Designing to Account for Variability

First National Stream Restoration Conference

August 1st, 2022

WATERVATION

Purpose

- Introduction to our thought process on how we develop restoration designs to account for variables that we can't (or can't yet) fully quantify.
- Triggered by:
  - Lack of available data
  - Inability to collect data due to impairment
  - Rapid change in environmental factors that influence data (wildfires, climate change)
  - Inherent unknowns associated with working in natural environments where most factors are outside of your control

Fountain Creek Restoration at Riverside

Fountain Creek Restoration at Riverside

- Many physical variables that exacerbate theoretical variables
- Sandy soils & enormous sediment load
- Extensive infrastructure constraints
- Severely impaired stream system
- Persistent hydromodification
- Flashy hydrograph
- Lack of quality data
- DA = 538 square miles (Q100=57,000 cfs?)

Problem: Channel Forming Flow?

- Channel forming flow estimations varied
- Lower flows probably move the most sediment

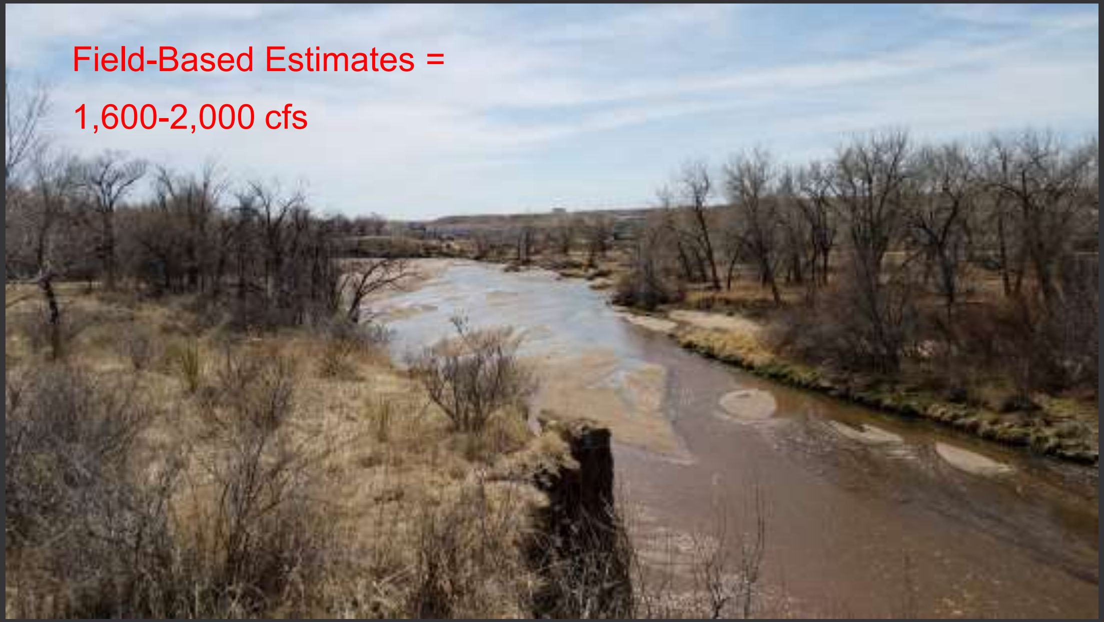
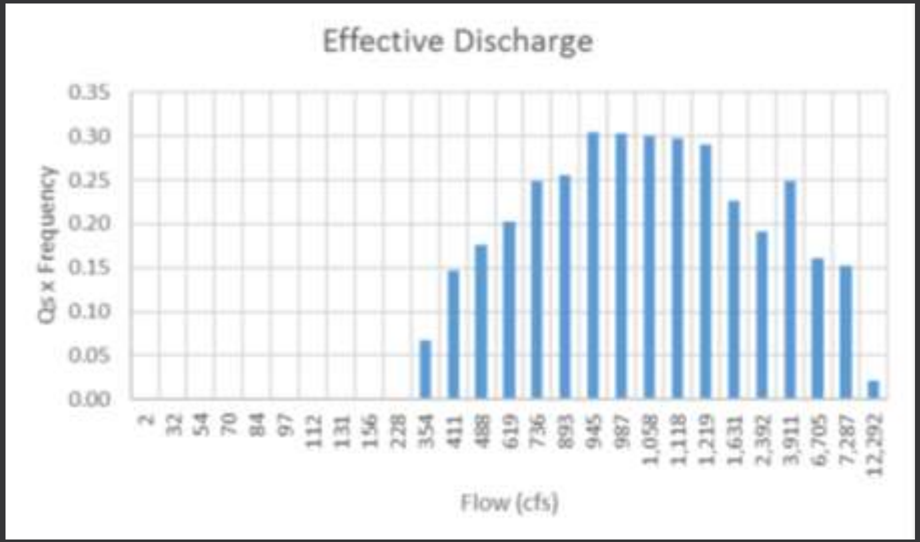


