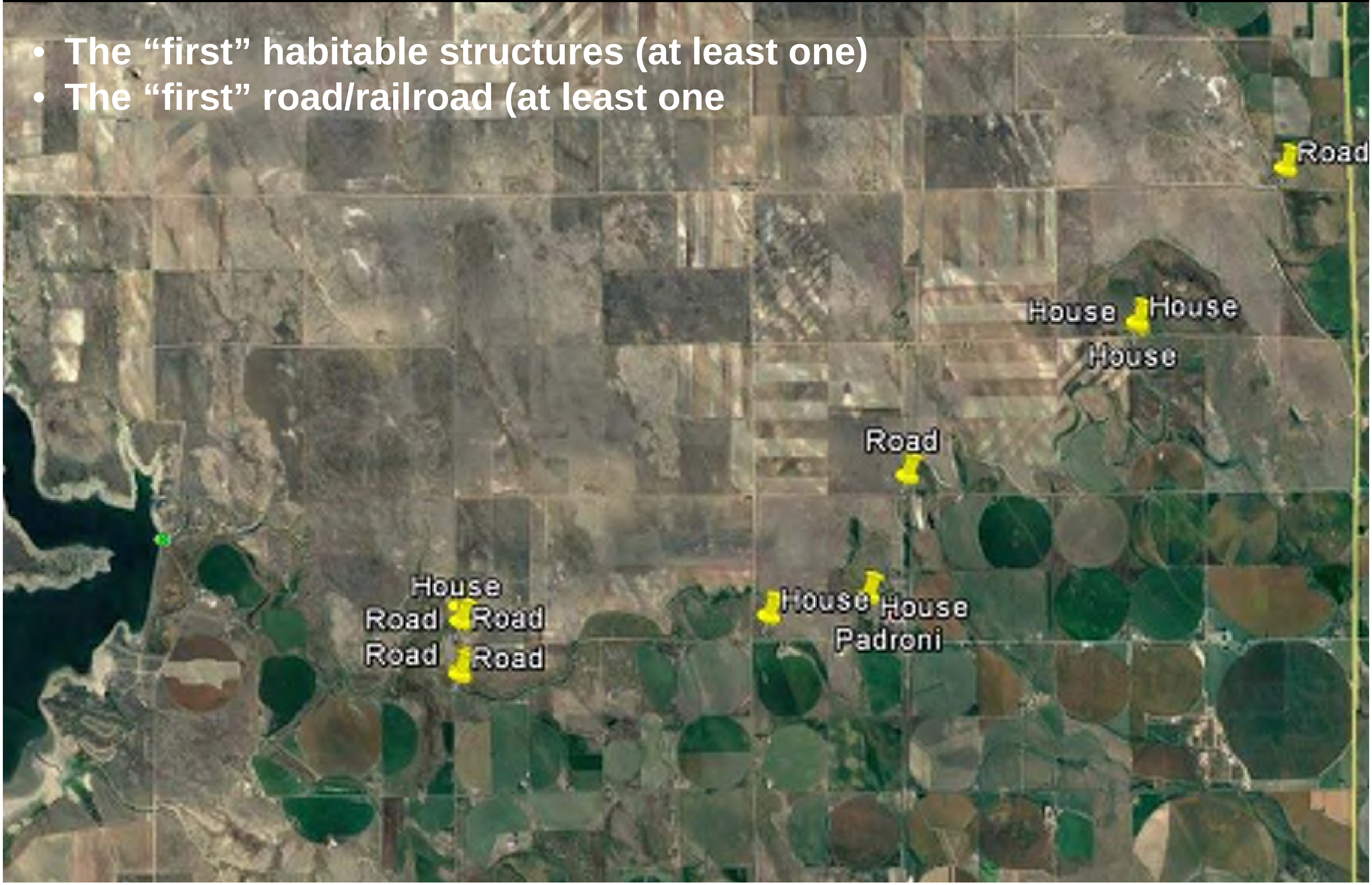
ts Study

Dam Name	Dam: Total Max. Controlled Discharge (cfs)	Streamflow Statistics at Dam: Dam and/or Main Channel Drainage Area (mi^2)	Dam Not Considered	Ranking 1 Drainage Area/Total Max. Controlled Discharge* Value	Ranking 1 Rank	Ranking 2 Q100/Total Max. Controlled Discharge* Value	Ranking 2 Rank	Ranking 3 Distance to Downstream Town** Value	Ranking 3 Rank	Ranking 4 Q100/Total Spillway Capacity Value	Ranking 4 Rank	Ranking 5 1/Total Max. Controlled Discharge Value	Ranking 5 Rank	Ranking 6 1/Total Spillway Capacity Value	Ranking 6 Rank	Total Score	Composite Ranking
Weight==>					1		1		1		1		1		1		
RUETER HESS	1242.7	10.52		0.00847	30	1.36799	52	0.1	1	0.06739	85	0.00080	38	0.00004	47	253	1
MAPLE GROVE	13467.0	10.40		0.00077	4	0.17599	3	0.1	1	0.17733	174	0.00007	3	0.00007	76	261	2
BEAR CREEK	2000.0	235.67		0.11784	142	1.56500	65	1.0	74	0.01385	13	0.00050	25	0.00000	3	322	3
CHATFIELD	8300.0	3020.77		0.36395	171	1.63855	67	0.1	1	0.07234	90	0.00012	5	0.00001	5	339	4
LEGGETT & HILLCREST	385.0	1.52		0.00394	15	1.06494	37	0.1	1	0.06072	75	0.00260	91	0.00015	122	341	5
KELLY ROAD DETENTION	690.0	10.65		0.01543	52	6.15942	127	0.1	1	0.07083	88	0.00145	61	0.00002	16	345	6
BLUNN	420.0	48.29		0.11497	140	2.47619	86	0.0	1	0.01625	17	0.00238	87	0.00002	15	346	7
STANDLEY LAKE	700.0	15.95		0.02279	69	5.55714	122	0.1	1	0.07125	89	0.00143	60	0.00002	20	361	8
RALSTON	650.0	46.41		0.07139	119	1.35692	51	1.0	74	0.02352	29	0.00154	62	0.00003	34	369	9
TRINIDAD	5500.0	671.86		0.12216	143	2.78182	96	1.0	74	0.03338	46	0.00018	10	0.00000	2	371	10
SOUTH PLATTE RESERVOIR	110.0	0.30		0.00276	10	2.48182	87	0.0	1	0.02093	26	0.00909	180	0.00008	78	382	11
MONTGOMERY	1243.0	7.84		0.00631	24	0.25744	8	5.0	174	0.04430	57	0.00080	37	0.00014	119	419	12
CHERRY CREEK	8100.0	385.67		0.04761	104	1.80247	71	0.1	1	0.25933	219	0.00012	6	0.00002	19	420	13
VALMONT 'A'	210.0	1.52		0.00721	27	1.95238	75	0.1	1	0.06072	75	0.00476	121	0.00015	122	421	14
ANTERO	1800.0	190.91		0.10606	138	0.82778	27	5.0	174	0.03311	45	0.00056	27	0.00002	26	437	15
LOWER CABIN CREEK	549.0	13.65		0.02486	75	0.57013	18	3.0	142	0.02833	36	0.00182	73	0.00009	94	438	16
HOLLY	195.0	2.05		0.01050	43	5.69231	124	0.1	1	0.07923	97	0.00513	126	0.00007	75	466	17
DILLON	4400.0	334.09		0.07593	122	0.86591	28	0.1	1	0.32414	236	0.00023	12	0.00009	89	488	18
CLEAR CREEK	2145.0	68.77		0.03206	88	0.58275	19	15.0	294	0.02976	39	0.00047	23	0.00002	29	492	19
BOULDER - NORTH	940.0	11.60		0.01234	45	4.85106	114	1.0	74	0.17882	175	0.00106	47	0.00004	45	500	20
CHAMBERS LAKE	1700.0	31.93		0.01878	56	0.67647	21	43.0	357	0.02114	27	0.00059	28	0.00002	21	510	21


Ranking Dams
What makes a "risky" dam?
• Ability to release "large" discharges relative to drainage area
• Large spillways
• Proximity to population
Ranking Relationships
• Drainage area/Total Maximum Controlled Discharge
• Q100/Total Maximum Controlled Discharge
• Distance to Downstream Town
• Q100/Total Spillway Capacity
• 1/Total Maximum Controlled Discharge
• 1/Total Spillway Capacity

Downstream Consequences

- The “first” habitable structures (at least one)
- The “first” road/railroad (at least one



CO High Hazard Dams Release Database
Potential Downstream Impacts Ranking

Gannett Fleming

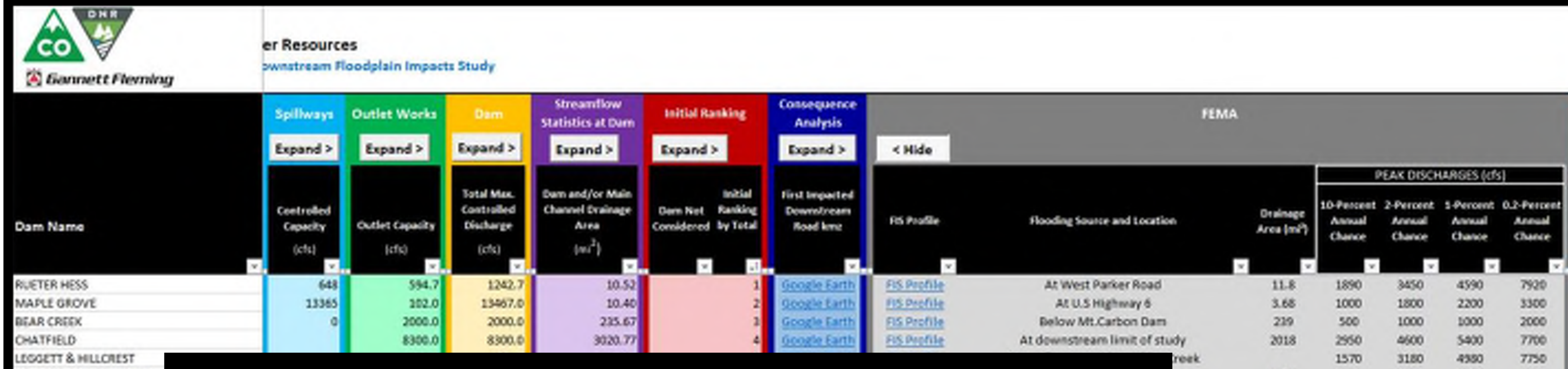
Colorado Division of Water Resources

High Hazard Dam Release - Downstream Floodplain Impacts Study

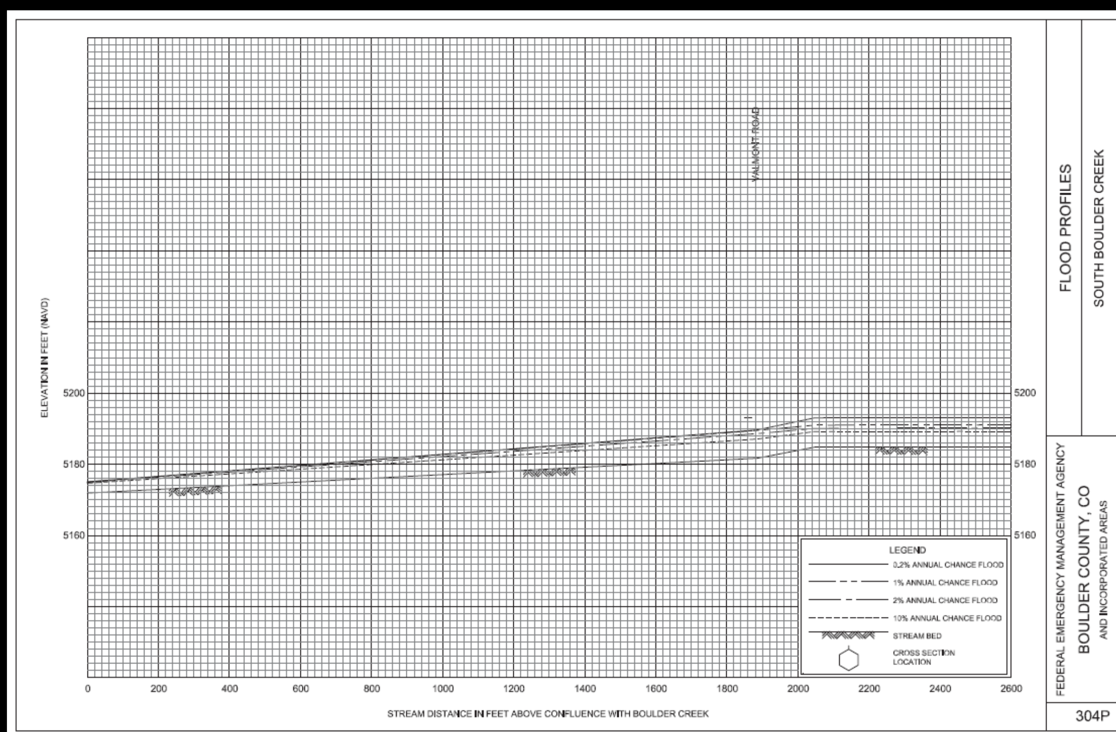
Revision Date: 7/17/2017

			General Info Expand >	Spillways Expand >	Outlet Works Expand >	Dam Expand >	Streamflow Statistics at Dam Expand >	Initial Ranking Expand >		Consequence Analysis < Hide			
Dam Name	Dam ID	NID ID	kmz	Controlled Capacity (cfs)	Outlet Capacity (cfs)	Total Max. Controlled Discharge (cfs)	Dam and/or Main Channel Drainage Area (mi^2)	Dam Not Considered	Initial Ranking by Total	First Impacted Downstream Road kmz	First Impacted Downstream Road Drainage Area (mi^2)	First Impacted Downstream Structure kmz	First Impacted Downstream Structure Drainage Area (mi^2)
RUETER HESS	080450	CO02949	Google Earth	648	594.7	1242.7	10.52		1	Google Earth	10.78	Google Earth	11.18
MAPLE GROVE	070219	CO00203	Google Earth	13365	102.0	13467.0	10.40		2	Google Earth	10.87	Google Earth	10.86
BEAR CREEK	090112	CO00004	Google Earth	0	2000.0	2000.0	235.67		3	Google Earth	255.00	Google Earth	238.51
CHATFIELD	080324	CO01281	Google Earth		8300.0	8300.0	3020.77		4	Google Earth	3100.00	Google Earth	3040.00
LEGGETT & HILLCREST	060131	CO00232	Google Earth		385.0	385.0	1.52		5	Google Earth	131.52	Google Earth	131.51
KELLY ROAD DETENTION	020609	CO02345	Google Earth		690.0	690.0	10.65		6	Google Earth	10.66	Google Earth	10.67
BLUNN	070302	CO00980	Google Earth		420.0	420.0	48.29		7	Google Earth	49.30	Google Earth	49.30
STANDLEY LAKE	020326	CO00101	Google Earth		700.0	700.0	15.95		8	Google Earth	18.45	Google Earth	17.05
RALSTON	070224	CO00205	Google Earth		650.0	650.0	46.41		9	Google Earth	47.04	N/A	N/A
TRINIDAD	190122	CO00050	Google Earth		5500.0	5500.0	671.86		10	Google Earth	749.38	Google Earth	749.48
SOUTH PLATTE RESERVOIR	080446	CO02858	Google Earth	0	110.0	110.0	0.30		11	Google Earth	3.12	N/A	N/A
MONTGOMERY	230134	CO00372	Google Earth		1243.0	1243.0	7.84		12	Google Earth	9.44	Google Earth	31.67
CHERRY CREEK	080116	CO01280	Google Earth		8100.0	8100.0	385.67		13	Google Earth	410.00	Google Earth	410.00
VALMONT 'A'	060221	CO00256	Google Earth		210.0	210.0	1.52		14	Google Earth	1.56	Google Earth	1.53
ANTERO	230102	CO00351	Google Earth		1800.0	1800.0	190.91		15	Google Earth	215.57	Google Earth	400.37
LOWER CABIN CREEK	070110	CO01240	Google Earth		549.0	549.0	13.65		16	Google Earth	15.19	Google Earth	29.65
HOLLY	080335	CO02214	Google Earth		195.0	195.0	2.05		17	Google Earth	2.07	Google Earth	2.07
DILLON	360104	CO00875	Google Earth		4400.0	4400.0	334.09		18	Google Earth		Google Earth	
CLEAR CREEK	110102	CO01143	Google Earth	1500	645.0	2145.0	68.77		19	Google Earth	549.05	Google Earth	553.06
BOULDER - NORTH	060104	CO00215	Google Earth		940.0	940.0	11.60		20	Google Earth	26.60	Google Earth	26.60
CHAMBERS LAKE	030115	CO00127	Google Earth		1700.0	1700.0	31.93		21	Google Earth	35.20	Google Earth	138.17
ENGLEWOOD	080221	CO00300	Google Earth		210.0	210.0	9.39		22	Google Earth	9.71	Google Earth	9.68
LEYDEN	070209	CO01216	Google Earth		193.0	193.0	8.87		23	Google Earth	9.80	Google Earth	9.80
TROUT CREEK	110233	CO02813	Google Earth		304.0	304.0	60.84		24	Google Earth	60.95	Google Earth	62.40
EXPOSITION PARK	020643	CO02816	Google Earth		109.0	109.0	5.00		25	Google Earth		Google Earth	
GROSS	060211	CO00247	Google Earth		1385.0	1385.0	92.96		26	Google Earth	93.35	Google Earth	95.75

CO High Hazard Dams Release Database – FEMA



Dam Name	Controlled Capacity (cfs)	Outlet Capacity (cfs)	Total Max. Controlled Discharge (cfs)	Dam and/or Main Channel Drainage Area (mi^2)	Dam Not Considered	Initial Ranking by Total	First Impacted Downstream Road kmz	FIS Profile	Flooding Source and Location	Drainage Area (mi^2)	10-Percent Annual Chance	2-Percent Annual Chance	1-Percent Annual Chance	0.2-Percent Annual Chance
RUETER HESS	648	594.7	1242.7	10.52		1	Google Earth	FIS Profile	At West Parker Road	11.8	1890	3450	4590	7920
MAPLE GROVE	13365	102.0	13467.0	10.40		2	Google Earth	FIS Profile	At U.S Highway 6	3.68	1000	1800	2200	3300
BEAR CREEK	0	2000.0	2000.0	235.67		3	Google Earth	FIS Profile	Below Mt.Carbon Dam	239	500	1000	1000	2000
CHATFIELD		8300.0	8300.0	3020.77		4	Google Earth	FIS Profile	At downstream limit of study	2018	2950	4600	5400	7700
LEGGETT & HILLCREST									reek		1570	3180	4980	7750
KELLY ROAD DETENTION									enue	N/A	570	870	1000	1320
BLUNN									per CK.		4091	7932	9700	13200
STANDLEY LAKE										11.4	2370	4800	6460	13260
RALSTON									am					
TRINIDAD										N/A	N/A	N/A	N/A	N/A
SOUTH PLATTE RESERVOIR									h Creek		1300	2200	2700	4000
MONTGOMERY														
CHERRY CREEK									dy	340	10300	31000	51000	150000
VALMONT 'A'										N/A	N/A	N/A	N/A	N/A
ANTERO														
LOWER CABIN CREEK									eek	30.7	420	580	640	790
HOLLY										2.07	1183	2413	3076	4330
DILLON										N/A	N/A	N/A	N/A	N/A
CLEAR CREEK										N/A	N/A	N/A	N/A	N/A
BOULDER - NORTH									am					
CHAMBERS LAKE										N/A	N/A	N/A	N/A	N/A
ENGLEWOOD											3410	7000	9010	12140
LEYDEN										9	850	1150	2200	3400
TROUT CREEK										N/A	N/A	N/A	N/A	N/A
EXPOSITION PARK										10.8	2700	4200	5000	6800
GROSS											1310	2640	4340	7400

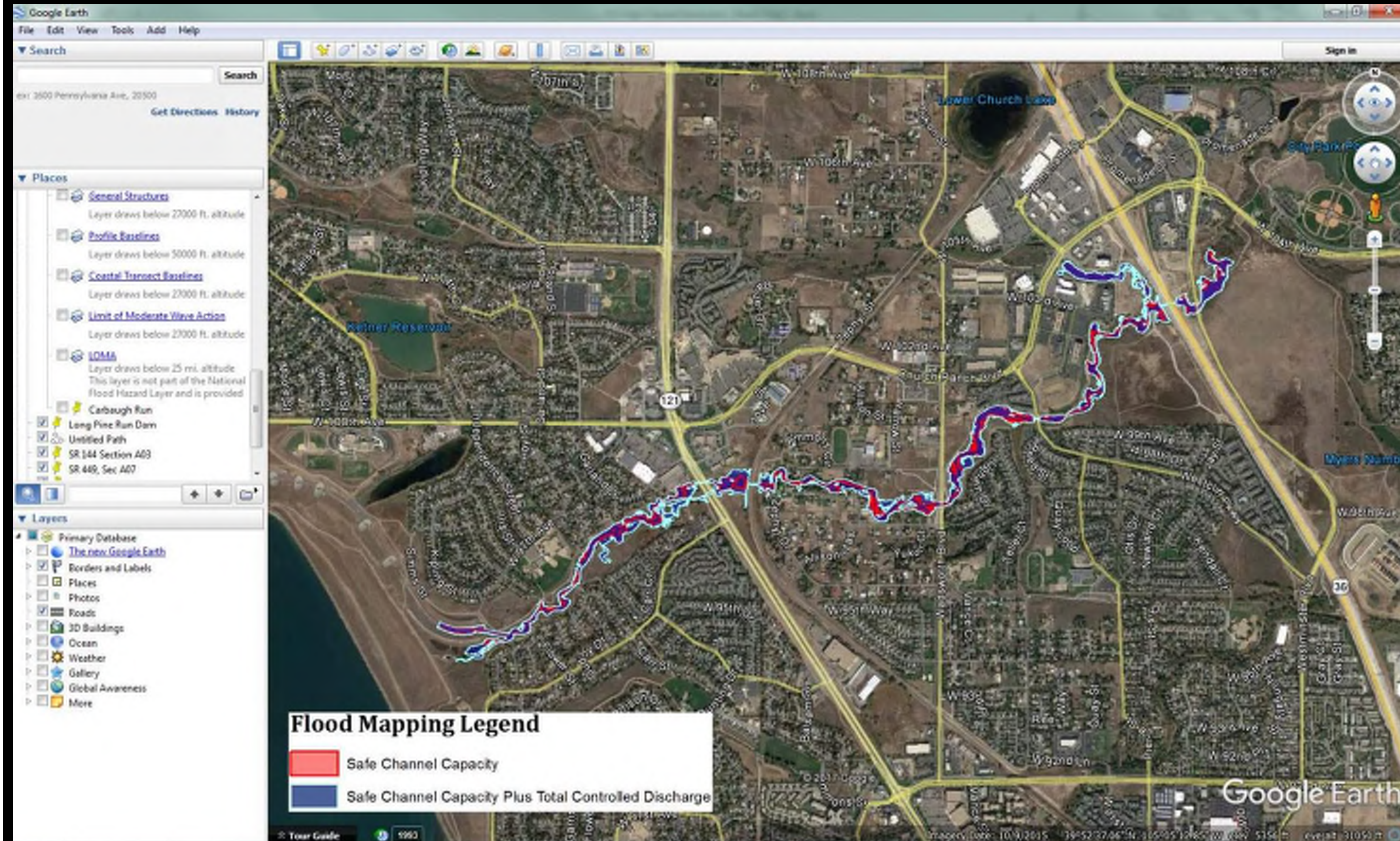


Hydraulic Analysis

More than 20 completed

Safe Channel Capacity – just before impacts

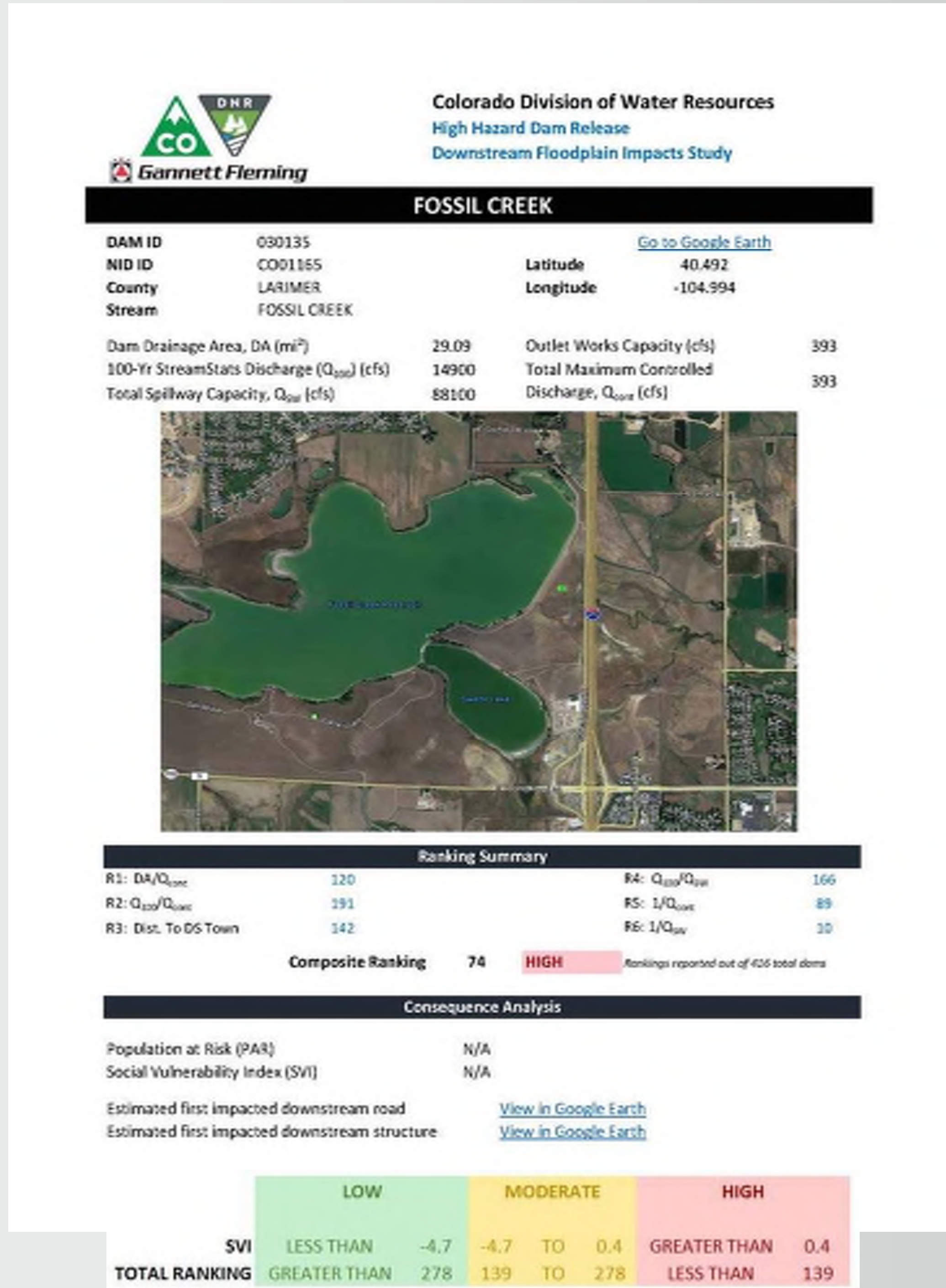
Hydraulic Analysis									
Hydraulic Analysis Performed by:	Safe Channel Capacity (cfs)	Safe Channel plus Total Max. Controlled Discharge (cfs)	Reference Flow 1 (cfs)	Reference Flow 1 Frequency and Source	Reference Flow 2 (cfs)	Reference Flow 2 Frequency and Source	Reference Flow 3 (cfs)	Reference Flow 3 Frequency and Source	Flood Mapping kmz
AJL		1242.7							
YW	350	13817.0	1000	10-year (FEMA	2200	100-year (FEMA)			
YW	1350	3350.0	730	2-yea					
YW	13700	22000.0	10300	50-ye					
WCH	2052	2742.0	668	25-ye					
YW	50	470.0	211	2-yea					
YW	380	1080.0	1130	10-ye					
YW	6040	6690.0	3052	50-ye					
		5500.0							
YW									
YW	4638	12738.0	2892	10-ye					
WCH		210.0							


Flood Mapping Legend
Safe Channel Capacity
Safe Channel Capacity Plus Total Controlled Discharge
Google Earth

Video Instruction

Harris Res. A
Fossil Creek Reservoir Natural Area
Kechter Rd
East Co Road 36
Frontage Rd
25
11
392
9
S Timberline Rd
E Co Rd 32
S Co Rd 5
S Co Rd 3
Google earth

Example – Fossil Creek Dam



Colorado Division of Water Resources
High Hazard Dam Release
Downstream Floodplain Impacts Study

Gannett Fleming

FOSSIL CREEK

DAM ID	030135		Go to Google Earth
NID ID	CO01165	**Latitude**	40.492
County	LARIMER	**Longitude**	-104.994
Stream	FOSSIL CREEK		

Dam Drainage Area, DA (mi^2)	29.09	Outlet Works Capacity (cfs)	393
100-Yr StreamStats Discharge (Q_{100}) (cfs)	14900	Total Maximum Controlled Discharge, Q_{cont} (cfs)	393
Total Spillway Capacity, Q_{SW} (cfs)	88100		

Ranking Summary

R1: DA/Q_{cont}	120	R4: Q_{100}/Q_{SW}	166
R2: Q_{100}/Q_{cont}	191	R5: $1/Q_{cont}$	89
R3: Dist. To DS Town	142	R6: $1/Q_{SW}$	10

Composite Ranking **74** HIGH *Rankings reported out of 416 total dams*

Consequence Analysis

Population at Risk (PAR)	N/A
Social Vulnerability Index (SVI)	N/A
Estimated first impacted downstream road	View in Google Earth
Estimated first impacted downstream structure	View in Google Earth

	LOW		MODERATE			HIGH	
SVI	LESS THAN	-4.7	-4.7	TO	0.4	GREATER THAN	0.4
TOTAL RANKING	GREATER THAN	278	139	TO	278	LESS THAN	139

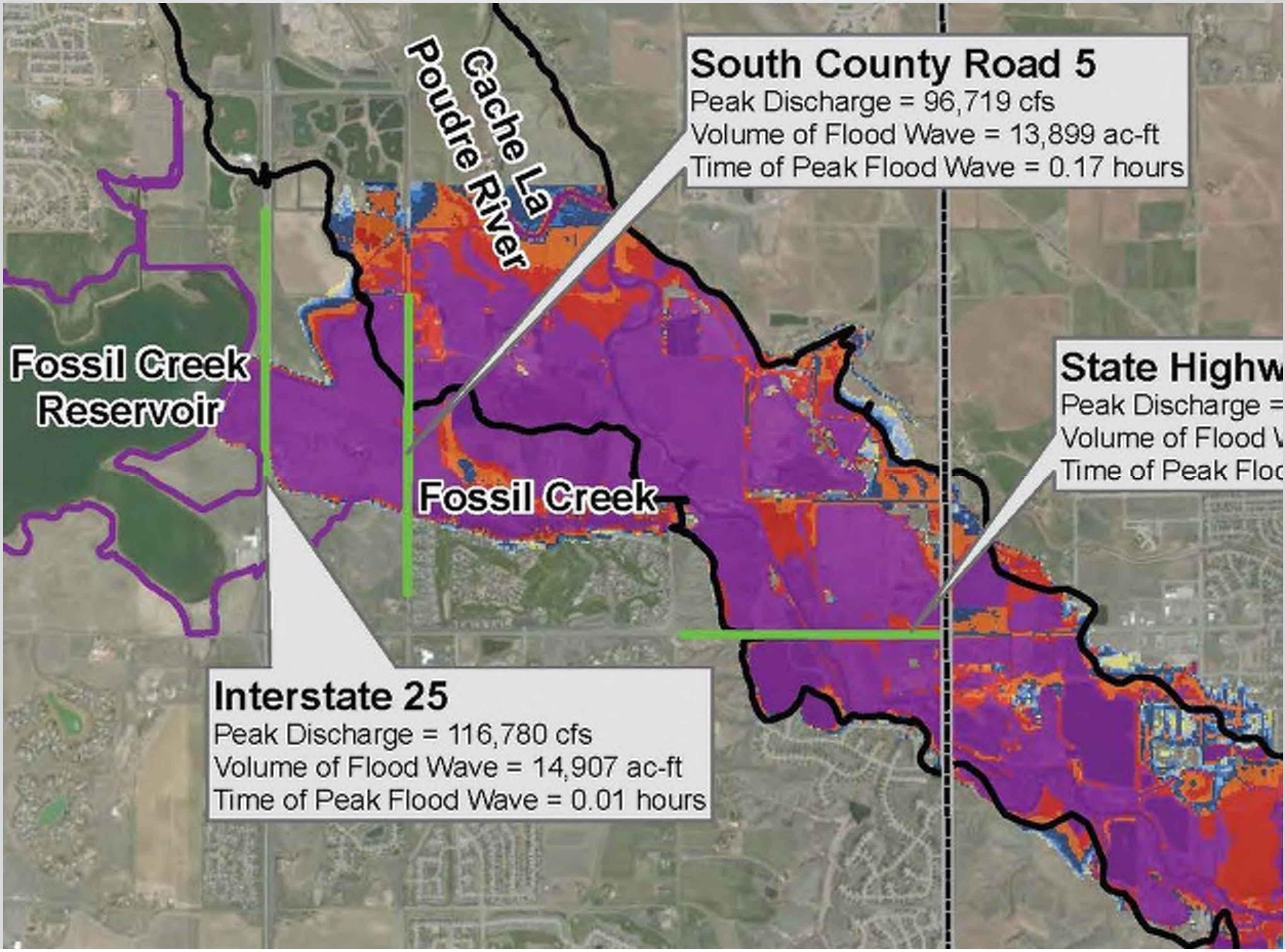
Hydraulic Analysis Summary

Dam Name	FOSSIL CREEK
Dam ID	030135
Safe Channel Capacity (cfs)	616
Safe Channel plus Total Max. Controlled Discharge Qcont (cfs)	1009
	Safe Channel Capacity Mapping in Google Earth
Reference Flow 1 (cfs)	516
Reference Flow 1 Frequency and Source	2-year (SS)
Reference Flow 2 (cfs)	3450
Reference Flow 2 Frequency and Source	10-year (SS)

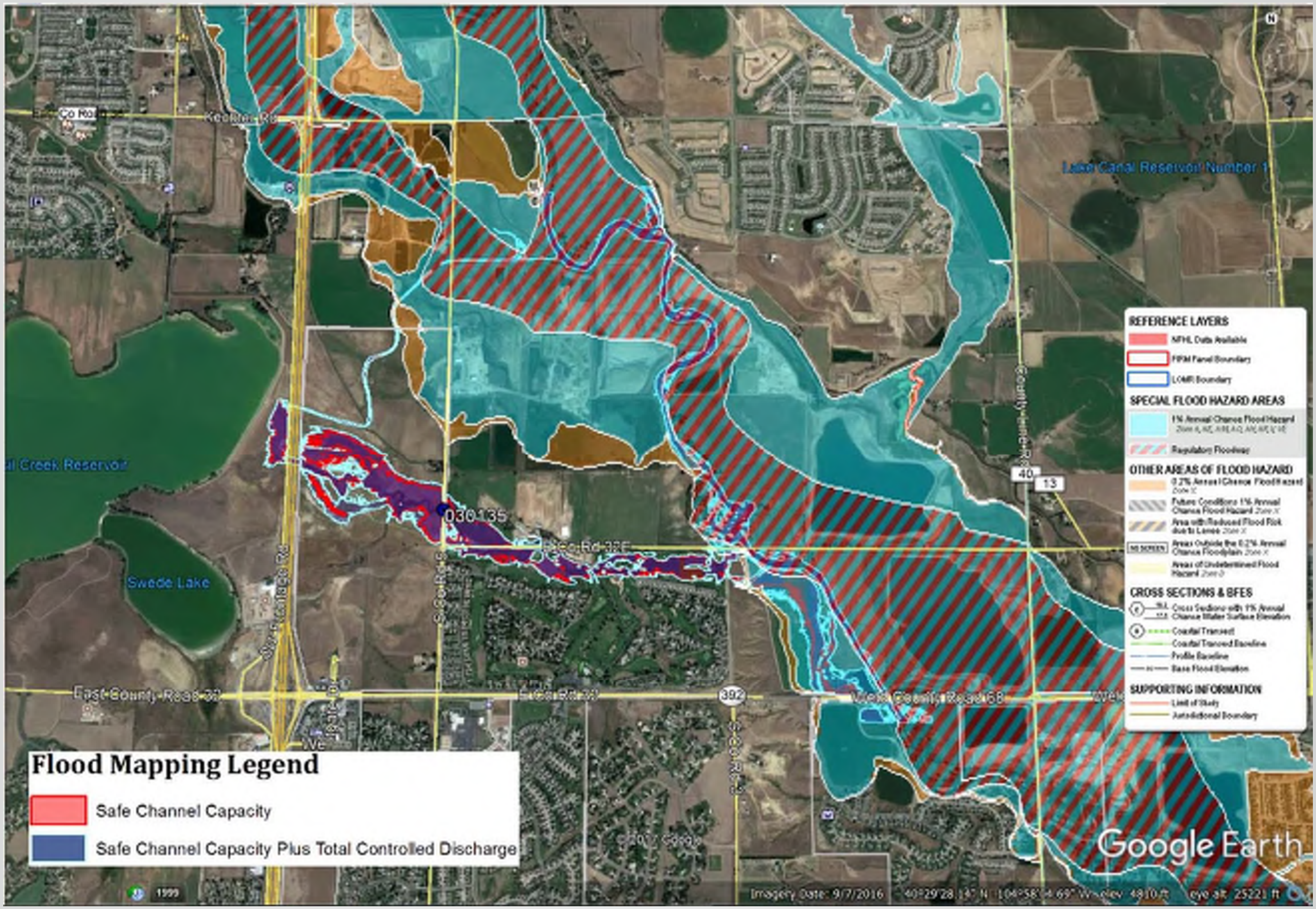
Hydraulic Analysis Findings

The safe channel capacity of the reach downstream of Fossil Creek Dam is estimated to be 616 cfs. The maximum controlled discharge is 393 cfs. For comparison, the 2-year peak discharge estimated by StreamStats is 516 cfs; the 10-year peak discharge estimated by StreamStats is 3450 cfs. The downstream impact area is rural. The first impacted roads downstream of the dam are South County Road 5, South County Road 3, and County Road 32 East. The roads may be overtopped at a peak discharge of approximately 616 cfs. The first impacted structure downstream of the dam is located at the end of Watson Drive. The residential house may be flooded at a peak discharge of approximately 616 cfs.

Fossil Creek Dam – Inundation Map



Fossil Creek Dam – Outlet Release



Message for Floodplain Managers

- We know the Risk exists
- Flooding can happen downstream of a dam because of operations
- Know what you don’t know
  - Database can sort by county
  - Information for all high hazard dams
- You might be surprised by the number of dams that can impact your floodplains
- Work together to manage floodplains below dams

COLORADO
Division of Water Resources
Department of Natural Resources

Next Steps

- Sharing the database
- Pilot study with Fort Collins:
  - Map outlet flows
  - Analyze data
  - guidelines

COLORADO
Division of Water Resources
Department of Natural Resources

Questions?


DENVER & THE WEST

DONATE: Contribute to flood-relief efforts.

FORECAST: More rain expected Sunday.

Front Range Flooding

"Normal has changed"

Fifth person presumed dead while authorities work to get hundreds to safety

Image Source: Denver Post

COLORADO
Division of Water Resources
Department of Natural Resources

SHOWCASING THE PILOT BOULDER COUNTY FLOOD RISK INFORMATION SYSTEM (FRIS)

HOLISTIC FLOOD RISK COMMUNICATION

Thuy Patton

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

Madeline Kelley

UNIVERSITY of DENVER

COLORADO'S 5-YEAR FLOOD ANNIVERSARY

DATE: Monday, September 10, 2018
TIME: 10:00AM-11:30AM
LOCATION: Bohn Park
199 2nd Avenue Lyons, CO 80540

When the rains of September 2013 poured down on Colorado and caused flooding, the town of Lyons was severely impacted. Today, however, Lyons is flourishing.

Please join Gov. Hickenlooper and leaders from across the state in commemorating Colorado's 5-year anniversary of the 2013 floods, and in celebrating the resilience of Colorado communities.

5 years later, Colorado communities continue to rebuild after devastating floods

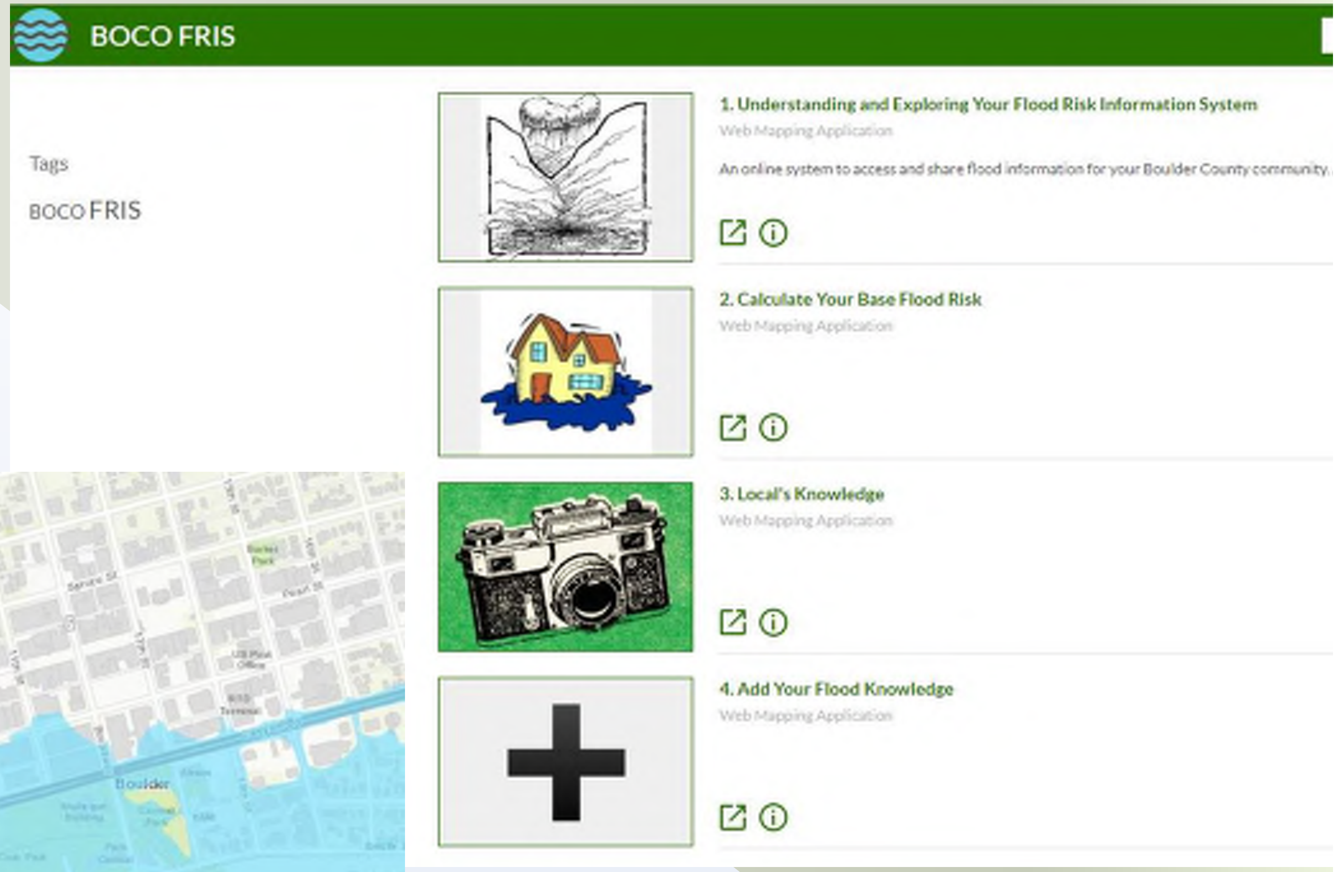
Five year anniversary of catastrophic floods

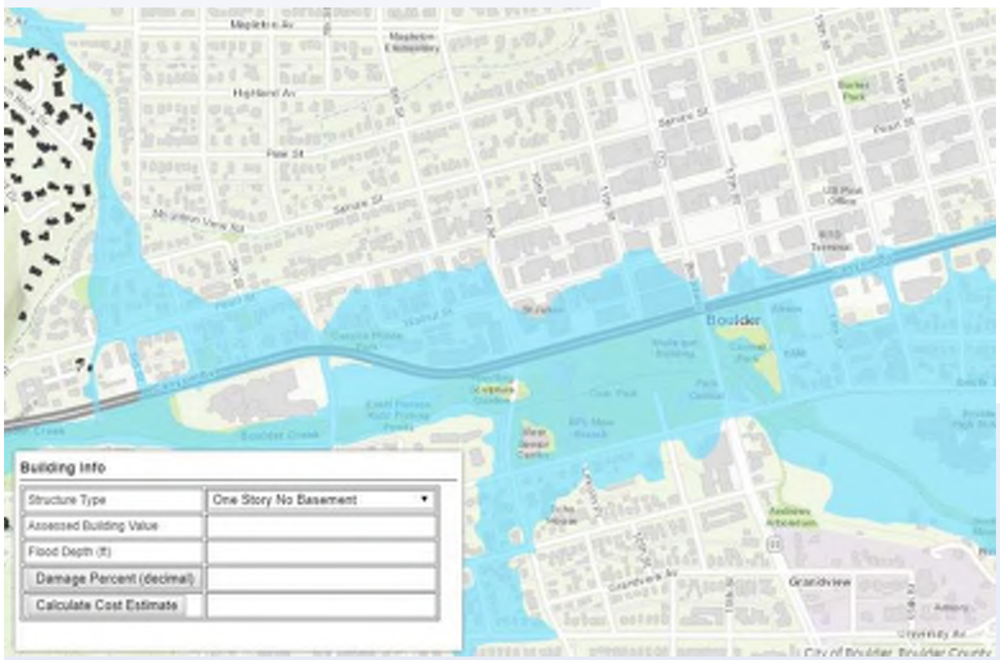
BY: Russell Haythorn
POSTED: 4:46 PM, Sep 10, 2018
UPDATED: 7:01 PM, Sep 10, 2018

TAG: colorado flooding anniversary | 2013 floods | floods in colorado | 5 year anniversary | 5 year anniversary of floods

TECHNICAL MAPPING ADVISORY COUNCIL

TMAC

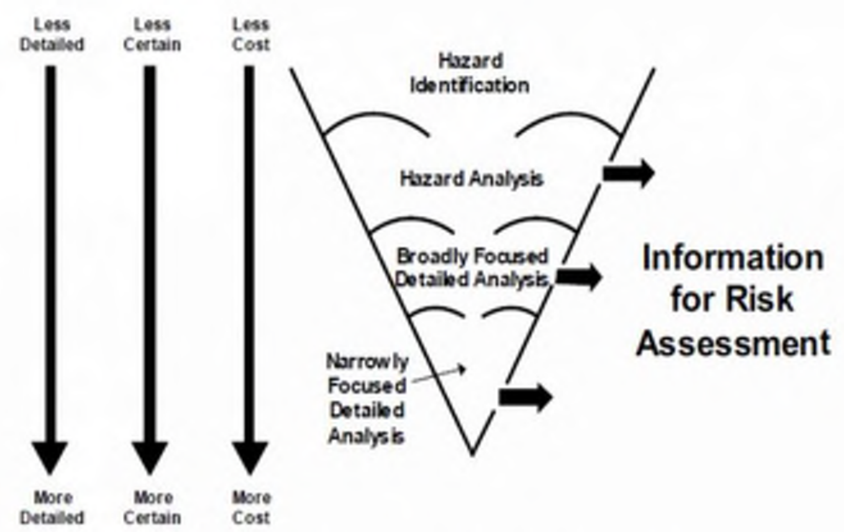

BOCO FRIS
Tags
BOCO FRIS
1. Understanding and Exploring Your Flood Risk Information System
Web Mapping Application
An online system to access and share flood information for your Boulder County community.
2. Calculate Your Base Flood Risk
Web Mapping Application
3. Local's Knowledge
Web Mapping Application
4. Add Your Flood Knowledge
Web Mapping Application


Boulder
Grandview
Building Info
Structure Type
One Story No Basement
Assessed Building Value
Flood Depth (ft)
Damage Percent (decimal)
Calculate Cost Estimate

Geographer and focused on the application of **geographic information science and remote sensing** to the *and science communication.* Interested in mixed methods and Participatory GIS

BA in Environmental Studies/GIS Certificate
University of Pittsburgh - 2014
MS in Geographic Information Science
University of Denver – 2018
PhD Geography Student
University of Arizona - current

Flood risk communication is complicated

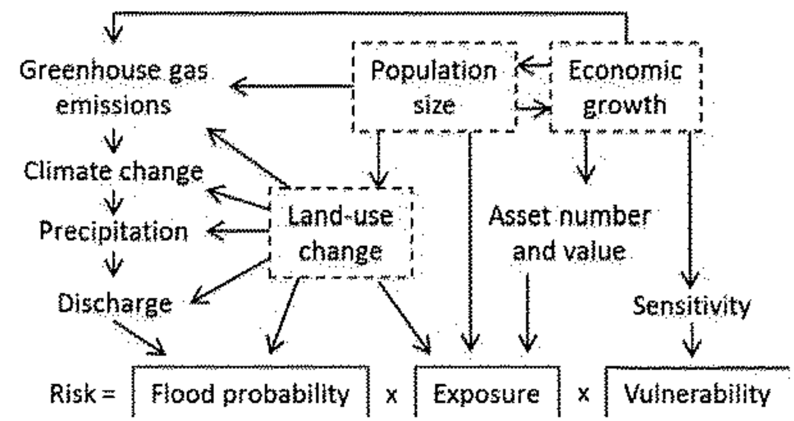


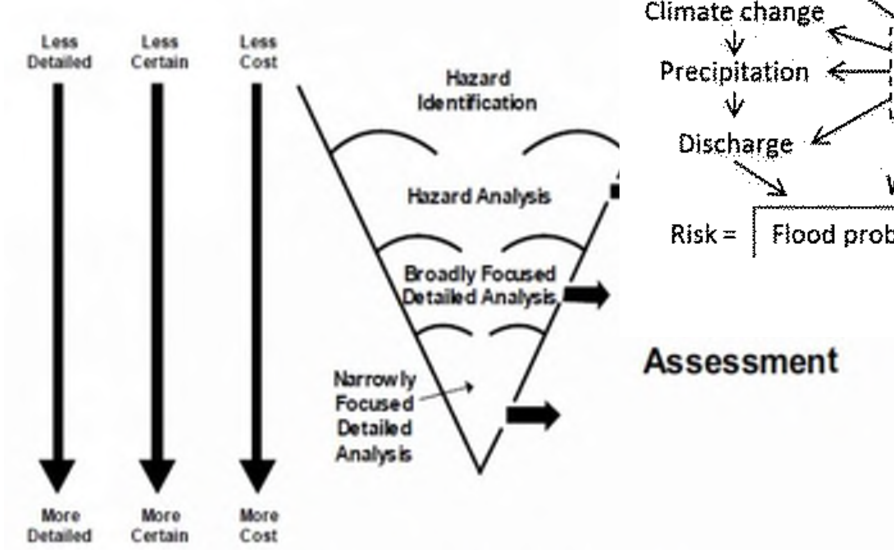
AIChE – CPS 2016

FIGURE 9.1. Levels of Hazard Evaluation and Risk Assessment

Flood risk communication is complicated

Source: Kundzewicz, Z. W.; Kanae, S.; Seneviratne, S. I.; et al., (2014) Flood risk and climate change: global and regional perspectives. Hydrol. Sci. J. 59(1), 1-28.





AIChE – CPS 2016

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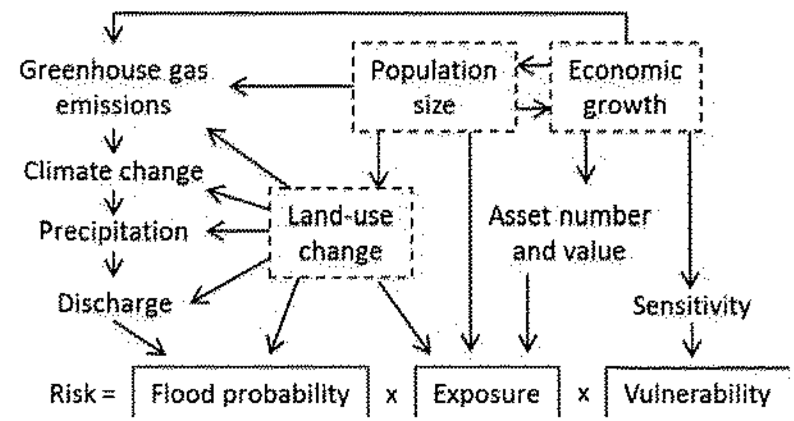
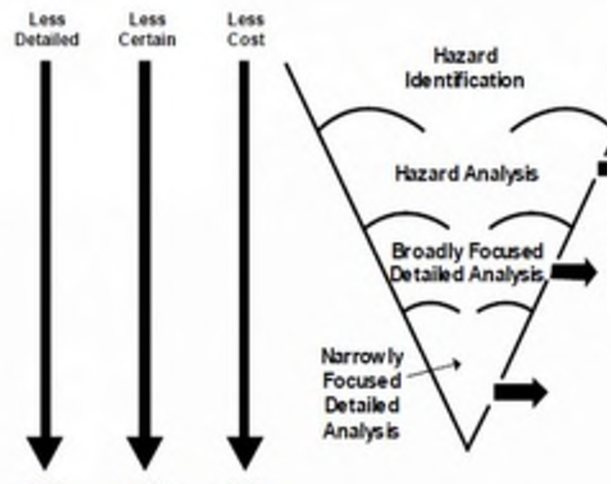
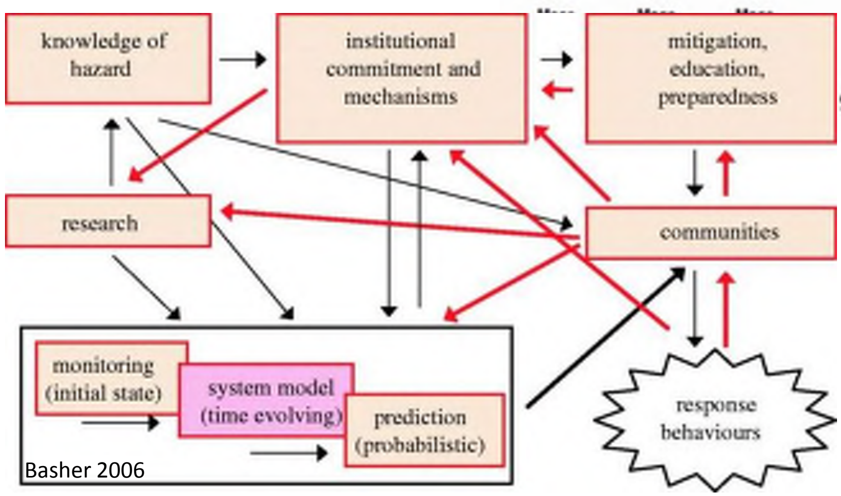




Assessment

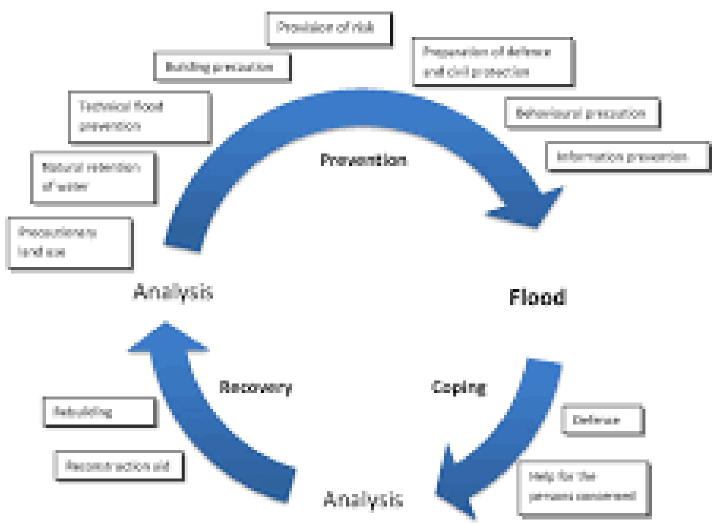
9.1. Levels of Hazard Evaluation and Risk Assessment



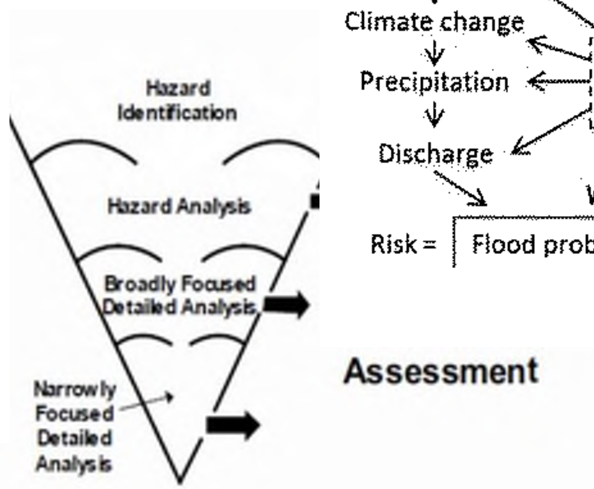
Basher 2006

Flood risk communication is complicated

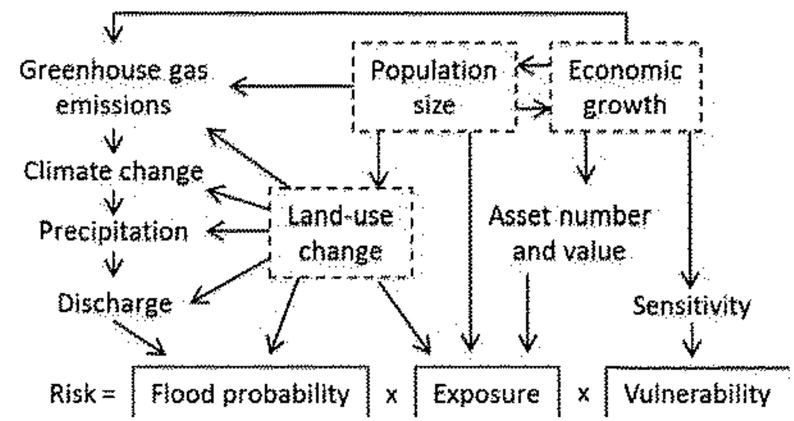
Source: Kundzewicz, Z. W.; Kanae, S.; Seneviratne, S. I.; et al., (2014) Flood risk and climate change: global and regional perspectives. Hydrol. Sci. J. 59(1), 1-28.

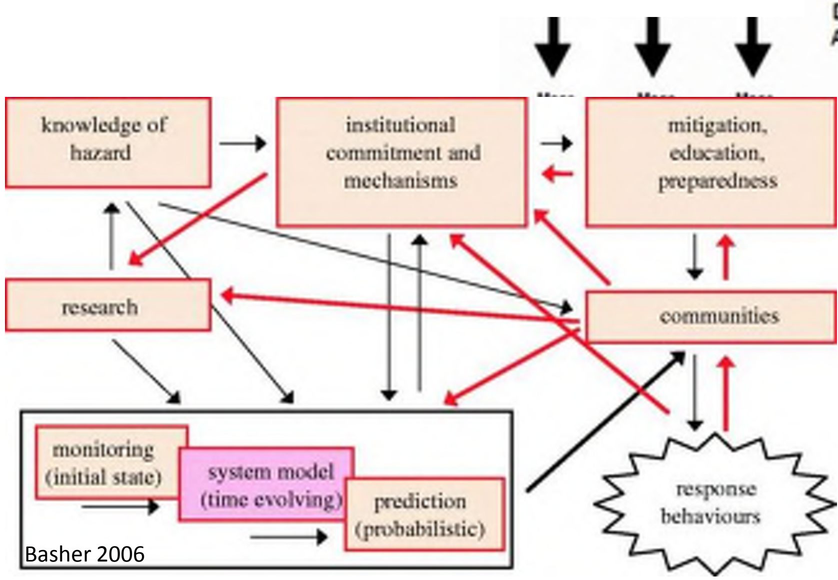


SECOM Flood Risk Management



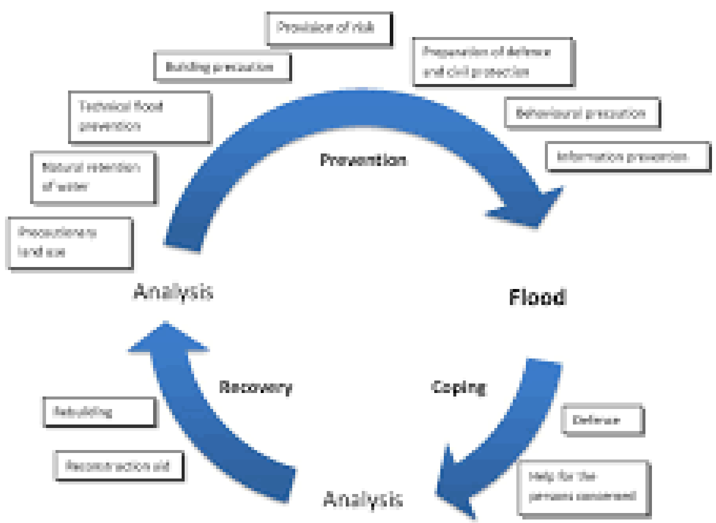
9.1. Levels of Hazard Evaluation and Risk Assessment



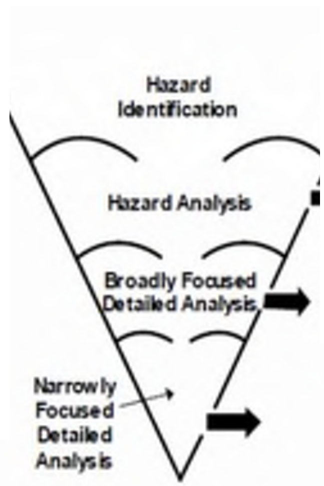


Basher 2006

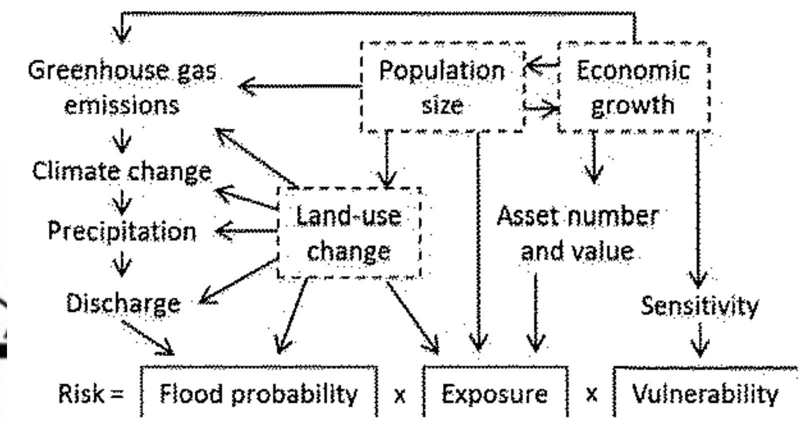
Flood risk communication is complicated



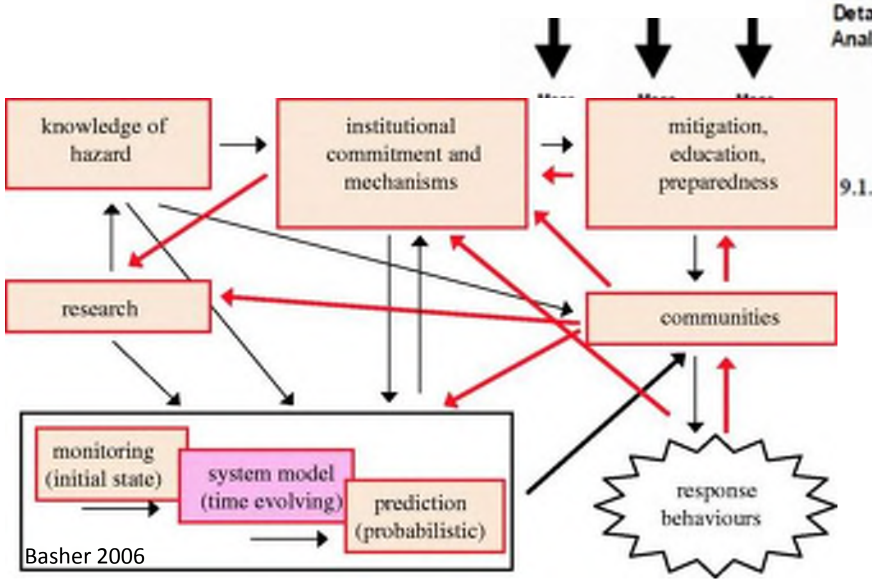
SECOM Flood Risk Management



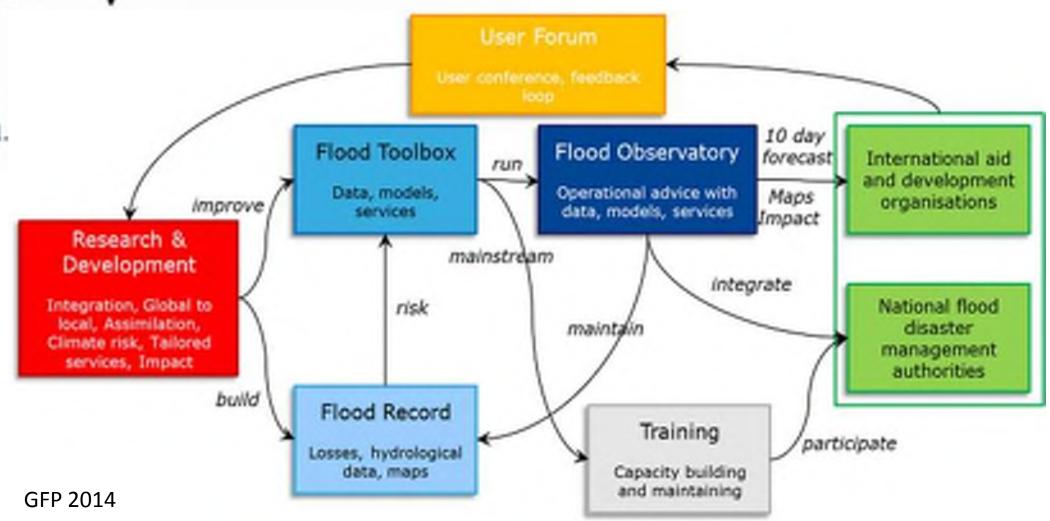
Source: Kundzewicz, Z. W.; Kanae, S.; Seneviratne, S. I.; et al., (2014) Flood risk and climate change: global and regional perspectives. Hydrol. Sci. J. 59(1), 1-28.



Assessment



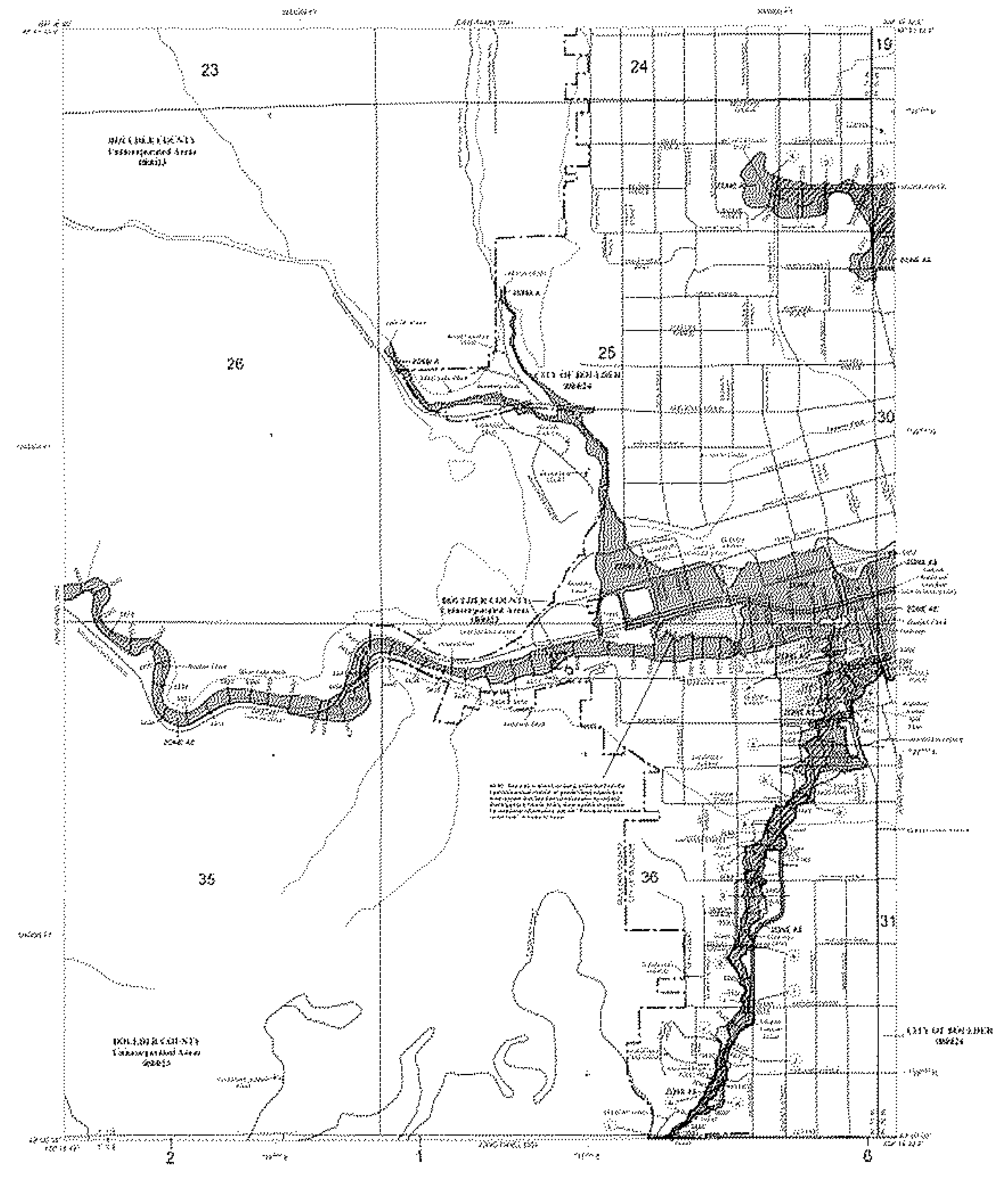
Basher 2006



GFP 2014

NOTES TO USERS

LEGEND



FIRM

FLOOD INSURANCE RATE MAP

BOULDER COUNTY, COLORADO

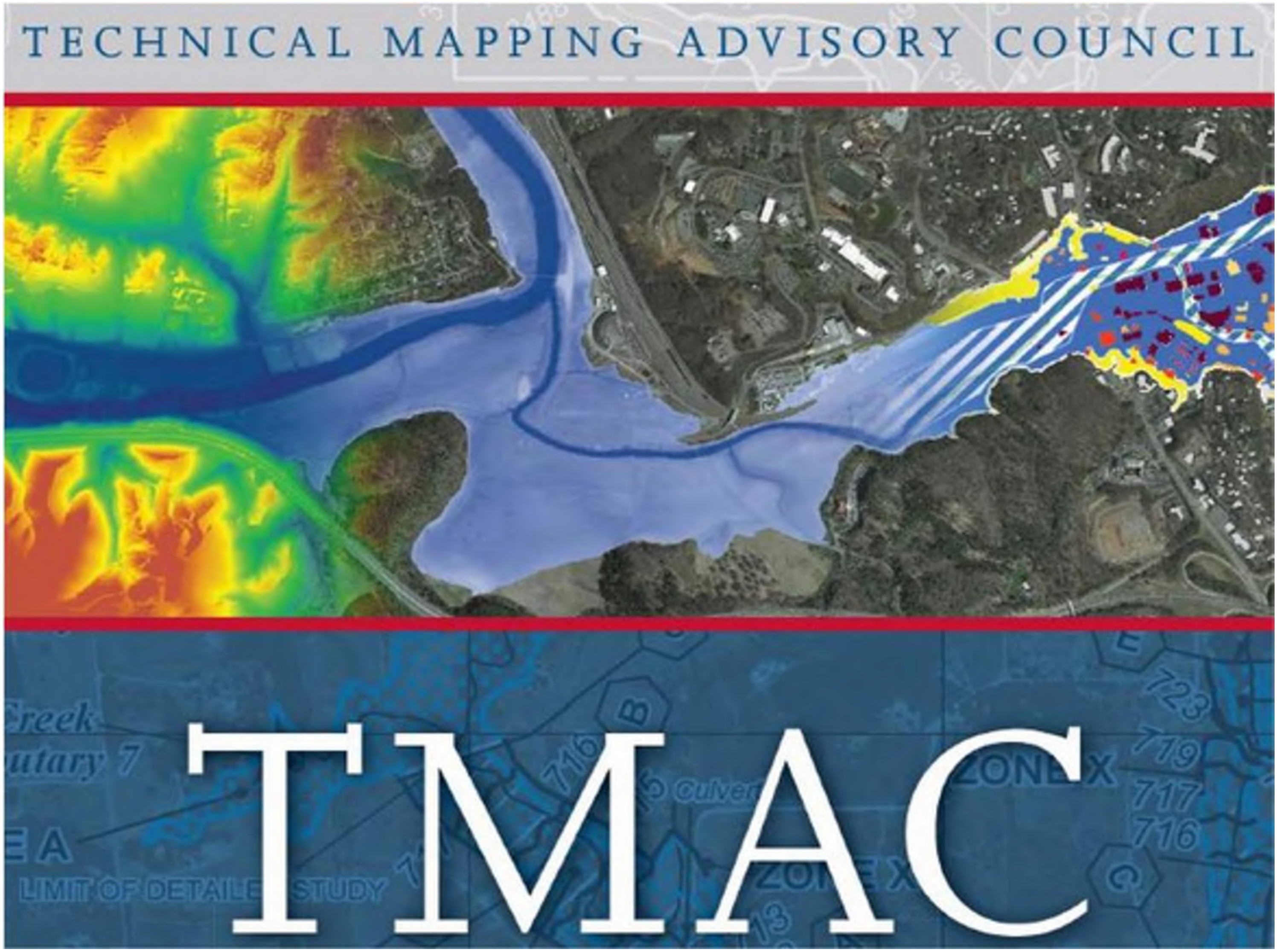
AND INCORPORATED AREAS

MAP REVISED

DECEMBER 18, 2012

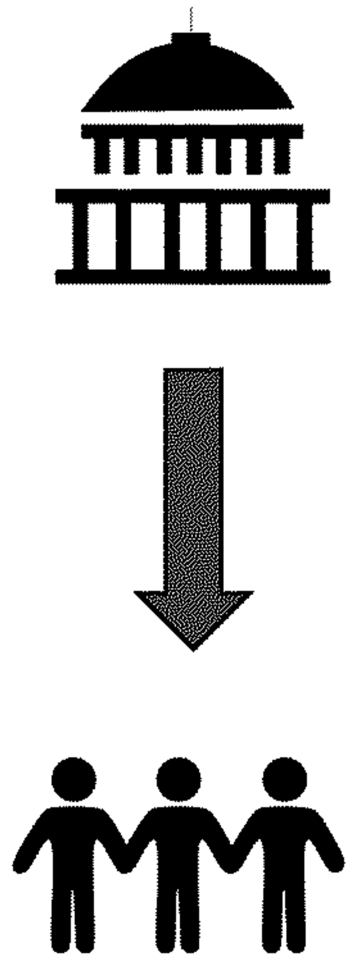
Federal Emergency Management Agency

More detailed information

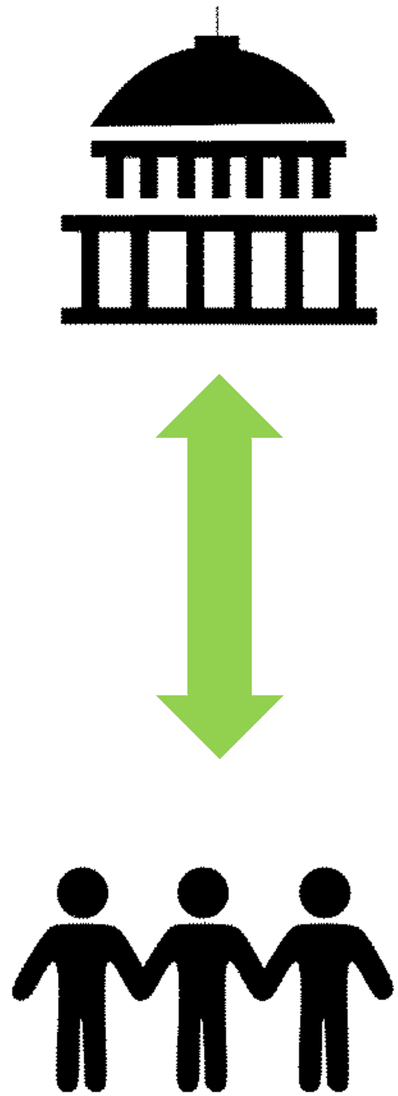


Case Study Location

Top-down, one-way flow of information



Two-way flow of information



Meyer's et. al (2012)

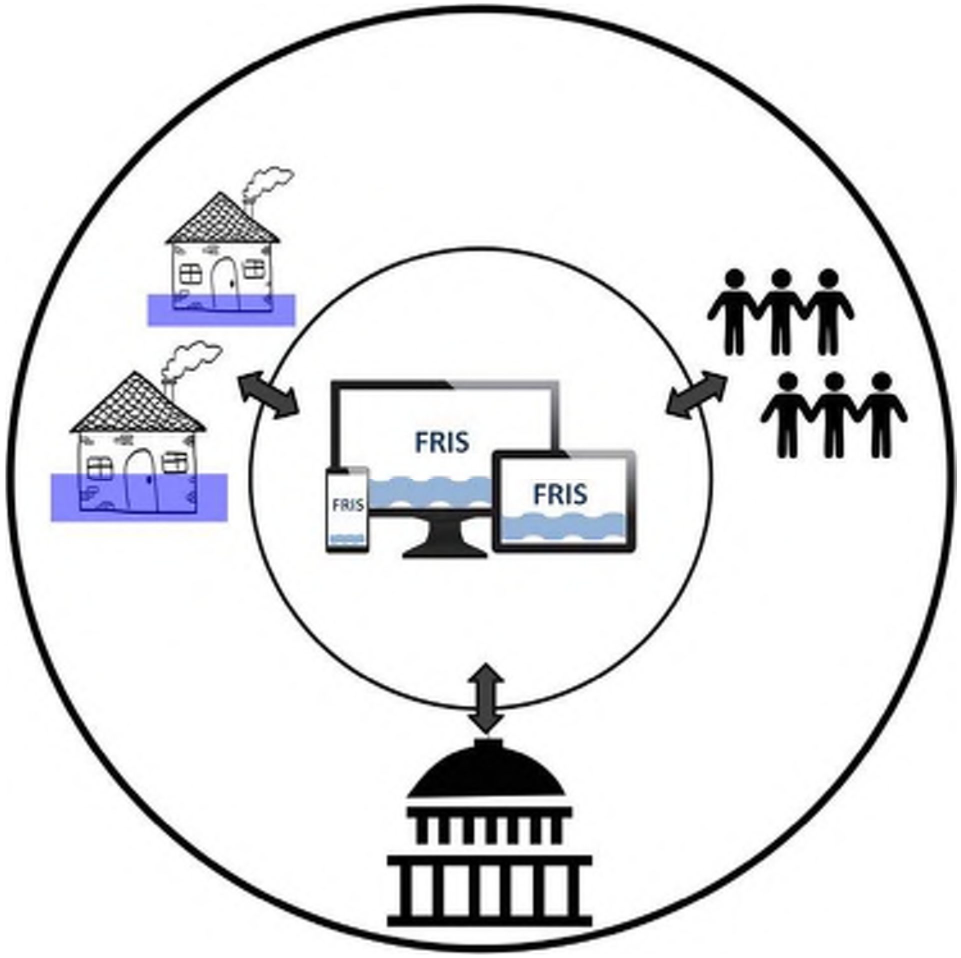
My Project

- Investigated the application of Geographic Information Science (GIS) to flood risk communication through a pilot project in Boulder County, Colorado

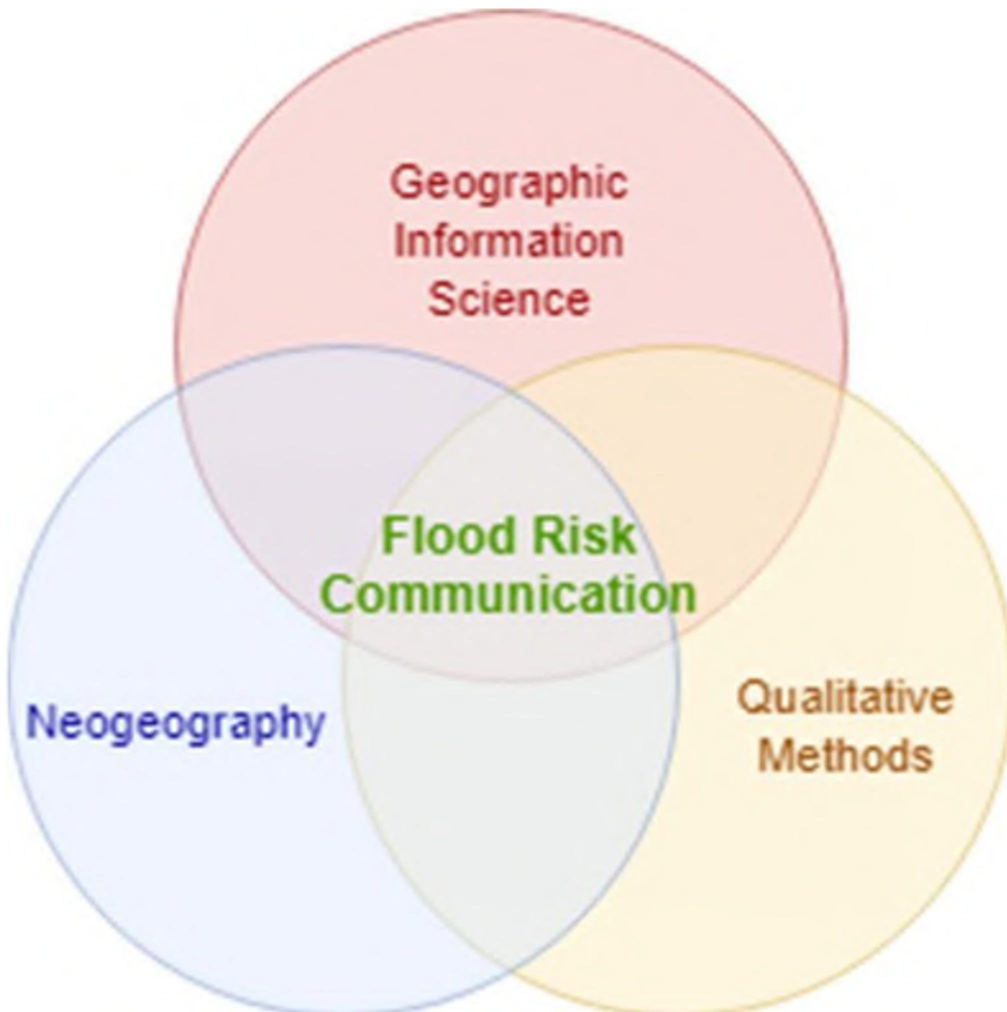
- Explored stakeholders' preferences in flood risk communication

- Proposed novel products and data layers

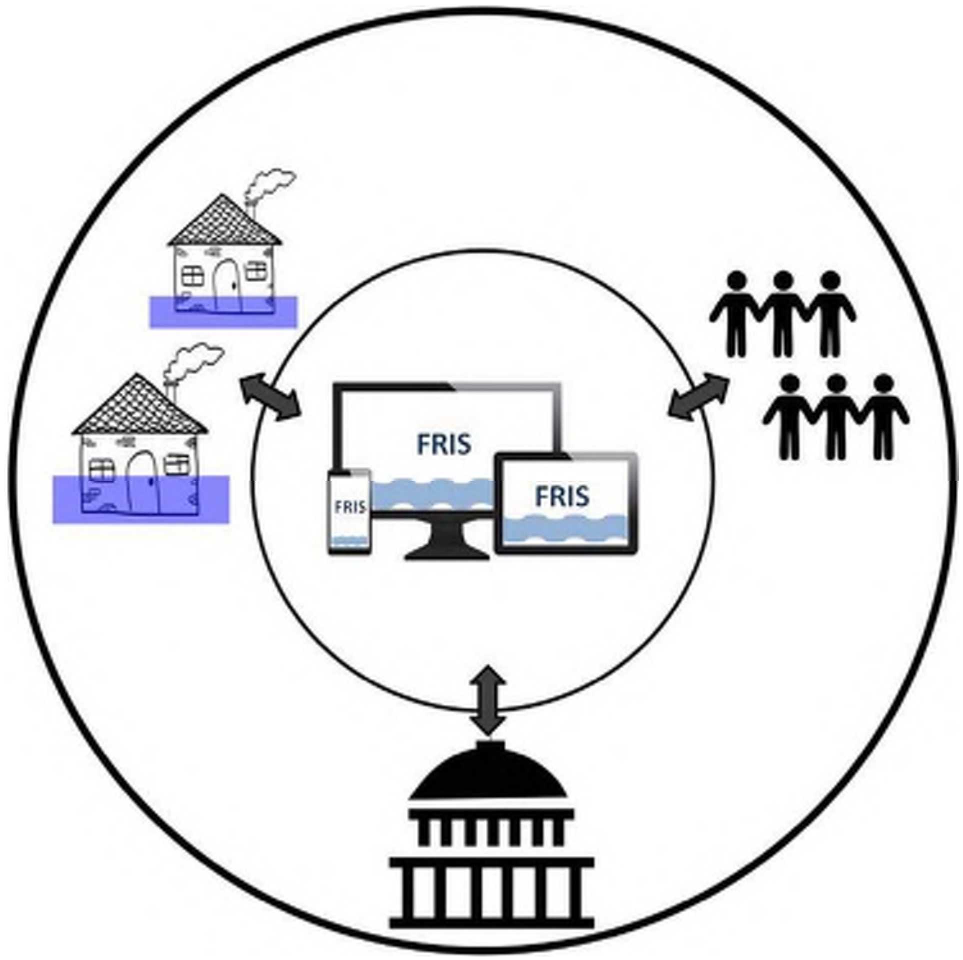
Proof-of-concept
New communication tool
Flood Risk Information System



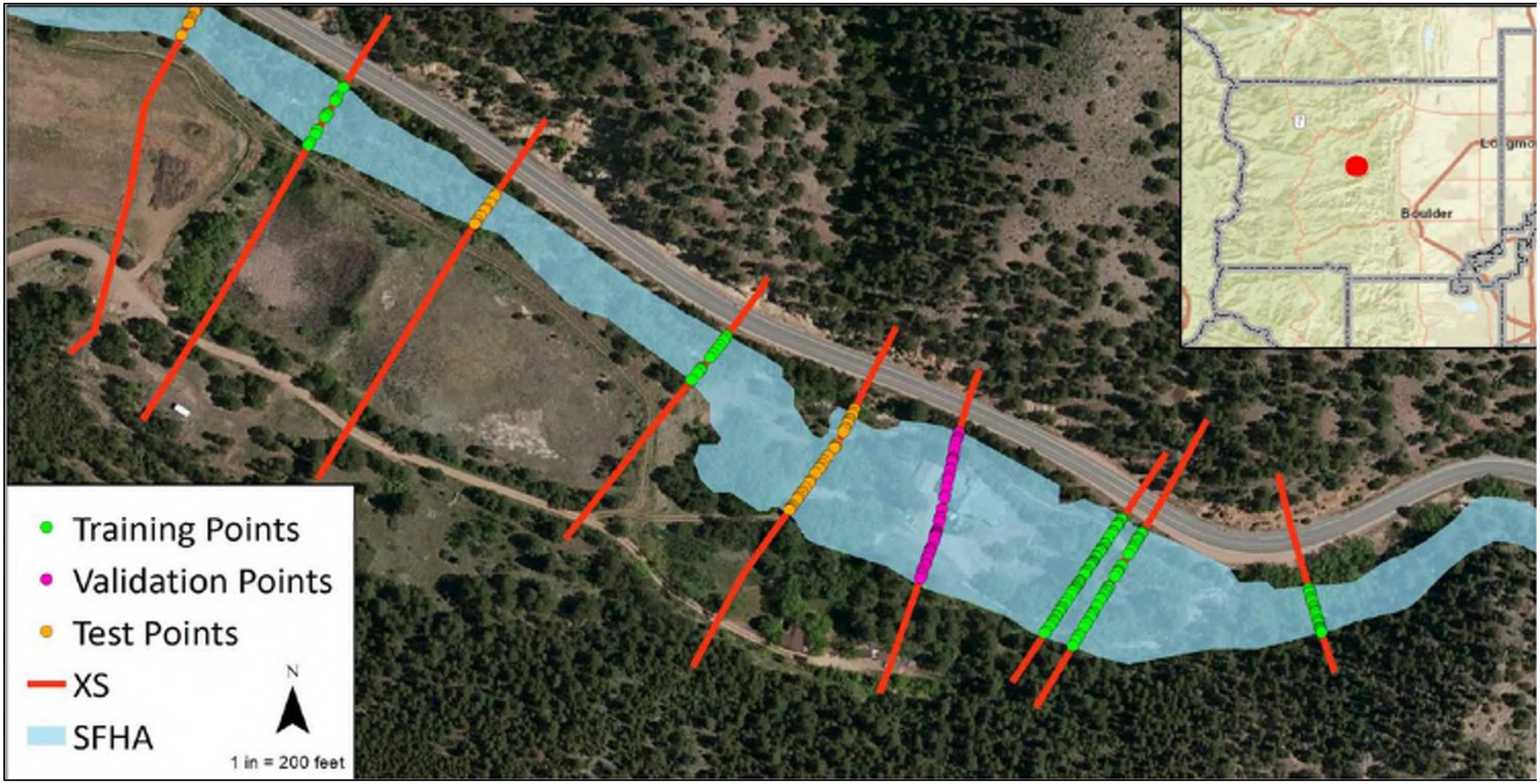
Theoretical framework



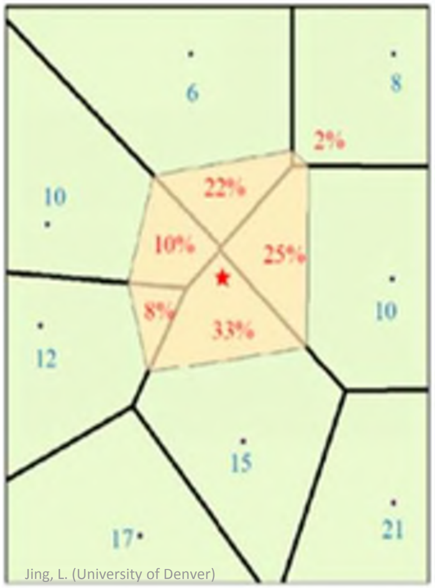
Structure-specific data



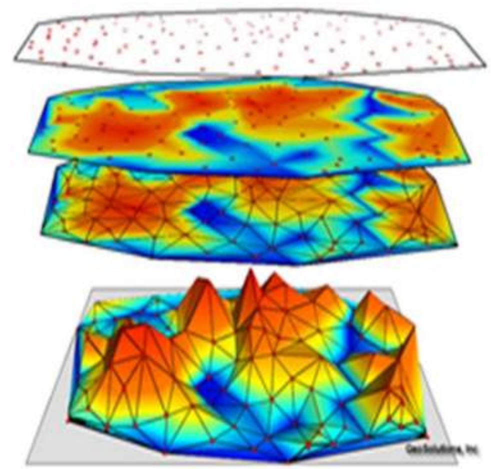
Public Data


Training Points
Validation Points
Test Points
XS
SFHA
N
1 in = 200 feet
Boulder

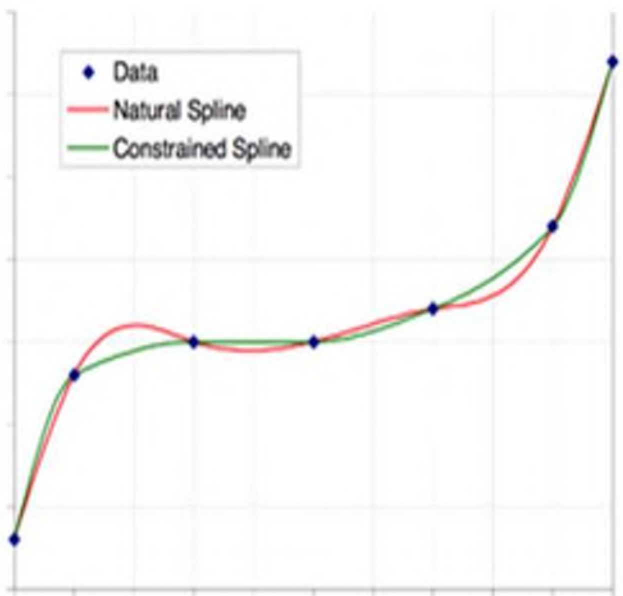
Natural Neighbor



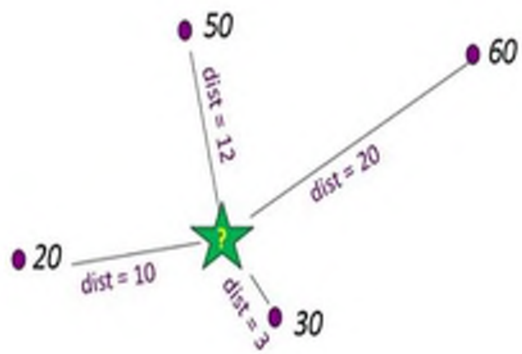
Triangular Irregular Networks (TIN)



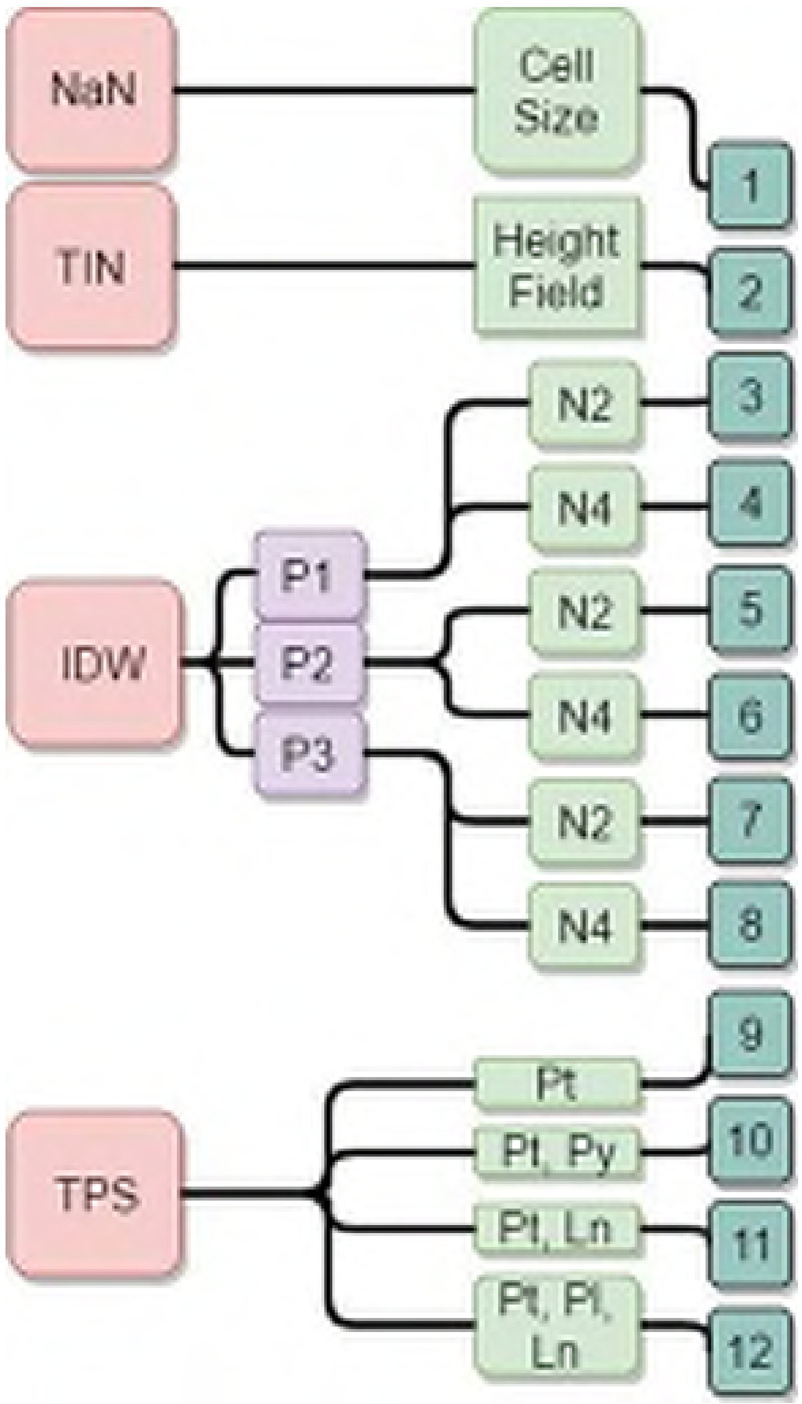
Topo to Raster



Inverse Distance Weighted (IDW)



August P., Wang Y (Coastal Institute in Kingston)



<u>Parameters</u>
Power (P)
Number of points/search radius (N)
Point input (Pt)
Line input (Ln)
Polygon input (Py)

Output	Goodness of Fit	Error	
Validation			
	R^2	RMSE	MRE
NaN	0.9999	6.013	0.0018
TIN	0.9999	6.231	0.0019
IDW 3	0.9995	11.462	0.0034
IDW 4	0.9995	11.355	0.0034
IDW 5	0.9995	11.461	0.0034
IDW 6	0.9995	11.350	0.0034
IDW 7	0.9995	11.461	0.0034
IDW 8	0.9995	11.349	0.0034
TPS 9	0.9998	6.746	0.0020
TPS 10	0.9998	7.039	0.0021
TPS 11	0.9998	6.694	0.0020
TPS 12	0.9998	6.677	0.0020
Test			
	R^2	RMSE	MRE
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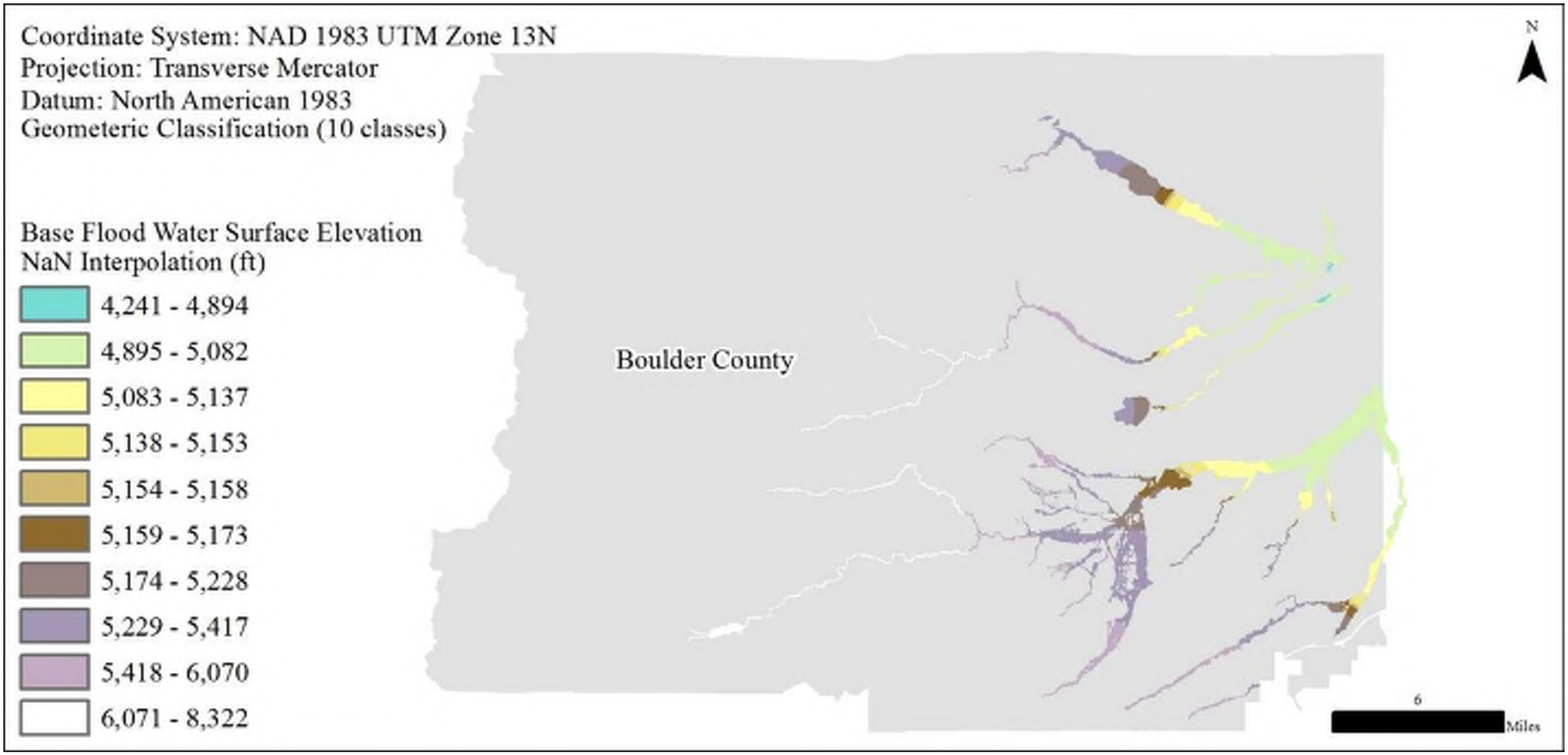

Coordinate System: NAD 1983 UTM Zone 13N
Projection: Transverse Mercator
Datum: North American 1983
Geometeric Classification (10 classes)
Base Flood Water Surface Elevation
NaN Interpolation (ft)
4,241 - 4,894
4,895 - 5,082
5,083 - 5,137
5,138 - 5,153
5,154 - 5,158
5,159 - 5,173
5,174 - 5,228
5,229 - 5,417
5,418 - 6,070
6,071 - 8,322
Boulder County
N
6
Miles

5 ft Flood Depth

$80,0000 Damage

3 ft Flood Depth

$40,0000 Damage

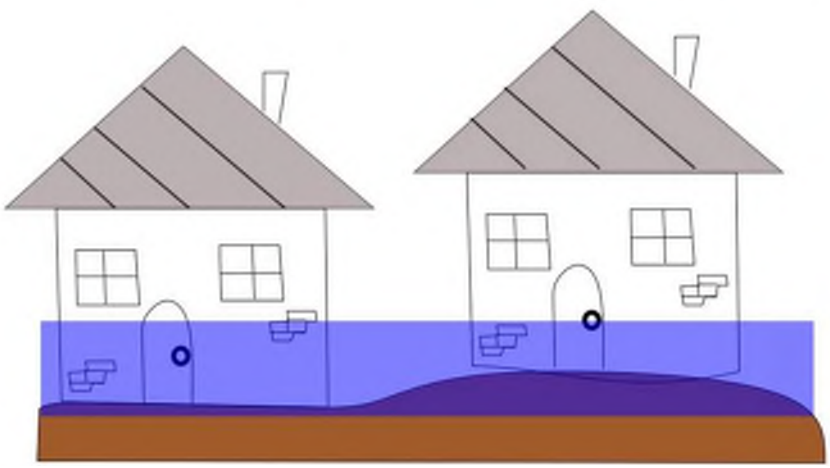
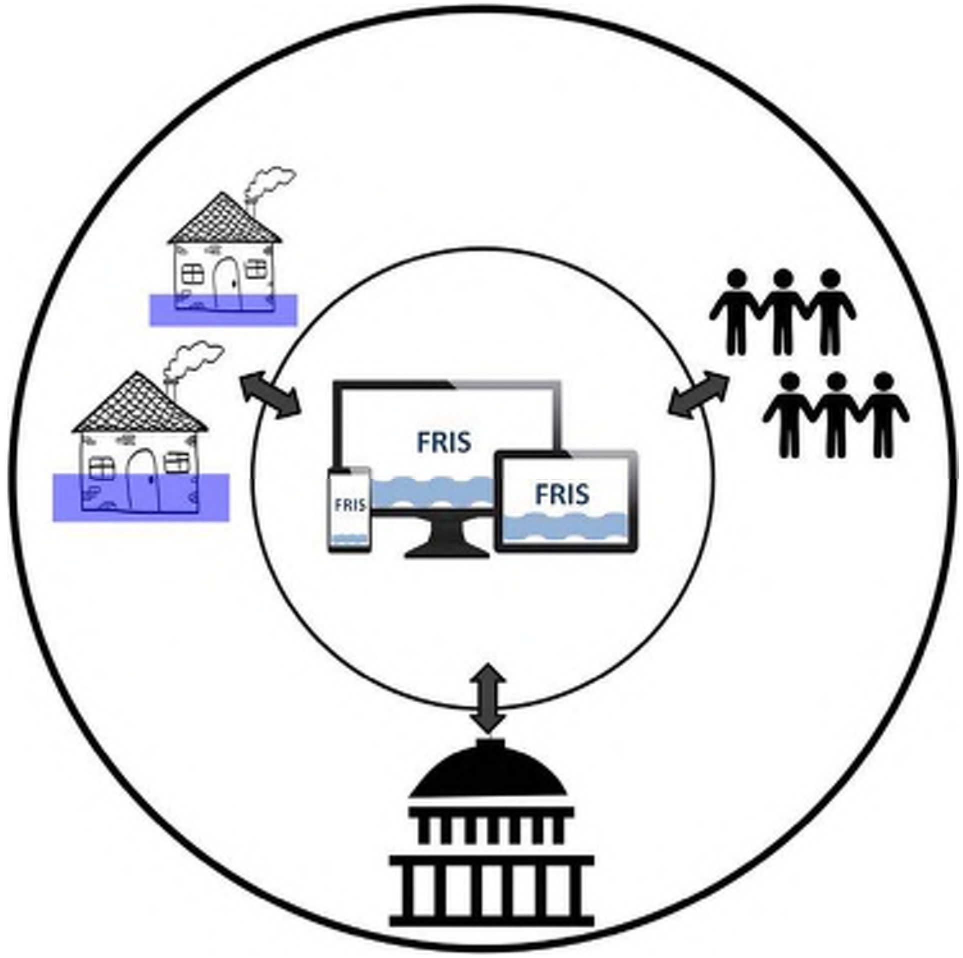


Table 2
Structure
Two or More Stories, With Basement

Depth	Mean of Damage	Standard Deviation of Damage
-8	1.7%	2.70
-7	1.7%	2.70
-6	1.9%	2.11
-5	2.9%	1.80
-4	4.7%	1.66
-3	7.2%	1.56
-2	10.2%	1.47
-1	13.9%	1.37
0	17.9%	1.32
1	22.3%	1.35
2	27.0%	1.50
3	31.9%	1.75
4	36.9%	2.04
5	41.9%	2.34
6	46.9%	2.63
7	51.8%	2.89
8	56.4%	3.13
9	60.8%	3.38
10	64.8%	3.71
11	68.4%	4.22
12	71.4%	5.02
13	73.7%	6.19
14	75.4%	7.79
15	76.4%	9.84
16	76.4%	12.36

US Army Corps Eng (EGM) 04-01 2003

Local Knowledge



Local Knowledge

Focus Groups:

- **Community Planners**: members/employees of the local, state, federal, or provate organizations
- **Community Members:** homeowners and renters in Boulder County

Event Tasks:

- Pre-survey
- Guided Group Discussion
- Post-survey

Community Members	**n=8**
Average Year Born	1957
Hispanic	100% - No
Race	100% - White
Gender	5 Female : 3 Male
Residence	100 % - Own Home
Time at current residence	<= 1 yr one: 2-4 yr two: 5-9 yr one: **>=10 four**
Current primary residence in a flood zone	*Response:* 1 Unsure: 4 No: 3 Yes *Reality:* 2 No : 6 Yes
Have you experienced a flooding event	100 % - Yes, personally

Focus Groups:

- **Community Planners**: members/employees of the local, state, federal, or provate organizations

Community Planners	**n=8**
Organization Type	LOCAL - 5 STATE - 1 FEDERAL - 1 PRIVATE - 1

- **Community Members:** homeowners and renters in Boulder County

Community Members	**n=8**
Average Year Born	1957
Hispanic	100% - No
Race	100% - White
Gender	5 Female : 3 Male
Residence	100 % - Own Home

Event Tasks:

- Pre-survey
- Guided Group Discussion
- Post-survey

Comparison of Static/Dynamic Product Formats				
Theme	**FG1**	**FG2**	**Total**	**Events**
Web map has more data/basemap provides context	**7**	**4**	**11**	**5**
Web map is interactive	**4**	**3**	**7**	**5**
Web map has color	1	3	4	4
Web map starts conversation	2	1	3	3
Web map is simple/understandable	1	1	2	2
Web map is more accessible	-	2	2	2
Static map is simple/understandable	**4**	**-**	**4**	**2**
Static map is more accessible	**1**	**3**	**4**	**3**
Static map has more data	2		2	2
Static map is more trustworthy	1	-	1	1

What are the pros and cons of structure-specific data?

Structure-Specific Data				
Theme	**FG1**	**FG2**	**Total**	**Events**
Provides more detailed risk info	**7**	**4**	**11**	**6**
Starts engagement	**2**	**1**	**3**	**3**
Simple/clear	2	-	2	2
Information is confusing	**3**	**3**	**6**	**5**
Provides too much info	**1**	**1**	**2**	**2**
Information not useful	-	2	2	2
A more general tool preferred	-	3	3	1

What are the pros and cons of incorporating local knowledge?

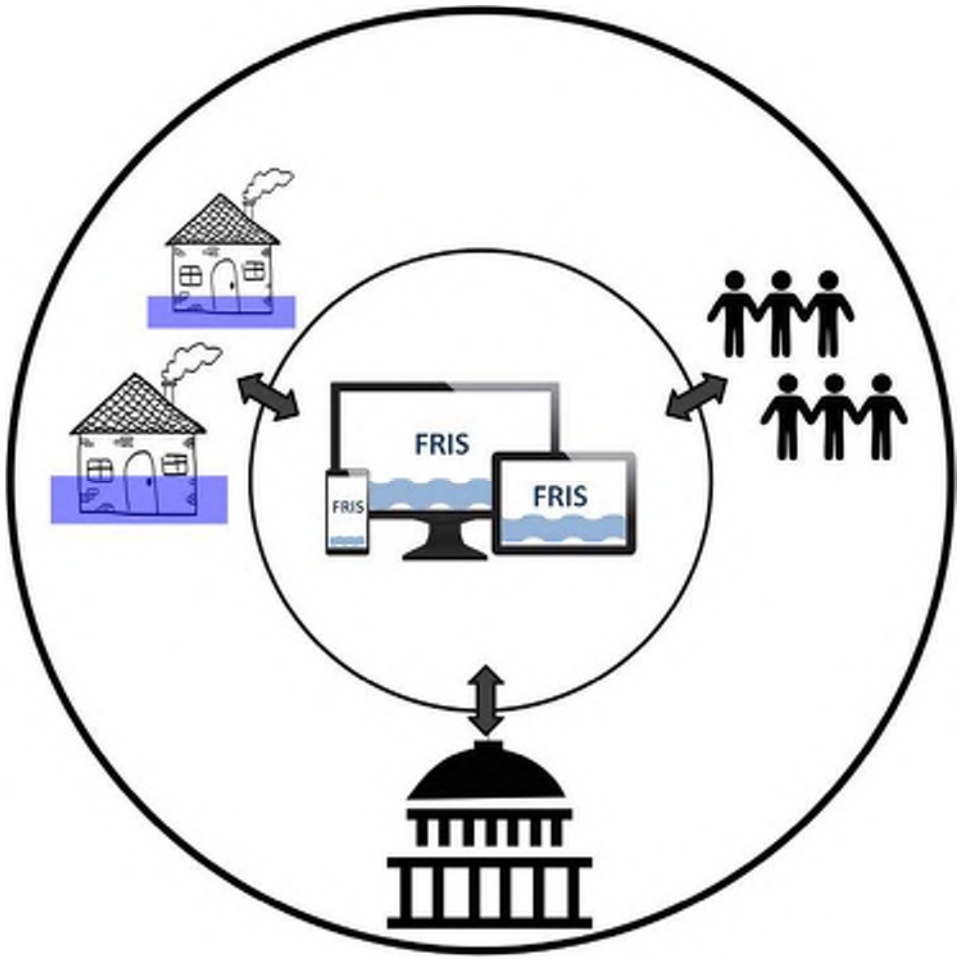
Local Knowledge				
Theme	**FG1**	**FG2**	**Total**	**Events**
Helpful format	**3**	**11**	**14**	**6**
Allows for contribution	**5**	**1**	**6**	**4**
Useful for mapping/other efforts	5	-	5	3
Impacts people quickly	2	1	3	3
Starts engagement	2	1	3	3
Provides too much information	**1**	**4**	**5**	**3**
Information purpose is confusing	**2**	**1**	**3**	**2**
Dislike data management requirement	2	-	2	1

What are the pros and cons of incorporating local knowledge?

Local Knowledge				
Theme	**FG1**	**FG2**	**Total**	**Events**
Helpful format	**3**	**11**	**14**	**6**
Allows for contribution	**5**	**1**	**6**	**4**
Useful for mapping/other efforts	5	-	5	3
Impacts people quickly	2	1	3	3
Starts engagement	2	1	3	3

What additional information or data would you like included in the FRIS?

Other Data/Information For FRIS				
Theme	**FG1**	**FG2**	**Total**	**Events**
Background, statistics, and information on flooding	**5**	**5**	**10**	**4**
Action information for during an event	**2**	**3**	**5**	**3**
Live flood data and warnings	**4**	**1**	**5**	**3**
Information for other types of local hazards	3	1	4	3
Information to protect/improve home	2	1	3	3
Characteristic of community relating to flooding and communication	2	1	3	2
Outreach information	-	2	2	2
Local insurance information	1	-	1	1


FRIS
FRIS
FRIS

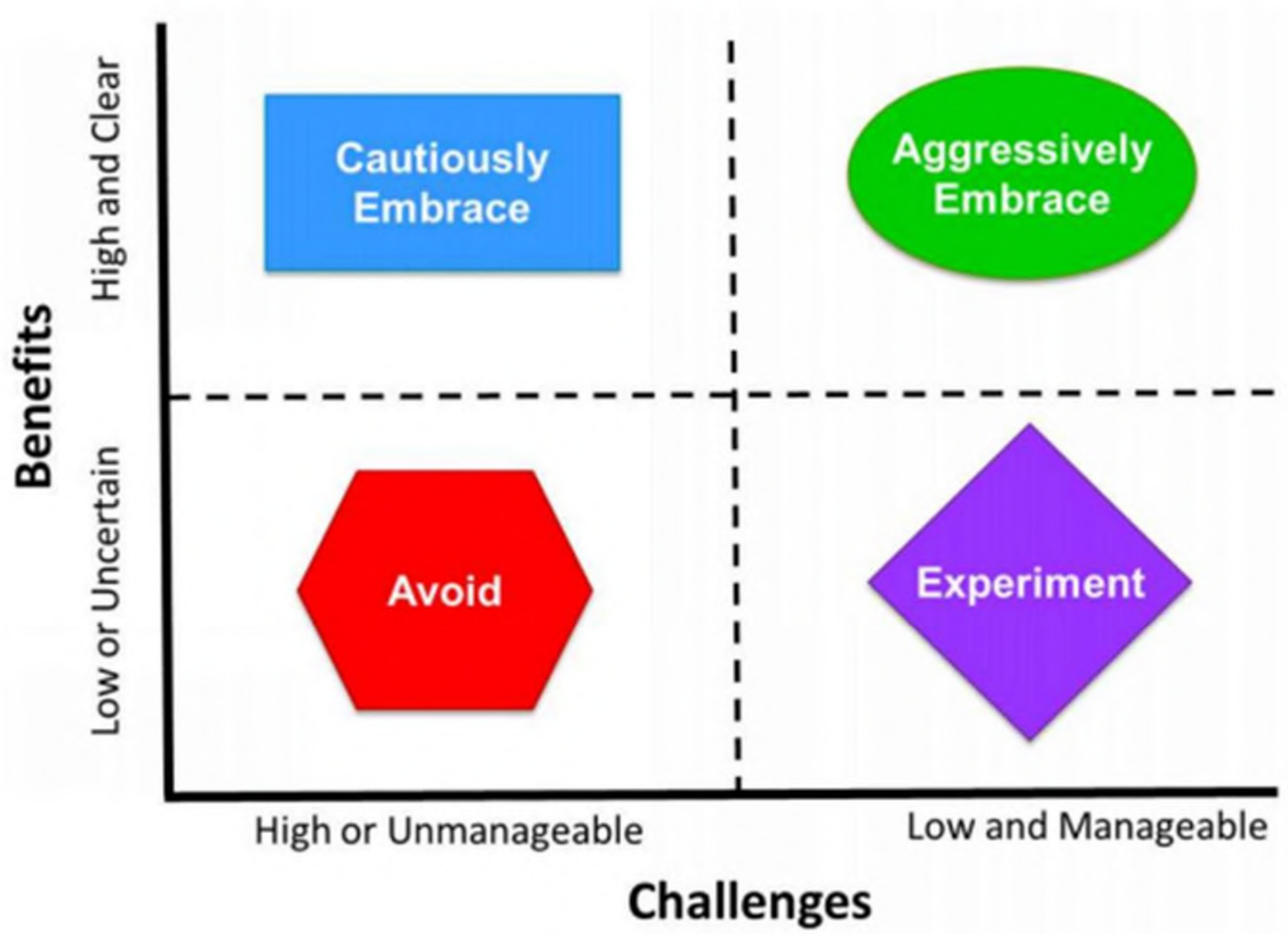
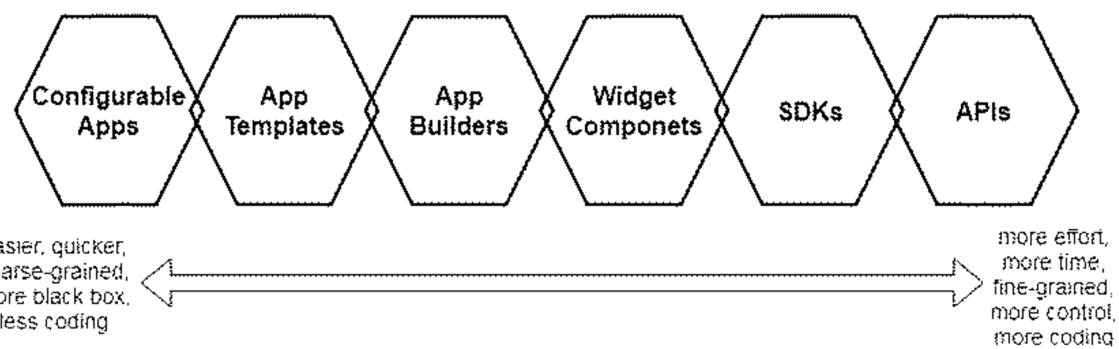
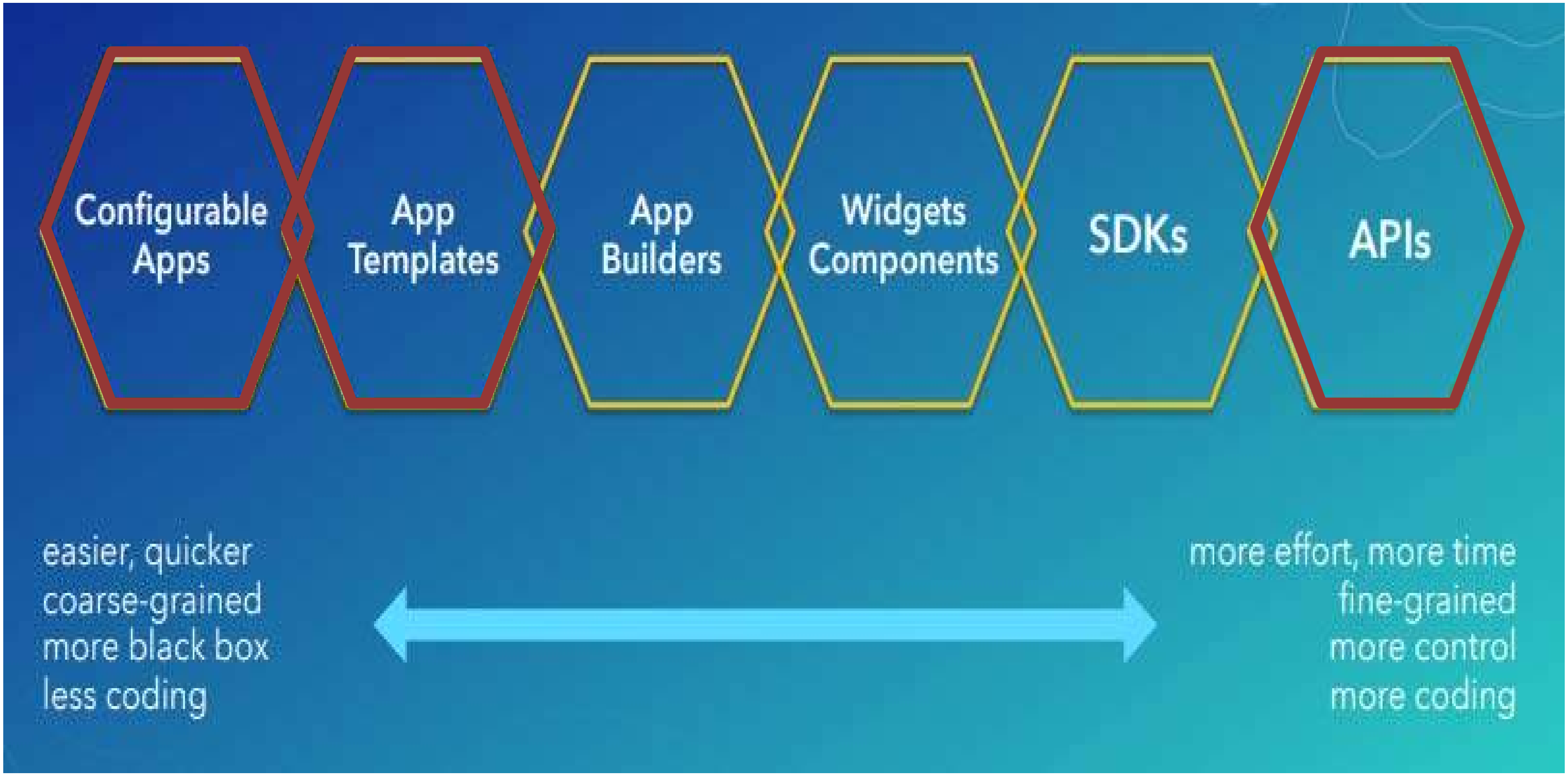


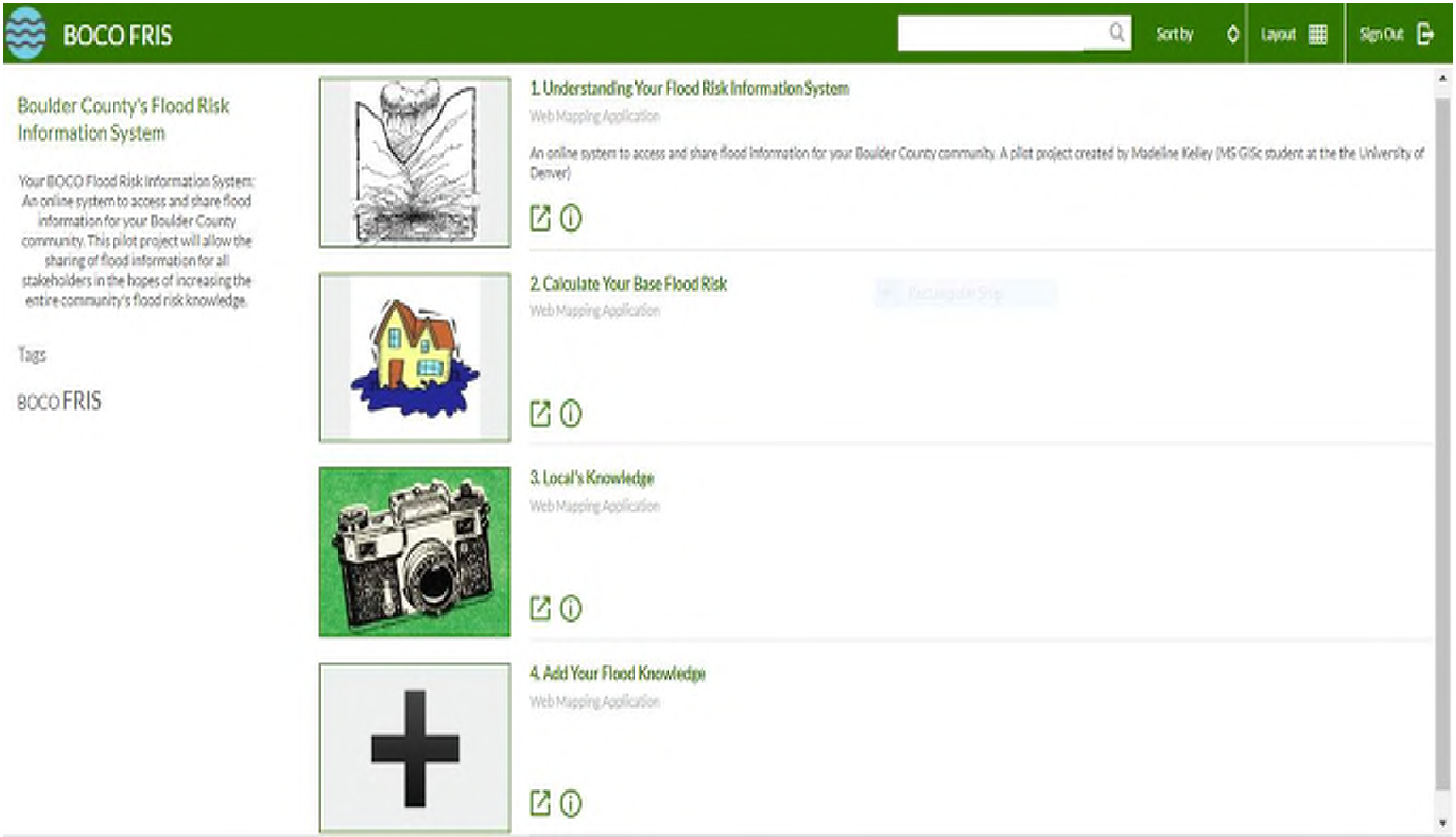
Figure 9: Project prioritization matrix evaluating benefits and challenges (Esri 2018)

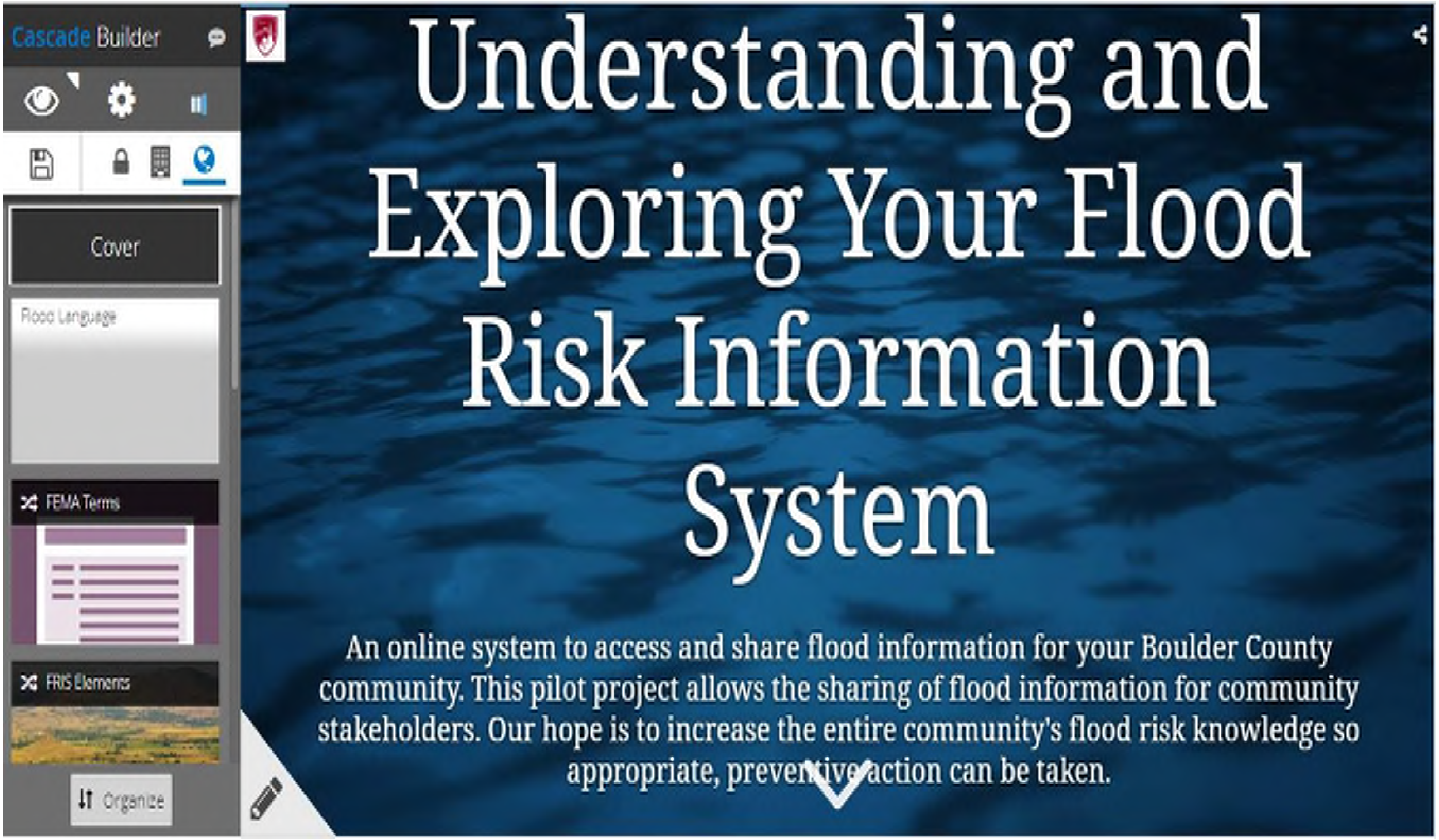
App Name	Description
FRIS App	An App of Apps. Organizes and displays other four applications
Understand Your Flood Risk Information System	A story map that provides background information on flooding and Boulder County
Calculate Your Base Flood Risk	Provides users with depth and cost estimates for structures
Local's Knowledge	Displays VGI and NFHL layers together
Add Your Flood Knowledge	Allows users to actively contribute to VGI layer




Configurable Apps
App Templates
App Builders
Widgets Components
SDKs
APIs
easier, quicker
coarse-grained
more black box
less coding
more effort, more time
fine-grained
more control
more coding

https://tinyurl.com/FRIS-CASFM




Cascade Builder
Cover
Flood Language
FEMA Terms
FRIS Elements
Organize
Understanding and Exploring Your Flood Risk Information System
An online system to access and share flood information for your Boulder County community. This pilot project allows the sharing of flood information for community stakeholders. Our hope is to increase the entire community's flood risk knowledge so appropriate, preventive action can be taken.

[redacted]

Online Community Flood Risk Products and Data

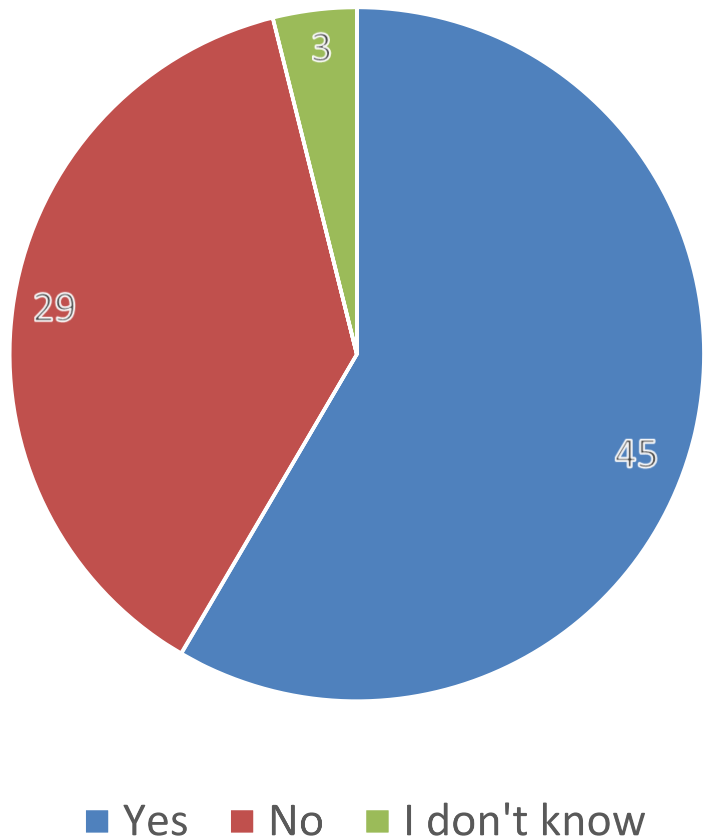
Electronic survey

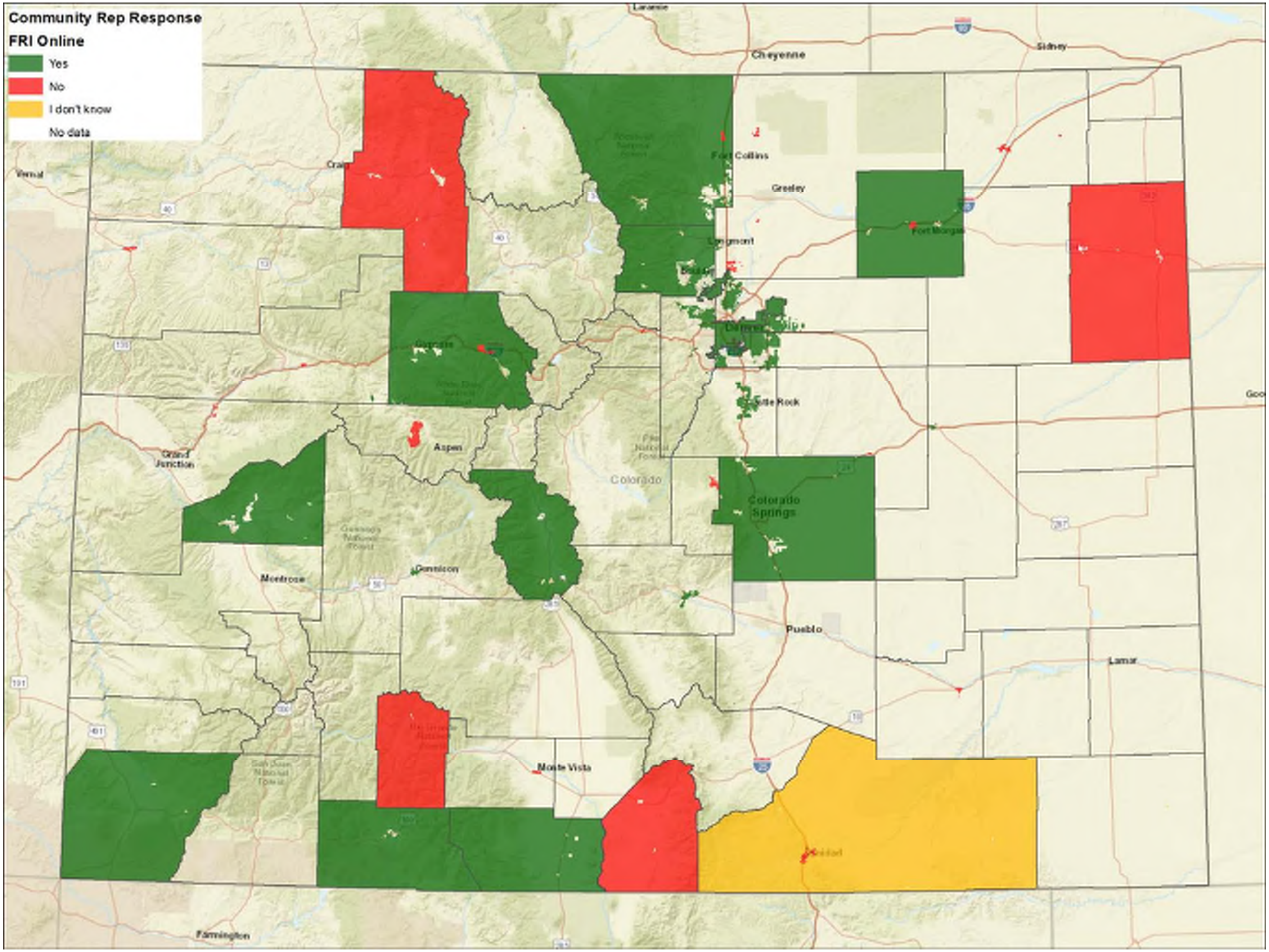
5 questions

77 responses

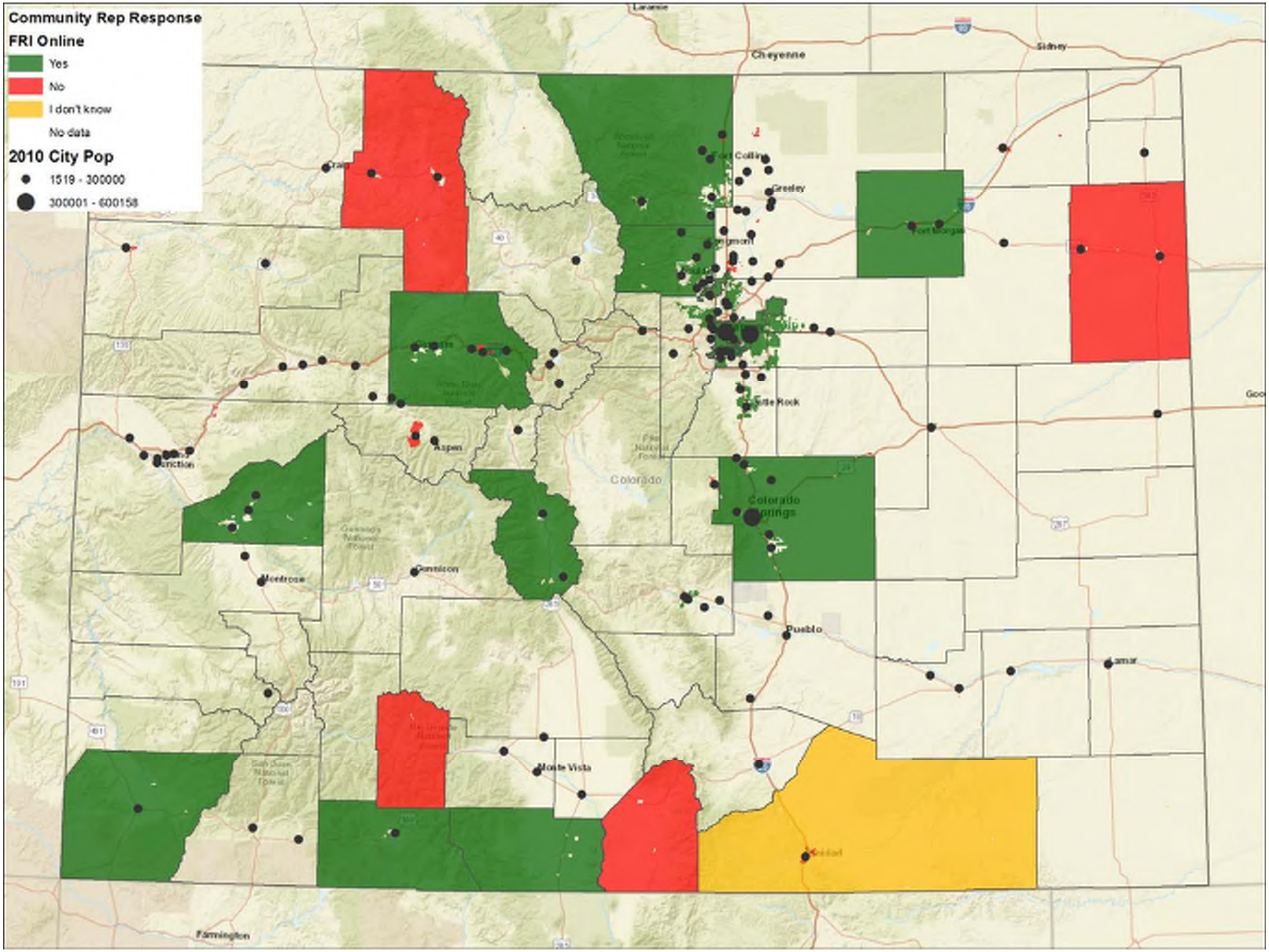
65 different communities

Does your community have flood risk information available online?



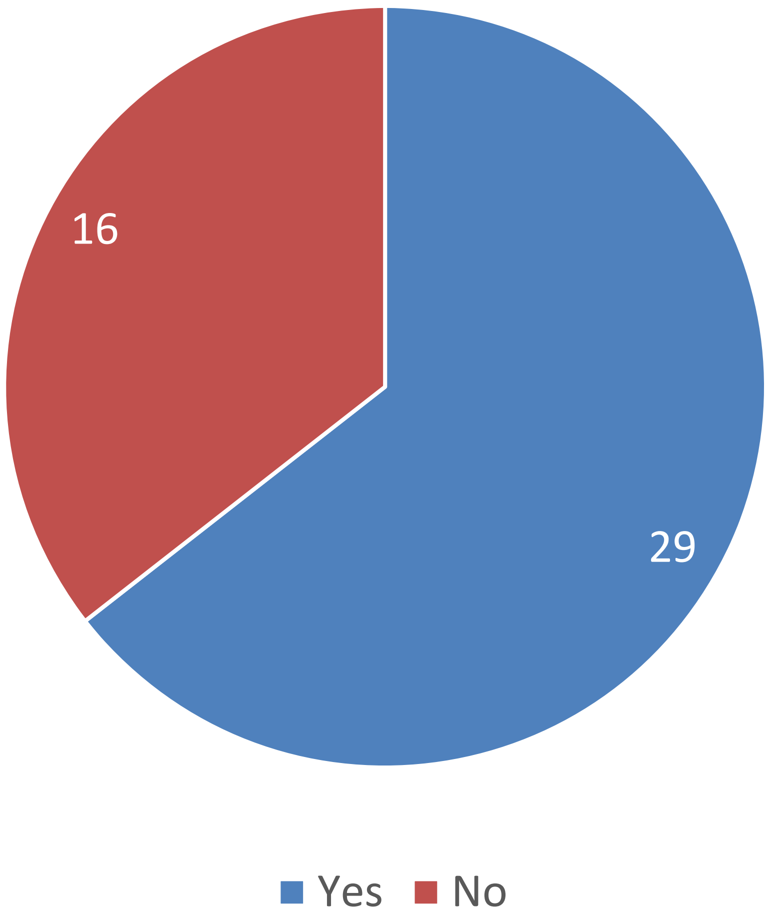


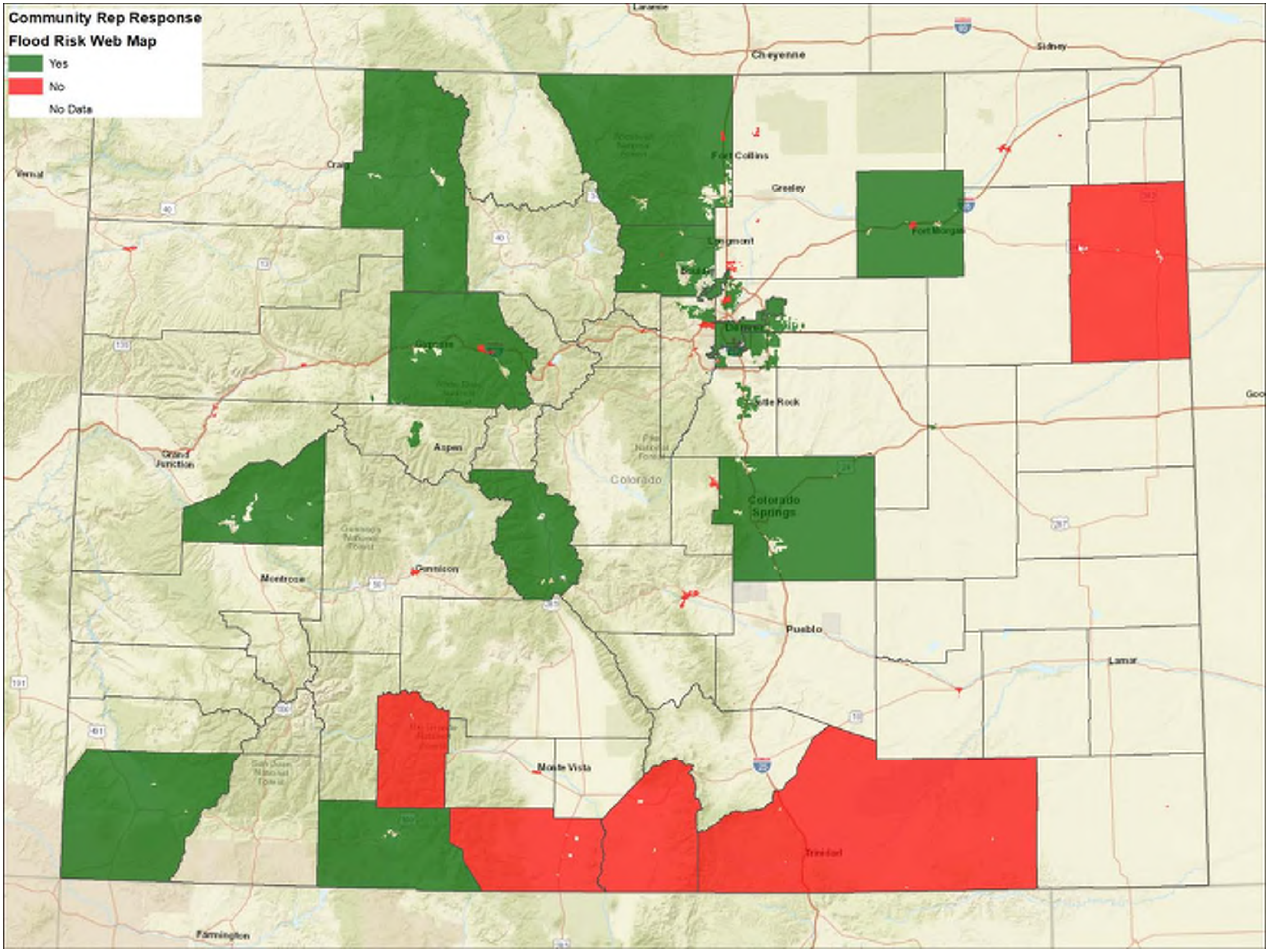
Community Rep Response
FRI Online
Yes
No
I don't know
No data
Cheyenne
Sidney
Fort Collins
Greeley
Craig
Vernal
Longmont
Boulder
Fort Morgan
Denver
Gypsum
Castle Rock
Aspen
Grand Junction
Colorado
Colorado Springs
Gunnison
Montrose
Pueblo
Lamar
Monte Vista
Trinidad
Farmington

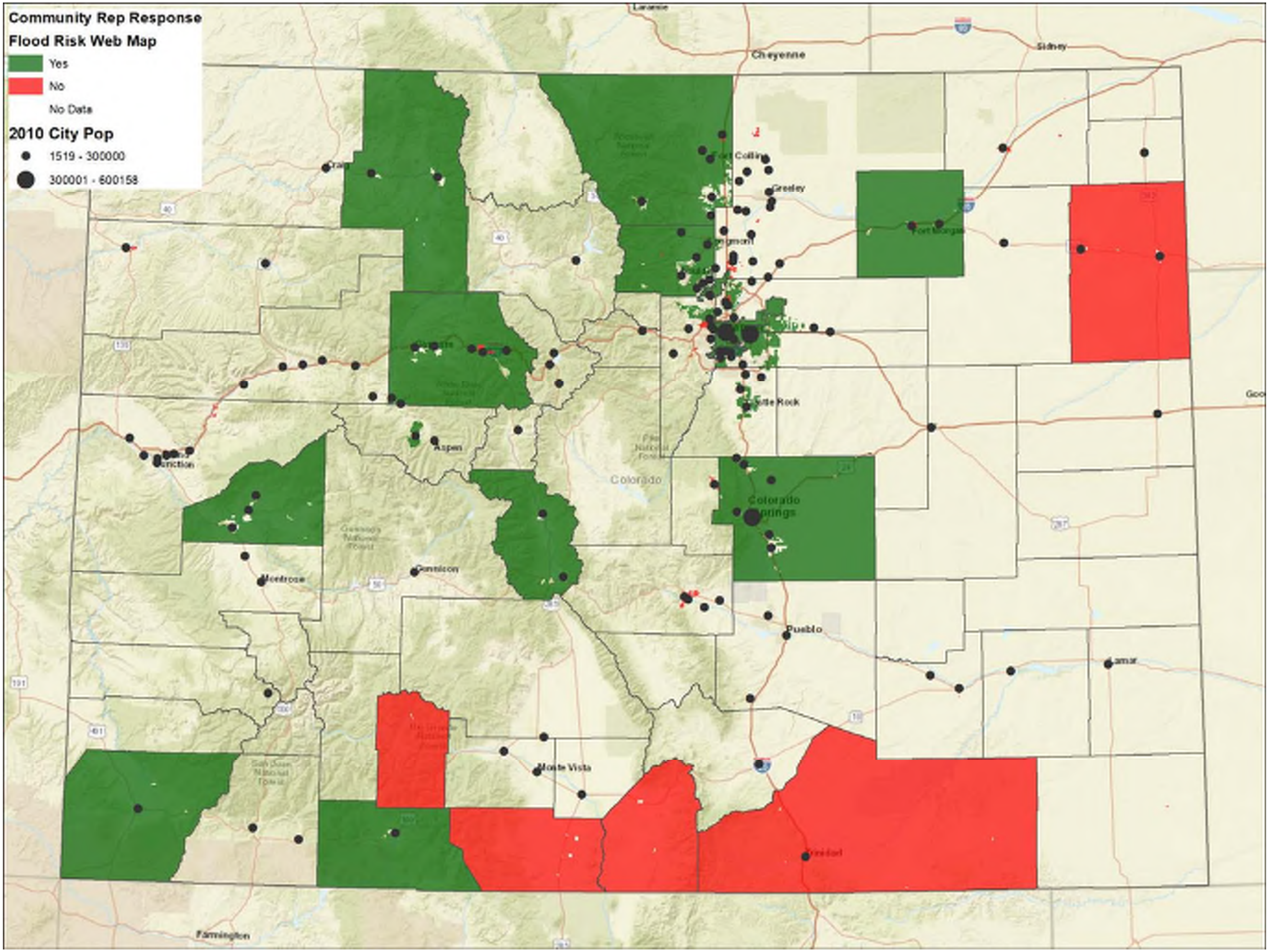

Community Rep Response
FRI Online
Yes
No
I don't know
No data
2010 City Pop
1519 - 300000
300001 - 600158
Cheyenne
Sidney
Fort Collins
Greeley
Fort Morgan
Castle Rock
Aspen
Colorado
Colorado Springs
Gunnison
Montrose
Pueblo
Lamar
Monte Vista
Farmington

Does the community's website have an interactive, dynamic WebApp or WebMap?

N= 45
(45 responded
'Yes' to online FRI)



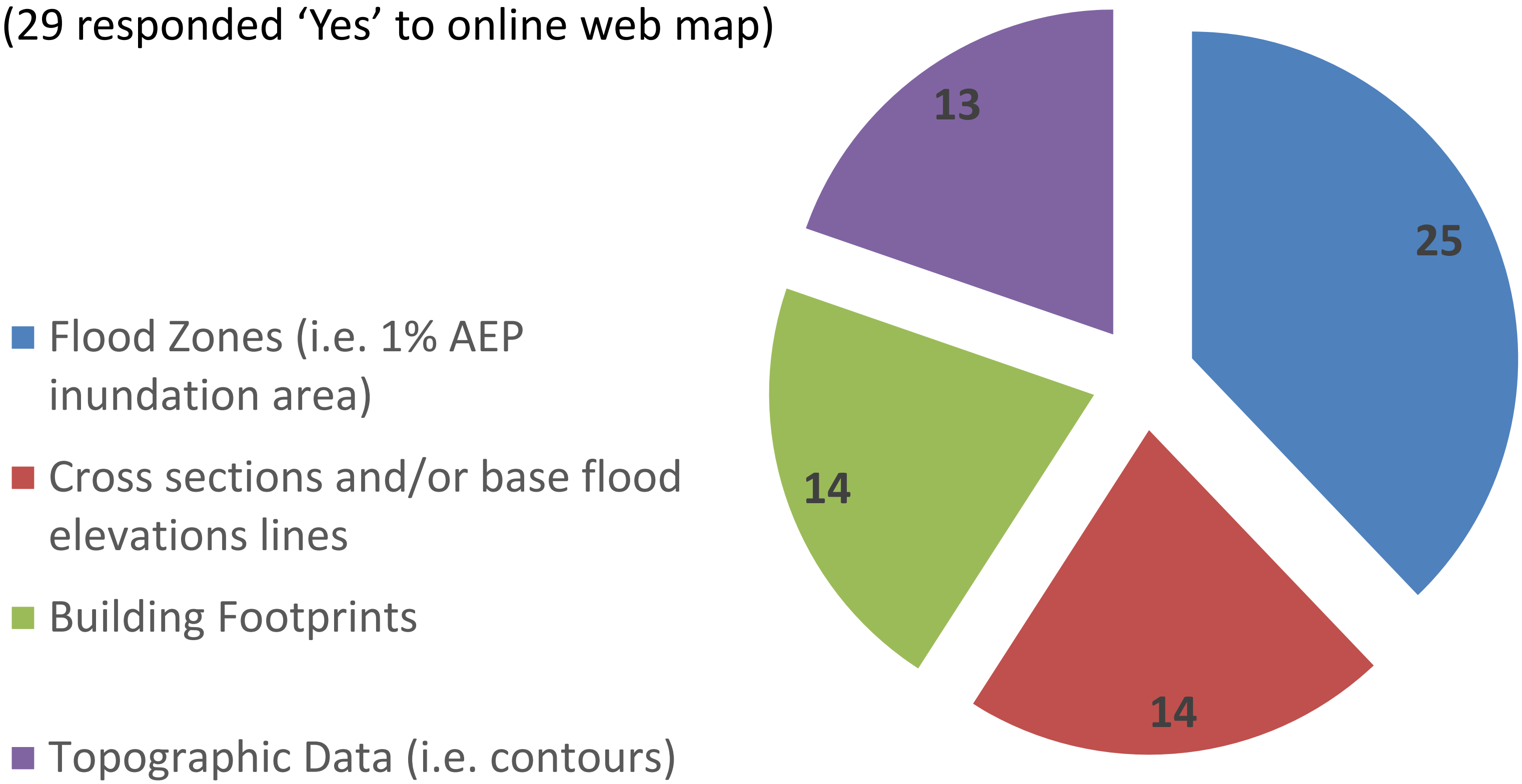

Community Rep Response
Flood Risk Web Map
Yes
No
No Data
Cheyenne
Sidney
Fort Collins
Greeley
Longmont
Boulder
Fort Morgan
Denver
Castle Rock
Vernal
Craig
Grand Junction
Gypsum
Aspen
Colorado
Colorado Springs
Montrose
Gunnison
Pueblo
Lamar
Monte Vista
Trinidad
Farmington



Community Rep Response
Flood Risk Web Map
Yes
No
No Data
2010 City Pop
1519 - 300000
300001 - 600158
Cheyenne
Sidney
Fort Collins
Greeley
Longmont
Fort Morgan
Castle Rock
Aspen
Colorado
Colorado Springs
Gunnison
Montrose
Pueblo
Lamar
Monte Vista
Trinidad
Farmington

Does the WebApp or WebMap have the following? (Select all that apply)

N= 27
(29 responded 'Yes' to online web map)



Discussion

•Set out to create a proof-of concept tool that promotes communication specifically the exchange of flood risk information.

•Limitations included, the FRIS was a successful proof-of-concept project that addresses the main gaps accentuated by government reports, academic literature, and the community feedback

•FRIS products are not "one size fits all" or static.

Future

•Incorporate new NFHL as it becomes effective

•Explore improvements for structure specific tool

•More focus groups to increase participants reprensentation of the community

•Product testing, implementation, improvemnt

• Use FRIS to adovate for more/new data (especially non-regulatory)

The University of Denver Geography and the Environment Department

DR. HILLARY B. HAMANN, DR. JING LI, DR. E. ERIC BOSCHMANN

Colorado Water and Conservation Board

THUY PATTON, STEPHANIE DIBETITTO, CAROLYN KEMP

Boulder County

ERIN COOPER, DAVE WATSON

The Urban Drainage and Flood Control District

TERRI FEAD, MORGAN LYNCH, KEVIN STEWART

The Army Corps of Engineers

PATRICK NOWAK

Funded by

Laurance C. Herold Fund

2017 GIS in the Rockies Scholarship

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Questions?

CASFM 2018 Annual Conference

Floodplain Management Sessions:

Session1: Local Choices and How They Can Impact the National Flood Insurance Program

Traci Sears (Montana DNRC)

Session2: Hyper Hydrology: A Holistic View of Colorado Hydrology

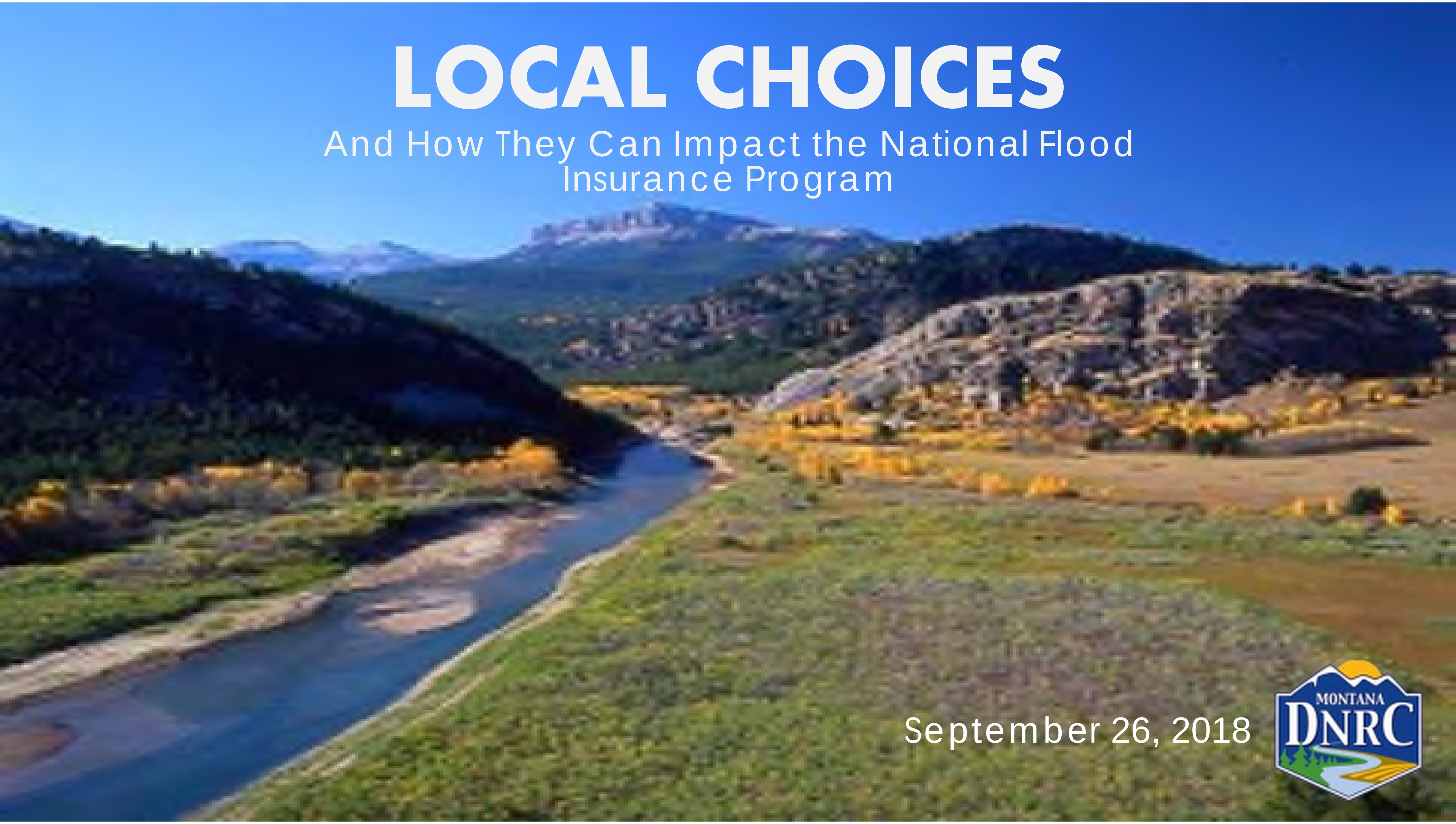
Chris Ide (Wood), Joshua Hill (Wood)

Making The Most Of It: Leveraging The CHAMP Study For Other Uses

Erin Cooper (Boulder County), Olivia Cecil (Boulder County), Kevin Doyle (Michael Baker Intl.)

LOCAL CHOICES

And How They Can Impact the National Flood Insurance Program



September 26, 2018

AN AGREEMENT

FEDERAL GOVERNMENT

makes subsidized
flood insurance available
within the community

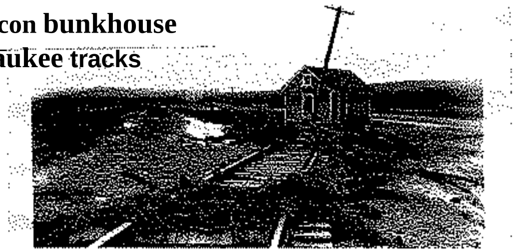
LOCAL COMMUNITIES

adopt and enforce
floodplain regulations that
meet FEMA requirements

(VOLUNTARY)

June 17, 1950 Flood of Alkali and Antelope Creeks

Ed S. Bacon bunkhouse
on Milwaukee tracks



Rich and Sue Knudson
Box 179
Harlowton, MT59036

MTDNRC
PO Box 201601
Helena, MT 59620-1601

Traci,

Here are copies of the letter my mom wrote to her aunt and uncle following the flood of 6/17/1950, here in Harlowton. The pictures are of her parents property a mile and a half north of town on the Old Gap Road. The house was moved into Harlo and we now live in it. My son and I still own the property north of town. According to her brother and Dad, the wall of water -9 feet high at the barn- came down Alkali Creek to start with as 9 earth dams breeched with the downpour.

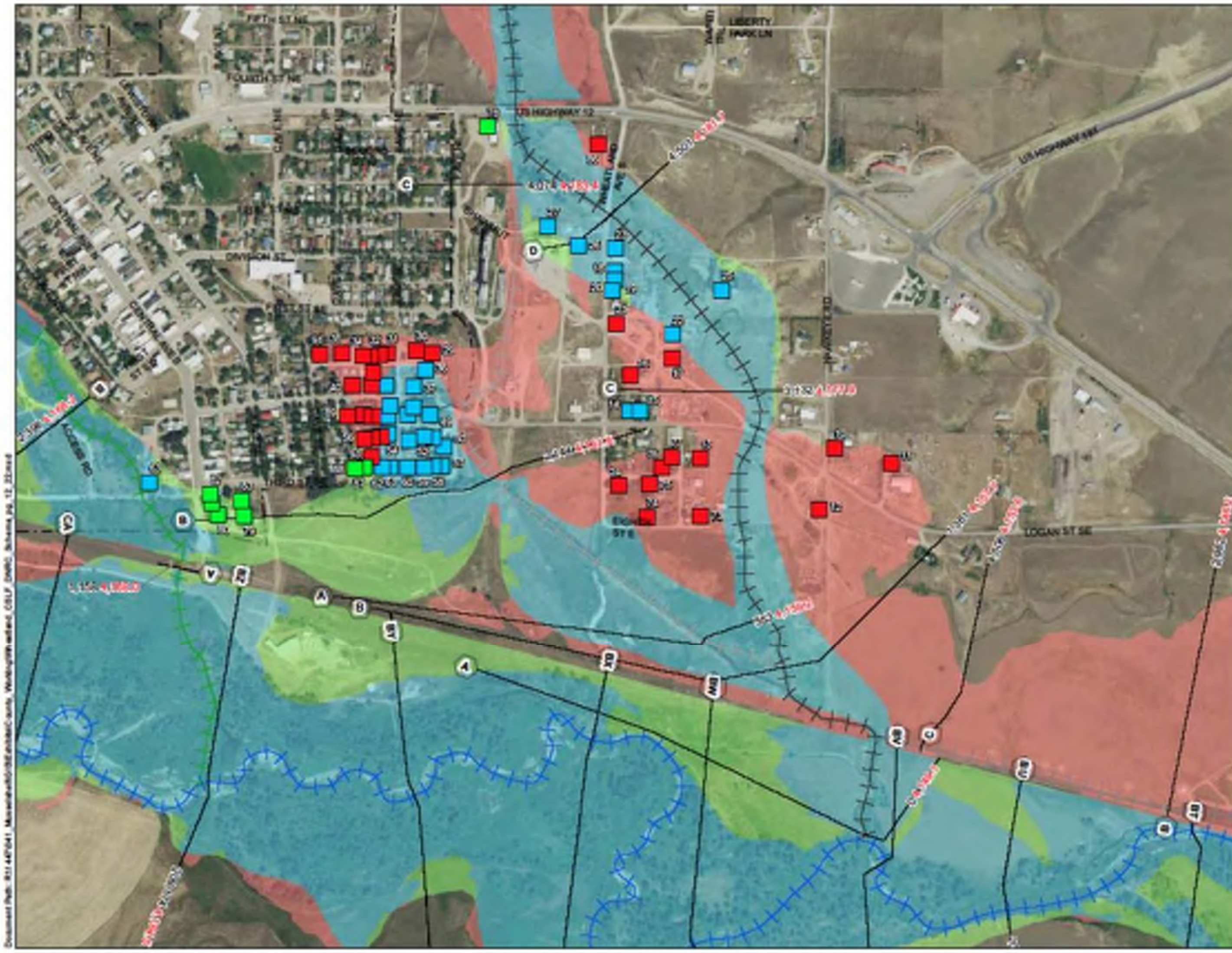
Our son has added to the bunkhouse and now lives in it. After the flood, it was moved to higher ground.

Hope you might find a use for these.

Happy Thanksgiving to all of your crew!

Rich and Sue Knudson

RECEIVED
NOV 13 2017
D.N.R.C



CHANGES SINCE LAST FIRM - PROPOSED STRUCTURE CHANGES FOR FLOODPLAIN

LEGEND

- Proposed 100-yr Floodplain - Increase
- Proposed 100-yr Floodplain - Decrease
- Proposed 100-yr Floodplain - No Change
- Structure - In Increase Area
- Structure - In Decrease Area
- Structure - In No Change Area

Labels

- A Cross Section Letter
- 79,725 River Station
- 4,700.0 Water Surface Elevation
- 100 Feet Along Profile Baseline

0 250 500 750 Feet

CSLF Work Map - Musselshell Watershed Project - Ph. II
Wheatland County, MT Risk MAP - MAS No. 2015-02
NAIP 2015, Horizontal Datum: NAD83
Submitted 4/25/2017

Morrison Maierle

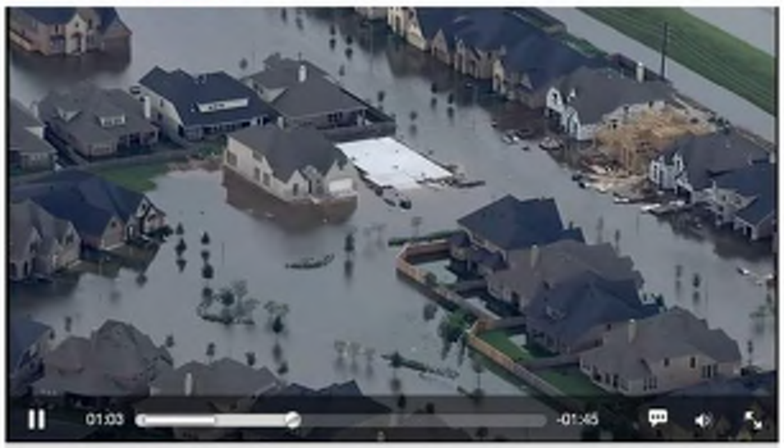
LOCATOR MAP

Musselshell River Map 18 of 22

abc13 SECTIONS TRAFFIC WATCH

'Neighborhood should have not been built': Homeowners file lawsuit against developer after flooding issues

Share G+ Tweet Email



EMBED </> MORE VIDEOS ▸

Homeowners suing developer in Sugar Land, Miya Shay reports.

Bloomberg Businessweek

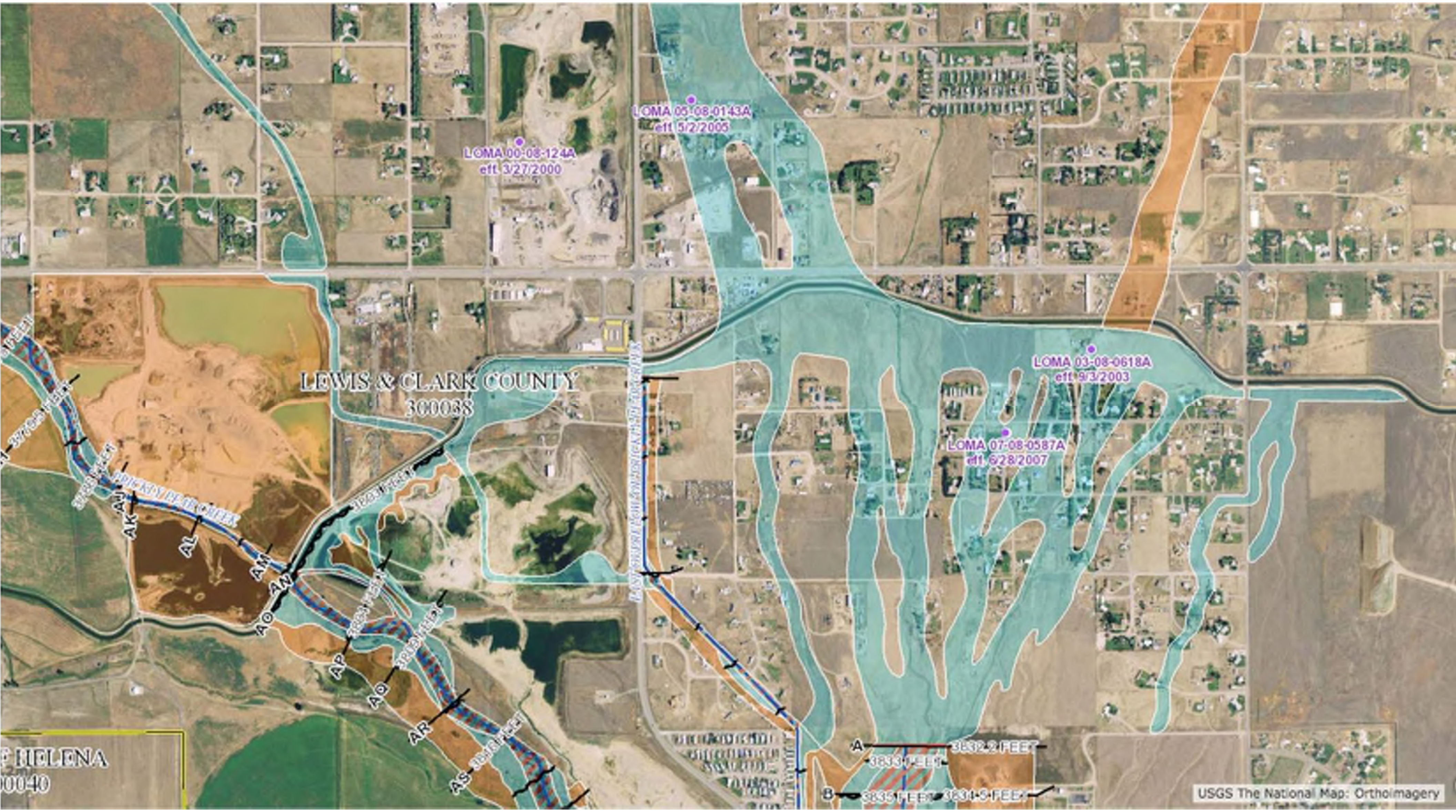
August 31, 2017, 3:00 AM MDT

Harvey Wasn't Just Bad Weather. It Was Bad City Planning

Houston exulted in sprawling, hands-off growth. That's no way to prepare for natural catastrophes.


PARTIAL FAILURE OF FORT PECK DAM AS SEEN FROM THE AIR.


Minot, ND (2011)



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eft. 3/2/2005
LOMA 00-08-124A
eft. 3/27/2000
LEWIS & CLARK COUNTY
300038
LOMA 03-08-0618A
eft. 9/3/2003
LOMA 07-08-0587A
eft. 6/28/2007
AJ
AK
AL
AM
AN
AO
AP
AQ
AR
AS
HELENA
A
3832.2 FEET
3833 FEET
B
3835 FEET
3834.5 FEET
USGS The National Map: Orthoimagery

Variances

Example Permit Application Request - Background Information

- Tongue River residential home
  - **Pre-FIRM – built in 1972**
  - **Mapped into floodplain in 2010 with new study**
  - **Since 2010 – entire home is located in AE Zone Floodway**
- In 2017, the homeowner submits floodplain application to:
  - **Add an addition to the house – one bedroom and additional bathroom**
  - **Proposed elevation of addition same as existing house**
- Permit was denied because:
  - **Existing code allows no new structures in floodway**
  - **Existing code requires New construction or substantial improvement of any residential structure …… lowest level of floor is at two feet above the base flood elevation**

The existing residential structure is one foot below the Base Flood Elevation (BFE)

MONTANA DNRC

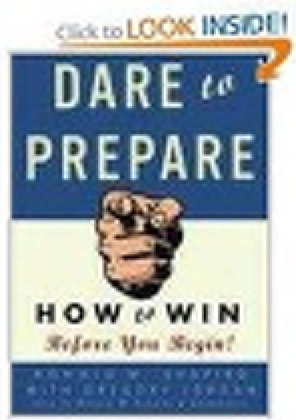
Variances

- **Proposed variances from must show the following**:
  - Good and Sufficient cause is shown
  - An exceptional hardship to the applicant exists
  - The variance provides the minimum necessary action to afford relief
  - The variance will not increase flood heights, cause additional threats to public safety, cause extraordinary public expense, create nuisances, cause fraud or victimization of the public, or conflict with local laws or ordinances.
  - If a variance is granted, the community must maintain a record of all variances
  - Variances are for floodplain management purposes only and could significantly affect insurance premium rates on affected structures.