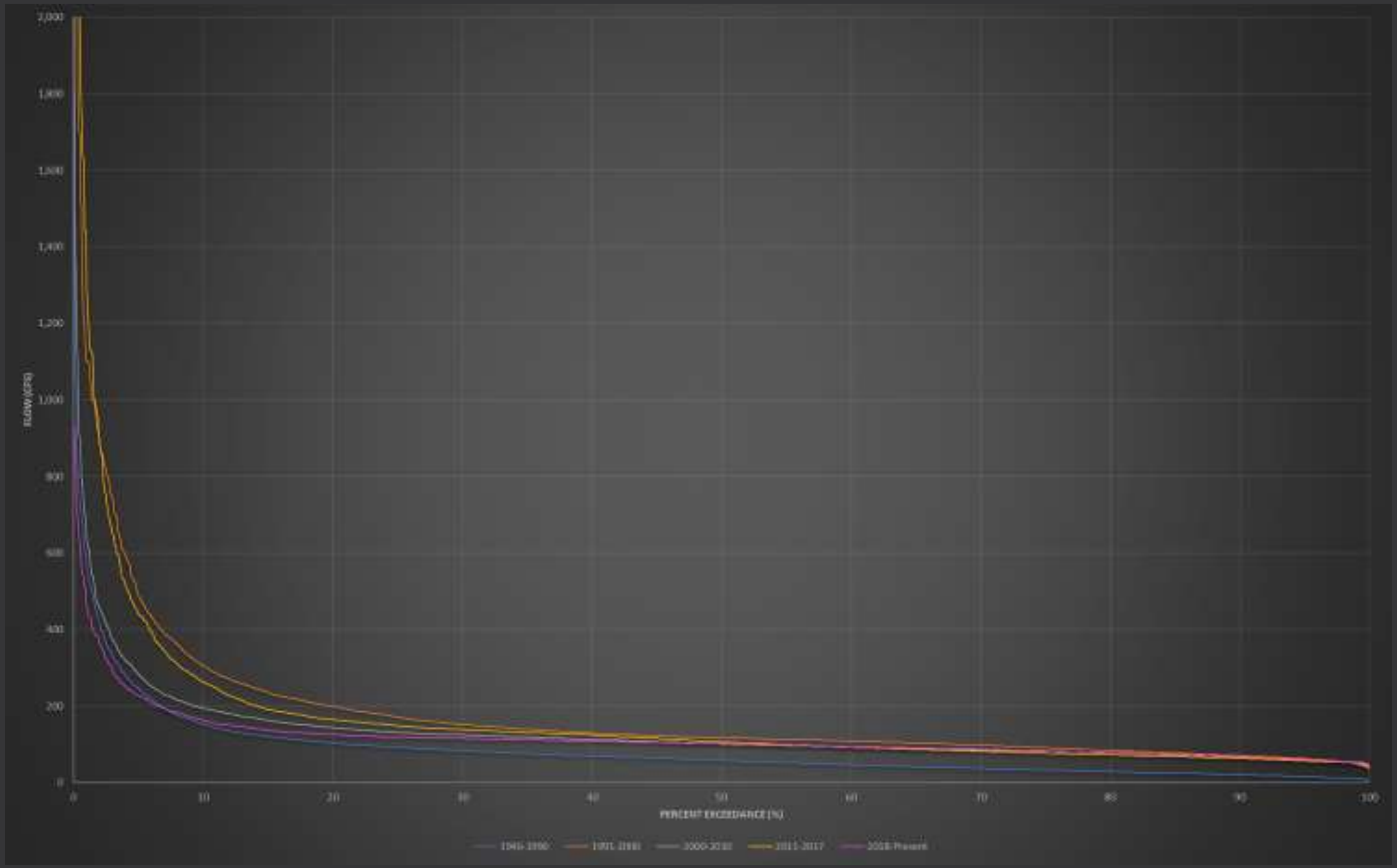
Table 3 – Log-Pearson Type III Statistical Analysis of USGS Gage Data

Recurrence	Flow (cfs)	
	USGS 70105800 (DA = 495 mi^2)	USGS 70106000 (DA = 681 mi^2)
1.01-Year	545	1,300
1.25-Year	2,203	3,448
1.5-Year	3,090	4,550
2-Year	4,864	5,870



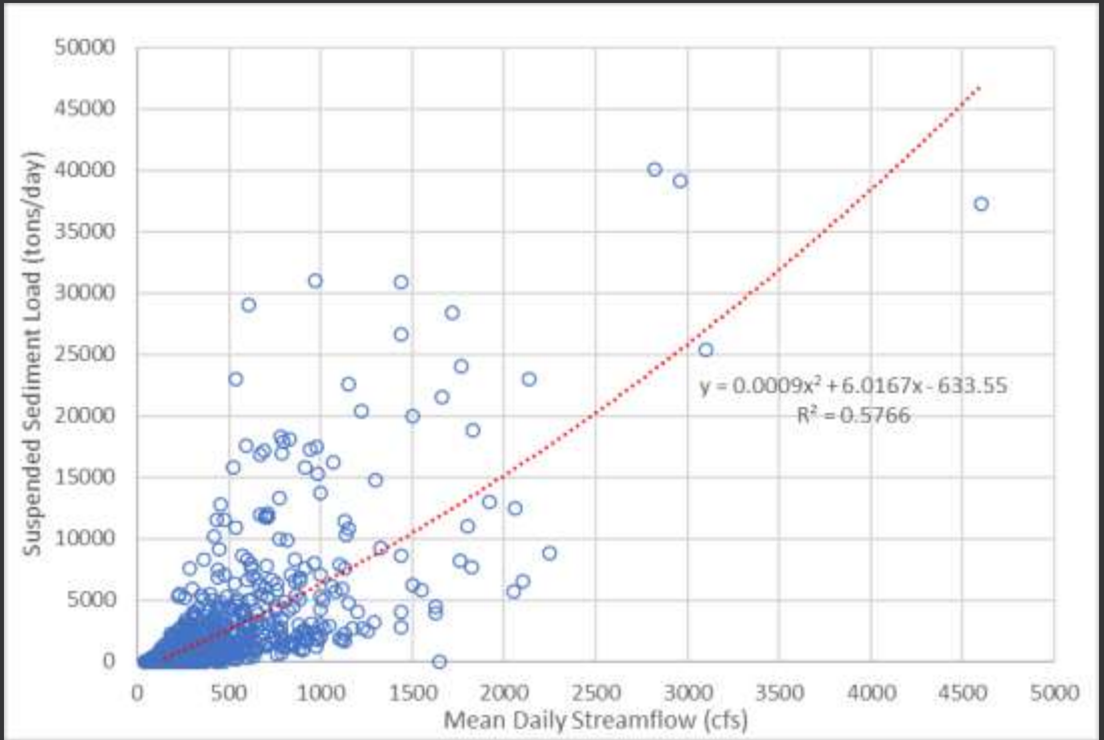
Problem: Flow Duration?