BEST ADVICE TO DECISION MAKING BOARDS – DON'T GRANT THESE VARIANCES UNLESS ABSOLUTELY NECESSARY

MONTANA DNRC

Mitigation and Recovery



- Keys to Recovery Success
  - Act quickly
  - Actively plan
  - Engage the community
  - Develop partnerships, networks and effective coordination strategies

- Systematic and inclusive
- Leadership and unity of effort
- Pre-disaster & post-disaster recovery planning

Basic Enforcement Process

- Right to inspection (inspection of work in progress)
- Stop work order
- Revocation of permit
- Right to periodic inspection
- Violations to be corrected
- Actions in event of failure to take corrective actions
- Order to take corrective actions
- Appeal
- Failure to comply
- Section 1316

How is Section 1316 used?

- Intended for use primarily as a backup for local enforcement actions (i.e., if a community could not force compliance through the enforcement mechanisms in its regulations, it could use Section 1316 as additional leverage)
- Not intended merely as a mechanism to remove bad risks from the policy base
- Section 1316 will only be implemented in instances where States or communities submit declarations specifically for that purpose.

No Adverse Impact

Managing principle focused on the impact on others

- Protects property rights—ensures action of any property owner does not adversely impact the property rights of others
- Leads to reduced flood losses while promoting better stewardship and community mitigation efforts
- Prevention of harm is treated different legally than making the community a better place—tougher to challenge in court

Thank you!

- **Traci Sears**
  (406) 444-6654
  tsears@mt.gov

wood.

Hyper Hydrology: A Holistic View of Colorado Hydrology

Through the Colorado Hazard Mapping Program

woodplc.com

Outline

- CHAMP III Overview
- Colorado's Hydrologic Regions
- Hydrology Methods
- Hydrologic Region Specifics

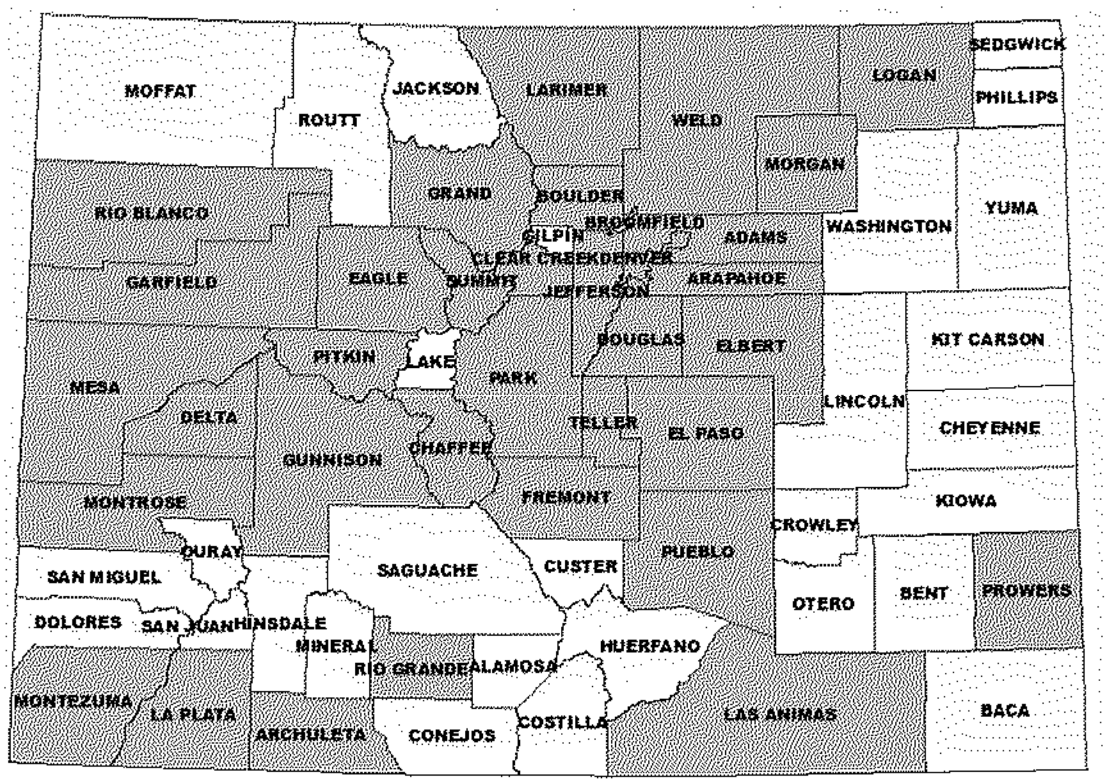
THANK YOU!

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

CHAMP III

Colorado Hazard Mapping Program – Phase III

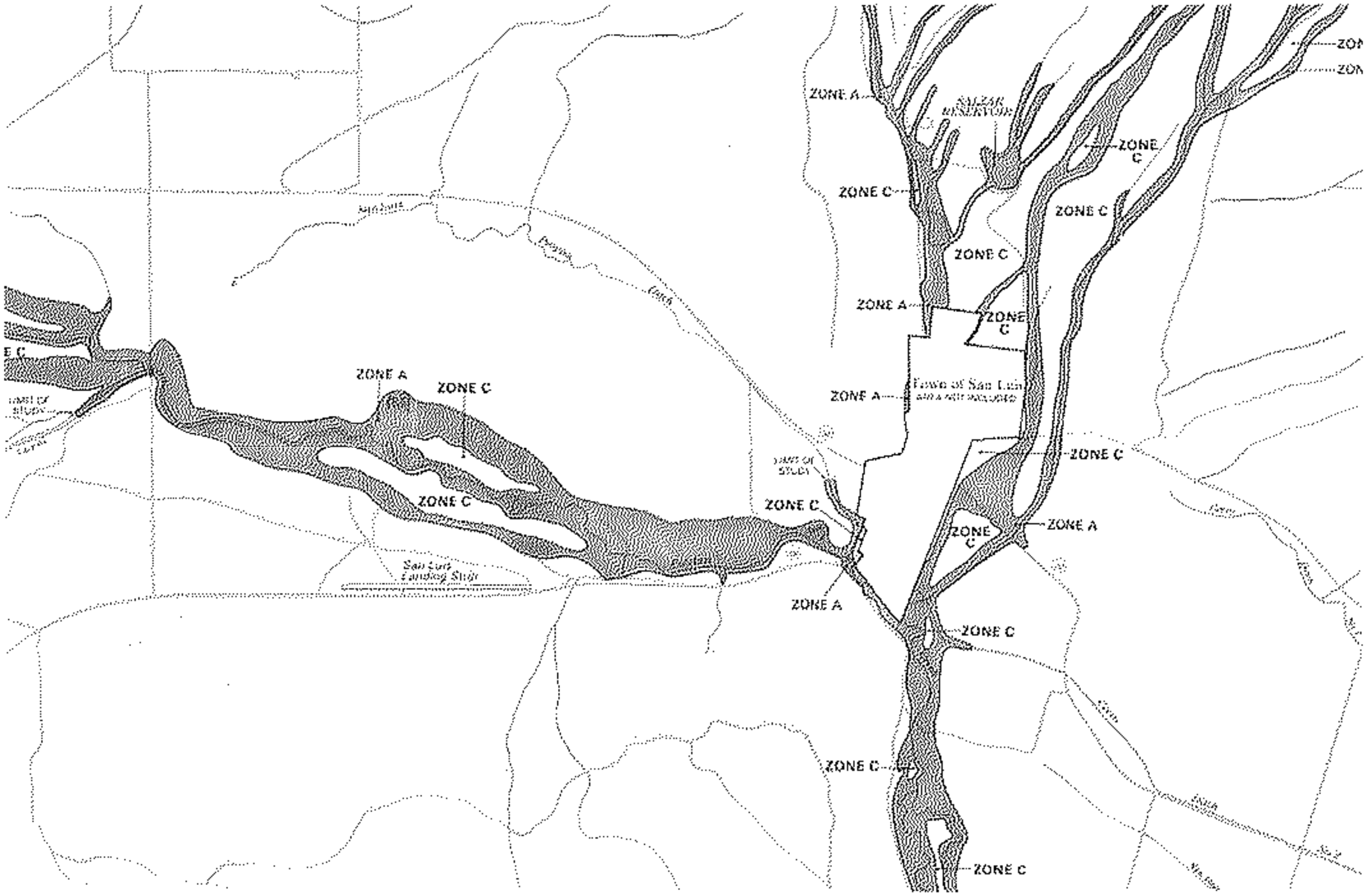
Modernized vs. Unmodernized



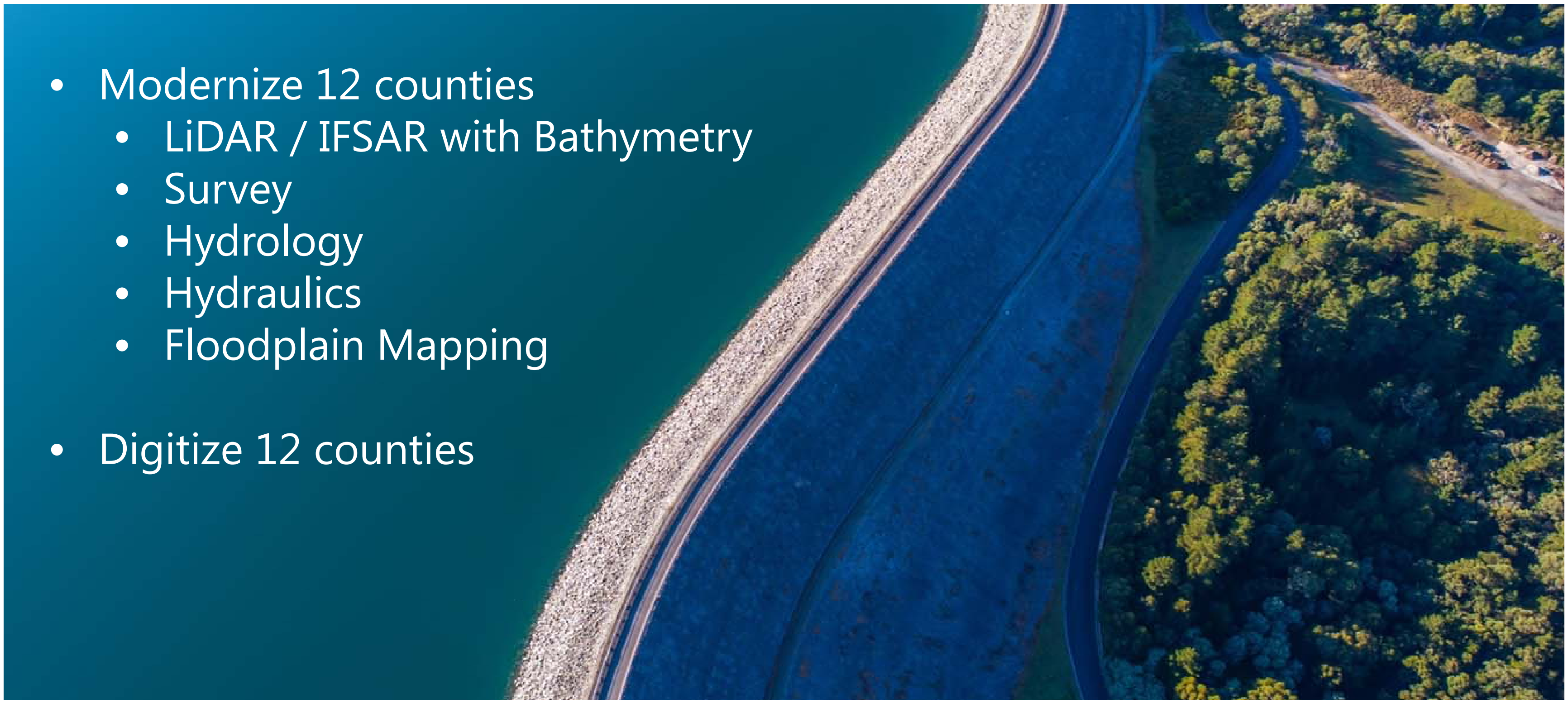
Modernized

Unmodernized

Modernized vs. Unmodernized

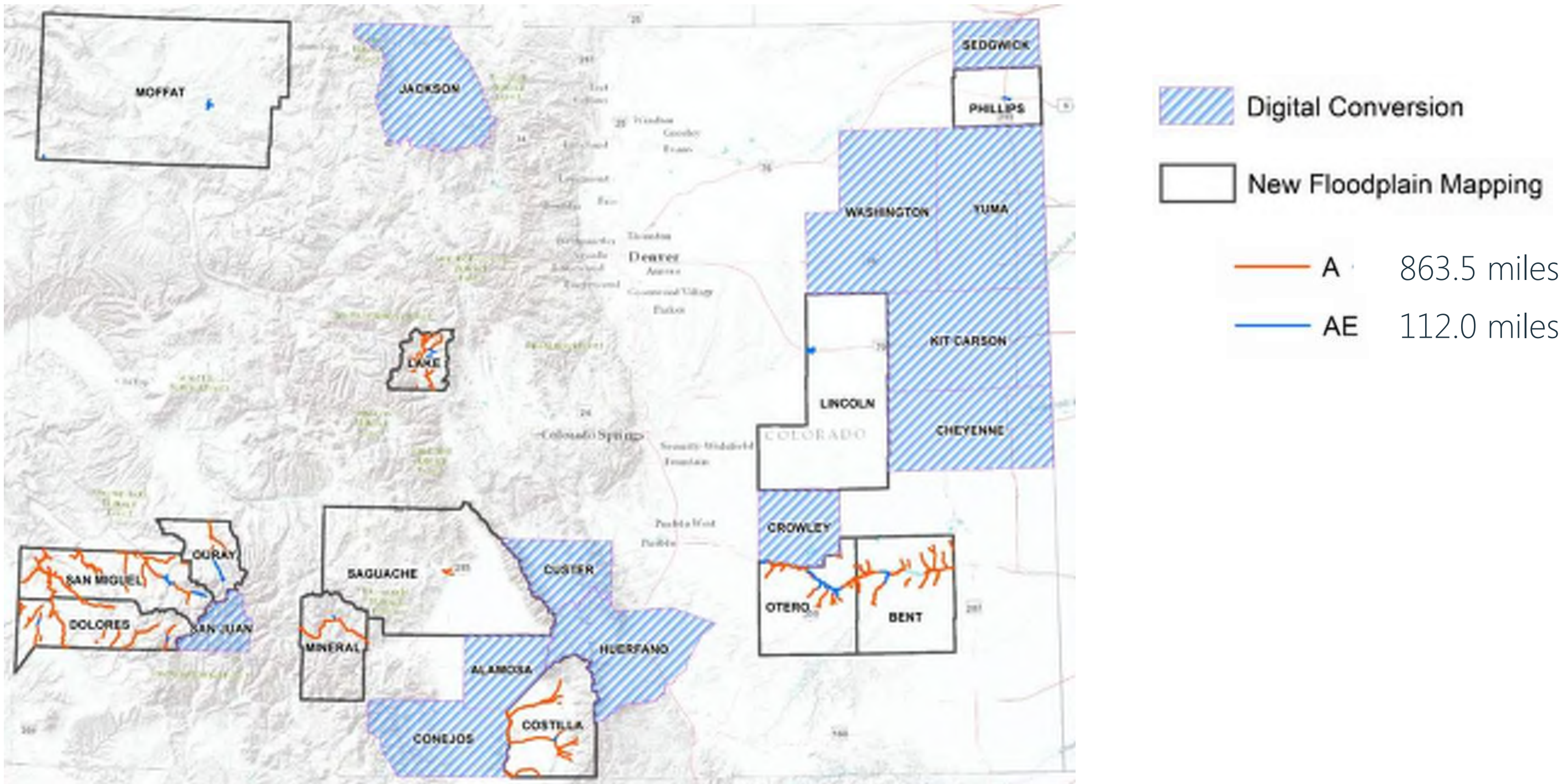


Phase III Goals



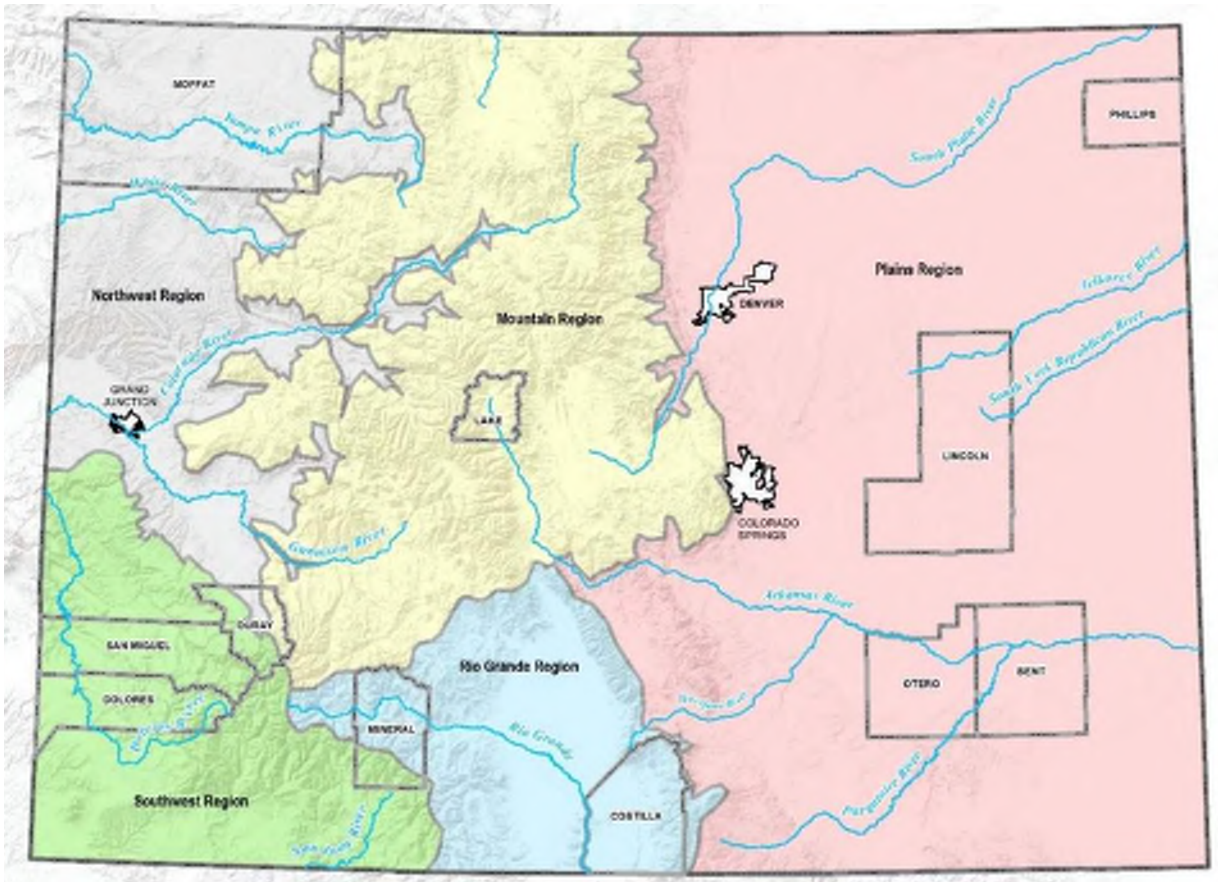
- Modernize 12 counties
  - LiDAR / IFSAR with Bathymetry
  - Survey
  - Hydrology
  - Hydraulics
  - Floodplain Mapping
- Digitize 12 counties

Phase III Scope



Colorado’s Hydrologic Regions

Colorado Hydrologic Regions



Plains Regions

Paleoflood Investigations to Improve Peak-Streamflow Regional-Regression Equations for Natural Streamflow in Eastern Colorado, 2015

USGS SIR 2016-5099

West Regions

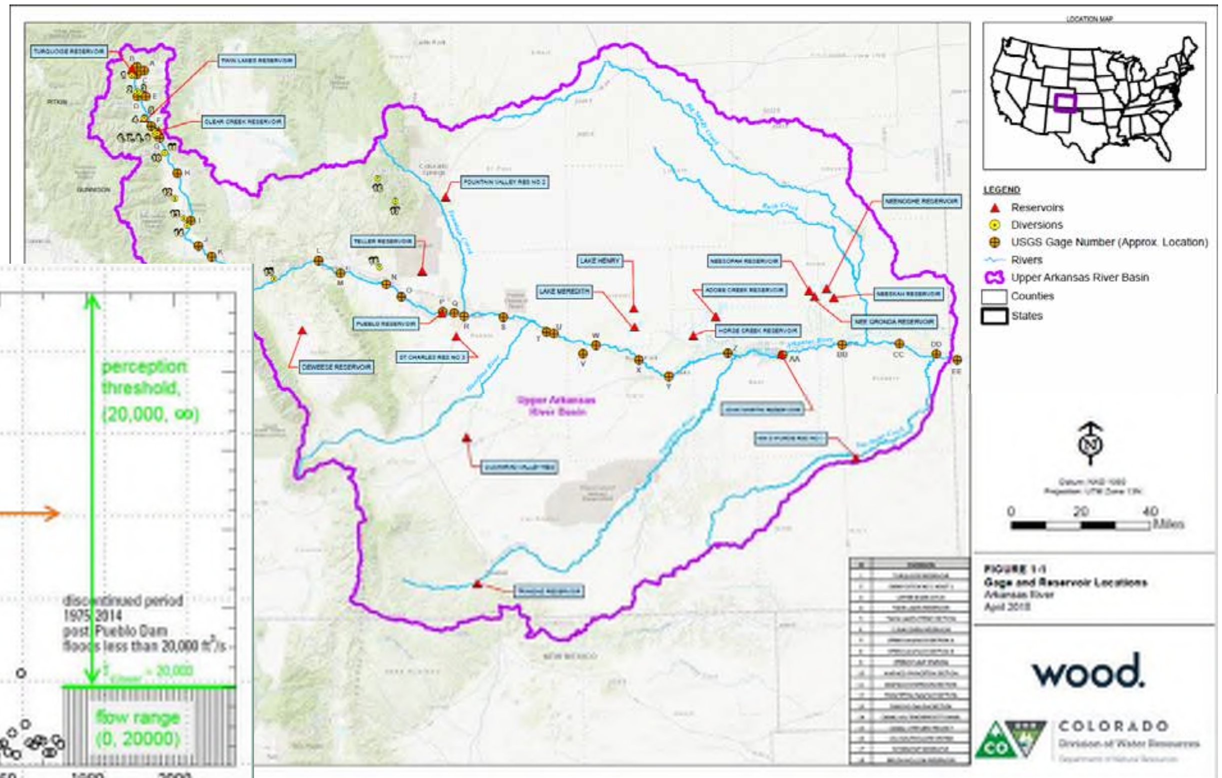
Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado, 2009

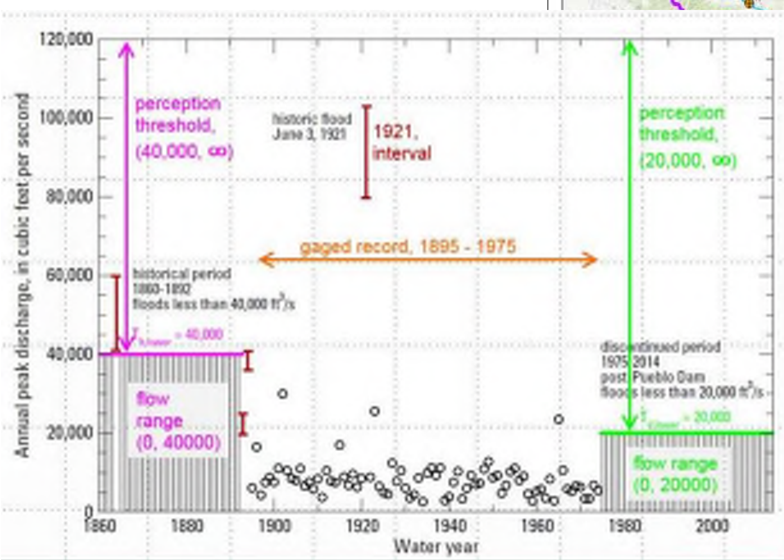
USGS SIR 2009-5136

Hydrology Methods

Bulletin 17C Gage Analysis

USGS and DWR Peak Flows

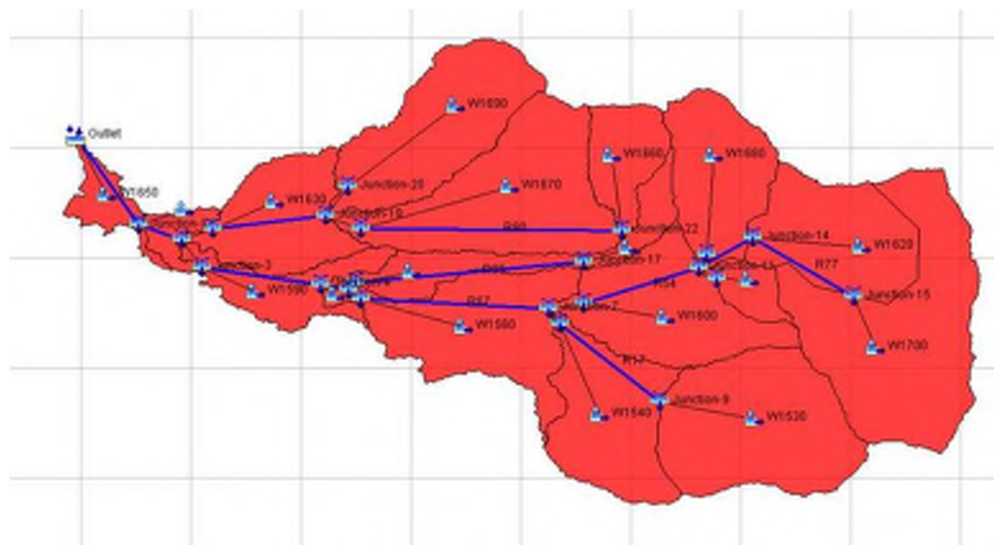




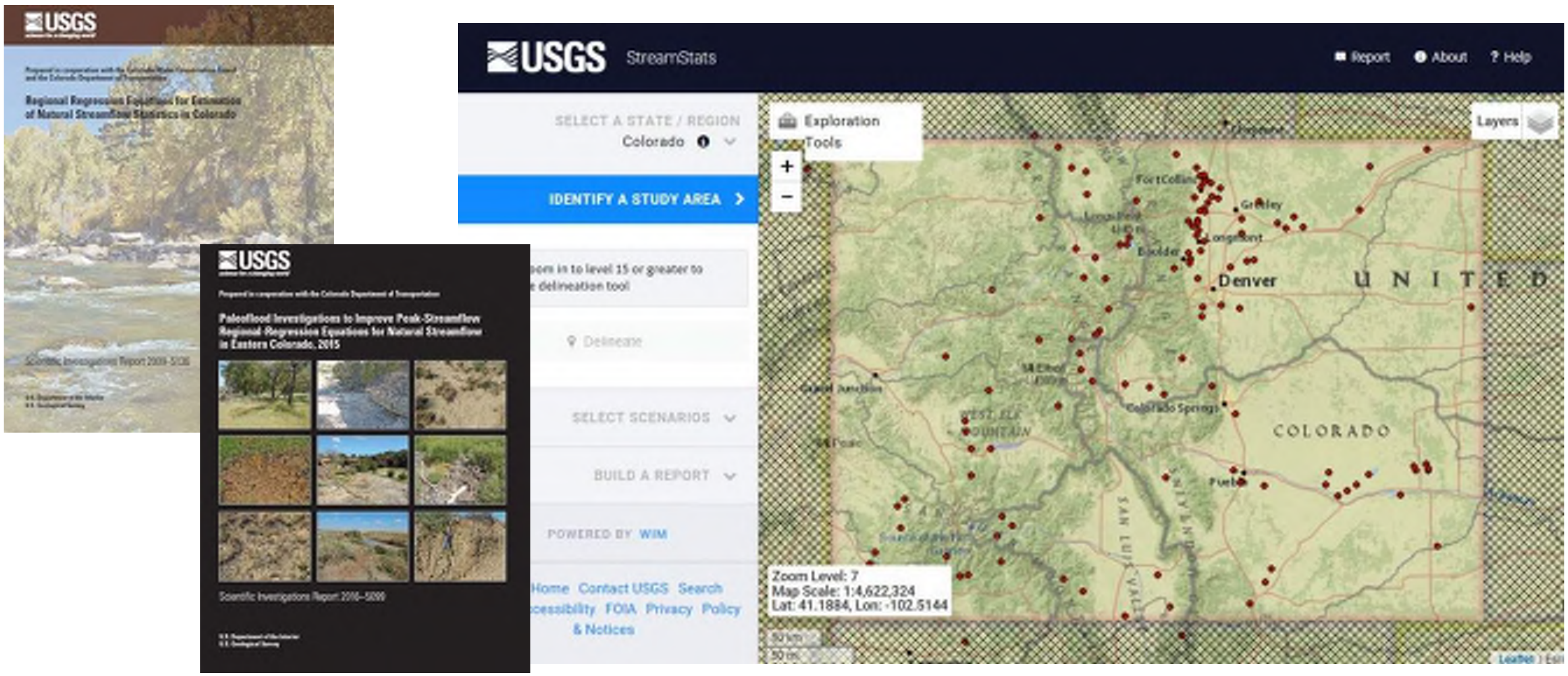
Hydrologic Modeling

HEC-HMS

- SCS Type II Rainfall Distributions
- Atlas 14 Rainfall Totals
- TR-55 Curve Number
- Wood Tools
  - Basin Delineation
  - Time of Concentration

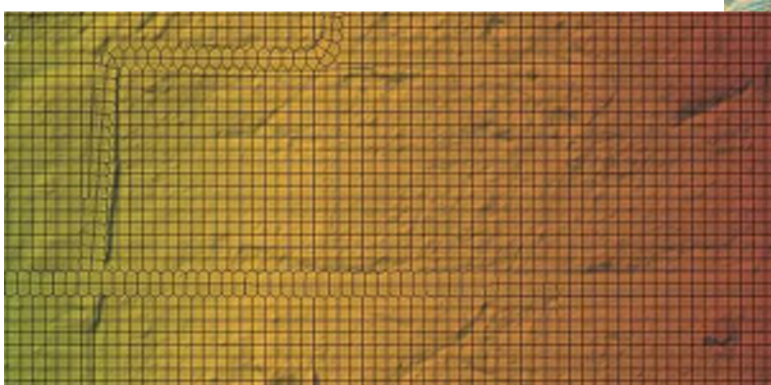


Regression Equations

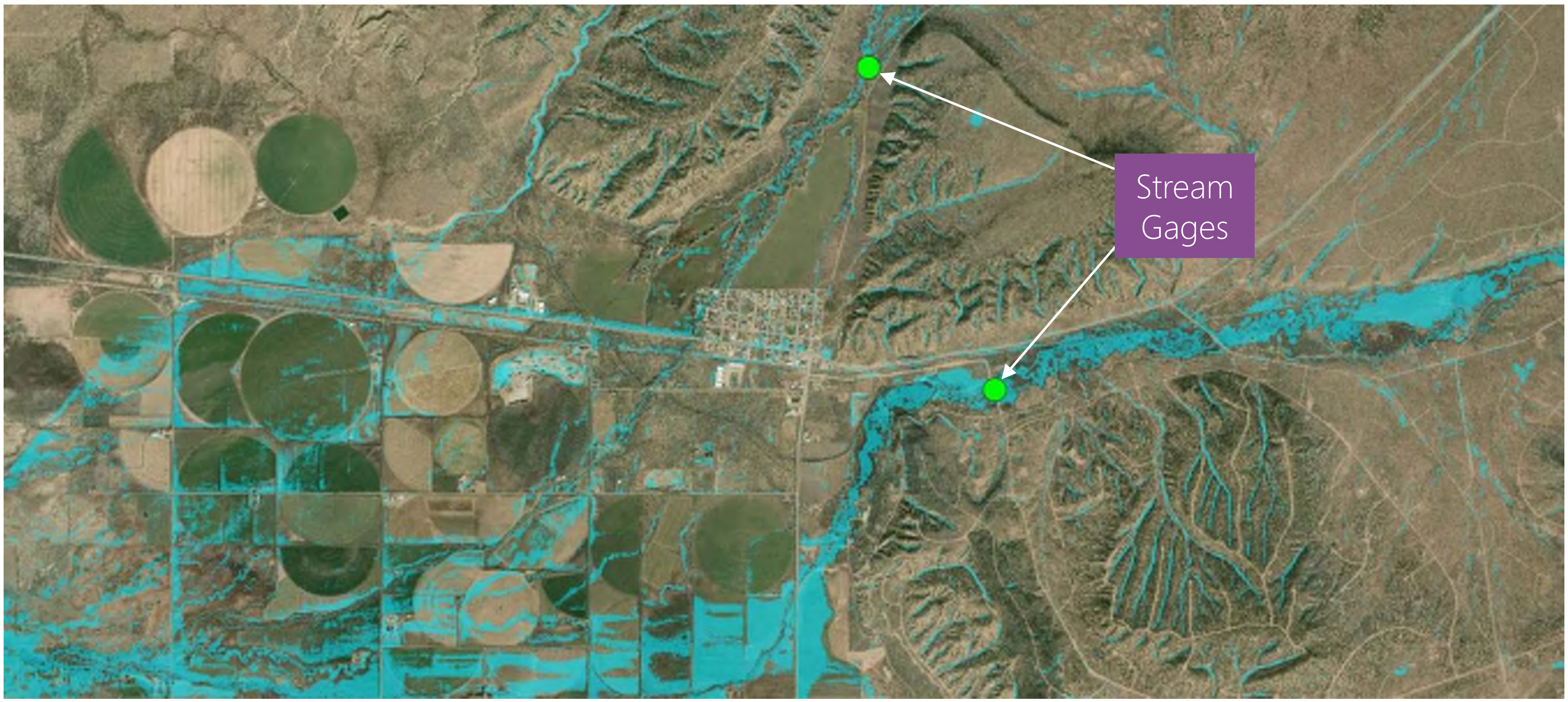


Rain-on-Grid

- HEC-RAS 5.0.5
  - HMS Parameters
  - Input Hydrographs



Rain-on-Grid



Hydrologic Region Specifics

Southwest Region

Peak Streamflow Regression Equation

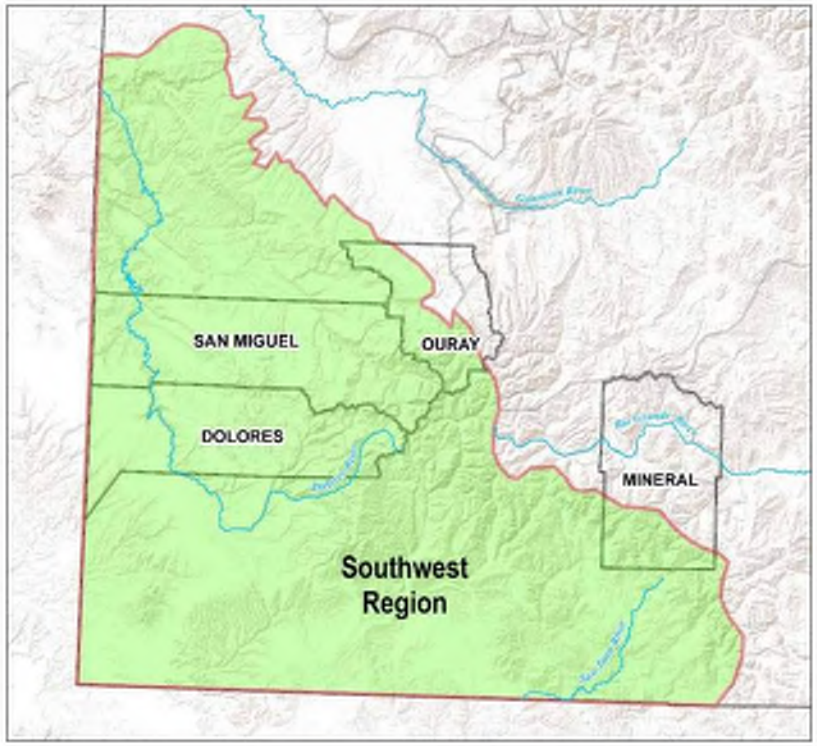
$$Q_{100} = 10^{2.91} A^{0.59} A_{7500}^{-0.33}$$

Drainage Area

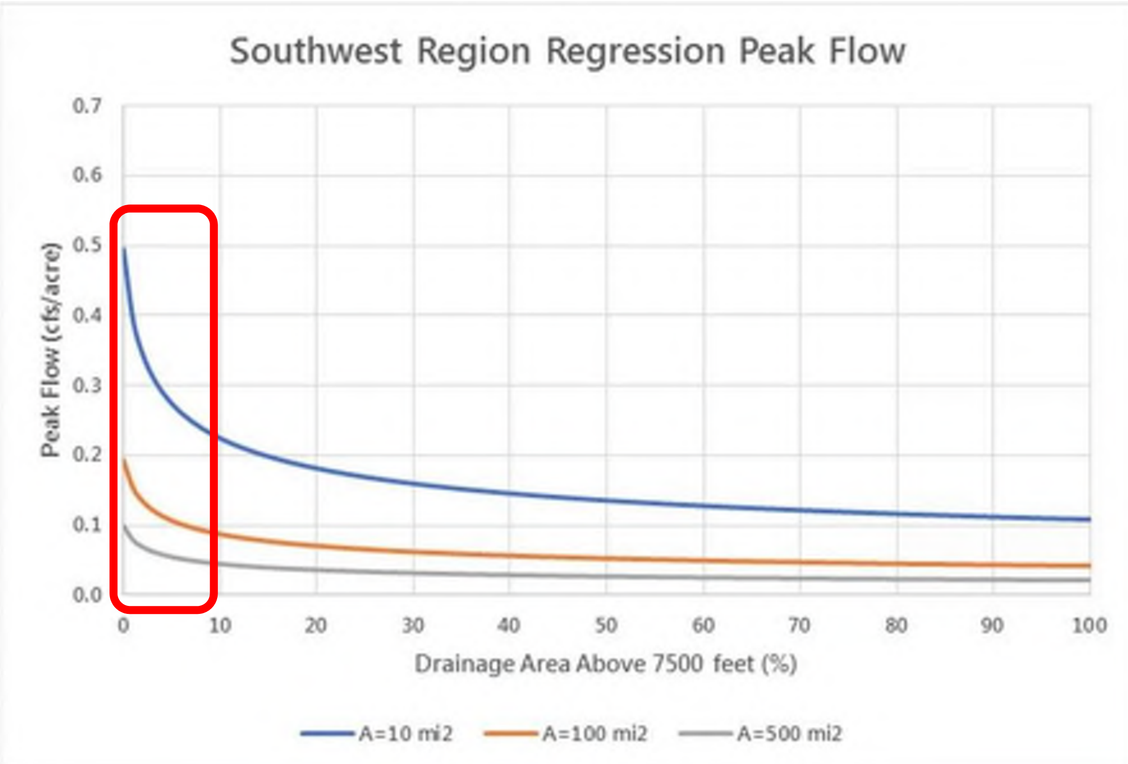
Percentage of A above 7,500 feet (plus 1)

Challenges:

- Regression was overestimating peak flows for low-lying areas.
- HEC-HMS models were overestimating runoff for high-elevation basins.

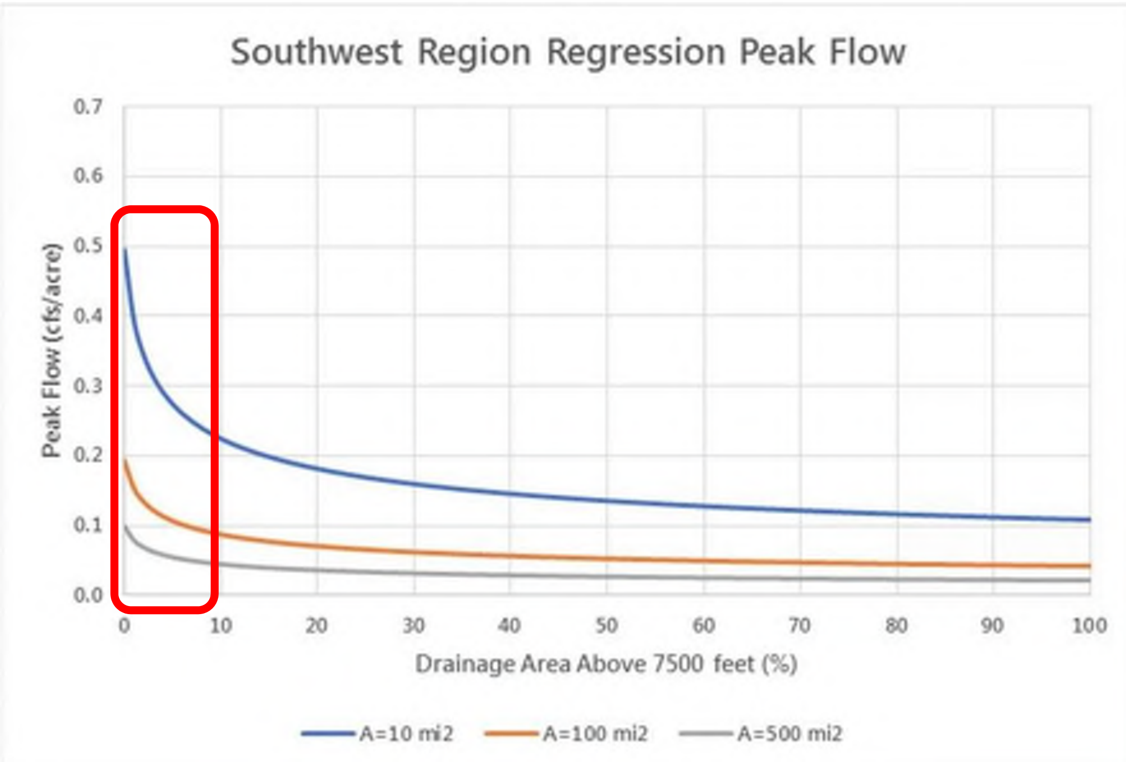


Southwest Region



The peak flow is overestimated when there is a small percentage of drainage area above 7,500 ft.

Southwest Region



The peak flow is overestimated when there is a small percentage of drainage area above 7,500 ft.

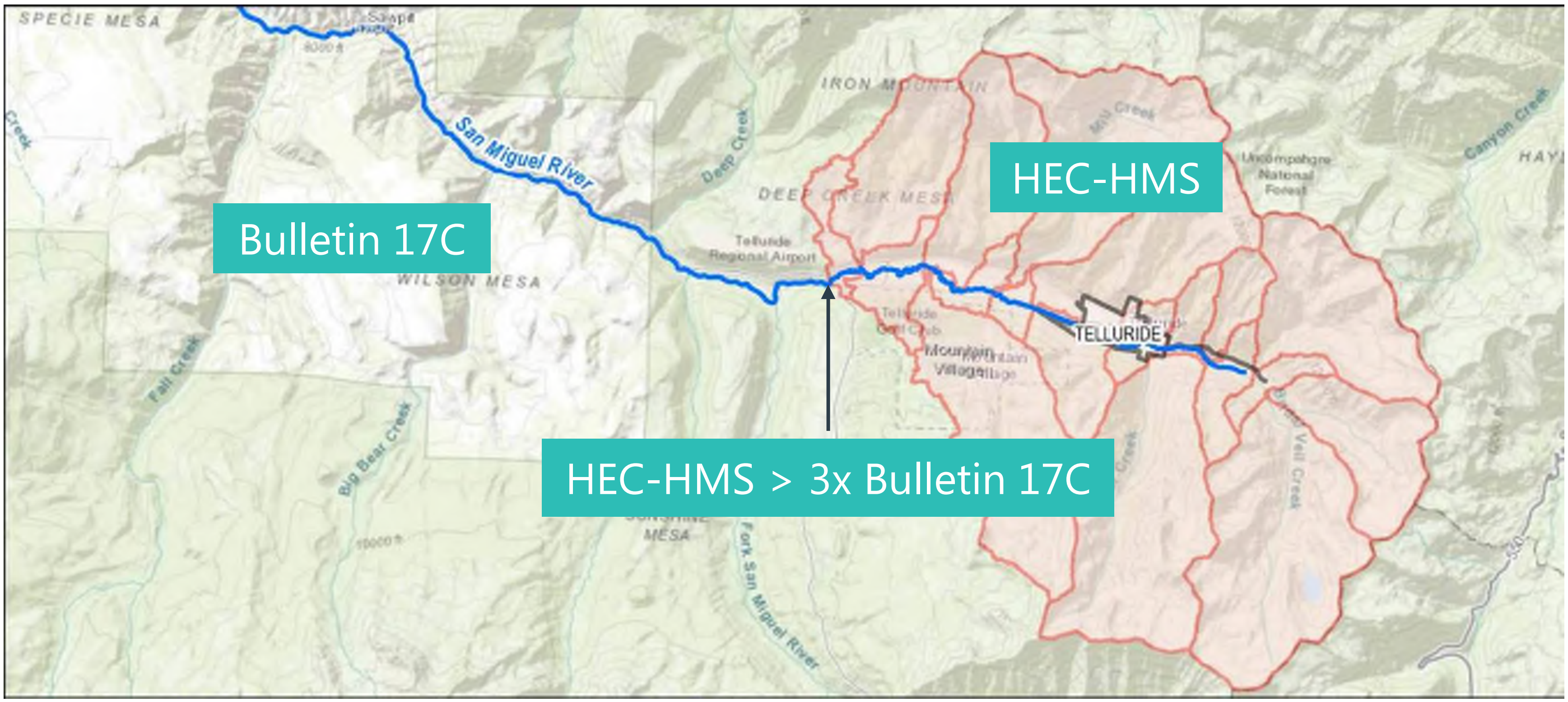
Used Utah regression equations for low-lying areas near Colorado-Utah border.

$$PK100 = 115{,}000\ DRNAREA^{0.391}\ (ELEV/1{,}000)^{-2.58}$$

Drainage Area → DRNAREA

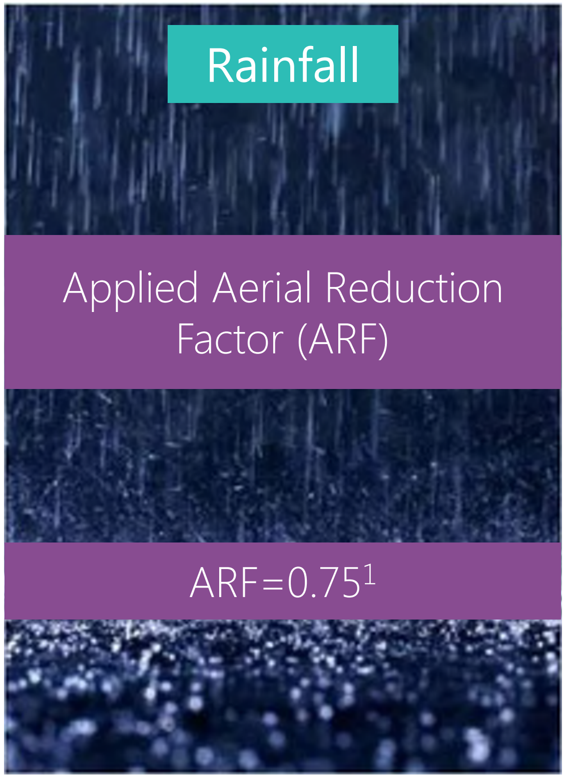
Average Basin Elevation → ELEV

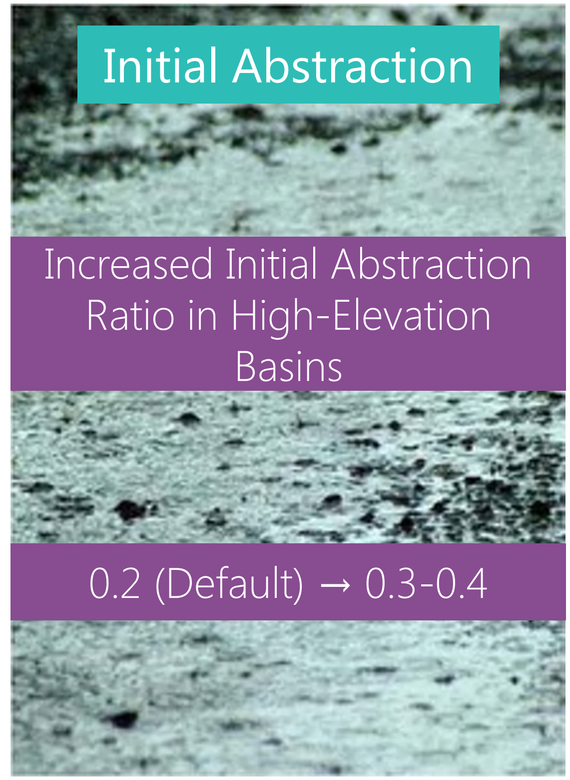
Southwest Region



Southwest Region

Southwest Region





1. NOAA Technical Memorandum NWS HYDRO-40 (1984)

Slide 22

IC1 Land use - Rock is not a CN 98
Ide, Christopher, 9/20/2018

IC2 Initial Abstraction - Porus rock as well.
Ide, Christopher, 9/20/2018

Northwest Region

Peak Streamflow Regression Equation

$$Q_{100} = 10^{0.93} A^{0.74} A_{7500}^{-0.81} P^{1.65}$$

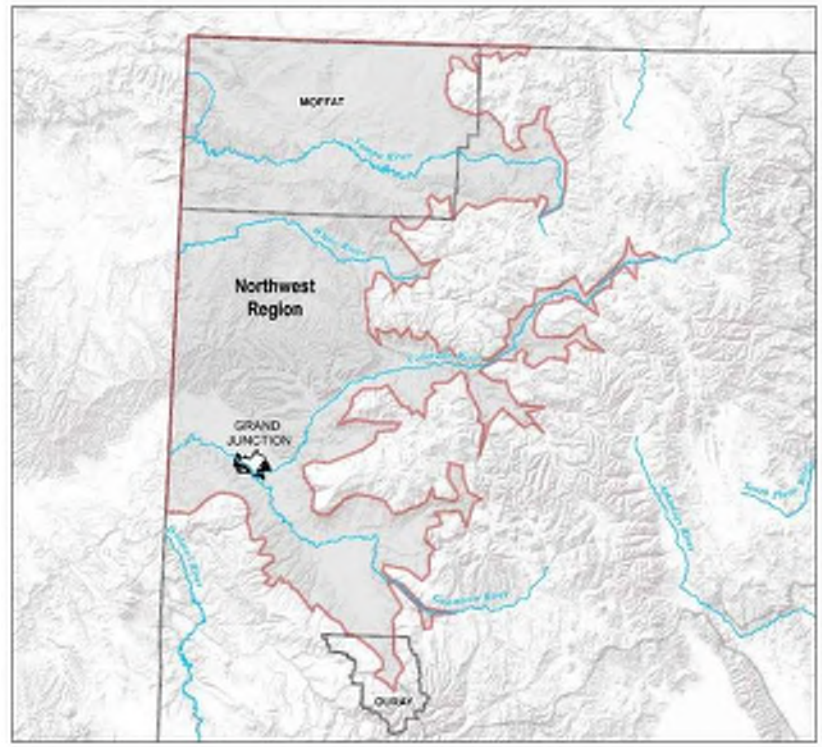
Drainage Area

Percentage of A above 7,500 feet plus 1

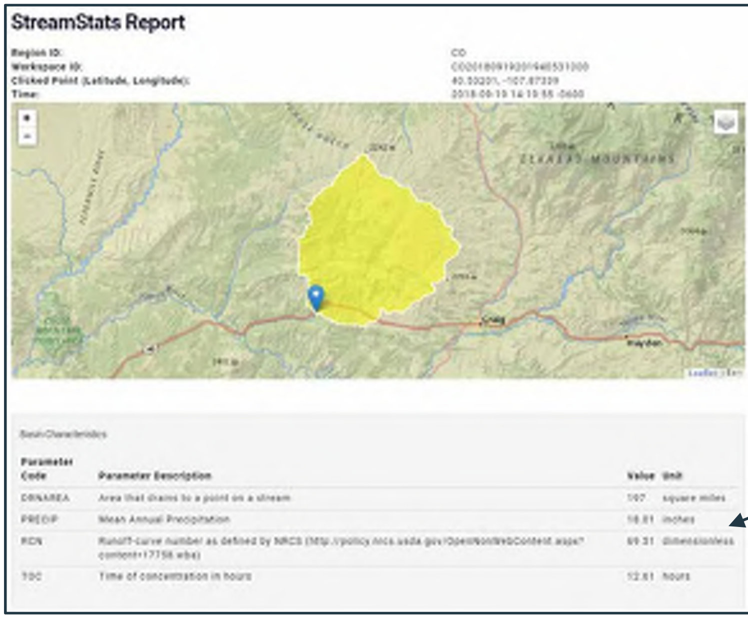
Mean Annual Precipitation

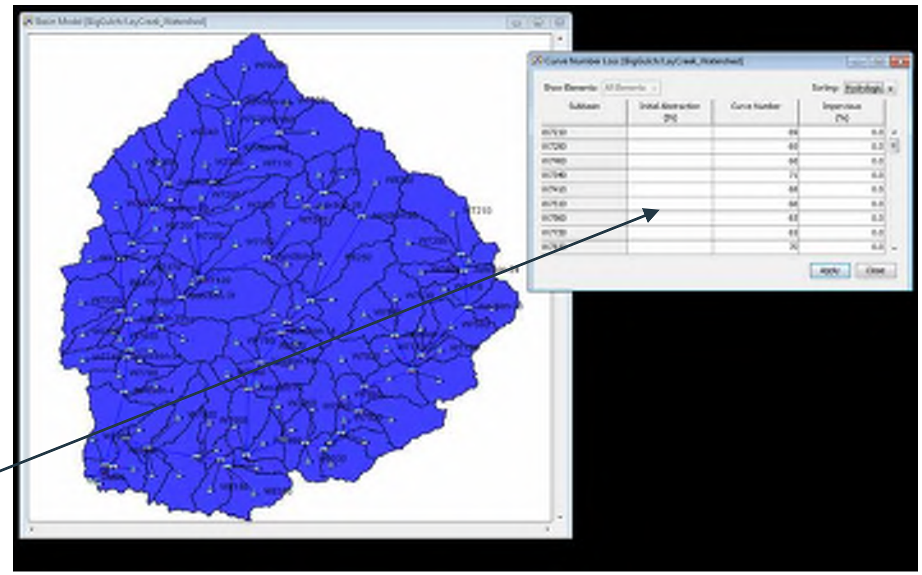
Challenges:

- Unable to calibrate HEC-HMS models using regression due to overestimation of peak flows for low-lying areas.
- Lack of nearby stream gage data to calibrate HEC-HMS models.



Northwest Region





Compared StreamStats drainage basin parameter outputs to HEC-HMS inputs

Precipitation

Time of Concentration

Curve Number

Mountain Region

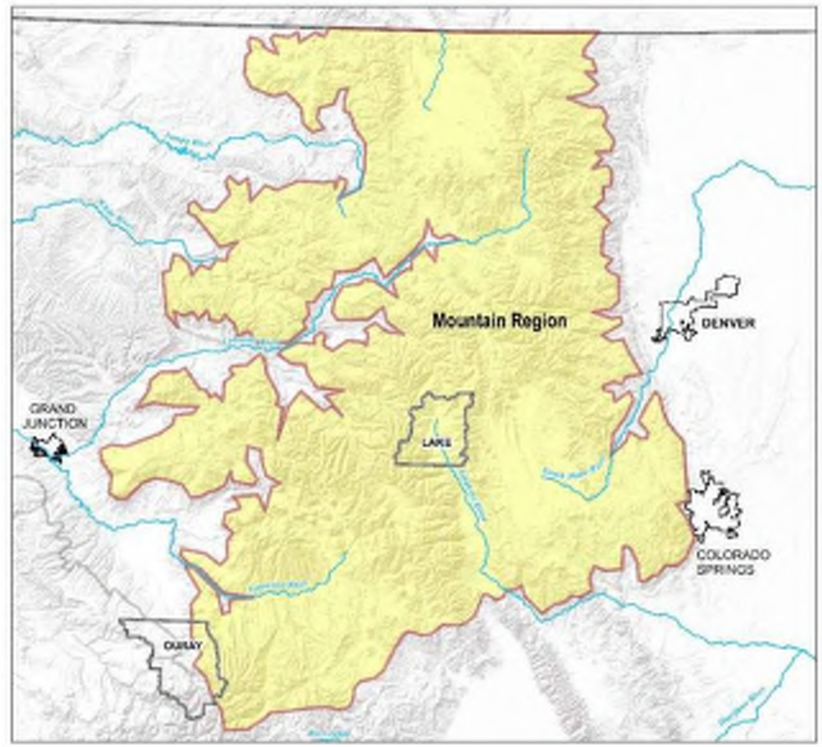
Peak Streamflow Regression Equation

$$Q_{100} = 10^{-0.46} A^{0.75} S^{0.14} P^{1.35}$$

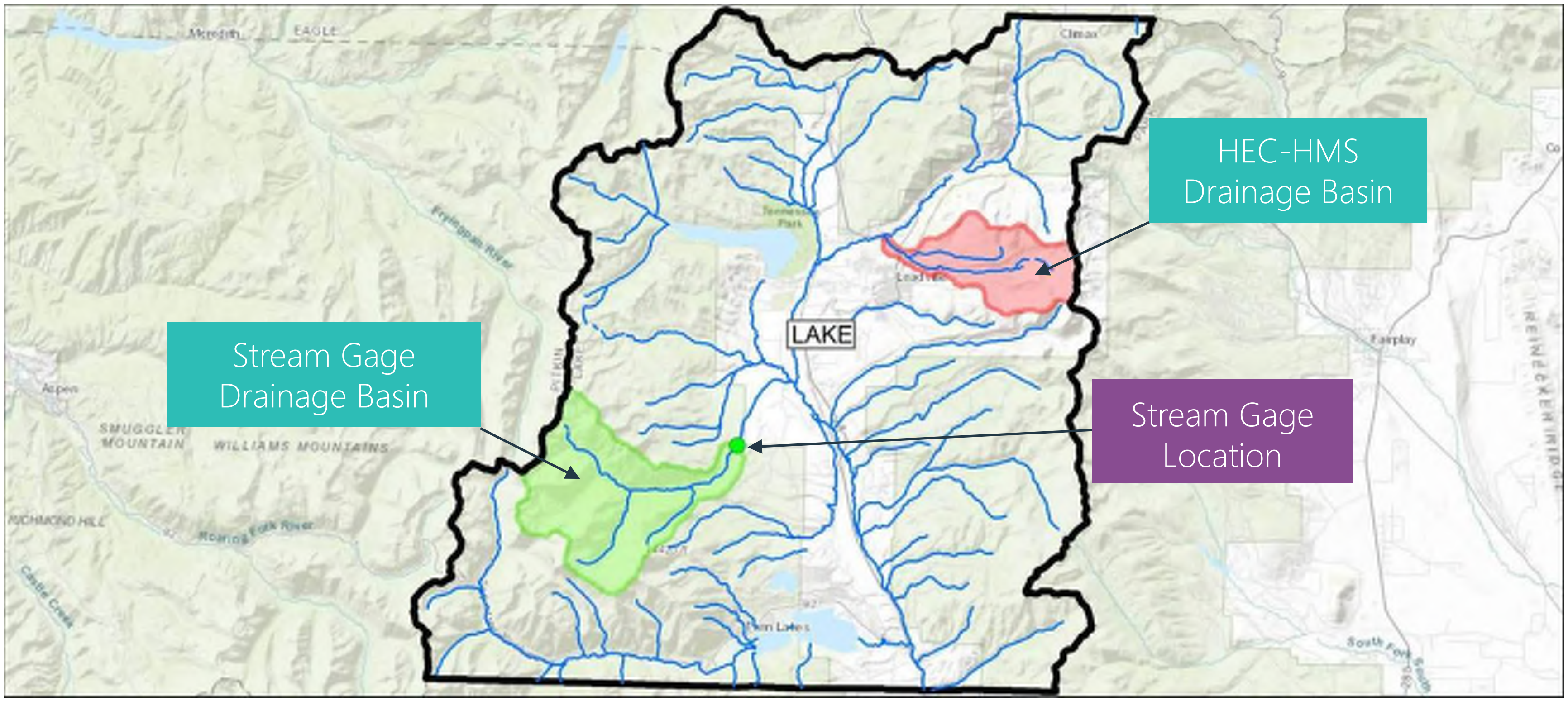
- A → Drainage Area
- S → Mean Watershed Slope
- P → Mean Annual Precipitation

Challenges:

- HEC-HMS models were overestimating runoff for high-elevation basins.



Mountain Region



Plains Region

Peak Streamflow Regression Equation

$$Q_{0.01} = 10^{-0.654} \; {}^{0.403} \; {}^{0.593} \; C^{2.470}$$

$$SEP = 136$$

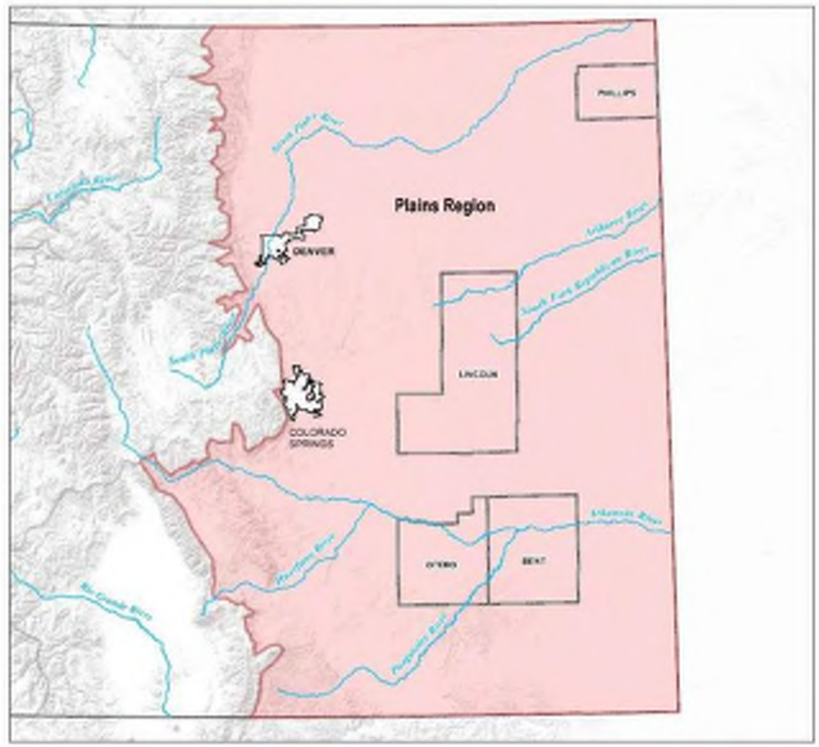
Drainage Area

Watershed Slope

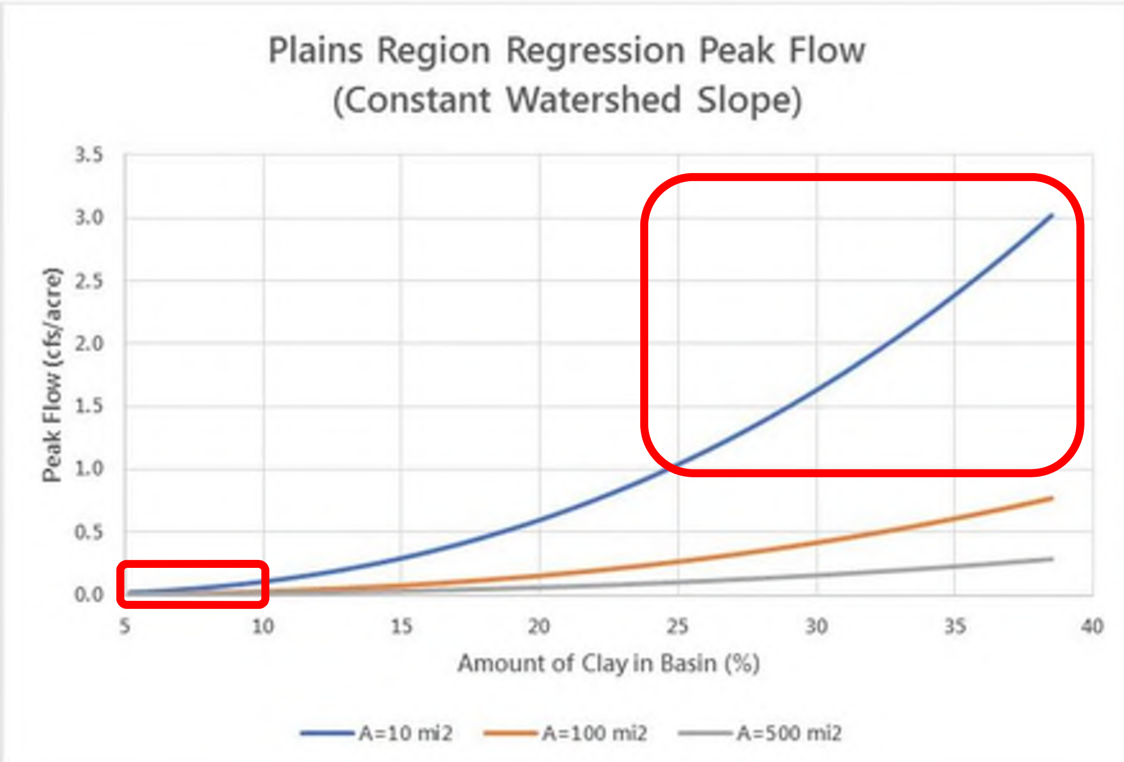
Percent of Clay in Basin

Challenges:

- Regression peak flows are highly dependent of the percentage of clay in the basin. Can produce highly variable and sometimes unreasonable results.



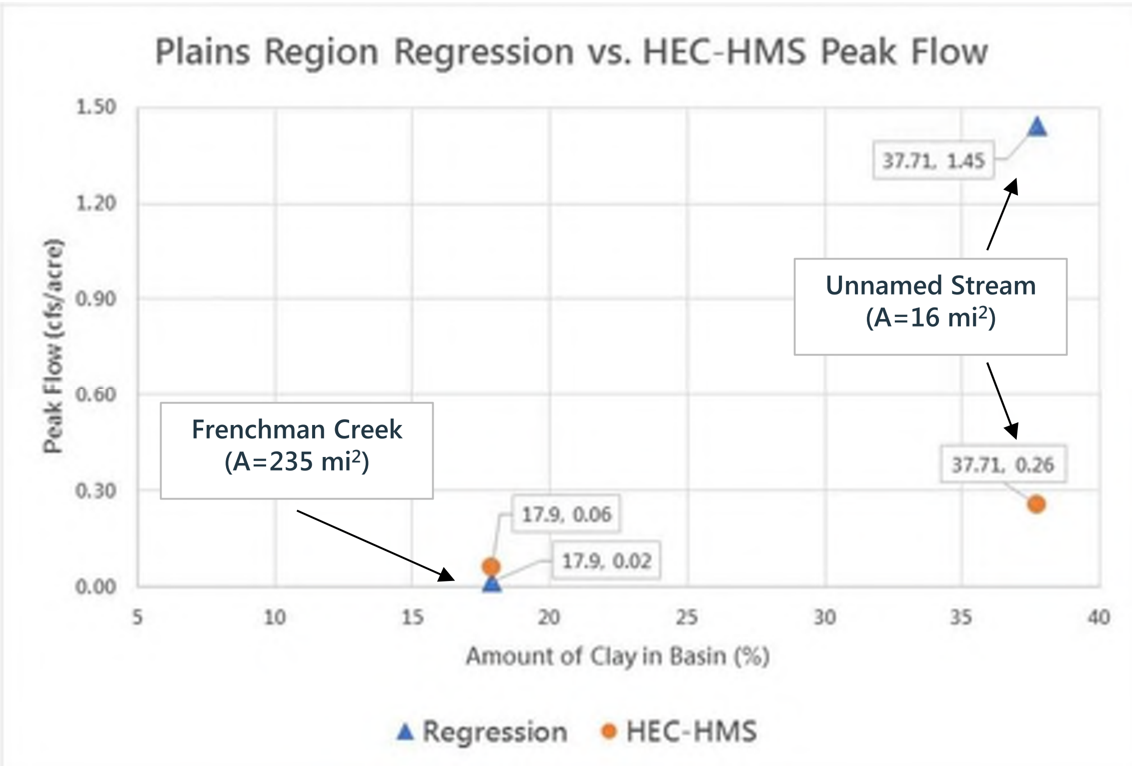
Plains Region



For smaller basins, higher percentages of clay can drastically increase peak flows

Small amounts of clay produce unreasonably low peak flows.

Plains Region



Regression results were highly variable and often did not produce reasonable results.

Verified HEC-HMS results using Kansas and Nebraska regression equations, StreamStats parameter comparisons, and other studies conducted in the area.

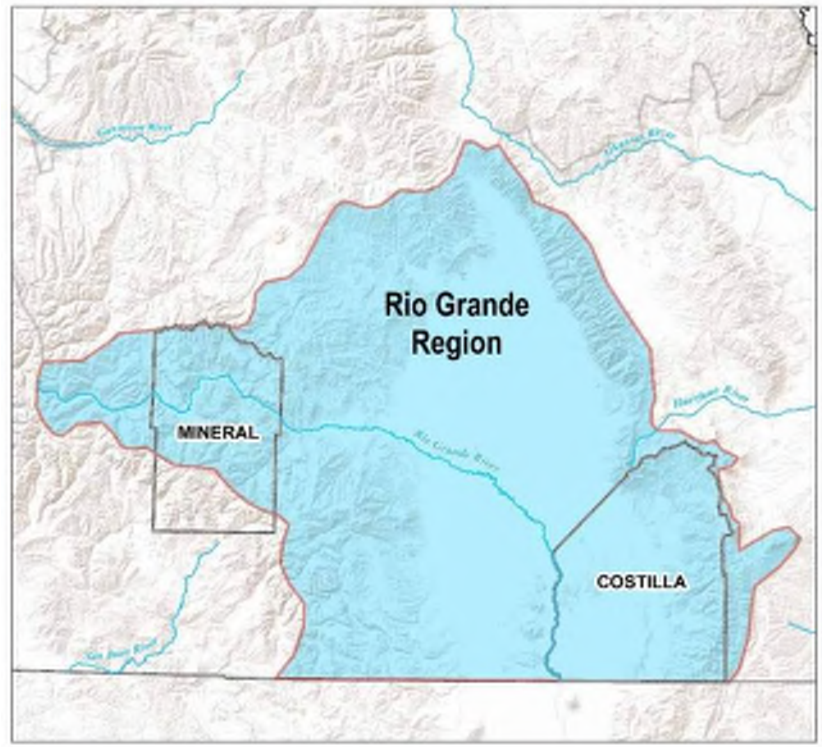
Rio Grande Region

Peak Streamflow Regression Equation

$$Q_{100} = 10^{-0.19} A^{0.87} P^{1.17}$$

Drainage Area (A)

Mean Annual Precipitation (P)

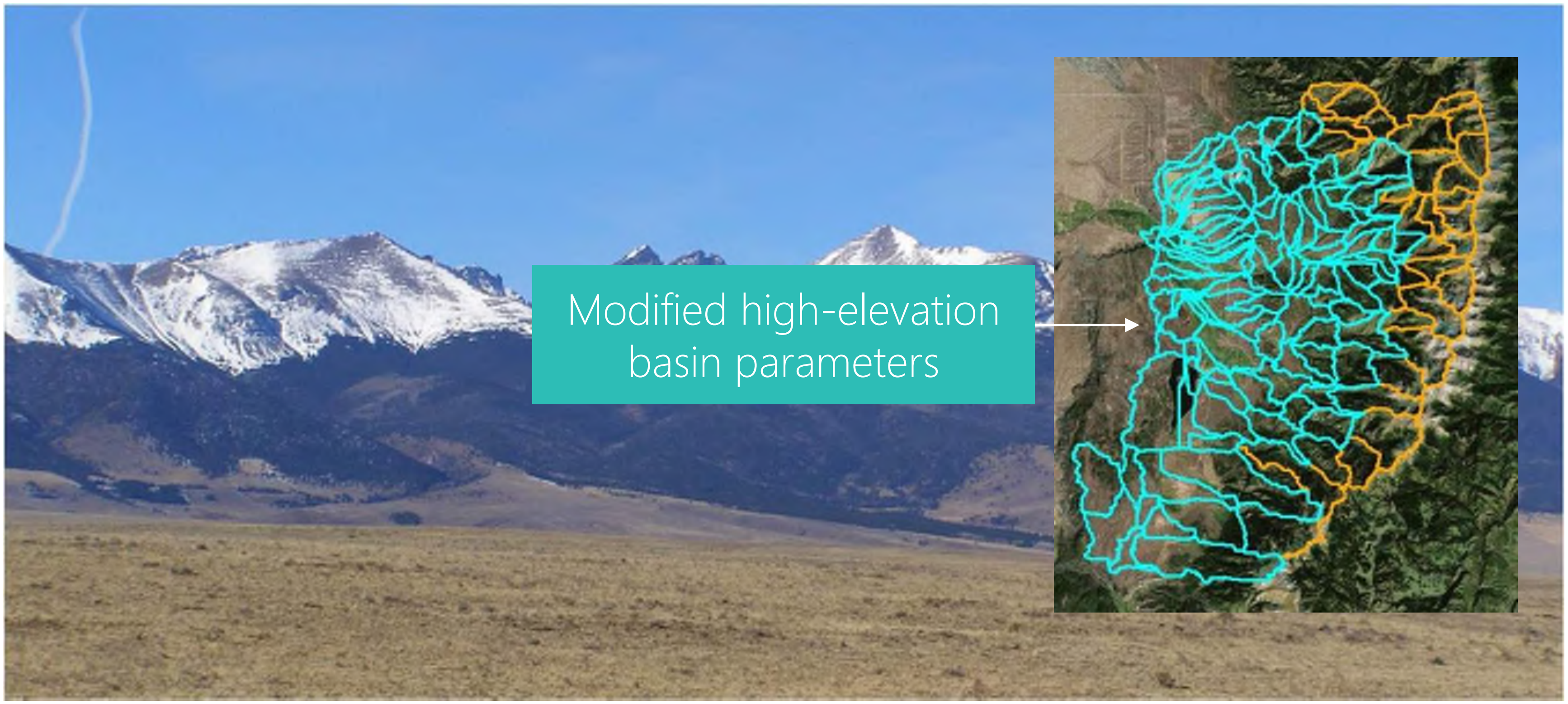


Challenges:

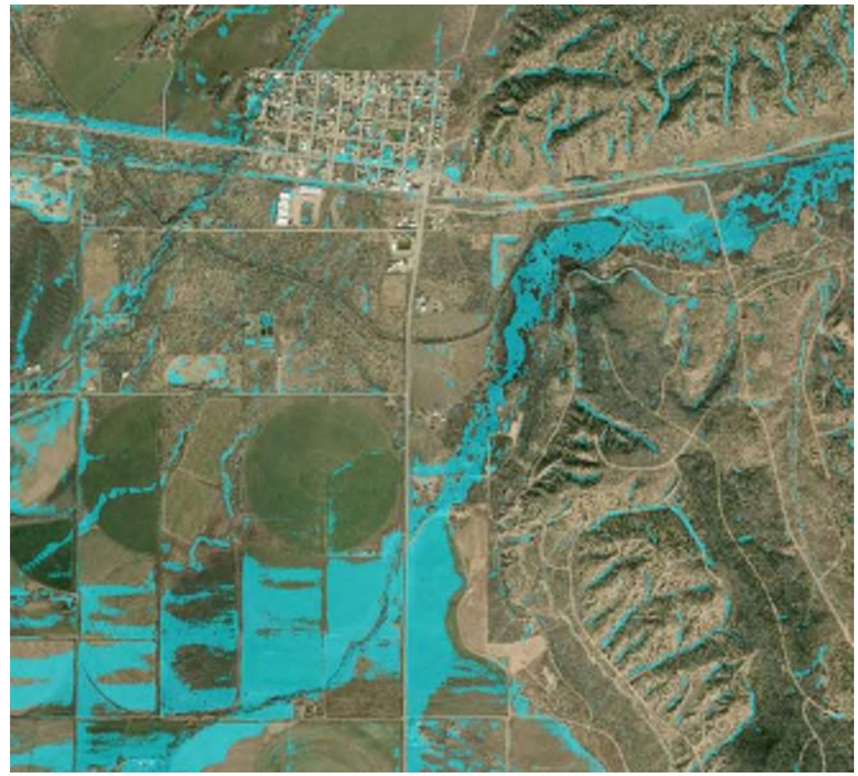
- HEC-HMS models were overestimating runoff for high-elevation basins.
- Difficult to model hydraulics in flat areas.

Rio Grande Region

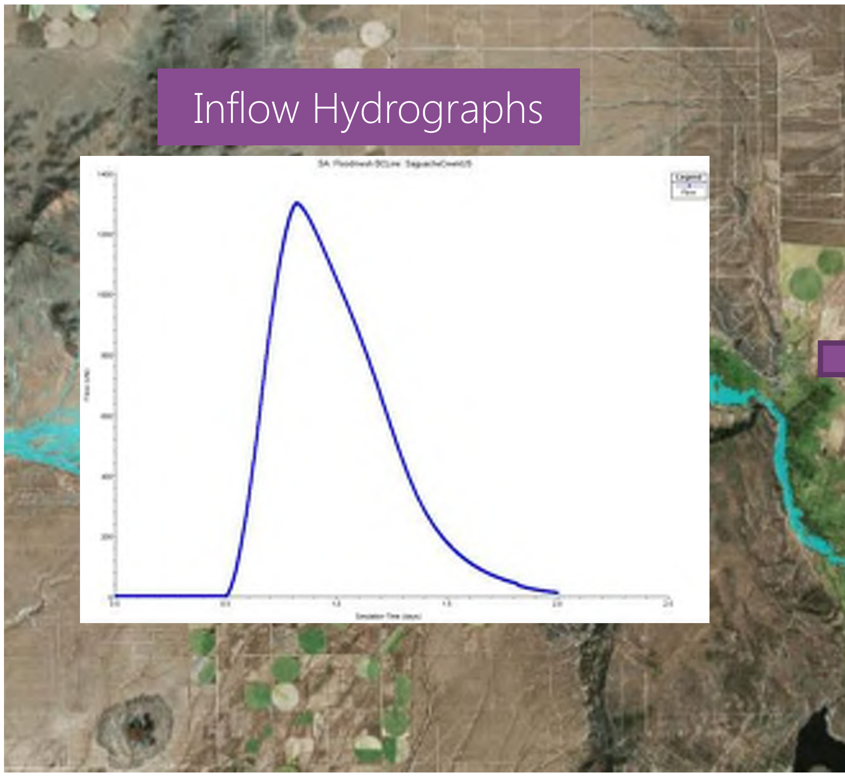
Rio Grande Region

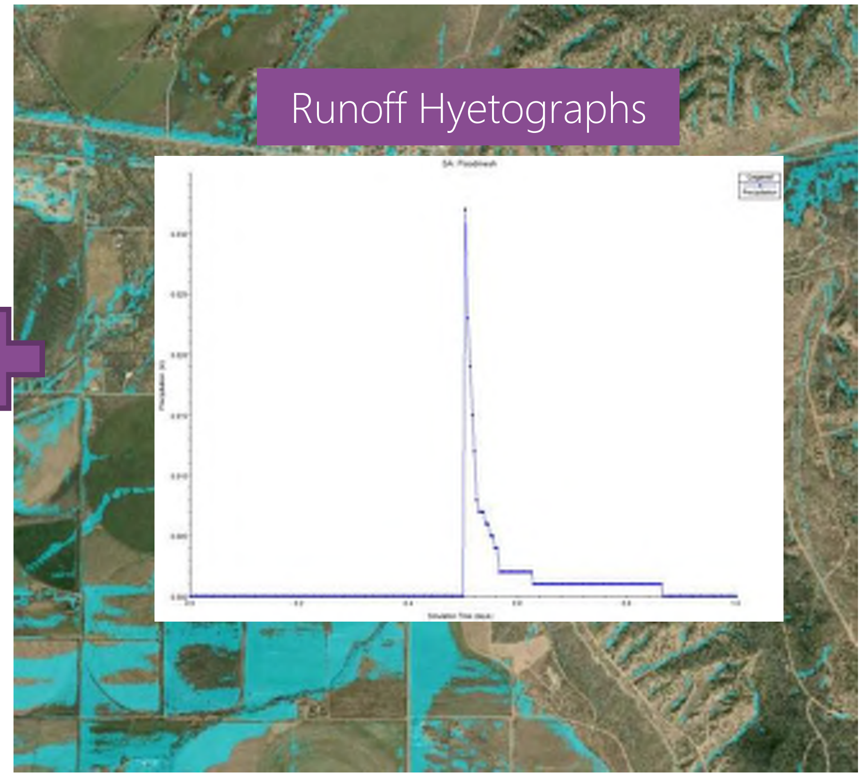


Rio Grande Region



Rio Grande Region





Summary

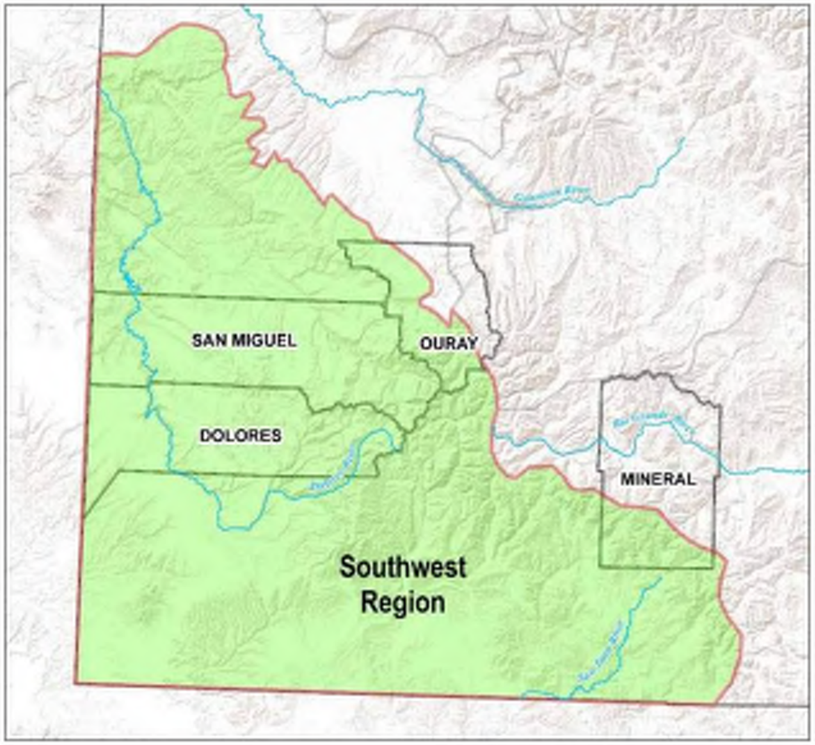
Summary – Southwest Region

Challenges:

- Regression was overestimating peak flows for low-lying areas.
- HEC-HMS models were overestimating runoff for high-elevation basins.

Solutions

- Used neighboring state regression equations (when appropriate).
- Modified HEC-HMS input parameters for high-elevation basins and calibrated to downstream stream gages.



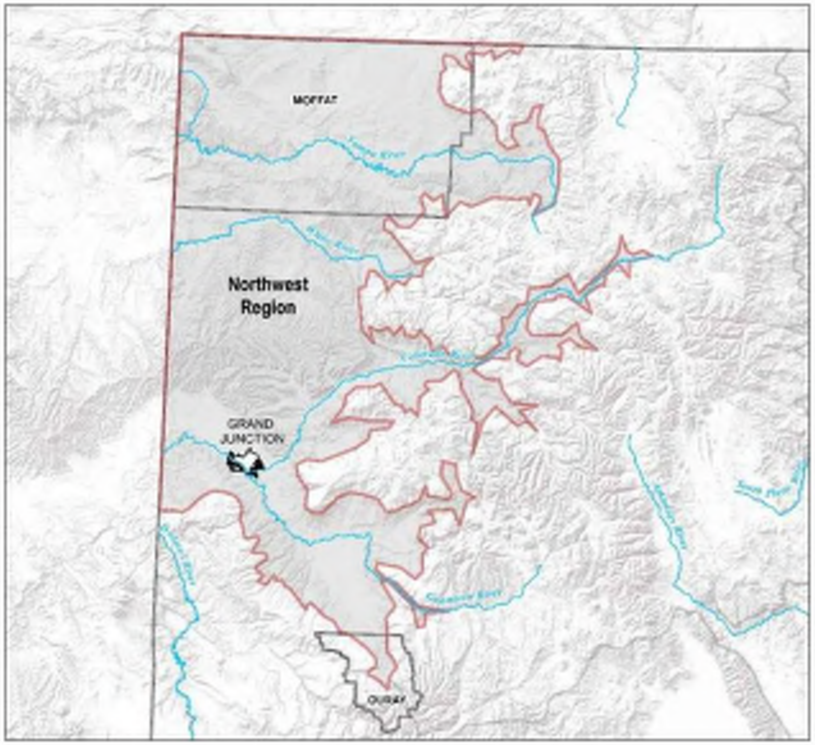
Summary – Northwest Region

Challenges:

- Unable to calibrate HEC-HMS models using regression due to overestimation of peak flows for low-lying areas.
- Lack of nearby stream gage data to calibrate HEC-HMS models.

Solutions

- Compared StreamStats drainage basin parameter outputs for HEC-HMS calibration.



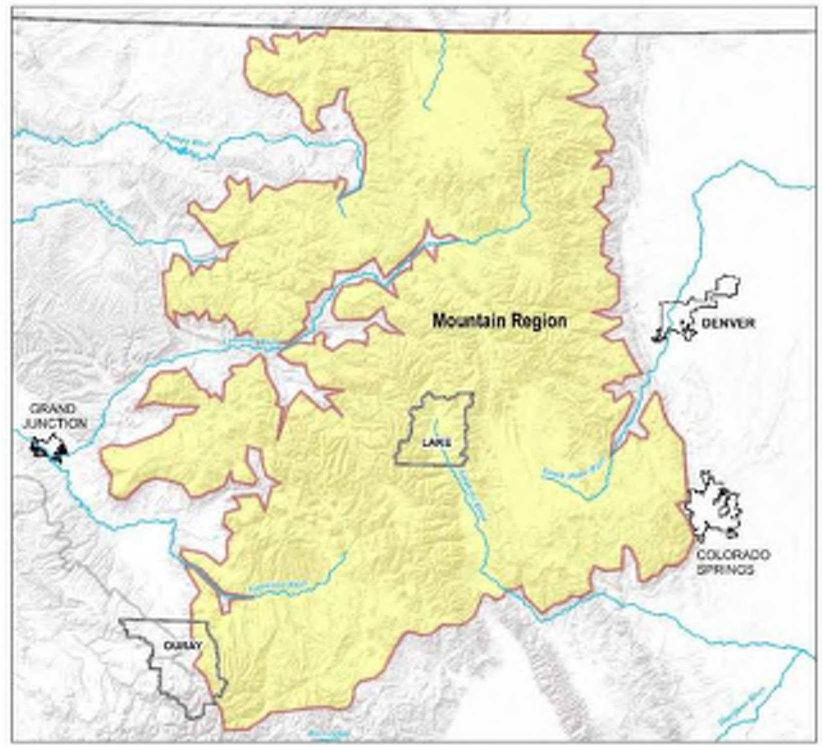
Summary – Mountain Region

Challenges:

- HEC-HMS models were overestimating runoff for high-elevation basins.

Solutions

- Modified HEC-HMS input parameters for high-elevation basins and calibrated to similar, nearby stream gage basins.