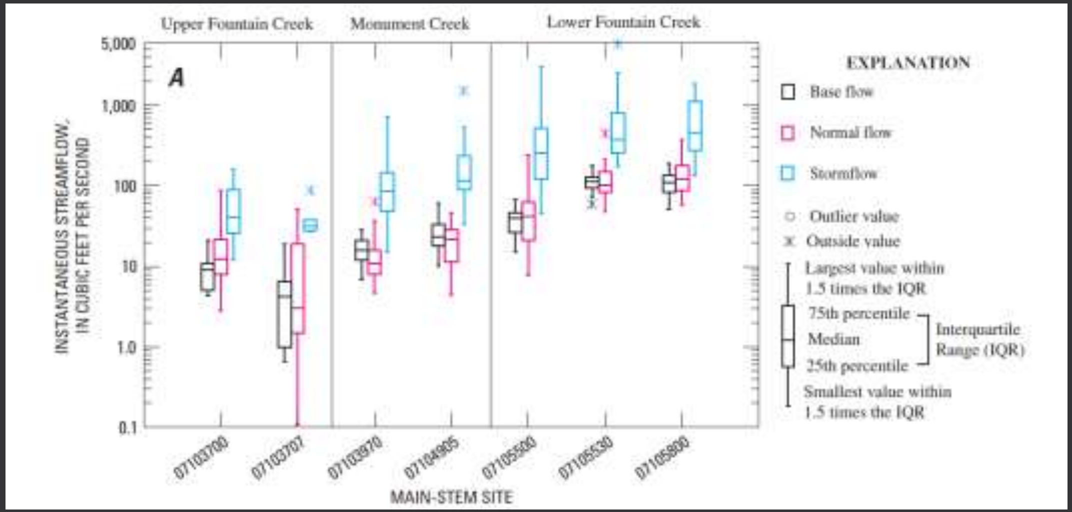
- Significant changes to flow duration over the past three decades
- Ongoing hydromodification
  - Development
  - Major water diversions
  - Fires
- Lower flows move the most sediment

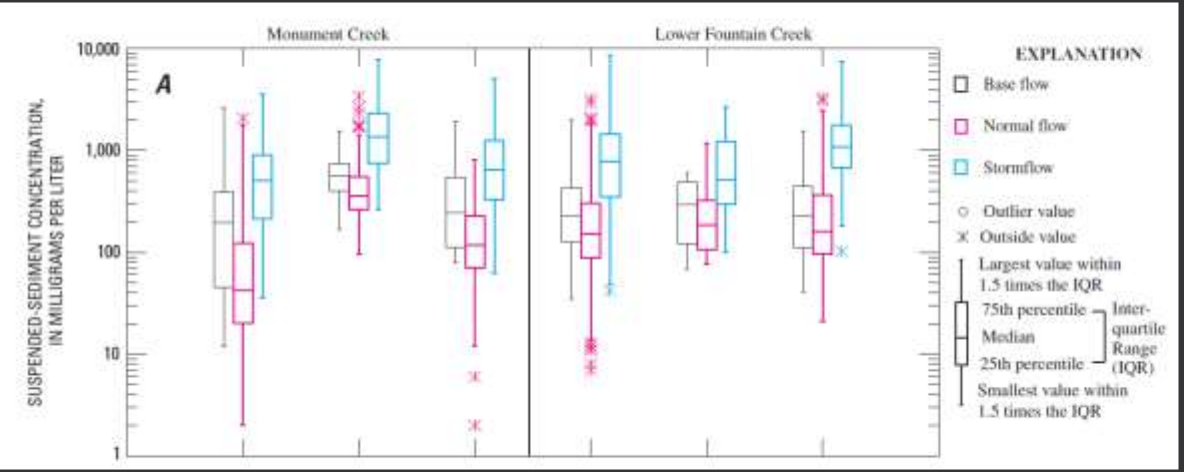


Problem: Suspended Sediment Load?

- Varies significantly based on flow







Problem: 100-Year Flood Flow?

- Sometimes a requirement for a project
- Flood maps and flood insurance are one thing
- Designing is another

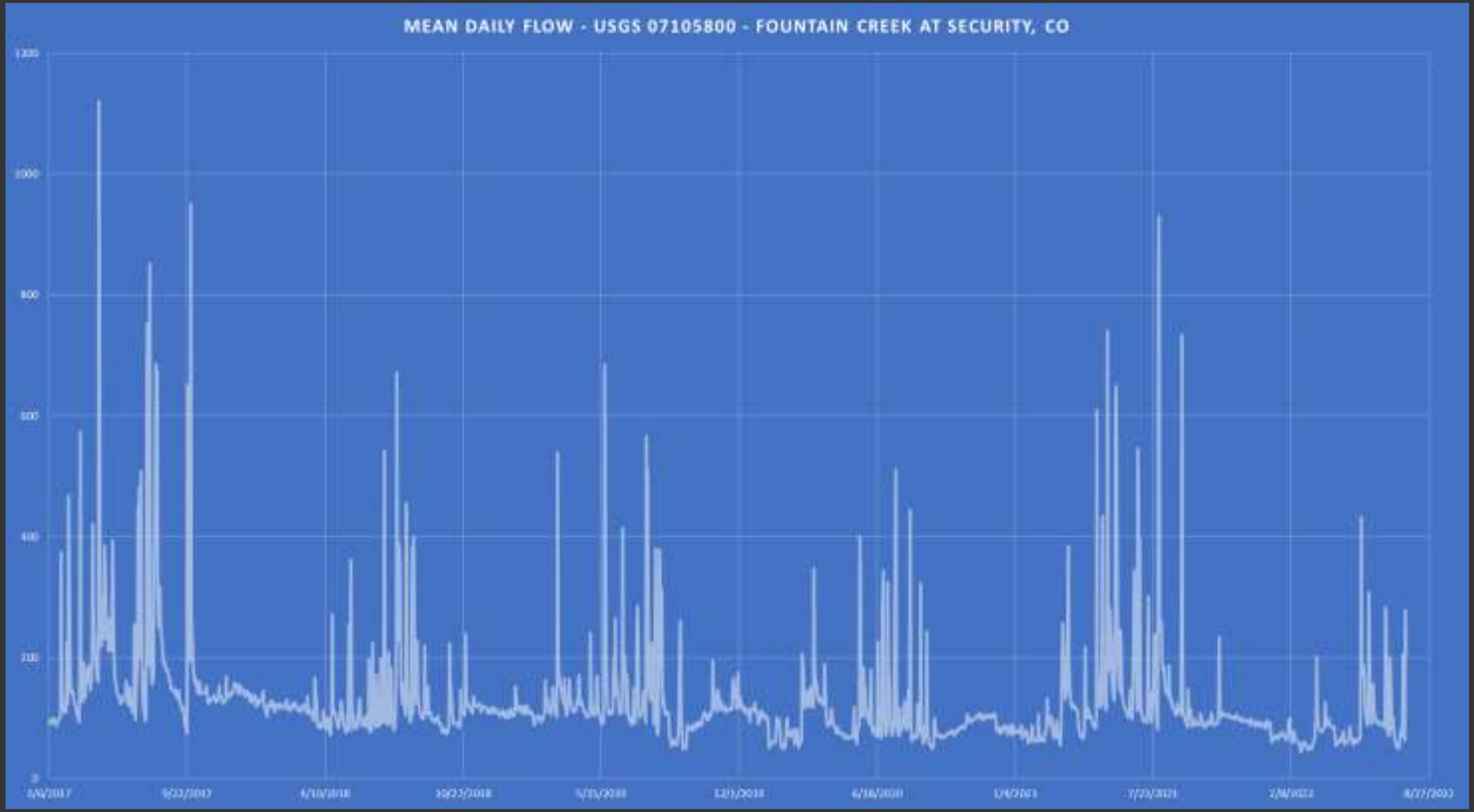
- FEMA FIS = 57,000 cfs
- Fountain Creek Hydrology Report = 26,674 cfs
- Stream Stats = 13,100 cfs