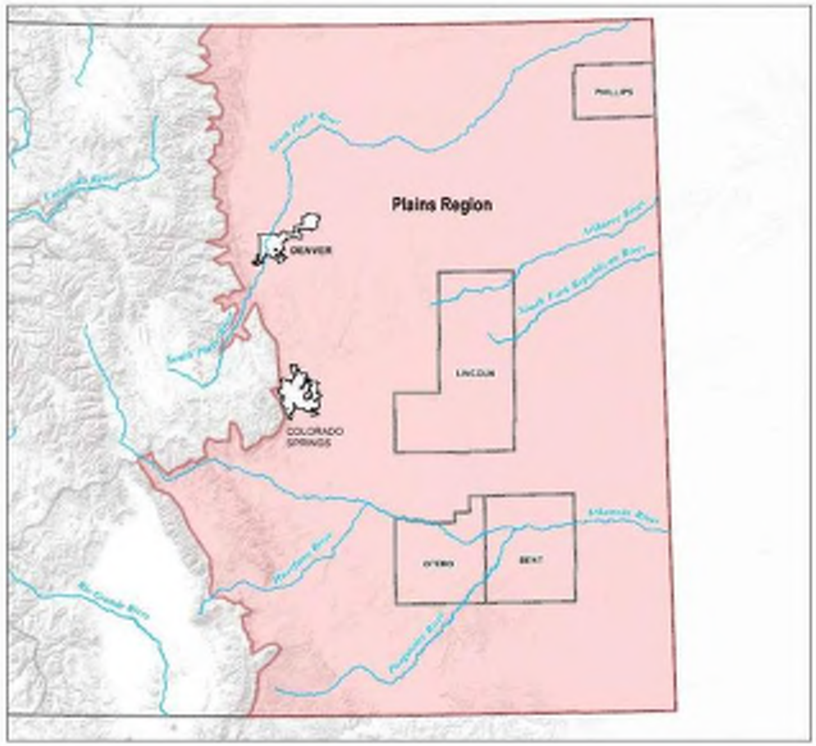
Summary – Plains Region

Challenges:

- Regression peak flows are highly dependent of the percentage of clay in the basin. Can produce highly variable and sometimes unreasonable results.

Solutions

- Use regression equations with caution when the percentage of clay is on either end of the allowable range.
- Use neighboring state regression equations (when appropriate) and StreamStats drainage basin parameter outputs for HEC-HMS calibration.



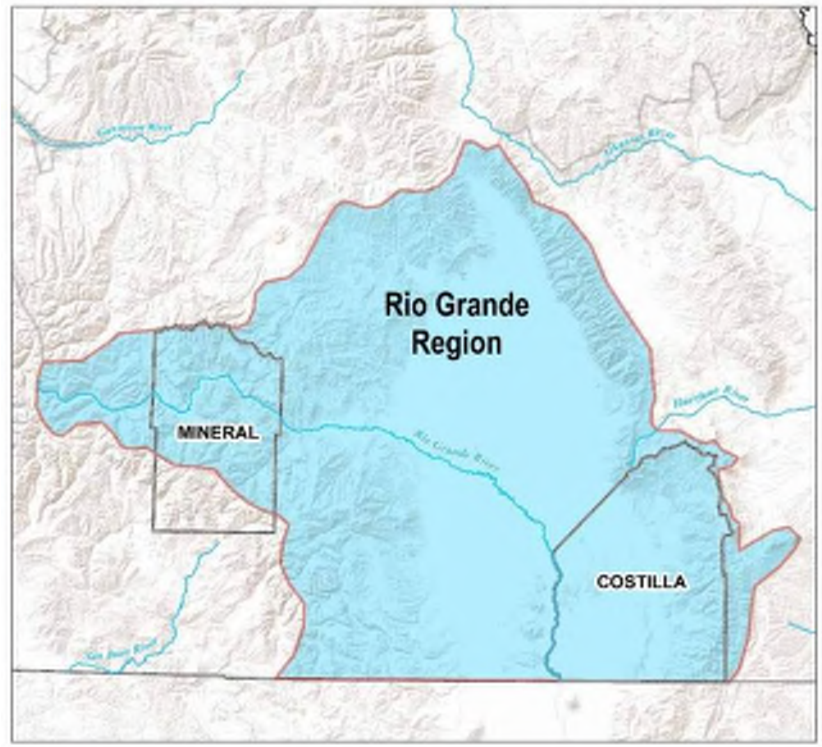
Summary – Rio Grande Region

Challenges:

- HEC-HMS models were overestimating runoff for high-elevation basins.
- Difficult to model hydraulics in flat areas.

Solutions

- Modified HEC-HMS input parameters for high-elevation basins and calibrated to similar, nearby stream gage basins.
- Modeled hydrology/hydraulics for streams in the flat San Luis Valley using 2-D methodologies.



Summary

Hydrologic Region	Challenges	Solutions
Southwest	Regression was overestimating peak flows for low-lying areas. HEC-HMS models were overestimating runoff for high-elevation basins.	Used neighboring state regression equations (when appropriate). Modified HEC-HMS input parameters for high-elevation basins and calibrated to downstream stream gages.
Northwest	Unable to calibrate HEC-HMS models using regression due to overestimation of peak flows for low-lying areas. Lack of nearby stream gage data to calibrate HEC-HMS models.	Compared StreamStats drainage basin parameter outputs for HEC-HMS calibration.
Mountain	HEC-HMS models were overestimating runoff for high-elevation basins.	Modified HEC-HMS input parameters for high-elevation basins and calibrated to similar, nearby stream gage basins.
Plains	Regression peak flows are highly dependent of the percentage of clay in the basin. Can produce highly variable and sometimes unreasonable results.	Use regression equations with caution when the percentage of clay is on either end of the allowable range. Use neighboring state regression equations (when appropriate) and StreamStats drainage basin parameter outputs for HEC-HMS calibration.
Rio Grande	HEC-HMS models were overestimating runoff for high-elevation basins. Difficult to model hydraulics in flat areas.	Modified HEC-HMS input parameters for high-elevation basins and calibrated to similar, nearby stream gage basins. Modeled hydrology/hydraulics for streams in the flat San Luis Valley using 2-D methodologies.

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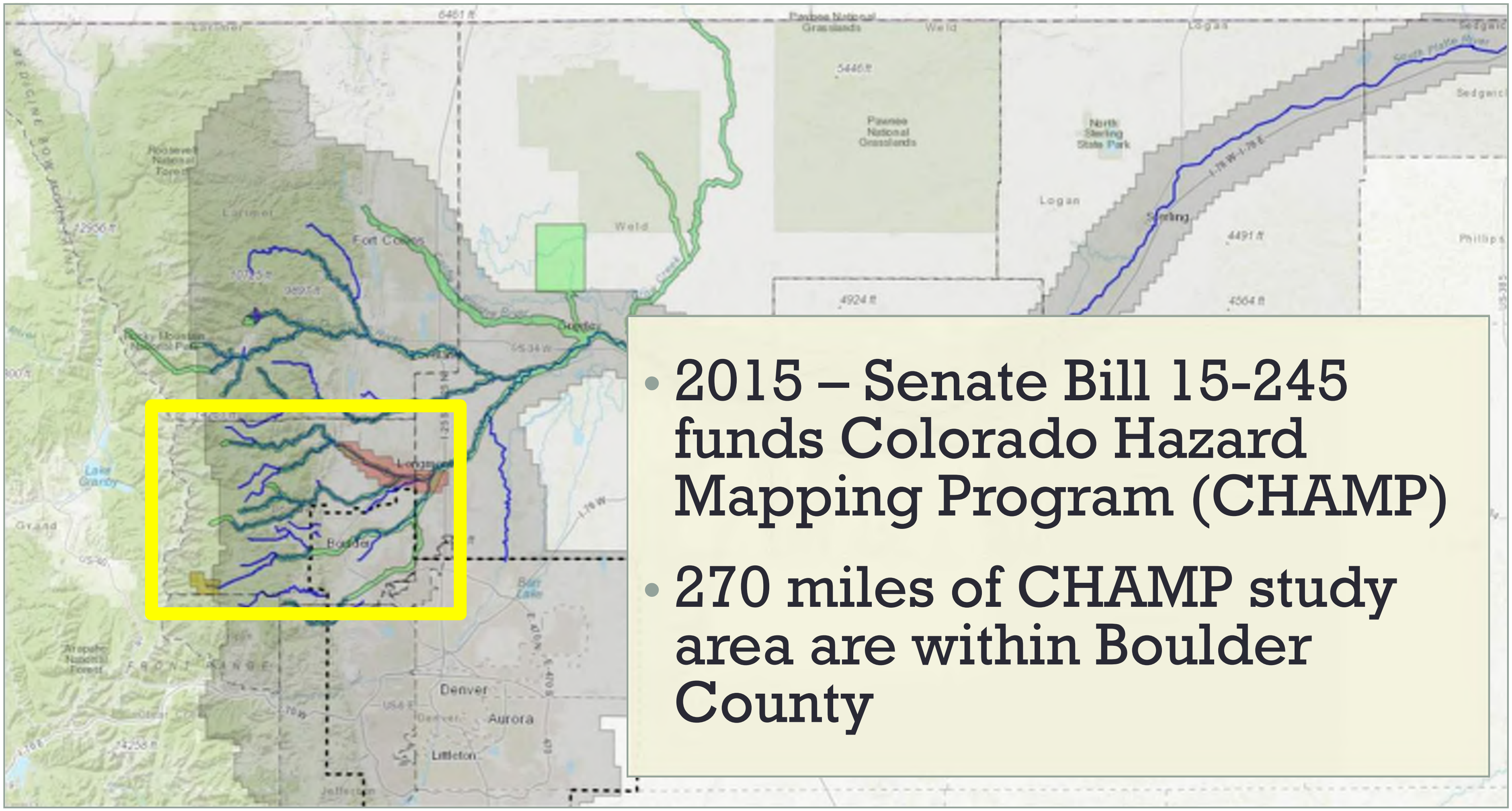
MAKING THE MOST OF IT: Leveraging The CHAMP Study For Other Uses

Erin Cooper, Boulder County
Olivia Cecil, Boulder County
Kevin Doyle, Michael Baker Intl.

Boulder County

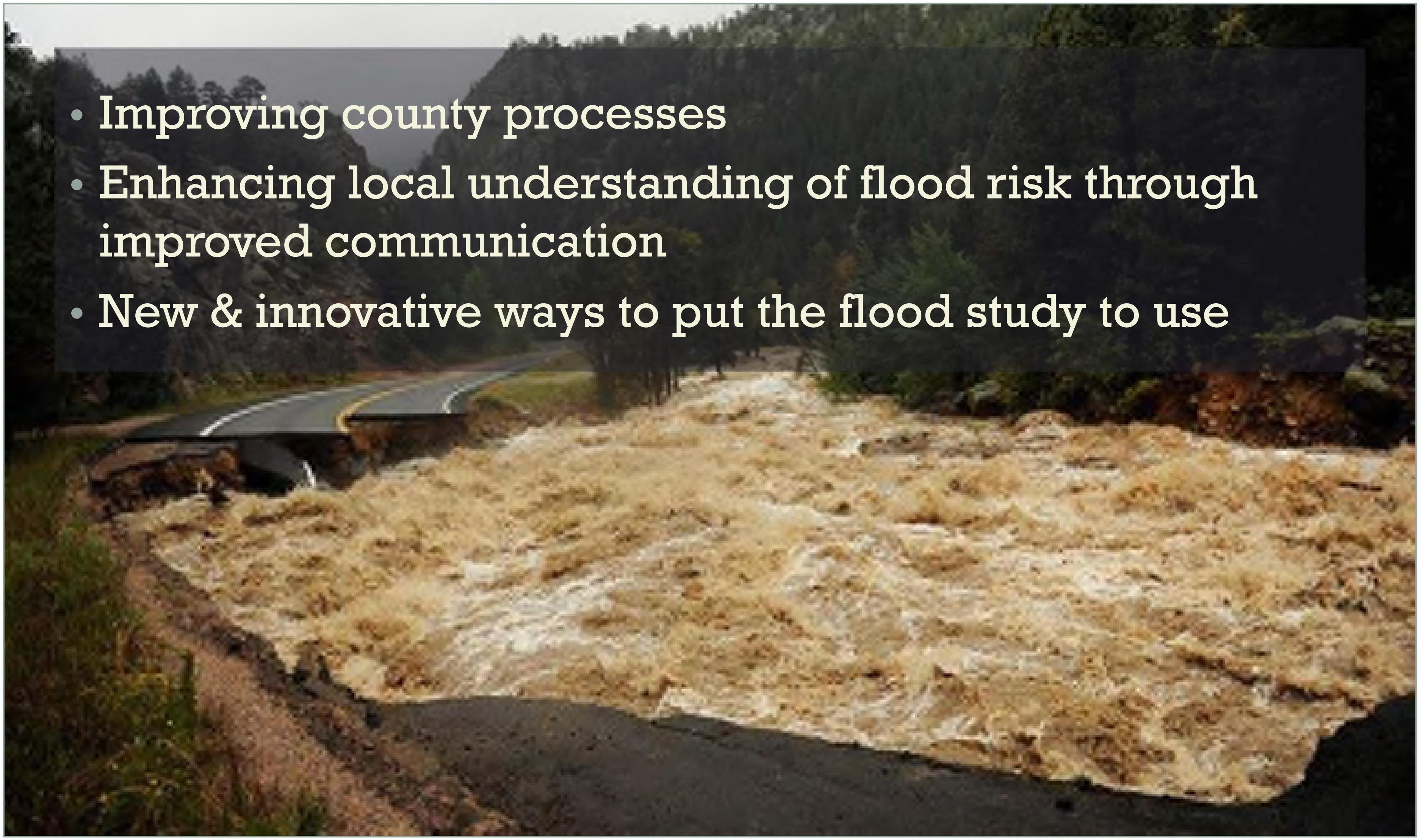
CHAMP & Boulder County

Boulder County



- 2015 – Senate Bill 15-245 funds Colorado Hazard Mapping Program (CHAMP)
- 270 miles of CHAMP study area are within Boulder County

Benefits from CHAMP study



- Improving county processes
- Enhancing local understanding of flood risk through improved communication
- New & innovative ways to put the flood study to use

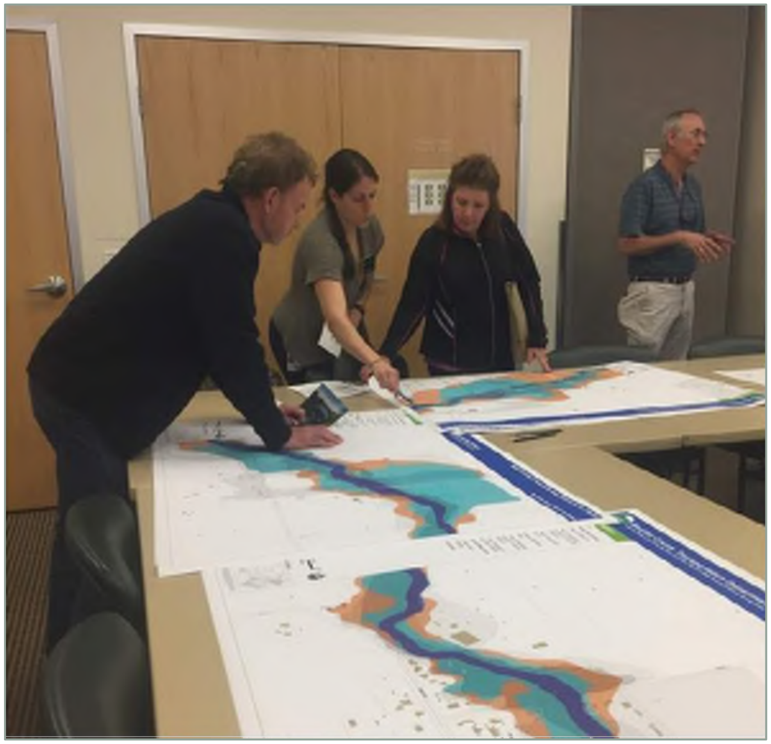
Putting CHAMP to Use

Some of the ways Boulder County has leveraged the CHAMP study:

1. Best Available Information
2. Planning & Permitting
3. FEMA CRS Credits
4. LiDAR LOMAs
5. Overtopping
   - Depth & Velocity Grids
   - Capacity
6. Evacuation Priorities

1. Best Available Information

Extensive outreach & early guidance on revised predictions for flood risk – powerful information to help property owners understand the coming changes



Boulder County "FO District"

=

FEMA Floodplain +

Boulder County Floodplain

1. Best Available Information

Floodplain maps now show two flood studies as one regulatory tool

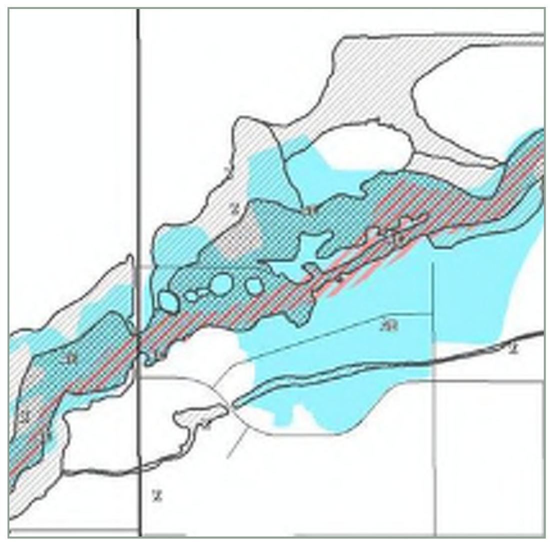
FEMA Regulatory Floodplain

FEMA Floodplain

FEMA Floodway

+

Boulder County Floodplain



CHAMP Floodplain

CHAMP Floodway

=

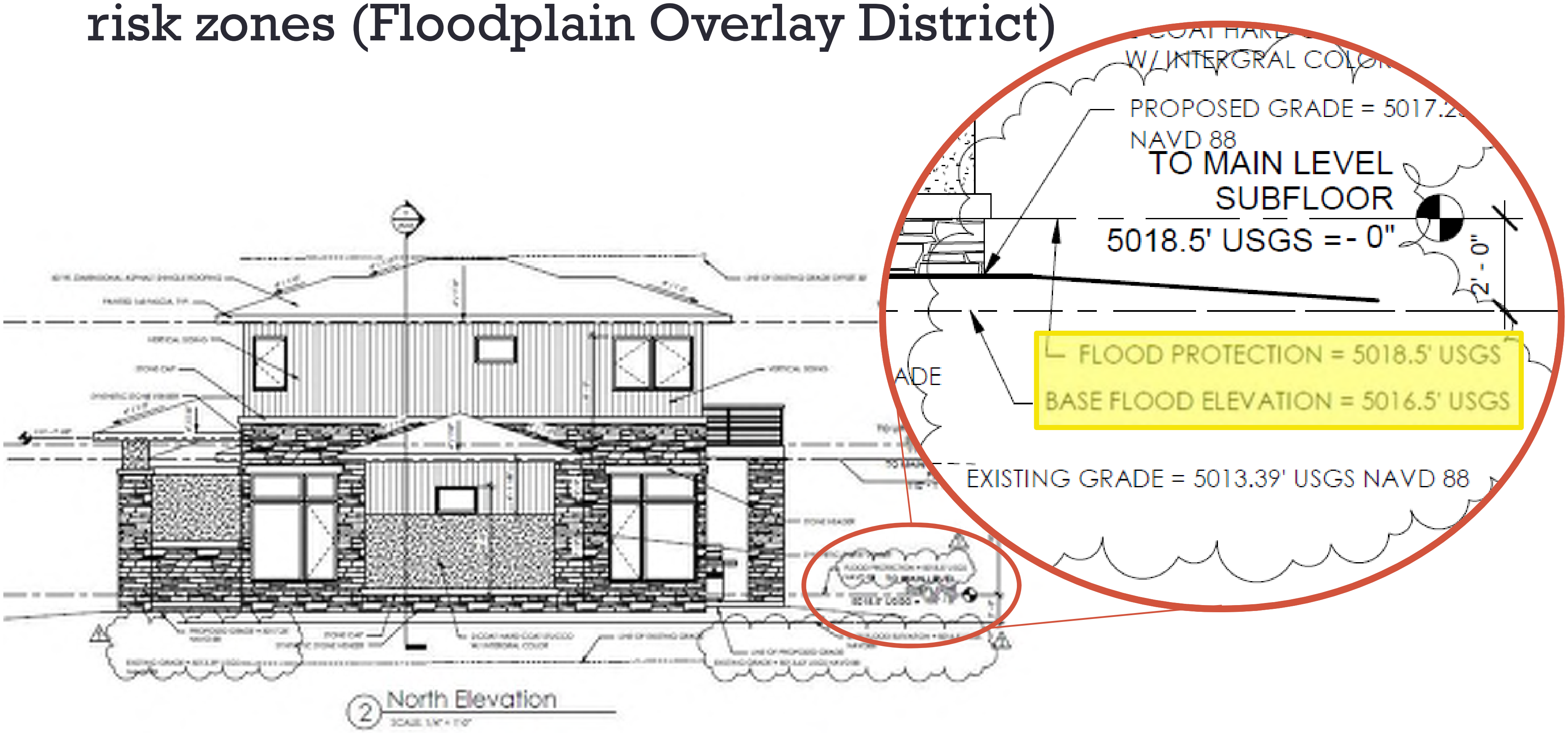
Floodplain Overlay District

Composite Floodplain

Composite Floodway

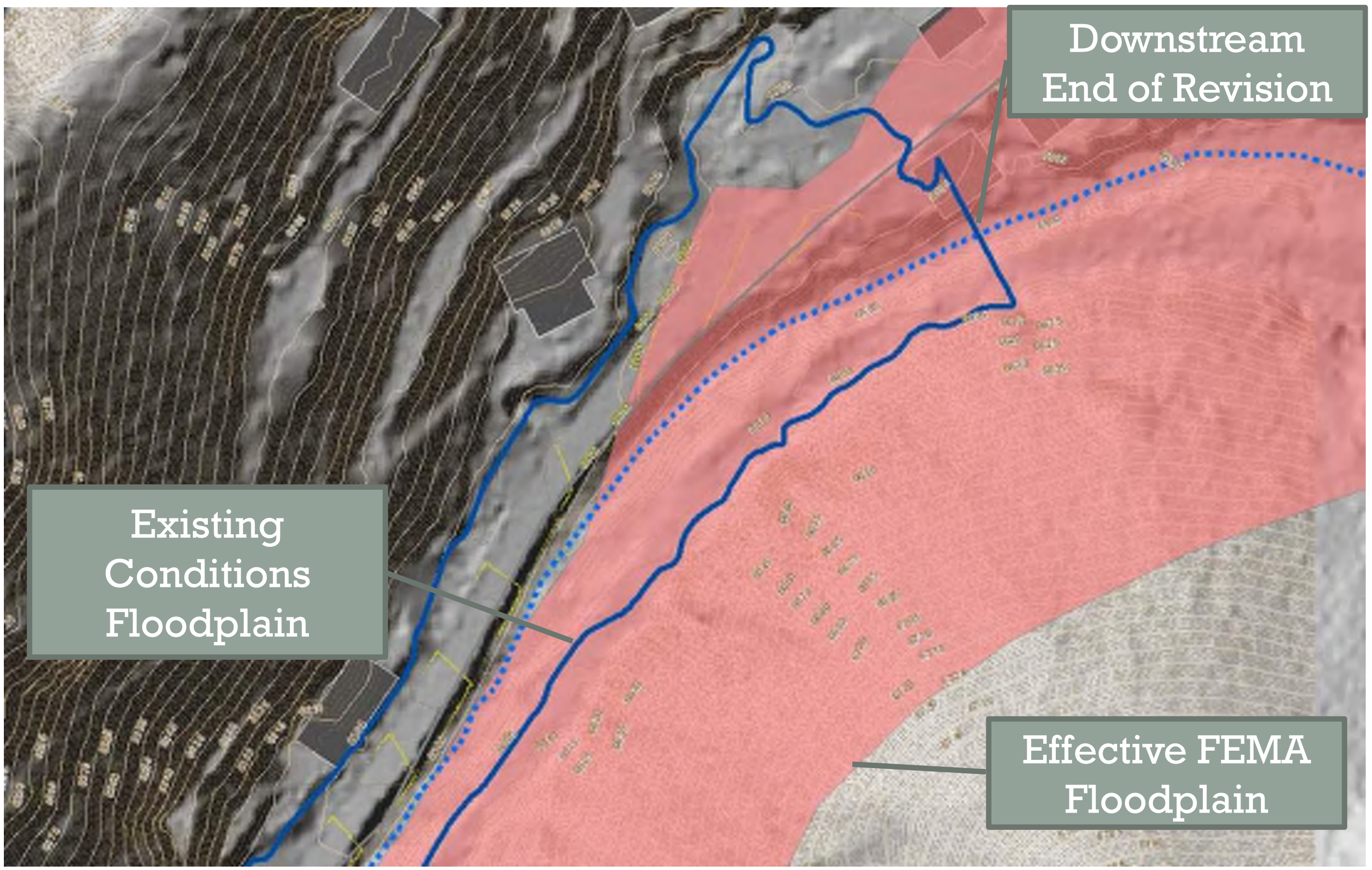
2. Permitting Decisions using BFEs

- New structures built above CHAMP BFE
- Permitting approved/denied based on CHAMP flood risk zones (Floodplain Overlay District)



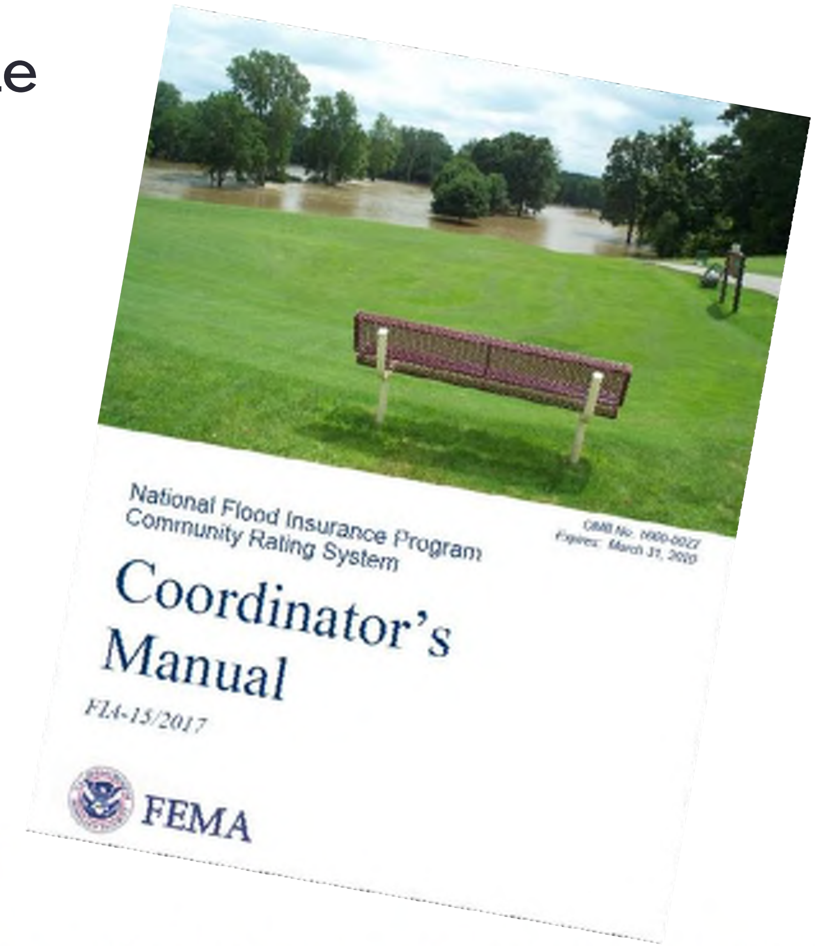
2. Permitting Decisions – comparing to CHAMP vs. Effective

No-rise & CLOMR/LOMR analyses compared to CHAMP vs compared to effective



3. FEMA Community Rating System

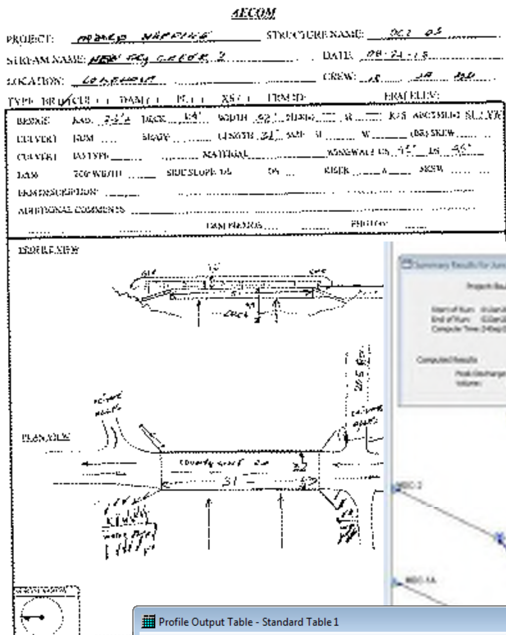
- Credit for early regulation to the CHAMP study
  - New Study credit
  - Floodway Standard
- Community discounts on flood insurance premiums



410 FLOOD HAZARD MAPPING

The OBJECTIVE of this activity is to improve the quality of the mapping that is used to identify and regulate development at risk from flood hazards.

What else can we do with all this data

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Colorado DFIRM</title>
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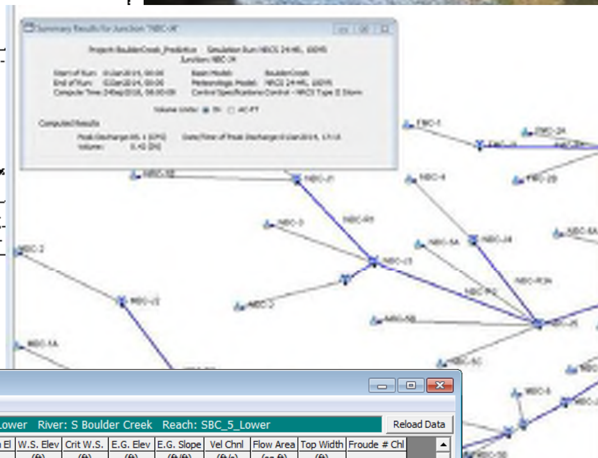