Problem: Natural Stream Tendency?

- Wandering low flow channel
- Largely influenced by where sediments deposited after last flood

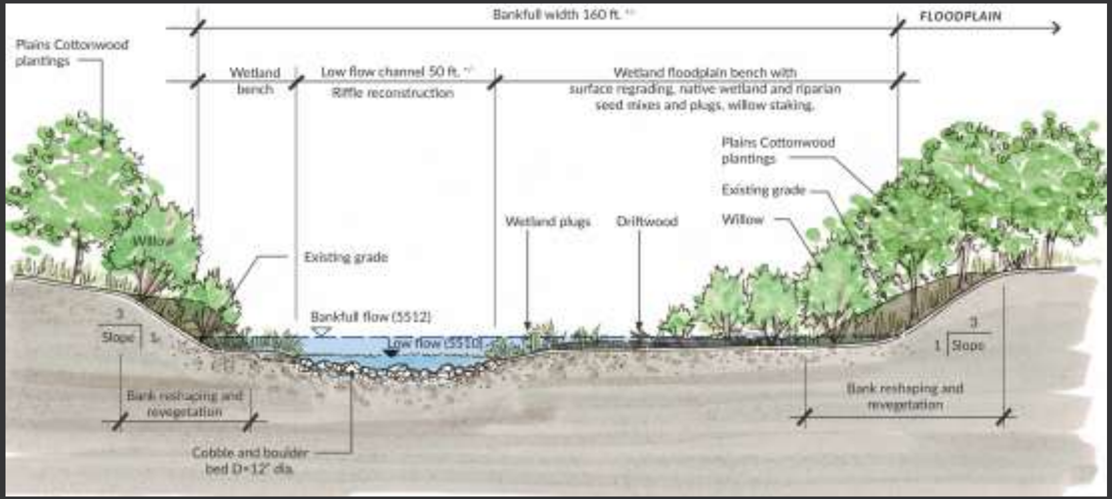
Stream Flashiness

- Extremely flashy rainfall/runoff response
- How do installed features respond to rapid change in stream power?