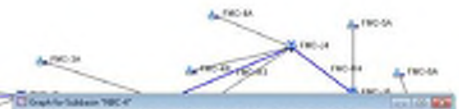


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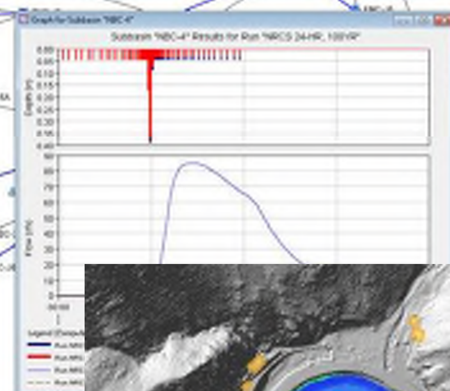
abase management technology make it possible to protect this
n was possible in the past. The minimum requirement for
and spatial datasets that are needed to implement the models.
pping.)</abstract>
ace elevations for floodplain mapping requires significant
vey data including cross-section and bridge surveys.</purpose>
```

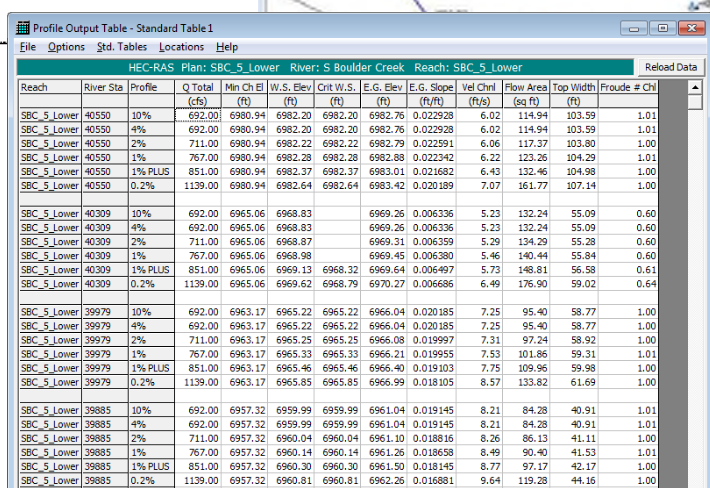
Profile Output Table - Standard Table 1

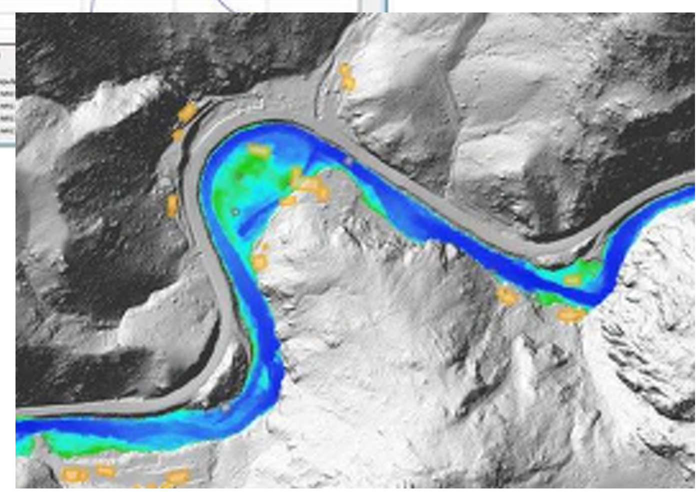
File Options Std. Tables Locations Help

HEC-RAS Plan: SBC_5_Lower River: S Boulder Creek Reach: SBC_5_Lower

Reload Data

Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
SBC_5_Lower	40550	10%	692.00	6980.94	6982.20	6982.20	6982.76	0.022928	6.02	114.94	103.59	1.01
SBC_5_Lower	40550	4%	692.00	6980.94	6982.20	6982.20	6982.76	0.022928	6.02	114.94	103.59	1.01
SBC_5_Lower	40550	2%	711.00	6980.94	6982.22	6982.22	6982.79	0.022591	6.06	117.37	103.80	1.00
SBC_5_Lower	40550	1%	767.00	6980.94	6982.28	6982.28	6982.88	0.022342	6.22	123.26	104.29	1.01
SBC_5_Lower	40550	1% PLUS	851.00	6980.94	6982.37	6982.37	6983.01	0.021682	6.43	132.46	104.98	1.00
SBC_5_Lower	40550	0.2%	1139.00	6980.94	6982.64	6982.64	6983.42	0.020189	7.07	161.77	107.14	1.00
SBC_5_Lower	40309	10%	692.00	6965.06	6968.83		6969.26	0.006336	5.23	132.24	55.09	0.60
SBC_5_Lower	40309	4%	692.00	6965.06	6968.83		6969.26	0.006336	5.23	132.24	55.09	0.60
SBC_5_Lower	40309	2%	711.00	6965.06	6968.87		6969.31	0.006359	5.29	134.29	55.28	0.60
SBC_5_Lower	40309	1%	767.00	6965.06	6968.98		6969.45	0.006380	5.46	140.44	55.84	0.60
SBC_5_Lower	40309	1% PLUS	851.00	6965.06	6969.13	6968.32	6969.64	0.006497	5.73	148.81	56.58	0.61
SBC_5_Lower	40309	0.2%	1139.00	6965.06	6969.62	6968.79	6970.27	0.006686	6.49	176.90	59.02	0.64
SBC_5_Lower	39979	10%	692.00	6963.17	6965.22	6965.22	6966.04	0.020185	7.25	95.40	58.77	1.00
SBC_5_Lower	39979	4%	692.00	6963.17	6965.22	6965.22	6966.04	0.020185	7.25	95.40	58.77	1.00
SBC_5_Lower	39979	2%	711.00	6963.17	6965.25	6965.25	6966.08	0.019997	7.31	97.24	58.92	1.00
SBC_5_Lower	39979	1%	767.00	6963.17	6965.33	6965.33	6966.21	0.019955	7.53	101.86	59.31	1.01
SBC_5_Lower	39979	1% PLUS	851.00	6963.17	6965.46	6965.46	6966.40	0.019103	7.75	109.96	59.98	1.00
SBC_5_Lower	39979	0.2%	1139.00	6963.17	6965.85	6965.85	6966.99	0.018105	8.57	133.82	61.69	1.00
SBC_5_Lower	39885	10%	692.00	6957.32	6959.99	6959.99	6961.04	0.019145	8.21	84.28	40.91	1.01
SBC_5_Lower	39885	4%	692.00	6957.32	6959.99	6959.99	6961.04	0.019145	8.21	84.28	40.91	1.01
SBC_5_Lower	39885	2%	711.00	6957.32	6960.04	6960.04	6961.10	0.018816	8.26	86.13	41.11	1.00
SBC_5_Lower	39885	1%	767.00	6957.32	6960.14	6960.14	6961.26	0.018658	8.49	90.40	41.53	1.01
SBC_5_Lower	39885	1% PLUS	851.00	6957.32	6960.30	6960.30	6961.50	0.018145	8.77	97.17	42.17	1.00
SBC_5_Lower	39885	0.2%	1139.00	6957.32	6960.81	6960.81	6962.26	0.016881	9.64	119.28	44.16	1.00

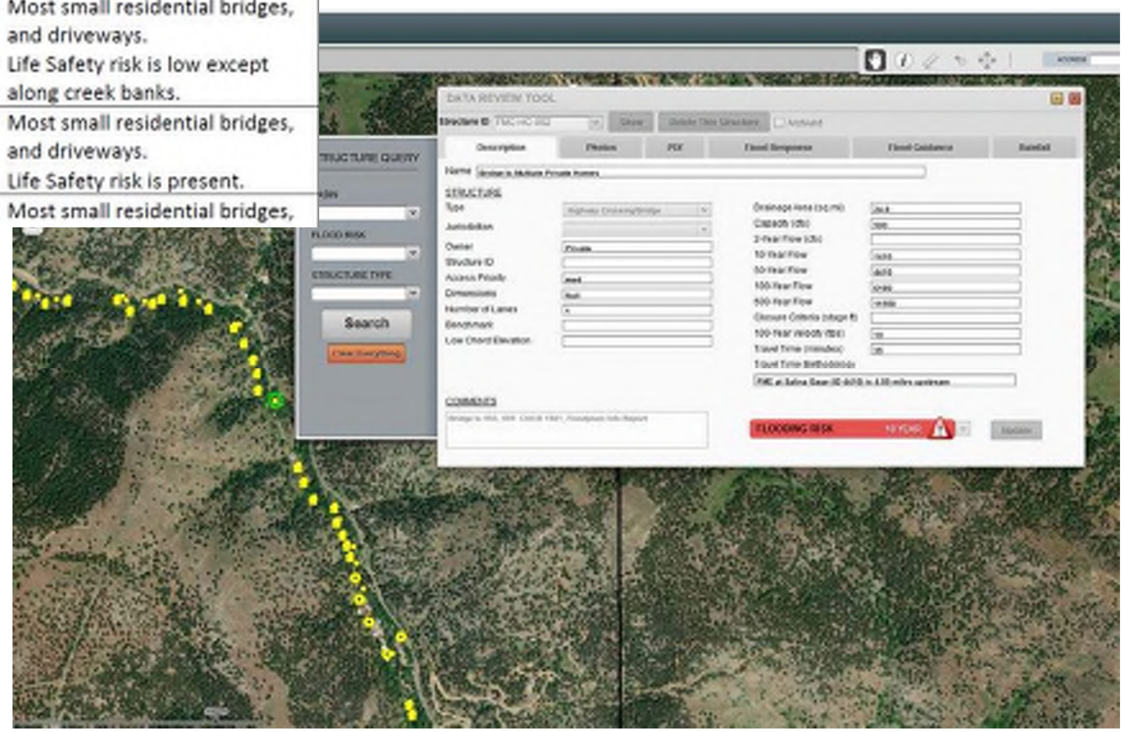




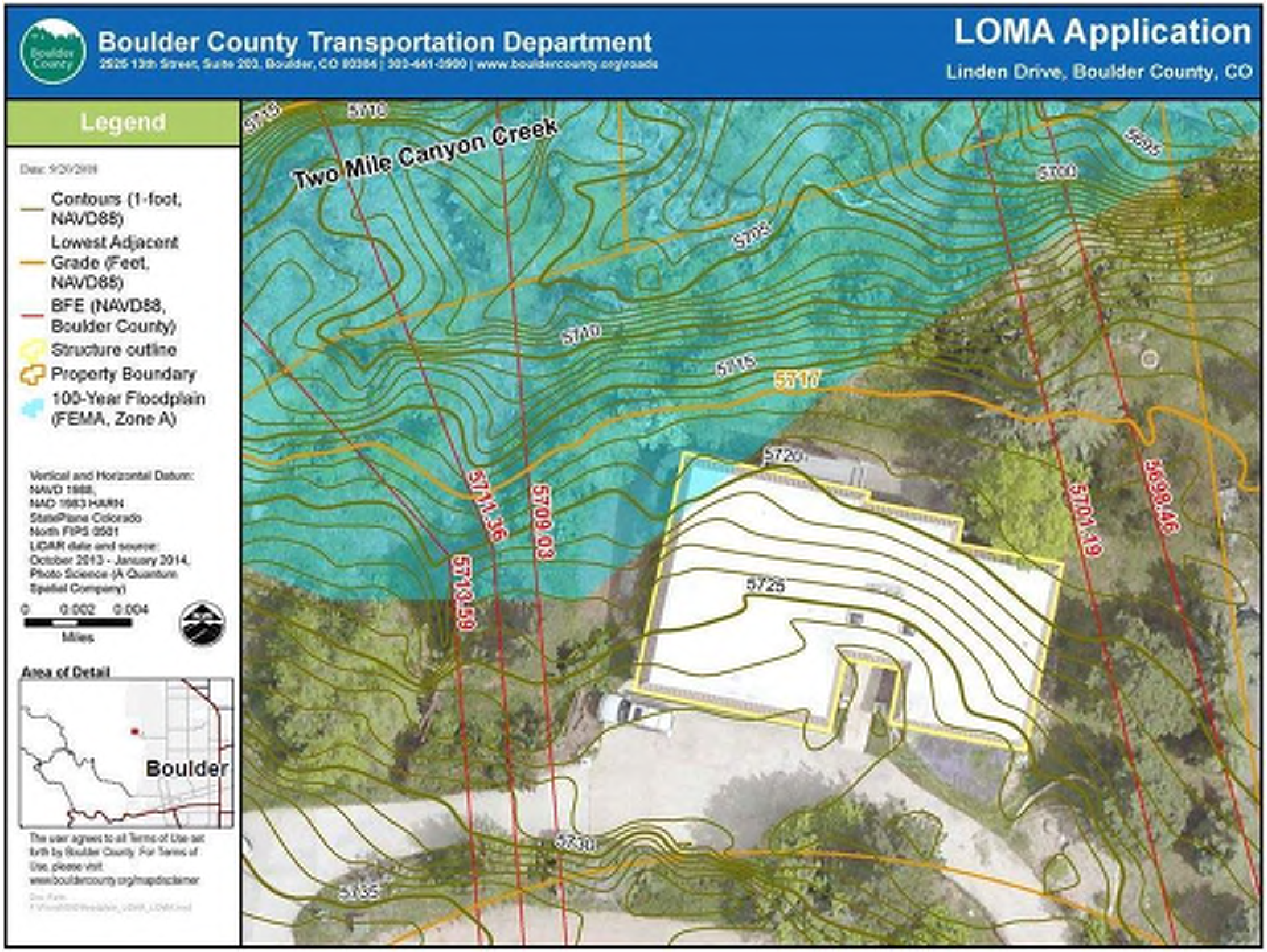
What other groups could use the data

Location	1-Hour Rainfall Threshold (inches)	Peak Flow Rate (cubic feet/ second)	Homes at Risk	Flood Affects Bridges & Roads Affected. Life Safety Risk
Fourmile Canyon Creek below burn area	3/4"	300 to 700	N/A	• Most small residential bridges, and driveways. • Life Safety risk is low except along creek banks.
Fourmile Canyon Creek below burn area	1"	600 to 1,000	N/A	• Most small residential bridges, and driveways. • Life Safety risk is low except along creek banks.
Fourmile Canyon Creek below burn area	1 ¼"	900 to 1,400	N/A	• Most small residential bridges, and driveways. • Life Safety risk is low except along creek banks.
Fourmile Canyon Creek below burn area	1½"	1,200 to 1,700	N/A	• Most small residential bridges, and driveways. • Life Safety risk is present.
Fourmile Canyon	1¾"	1,600	N/A	• Most small residential bridges,

- Floodplain Department
- OEM
- Transportation
- Land Use Planning
- Public Health



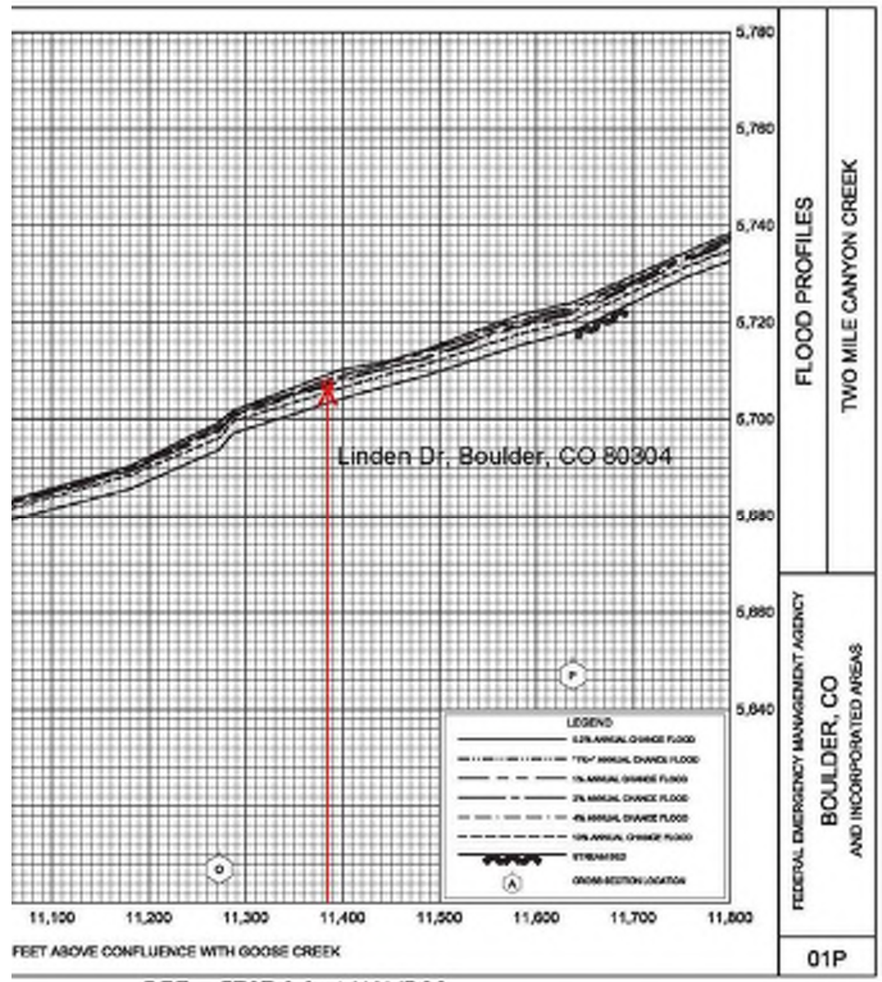
4. LiDAR LOMAs



4. LiDAR LOMAs

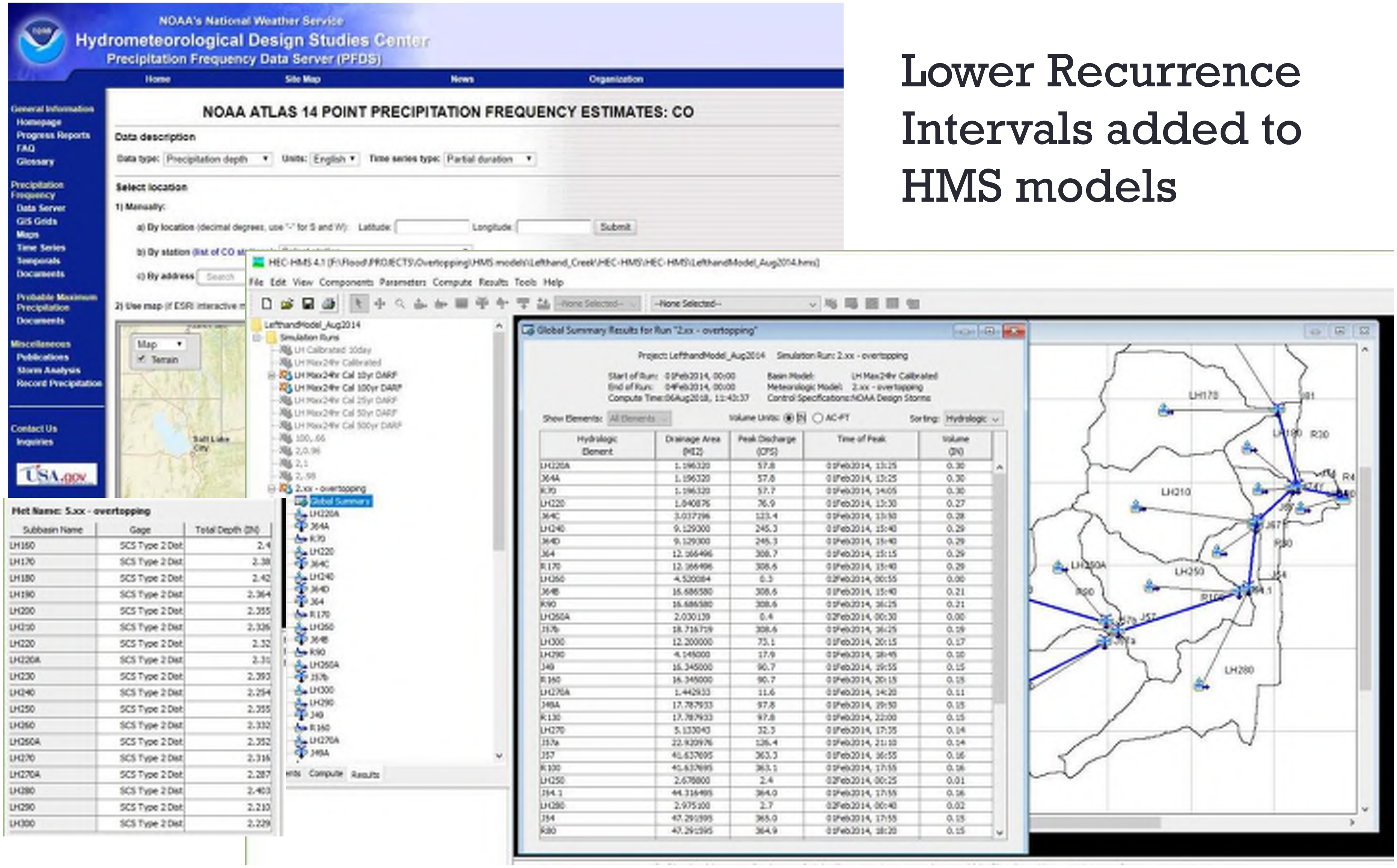
Boulder County Successes:
- 10+ LiDAR LOMAs approved for residents
- Residents are eligible for a flood insurance reimbursement

Data included in LOMA submittal:
- Annotated FIRM, FIRMette
- CHAMP FIS profile with BFE shown
- LiDAR Final Accuracy Report
- Topographic Map
- Subdivision Plat Map
- CHAMP Phase I data for reach
- Memo to FEMA from Boulder County



BFE = 5707.0 feet NAVD88
11,385 feet above confluence

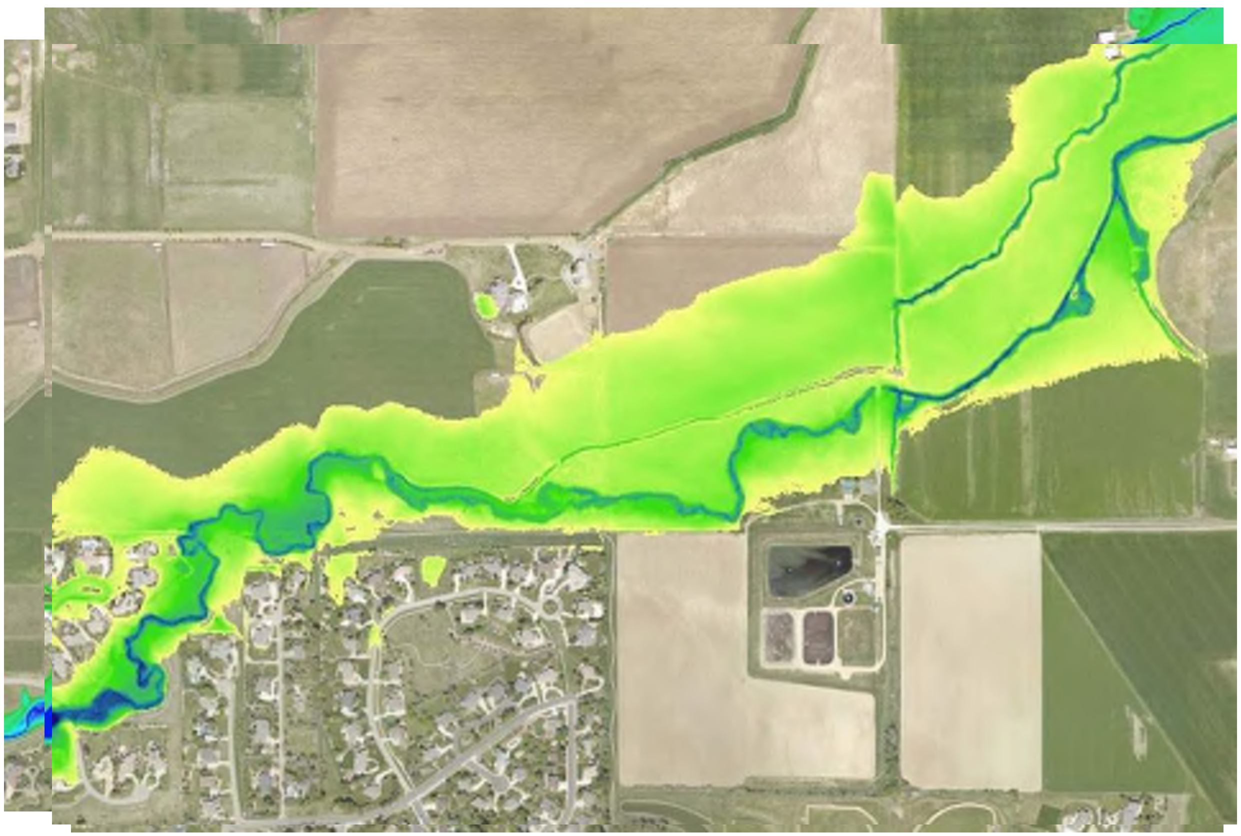
5 & 6. Overtopping and Evacuation



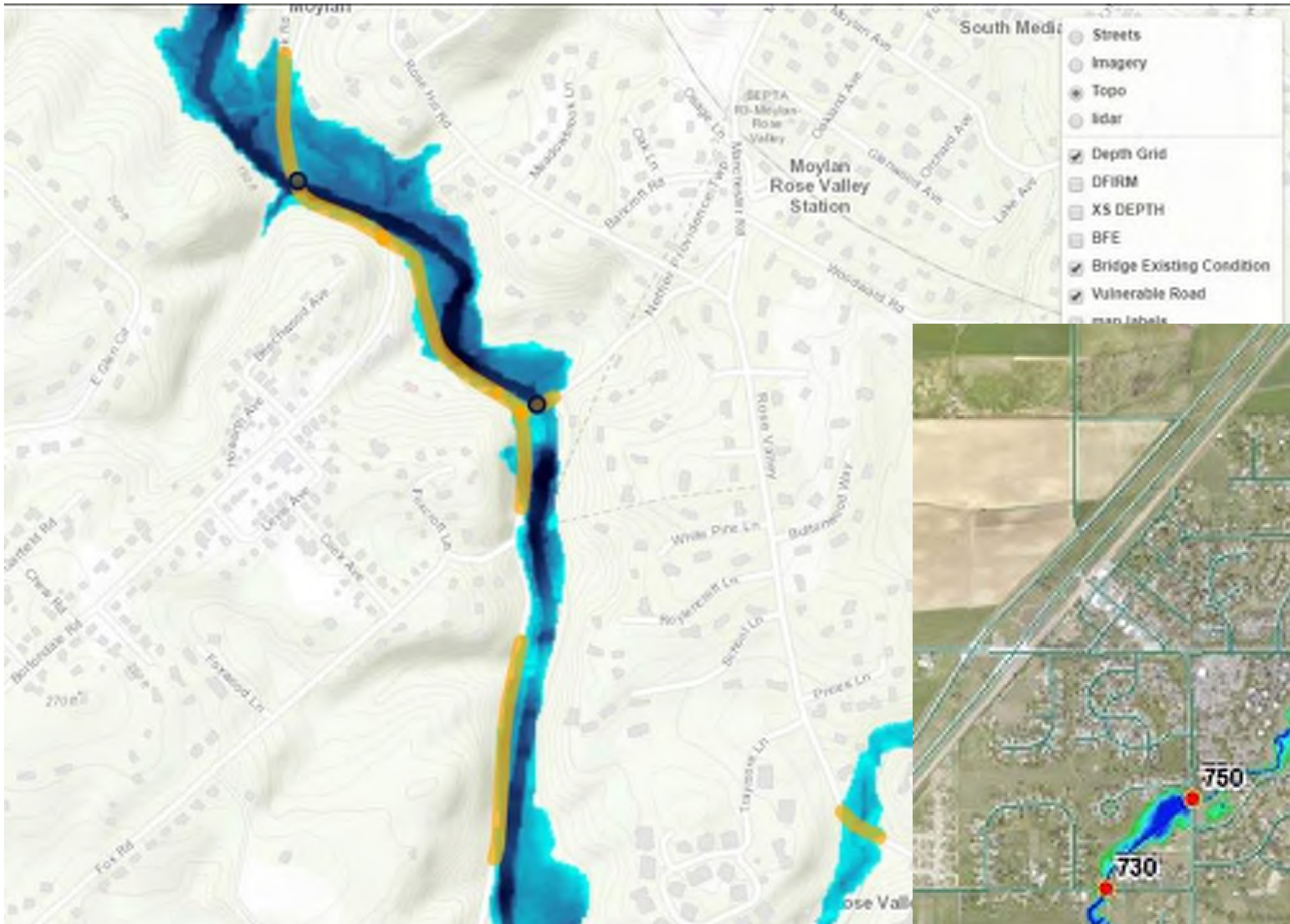
Lower Recurrence Intervals added to HMS models

5 & 6. Overtopping and Evacuation

Additional Products created with existing 10, 25, and 50 year flow data



5 & 6. Overtopping and Evacuation



Vulnerable Roads & Bridge Spatial Files

Bridge Capacity Spatial Files

Closing

- Applying CHAMP data and products to the benefit of existing County processes, plans, and programs.
- Developing new ways to put flood study data to work to benefit the County & residents and build Resilience.
- "Standing on the Shoulders of Giants"

Thank you!

Boulder County

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Michael Baker International

Kevin Doyle, PE
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CASFM 2018 Annual Conference

Green Infrastructure Sessions:

Session1: Quantifying Volume Reduction in Grass Buffers and Swales

Andrew Earles (Wright Water Engineers), Derek Rapp (Peak Stormwater), Jim Wulliman and Sara Johnson (Muller Engineering), Holly Piza (UDFCD)

Session2: Navigating the New Jersey & Washington State Stormwater Programs as Models for Approving Manufactured Treatment Devices

Mark B. Miller (AquaShield, Inc.)

Permaculture and Low Impact Development (LID)

Patrick Padden (Padden Permaculture)

Comprehensive Watershed Planning: Prioritize, Target and Implement Multipurpose Projects

Darren Beck (HR Green, Inc.)

Developing a Comprehensive Stormwater Infrastructure Master Plan

Drew Beck (Matrix Design Group)

Strategic Planning for Green Infrastructure in Boulder

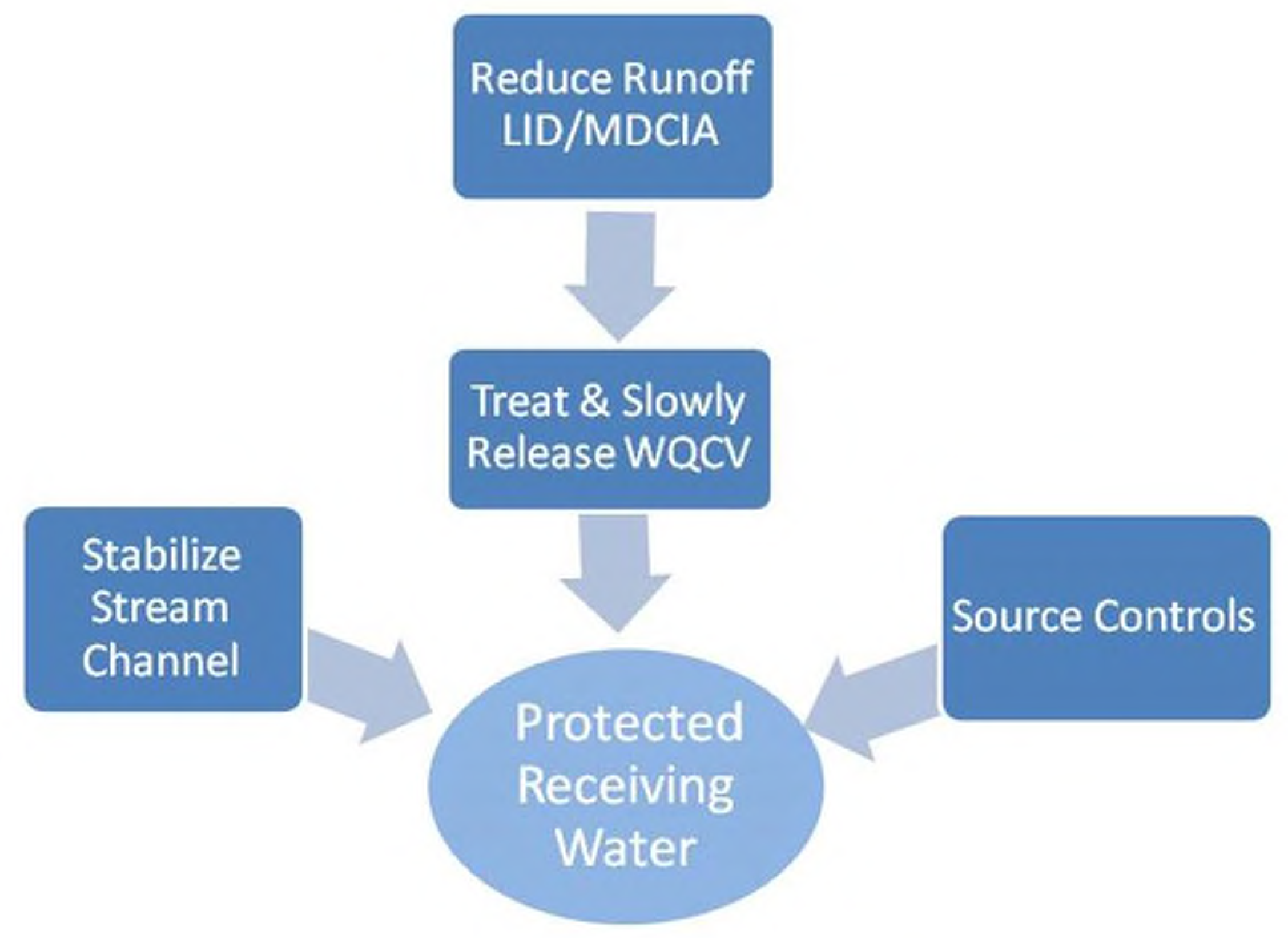
Candice Owen (City of Boulder)

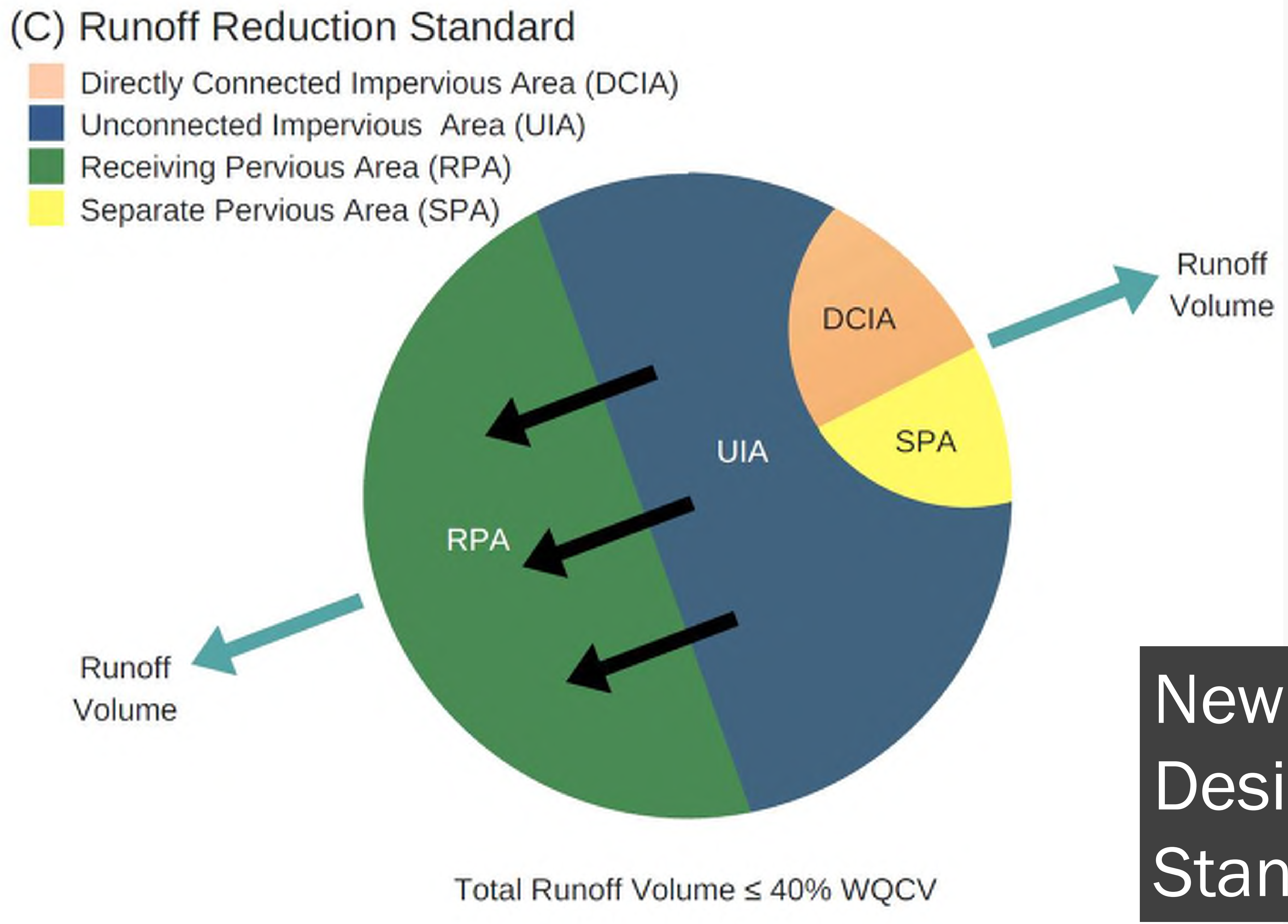
QUANTIFYING VOLUME REDUCTION IN GRASS BUFFERS AND SWALES

Andrew Earles, Wright Water Engineers
Derek Rapp, Peak Stormwater
Jim Wulliman and Sara Johnson, Muller Engineering
Holly Piza, UDFCD

CASFM 2018

4-Step Process

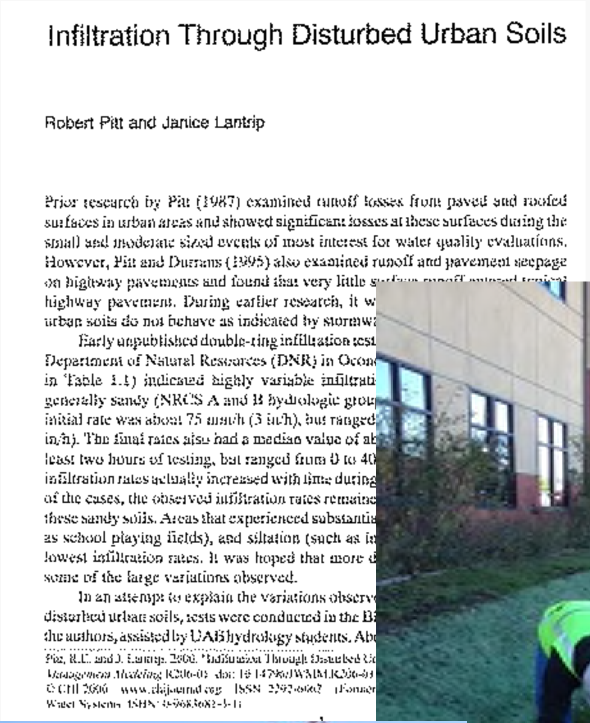




New MS4 Design Standard

Infiltration

- Infiltration Research
  - *Pitt and Lantrip, 2000*
  - *Colorado Field Studies*
- Soil
- Vegetation



Infiltration Through Disturbed Urban Soils

Robert Pitt and Janice Lantrip

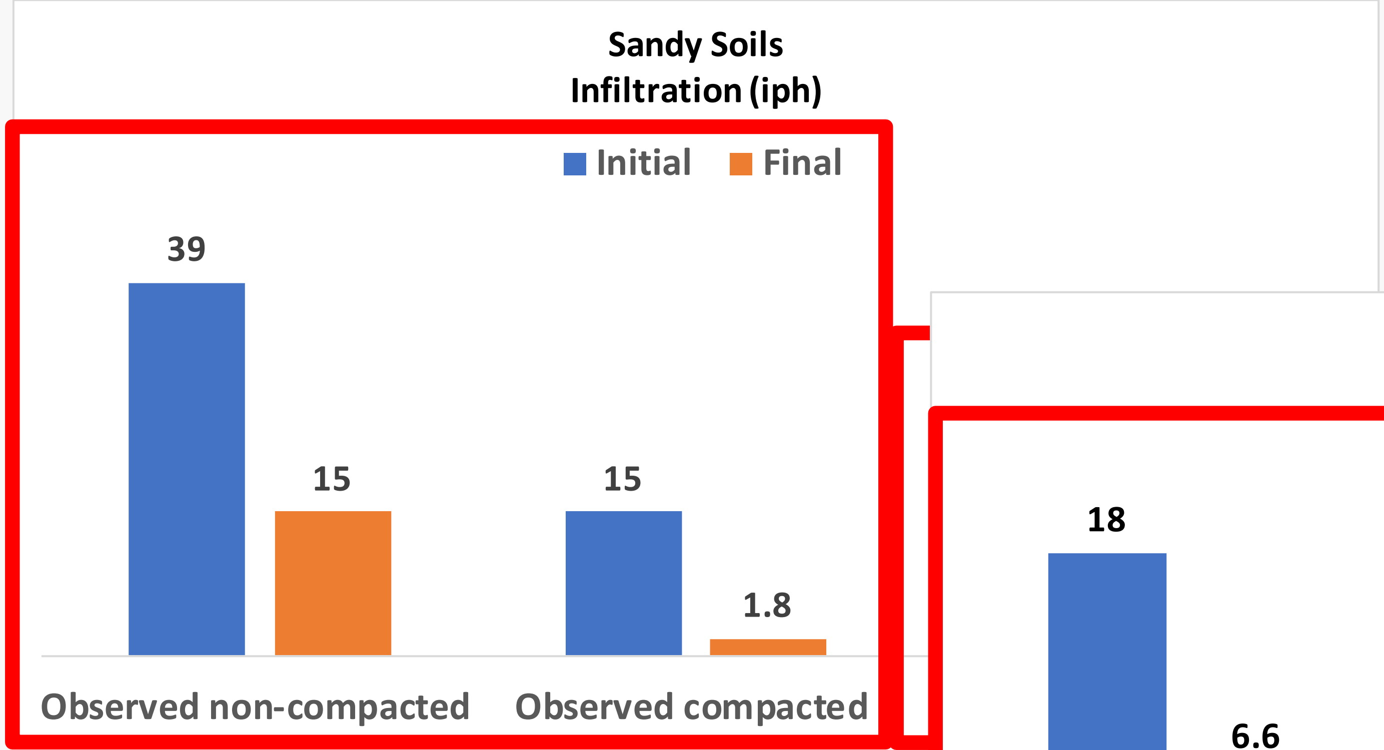
Prior research by Pitt (1987) examined runoff losses from paved and roofed surfaces in urban areas and showed significant losses at these surfaces during the small and moderate sized events of most interest for water quality evaluations. However, Pitt and Durrans (1995) also examined runoff and pavement seepage on highway pavements and found that very little s
highway pavement. During earlier research, it w
urban soils do not behave as indicated by stormw

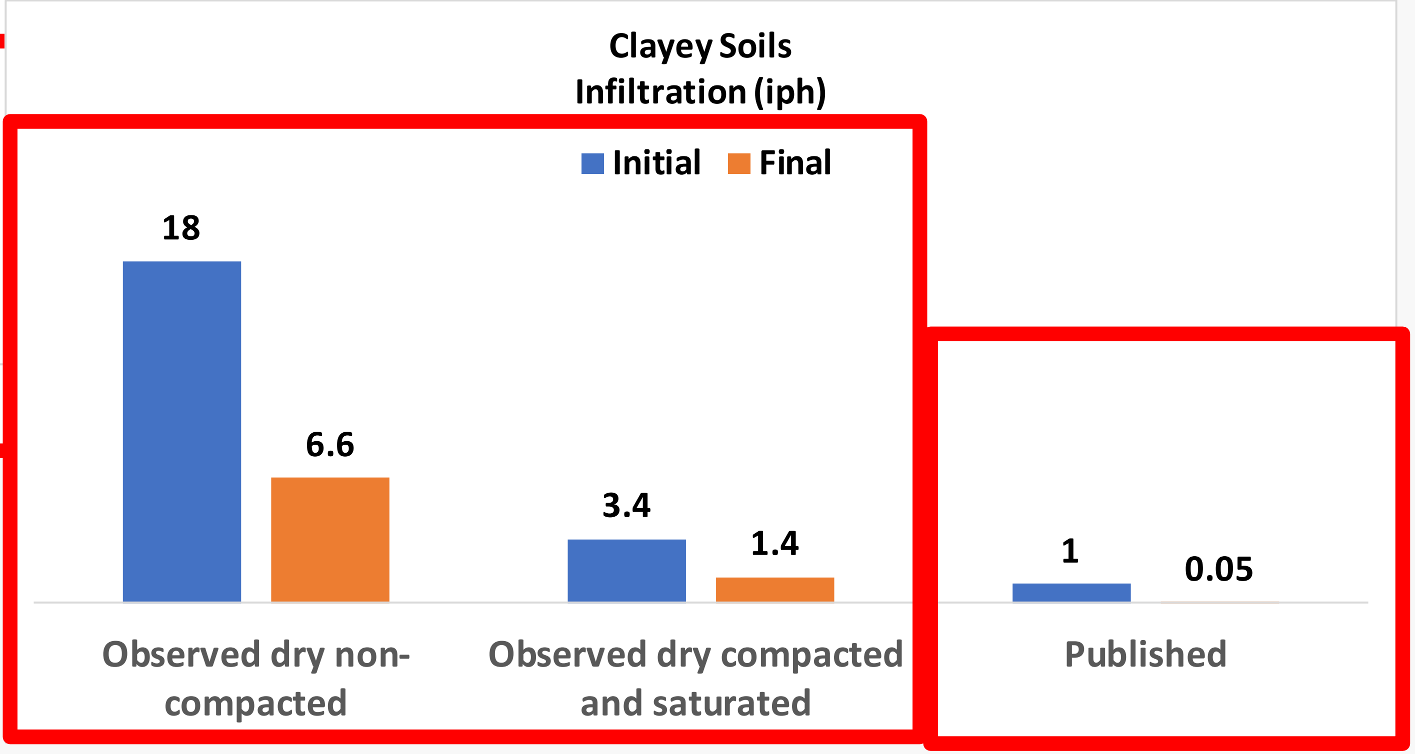
Early unpublished double-ring infiltration test
Department of Natural Resources (DNR) in Ocon
in Table 1.1) indicated highly variable infiltrati
generally sandy (NRCS A and B hydrologic grou
initial rate was about 75 mm/h (3 in/h), but ranged
in/h). The final rates also had a median value of ab
least two hours of testing, but ranged from 0 to 40
infiltration rates actually increased with time during
of the cases, the observed infiltration rates remaine
these sandy soils. Areas that experienced substantia
as school playing fields), and siltation (such as in
lowest infiltration rates. It was hoped that more d
some of the large variations observed.

In an attempt to explain the variations observ
disturbed urban soils, tests were conducted in the B
the authors, assisted by UAB hydrology students. Ab

Infiltration Rates

(Pitt and Lantrip, 2000)



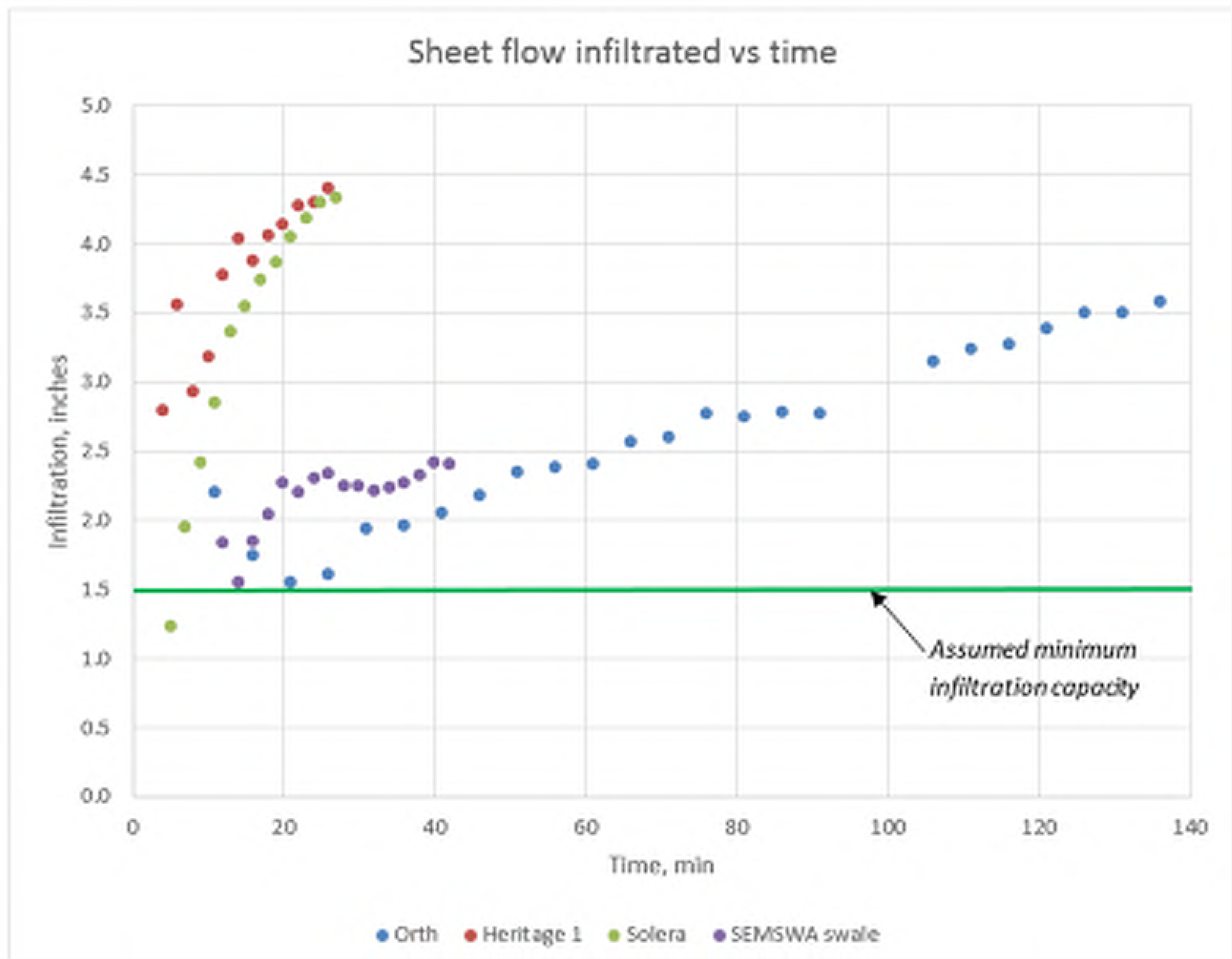


Central Colorado Field Studies

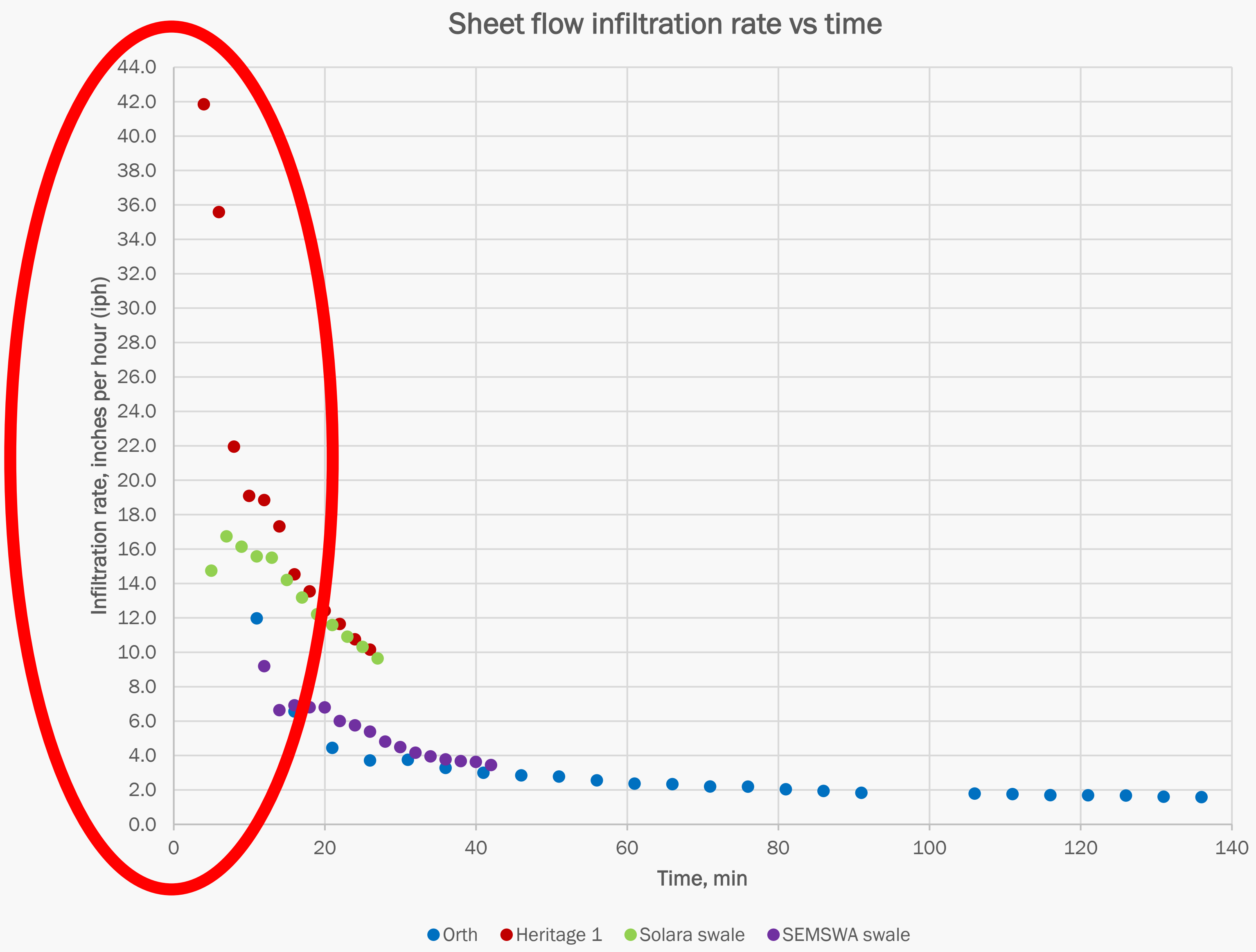
- Douglas County/SEMSWA
- 4 Sites (2012-2015)
  - *Residential*
  - *Park*
  - *Commercial*
  - *SEMSWA Office Swale*
- Soil types
  - *Sandy Loam*
  - *Clay Loam*
- Sheet flow infiltration

SEMSWA office swale

Central Colorado Field Studies



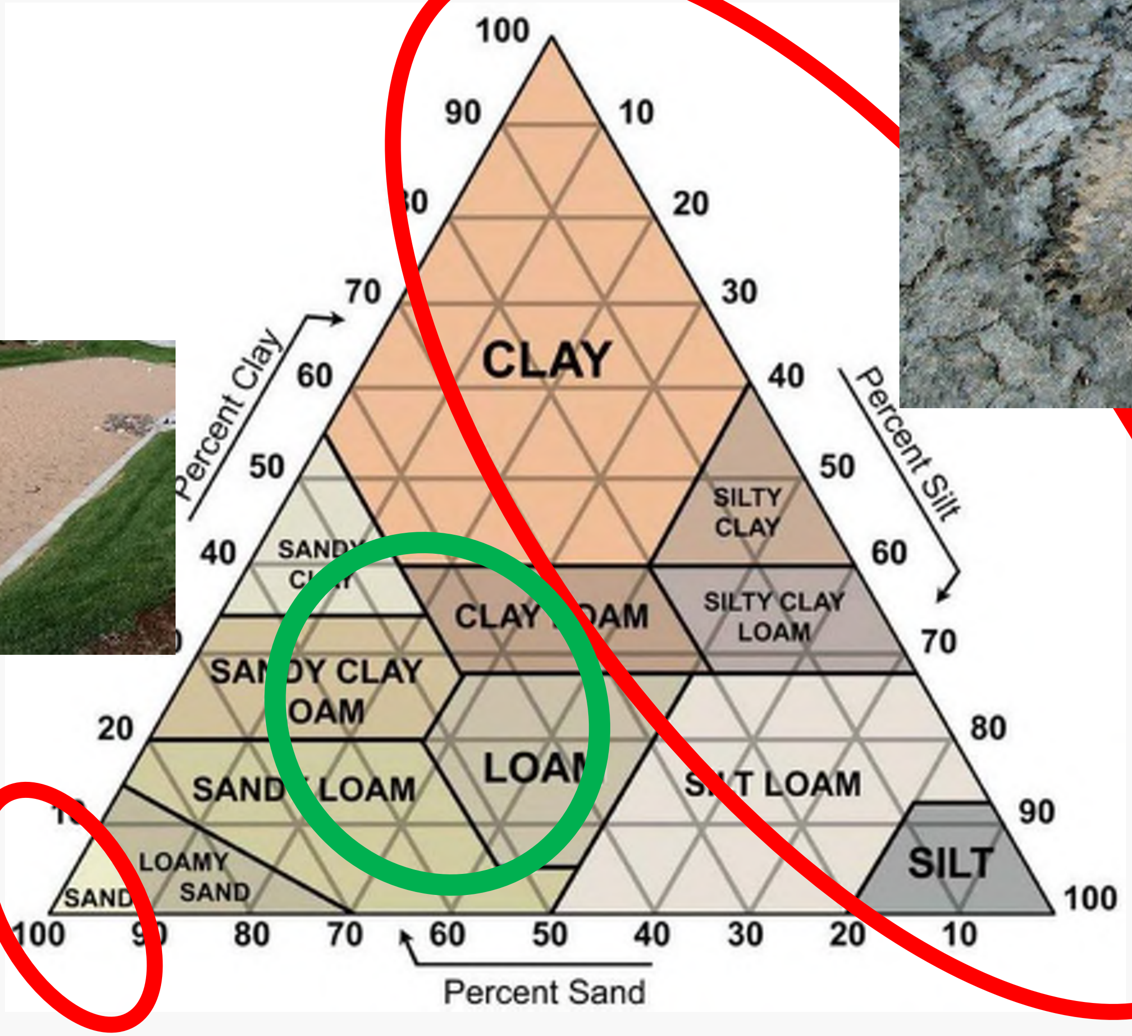
Central Colorado Field Studies



Two Ends of the Soil Spectrum

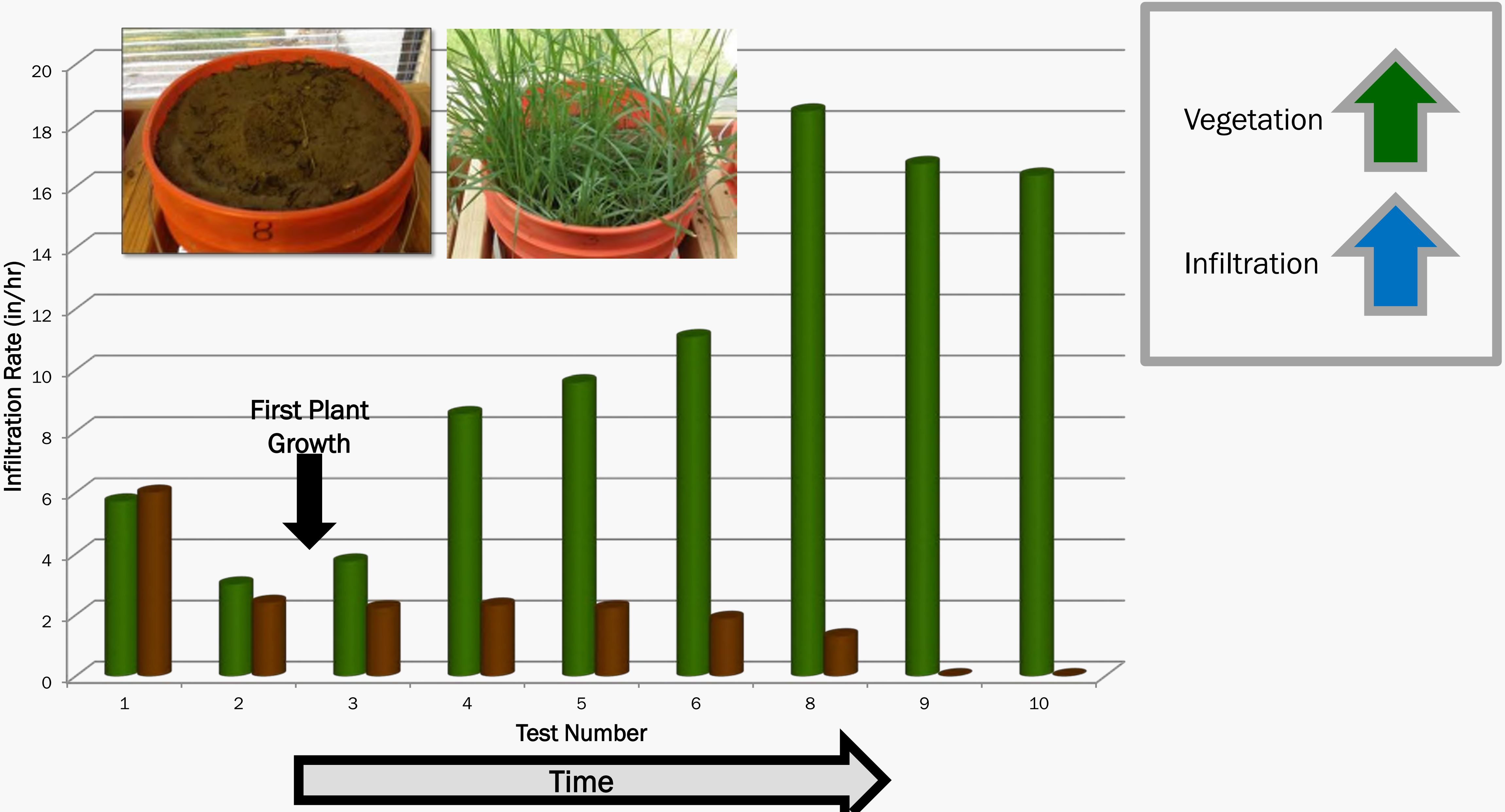
Property	**Sandy**	**Clayey**
Drainage rate	High	Low
Aeration	High	Low
Water holding capacity	Low	High
Organic content	Low	High
Ability to store plant nutrients	Low	High
Adsorption of pollutants	Low	High

Topsoil: “Searching for the Sweet Spot”



“SWEET SPOT”

Vegetation Studies



SWMM

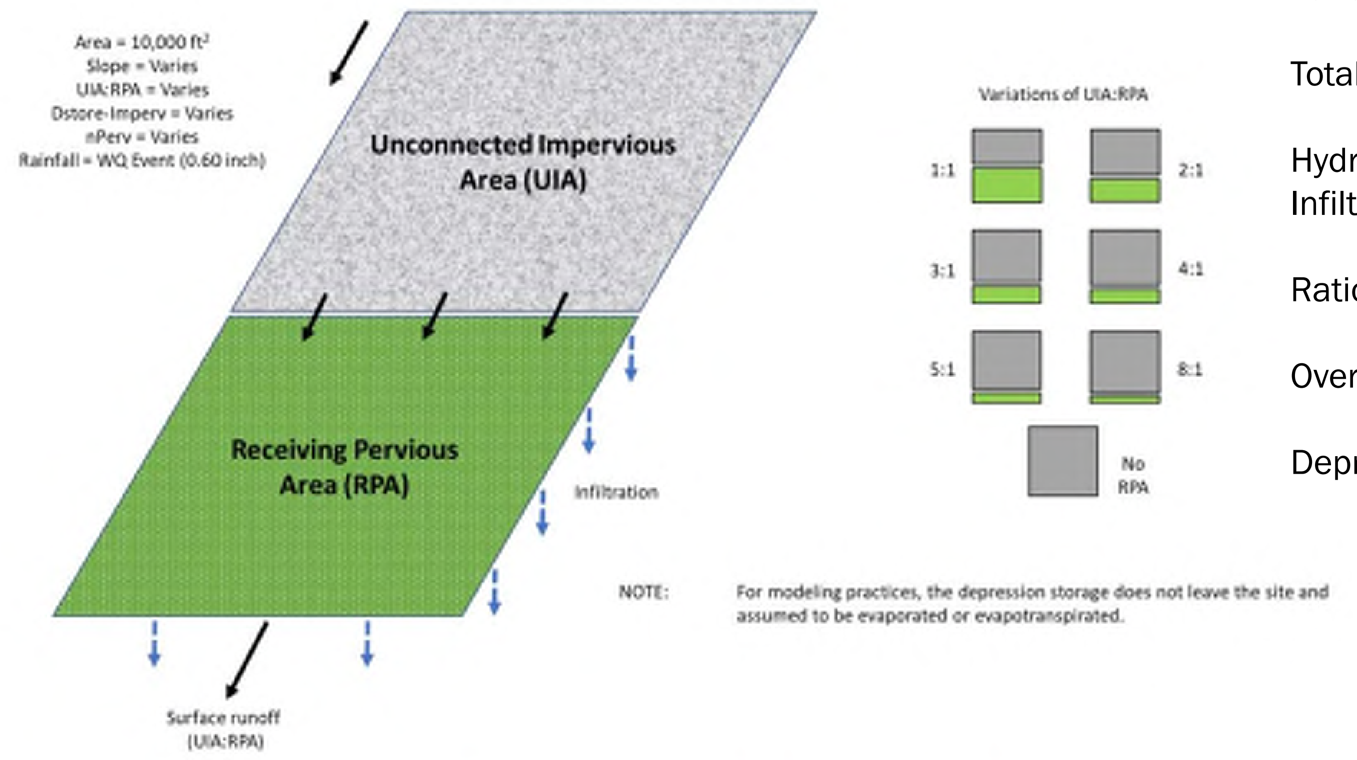


Figure 2 – Simplified SWMM Layouts for Varying UIA:RPA Ratios

Variables Considered

Total Area

Hydrologic Soil Group/ Horton Infiltration Parameters

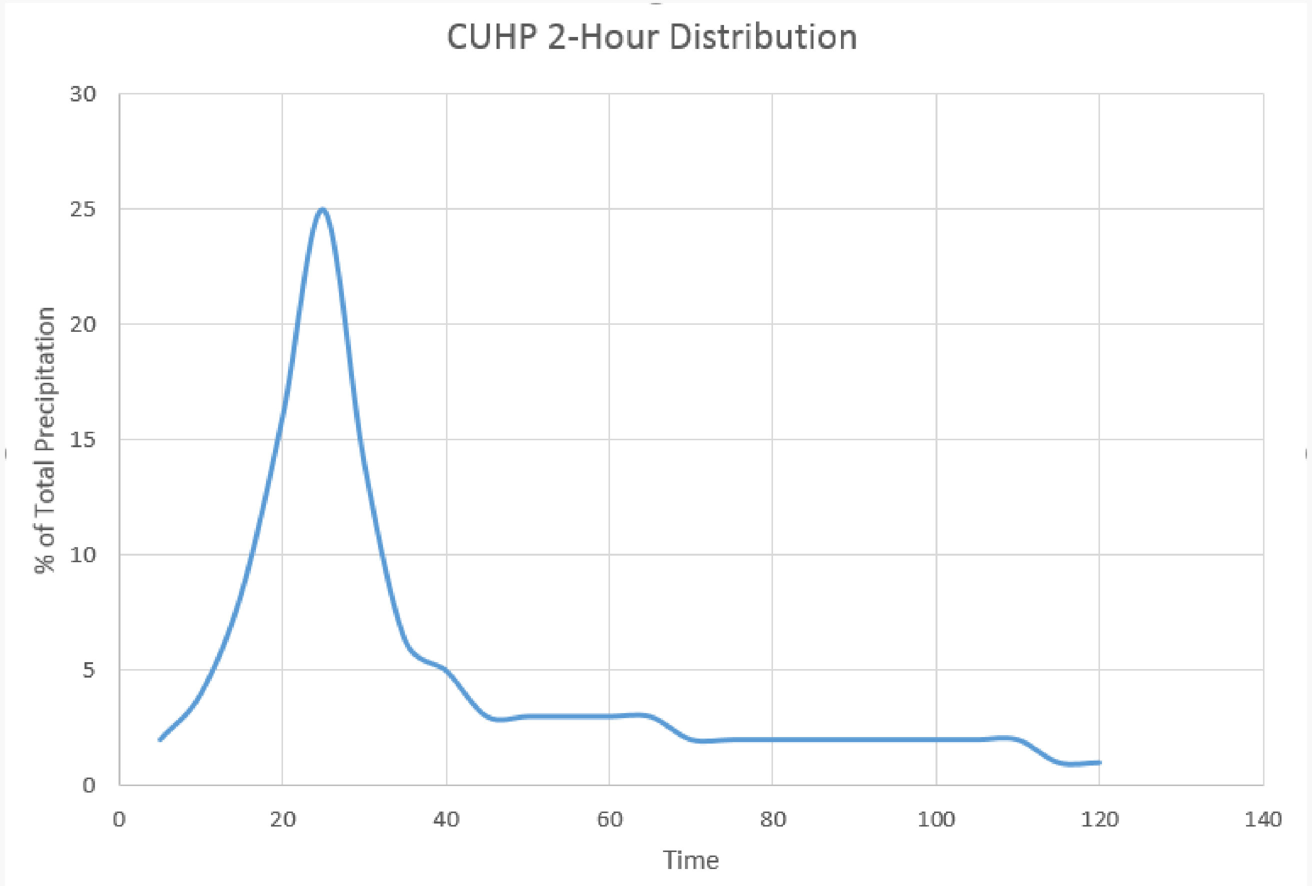
Ratio of UIA to RPA

Overland Slope

Depression Storage

Rainfall

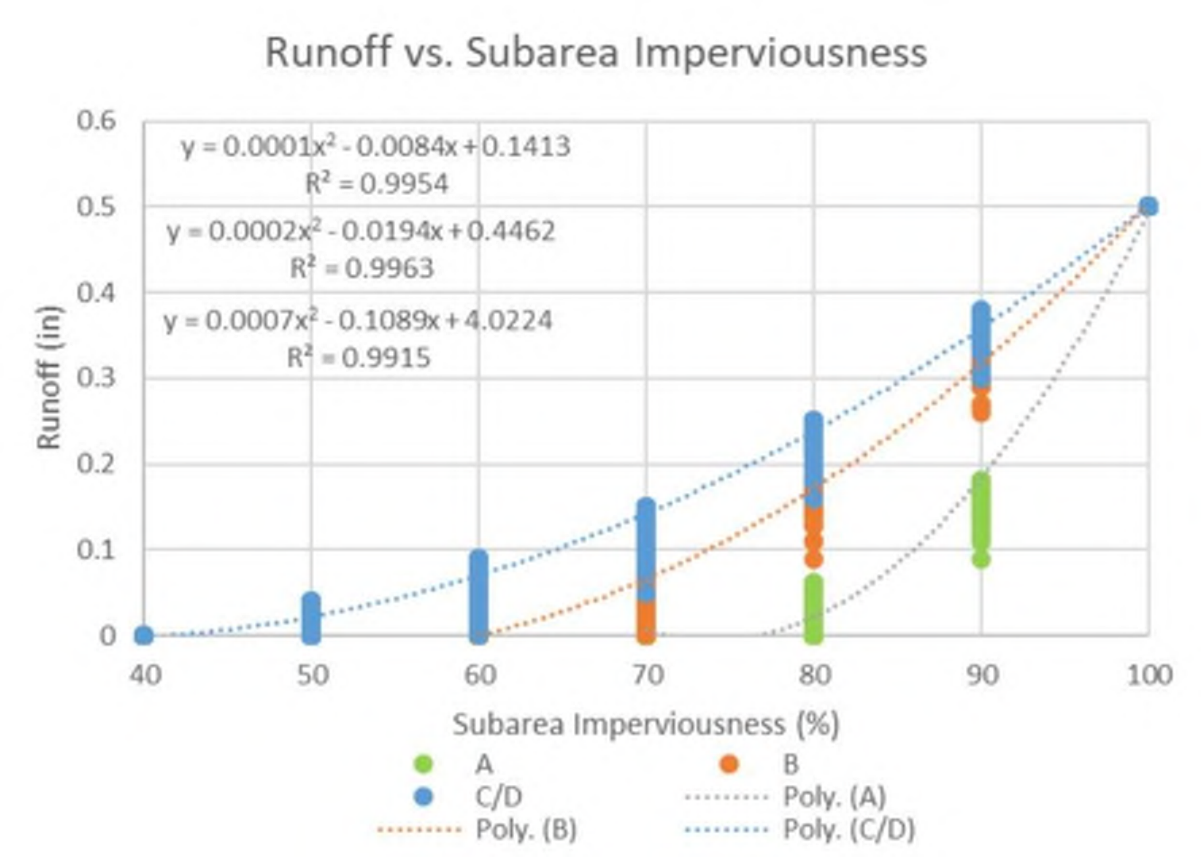
- Water Quality Capture Volume (WQCV) for Denver = 0.6 inches of rainfall
- 0.6 inches depth distributed over 2 hours using CUHP temporal distribution
- Analyzed range from 0.25 to 0.95 inches

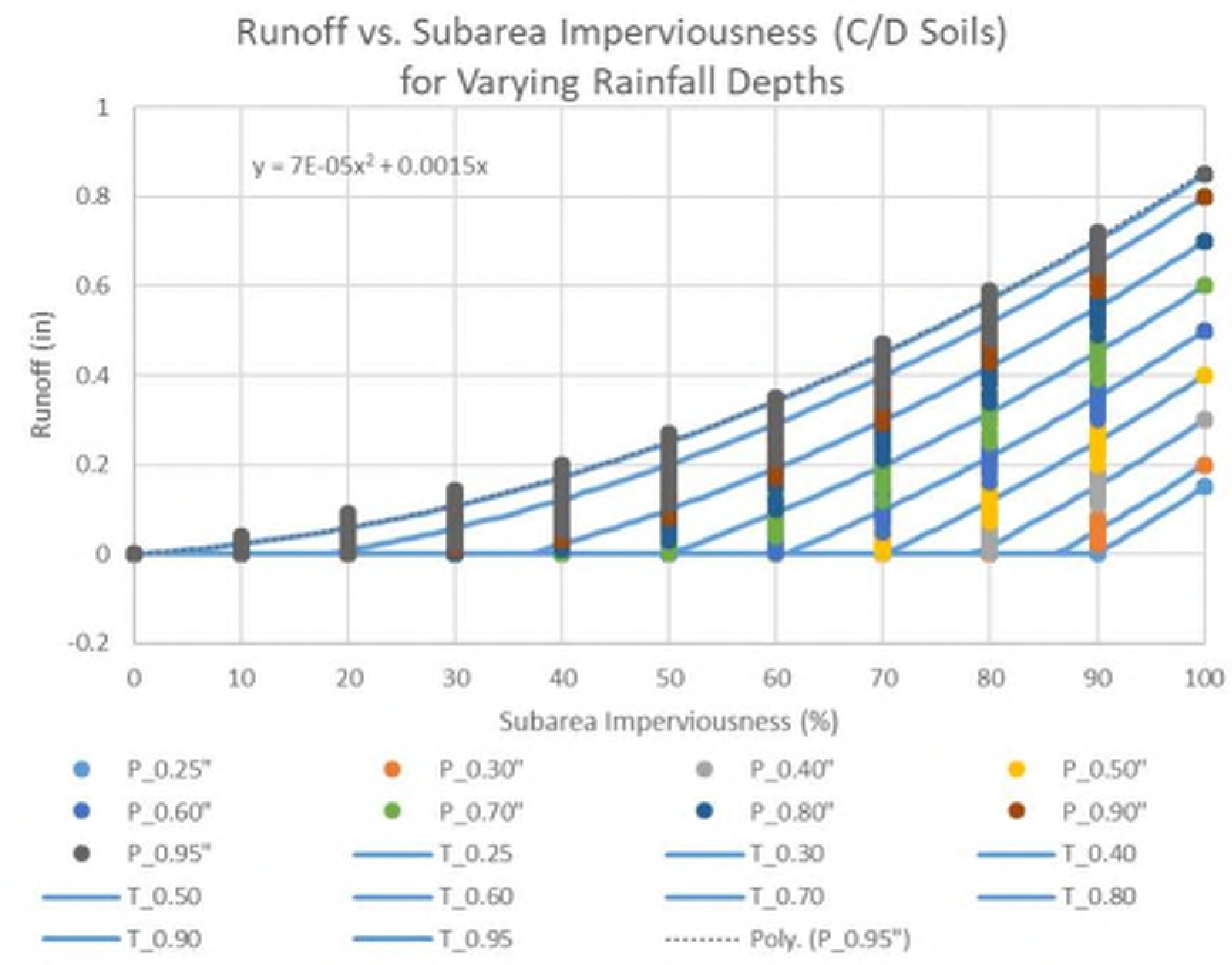


Largest impacts

- Soil Type
- UIA:RPA ratio

  (imperviousness)





Runoff vs. Subarea Imperviousness (C/D Soils)
for Varying Rainfall Depths
y = 7E-05x² + 0.0015x
Runoff (in)
1
0.8
0.6
0.4
0.2
0
-0.2
0
10
20
30
40
50
60
70
80
90
100
Subarea Imperviousness (%)
P_0.25"
P_0.30"
P_0.40"
P_0.50"
P_0.60"
P_0.70"
P_0.80"
P_0.90"
P_0.95"
T_0.25
T_0.30
T_0.40
T_0.50
T_0.60
T_0.70
T_0.80
T_0.90
T_0.95
Poly. (P_0.95")

$$Q = C_0 + C_1(0.95 - P_2) + C_2(Area) + C_3(L:W) + C_4(Slope) + C_5(Imp) + C_6 Imp^2 \quad \textbf{\textit{Equation 1}}$$

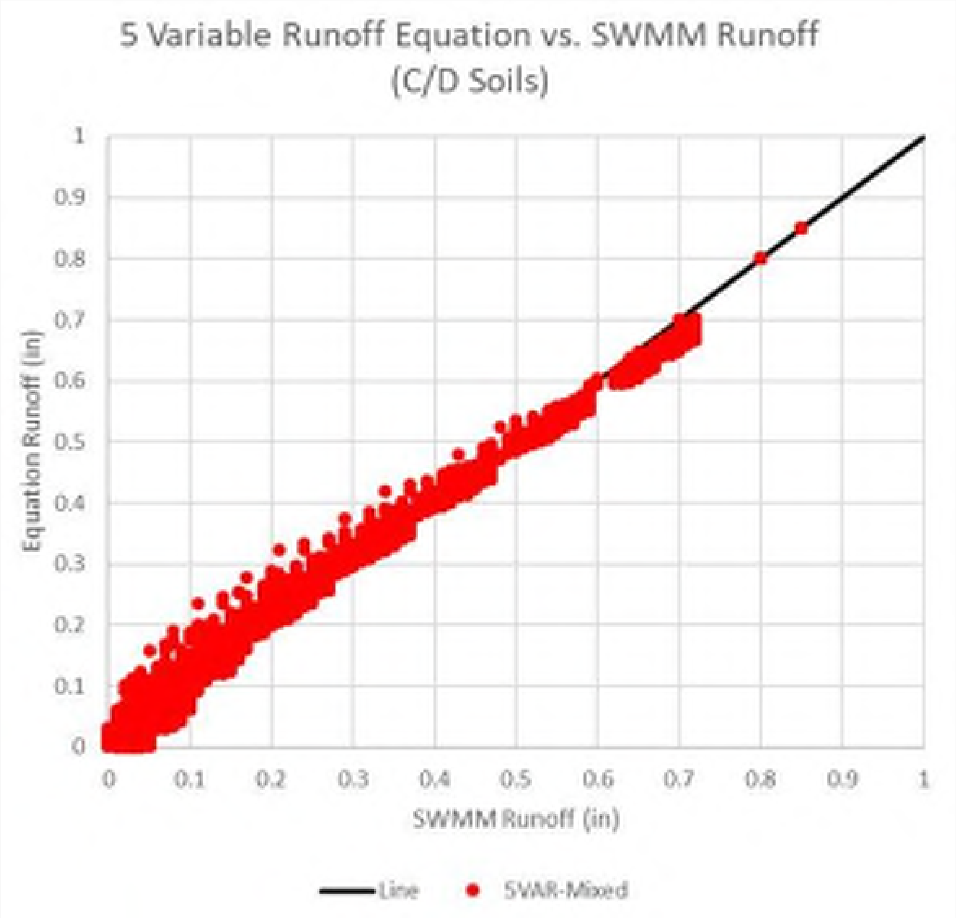
Where:

Q = Runoff (inches)
P_2 = 2-hour WQCV Rainfall Depth (inches)
Area = total subarea, sum of UIA and RPA (acres)
L:W = Ratio of total flow length to catchment width
Slope = average overland slope (%)
Imp = subarea imperviousness (%) calculated as (UIA / (UIA+RPA)) * 100
C_x = coefficients determined through regression analysis

Table 3: Empirical Runoff Equation Coefficients.

Soil Type	Constant C_0	Rainfall (in) C_1	Area (ac) C_2	L:W C_3	Slope (%) C_4	%Imp C_5	%Imp² C_6
A	5.81E-01	-7.79E-01	-1.45E-02	-1.93E-03	7.03E-04	-2.49E-02	2.64E-04
B	-7.77E-02	-9.25E-01	-1.07E-02	-1.45E-03	5.02E-04	-1.36E-04	9.24E-05
C/D	-1.13E-02	-8.99E-01	-1.17E-02	-1.57E-03	5.45E-04	3.55E-03	4.64E-05

Equation vs. SWMM Runoff

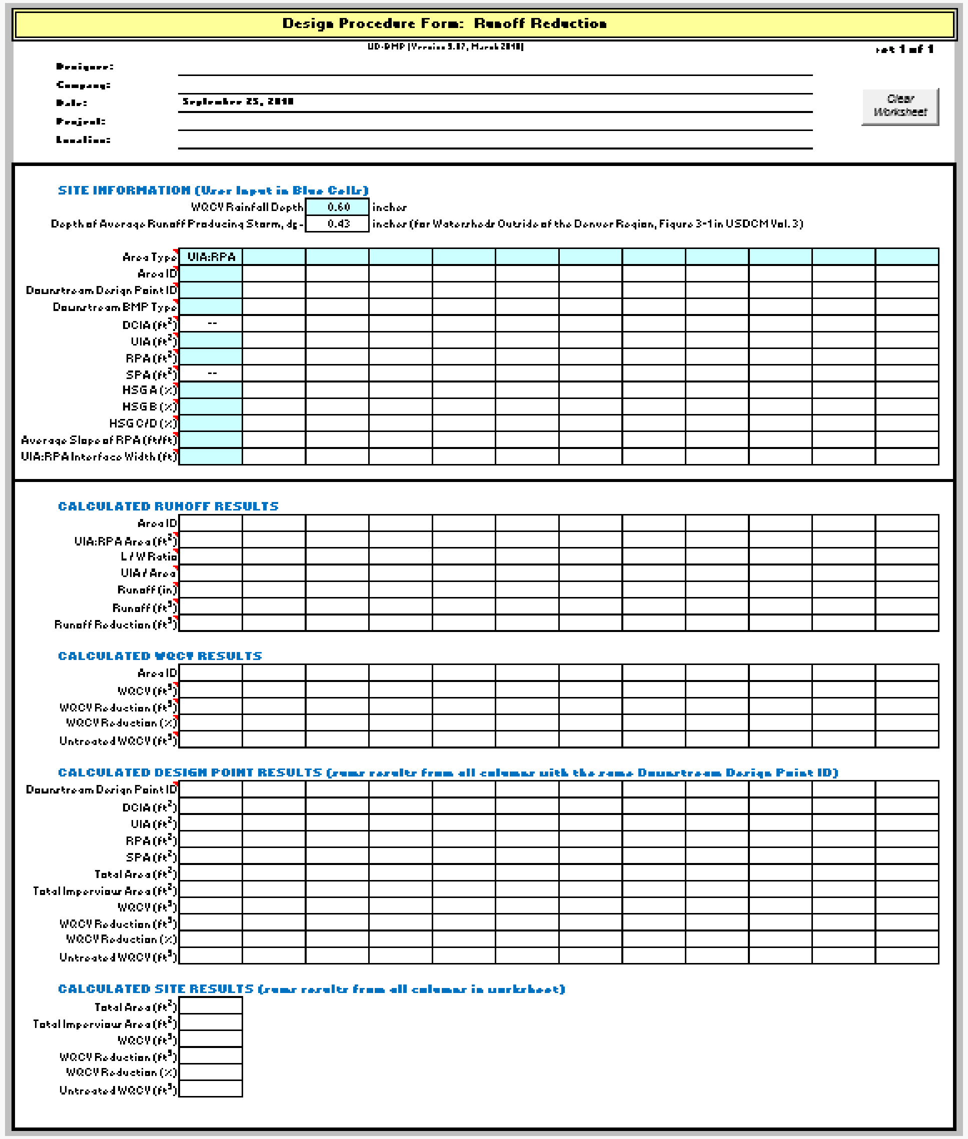


Recommended Constraints

- 0.25 inches < Precipitation <0.95 inches
- 0.025 acres < Area < 2.0 acres
- 0.0625 < L:W ratio < 16.0
- 0.5% < Slope < 33%

Quantifying Runoff Reduction

- Intro to UD-BMP – Runoff Reduction
- Examples



Design Procedure Form: Runoff Reduction

Sheet 1 of 1

Designer:

Company:

Date: September 25, 2018

Project:

Location:

Clear Worksheet

SITE INFORMATION (User Input in Blue Cells)

WQCV Rainfall Depth: 0.60 inches

Depth of Average Runoff Producing Storm, d_6 = 0.43 inches (for Watersheds Outside of the Denver Region, Figure 3-1 in USDCM Vol. 3)

Area Type	UIA:RPA											
Area ID												
Downstream Design Point ID												
Downstream BMP Type												
DCIA (ft^2)	--											
UIA (ft^2)												
RPA (ft^2)												
SPA (ft^2)	--											
HSG A (%)												
HSG B (%)												
HSG C/D (%)												
Average Slope of RPA (ft/ft)												
UIA:RPA Interface Width (ft)												

CALCULATED RUNOFF RESULTS

Area ID												
UIA:RPA Area (ft^2)												
L / W Ratio												
UIA / Area												
Runoff (in)												
Runoff (ft^3)												
Runoff Reduction (ft^3)												

CALCULATED WQCV RESULTS

Area ID												
WQCV (ft^3)												
WQCV Reduction (ft^3)												
WQCV Reduction (%)												
Untreated WQCV (ft^3)												

CALCULATED DESIGN POINT RESULTS (sums results from all columns with the same Downstream Design Point ID)

Downstream Design Point ID												
DCIA (ft^2)												
UIA (ft^2)												
RPA (ft^2)												
SPA (ft^2)												
Total Area (ft^2)												
Total Impervious Area (ft^2)												
WQCV (ft^3)												
WQCV Reduction (ft^3)												
WQCV Reduction (%)												
Untreated WQCV (ft^3)												

CALCULATED SITE RESULTS (sums results from all columns in worksheet)

Total Area (ft^2)	
Total Impervious Area (ft^2)	
WQCV (ft^3)	
WQCV Reduction (ft^3)	
WQCV Reduction (%)	
Untreated WQCV (ft^3)	

Quantifying Runoff Reduction

Intro to UD BMP – Runoff Reduction

- Inputs
  - *Site Information*
    - Area Type and how much of each
      - *UIA/RPA*
      - *DCIA*
      - *SPA*
    - Soils
    - HSG A, B, C/D (%)
    - Average Slope of RPA
    - Interface width (Area Type UIA:RPA only)

SITE INFORMATION (User Input in Blue Cells)

WQCV Rainfall Depth	0.60	inches
Depth of Average Runoff Producing Storm, d_6 =	0.43	inches

Area Type				
Area ID				
Downstream Design Point ID				
Downstream BMP Type				
DCIA (ft^2)				
UIA (ft^2)				
RPA (ft^2)				
SPA (ft^2)				
HSG A (%)				
HSG B (%)				
HSG C/D (%)				
Average Slope of RPA (ft/ft)				
UIA:RPA Interface Width (ft)				

Quantifying Runoff Reduction

Intro to UD BMP – Runoff Reduction

- Runoff Output/Results
  - *Total Area*
  - *L/W Ratio*
  - *UIA/Area*
  - *Runoff (from UIA:RPA pair)*
    - Depth
    - Volume
    - Reduction (Infiltration into RPA+ Depression Storage)

CALCULATED RUNOFF RESULTS

Area ID				
UIA:RPA Area (ft^2)				
L / W Ratio				
UIA / Area				
Runoff (in)				
Runoff (ft^3)				
Runoff Reduction (ft^3)				

Quantifying Runoff Reduction

Intro to UD BMP – Runoff Reduction

- WQCV Output/Results
  - *Calculated WQCV based on <u>impervious area</u> only*
  - *WQCV Reduction (as volume and as %)*
  - *Untreated WQCV*

CALCULATED WQCV RESULTS

Area ID				
WQCV (ft^3)				
WQCV Reduction (ft^3)				
WQCV Reduction (%)				
Untreated WQCV (ft^3)				

Quantifying Runoff Reduction

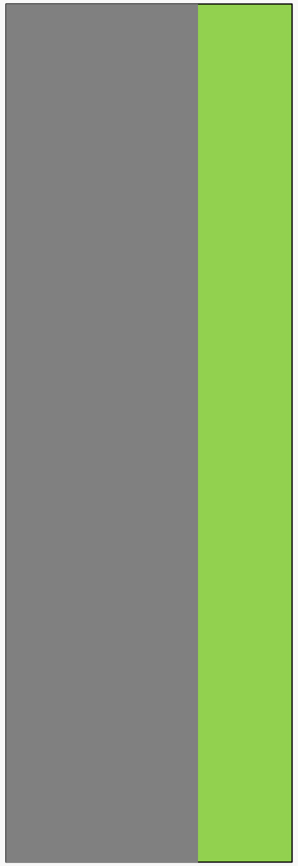
- Regional Trail 10 ft wide x 100 ft long
  - *B Soils*

CALCULATED RUNOFF RESULTS

Area ID	Trail 1
UIA:RPA Area (ft^2)	1,500
L / W Ratio	0.15
UIA / Area	0.6667
Runoff (in)	0.00
Runoff (ft^3)	0
Runoff Reduction (ft^3)	42

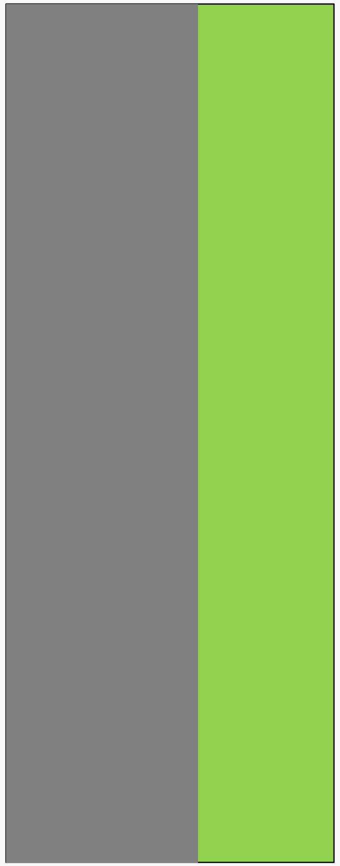
CALCULATED WQCV RESULTS

Area ID	Trail 1
WQCV (ft^3)	42
WQCV Reduction (ft^3)	42
WQCV Reduction (%)	100%
Untreated WQCV (ft^3)	0



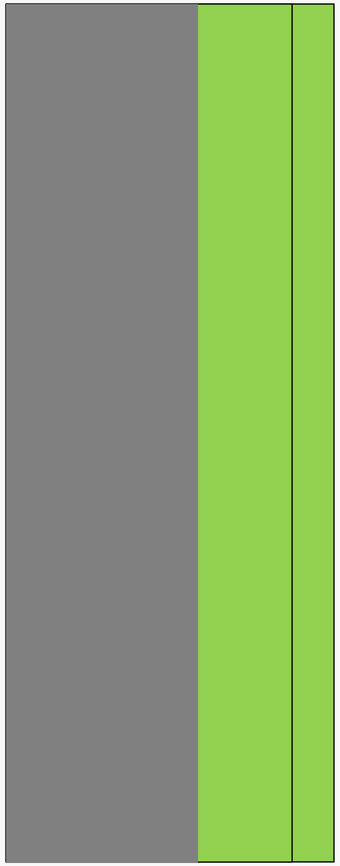
Quantifying Runoff Reduction

- Regional Trail 10 ft wide x 100 ft long
  - *C\D Soils – 852* ft^2



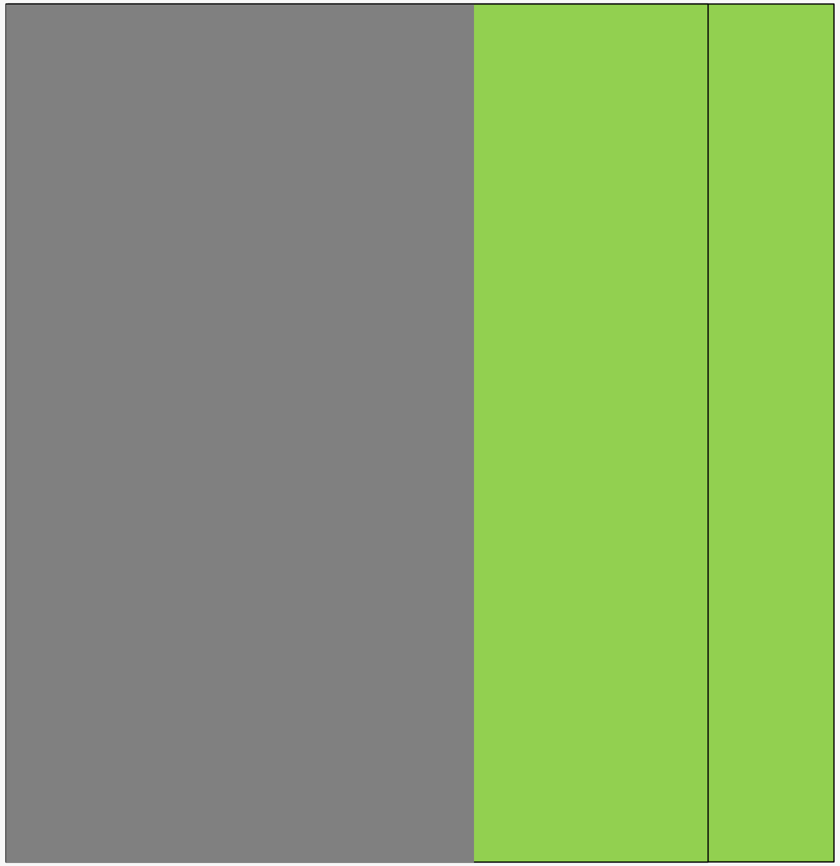
Quantifying Runoff Reduction

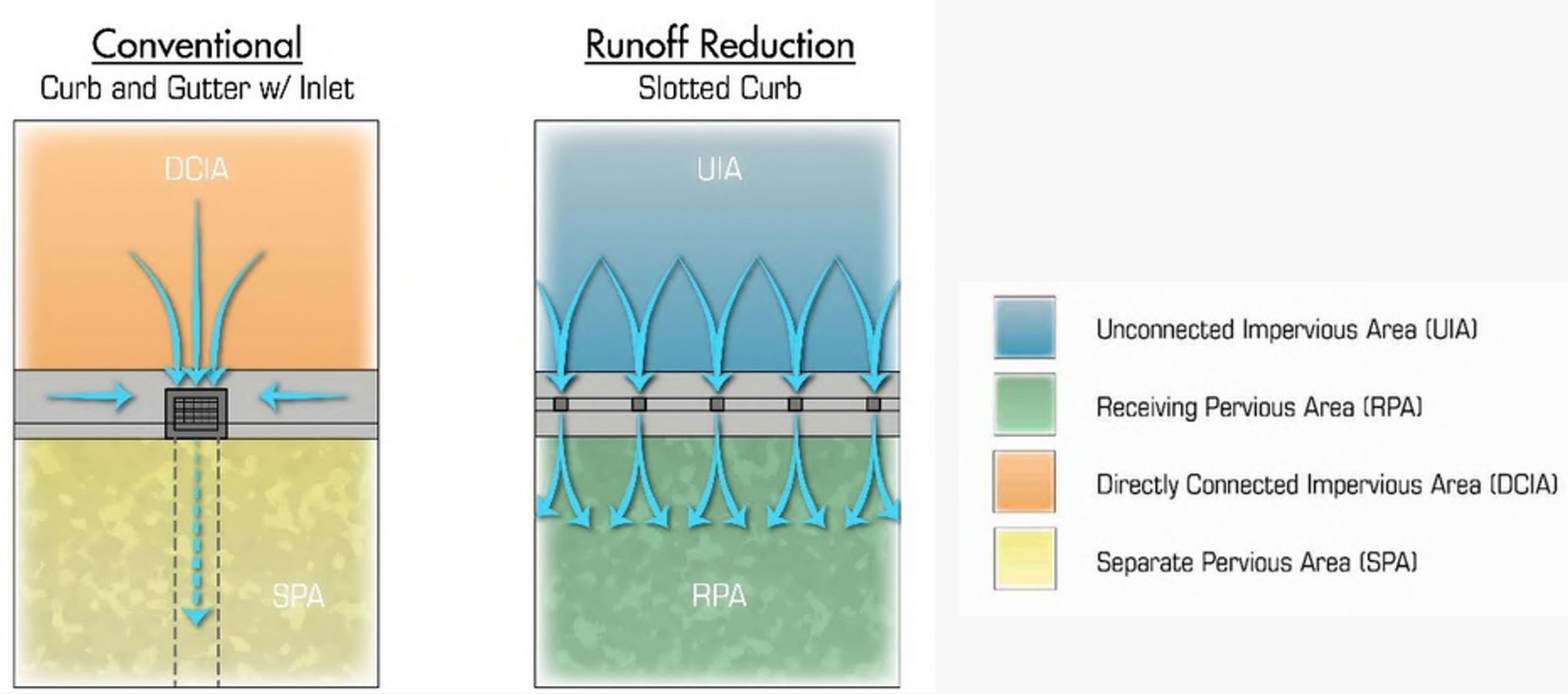
- Regional Trail 10 ft wide x 100 ft long
  - *B Soils – RPA 5 feet wide along the 100 ft trail*
  - *C/D Soils – RPA 8.5 feet wide along the 100 ft trail*



Quantifying Runoff Reduction

- Parking Lot 7,000 ft^2
  - *B Soils – RPA = 3,500 ft^2*
  - *C/D Soils – RPA = 5,910 ft^2*




Conventional
Curb and Gutter w/ Inlet
DCIA
SPA
Runoff Reduction
Slotted Curb
UIA
RPA
Unconnected Impervious Area (UIA)
Receiving Pervious Area (RPA)
Directly Connected Impervious Area (DCIA)
Separate Pervious Area (SPA)

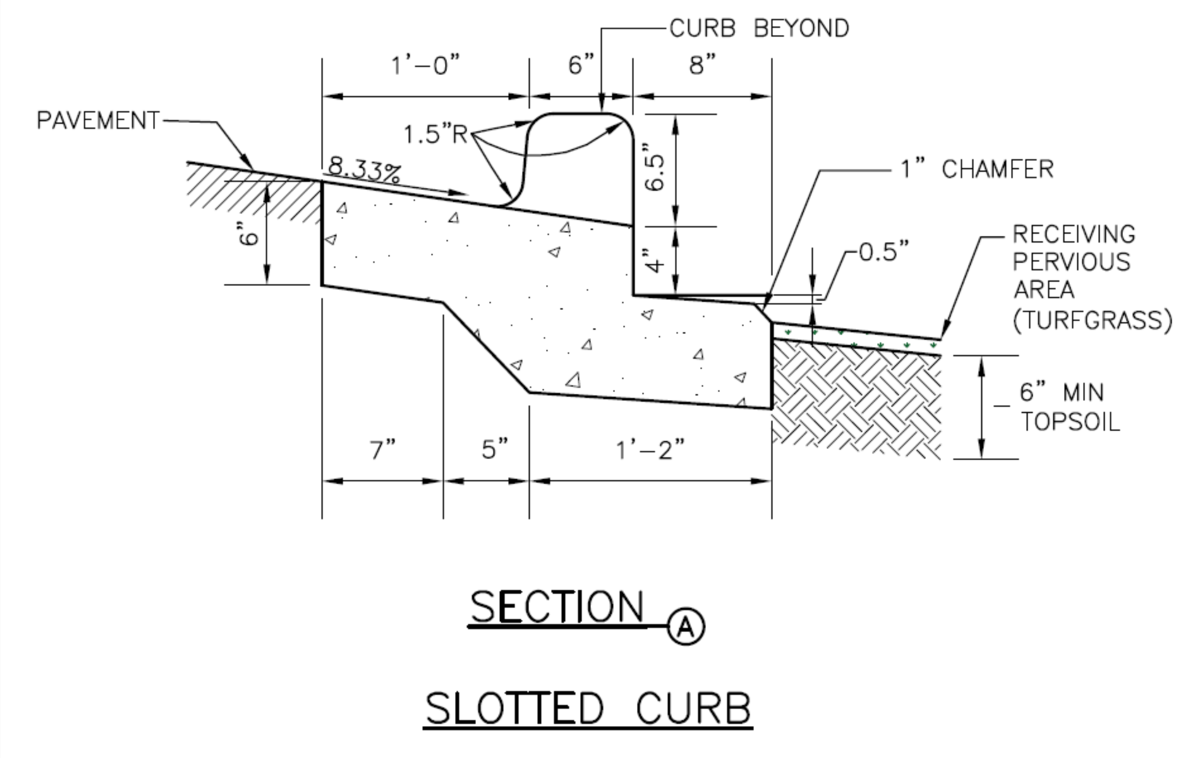
Verifying Soil Type

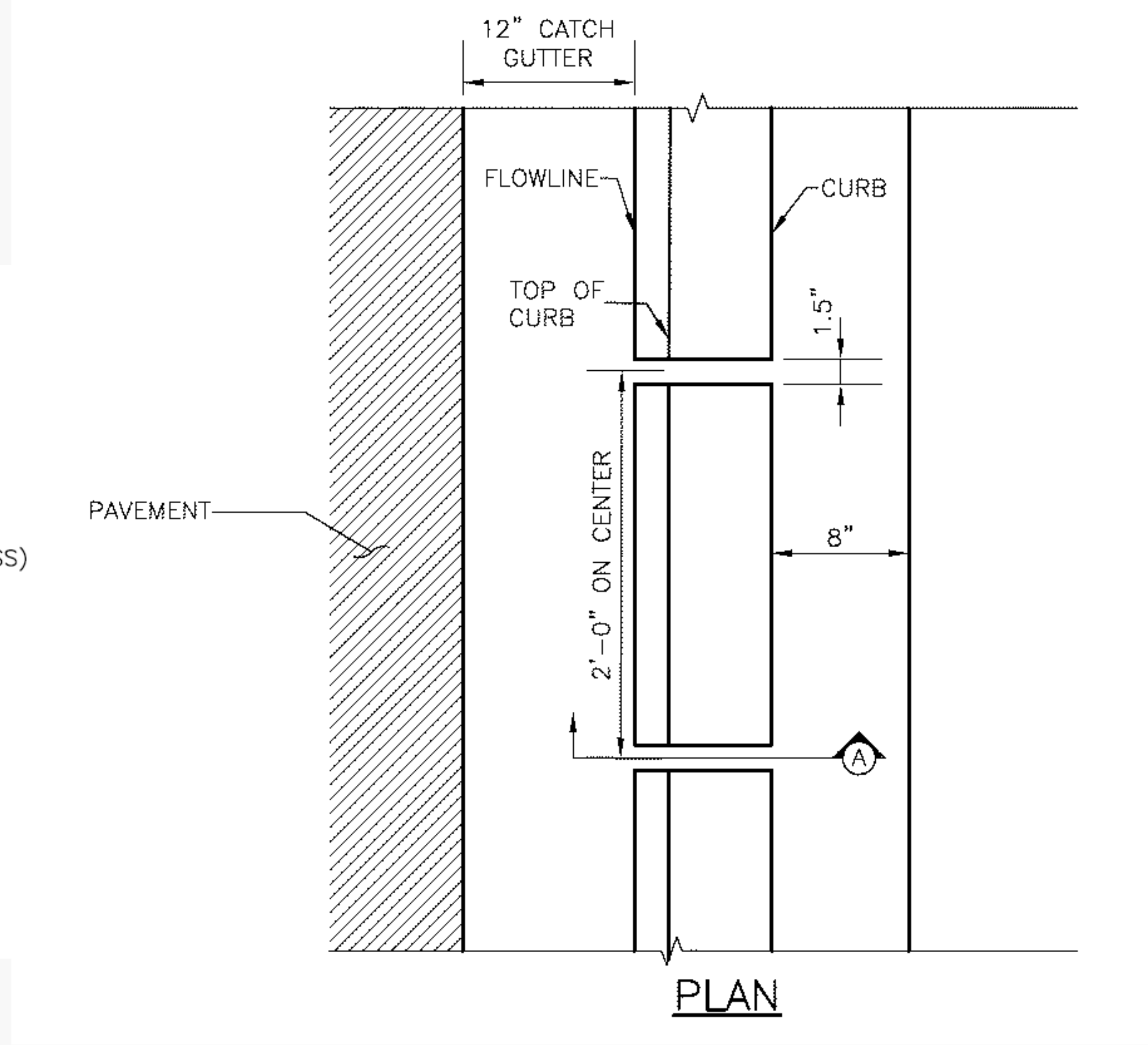
Run-on ratio

When you need a level spreader (?)

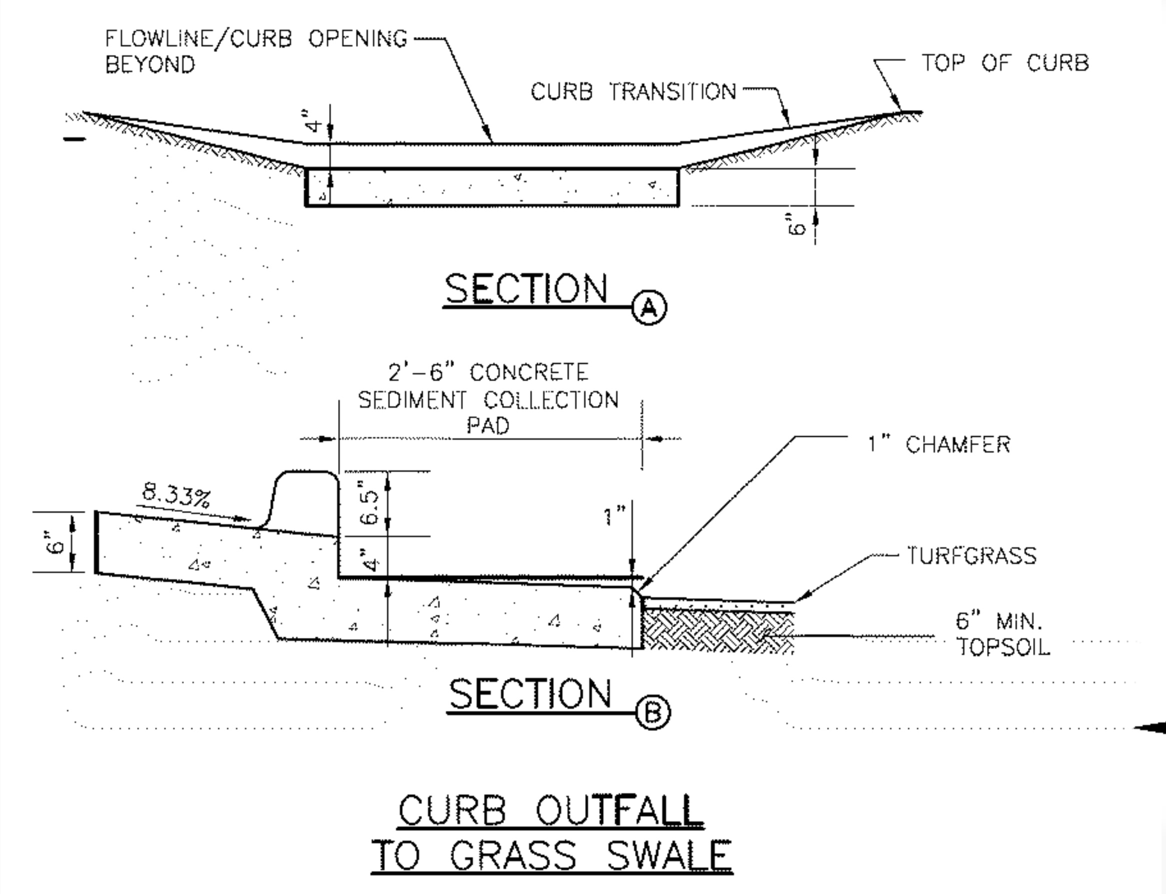
Defining the RPA

Slotted Curb





Sediment Pad at Swale Entry



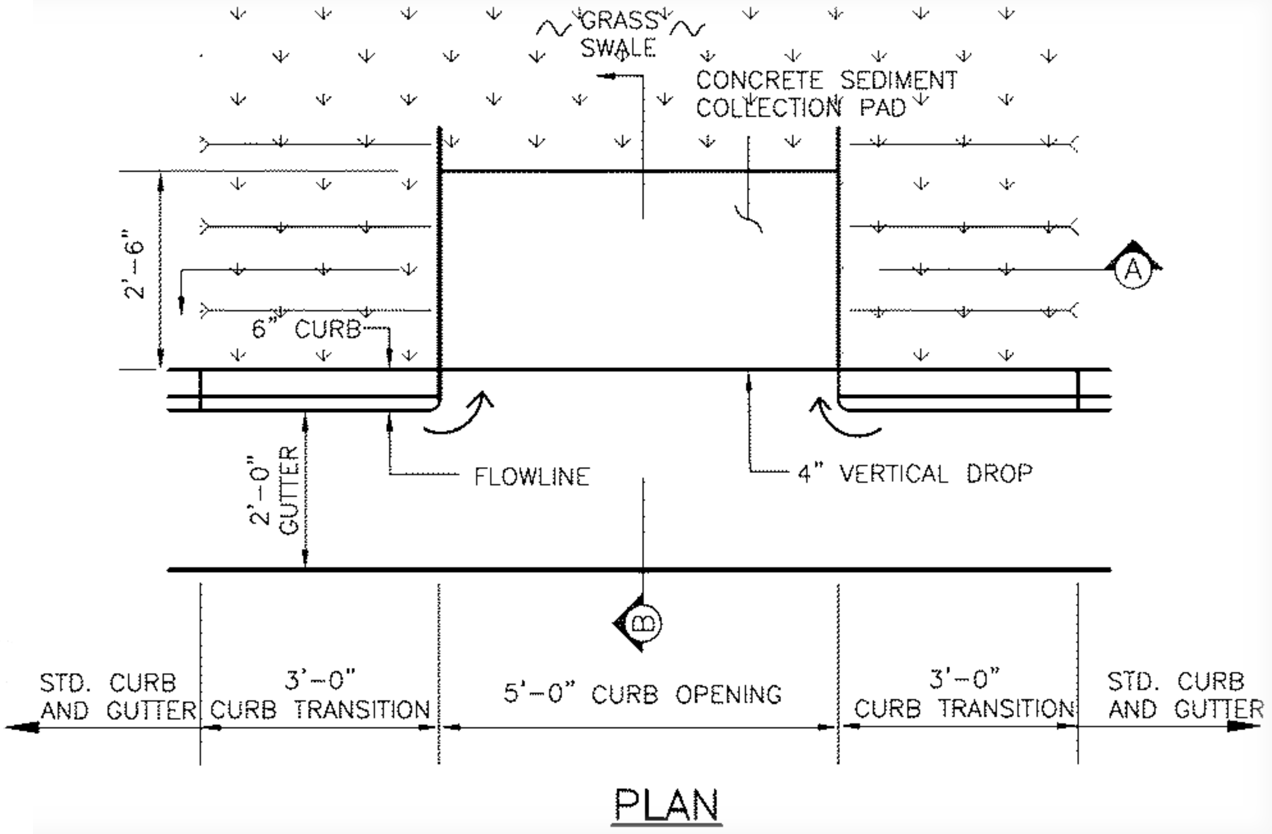


Photo Courtesy Bill Wenk

More Information Available

www.UDFCD.org

- *Technical Memorandum, Determination of Runoff Reduction Method Equations (UIA to RPA) based on Multivariable SWMM Analysis, Piza and Rapp 2018*
- *Criteria Manual, Volume 3, Fact Sheet T-0*
- *UD-BMP (Excel Based Tool for calculating runoff)*
- *Flood Control District Youtube video for using UD-BMP*

Coming soon

Topsoil
Management
Guidance

Thank You

PEAK STORMWATER ENGINEERING, LLC

DOUGLAS COUNTY COLORADO

MULLER ENGINEERING COMPANY

Southeast Metro Stormwater Authority

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT

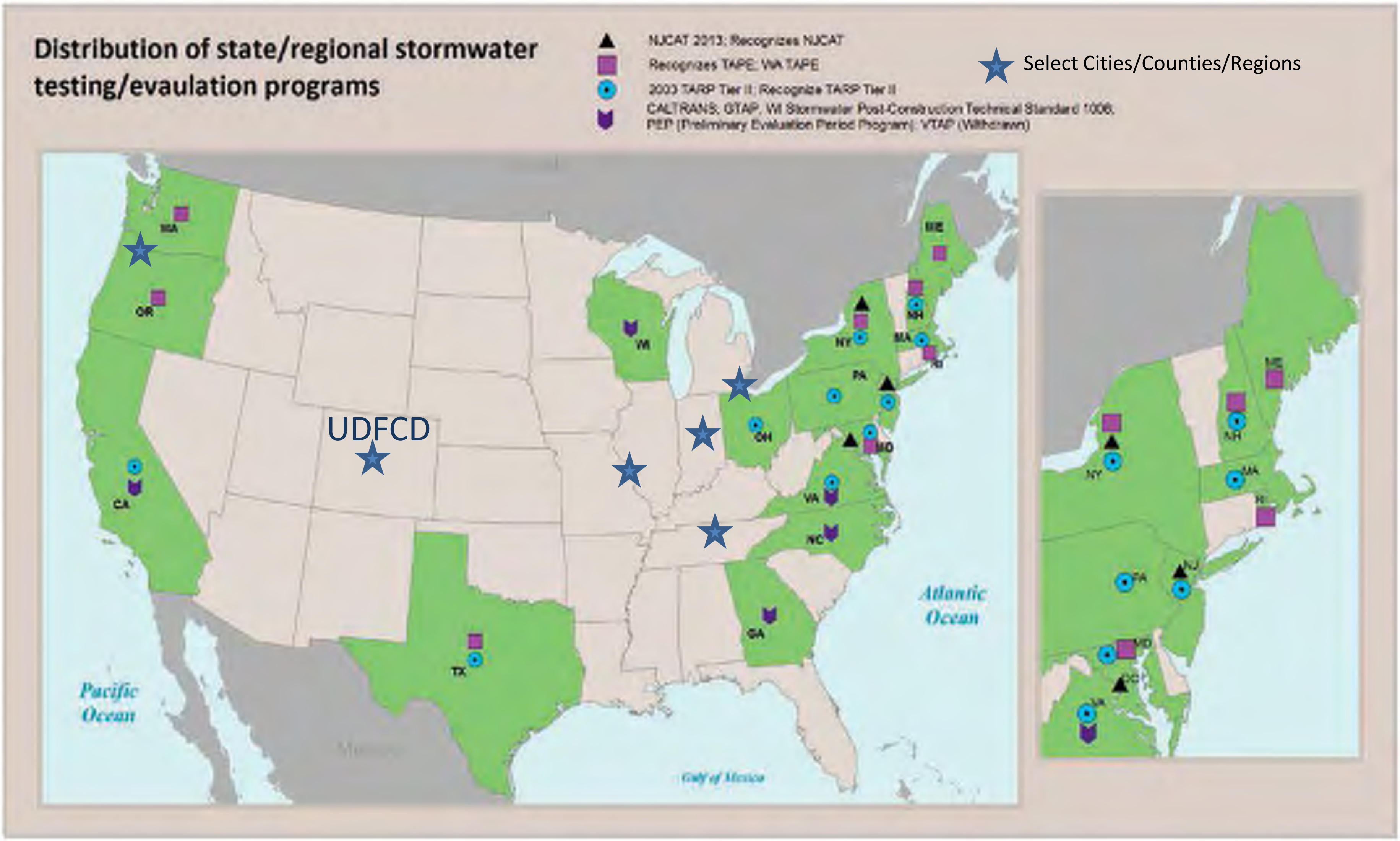
WWE WRIGHT WATER ENGINEERS, INC.

Navigating the New Jersey & Washington State Stormwater Programs as Models for Approving Manufactured Treatment Devices

Mark B. Miller, P.G.
Research Scientist
mmiller@aquashieldinc.com
Chattanooga, Tennessee
(888) 344-9044

Colorado Association of Stormwater & Floodplain Managers
September 25-28, 2018
Snowmass Village, CO

A bunch of stormwater Quality programs



Modified from www.werf.org, Executive Summary, Document #INFR2R14

AquaShield WATER TREATMENT SOLUTIONS

Colorado Urban Drainage & Flood Control District

- Urban Storm Drainage Criteria Manual Volume 3 -

To evaluate performance of an underground proprietary BMP, data should be provided to the local jurisdiction to demonstrate that anticipated BMP performance will be comparable to that of surface-based BMPs such as extended detention basins, constructed wetland basins, sand filter basins, or retention ponds. Underground BMPs approved for standalone treatment should be capable, on an annual basis, of producing effluent quality with a median TSS concentration of no more than 30 mg/L. This level of treatment is comparable to the long-term effluent median concentrations from the International Stormwater BMP Database for surface-based BMPs.

Data collected to substantiate performance of proprietary BMPs should meet the following criteria:

1. Testing must consist of field data (not laboratory data) collected in compliance with the criteria in Table UG-1. Laboratory studies and/or vendor-supplied studies without third party involvement or verification should not be considered. The Technology Acceptance Reciprocity Partnership (TARP) Protocol for Stormwater Best Management Practice Demonstrations may provide additional useful information on development of a monitoring program for evaluation of underground BMPs. Information on the TARP program can be found in several locations on the internet, including http://www.dep.state.pa.us/dep/deputate/pollprev/techservices/tarp/. Forthcoming field testing guidelines from the American Society of Civil Engineers Urban Water Resources Research Council (ASCE UWRRC) Task Committee developing Guidelines for Certification of Manufactured Stormwater BMPs (Sansalone et al. 2009) may also be applicable in the future.

2. Data collected in environments similar to the Colorado Front Range (i.e., semi-arid with freezing and thawing in the winter) are preferable. This is particularly important for flow based devices where differences in rainfall intensity and duration may affect performance.

3. Data should be collected and analyzed in accordance with the guidance provided in *Urban Stormwater BMP Performance Monitoring* (Geosyntec and WWE 2009; available online at www.bmpdatabase.org). When reviewing performance data, it is important to recognize that the use of percent removal may be more reflective of how "dirty" the influent water is rather than how well the BMP is actually performing (Jones et. al. 2008). Instead, look at effluent concentrations for a range of influent concentrations. **The device should have performance data that demonstrates the ability to meet a median TSS effluent concentration of approximately 30 mg/L or lower on an annual basis.**

4. Data should be collected or verified by independent third parties in accordance with good Quality Assurance/Quality Control (QA/QC) procedures.

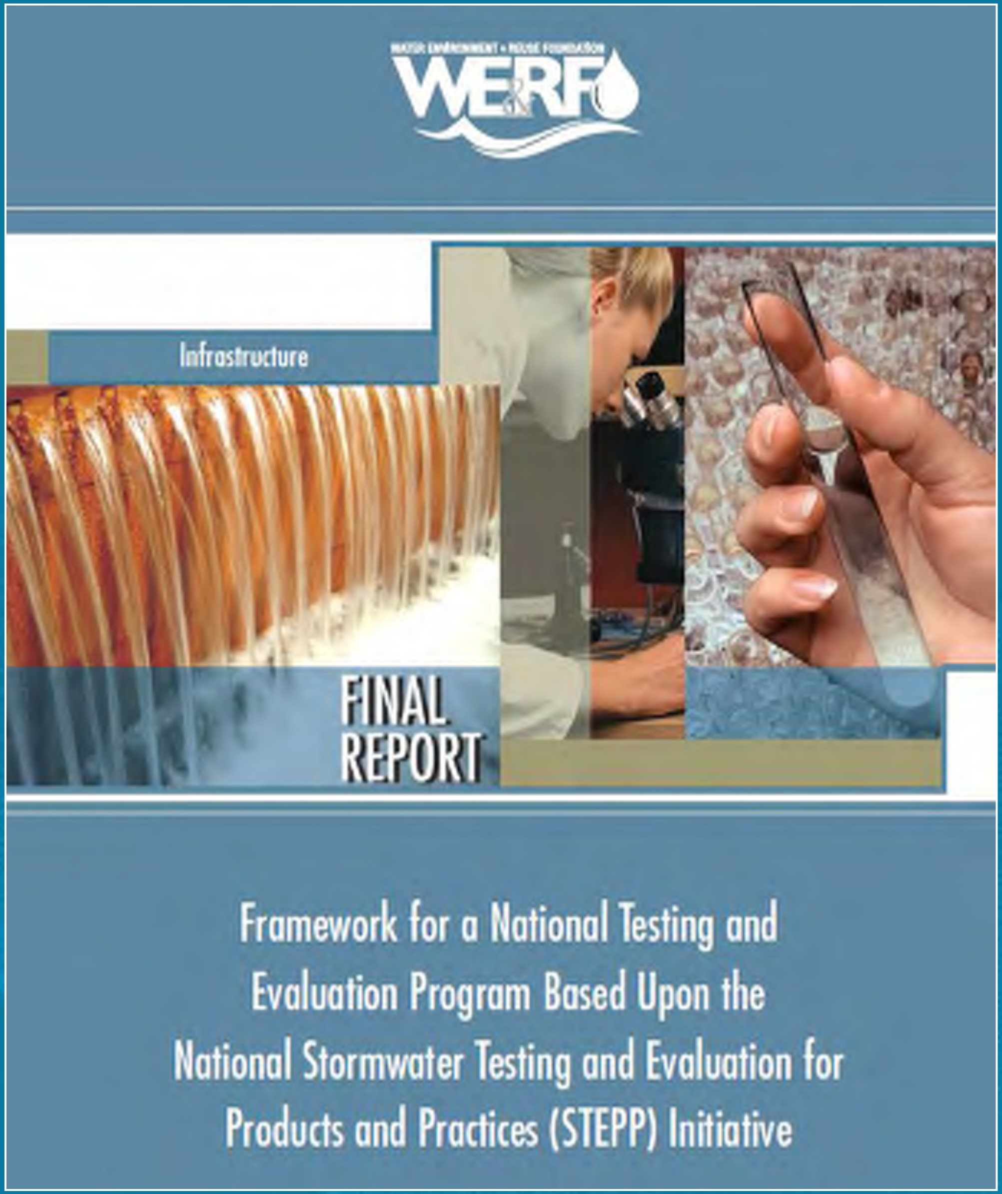
Many studies have been conducted over the past decade to document the performance of underground BMPs. Sources of data that may be used to support using a proprietary BMP include the following:

- New Jersey Corporation for Advanced Technology (NJCAT) Technology Verification Program (http://www.njcat.org/verification/protocol.cfm).
- Washington State Department of Ecology (2002). Guidance for Evaluating Emerging Stormwater Treatment Technologies, Technology Assessment Protocol – Ecology (TAPE), October 2002 (Revised June 2004), Publication Number 02-10-037. (http://www.ecy.wa.gov/biblio/0210037.html).
- International Stormwater BMP Database (www.bmpdatabase.org).
- University of Massachusetts Amherst Stormwater Technologies Clearinghouse (www.mastep.net).

AquaShield™
WATER TREATMENT SOLUTIONS

Then in mid-2016…

- ❖ *Proposes a National program to evaluate products and practices.*
- ❖ *Draws upon New Jersey & Washington State stormwater programs for MTD evaluations.*



From WERF 2016

Let's look at 2 stormwater programs as models for approving (evaluating) Manufactured Treatment Devices (MTDs)…

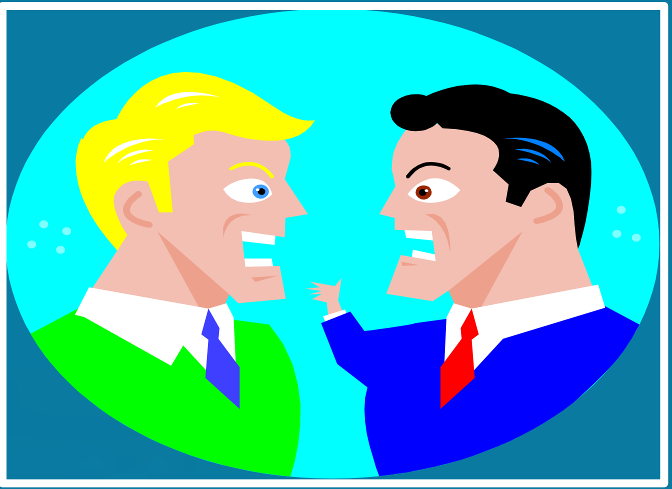
STATE OF NEW JERSEY
DEPARTMENT OF ENVIRONMENTAL PROTECTION
NJ STORMWATER.ORG
Stormwater in New Jersey

Lab testing protocol

DEPARTMENT OF
ECOLOGY
State of Washington

Field testing protocol

A Spirited Debate: Lab vs. Field Testing



- ***Lab testing*** provides repeatable and defensible results under controlled conditions to allow for side by side comparsions of MTD performance testing.
- ***Field testing*** is a logical progression from lab testing and provides long term, real world results under random storm conditions under which an MTD would be expected to encounter.

Two Step Process for NJDEP "Certification"

Step 1: NJCAT "Verification"

NJCAT
Corporation for Advanced Technology

www.njcat.org

Step 2:
NJDEP "Certification"
(if eligible)

State of New Jersey
Department of Environmental Protection
NJ Stormwater.org
Stormwater in New Jersey

www.njstormwater.org/treatment.html

STATE OF NEW JERSEY
DEPARTMENT OF ENVIRONMENTAL PROTECTION
NJ STORMWATER.ORG
Stormwater in New Jersey

NJCAT Verification vs. NJDEP Certification

- ***NJCAT Verification provides independent documentation of a protocol-based performance claim for an MTD in either a lab and/or field test setting.***

- ***NJDEP Certification allows an eligible MTD to be specified within New Jersey under conditions specific to state stormwater rules.***

We'll talk about eligibility later…..

Process for Approval of MTDs

New Jersey Department of Environmental Protection
Process for Approval of Use for Manufactured Treatment Devices
January 25, 2013

This document outlines the process for a stormwater manufactured treatment device (MTD) to be approved by the New Jersey Department of Environmental Protection (NJDEP) in compliance with the Stormwater Management rules, N.J.A.C. 7:8. Prior to a MTDs entrance into the NJDEP process, the MTD must obtain Verification through the New Jersey Corporation for Advanced Technology (NJCAT). The process for NJCAT Verification is available at www.njcat.org entitled "Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology: For use in accordance with the Stormwater Management Rules, N.J.A.C. 7:8". In addition to these process documents there are protocols for sedimentation and filtration MTDs that must be used for approval, the protocols are available at www.njstormwater.org.

NJDEP Process

Upon successful completion of the technical and regulatory standards and the completion of the reporting of those standards in the NJCAT Verification Report, NJCAT will provide NJDEP's Stormwater Management Unit a link to their website where the Verification Report can be found. In addition to the Verification Report link, NJCAT will supply the MTD name, the MTD manufacturer name and the respective TSS percent removal rate.

The NJCAT Verification will include the following components: Description of Technology, Laboratory Test Setup, Performance Claims, Supporting Documentation, Design Limitations, Maintenance Plans, Statements of Compliance and a Verification Appendix. The Verification Appendix will highlight and translate the design specifications found in the rest of the Verification Report to the design engineer.

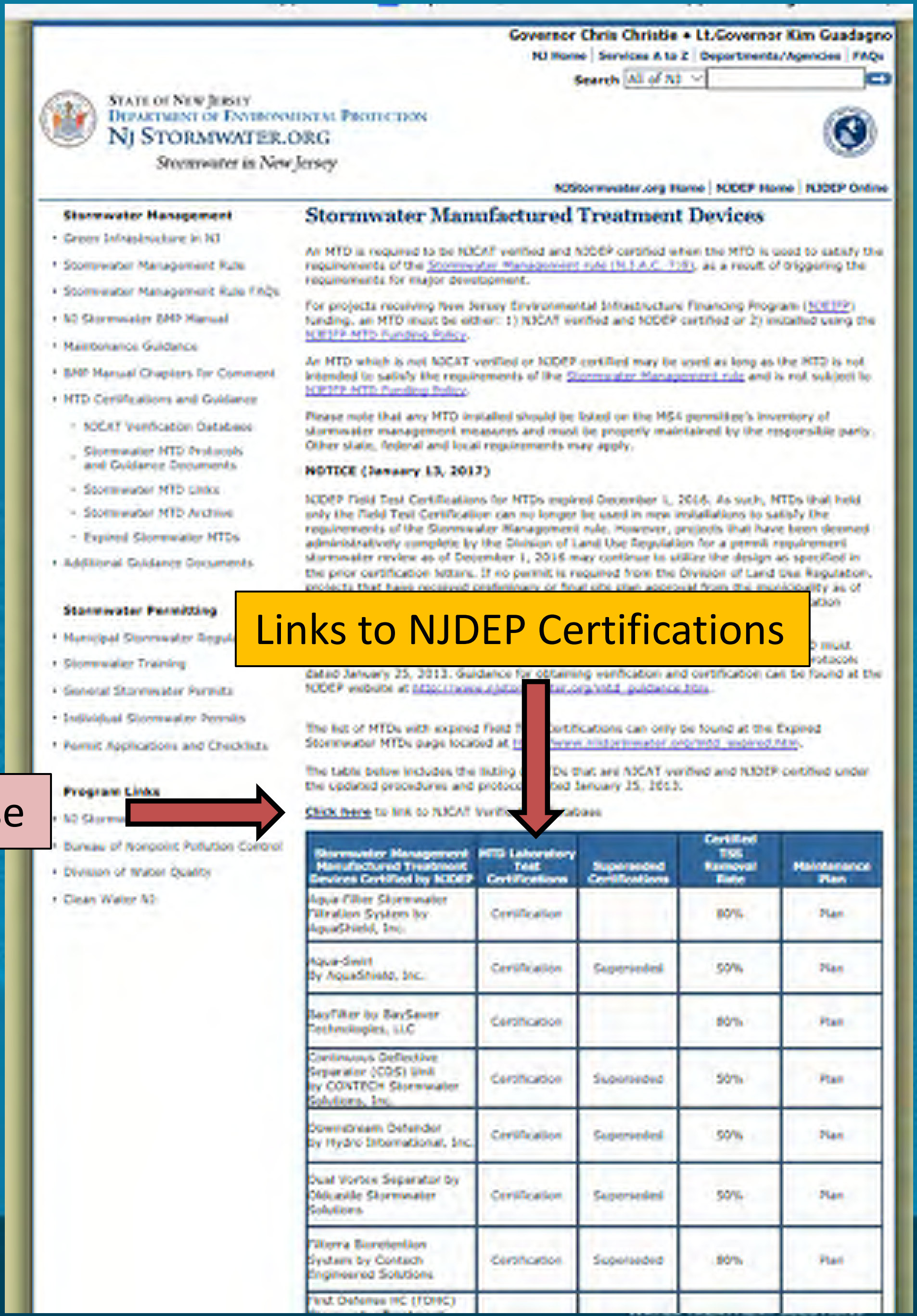
Formal representation of a NJDEP approval will be established on the NJDEP stormwater website at www.njstormwater.org. The website will contain the MTD name, the MTD manufacturer name and the respective TSS percent removal rate. Upon approval, the MTD can be used for compliance with the Stormwater Management rule as long as the conditions of the NJCAT Verification are met.

AquaShield
WATER TREATMENT SOLUTIONS

NJDEP Lists MTD Certifications @
www.njstormwater.org/treatment.html

Links to NJDEP Certifications

Link to NJCAT Verification Database