Solution: Channel Forming Flow

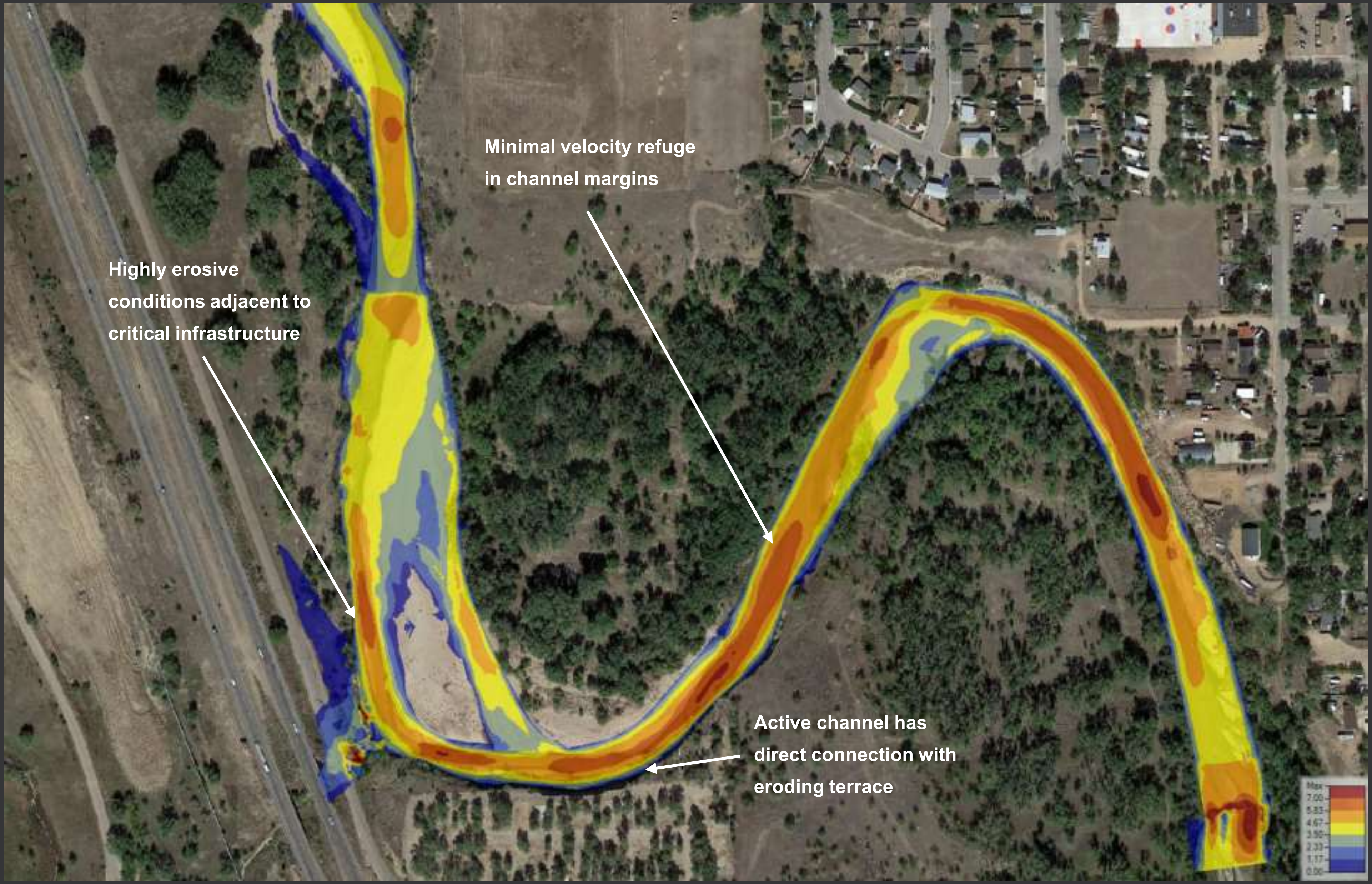
- Bankfull channel designed for the most probable channel forming flow (see previous)
- *What if* actual flow is <u>lower</u>
  - Entrenchment of flood flows→erosion
  - Shallow depths at low flow→fish barrier
- *What if* actual flow is <u>higher</u>
  - Frequent overbank flows→impacts to infrastructure
- Our solution
  - Designed mild sloping bankfull slide slopes w/ screened alluvium and dense plantings
  - Designated low flow channel
  - Modeled range of low flow scenarios to ensure velocity barriers were avoided
  - Incorporated scattered boulder clusters to provide pocket water and velocity refuge
  - Designed floodplain grading and overflow channels to direct overbank flows away from critical infrastructure