Governor Chris Christie • Lt.Governor Kim Guadagno

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State of New Jersey
Department of Environmental Protection
NJ STORMWATER.ORG
Stormwater in New Jersey

NJStormwater.org Home | NJDEP Home | NJDEP Online

Stormwater Management
- Green Infrastructure in NJ
- Stormwater Management Rule
- Stormwater Management Rule FAQs
- NJ Stormwater BMP Manual
- Maintenance Guidance
- BMP Manual Chapters for Comment
- MTD Certifications and Guidance
  - NJCAT Verification Database
  - Stormwater MTD Protocols and Guidance Documents
  - Stormwater MTD Links
  - Stormwater MTD Archive
  - Expired Stormwater MTDs
- Additional Guidance Documents

Stormwater Permitting
- Municipal Stormwater Regul[illegible]
- Stormwater Training
- General Stormwater Permits
- Individual Stormwater Permits
- Permit Applications and Checklists

Program Links
- NJ Storm[illegible]
- Bureau of Nonpoint Pollution Control
- Division of Water Quality
- Clean Water NJ

Stormwater Manufactured Treatment Devices

An MTD is required to be NJCAT verified and NJDEP certified when the MTD is used to satisfy the requirements of the Stormwater Management rule (N.J.A.C. 7:8), as a result of triggering the requirements for major development.

For projects receiving New Jersey Environmental Infrastructure Financing Program (NJEIFP) funding, an MTD must be either: 1) NJCAT verified and NJDEP certified or 2) installed using the NJEIFP MTD Funding Policy.

An MTD which is not NJCAT verified or NJDEP certified may be used as long as the MTD is not intended to satisfy the requirements of the Stormwater Management rule and is not subject to NJEIFP MTD Funding Policy.

Please note that any MTD installed should be listed on the MS4 permittee's inventory of stormwater management measures and must be properly maintained by the responsible party. Other state, federal and local requirements may apply.

NOTICE (January 13, 2017)

NJDEP Field Test Certifications for MTDs expired December 1, 2016. As such, MTDs that held only the Field Test Certification can no longer be used in new installations to satisfy the requirements of the Stormwater Management rule. However, projects that have been deemed administratively complete by the Division of Land Use Regulation for a permit requirement stormwater review as of December 1, 2016 may continue to utilize the design as specified in the prior certification letters. If no permit is required from the Division of Land Use Regulation, projects that have received preliminary or final site plan approval from the municipality as of [illegible]

[illegible] dated January 25, 2013. Guidance for obtaining verification and certification can be found at the NJDEP website at [illegible]

The list of MTDs with expired Field [illegible] Certifications can only be found at the Expired Stormwater MTDs page located at [illegible]

The table below includes the listing [illegible] MTDs that are NJCAT verified and NJDEP certified under the updated procedures and protoco[illegible] dated January 25, 2013.

Click here to link to NJCAT Verifi[illegible]

Stormwater Management Manufactured Treatment Devices Certified by NJDEP	MTD Laboratory Test Certifications	Superseded Certifications	Certified TSS Removal Rate	Maintenance Plan
Aqua-Filter Stormwater Filtration System by AquaShield, Inc.	Certification		80%	Plan
Aqua-Swirl by AquaShield, Inc.	Certification	Superseded	50%	Plan
BayFilter by BaySaver Technologies, LLC	Certification		80%	Plan
Continuous Deflective Separator (CDS) Unit by CONTECH Stormwater Solutions, Inc.	Certification	Superseded	50%	Plan
Downstream Defender by Hydro International, Inc.	Certification	Superseded	50%	Plan
Dual Vortex Separator by Oldcastle Stormwater Solutions	Certification	Superseded	50%	Plan
Filterra Bioretention System by Contech Engineered Solutions	Certification	Superseded	80%	Plan
First Defense HC (FDHC) [illegible]				

www.njcat.org

NJCAT Corporation for Advanced Technology

Promoting Emerging Energy and Environmental Technologies

About Us

Verification Process

Technology Verification

The Energy and Environmental Technology Verification (EETV) Act at N.J.S.A. 13:1D-134 et seq., establishes the guidelines for a verification and certification process to approve the use of innovative energy and environmental technologies that benefit the environment and economy of New Jersey. The New Jersey Legislature found that, in establishing the technology verification and certification program, it is in the public's interest to encourage the commercial development and use of new technology-based environmental and energy related products, services and systems that abate and prevent environmental pollution and promote energy conservation in the most cost-effective and environmentally efficient manner in the State.

Highlights

Although innovative environmental and energy technologies often consume fewer natural resources than traditional methods, they encounter numerous technical, financial and regulatory impediments. Over the years, NJCAT has broken down many of the barriers, but there are still daunting challenges facing innovative technologies.

Stormwater Treatment Systems

Stormwater Management Technologies in particular are difficult to evaluate. Pollutant removal performance depends upon many factors, e.g., influent particulate size distribution, influent pollutant concentration (loading), stormwater flow rate, sump design and capacity, and maintenance. NJCA

involvement and activities over the past decade in identifying and evaluating a number of pre-manufactured stormwater treatment devices has created the knowledge and experience base necessary to effectively and confidently assess anticipated sediment removal performance.

The New Jersey Stormwater rules (35 N.J.R. 154) clearly establish that manufactured stormwater

News

About NJCAT

NJCAT was created to promote in New Jersey the retention and growth of technology-based businesses in emerging fields such as environmental and energy. NJCAT provides innovators with the regulatory, commercial, and technological assistance required to bring their ideas to market successfully. Specifically, NJCAT functions to:

*** advance policy strategies and regulatory mechanisms to promote technology commercialization,**

*** identify, evaluate, and recommend specific technologies for which the regulatory and commercialization process should be facilitated,**

*** establish relationships/alliances to bring new technologies to market and new business to the state, and**

*** assist in the identification of markets and applications for commercialized technologies.**

Operating as a public private partnership is the cornerstone of the NJCAT programs; in this manner, the commercial marketplace has direct input to the technology development and commercialization process and the public sector gains confidence in technology solutions through reliance on an independent honest broker examination of technology performance.

Richard S. Magee Sc.D., P.E., BCEE
Executive Director
New Jersey Corporation for Advanced Technology
Center for Environmental Systems
Stevens Institute of Technology
Castle Point on Hudson
Hoboken, NJ 07030
973-879-3056 (M) rsmagee@rcn.com

NJCAT
Corporation for Advanced Technology
...g Energy and Environmental Technologies

- About Us
- Verification Process

Lab Verifications

NJCAT MTD Verifications @
www.njcat.org/verification-process/technology-verification-database.html

Stormwater Technologies: Laboratory Verified

Company	Product	Verification Date	Link to Report
AquaShield Inc.	Aqua-Filter	Sept. 2005, Updated December 2005, Addendum 2007	Download
AquaShield Inc.	Aqua-Swirl	Sept. 2005, Updated December 2005	Download
AquaShield, Inc.	Aqua-Filter Stormwater Filtration System with Perlite Media	March 2017	Download
AquaShield, Inc.	Aqua-Swirl Stormwater Treatment System	November, 2016	Download
BaySaver Technologies	BayFilter	June 2008	Download
BaySaver technologies	BaySeparator	December 2004	Download
BaySaver Technologies, LLC	BayFilter Enhanced Media Cartridge	November, 2016	Download
Bio Clean Environmental Services	Kraken Membrane Filtration System	April 2016	Download
			Download
		...nuary 2017	Download
			Download
			Download
		...uary 2017	Download
Environment 21 LLC	V2B1	March 2009	Download
Fresh Creek Technologies Inc.	SiteSaver Stormwater Treatment Device	February 2016, Updated January 2017	Download
FreshCreek Technologies, Inc.	StormTrap SiteSaver - 4 Hydrodynamic Separator	June 2017	Download
FreshCreek Technologies, Inc.	StormTrap SiteSaver-4 Hydrodynamic Separator: Large PSD	August 2017	Download
Hydro International	First Defense HC	September 2016	Download
Hydro International	Up-Flo Filter (with Filter Ribbon Media)	December 2016	Download
Hydro International Inc	Downstream Defender	December 2015	Download
Hydro International Inc	First Defense HC	February 2016, Updated January 2017	Download
Hydro International Inc	Up-Flo Filter	November 2008	Download
Hydro International Inc.	Downstream Defender	August 2015, Updated January 2017	Download
Hydroworks LLC	Hydroguard	July 2009	Download
Imbrium Systems	Stormceptor OSR	August 2007	Download
Imbrium Systems	Stormceptor STC	September 2004, Addendum June 2010	Download
Kristar Enterprises Inc.	FloGard Dual-Vortex	July 2009	Download
Lane Enterprises Inc.	Stormkeeper Chamber Sediment Strip	May 2017	Download
Oldcastle Precast Stormwater	Oldcastle PerkFilter System with ZPC Media	May 2017	Download
Oldcastle Stormwater Solutions	Dual Vortex Separator (DVS)	July 2015, Updated January 2017	Download
Suntree Technologies Inc.	NS... Evaluation with 100 micron Particles	June 2013	Download
Suntree Technologies Inc.	...utrient Separating Baffle Box	November 2008, Addendum October 2013	Download
Suntree Technologies Inc.	N... t Separating Baffle Box with Hydro-Variant Technology	October, 2016	Download
Terre Hill Stormwater Systems	...e Kleen Hydrodynamic Separator	January 2017	Download
Terre Hill Stormwater Systems	Terre Kleen Separator	August 2007	Download

Field Verifications per TARP or NJDEP 2009

Stormwater Technologies: Field Verified

Company	Product	Verification Date	Link to Report
AquaShield Inc.	Aqua-Filter	November 2013	Download
AquaShield Inc.	Aqua-Swirl	November 2012	Download
CONTECH Stormwater Solutions	C... ...uous Deflective Separator (CDS)	January 2010, Amended August 2012	Download
CONTECH Stormwater Solutions	...edia Filtration System (MFS)	January 2010	Download
CONTECH Stormwater Solutions	StormVault	August 2007	Download
CONTECH Stormwater Solutions	Vortechs	April 2011	Download
Hydro International Inc.	Up-Flo Filter	January 2015	Download
Imbrium Systems	Jellyfish	January 2012	Download

Lab Verifications open for Public Comment

Stormwater Technologies: For Public Comment

Company	Product	Public Comment Period Opens	Public Comment Period Closes	Link to Report
BaySaver technologies, LLC	BaySaver Barracuda Hydrodynamic Separator	August 2, 2017	August 31, 2017	Download

Small-scale Co-generation Technologies

Company	Product	Verification Date	Link to Report
Aegis Energy Services Inc.	AEGEN TP-75 CHP Module	February 2014	Download

Ever heard of TARP? Well, it is no longer applicable to NJDEP

The Technology Acceptance Reciprocity Partnership

Protocol for

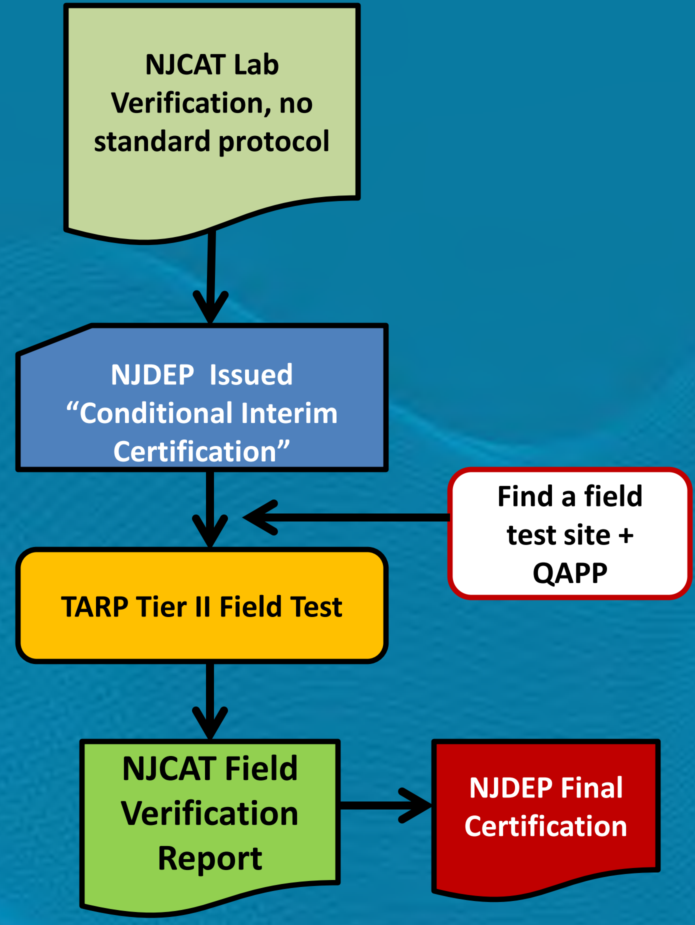
Stormwater Best Management Practice Demonstrations

Endorsed by
California, Massachusetts, Maryland,
New Jersey, Pennsylvania, and Virginia

Final Protocol 8/01
Updated: 7/03

TARP
Technology Acceptance and Reciprocity Partnership

Original NJDEP Certification Process



There was no TARP Tier I

AquaShield
WATER TREATMENT SOLUTIONS

STATE OF NEW JERSEY
DEPARTMENT OF ENVIRONMENTAL PROTECTION
NJ STORMWATER.ORG
Stormwater in New Jersey

New Jersey Lab Testing Protocols for HDSs and Filters

New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device

January 25, 2013

New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device

January 25, 2013

http://www.njstormwater.org/treatment.html

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STATE OF NEW JERSEY
DEPARTMENT OF ENVIRONMENTAL PROTECTION
NJ STORMWATER.ORG
Stormwater in New Jersey

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Stormwater Management

- Green Infrastructure in NJ
- Stormwater Management Rule
- Stormwater Management Rule FAQs
- NJ Stormwater BMP Manual
- Maintenance Guidance
- BMP Manual Chapters for Comment
- MTD Certifications and Guidance
  - NJCAT Verification Database
  - Stormwater MTD Protocols and Guidance Documents
  - Stormwater MTD Links
  - Stormwater MTD Archive
  - Expired Stormwater MTDs
- Additional Guidance Documents

Stormwater Manufactured Treatment Device Protocols and Guidance Documents

- NJDEP MTD Process - January 25, 2013, pdf, 70kb
- NJCAT MTD Process - January 25, 2013, pdf, 182 kb
- HDS Protocol - January 25, 2013, pdf 350 kb
- Filter Protocol - January 25, 2013, pdf, 290kb
- Funding of MTDs by the New Jersey Environmental Infrastructure Financing Program, pdf 112kb
- Transition for Manufactured Treatment Devices July 15, 2011, pdf, 29kb
- Interim Process for Certification of Manufactured Treatment Devices - Posted 4/23/09, pdf 72kb

http://www.njstormwater.org/mtd_guidance.htm

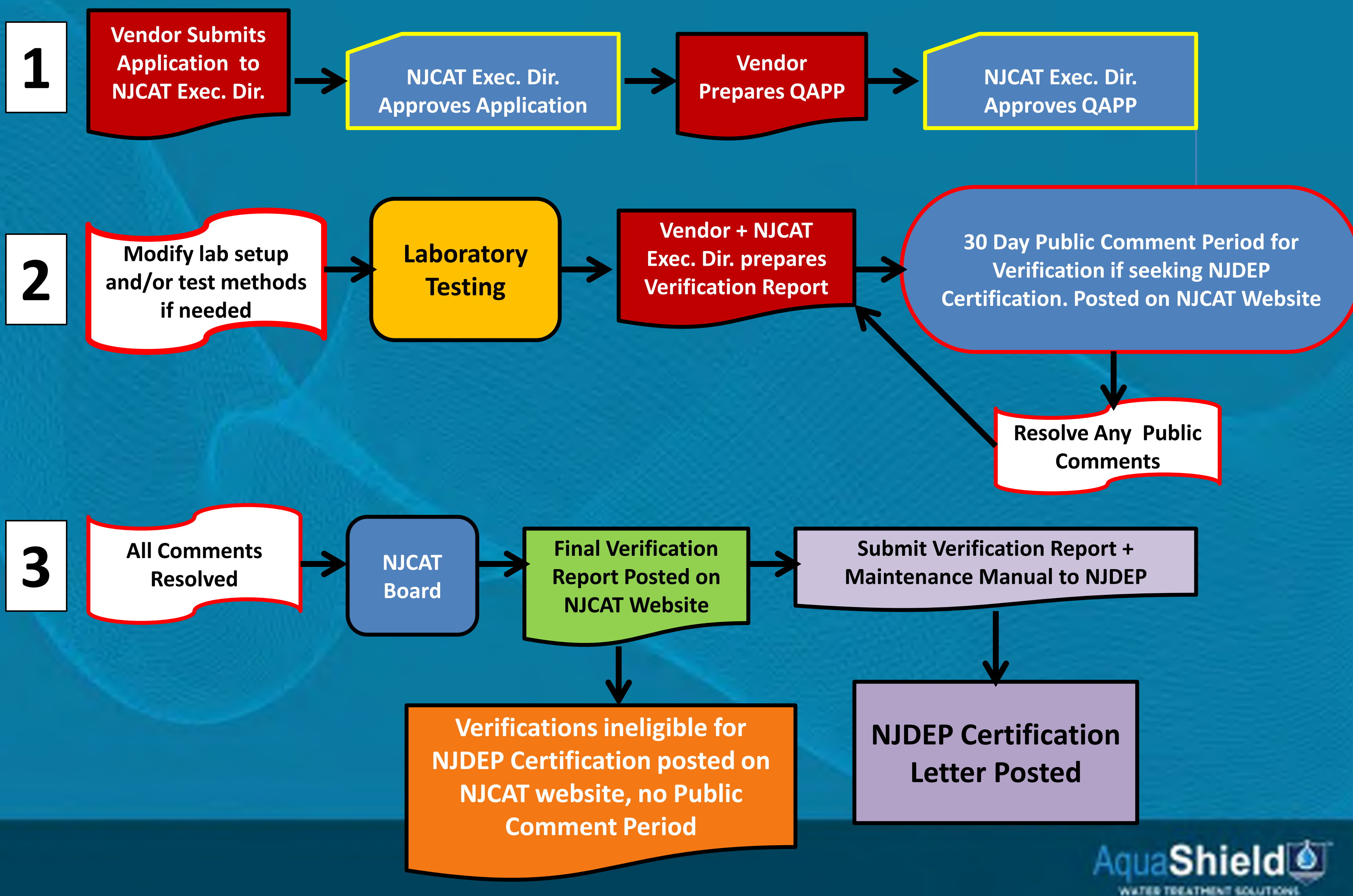
AquaShield
WATER TREATMENT SOLUTIONS

Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology

For use in accordance with the Stormwater Management Rules, N.J.A.C. 7:8

January 25, 2013

NJCAT Verification + NJDEP Certification Process



Example NJDEP Certification Letter

(1st page)

NJDEP Limits:

HDSs to 50% annual TSS

Filters to 80% annual TSS

Regardless of whether the NJCAT Verification is for a greater annual TSS removal efficiency percentage.

KIM GUADAGNO

CHRIS CHRISTIE
Governor

Lt. Governor

State of New Jersey

DEPARTMENT OF ENVIRONMENTAL PROTECTION
Bureau of Nonpoint Pollution Control
Division of Water Quality
401-02B
Post Office Box 420
Trenton, New Jersey 08625-0420
609-633-7021 Fax: 609-777-0432
http://www.state.nj.us/dep/dwq/bnpc_home.htm

BOB MARTIN
Commissioner

March 15, 2017

Mark B. Miller, Research Scientist
AquaShield™, Inc.
2733 Kanasita Drive, Suite 111
Chattanooga, Tennessee 37343

Re: Revised MTD Lab Certification
Aqua-Swirl® Stormwater Treatment System by AquaShield™, Inc.

TSS Removal Rate 50%

Dear Mr. Miller:

This revised certification letter supersedes the Department's prior certification dated December 1, 2016. This revision only removes the Required Sediment Removal Interval column from Table A-1 in order to avoid confusion regarding maintenance requirements. All other conditions of the certification remain unchanged.

The Stormwater Management rules under N.J.A.C. 7:8-5.5(b) and 5.7 (c) allow the use of manufactured treatment devices (MTDs) for compliance with the design and performance standards at N.J.A.C. 7:8-5 if the pollutant removal rates have been verified by the New Jersey Corporation for Advanced Technology (NJCAT) and have been certified by the New Jersey Department of Environmental Protection (NJDEP). AquaShield™, Inc. has requested an MTD Laboratory Certification for the Aqua-Swirl® Stormwater Treatment System, which is a vortex hydrodynamic separator.

The verification is subject to the "Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advance Technology" dated January 25, 2013. The applicable protocol is the "New Jersey Laboratory Testing Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device" dated January 25, 2013.

NJCAT verification documents submitted to the NJDEP indicate that the requirements of the aforementioned protocol have been met or exceeded. The NJCAT letter also included a recommended certification TSS removal rate and the required maintenance plan. The NJCAT Verification Report with the Verification Appendix (dated November 2016) for this device is published online at http://www.njcat.org/verification-process/technology-verification-database.html

?

If following NJDEP as a model for local approval…

Require only NJCAT Verification?

NJCAT
Corporation for Advanced Technology

Then which Verification?

- 2013 Lab + MTDs Ineligible for Certification
- CIC Lab (Certifications expired)
- NJDEP 2009 Field (Certifications expired)
- TARP Tier II Field (Certifications expired)

OR…

STATE OF NEW JERSEY
DEPARTMENT OF ENVIRONMENTAL PROTECTION
NJ STORMWATER.ORG
Stormwater in New Jersey

Require NJDEP Certification per 2013 Protocol?

"***Level Playing Field***", all hold Final Certification

Consider 4 fundamental aspects of the NJDEP/NJCAT MTD Process

1. NJDEP Certification is specific to New Jersey stormwater rules. An MTD must hold NJDEP Certification in order to be specified in New Jersey.

2. NJDEP Certification does not necessarily carry a higher level of technical scrutiny beyond that of an NJCAT Verification. However, NJDEP reviews maintenance manuals, NJCAT does not. NJDEP Certifications includes Maintenance Manual as part of Cert. Letter.

3. Not all NJCAT Verifications for an MTD are eligible for NJDEP Certification when there is a deviation from the protocol. This has significant ramifications for MTD sizing outside of NJ.

4. An NJCAT Verification can be issued for an MTD *technology* that is not recognized by NJDEP to be eligible for Certification. This has significant ramifications for MTD technology approval outside of NJ.

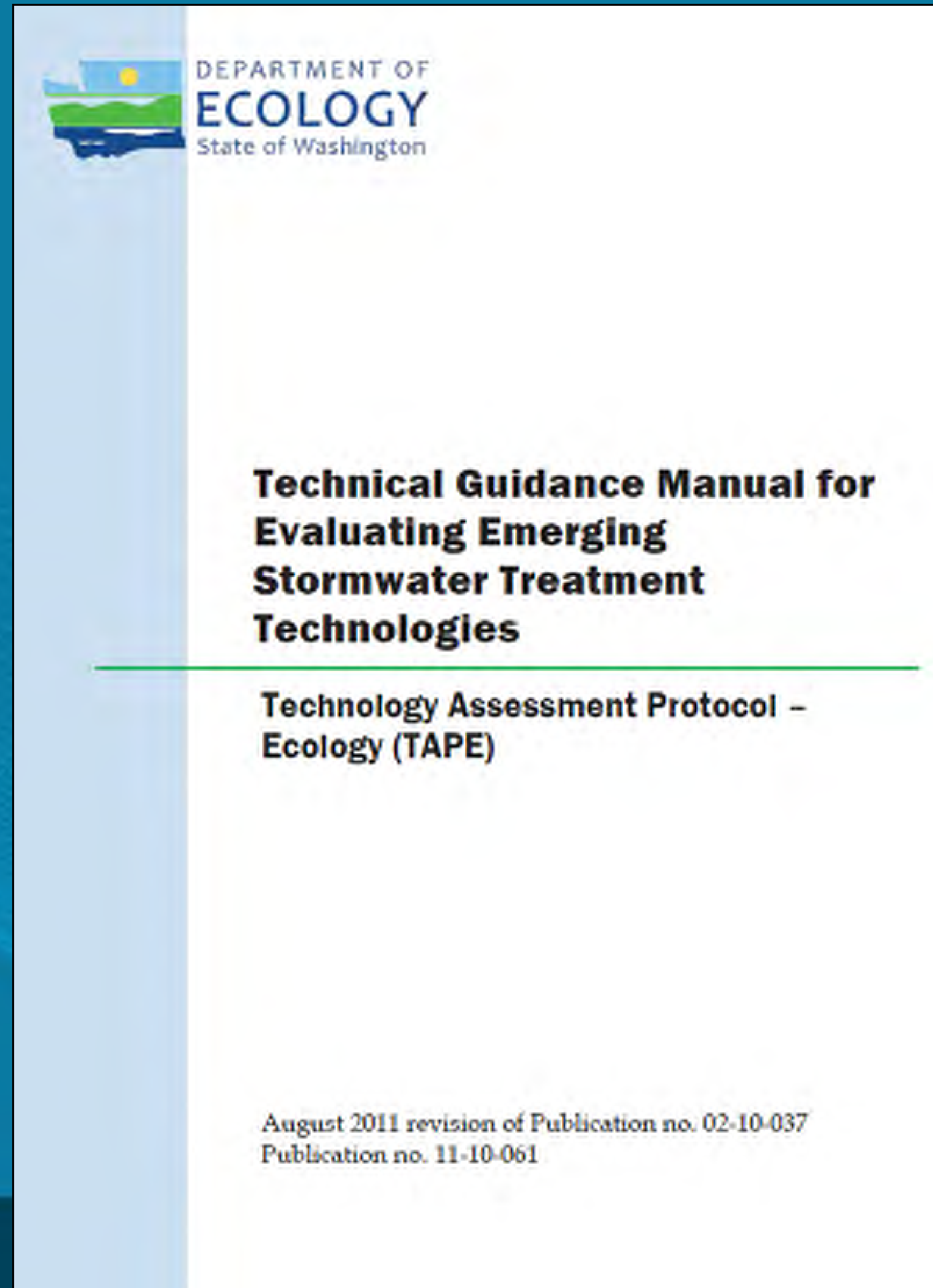
Let's look closer at NJCAT/NJDEP Aspects #3 & #4

#3: Deviation from Protocol - Sizing: An MTD test follows the protocol but uses a coarser PSD. An NJCAT Verification could still be obtained but that test would ***not be eligible*** for NJDEP Certification since the test purposefully deviated from the protocol to obtain a more favorable performance result. If an agency outside of NJ accepts NJCAT verifications only, then this test would allow for MTD sizing to be more favorable (smaller MTD) compared to those MTDs that tested to the protocol using the finer specified PSD (larger MTD). ***Could this lead to undersizing?***

#4: Ineligible Technology for Certification: The NJCAT Application will identify whether an MTD technology is accepted by NJDEP, and whether the proposed MTD test will be eligible for NJDEP Certification. For example, NJDEP considers underground infiltration structures (inclusive of fabric) not to be filtration MTDs and not eligible for Certification. However, NJCAT can issue a Verification for that technology as a pretreatment device but not NJDEP eligible. Agencies outside of New Jersey can then make their determination whether (a) that technology is an MTD, or (b) to allow the Verification (and sizing) for pretreatment and/or filtration.

- "TAPE" is Ecology's process for approving emerging & proprietary technologies (MTDs)
- Current TAPE is August 2011, Revised Version in progress

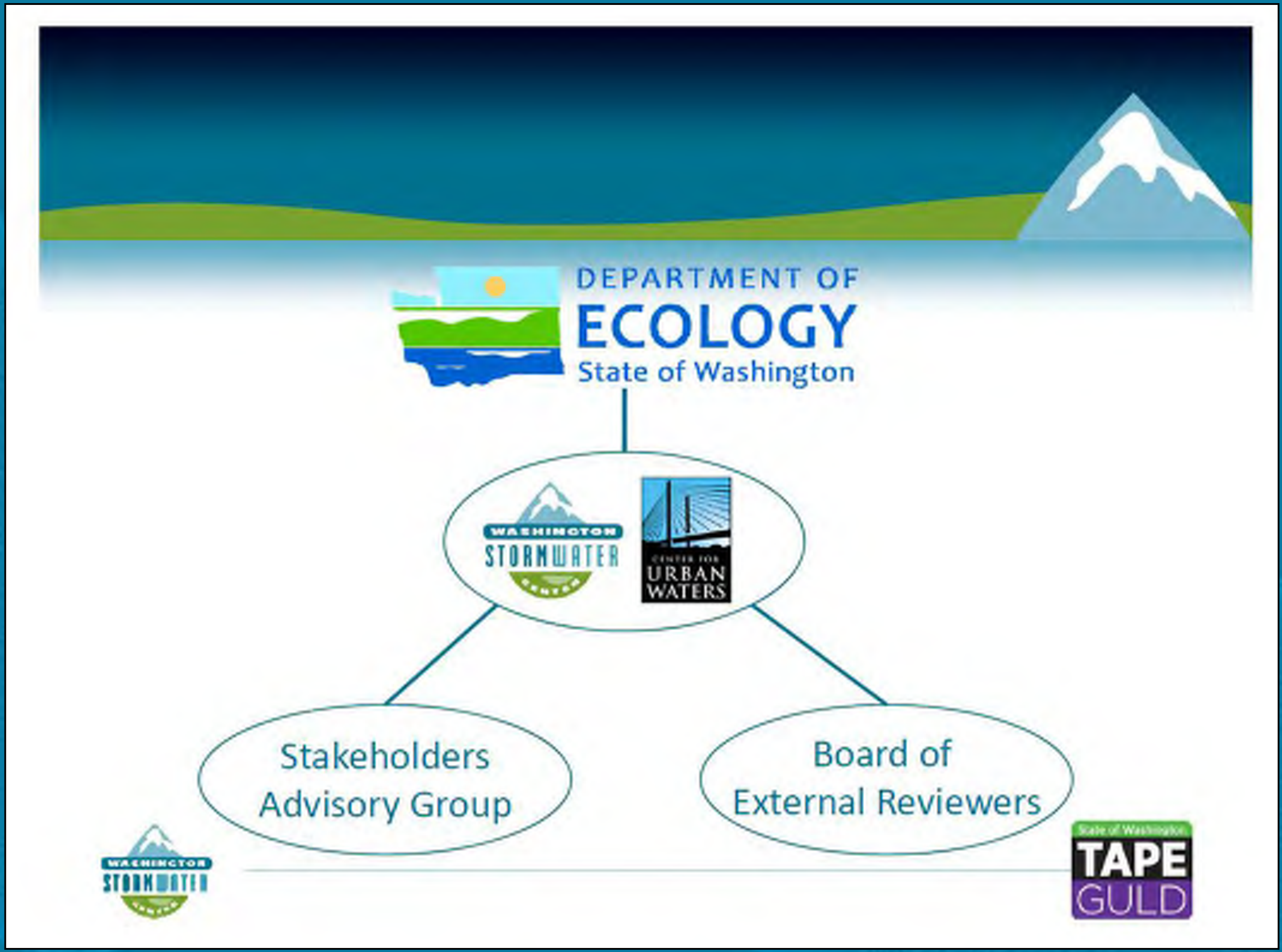
How hard could it be to get some field samples?
Well, 73 pages worth.


DEPARTMENT OF
ECOLOGY
State of Washington

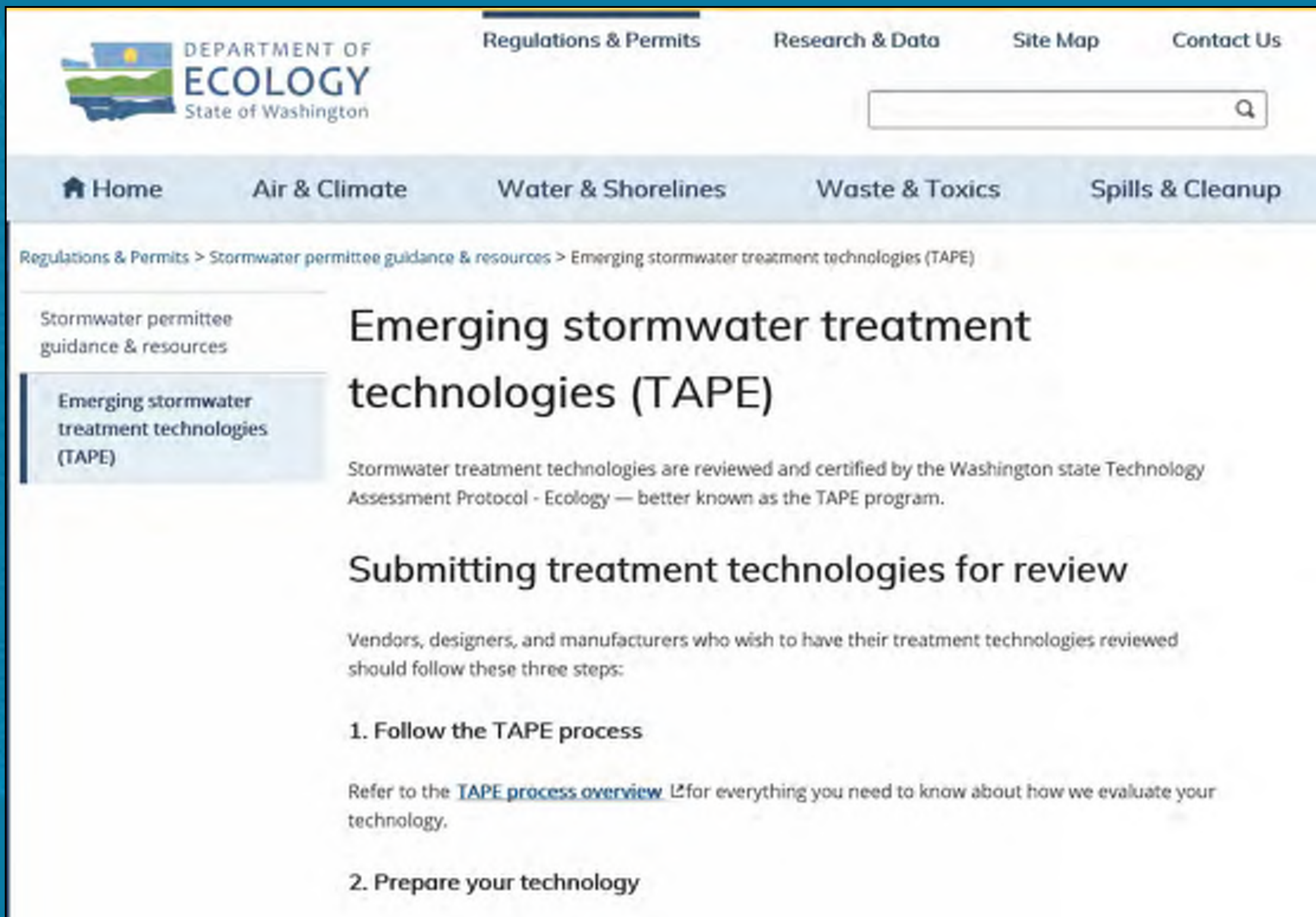
Technical Guidance Manual for Evaluating Emerging Stormwater Treatment Technologies

Technology Assessment Protocol – Ecology (TAPE)

August 2011 revision of Publication no. 02-10-037
Publication no. 11-10-061



Select WDOE/TAPE slides taken from presentation at Washington State Municipal Stormwater Conference, May 17, 2017, Carla Milesi, WSC https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies


DEPARTMENT OF ECOLOGY State of Washington

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Home | Air & Climate | Water & Shorelines | Waste & Toxics | Spills & Cleanup

Regulations & Permits > Stormwater permittee guidance & resources > Emerging stormwater treatment technologies (TAPE)

Stormwater permittee guidance & resources

Emerging stormwater treatment technologies (TAPE)

Emerging stormwater treatment technologies (TAPE)

Stormwater treatment technologies are reviewed and certified by the Washington state Technology Assessment Protocol - Ecology — better known as the TAPE program.

Submitting treatment technologies for review

Vendors, designers, and manufacturers who wish to have their treatment technologies reviewed should follow these three steps:

1. Follow the TAPE process

Refer to the TAPE process overview for everything you need to know about how we evaluate your technology.

2. Prepare your technology

2. Prepare your technology

Refer to the 2011 TAPE guidance manual as you prepare your technology for review and certification.

3. Send in your application

The application form and fee must be submitted **both** as a hard copy and digitally to:

TAPE Program
Washington State Department of Ecology
Cashiering
PO Box 47611
Olympia, WA 98504-7696

Email: douglas.howie@ecy.wa.gov

We also review chemical technologies

We also accept applications to the Chemical Technology Assessment Protocol – Ecology (C-TAPE) program. See the construction site chemical technology guidance for more information.

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Approved technologies

The following table lists the devices that have received a designation through the TAPE process.

In addition to our certification, local jurisdiction approval is required (and not guaranteed) for installation of treatment technologies we have evaluated and given a use designation.

All | Pretreatment | Oil | Enhanced | Basic | Phosphorus | Construction

Manufacturer	Device Name	Treatment Type	Use Designation
AquaShield, Inc.	Aqua-Filter System, Aqua-Blend C Filter Media	Basic Treatment	Pilot Level
AquaShield, Inc.	Aqua-Filter System, Coarse Perlite Filter Media	Basic Treatment	Cond Level
BaySaver Technologies, Inc.	BayFilter w/ BFC Media	Basic Treatment	Gene Level
BaySaver Technologies, Inc.	BayFilter w/EMC Media	Basic Treatment	Gene Level
BaySaver Technologies, Inc.	BayFilter w/GAC Media	Basic Treatment	Pilot Level

AquaShield WATER TREATMENT SOLUTIONS

Example GULD for Pretreatment (50% TSS per storm)

(Page 1 of 5)

WASHINGTON STATE DEPARTMENT OF ECOLOGY

April 2017

GENERAL USE LEVEL DESIGNATION FOR PRETREATMENT

For
AquaShield™, Inc.'s Aqua-Swirl® Stormwater Treatment System

Ecology's Decision:

Based on AquaShield™, Inc. application submissions, Ecology hereby issues the following use level designations:

1. General Use Level Designation (GULD) for the Aqua-Swirl® for pretreatment use (a) ahead of infiltration treatment, or (b) to protect and extend the maintenance cycle of a Basic or Enhanced Treatment device (e.g., sand or media filter)
2. The following table shows flowrates associated with various Aqua-Swirl models

Model	Diameter (ft)	WQF (cfs)
AS-2	2.5	0.25
AS-3	3.5	0.64
AS-4	4.5	1.31
AS-5	5	1.78
AS-6	6	2.98
AS-7	7	4.63
AS-8	8	6.78
AS-9	9	9.48
AS-10	10	12.80
AS-11	11	16.79
AS-12	12	21.52
AS-13	13	27.03

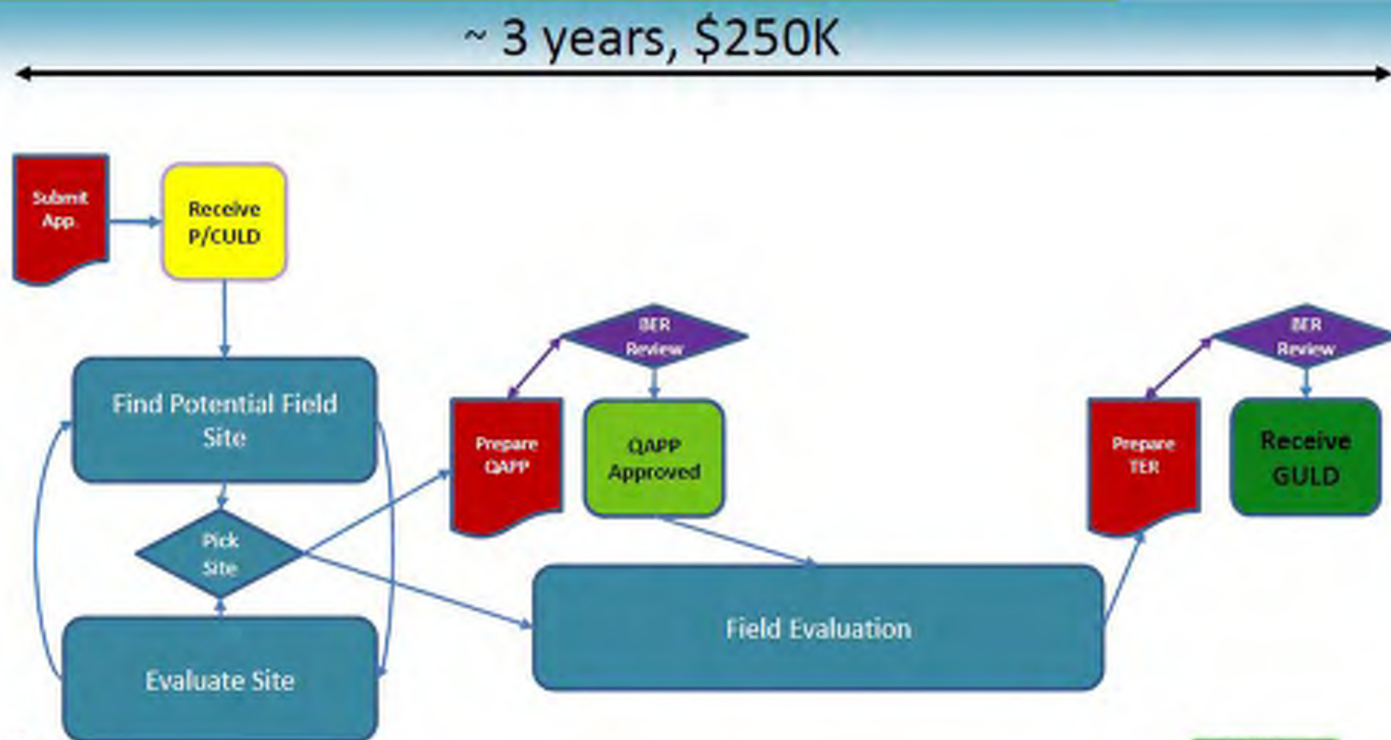
TAPE Use Level Designations

Use Level Designation	Minimum Data	Months (justified extensions allowed)	Max. # of Installations in WA	Field Testing Required
Pilot (PULD)	Lab data	30	5, Unlimited for Retrofits	All installation sites to be monitored. At least 1 indicative of or in Pacific NW
Conditional (CULD)	Field data, lab data may supplement	30	10, Unlimited for Retrofits	1 site indicative of or in Pacific NW
General (GULD)	Field data, lab data may supplement	Unlimited	Unlimited	None

Requirements for New/Redevelopment

- Treatment Facilities
  - Pretreatment (Total Suspended Solids)
  - Basic (Total Suspended Solids)
  - Enhanced (Dissolved Copper and Zinc)
  - Phosphorus (Total Phosphorus)
  - Oil (motor oil fraction of Total Petroleum Hydrocarbons)

TAPE Approval Timeline



TAPE Performance Goals (*per event*)

Performance Goal	Influent Range	Criteria	Required Water Quality Parameters
Basic Treatment	20-100 mg/L TSS	Effluent goal ≤ 20 mg/L TSS [a]	TSS
	100-200 mg/L TSS	≥ 80% TSS removal [b]	
	> 200 mg/L TSS	> 80% TSS removal [b]	
Dissolved Metals Treatment	Dissolved copper 0.005 – 0.02 mg/L	Must meet basic treatment goal and better than basic treatment currently defined as > 30% dissolved copper removal [b,d]	TSS, hardness, total and dissolved Cu and Zn
	Dissolved zinc 0.02 – 0.3 mg/L	Must meet basic treatment goal and better than basic treatment currently defined as > 60% dissolved zinc removal [b,d]	
Phosphorus Treatment	Total phosphorus (TP) 0.1 to 0.5 mg/L	Must meet basic treatment goal and exhibit ≥ 50% TP removal [b]	TSS, TP, orthophosphate
Oil Treatment	Total petroleum hydrocarbons (TPH) > 10 mg/L [e]	1) No ongoing or recurring visible sheen in effluent 2) Daily average effluent TPH concentration < 10 mg/L [a,e] 3) Maximum effluent TPH concentration of 15 mg/L [a,e] for a discrete (grab) sample	NWTPH-Dx, visible sheen
Pretreatment	50-100 mg/L TSS	Effluent goal ≤ 50 mg/L TSS [a]	TSS
	≥ 100 mg/L TSS	> 50% TSS removal [b]	

And in conclusion…

- Both the NJDEP/NJCAT & Ecology MTD approval processes provide robust performance testing programs to serve as models to assist other state/local regulators to evaluate MTD performance claims with greater confidence.
- MTD testing presents many challenges in the field and lab. Understanding the limitations of both is critical for any performance evaluation.
- The NJDEP/NJCAT lab-based approach allows for side-by-side comparison of MTD performance claims.
- Ecology's field-based approach provides long term, real-world performance and functionality to support MTD performance claims based on initial laboratory testing.
- NJDEP MTD certifications are specific to New Jersey to allow for MTD sales in New Jersey. Just because an MTD may hold NJCAT Verification, that verification may not be eligible for NJDEP Certification. Has significant marketplace implications outside of NJ.

It's all about good clean water…

Tennessee River, Chattanooga

Thank you.

AquaShield
WATER TREATMENT SOLUTIONS

INNOVATING GOOD CLEAN WATER

Mark Miller mmiller@aquashieldinc.com

2733 Kanasita Drive, Suite 111
Chattanooga, Tennessee 37343
888-344-9044

www.AquaShieldInc.com

Permaculture and Low Impact Development (LID)

By Patrick Padden

CASFM Annual Conference

September 27, 2018

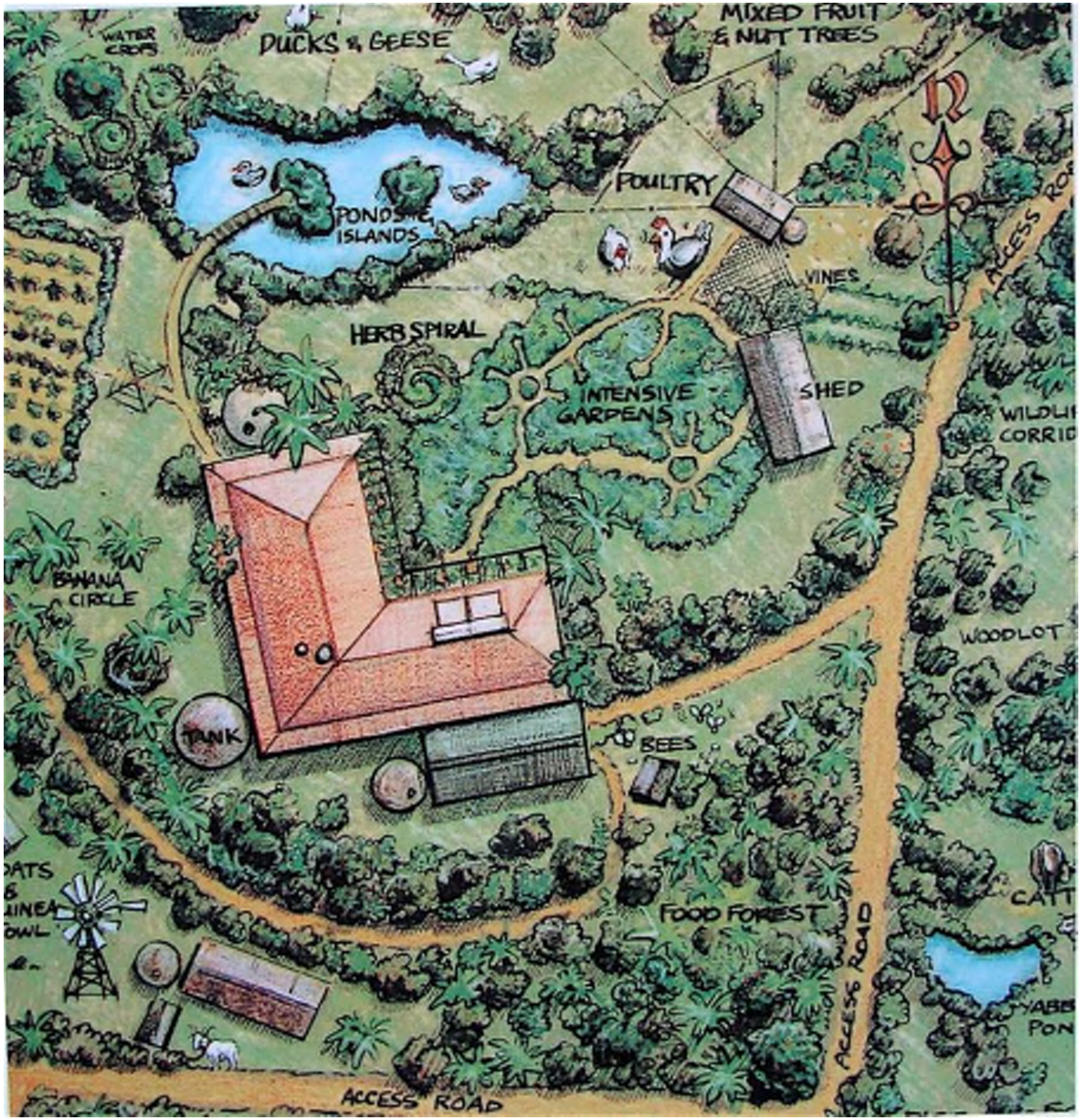
PADDEN PERMACULTURE

Ecological Landscape Design and Build

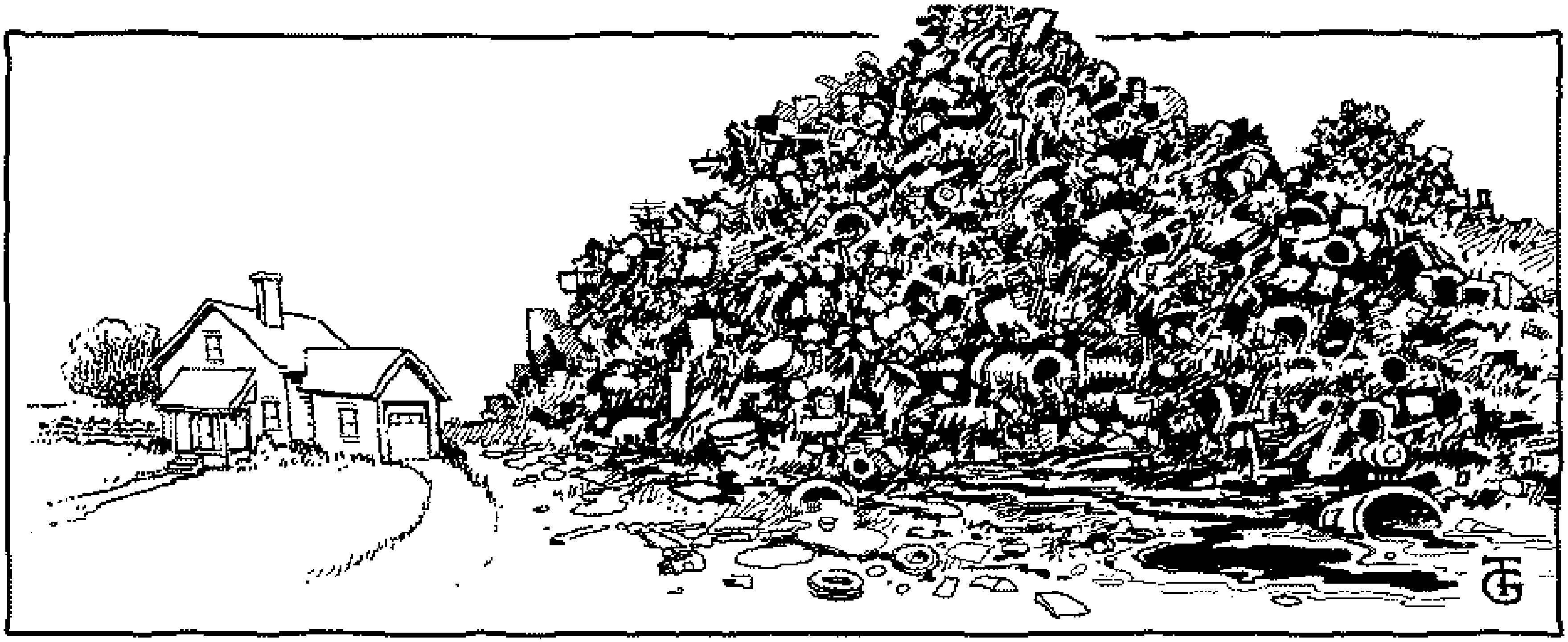
970-999-4306

Permaculture is a combination of sustainable site design, energy smart technology, edible landscaping, and innovative water management practices.

PERMACULTURE



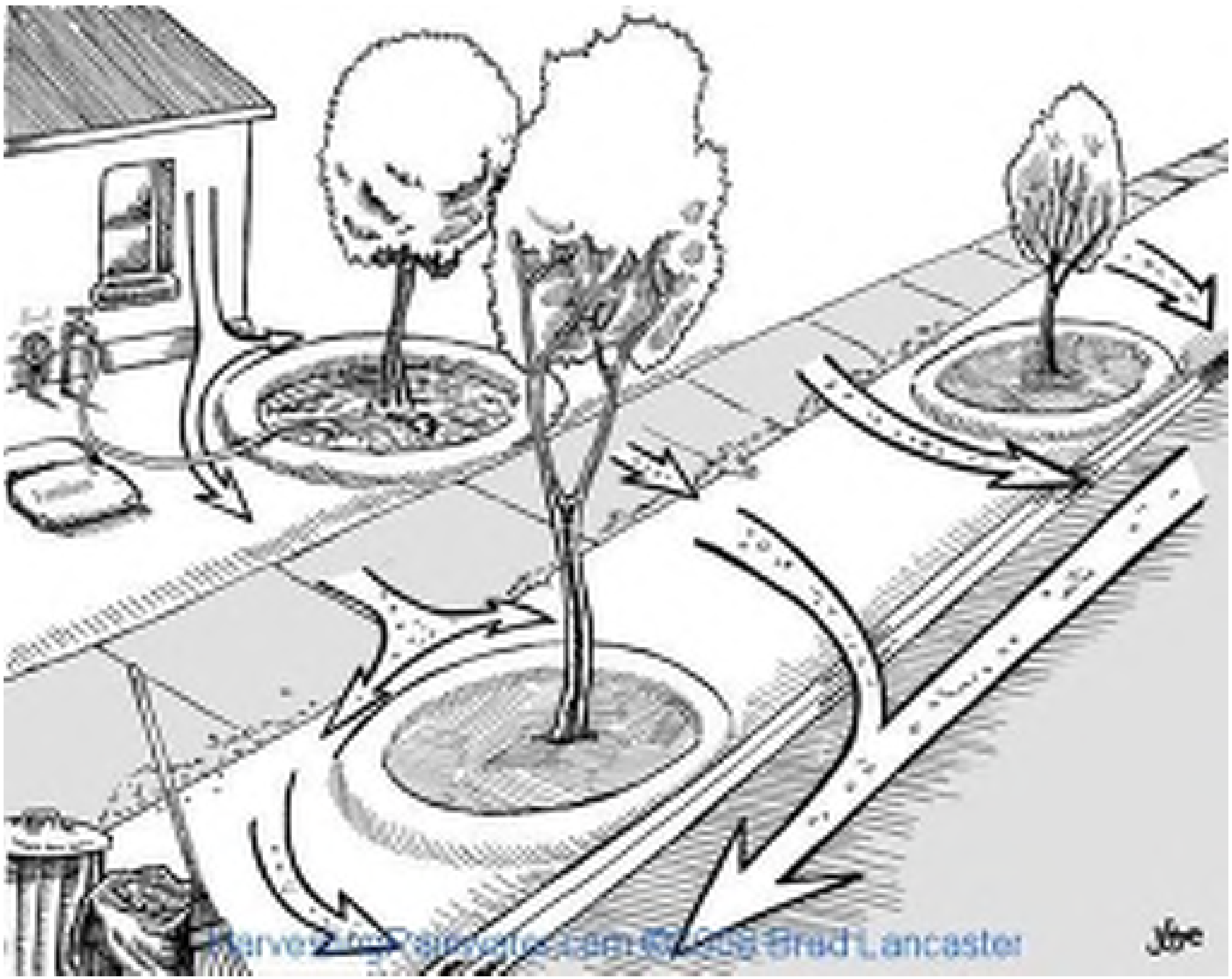
Bill Mollison's *Permaculture One*

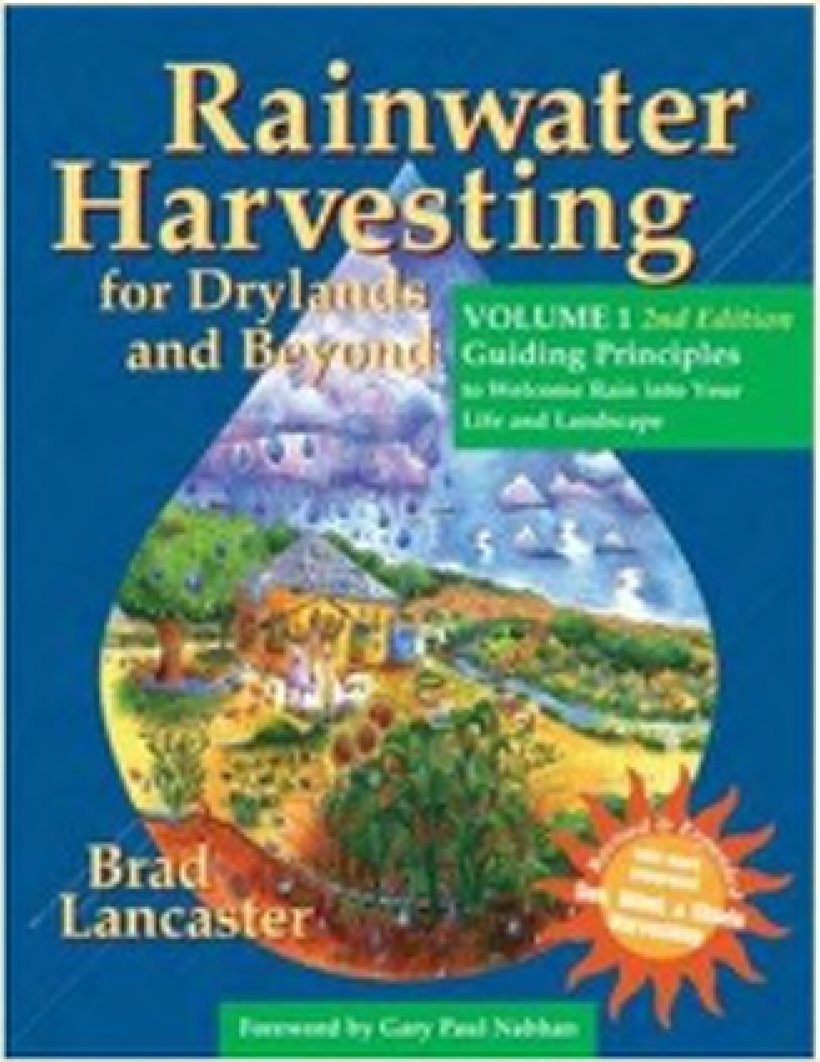


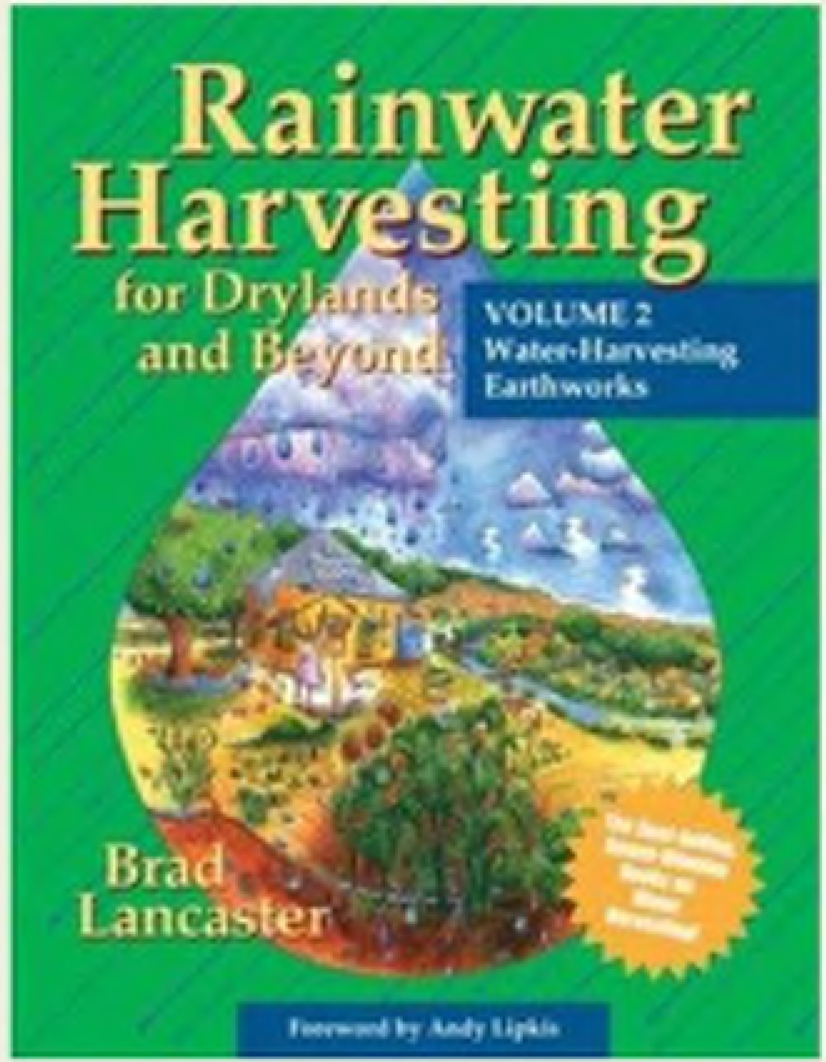
Joseph Jenkins Humanure *Handbook*


Established Pattern
Front Range Cities, Colorado

A landscape on the wasteful path to scarcity. Rain, runoff, and topsoil are quickly drained off the landscape to the street where the sediment-laden water contributes to downstream flooding and contamination. The landscape is dependent upon municipal/well water irrigation and imported fertilizer




Rainwater Harvesting
for Drylands and Beyond
VOLUME 1 2nd Edition
Guiding Principles
to Welcome Rain into Your Life and Landscape
Brad Lancaster
Foreword by Gary Paul Nabhan


Rainwater Harvesting
for Drylands and Beyond
VOLUME 2
Water-Harvesting Earthworks
Brad Lancaster
Foreword by Andy Lipkis

A landscape on the stewardship path to abundance. Rain, runoff, leaf drop, and topsoil are harvested and utilized with the landscape contributing to flood control and enhanced water quality. The system is self-irrigating with rain and self-fertilizing with harvested organic matter.

Xeriscape Projects

•

Xeriscape is not one particular style or look –
it's the creation of a healthy, attractive landscape that conserves water.

Xeriscape
•Provides a diversity of seasonal colors and textures
•Lowers outdoor water use 30-50 percent
•Reduces yard maintenance

Padden Permaculture

Padden Permaculture

Padden Permaculture

Patio Projects

Perennial Polycultures
I group plants together in a way that mimics natural ecosystems, but I select species that are especially productive for humans.

Plant List
-Toka Plum
-Stanley Plum
-Golden Raspberry
-Blackberry
-Strawberry
-Lead Plant (Nitrogen Fixer)
-Comfery (Dynamic Accumulator for soil fertility)
-Goji Berry
-Western Sand Cherry
-Black and Red Currant
-Culinary Herbs
-Alliums and Citronella for Insect repellent

Rainwater Harvesting Patios
I always design an infiltration basin around the perimeter of my patios. This feature allows runoff to passively irrigate useful plants

Downspout Incorporation
The runoff from downspouts is often an under valued resource in conventional landscape designs, but is always integrated in a Padden Permaculture Design


HITACHI

Padden Permaculture


Greywater Harvesting Laundry Machine
Brad Lancaster Design
Tucson, Arizona
ORANGE
FIG
HarvestingRainwater.com ©2008 Brad Lancaster

Padden Permaculture

Edible Landscaping

Landscapes designed with permaculture in mind will often incorporate groupings of fruits and veggies, usually perennial varieties to make the most efficient use of space


STOP


STOP

Padden Permaculture

White Mulberry

Sea Berry

Concord Grape

Siberian Pea
Shrub

Storm Water
Overflow Apron

Desert four
o'clocks

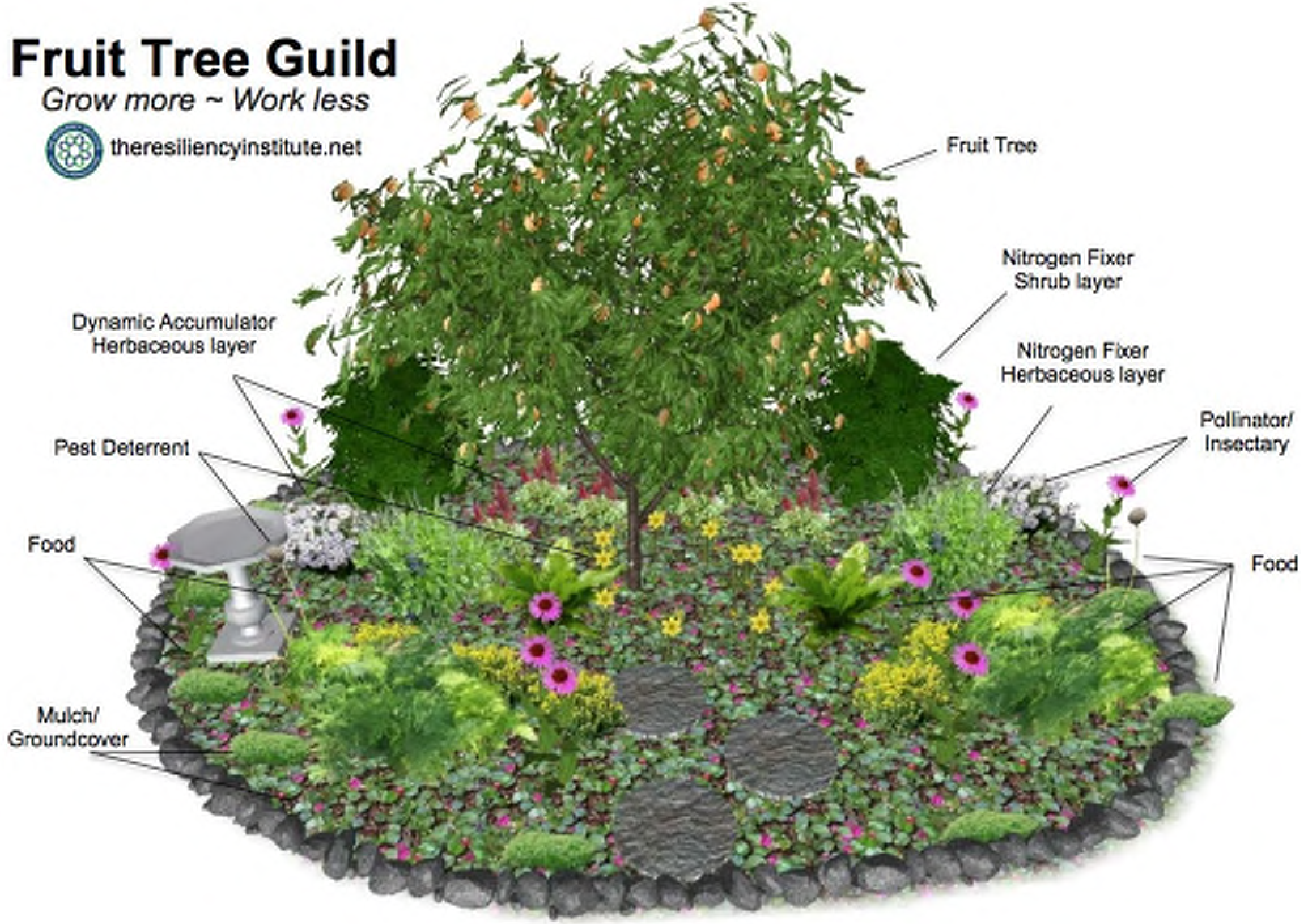
Nanking Cherry

Lavender

Sweet Pea

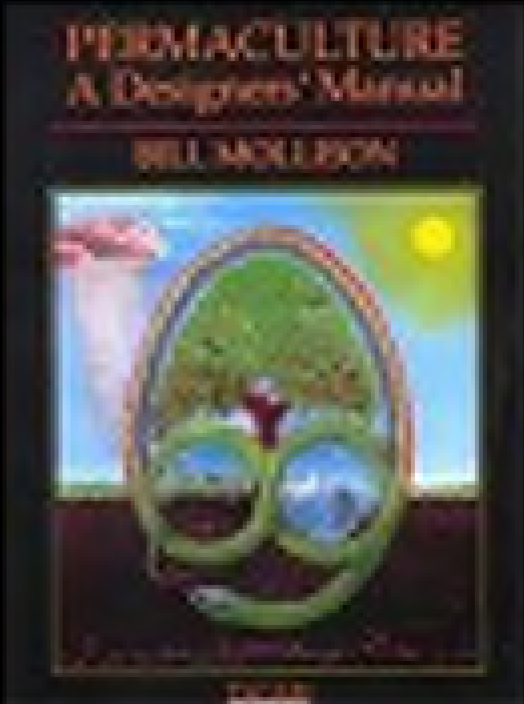
Strawberry

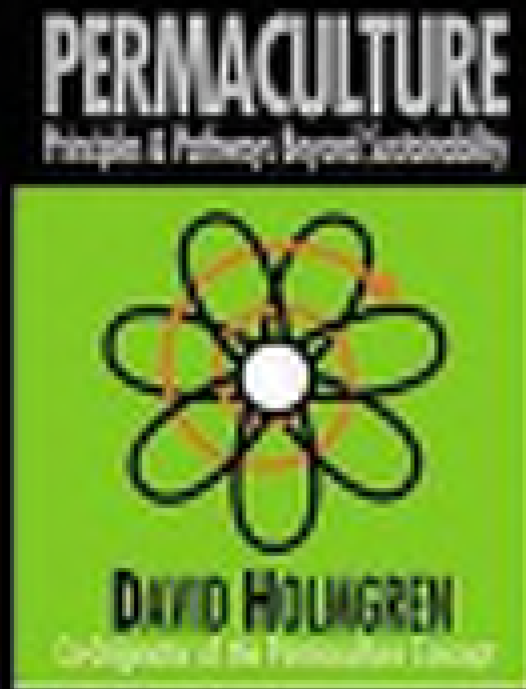
Collection Basin



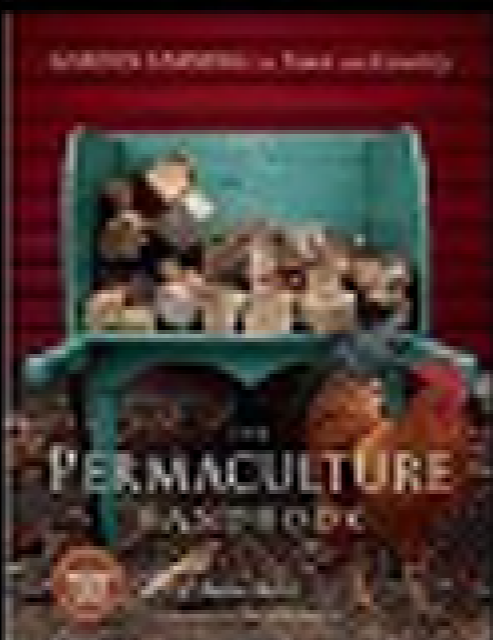
Fruit Tree Guild
Grow more ~ Work less
theresiliencyinstitute.net
Fruit Tree
Nitrogen Fixer
Shrub layer
Dynamic Accumulator
Herbaceous layer
Nitrogen Fixer
Herbaceous layer
Pollinator/
Insectary
Pest Deterrent
Food
Food
Mulch/
Groundcover

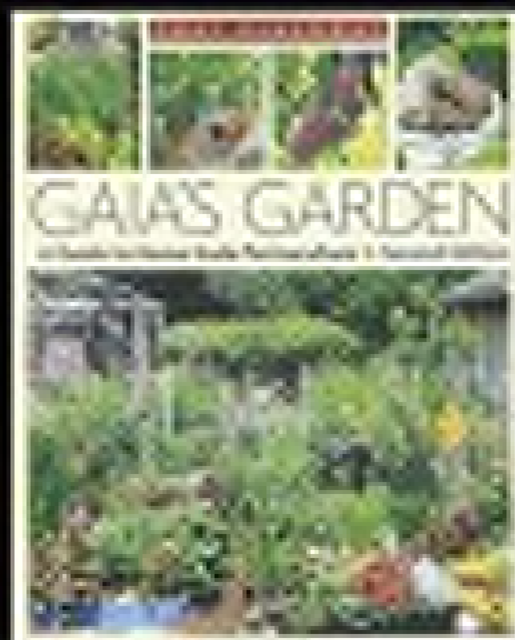

Harvesting Street Runoff
People's Food Co-op
Portland, Oregon

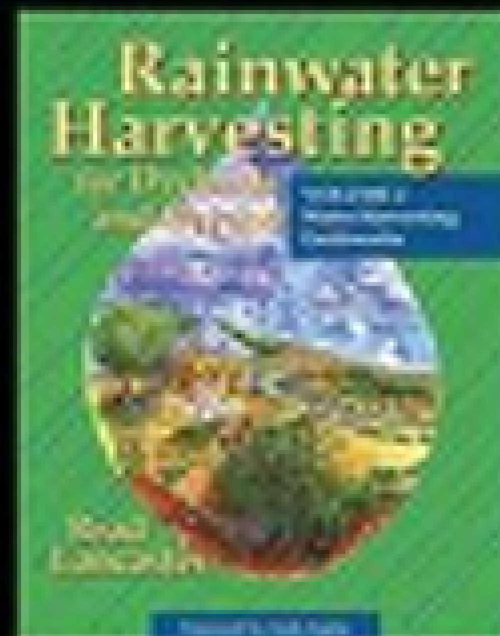

PERMACULTURE
A Designers' Manual
BILL MOLLISON


PERMACULTURE
Principles & Pathways Beyond Sustainability
DAVID HOLMGREN

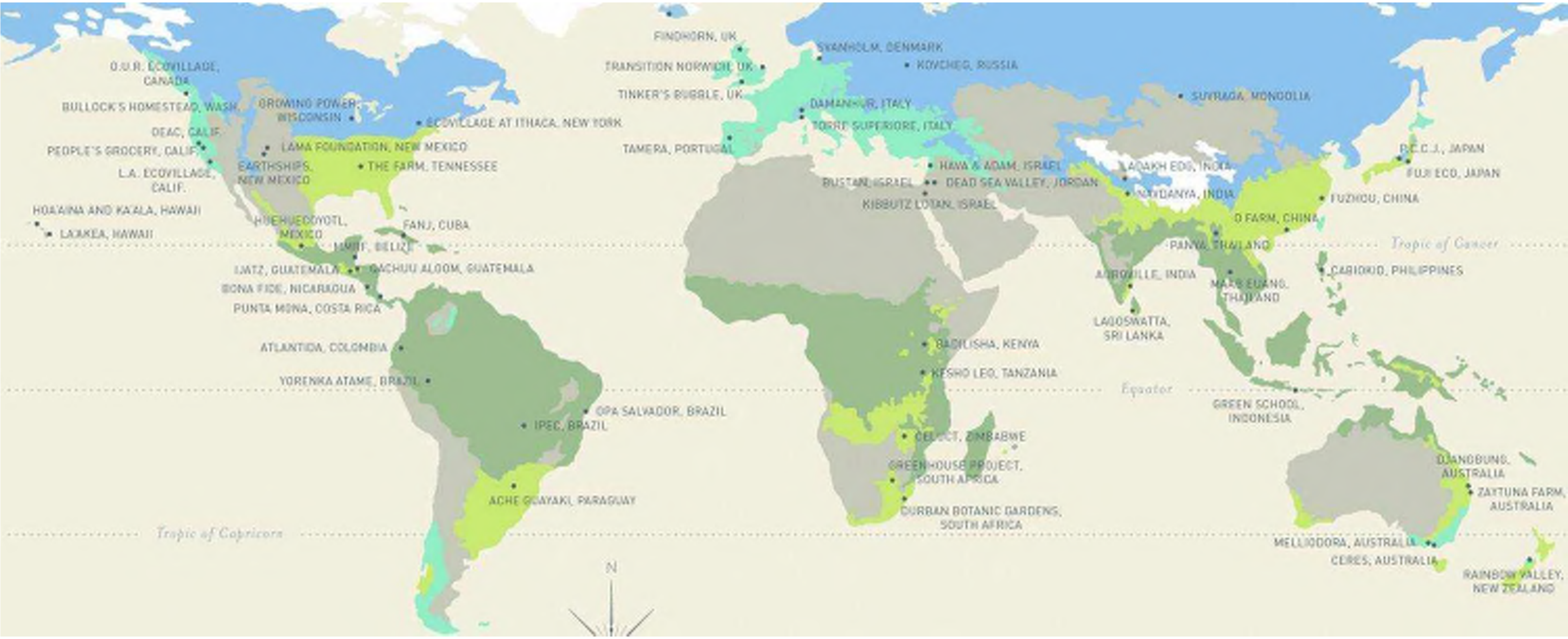

guide to
permaculture


PERMACULTURE


GAIA'S GARDEN


Rainwater
Harvesting

Permaculture Sites Around the World



Permaculture is a global movement that is providing solutions to many of the world's social and ecological challenges.

Permaculture Action Day, Loveland Colorado 2015

SUNRISE
RANCH

Permaculture Design Certificate (PDC)

July 20— Aug. 1, 2019
Sunrise Ranch, Colorado

11 day permaculture course

-permaculture design process

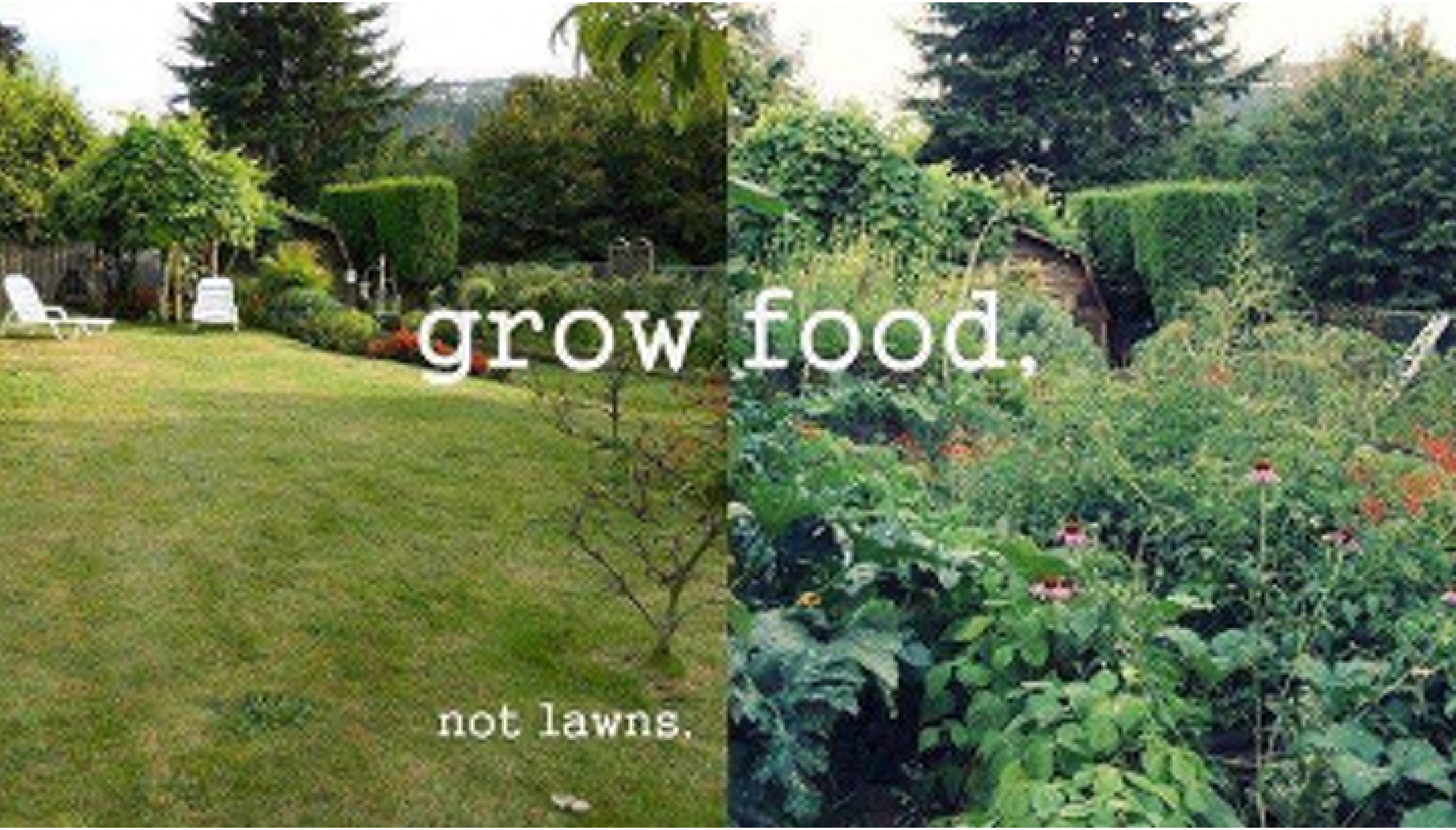
-rainwater harvesting and earthworks

-natural building and appropriate technology

-regenerative tools and techniques

-permaculture gardening and food forestry

-animals, soils, compost


grow food,
not lawns.

Comprehensive Watershed Planning: Prioritize, Target and Implement Multipurpose Projects

2018 Annual CASFM Conference
Texas Floodplain Management Association

HRGreen

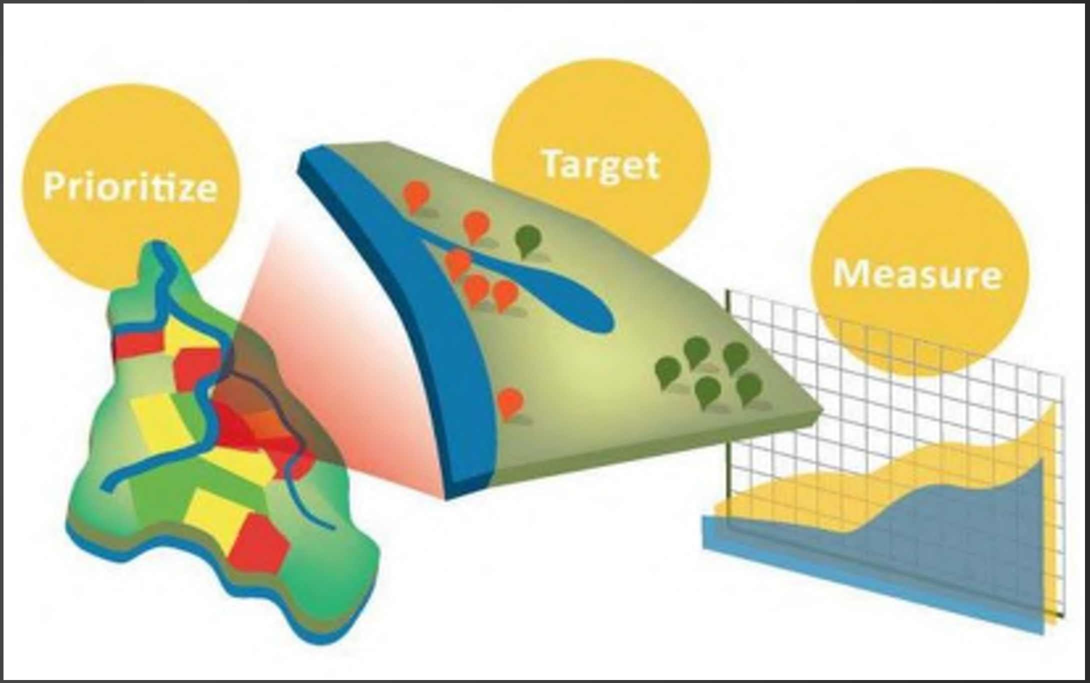
Introduction

- PART 1
  - What is 1W1P?
  - How it came to be
  - Planning funding
  - Operation of plan
  - Implementation funding
- PART 2
  - Case study

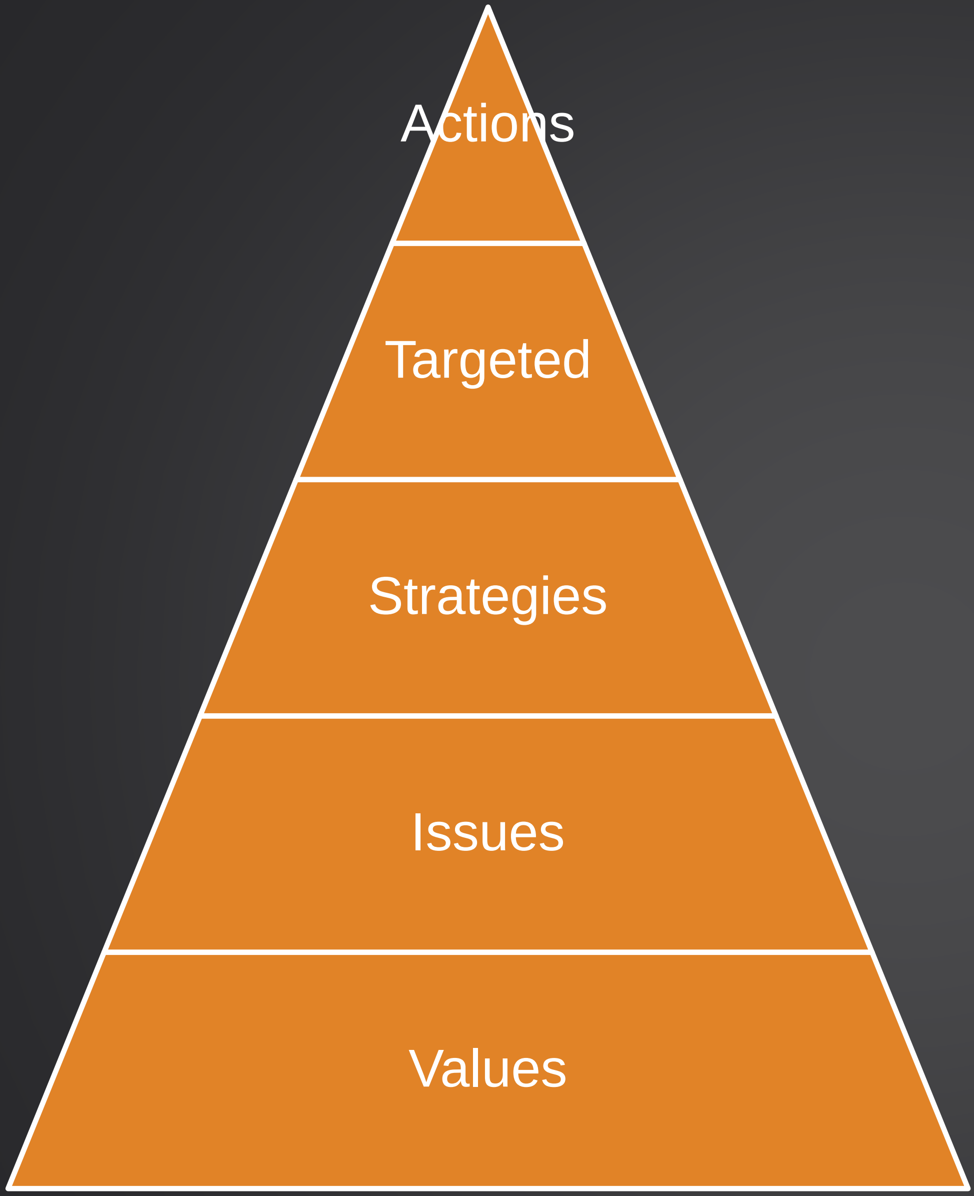
PART ONE – 1W1P OVERVIEW

What is 1W1P?

- Aligns local water planning towards watershed-based implementation
- 63 HUC8 (~700 mi^2)
- Comprehensive
- Formal agreements
- No new governing agency



HRGreen



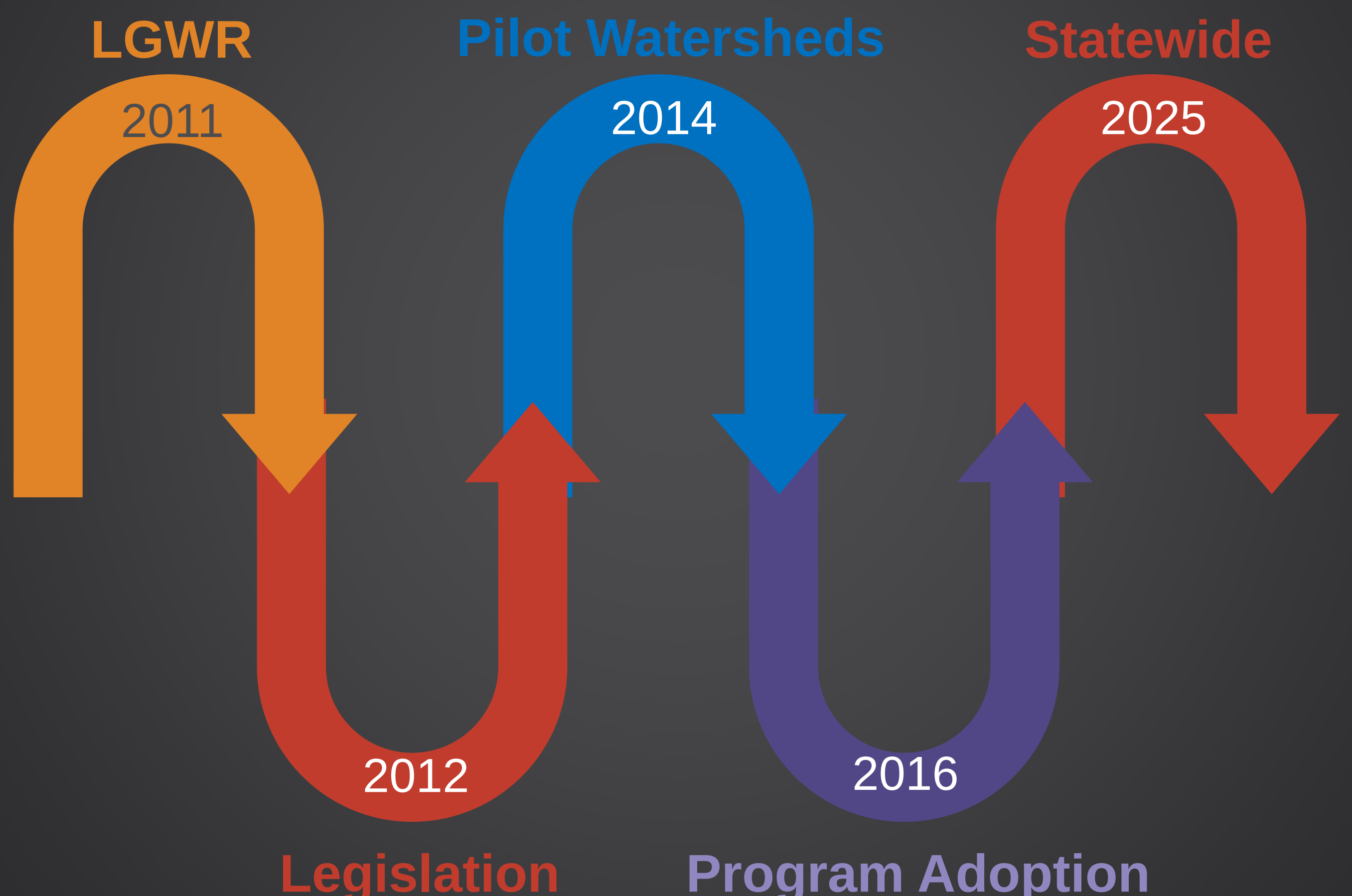
- Assemblage of all locally-relevant plans, programs and studies
- Statement of existing watershed status
- Unified agreement on priority values
- Vision of long-term management goals by value
- Selection of 10-year management targets
- Identification of implementation actions
- Prioritization of actions based on ability to meet multiple goals
- Prioritized, targeted and measurable goals

What is 1W1P?

Part of MN's 10-yr management cycle

1. Monitoring
2. Issues and stressors
3. WRAPS
4. 1W1P
5. Voluntary implementation

How it came to be



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Planning funding

Nov 2008 voters approved CWF to:

- Protect drinking water sources
- Protect, enhance, and restore lakes, rivers, streams, and groundwater
- Protect, enhance, and restore wetlands, prairies, forests, and fish, game, and wildlife habitat
- Support parks and trails
- Preserve arts and cultural heritage

CLEAN WATER LAND & LEGACY AMENDMENT

Operation of plan development

Planning Groups	Description
Policy Committee	Local plan authorities purposed with making final decisions about plan content and regarding expenditure of planning funds. Final owner and operator.
Advisory Committee	Various local, State, Federal, Tribal and NGO technical members. Makes recommendations on plan content and implementation to the Policy Committee.
Work Planning Group / Steering Committee	A small group of local staff, BWSR Board Conservationist, and consultants for the purposes of logistical and process decision-making in the plan development process.

Plan partners

- Municipalities/Townships
- Counties
- Soil and Waters Conservation Districts
- Watershed Districts
- Flood Management Authorities
- State BWSR, DNR, DOT, DOH, etc.
- USFS, USACE, USFWS
- Tribal Government
- NGOs and Public

Required
Voluntary

Planning process

Plan content

- Executive summary
- Land and Water narrative
- Priority resources and issues
- Measurable goals
- Targeted implementation schedule
- Plan implementation programs
- Plan administration and coordination

Operation of plan implementation

Type of Governance Agreement	Description
Memorandum of Agreement (MOA)	An agreement between multiple parties; method of formally recognizing a partnership; specifies mutually-accepted expectations and guidelines
Joint Powers Agreement (JPA)	Agreement to jointly deliver a service or a product
Joint Powers Board (JPB)	Type of JPA that specifically establishes a new entity or board that operates autonomously from the members. Risk is transferred to this entity.
Watershed District (WD)	Formal local unit of government, defined by hydrologic boundary and formed by a local petition process

Implementation funding

- Watershed-based funding
- $4,875,000 Y1
- $4,875,000 Y2
- 10% non-State match (cash or in-kind)
- Eligible activities

PART TWO – CASE STUDY

Case study – Leech Lake River 1W1P

- 1,335 mi^2
- 3 counties
- Leech Lake Bank of Ojibwe
- 277 river miles
- 750 lakes (166,374 acres)
- Northern Lakes and Forest Ecoregion
- Largely forested
- 46% privately held land
- Some of most pristine lands in MN

Case study – Leech lake River 1W1P

Planning Groups	Description
Policy Committee	Cass Environmental Services Dept, Cass SWCD, Hubbard County, Hubbard SWCD
Advisory Committee	Cities, Chamber of Commerce, Counties, The Nature Conservancy, USACE, MNDNR, USFS
Work Planning Group / Steering Committee	Cass and Hubbard SWCD Administrators, BWSR BC, Leech Lake Band of Ojibwe, Leech Lake Area Watershed Foundation, Consultants

Case study – Leech Lake River 1W1P

Natural Resources

Case study – Leech Lake River 1W1P

Climate and Risk

Case study – Leech Lake River 1W1P

Leadership

HRGreen

Case study – Leech Lake River 1W1P

Quality of Life

Case study – Leech Lake River 1W1P

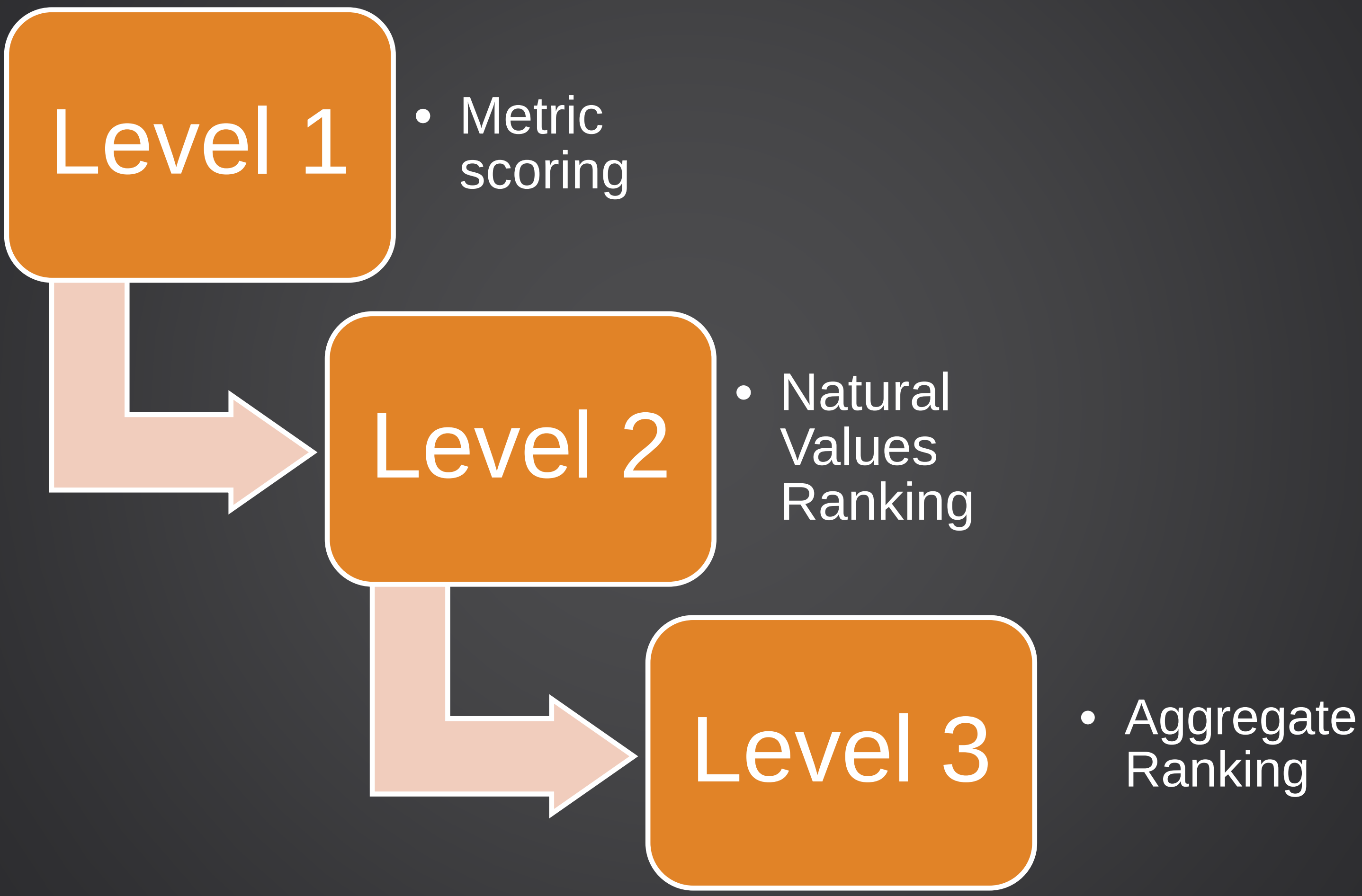
1. High Quality Lakes
2. Recreational Lakes
3. Impoundments
4. Impaired Lakes
5. High Value/Priority Rivers and Streams
6. Declining, Impaired and Channelized Rivers and Streams
7. Wetlands
8. Groundwater
9. Upland Resources – Forests
10. Upland Resources – Habitat
11. Upland Resources - Working lands
12. Upland Resources - Cities and towns

Case study – Leech Lake River 1W1P

PRIORITY NATURAL WORLD VALUES AND THE 10-YEAR PLAN GOAL ATTAINMENT LEVEL

HRGreen

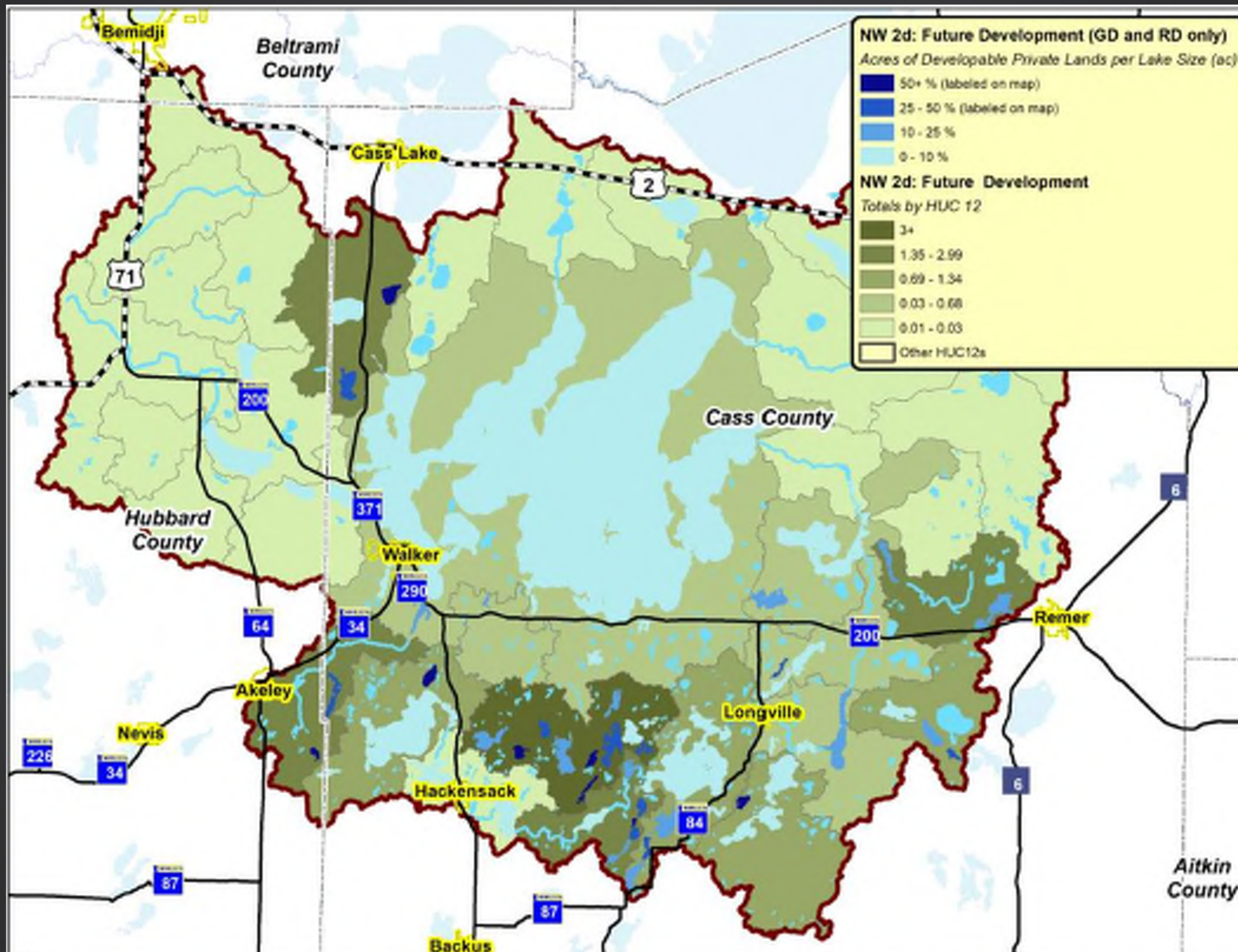
Case study – Leech Lake River 1W1P



Case study – Leech Lake River 1W1P

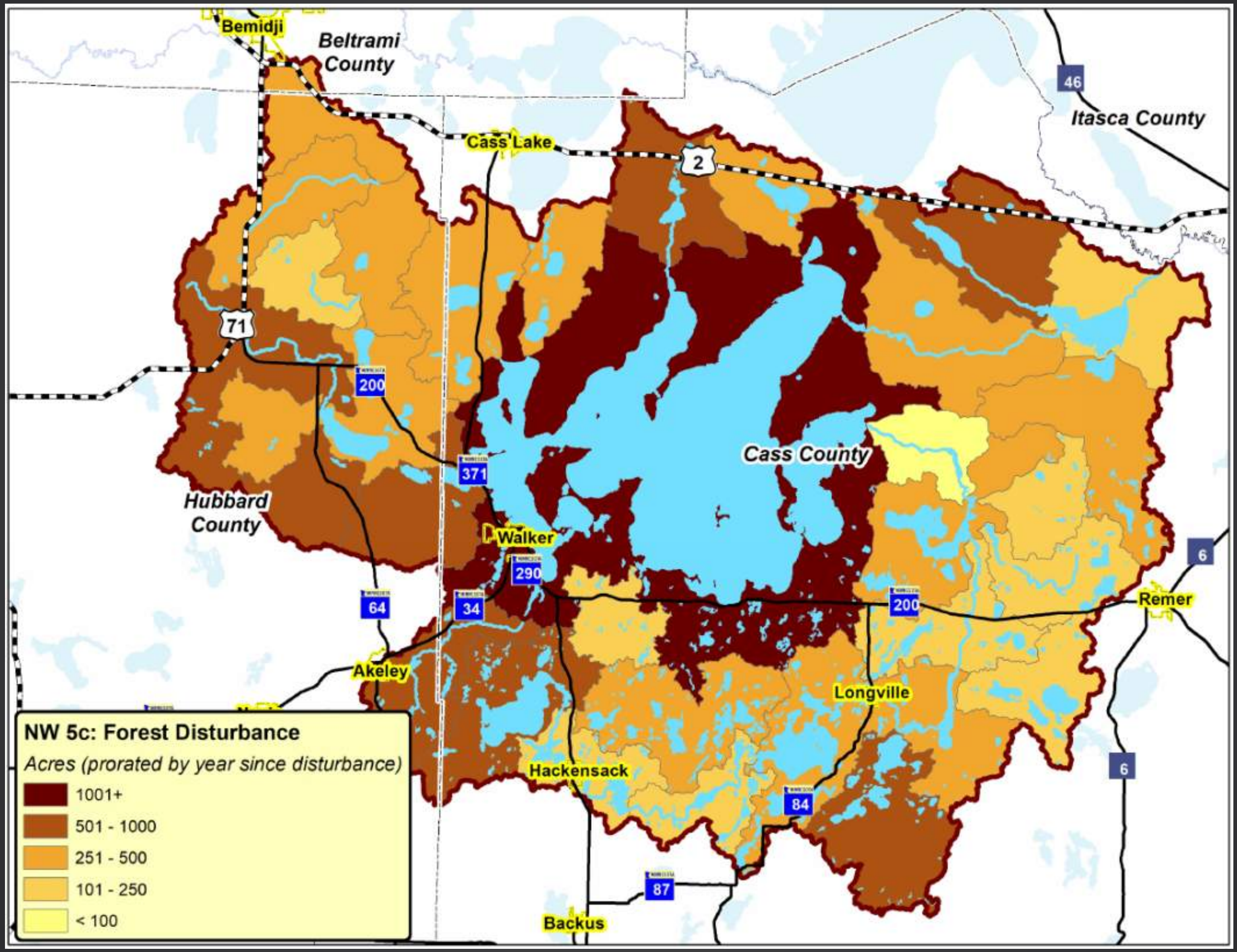
HIGH QUALITY LAKES METRICS	SCORING	DATA SETS
Coldwater Habitat Presence	Yes = 1, No = 0.01	WRAPS
P-Sensitivity Lake Presence	0.33, 0.66 and 1.0; high, higher highest	State 2108 data
WQ Trend	Close to threshold = 1 Declining trend = 0.66 No data = 0.33; rising = 0.01	State 2017 data
Forest	Composite score above mean = 1 (X=99.08; range = 15 – 175)	Forests of the Future data
Terrestrial Biodiversity	Yes = 1, No = 0.01	State MCBS Biodiversity data
WRAPS Priority Lake	Yes = 1, No = 0.01	WRAPS
Lakes of Biological Significance	Outstanding =1 High = 0.66 Moderate = 0.33	WRAPS
Wild Rice Lake	High = 1 (local = high and/or DNR List = high) High = 0.66 Moderate = 0.33 No data or zero value = 0.01	State Top 350 lakes and Local Preference data

Case study – Leech Lake River 1W1P



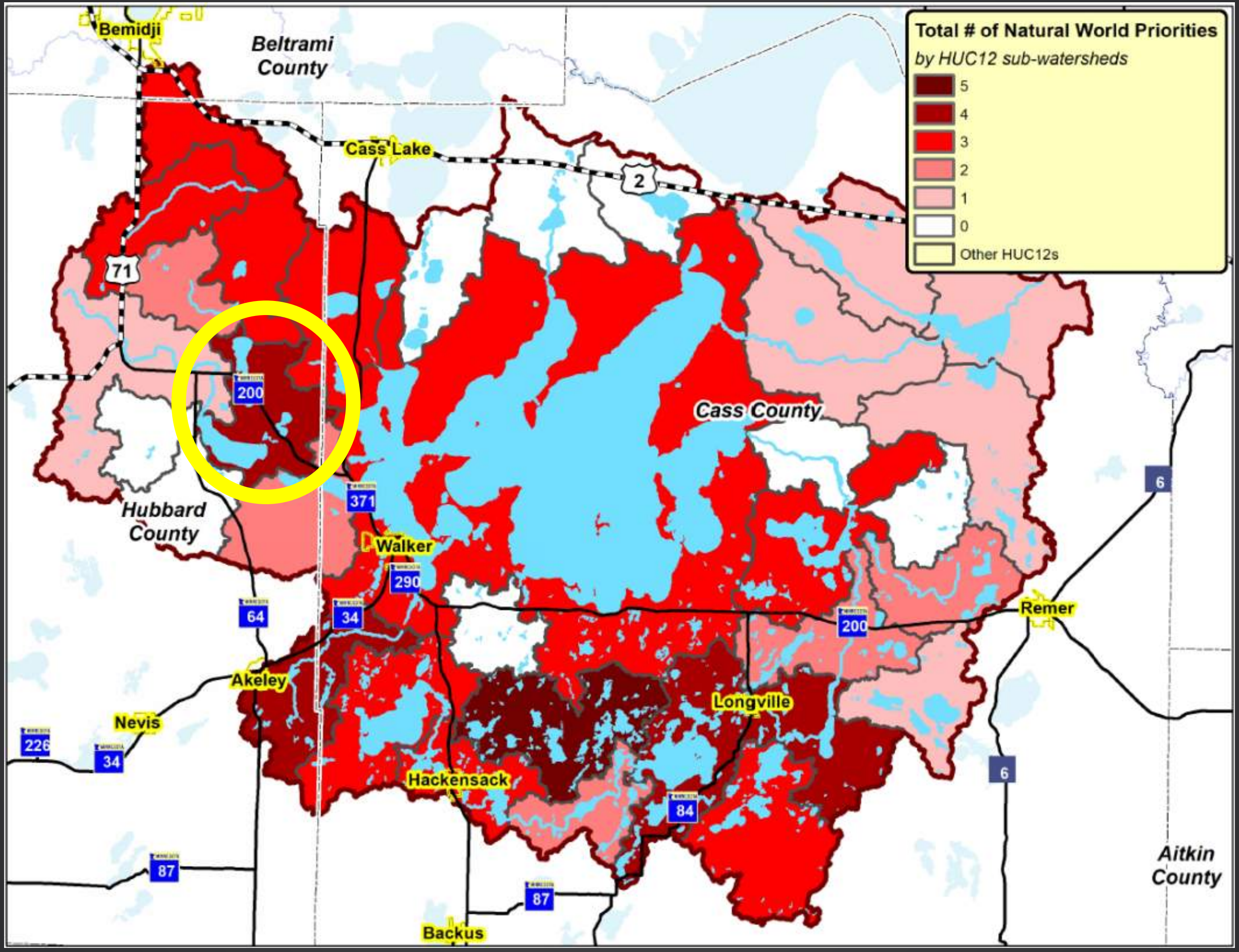
HRGreen

Case study – Leech Lake River 1W1P



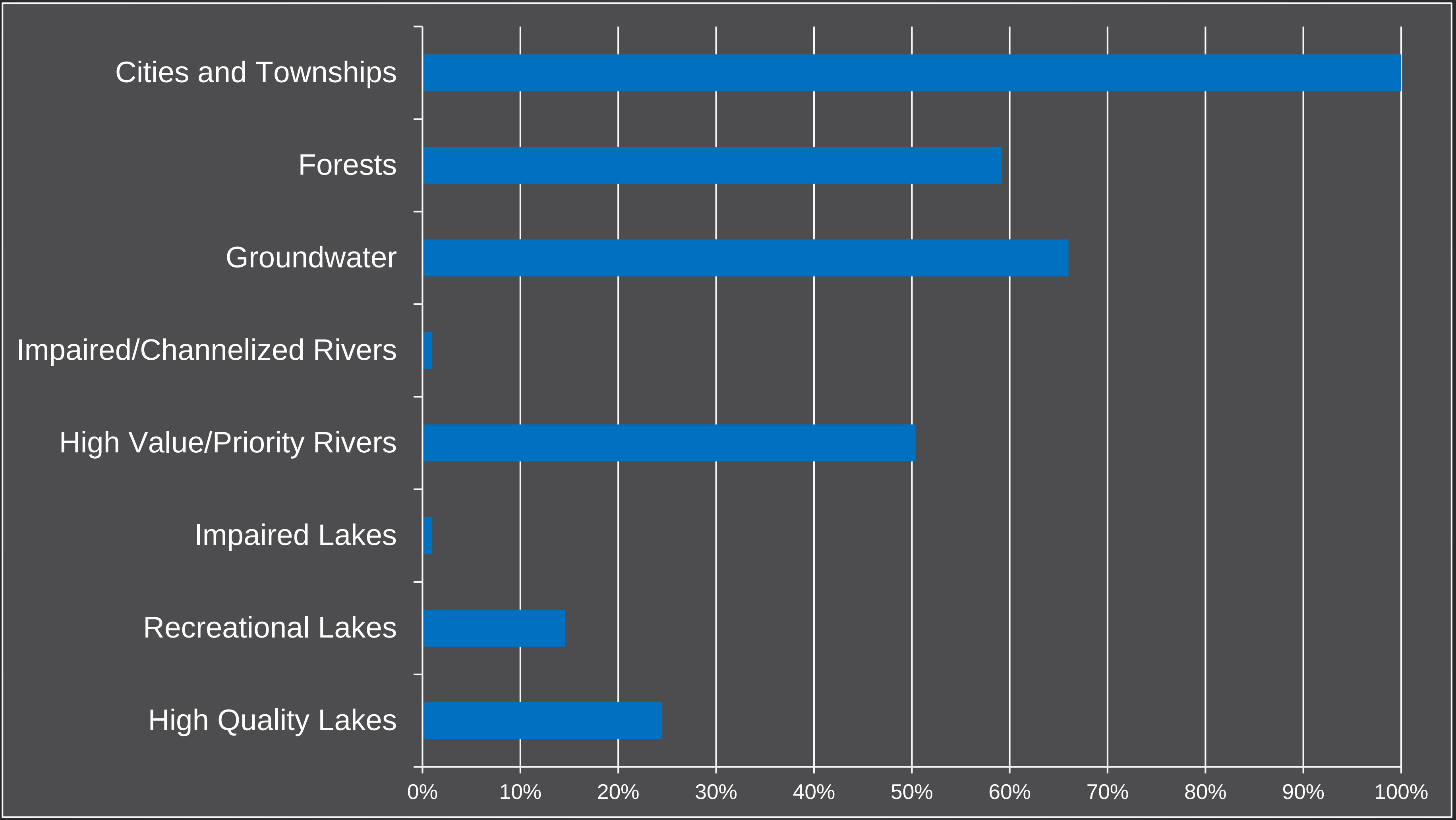
HRGreen

Case study – Leech Lake River 1W1P



HRGreen

Case study – Leech Lake River 1W1P



Case study – Leech ake River 1W1P

Resource	Management Strategy
Cities and Townships	1. Urban stormwater management for City of Laporte (particular attention to highway runoff) 2. Update stormwater management. 3. Stormwater management plan for future development including land development and Stormwater ordinance updates.
Groundwater	1. Update ground water plan with Geologic Atlas and shallow well data. 2. Targeted well-monitoring. 3. SSTS Management (inventory, functional assessment) for Garfield Lake 4. Groundwater/Wetland management in Garfield Lake lakeshed.
Forests and Working Lands	1. Conservation easements and forestry management incentives on private lands (riparian and non-riparian) in Garfield and Kabekona lakesheds.
Kabekona River	1. SSTS Management (inventory, functional assessment, regulatory) 2. River corridor regulation 3. Wild Rice easements 4. Riparian easements and acquisitions 5. Riparian conservation and stewardship 6. Stormwater water quality and temperature stormwater BMPs 7. Culvert hydraulic, hydrologic, sediment transport and fish barrier inventory and assessment priority. 8. Pasture management.

PART THREE – LOCAL EXAMPLE

COLORADO WATER PLAN

"Productive economy, vibrant and sustainable cities, productive agriculture, strong environment, robust recreational industry"

Social, Economic and Environmental Values for Vision to shape mission of plan.

HRGreen


Subbasin
14010001
Subbasin
10190005
Subbasin
10190003
Denver
Subbasin
10190004
Subbasin
10190011
Subbasin
10190002
Subbasin
10190001
Colorado
Subbasin
11020003
Subbasin
11020004
Subbasin
11020008

MANAGEMENT GROUPS

- Federal Agencies
  - USACE
  - USFS
  - USFWS
  - NRCS
- State of Colorado
  - CO Water Cons. Board
  - CO Watershed Assembly
  - DNR
  - DOT
  - DOA
- Local drainage authorities
  - Urban Drainage and Flood Control District
- Counties
- Conservation Districts
- Municipalities/Townships
- NGO's
  - The Greenway Foundation
  - Trout Unlimited

EXAMPLE PLANS

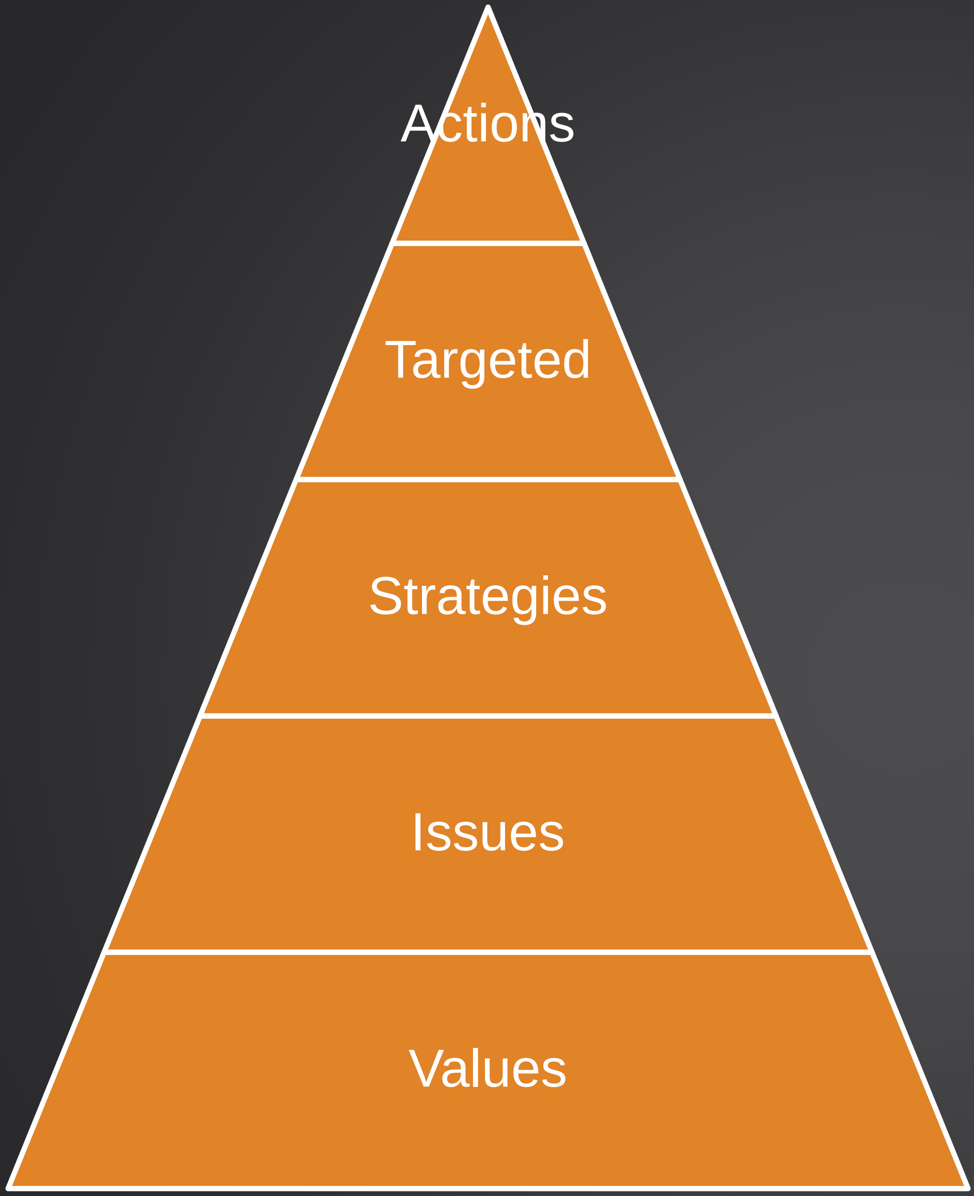
- Colorado Water Plan
- Statewide Water Supply Initiative
- Basin Improvement Plans
- Stream Management Plans
- Watershed Protection Plans
- …several others

LOCAL POLICY COMMITTEE & PLAN OWNER/OPERATOR

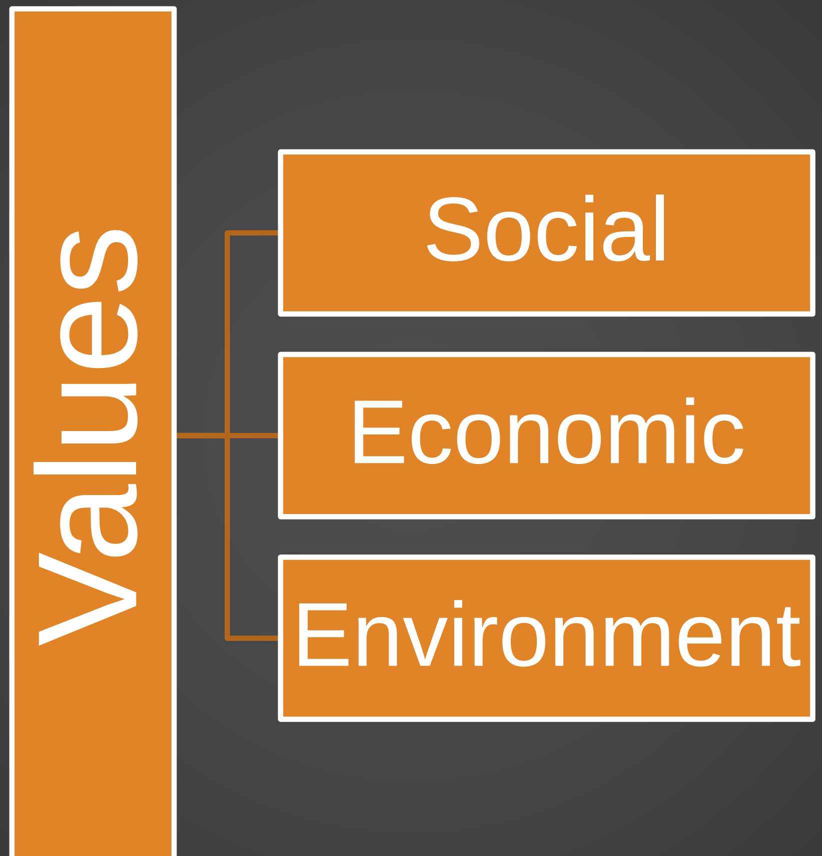
- **Urban Drainage and Flood Control District**
- **Conservation Districts**
- **Colorado Watershed Assembly**

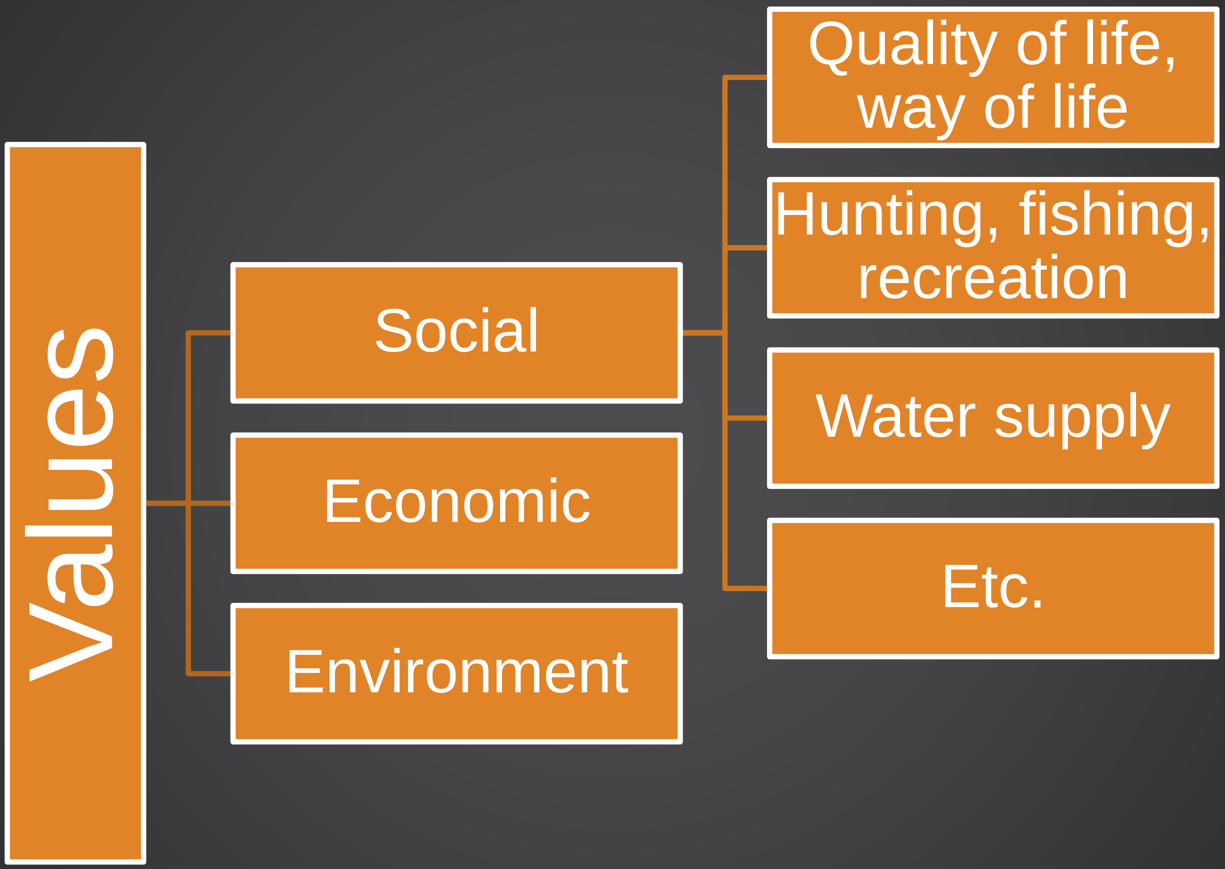
STEERING COMMITTEE

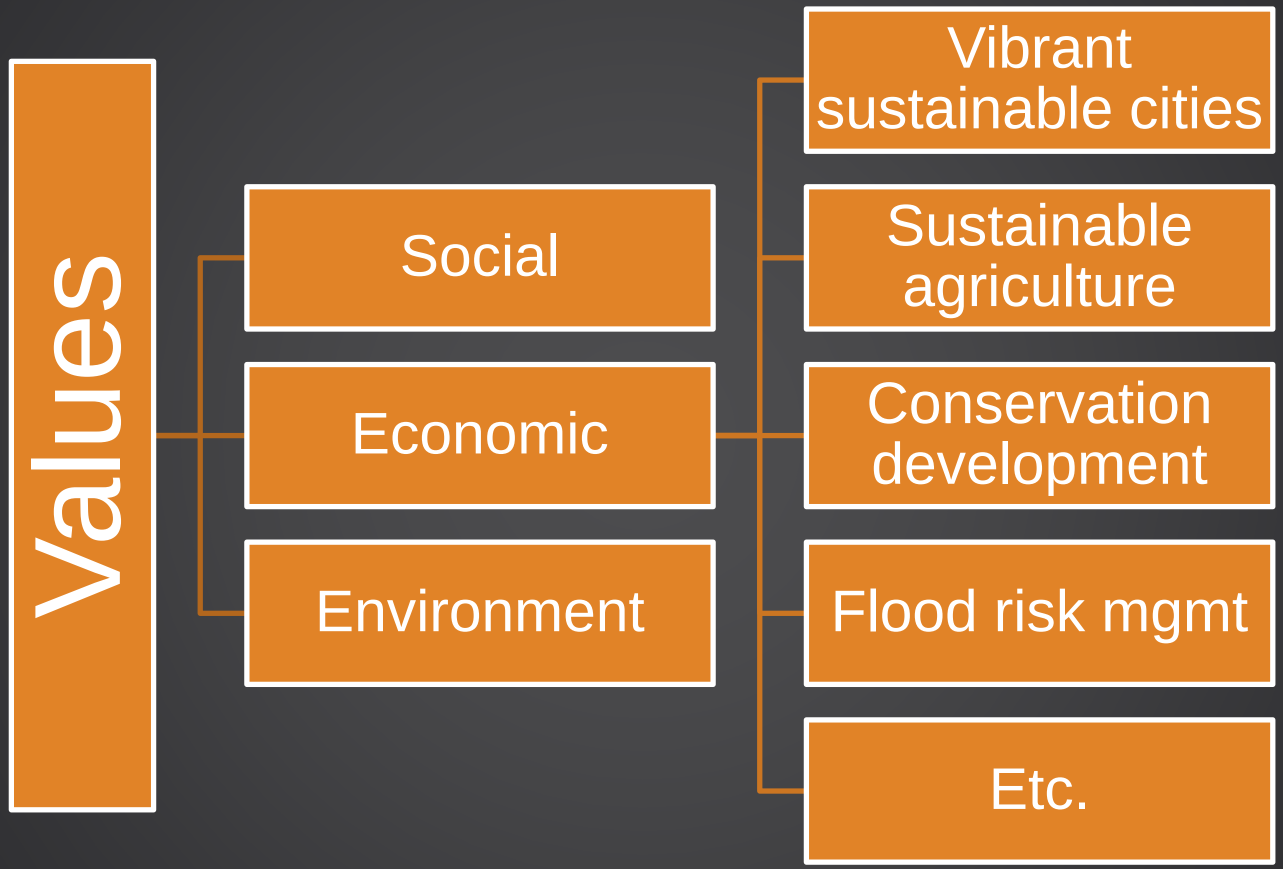
- **The Greenway Foundation**
- **USACE**
- **USFS**
- **USFWS**
- **NRCS**
- **DNR**
- **Co Water Cons. Board.**
- **DOT**
- **DOA**
- **Municipalities/Townships**
- **Trout Unlimited**

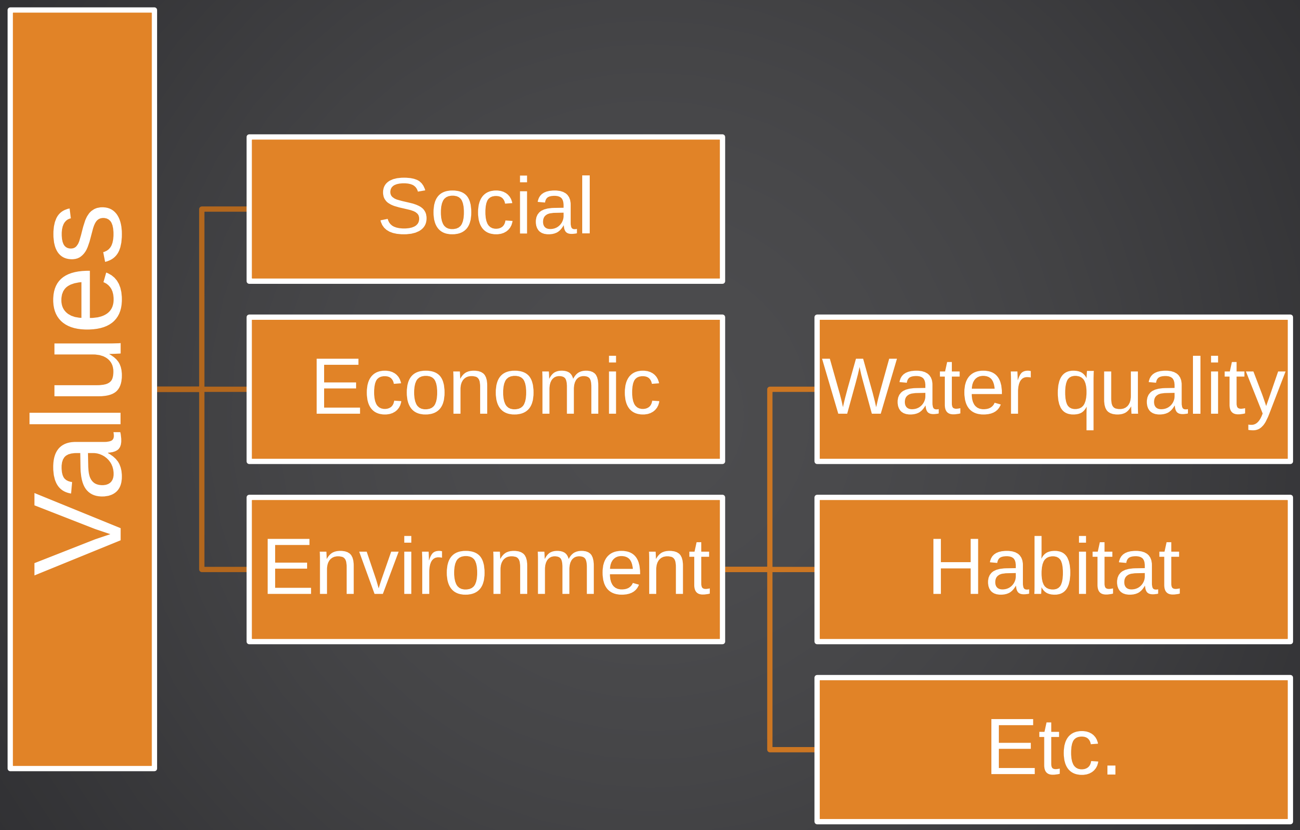


- Colorado Water Plan
- Basin Improvement Plans
- Stream Management Plans
- Watershed Protection Plans
- Statewide Water Supply Initiative
- Local drainage authorities (e.g., Urban Drainage and Flood Control District, Denver area)
- Federal Agencies
- NGO/Special interest Groups
    - Greenway Foundation
    - Trout Unlimited

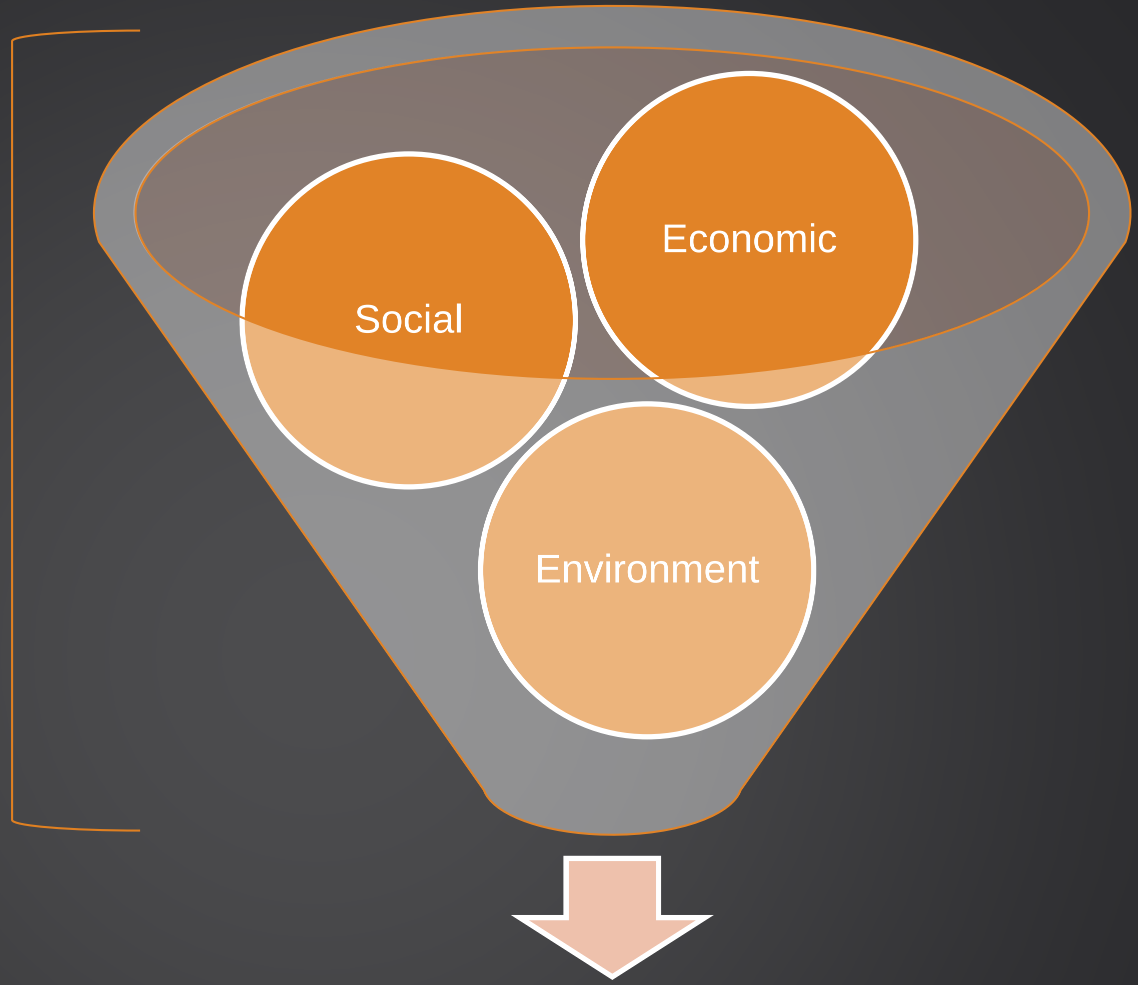

Values
Social
Economic
Environment


Values
Social
Economic
Environment
Quality of life, way of life
Hunting, fishing, recreation
Water supply
Etc.


Values
Social
Economic
Environment
Vibrant sustainable cities
Sustainable agriculture
Conservation development
Flood risk mgmt
Etc.


Values
Social
Economic
Environment
Water quality
Habitat
Etc.

- Synthesis of existing information.
- Based on right project, right location, right costs



Prioritized, targeted and measurable local 10-yr implementation plan

Contact Information

Shawn Tracy, Water Resource Project Manager
651.659.7747
stracy@hrgreen.com

One Watershed, One Plan
http://www.bwsr.state.mn.us/planning/1W1P/index.html

CASFM 2018 – Snowmass, CO

Developing a Comprehensive Stormwater Infrastructure Master Plan

COLORADO SPRINGS
OLYMPIC CITY USA

Drew Beck, PE, CFM
Tim Biolchini, PE
Richard Mulledy, PE

September 27, 2018



Matrix DESIGN GROUP

WILSON & COMPANY

Enginuity

DDS

HDR

ICON ENGINEERING, INC

- Background
- Goals
- Approach
- Database and Web Application
- Takeaways

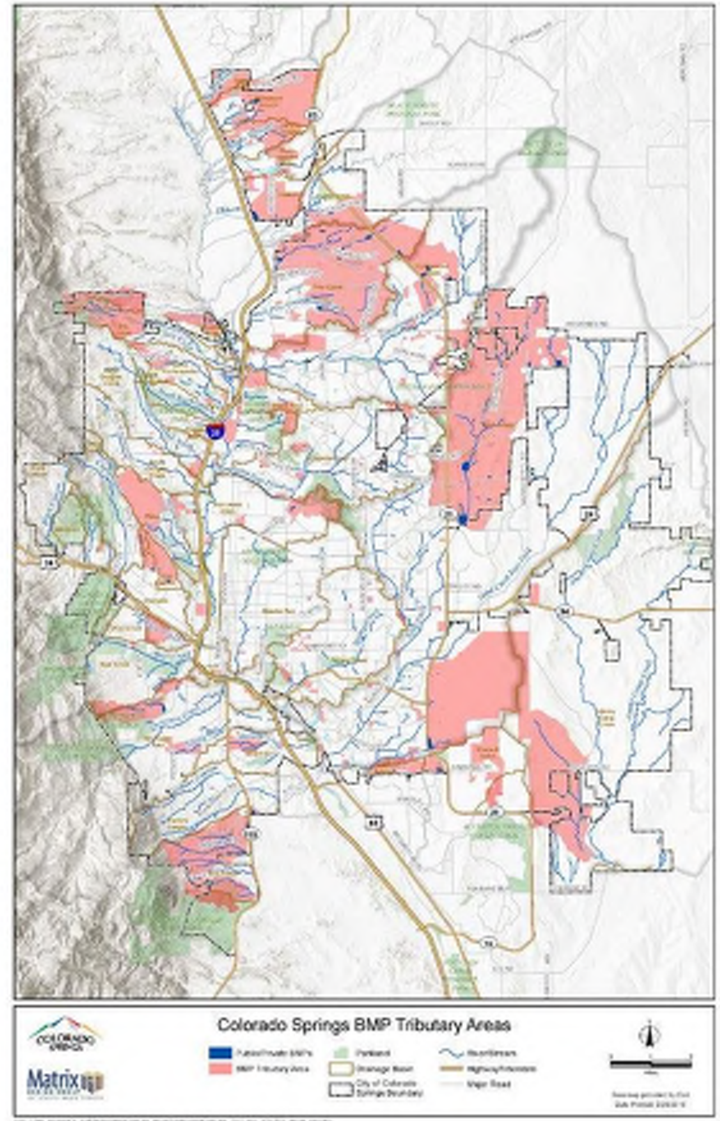
Problems






Project Goals

- GIS-based web application for CIP planning
- Existing infrastructure gaps
- CIP prioritization and budgeting tool
- Create a Stormwater Channel Assessment Program framework
- BMP tracking system



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Strategic Vision

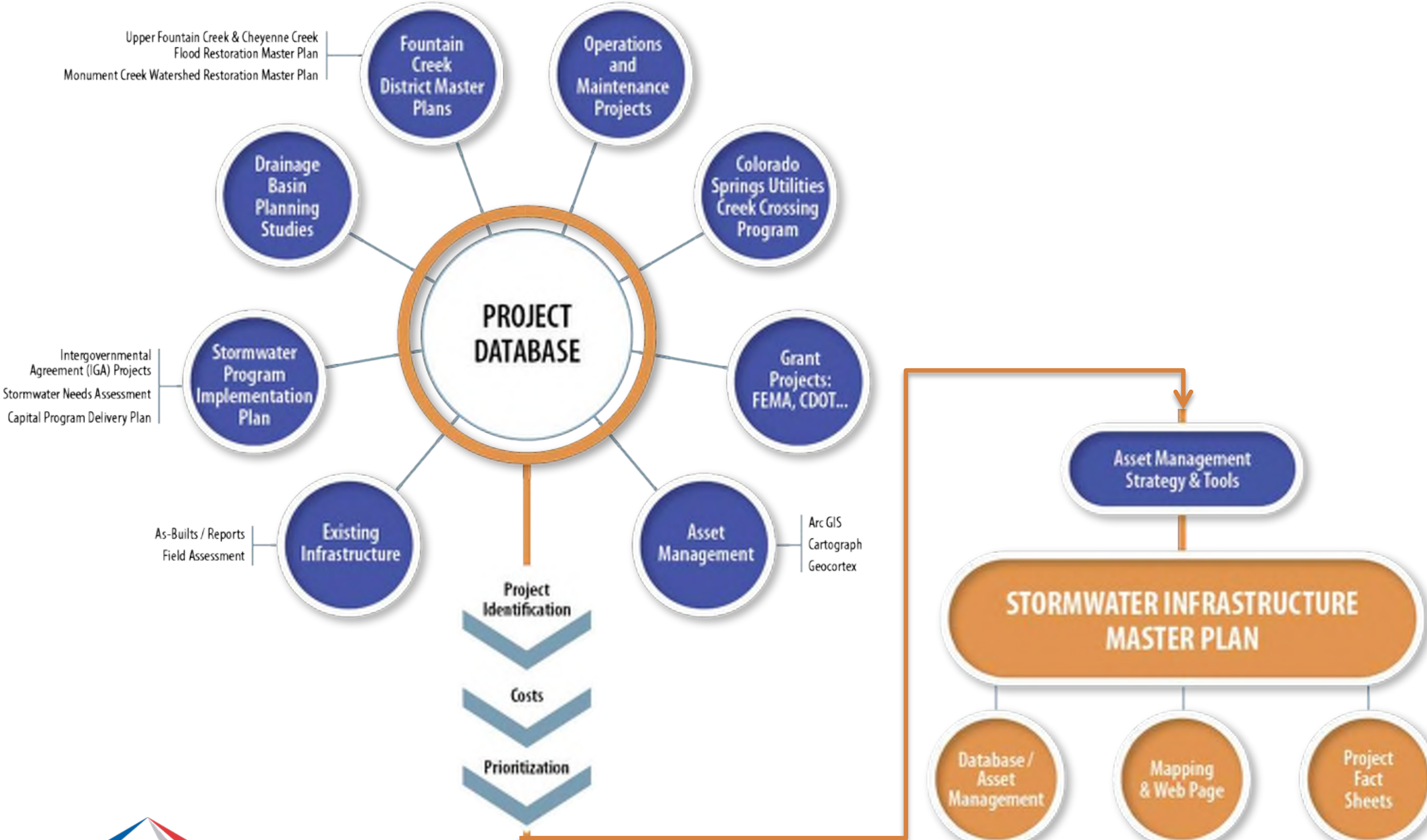
- Colorado Springs Utilities
- Operations & Maintenance
- Development Review
- Fountain Creek Watershed Flood Control & Greenway District
- CIP Delivery
- Parks & Open Space
- GIS and IT

Benchmarking

- City of Aurora
- City & County of Denver
- Urban Drainage & Flood Control District

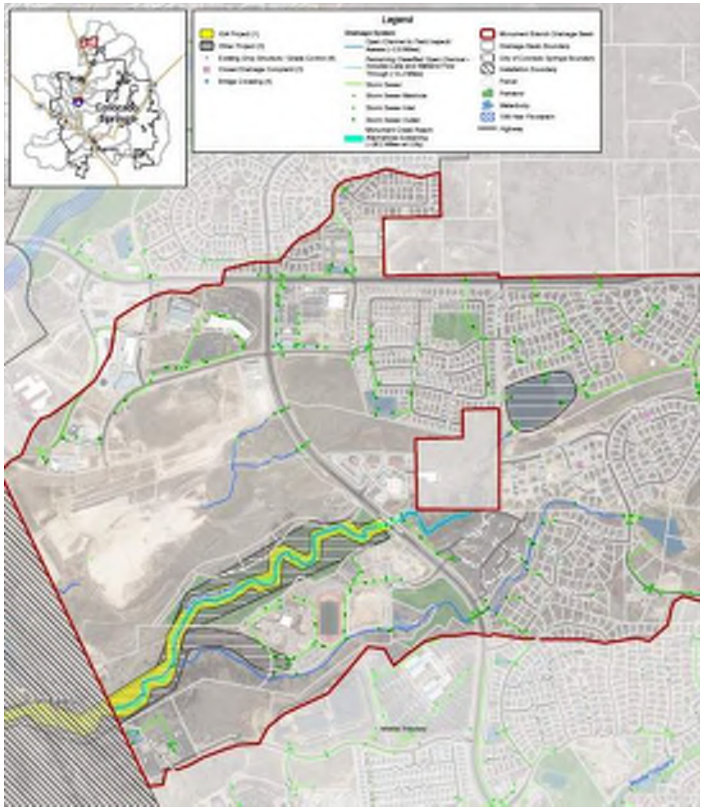
- Project Definitions
- Sub-Projects
- Prioritization
- Querying
- Cut Sheets
- Work Flow
- Cost Index
- Editability
- Accessibility

Approach


Upper Fountain Creek & Cheyenne Creek Flood Restoration Master Plan
Monument Creek Watershed Restoration Master Plan
Fountain Creek District Master Plans
Operations and Maintenance Projects
Drainage Basin Planning Studies
Colorado Springs Utilities Creek Crossing Program
PROJECT DATABASE
Intergovernmental Agreement (IGA) Projects
Stormwater Needs Assessment
Capital Program Delivery Plan
Stormwater Program Implementation Plan
Grant Projects: FEMA, CDOT...
As-Builts / Reports
Field Assessment
Existing Infrastructure
Asset Management
Arc GIS
Cartograph
Geocortex
Project Identification
Costs
Prioritization
Asset Management Strategy & Tools
STORMWATER INFRASTRUCTURE MASTER PLAN
Database / Asset Management
Mapping & Web Page
Project Fact Sheets

Data Collection – Field Review

- Over 258 mi of open channel
  - 37 major drainage basins
  - 63 mi improved/195 unimproved
  - 1,260 grade control structures
  - 800+ existing BMPs
- GIS data
  - Tablet data collection
  - Geolocated photos



Data Collection – Field Review

- Parameters collected
  - Location - GPS
  - Improvement type
  - Condition
    - Tier 1
    - Tier 2
  - Height
  - Vegetation

Data Collection – Field Review

Tier 1 – Infrastructure Condition

- Health/safety/flooding
- Channel stability
- Utility risks
- Road/bridge/structure risk
- Criteria – headcuts, unstable banks, severe floodplain disconnect, undermined drop structures

Tier 2 – Corridor Function

- Recreation
- Habitat/riparian function
- Aesthetics
- Criteria – geomorphic floodplain connection, vegetation quality and connection, bedrock

Field Assessment

- Tier 1 – Infrastructure Condition: Examples
- Good (green) – healthy stream corridor; sustainable [35%/67%]
- Fair (yellow) – some instability but no adjacent risks; at risk in large flood; maintenance [50%/28%]
- Poor (orange) – instability with adjacent risks; could need a CIP [10%/4%]
- Critical (red) – needs immediate attention; imminent risk [<5%/<1%]

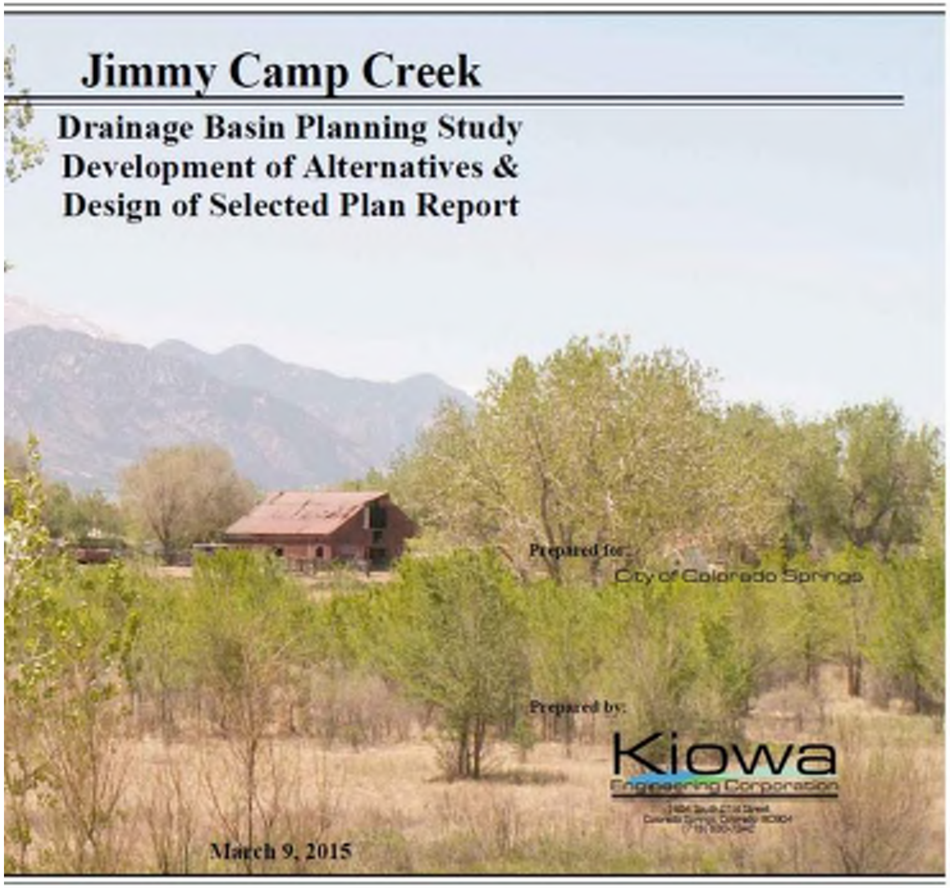
- Tier 2 – Corridor Value: Examples
- Good (green) – healthy stream corridor; high aesthetic and habitat value [30%/48%]
- Fair (yellow) – some impaired habitat but mostly functioning [45%/35%]
- Poor (orange) – disconnected floodplain, sparse vegetation [20%/16%]
- Critical (red) – minimal habitat value[<5%/<1%]

Field Assessment

- Examples
- Tier 1 – Good
- Tier 2 - Poor

Data Collection - Documents

- Over 400 documents
  - Plans/Reports
  - IGA Projects
  - Needs Assessment
  - Databases
  - Spreadsheets
  - Hand written notes
  - Individual staff knowledge
- GIS data


Jimmy Camp Creek

Drainage Basin Planning Study
Development of Alternatives &
Design of Selected Plan Report

Prepared for:
City of Colorado Springs

Prepared by:
Kiowa
Engineering Corporation

March 9, 2015

COLORADO SPRINGS
OLYMPIC CITY USA

Project Identification

- Over 462 Potential Projects
  - 326 Channel projects
  - 55 Detention projects
  - 81 Storm drain projects

PROJECT ORGANIZATION: INVENTORY SPREADSHEET

	No.	ID	Cost Table (SIMP ID) (NEW)	Attribute Only (SIMP ID) (New)	IGA ID (NEW)	Improvement Name	Location (Street Names)	Drainageway	…	Category	Description	Unit	Quantity	Unit Cost	Cost Subtotal	…	Status	…
Document Summary	1	1-0				**Sand Creek DBPS - Detention Basin Cost Estimate**	**Sand Creek Basins**	-		**0 - Project summary**	-	-	**LS**	**1**	**$$$**			
Improvement	1	1-1	**SC-C6**		-	Sand Creek DBPS	Lower Sand Creek	Sand Creek		X - Channel - Grade Control	Grade control	EA	6	$27,000	$162,000		Constructed	
Improvement	1	1-2	**SC-C6**		-	Sand Creek DBPS	Lower Sand Creek	Sand Creek		X - Channel - Lining	Sel linings (1 side)	LF	350	$127	$44,450		Not constructed	
	1	1-3	**EFSC-C8**		-	Sand Creek DBPS	East Fork Sand Creek Tributaries	East Fork Sand Creek		X - Channel - Lining	Selective riprap lining	LF	5700	$85	$484,500		Not construct ed	
	1	1-4	**EFSC-D1**		-	Sand Creek DBPS	Constitution Ave and East Fork Sand Creek	East Fork Sand Creek		X - Detention	Public regional 100-year detention with water quality (278 AF)	AC-FT	278	$10,000	$2,795,000		Not constructed	
	1	1-5	**EFSC-D1**		-	Sand Creek DBPS	Constitution Ave and East Fork Sand Creek	East Fork Sand Creek		X - Detention	Land acquisition	AC	26.9	$15,900	$427,710		Not constructed	
	1	1-6	**EBSC-B160**		-	Sand Creek DBPS - Roadway Culvert Crossing Cost Estimate	Bridlespur Road	East Bierstadt Creek		X - Culvert	2-8'Hx10'W CBC	LF	160	$750.00	$120,000		Not constructed	
	1	1-7	**EBSC-B47A**		-	Sand Creek DBPS - East Fork Sand Creek Bridge Crossing Cost Estimate	Unnamed Roadway	East Bierstadt Creek		X - Bridge / Full span	2-10'Hx14'W CBC	LF	250	$1,250.00	$312,500		Not constructed	

Project Organization

Project Organization

Legend:

Summary of costs by document.

Project Improvements identified in the reviewed document.

Steps in inventory spreadsheet to define project organization.

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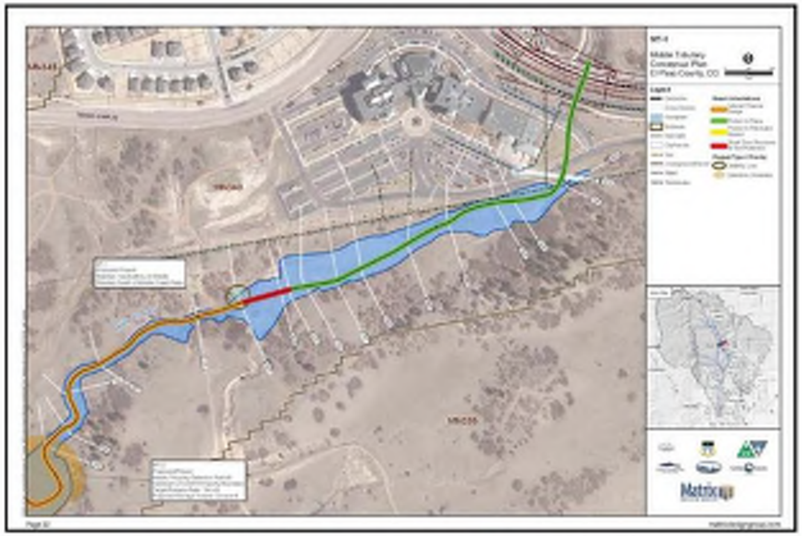
Example Cut Sheet

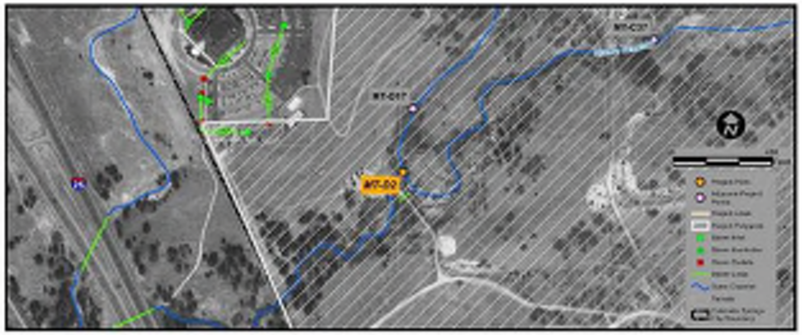
Middle Tributary

MT-D2 Detention

Priority:
Date Generated: 8/15/2018

Project Description:
Middle Tributary Detention Retrofit Upstream of USAFA Property Boundary





Cost Analysis:

MT-D2	UNIT	QUANTITY	UNIT COST	COST SUBTOTAL
Erosion control blanket	SY	10,285	8.00	$82,280
Grouted 2' Dia boulder rundown	SY	108	216.80	$23,414
Outlet structure trash rack, screen and railing	LS		0.00	$5,000
6' conc. trickle channel (6" thick, 6" deep)	LF	375	44.00	$16,500
Access road (12' wide, 8" class 6 gravel)	LF	700	9.00	$6,300
Outlet pipe, RCP	LF	50	91.00	$4,550
Outlet pipe protection - FES w/ riprap	EA	1	1,230.00	$1,230
Concrete crest wall, 12" thick	CY	59	892.56	$52,661
EmergenCY spillway (Type M riprap)	CY	990	75.97	$75,210
Excavation (haul)	CY	5,796	30.00	$173,870
Excavation/ embankment (onsite)	CY	901	14.01	$12,619
Forebay riprap (Type L) w/ bedding	CY	114	69.88	$7,966
Inlet/ forebay (8" conc. Bottom)	CY	448	299.87	$134,340
Outlet structure - 8" walls	CY	8	722.00	$5,776
Place topsoil	CY	4,571	12.00	$54,853
Stockpile topsoil	CY	4,571	10.00	$45,711
Mulching	AC	9	566.67	$5,100
Seeding, native	AC	9	585.56	$5,270
Contingency	%	20	7,150.00	$143,000
Design / Engineering	%	15	7,133.33	$107,000

Total: $962,650

Potential Partnership:

COLORADO SPRINGS
OLYMPIC CITY USA

Prioritization

- Planning
  - Drainage Basin Planning Studies
  - Existing Infrastructure Needs Assessment
- Condition
- Capacity

Planning Prioritization

Technical (60%)									Situational Awareness (40%)	Weighted Score
Drainage Basin	DBPS Published Date	Age of DBPS	Design Standard	Degree of Future Development	Existing Regional Detention	Future Regional Detention	Potential Natural Stream Preservation/ Restoration Opportunities	Closed Basin	City-Input (based on economic, social and political climate at the time of ranking)	
Score Range	-	0-3	0-4	0-3	0-3	0-3	0-1	0-1	0-5	0-100
Scaling Multiplier	-	5	5	12	1	1	10	6	5	
Black Canyon	2/1/1980	1	3	2	3	1	1	1		63
Black Squirrel Creek	1/1/1989	2	3	3	1	1	0	1		61
North Douglas Creek	3/1/1981	1	4	2	3	2	0	1		57
South Douglas Creek	3/1/1981	1	4	2	3	2	0	1		57
Mesa	3/1/1986	1	4	2	2	1	0	1		57
Sand Creek (including Upper Sand Creek)	3/1/1996	3	2	3	1	3	0	1		57
Camp Creek	10/1/1964	0	4	1	3	1	1	1		56
Westside	10/1/1975	0	4	1	2	1	1	1		55
Peterson Field (Sand Creek)	8/1/1984	1	4	1	3	1	1	1		55

Project Prioritization

DCM Principles

- Regional implications
- Infrastructure integration
- Land allocation
- Runoff mitigation
- Multi-purpose
- Natural systems
- Downstream impacts
- Maintenance
- Flood hazard
- Legal/permit obligations

Technical criteria

- Channels
- Detention
- Storm drains

Decision Matrix

Technical Criteria - Channels

Channel Technical Criteria	DCM Principle
Tier 1 Score (Infrastructure condition)	Downstream Impacts Maintenance Flood Hazard
Tier 2 Score (Corridor function)	Multi-Purpose Preservation
Bank Risk	Infrastructure Integration Downstream Impacts Maintenance
Bank Height	
Improvement type (if any)	
K-Factor score (susceptibility to erosion)	
303(d) impairments	Downstream Impacts Legal/Permit
Adjacent utilities, institutions, and facilities	Infrastructure Integration

Technical Criteria - Detention

Detention Technical Criteria	DCM Principles
Location in watershed	Runoff Mitigation Downstream Impacts Flood Hazard
Closed basins & Parcel ownership	Land Allocation
Proposed detention pond volume	Runoff Mitigation Downstream Impacts Flood Hazard
Underlying Hydrologic Soil Group	Preservation Natural Systems
Maximizing BMP treatment area within the City	Preservation Multi-Purpose Downstream Impacts

Provide protection for people as permanent and recreational users?		Protect or improve habitat, water quality, and geomorphology?			Contribute to achieving MS4 requirements?	
Infrastructure Integration, Flood Mitigation, Flood Hazard, Downstream Impacts, Multi-Purpose		**Preservation**			**Downstream Impacts, Legal/Permit**	
Permanent user protection? Applicable justifications: Neighborhood access Heavily traveled road Other (specify)	Recreational user protection? Applicable justifications: Trail users Golf course users Other (specify)	Protects or improves water quality? Applicable justifications: Treats WQCV Stabilizes highly erodible banks/channels Natural channel preservation/ design Other (specify)	Protects or improves habitat? Applicable justifications: Reconnects channel and floodplain Re-vegetation of stream corridor Other (specify)	Protects or improves geomorphology? Applicable justifications: Preserves/ reclaims stream corridor Crossings promote floodplain connectivity Other (specify)	Meets MS4 requirements and brings existing system up to compliance?	Meets MS4 requirements and the existing system is already in compliance?

Decision Matrix

Create infrastructure investments that are high value and reasonable to construct?	Improve downstream conditions?	Serve a large population?
Infrastructure Integration, Land Allocation, Maintenance	**Downstream Impacts, Flood Hazard**	**Regional Implications**
Applicable justifications: Low maintenance needs Low cost, high return Moderate to high cost, but foundational Closed basin Land acquisition Other (specify)	Applicable justifications: Improves downstream channel Reduces downstream flooding Other (specify)	Applicable justifications: Project benefits at community-level Other (specify)

Technical Score

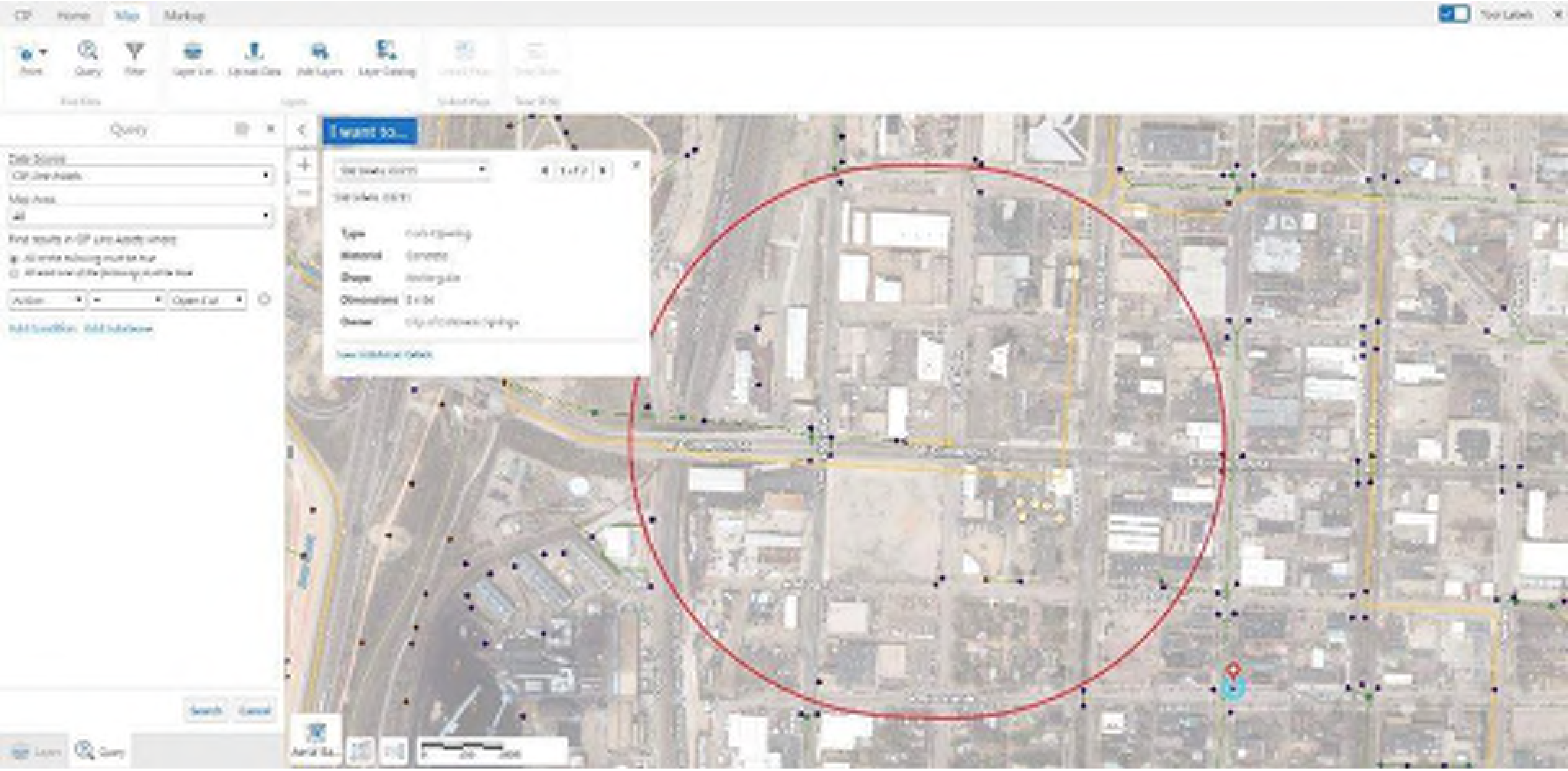
+

Decision Score

=

Priority Rank

Web Application



Takeaways

- Evolution is painful
- Deferred maintenance is not the sum of its parts
- Leverage existing data
- Listen to users
- Communicate

Special Thanks

City Project Manager – Tim Biolchini
Engineering Stormwater Division Manager – Richard Mulledy
Stormwater Capital Programs Manager – Brian Kelley

Matrix DESIGN GROUP

Questions

COLORADO SPRINGS OLYMPIC CITY USA

Strategic Planning for Green Infrastructure in Boulder

Candice Owen, P.E.

September 27, 2018


VOLS
WORK IN PROGRESS

Overview

- Background
- Project Components
  - Stakeholder Group
  - Process and Policy
  - Prioritization and Pilots
- Next Steps

Shifting Paradigms..
The GI Way of Thinking

Gray infrastructure:
- Use **basins, pipes** & **ditches** to **remove** pollutants from **stormwater** where it collects

Green infrastructure:
- Use **soil** and **vegetation** to manage **rainwater** close to where it falls

Source: Tompkins County NY (Bioswale)

Shifting Paradigms..
The GI Way of Thinking

Soil & **Vegetation** are now Infrastructure

At the pre-design stage:
LID Opportunities

During design & construction:
BMP Design Elements

After construction:
BMP Maintenance Elements

Background: Stormwater in Boulder

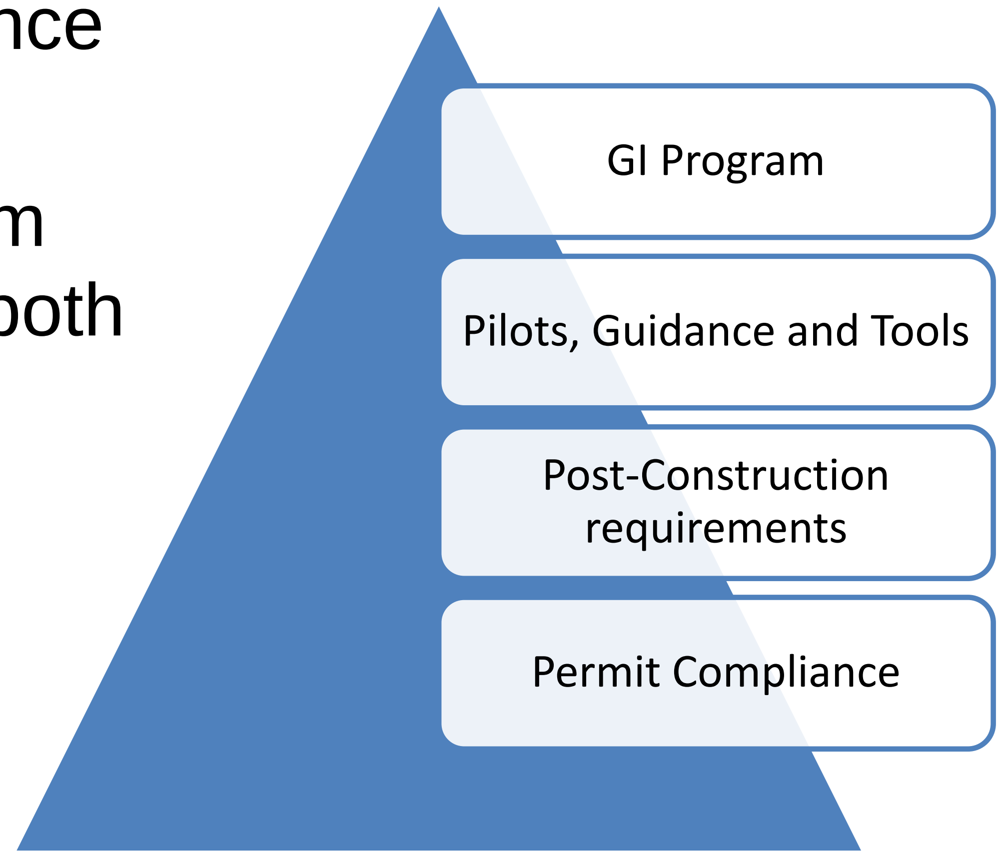
- Boulder is mostly infill on marginally draining urban soils
- Many sites are dense and space is very valuable
- Approval process for changing criteria is challenging
- New MS4 permit requirements posed challenges

How do we do this in Boulder?

- What are we required to do?
  - *MS4 permit requirements*
- What can we do?
  - *Understand ability to infiltrate*
- What should we do?
  - *Set by stakeholder group*

Project Goals

- MS4 Permit Compliance
- Build a Green Infrastructure Program that promotes GI on both Private and Public Projects



Project Design

Internal Stakeholder Process

Support decisions made through out the project and provide critical feedback through 5 meetings

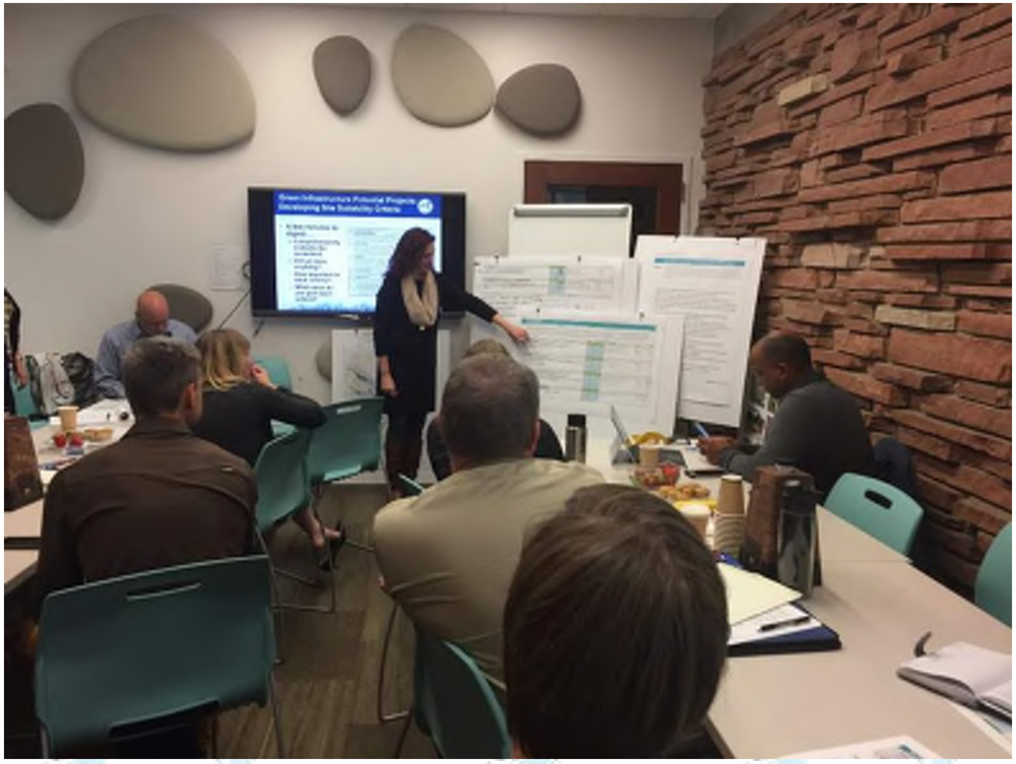
GI Process & Policy

MS4 Permit Compliance and inclusion of GI in city development requirements

Prioritization & Pilots

5 conceptual designs for GI projects and tools to repeat prioritization and GI installation types

STAKEHOLDER GROUP PROCESS



5 Stakeholder Meetings

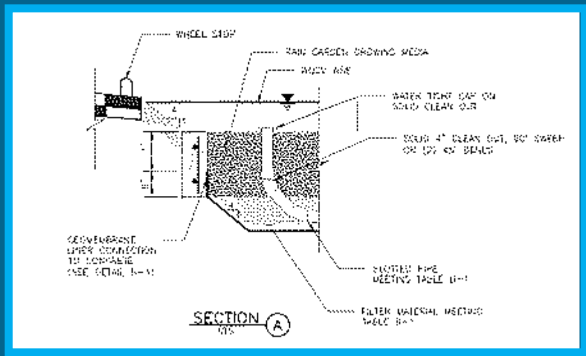
VISION

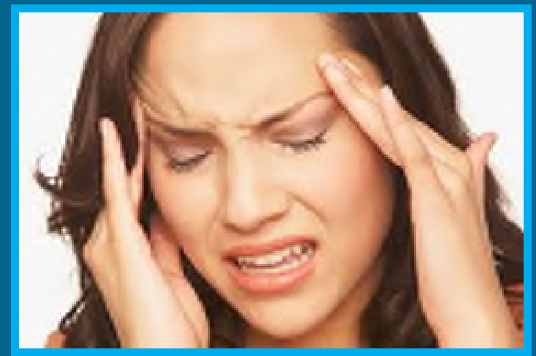
What do YOU envision for the final outcome of this project?

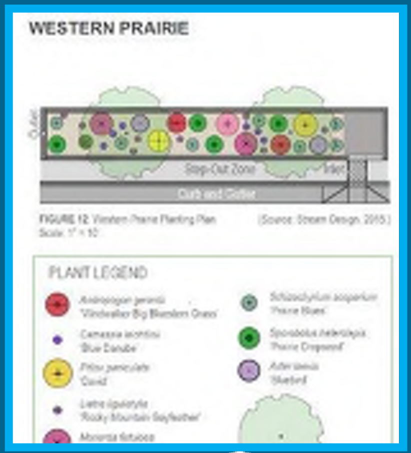
CRITICAL SUCCESS FACTORS

What must this project and process accomplish in order for you to think it has been successful?

Making policy & process changes


SECTION A



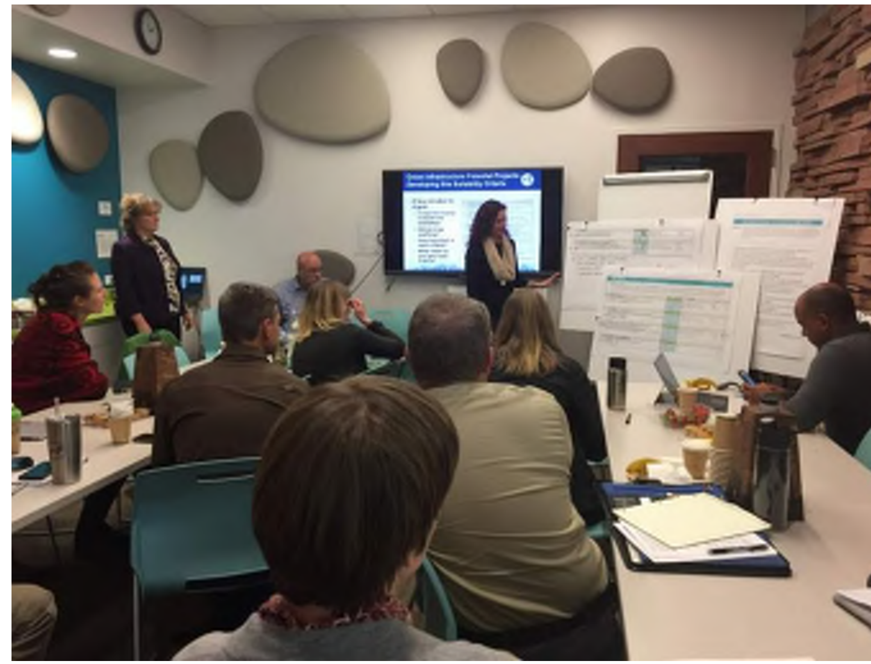

WESTERN PRAIRIE
Step-Out Zone
Curb and Gutter
PLANT LEGEND

Resulting Policies

- Prioritization factors for pilot projects

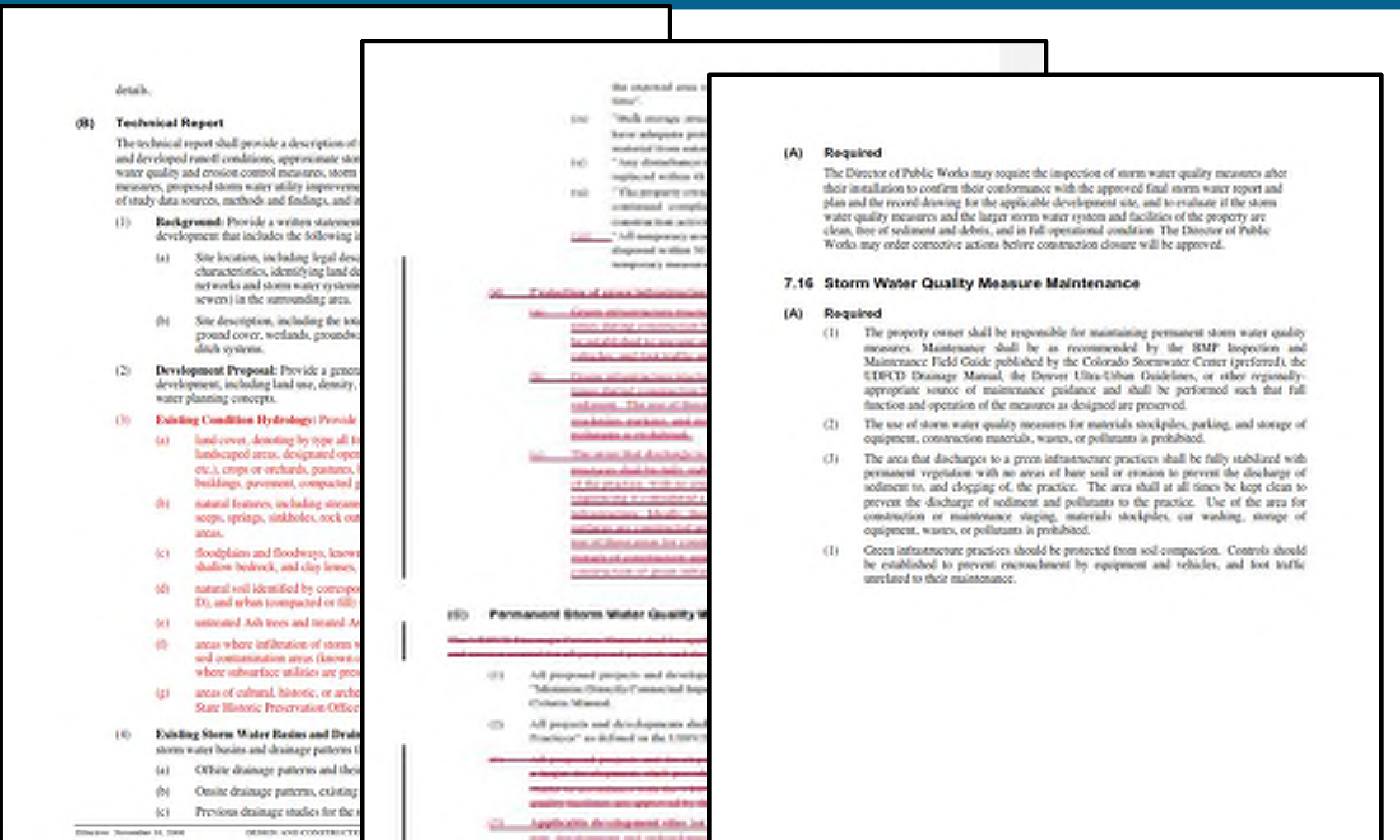
- MEP of LID for <1 acre development

- Do as much GI as practicable on city projects



POLICY AND PROCESS

Code and Design Standards Revisions



(A) **Required**

The Director of Public Works may require the inspection of storm water quality measures after their installation to confirm their conformance with the approved final storm water report and plan and the record drawing for the applicable development site, and to evaluate if the storm water quality measures and the larger storm water system and facilities of the property are clean, free of sediment and debris, and in full operational condition. The Director of Public Works may order corrective actions before construction closure will be approved.

7.16 Storm Water Quality Measure Maintenance

(A) **Required**

(1) The property owner shall be responsible for maintaining permanent storm water quality measures. Maintenance shall be as recommended by the BMP Inspection and Maintenance Field Guide published by the Colorado Stormwater Center (preferred), the UDFCD Drainage Manual, the Denver Ultra-Urban Guidelines, or other regionally-appropriate source of maintenance guidance and shall be performed such that full function and operation of the measures as designed are preserved.

(2) The use of storm water quality measures for materials stockpiles, parking, and storage of equipment, construction materials, wastes, or pollutants is prohibited.

(3) The area that discharges to a green infrastructure practices shall be fully stabilized with permanent vegetation with no areas of bare soil or erosion to prevent the discharge of sediment to, and clogging of, the practice. The area shall at all times be kept clean to prevent the discharge of sediment and pollutants to the practice. Use of the area for construction or maintenance staging, materials stockpiles, car washing, storage of equipment, wastes, or pollutants is prohibited.

(4) Green infrastructure practices should be protected from soil compaction. Controls should be established to prevent encroachment by equipment and vehicles, and foot traffic unrelated to their maintenance.

Code and Design Standards Revisions

Policy & Process Questions

- What does MS4 compliance and GI look like in Boulder?
- What happens <1 acre?
- How can we best integrate with capital projects throughout the city to install GI?
- How do we create better, clearer policy and back that up with assisting documents and guidance?

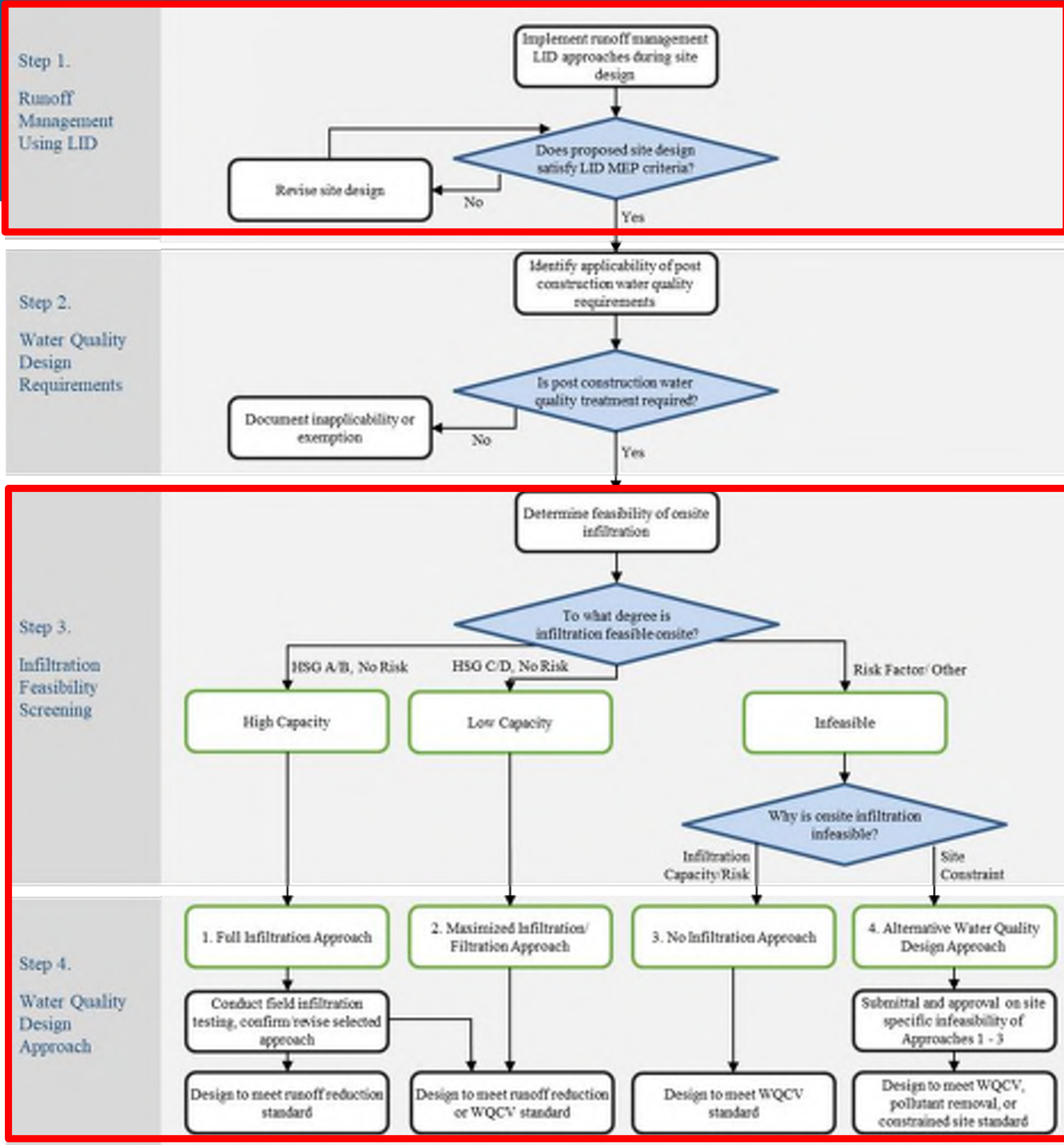
MS4 Post-Construction Requirements

Runoff Reduction

Water Quality Capture Volume

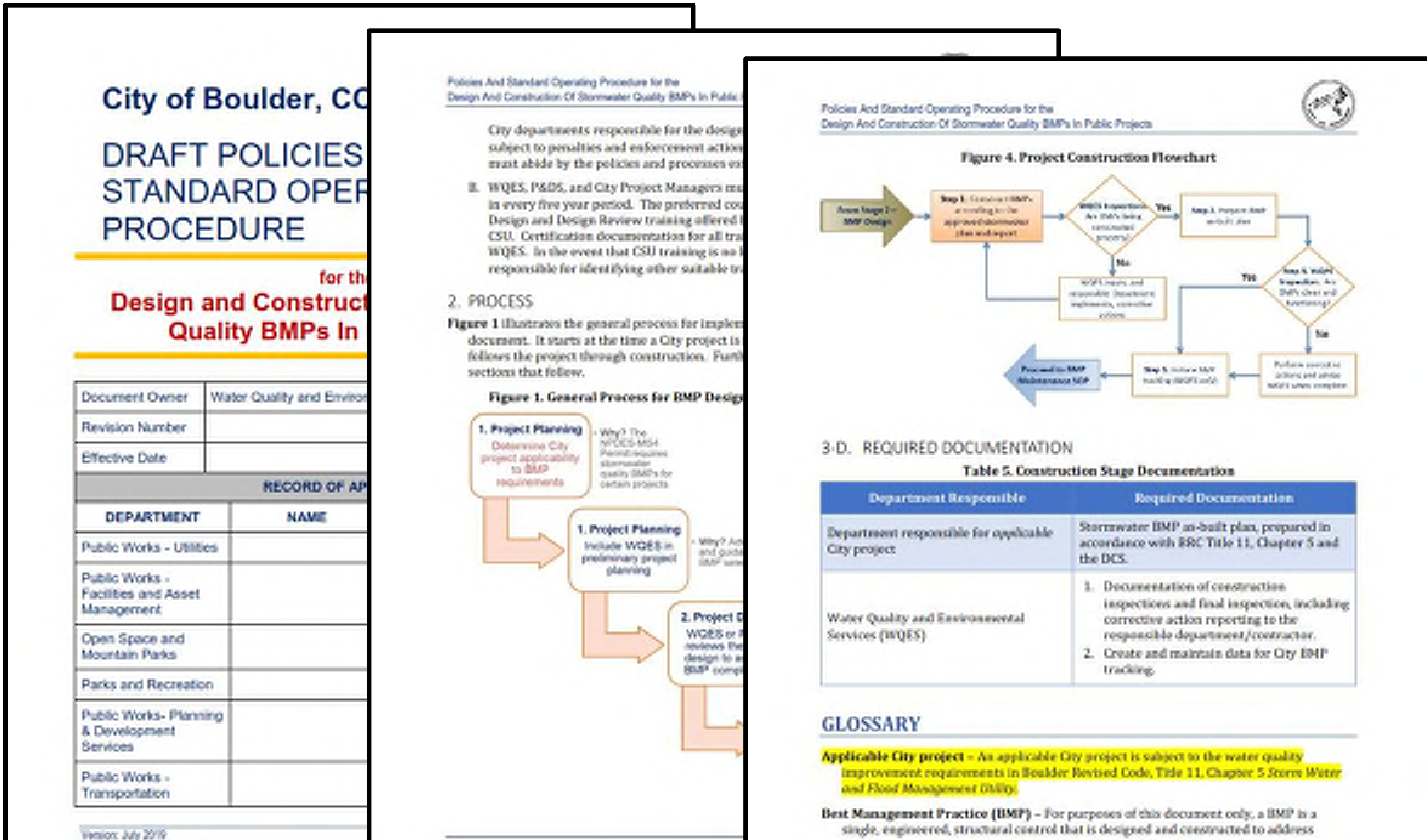
MS4 Post-Construction Requirements

Pollutant Removal



Step 1.
Runoff Management Using LID
Implement runoff management LID approaches during site design
Does proposed site design satisfy LID MEP criteria?
Revise site design
No
Yes
Step 2.
Water Quality Design Requirements
Identify applicability of post construction water quality requirements
Is post construction water quality treatment required?
Document inapplicability or exemption
No
Yes
Step 3.
Infiltration Feasibility Screening
Determine feasibility of onsite infiltration
To what degree is infiltration feasible onsite?
HSG A/B, No Risk
HSG C/D, No Risk
Risk Factor/ Other
High Capacity
Low Capacity
Infeasible
Why is onsite infiltration infeasible?
Infiltration Capacity/Risk
Site Constraint
Step 4.
Water Quality Design Approach
1. Full Infiltration Approach
2. Maximized Infiltration/ Filtration Approach
3. No Infiltration Approach
4. Alternative Water Quality Design Approach
Conduct field infiltration testing, confirm/revise selected approach
Submittal and approval on site specific infeasibility of Approaches 1 - 3
Design to meet runoff reduction standard
Design to meet runoff reduction or WQCV standard
Design to meet WQCV standard
Design to meet WQCV, pollutant removal, or constrained site standard

MOUs for Permit Compliance



Supporting Documents

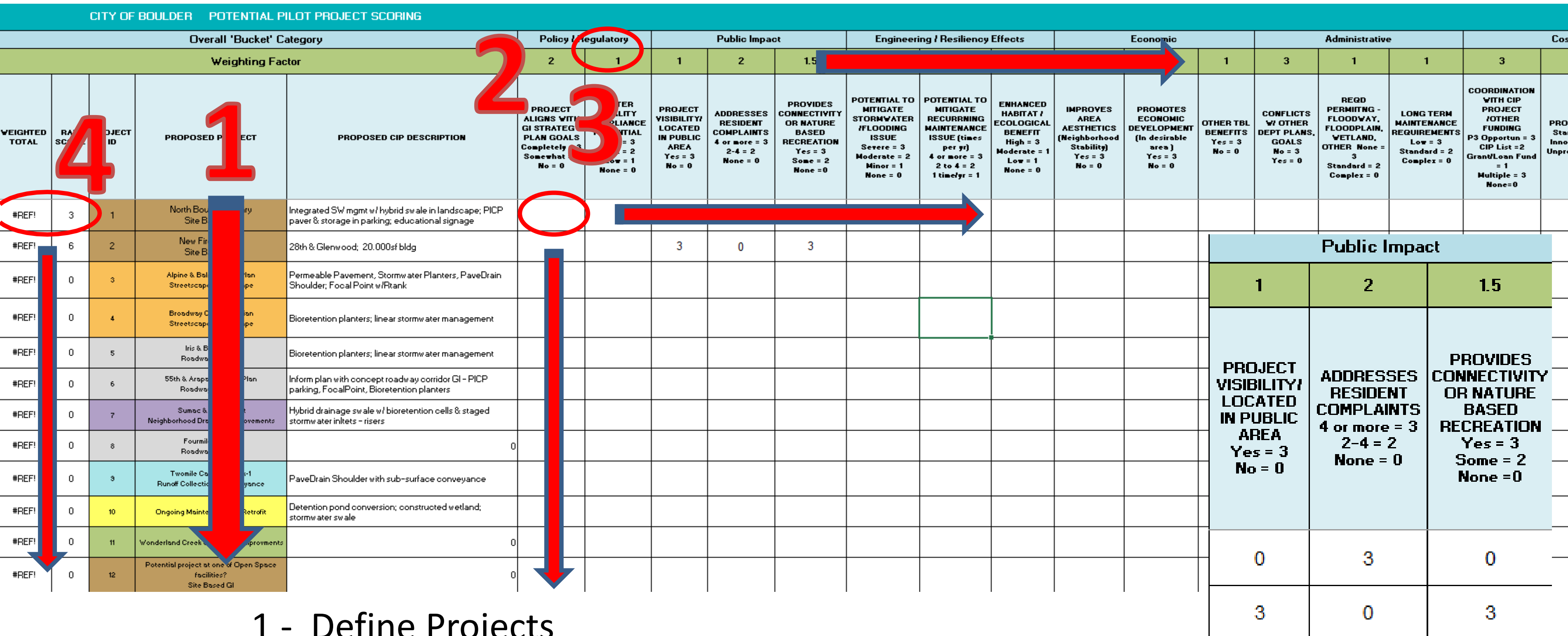
- Compliance "Packet"
  - Checklists
- Example GI projects
- MEP LID Guidance

PILOT PROJECTS

Project Components

- Unique GI
  - Based on GIS analysis and prioritization
- CIP project opportunities
- Planning for future use of capital funds

GI Potential Capital Projects- Compiling the List



1 - Define Projects

2- Assign weighting factor importance to site suitability categories

3- Assign numerical ranking to detailed evaluation criteria for each project

4- Review project raw score and weighted total for project prioritization

5- Sort the list by the weighted total to list in order of prioritization

Green Infrastructure Potential Projects-Evaluation

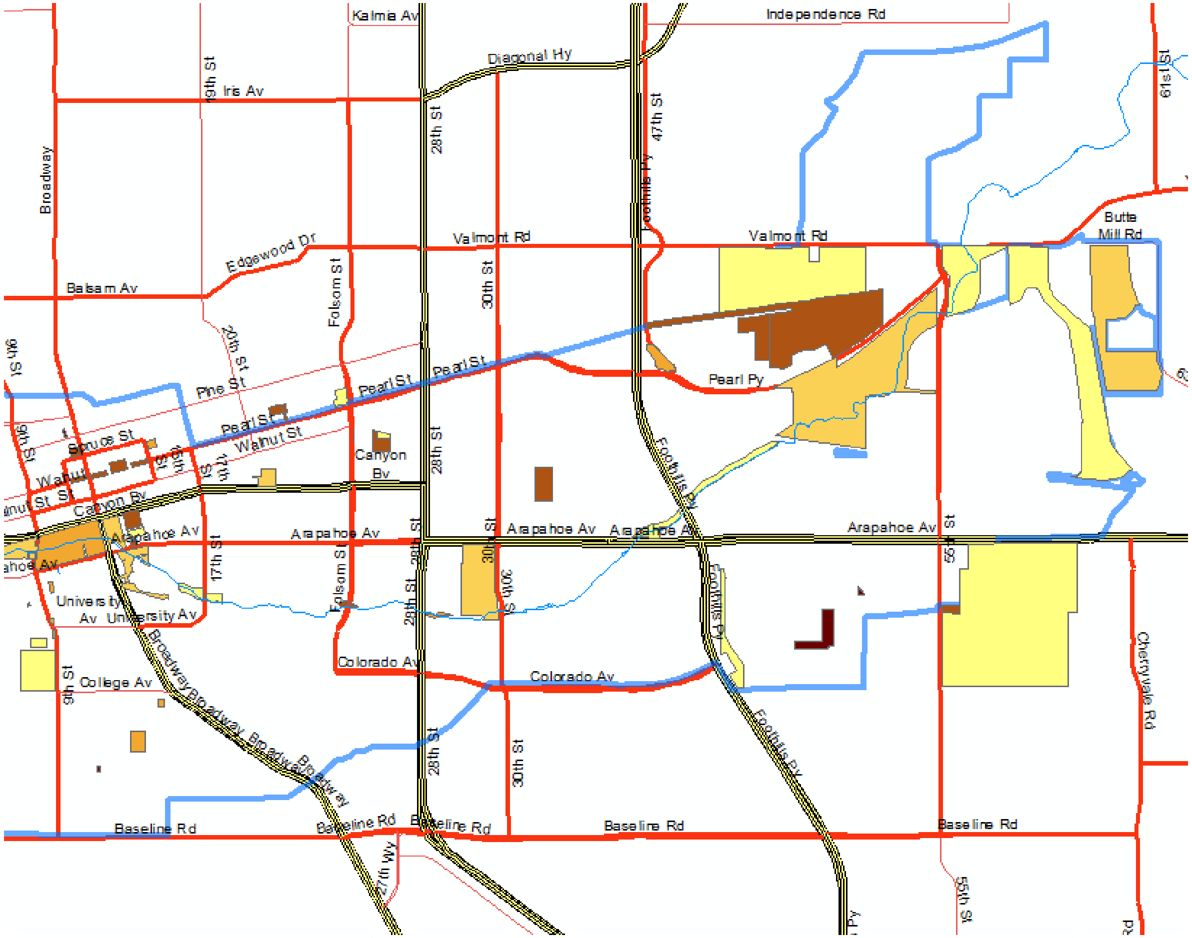
TABLE X Boulder - PRIORITY RANKING

OVERALL PRIORITY RANKING	WEIGHTED TOTAL	PROJECT ID	PROPOSED PROJECT	PROPOSED CIP DESCRIPTION	CIP PROJECT COST	GI - STORMWATER EST COST
1	74.5	7	Sumac & 19th Street (Wonderland Creek 2) Neighborhood Drainage Improvements	PaveDrain & Hybrid drainage swale w/ bioretention cells & staged stormwater inltets - risers	$748,200	
2	74	11	Valmont City Park Development	Integrated SW mgmt w/ hybrid swale in landscape; bioretention; PICP paver & storage in parking; educational signage	$5,000,000	
3	65.5	18	CU South Planned Open Space	Passive GI and regional storage	TBD	
4	62	9	Twomile Canyon Creek-1 Runoff Collection & Conveyance	Kalmia & Jupiter improvements PaveDrain Shoulder & Bioswale with sub-surface conveyance and capacity improvements to creek/road crossing	$1,000,000	
5	60.5	1	North Boulder Library Site Based GI	Integrated SW mgmt w/ hybrid swale in landscape; PICP paver & storage in parking; educational signage	$5,000,000	
6	60.5	2	New Fire Station Site Based GI	Integrated SW mgmt w/ hybrid swale in landscape; PICP paver & storage in parking; educational signage	$12,500,000	
7	59	3	Alpine & Balsam Area Plan Streetscape / Landscape	Permeable Pavement, Stormwater Planters, PaveDrain Shoulder; Focal Point w/Rtank	$1,000,000	
8	58	13	30th & Colorado Bike/Ped Underpass	Inform plan with concept roadway corridor GI - PICP parking, FocalPoint, Bioretention planters	$5,900,000	
9	56	16	Elmer's Twomile Creek-2 - New and Replacement Storm Sewer	Integrated stormwater management mix of GI bioretention swale, infiltration trenches w/storm collection system	$3,874,000	

Project Categories

- Runoff Collection & Conveyance GI
- LID/Greenspace/ Passive Recreation GI
- Site Based GI Practices
- Streetscape /Urban Landscape GI
- Neighborhood Drainage/Flooding Improvements
- Ongoing Maintenance GI Retrofit
- Roadway Corridor GI Practices

Unique GI Projects



NEXT STEPS

Next Steps

- Two more Stakeholder Meetings
- Finalize Pilot Projects – Format
- Path forward with funding for GI projects
- Incorporate Code and policy changes
- Finalize compliance tools

Candice Owen
owenc@bouldercolorado.gov

5 Stakeholder Meetings

- What is our vision for this program?
- What level of stormwater management is enough?
- How do we incorporate these concepts in city projects and on private development?

CASFM 2018 Annual Conference

Professional Development Sessions:

Session1: The Truth About Motivation & Team Building

Emily C. Villines (Calibre Engineering, Inc.)

Session2: Wonderland Creek Construction Lessons Learned

Kurt Bauer & Robby Glenn (City of Boulder, Public Works)

The Truth About Motivation & Team Building

Emily C. Villines, MA, CPSM
Calibre Engineering, Inc.
evillines@calibre-engineering.com

13-30% of staff actively engaged

Strong corporate culture = 500% more revenue growth than an average company

Strong corporate culture = 765%+ net income over 10 years

High Functioning Group Dynamics: People have to feel safe in and connected to the group

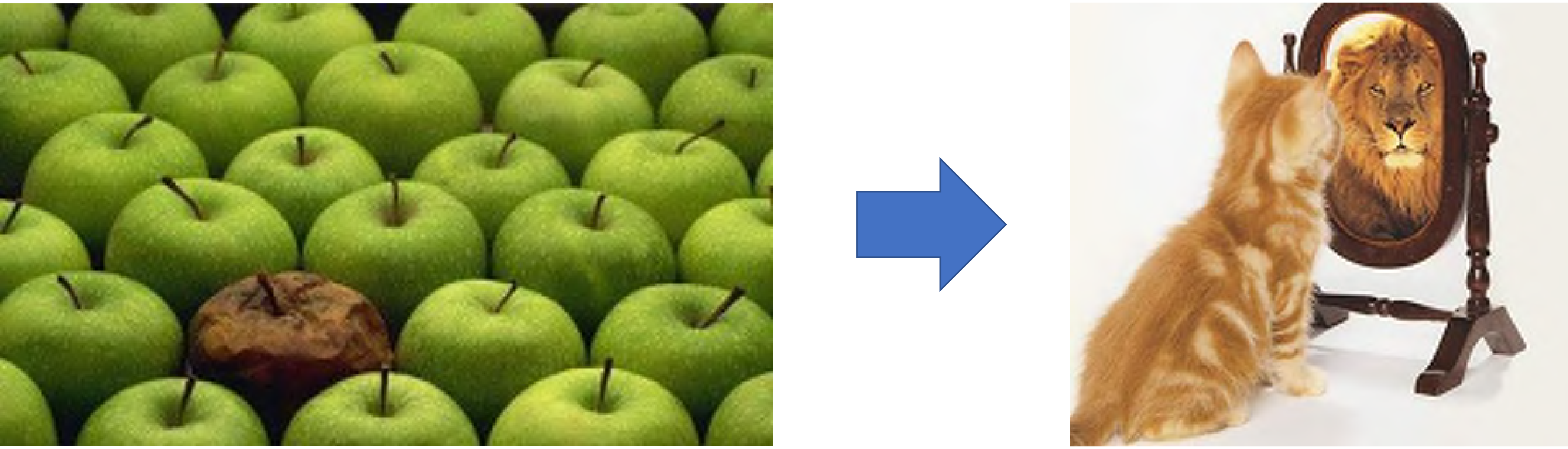
- Purposefully invest in exchanges
- Acknowledge individual value
- Actively practice an open forum of communication
- Leadership puts the team's interest ahead of everything (and everyone) else

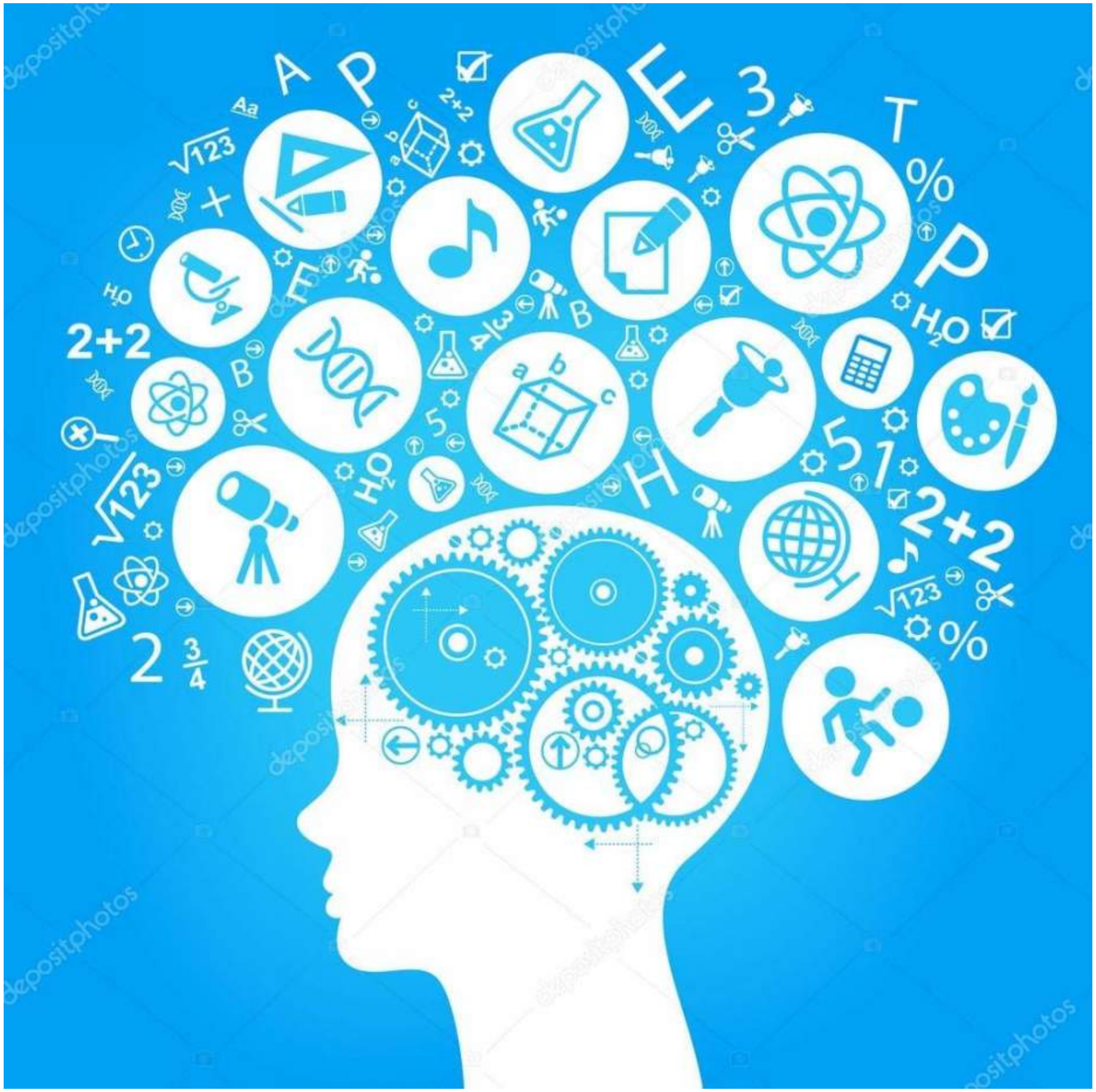
High Functioning Group Dynamics: People have to trust each other

- Trust comes from vulnerability
  - Leaders have to be vulnerable first
  - Use vulnerable language
- Eliminate hierarchy
  - Do the hard stuff together
  - Fight authority bias
  - Discuss issues without leaders
- Encourage a spirit of curiosity
  - Support open communication
  - Give staff a platform
  - Ask without intent to answer
  - Explore together without trying to win

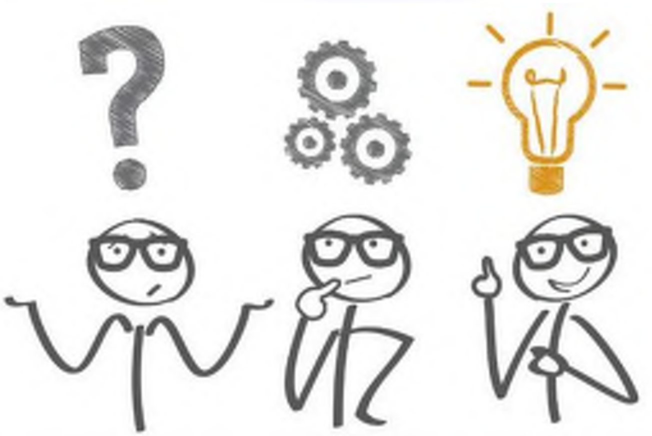
High Functioning Group Dynamics: People have to be driven by a common, clarified purpose

- Develop purpose together
- Create beacons, language, priorities, and catch phrases
- Assign advocates
- Link to present and future




A P
E 3
T
%
P
2+2
H2O
√123
2 3/4
depositphotos

What motivates us?
The fun of mastering a challenge.



We need...

- Creativity at work
- Opportunities for quality and continual improvement
- Genuine achievement
- Opportunity to increase competence
- New and engaging intellectual challenges

Work needs to...

- Create situations for progression
- Offer opportunities for learning and improvement
- Encourage experimentation
- Encourage time devoted to enjoyable work

What motivates us?
Having control

We need a work environment in which…

- Goals are clear
- Feedback is immediate
- We are able to focus on output (our work) instead of input (our hours)
- We are able to create new domains for ourselves and processes for our work
- We are given the freedom to make decisions and manage our work

What motivates us?
Working for a bigger purpose

- Establish a purpose
- Give to charity or non-profit causes related to work
- Take time to do non-commissioned work related to what you love

Resources

- Coyle, Daniel. The Culture Code: The Secrets of Highly Successful Groups.
- McGregor, Lindsay & Doshi, Neel. How to Motivate Frontline Employees.
- Pink, Daniel. The Surprising Truth About What Motivates Us.
- Sackstein, Starr. Educators' Powerful Role in Motivation and Engagement.
- Subat, Alex. Tips on Enhancing and Tracking Employee Motivation.
- Thompson, Sonia. 3 Science Backed Ways to Improve Your Performance.
- Zvada, Emmanuel. Management Blunders that Kill Employee Morale and Motivation.

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WONDERLAND CREEK CONSTRUCTION LESSONS LEARNED

2018 CASFM – SNOMASS, CO

Kurt Bauer & Robby Glenn

City of Boulder

Public Works

WONDERLAND CREEK PROJECT

- Nine years in the making
- 100-year channel improvements
- 450 dwelling units no longer in 100-year floodplain
- Missing Multi-use path link

2013 Flood Event

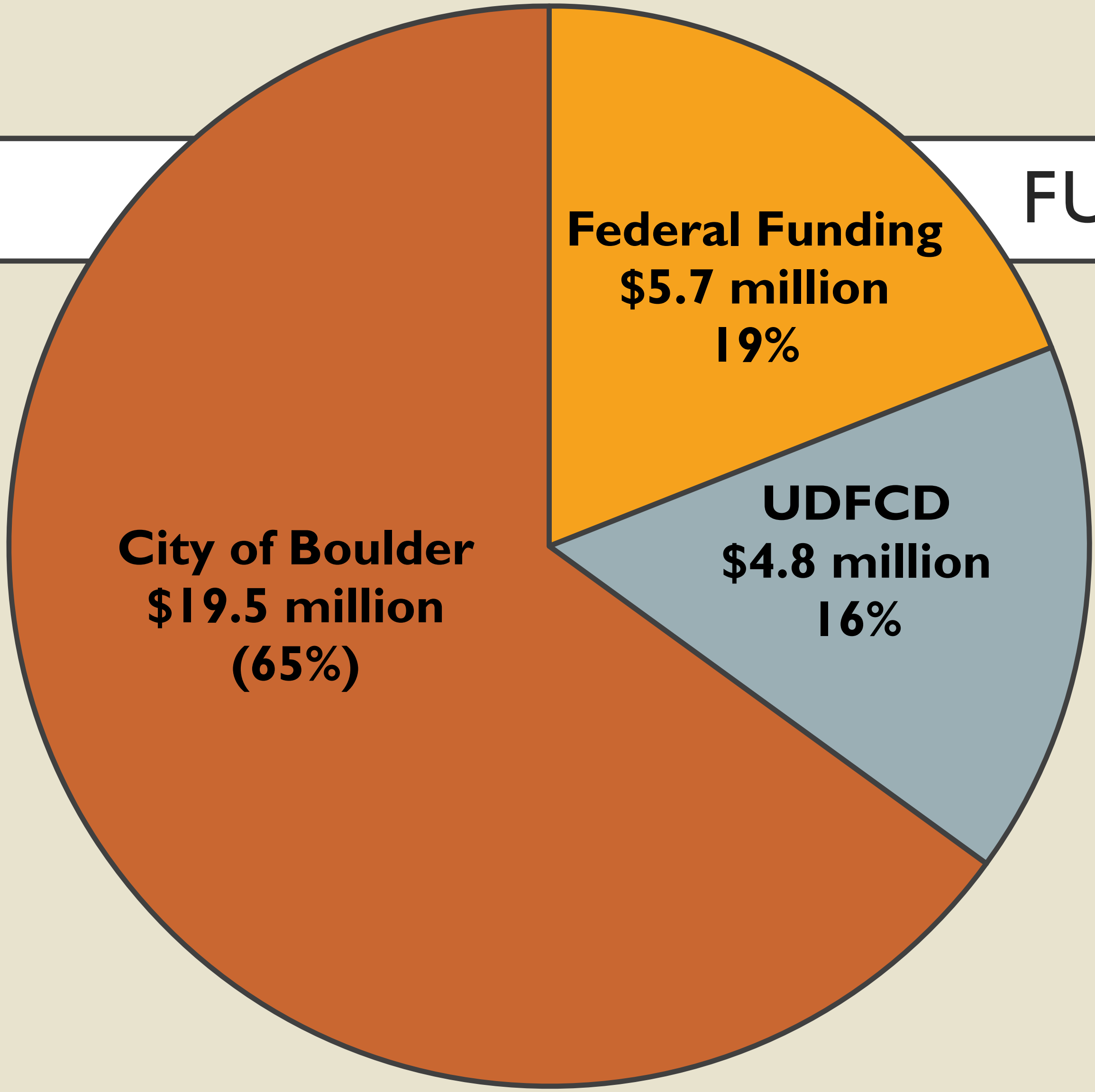
Project Complexity

- BNSF Railroad
- Boulder White Rock Ditch
- Fully urbanized area
- Numerous utilities

FINANCES

- $20.3 million original bid
- $22 million final construction cost
- $8 million design + Construction Services
- **$30 million total project cost**

FUNDING SOURCES



Percentage of project using outside funds
35%

CONSTRUCTION TIMELINE

- January 2016 construction begins
- Original Contract length 2 years
- Substantially complete June 23rd 2018 (6-month delay)
- Final Acceptance deadline October 31st, 2018

KEY LESSONS LEARNED

1. Consider consequences of grant administration
2. Utilize contractor and internal staff in design
3. Establish city-private utilities relationship

HOW MANY FULL-TIME ONSITE INSPECTORS?

(a) One

(b) Two

(c) Three

(d) Four

FEDERAL FUNDING

1. The consequences of federal funding

CDOT FORMS

- *Form 205 – Sublet Application*
- *Form 266 – Inspectors Progress Report*
- *Form 832 –* Trainee Status and Evaluation Report
- *Form 838 – On the Job Trainee/Apprentice Record*
- Form 1391 – *Contractors Annual EEO Report*
- *Form 1415 – Anticipated DBE Participation Plan*
- *Form 1418 – Monthly payment summary*
- *Form 1419 – DBE Participation Report*
- ***Form 90 – Contract Modification Order (CMO) – 48 change orders on project***

MINOR CONTRACT REVISIONS

- Incorporate MCR's into bid tab.
  - 5-10% of project cost
  - Accounts for small changes
  - Can be combined into one CMO
  - Approx. 50% of our CMO could have been MCR's

CONSTRUCTION MANAGEMENT

CDOT FUNDING:

- Design engineer cannot be primary construction manager
- Project Delivery Method selection
  - Design/bid/build
  - Construction Manager/General Contractor
  - Design/Build

HUD VS. CDOT

- Davis Bacon FHWA and HUD forms are different
  - Verify prevailing wages
- Every payroll can be audited
- Underestimated administrative time

HUD & CDOT

- Expect full-time employee to administer paperwork

- ~10% of funds will likely go to administration of grant (just city)

2. CONTRACTOR AND INTERNAL REVIEW IN DESIGN

HOW MANY HOURS OF TRAFFIC CONTROL FLAGGING ARE REQUIRED FOR A PROJECT OF THIS SCALE?

(a) 5,000

(b) 10,000

(c) 20,000

(d) 30,000 Total Cost = $580,000

CONSTRUCTABILITY REVIEW

Consider CM/GC option or 3rd party contractor review

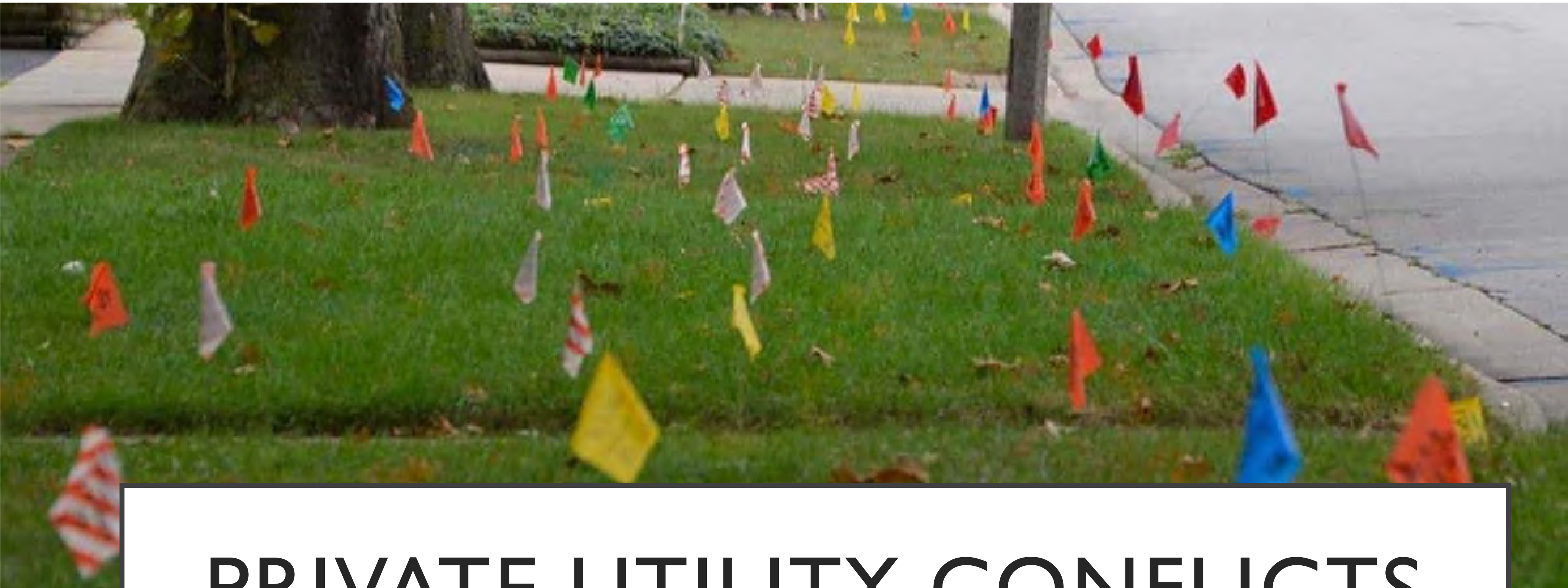
- Constructability
- Phasing

CONSTRUCTABILITY REVIEW

Consider CM/GC option or 3rd party contractor review

- Ensure Specs address complex phasing

- Consider liquidated damages



PRIVATE UTILITY CONFLICTS

3. Establish and maintain city-private utilities relationship

COORDINATION

- Include private utilities in design
- Relocation design: 4 to 6 months
- Pothole (Include in bid documents)
- Meet as frequently as needed

CONSTRUCTION

- Designated utility coordinator
- Utility relocates are contractor's responsibility
- Be involved with observation
- Be ready for unknown utilities

PROJECT COMMUNICATIONS

- Build rapport with community during design
- Identify businesses w/critical needs
- Inform public of progress & milestones
- Over deliver under promise

KEY LESSONS LEARNED

1. Consider consequences of grant administration
2. Utilize contractor and internal staff in design
3. Establish city-private utilities relationship


QUESTIONS?

BACKUP SLIDES

CONSTRUCTION STAFF AND ROLES

Are all aspects of the project covered?

INSPECTORS

Construction Manager

Assistant Construction Manager

Missing Areas

- Inadequate field staffing
- Experience with stream work
- Water Utility (pipe) inspection
- Clarity on decision making authority

EXECUTION PLAN

- Project Execution Plan (PEP)
  - Role responsibilities
  - Resource allocation
  - Organization chart

POTHOLING

- Pothole during design
- Verify tie-ins, material, elevations, and diameters
- Don't assume as-builts are correct
- Bill SB 18-167

APPROXIMATE PERCENTAGE OF TIME SPENT BY CONSTRUCTION MANAGER ON CDOT PAPERWORK?

(a) Twenty

(b) Forty

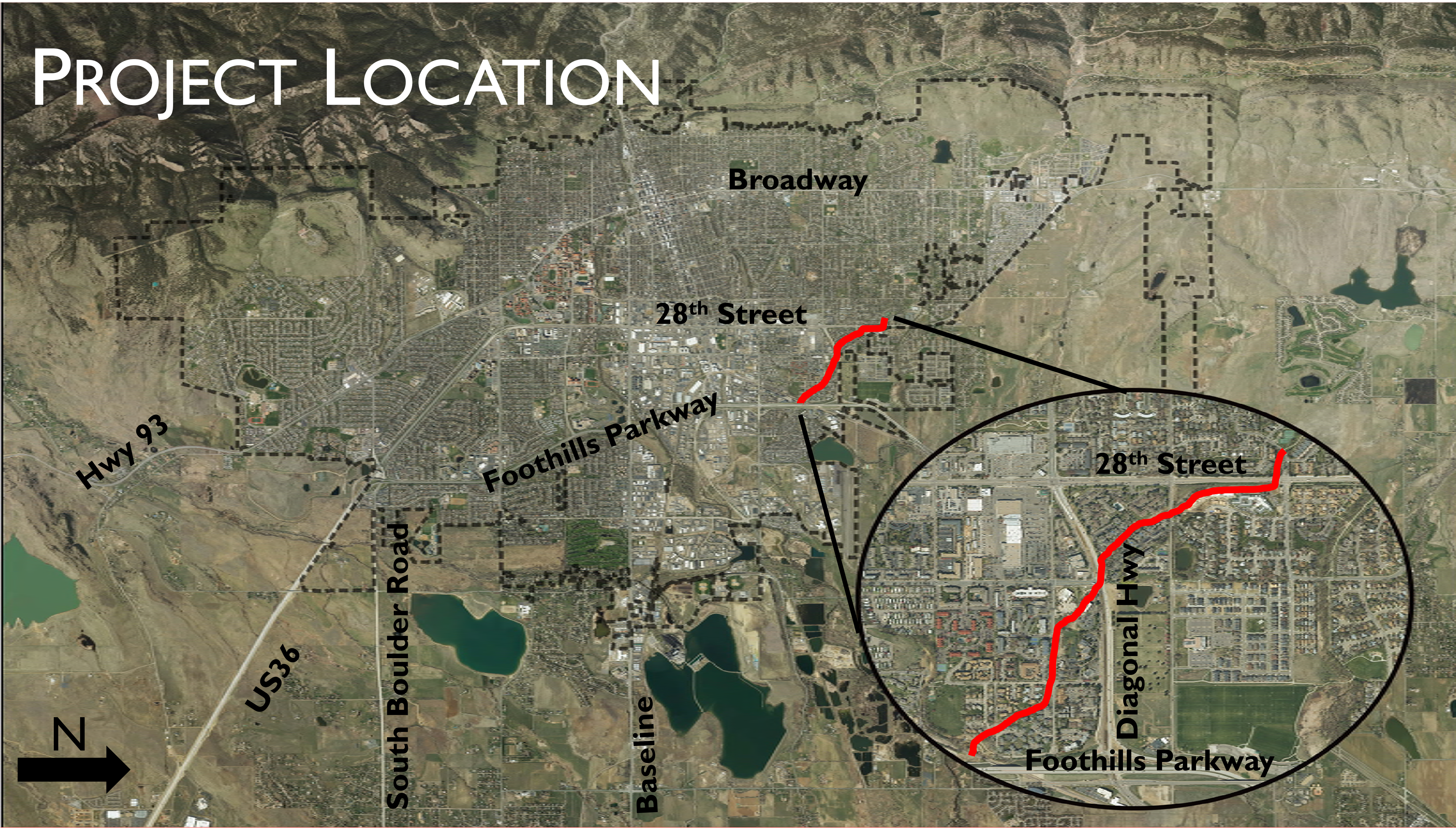
(c) Sixty

(d) Eighty

CONCLUSIONS

- Ensure all aspects of project are covered by CM team
- Verify requirements for federal funding and associated implications
- Perform a constructability review
- Coordinate as early and as often as you can with Private Utilities
- Have a construction team that can flex with whatever may happen

Project Location



CASFM 2018 Annual Conference

Stream Restoration Sessions:

Session1: When Engineers Go Wild!

Richard Borchardt & Barb Chongtoua (UDFCD)

Session2: Urban Stream Design – How We Got to Now

Mary Powell (Corvus Environmental), Dave Skuodas (UDFCD)

Action & Reaction: Approaches for Understanding Sedimentation & Erosion

Matthew Johnson & Brinton Swift (HDR)

The Gunnison River and Riparian Habitat Rehabilitation Project Local Partnerships at Work

Dan Brauch & Steve Westbay (City of Gunnison)

Drone Based Riprap Imaging and Gradation Measurement

LeAndra Nelson (Kiewit Engineering Group)

When Engineers Go Wild!

CASFM Annual Seminar

September 27, 2018

Richard Borchardt, The Flood Control District, Project Manager

Barb Chongtoua, The Flood Control District, Project Manager

Wild about Cherry Creek

Wild about Cherry Creek

?

Wild about Cherry Creek

Wild about Streams

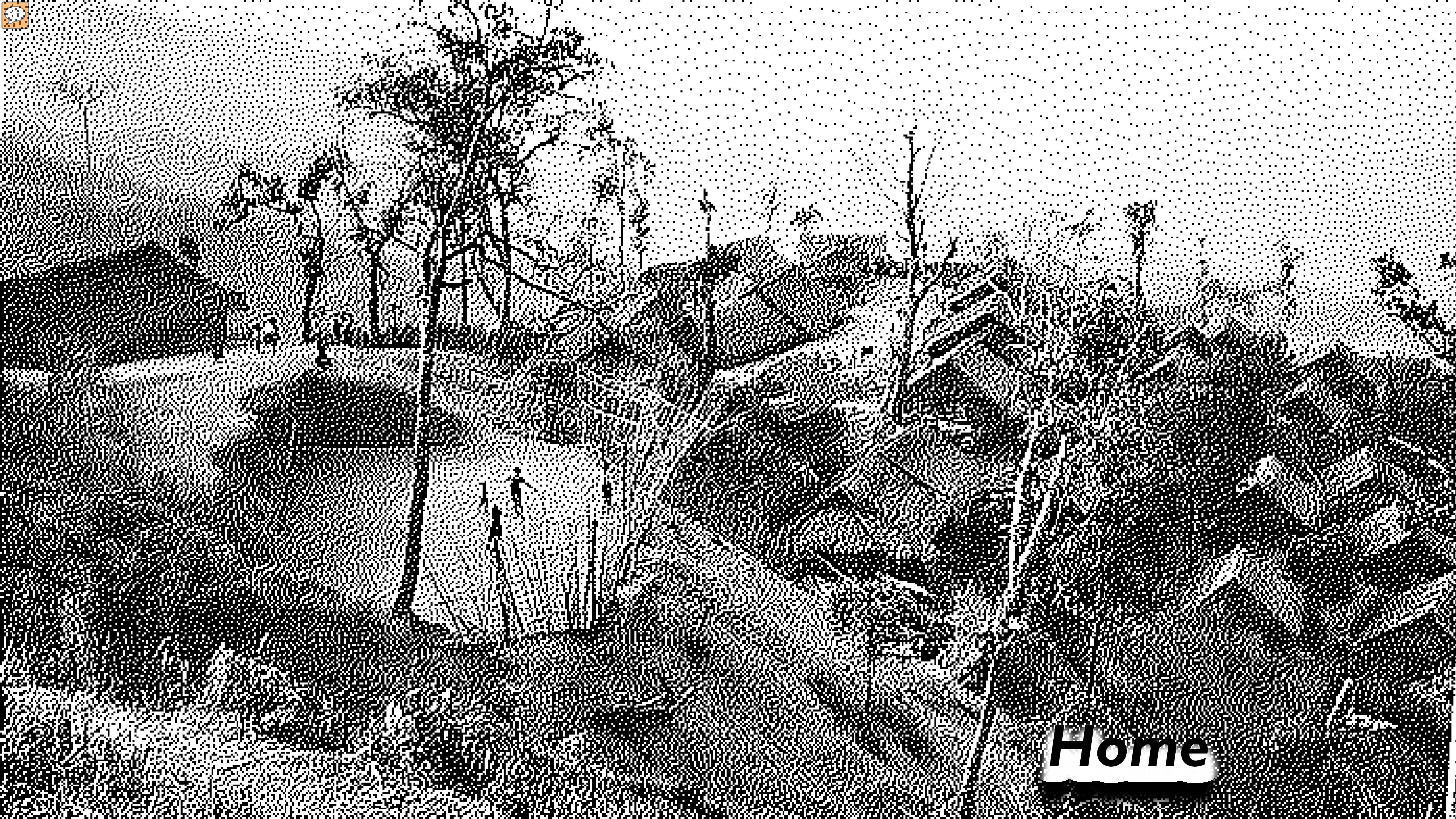
?

Have you ever wondered…….

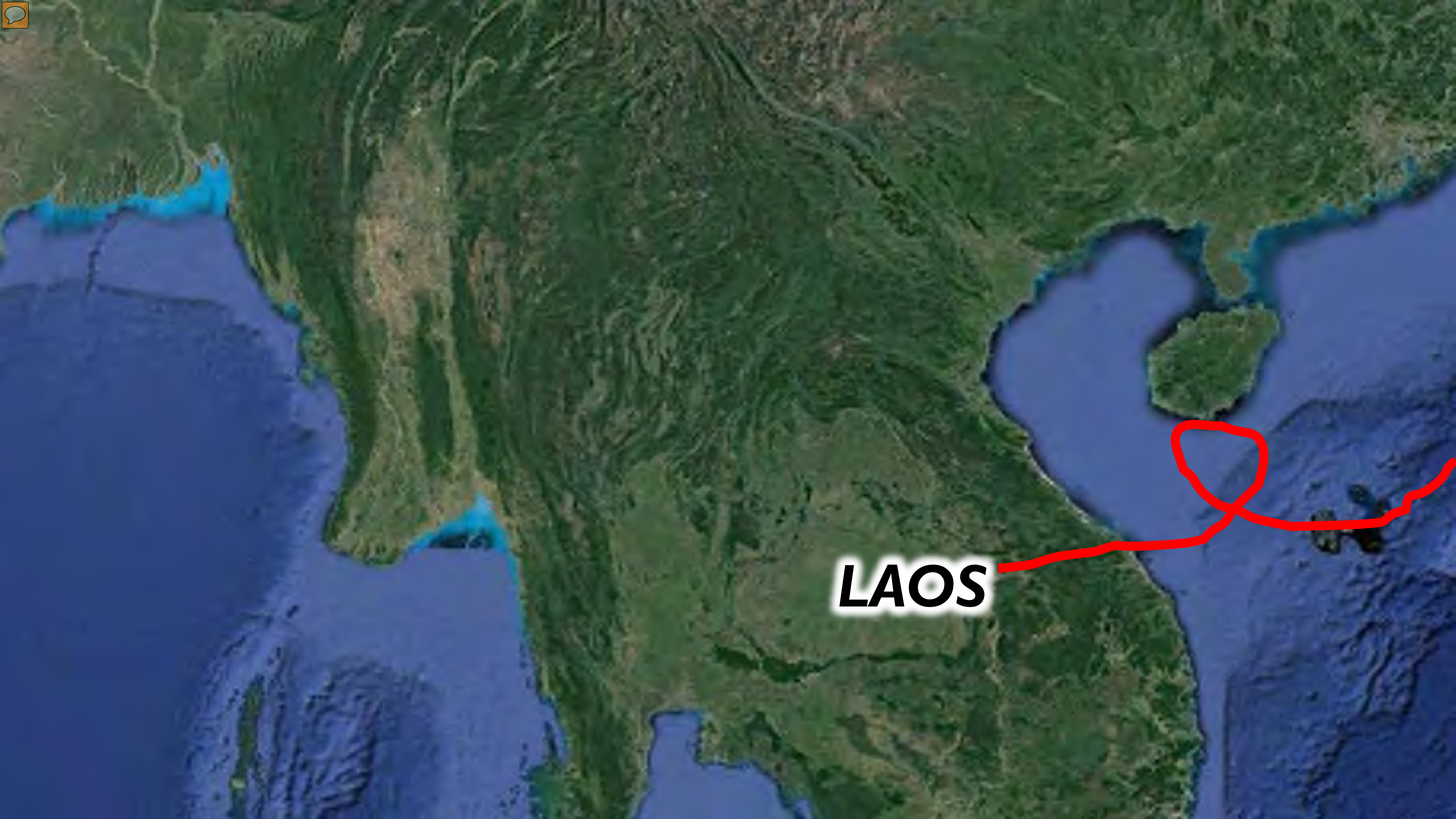
……what events shaped you?

War

Photo Credit: NBC



Home


LAOS


US

Family

Failures


2015
Constructed Banks

CASFM

Ben Urbonas Andrew Earles Brian Murphy

Luke Swan JoAnna Curran Will Harman

Georges Anastankes Doug Shields EWRI

David Bidelspach Chris Sturm Dan Baker

Troy Thompson

John Schwartz

George Annandale Dave Rosgen Jim Wulliman

Brian Bledsoe Julie Ash

Colorado Riparian Association

Have you ever wondered…….

……what events shaped streams?

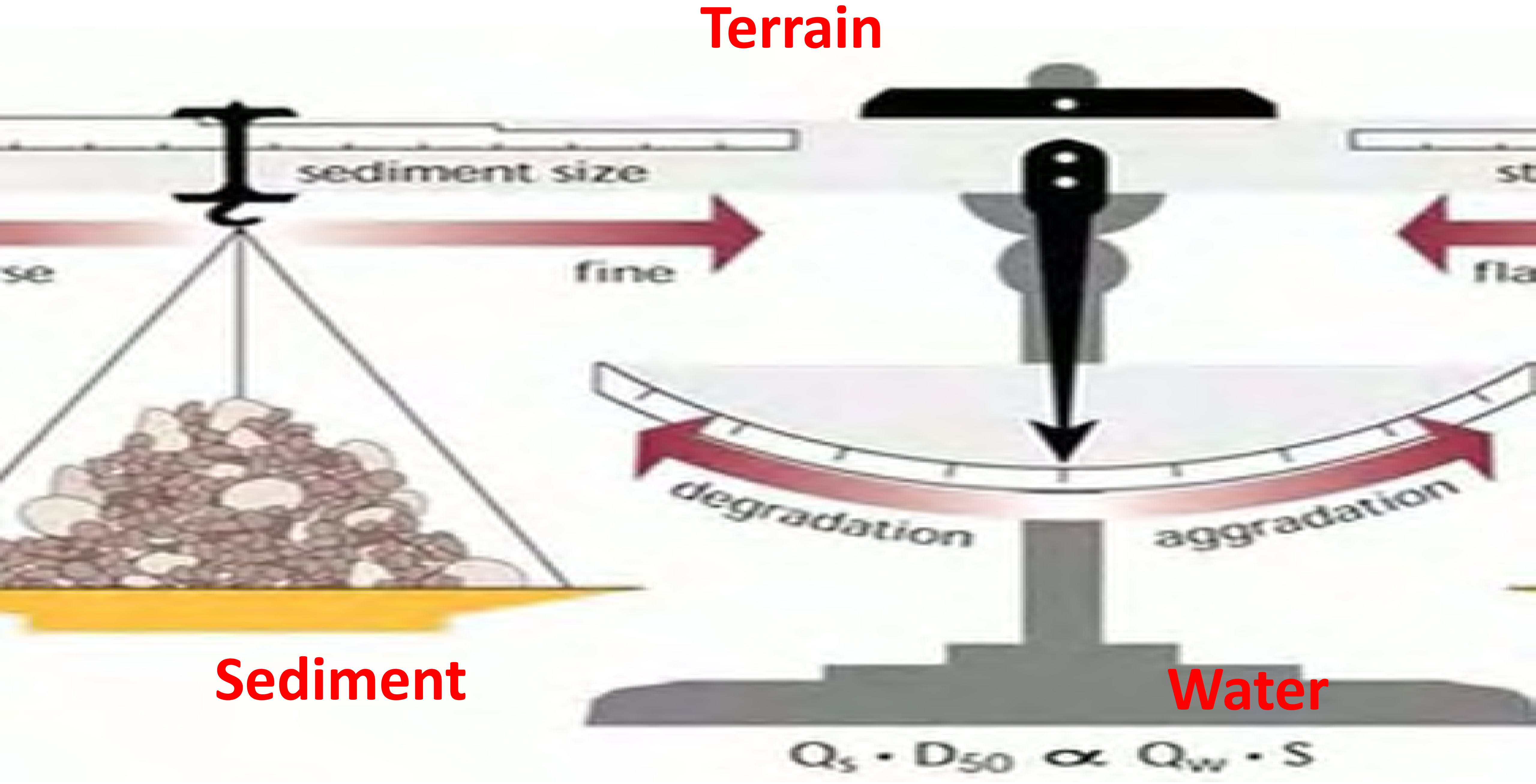
Water

Sediment


Photo Credit:
National Geographic

Terrain

The stream
is
living history
of
these events


Terrain
sediment size
fine
degradation
aggradation
Sediment
Water
$Q_s \cdot D_{50} \propto Q_w \cdot S$

Stream

will change

if

one factor changes


1993
Chatfield
85


1999
Chatfield

2010
Chatfield

1994 | 1999 | 2000 | 2001 | 2002

Development starting to occur in the basin

The channel is coming apart.

Downstream reaches near Santa Fe experiencing soil depoition due to upstream soil movement.

Improvements in upstream reaches completed.

Improvements in upstream reaches completed.

Another reach improved.

The channel is coming apart.

Another reach improved.

1994 | 1999 | 2000 | 2001 | 2002

Development starting to occur in the basin

Downstream reaches near Santa Fe experiencing soil depoition due to upstream soil movement.

Improvements in upstream reaches completed

Improvements in upstream reaches completed.


2010


Before


After


After


Check
Newlin Gulch

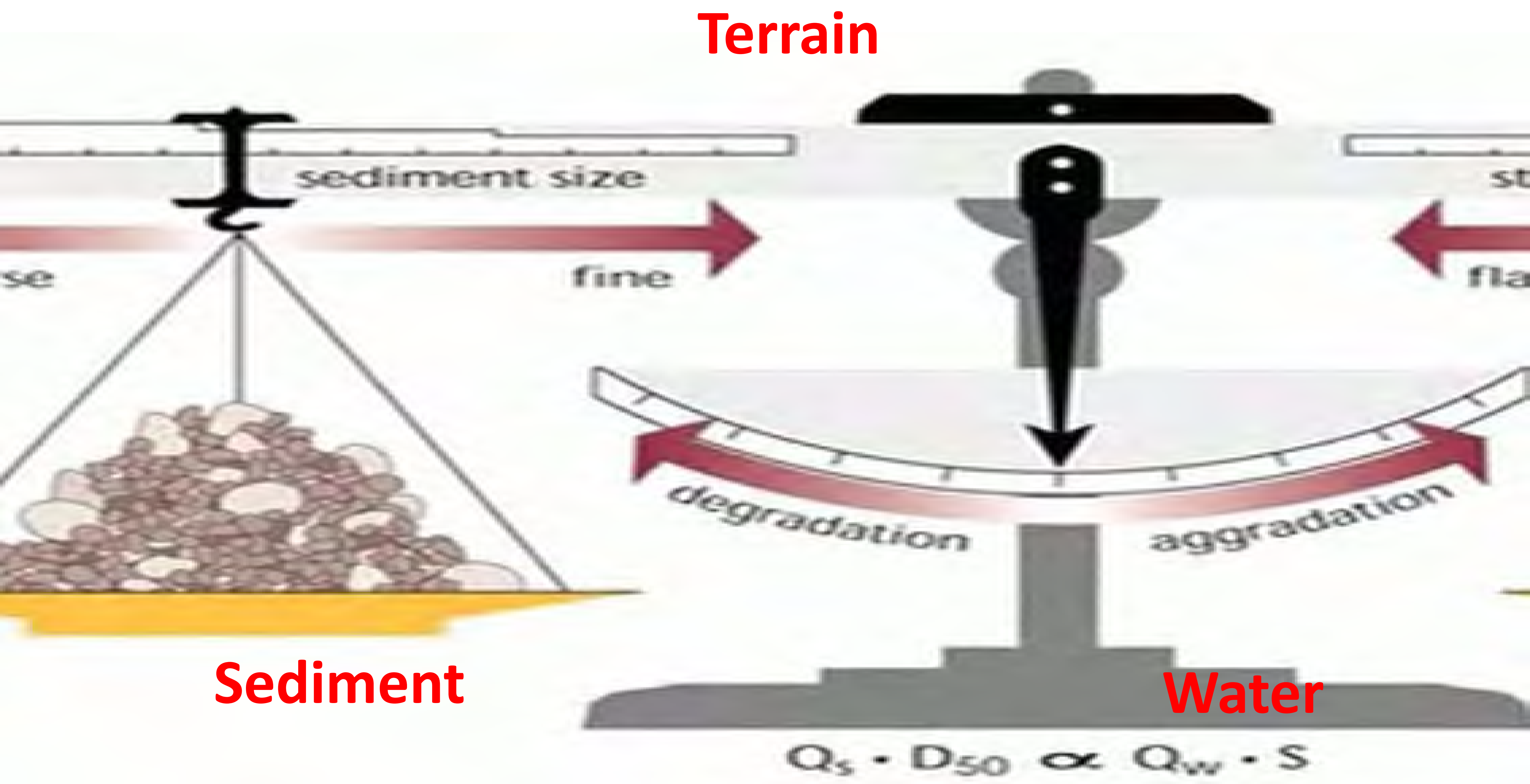

Check
Newlin Gulch


Before


After


Before


After

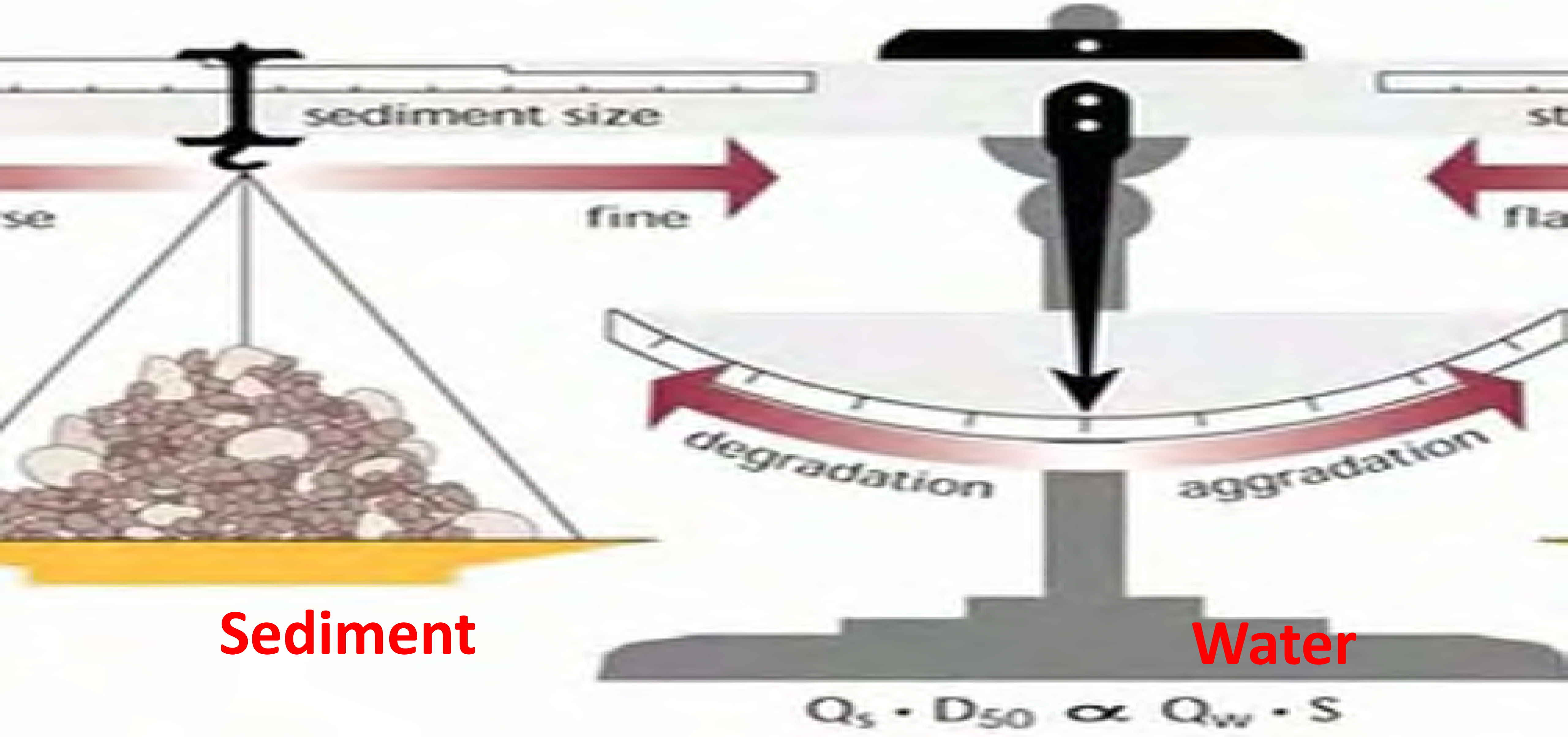

Terrain
sediment size
se
fine
degradation
aggradation
Sediment
Water
$Q_s \cdot D_{50} \propto Q_w \cdot S$

Be wild

Push beyond conventional bounds


Stroh Gulch

Terrain


sediment size
fine
degradation
aggradation
$Q_s \cdot D_{50} \propto Q_w \cdot S$
Sediment
Water

Oak Gulch

Oak Gulch

Oak Gulch


Mesa Trib


South Newlin Gulch

Coyote Gulch


Harvard Gulch


Cherry Creek


Montbello Channels


Big Dry Creek
Before


After

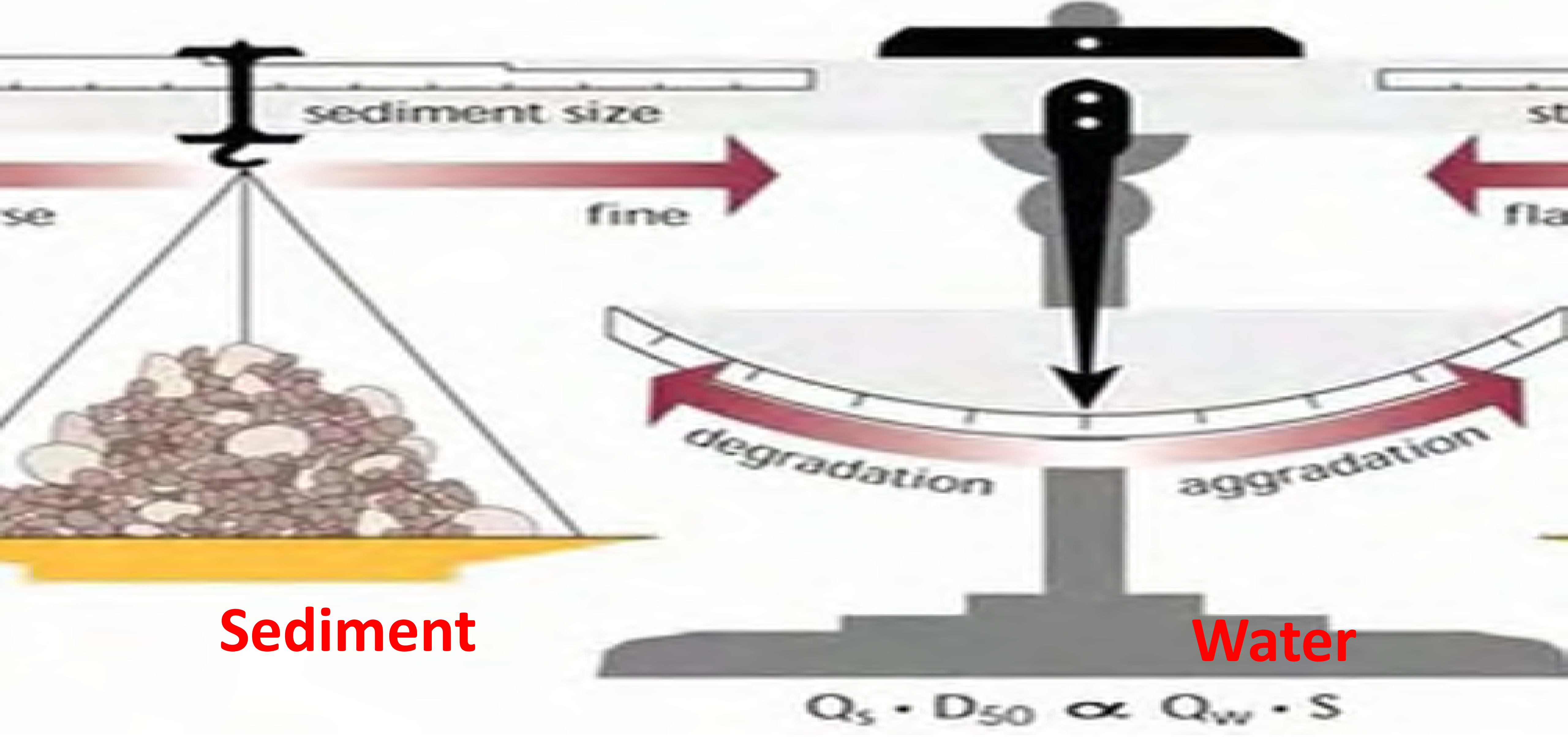

After


Dad Clark
Before


Before


After

Terrain



sediment size
fine
degradation
aggradation
Sediment
Water
$Q_s \cdot D_{50} \propto Q_w \cdot S$

Water

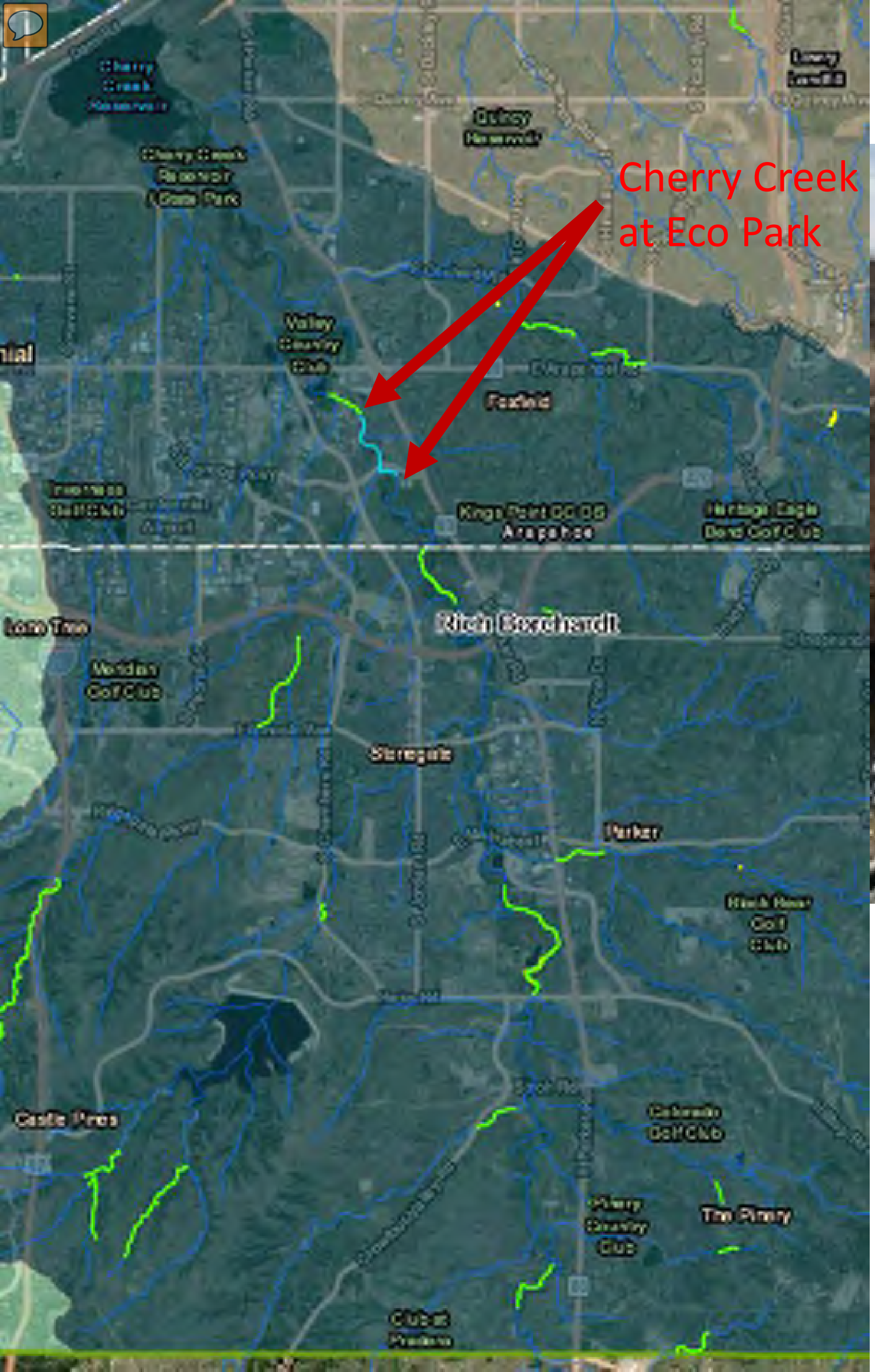
Sediment

Terrain

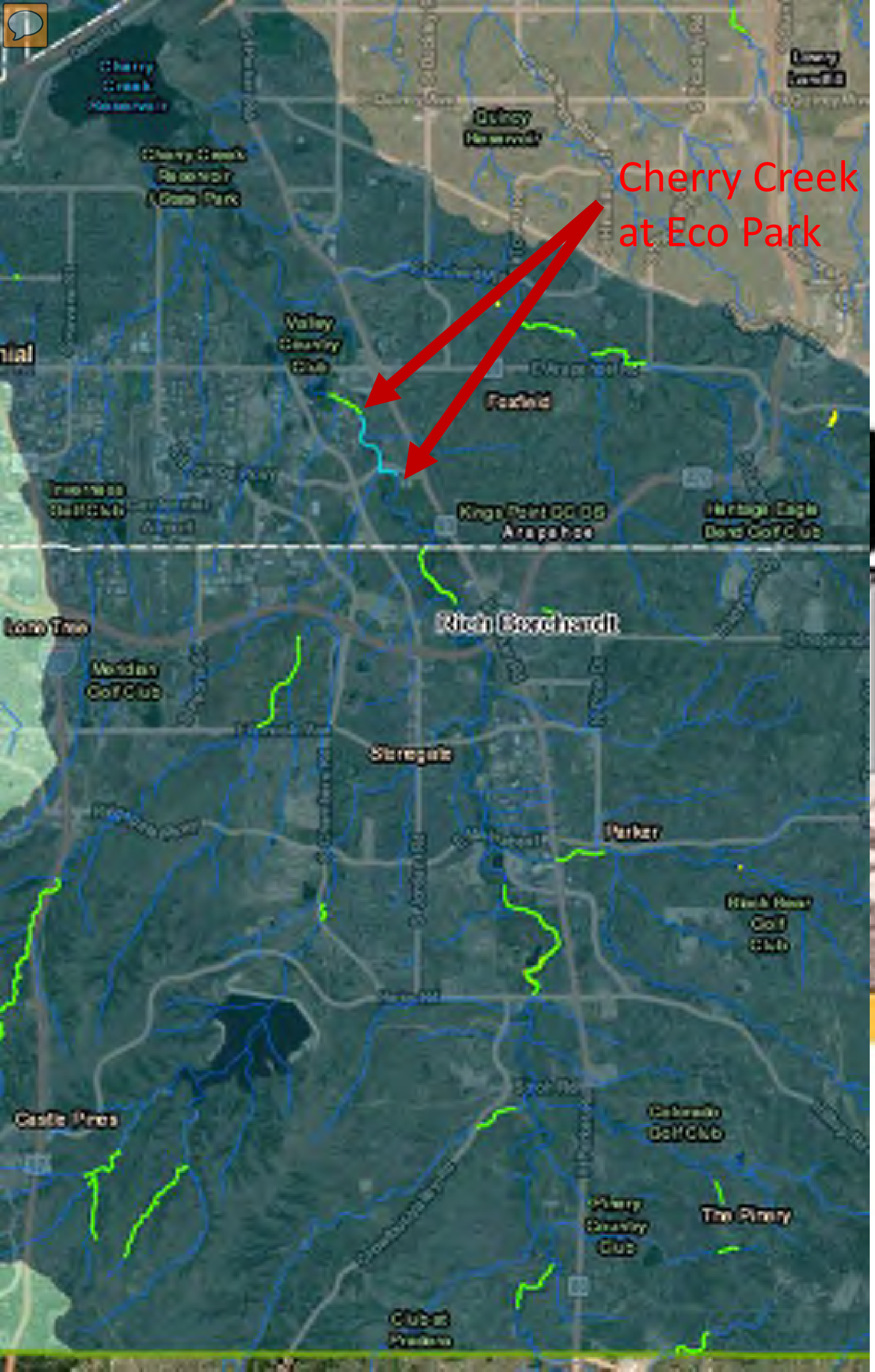
Wild about Streams

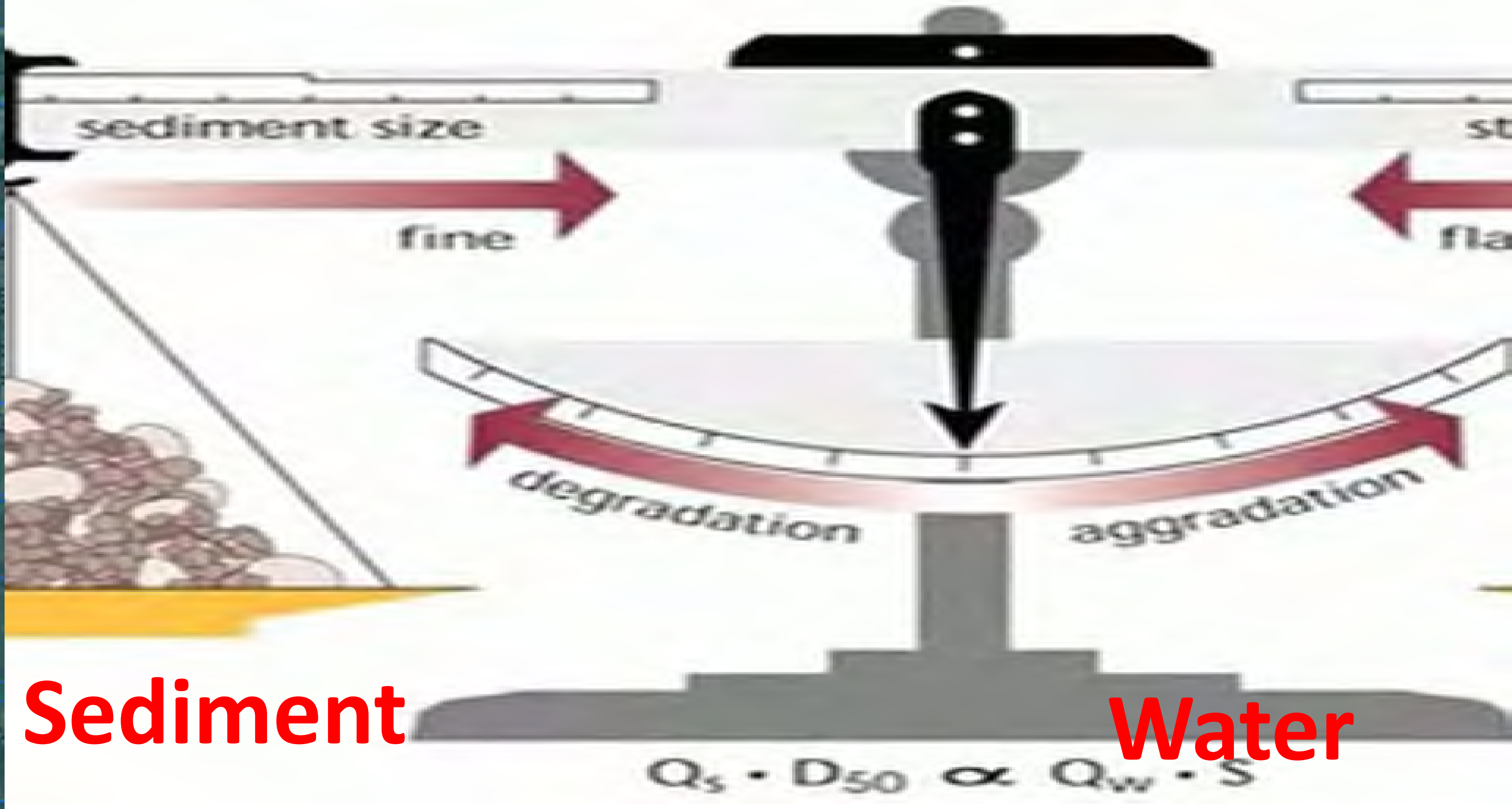
?

Wild about Sediment Transport



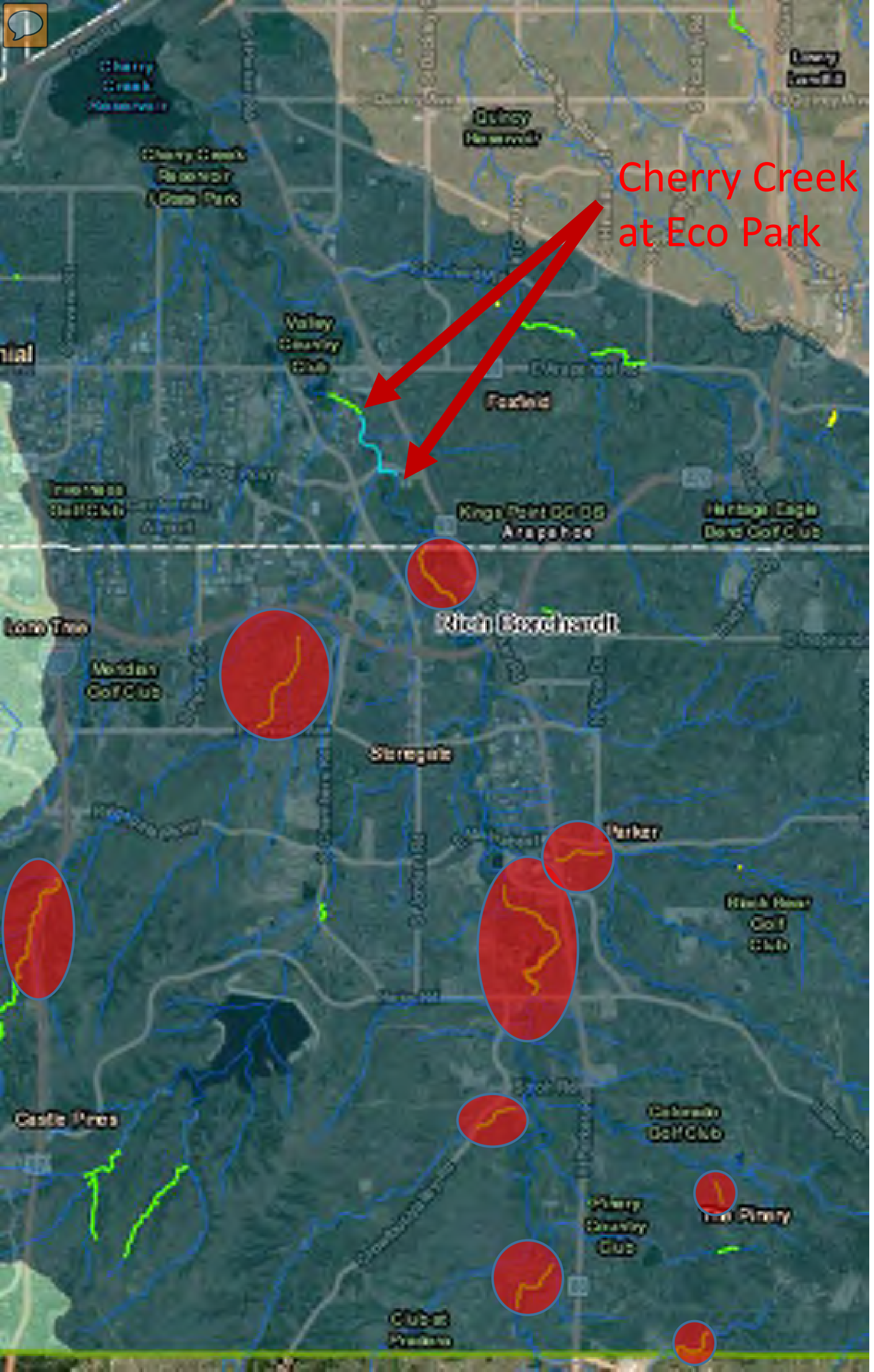
Wild about Sediment Transport

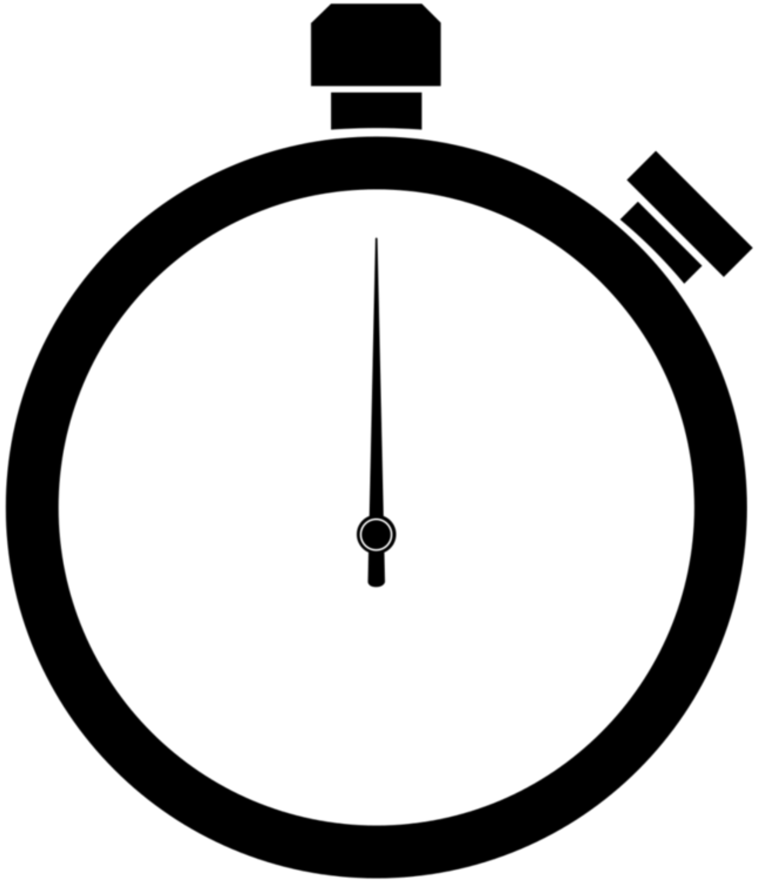




Wild about Sediment Transport

Wild about Sediment Transport





Wild about Sediment Transport

Wild about Sediment Transport

Wild about Sediment Transport

Wild about Sediment Transport and Storage

Photo Courtesy of Muller Engineering

Wild about Sediment Transport and Storage

Wild about Sediment Transport and Storage

Wild about Sediment Transport and Storage

Bank of Cherry Creek

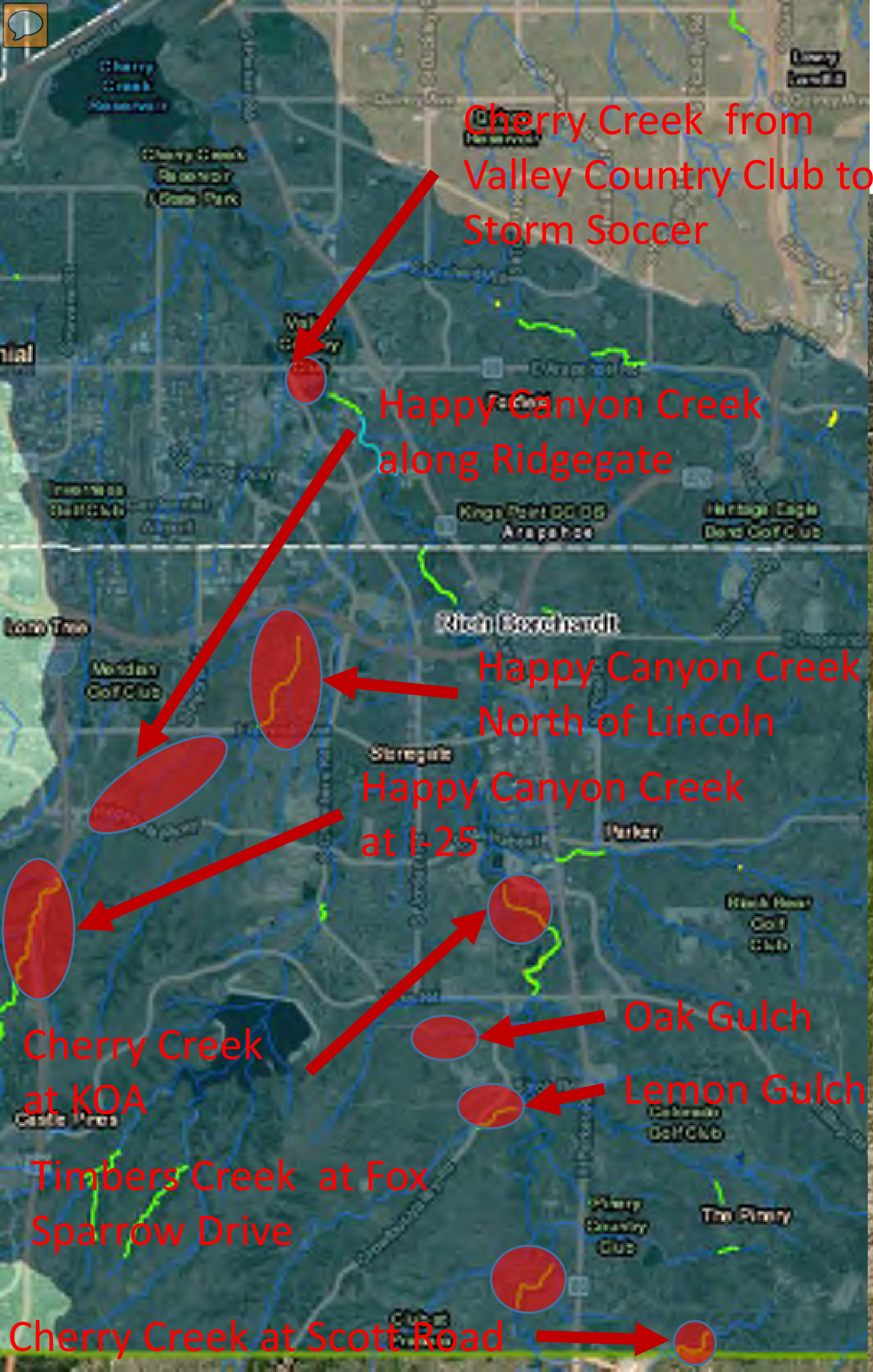

Wild about Sediment Transport
Wild about Sediment Transport and Storage

Wild about Maintenance

Wild about Maintenance

Wild about Maintenance

Wild about the Future



Wild about the Future

Wild about the Future

When Engineers Go Wild!

Richard Borchardt, The Flood Control District, Project Manager
Barb Chongtoua, The Flood Control District, Project Manager