Solution: Channel Forming Flow

Pre-Project Conditions

1,676 cfs

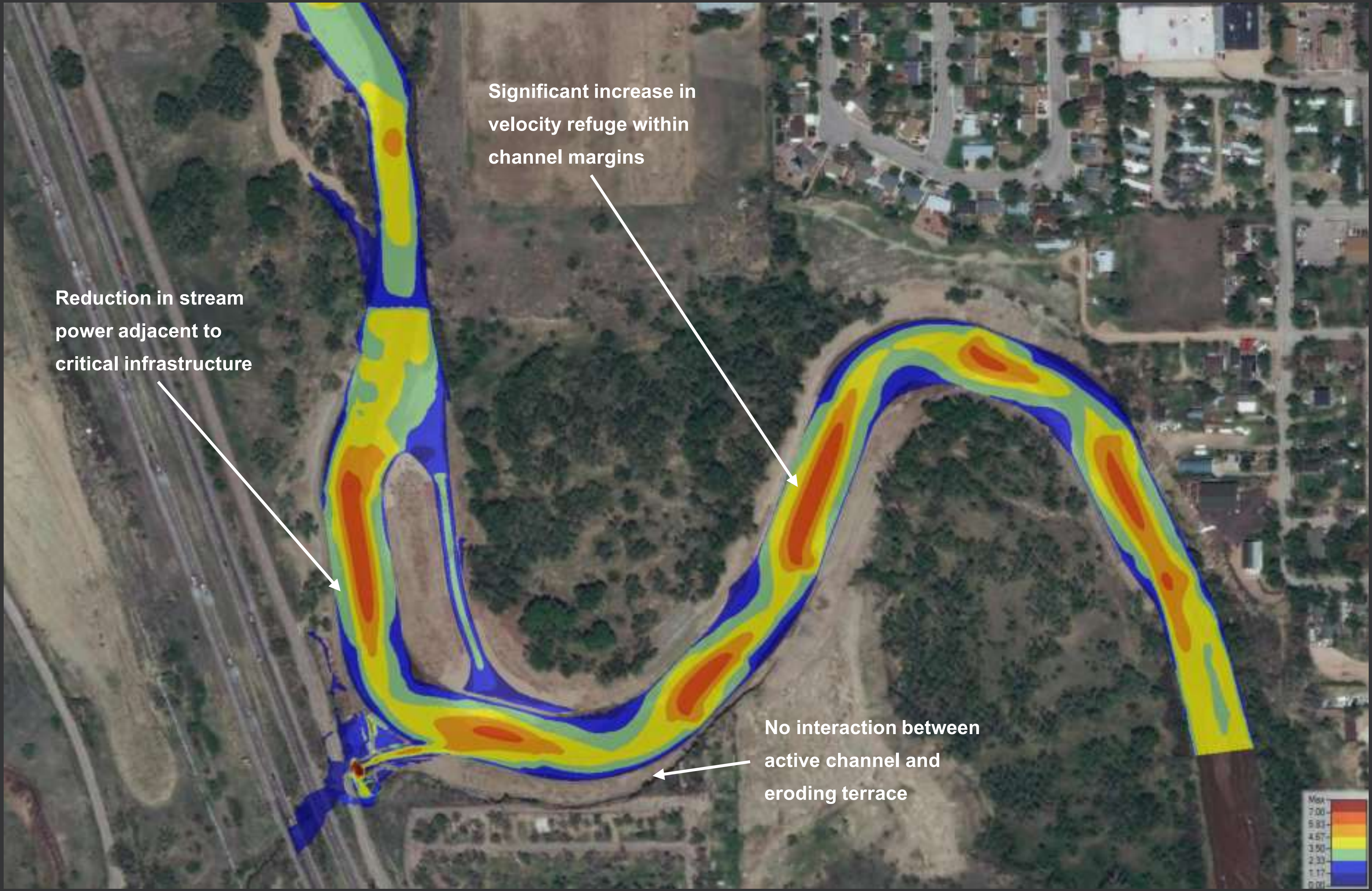


Velocity (ft/s)

Solution: Channel Forming Flow

Post-Project Conditions

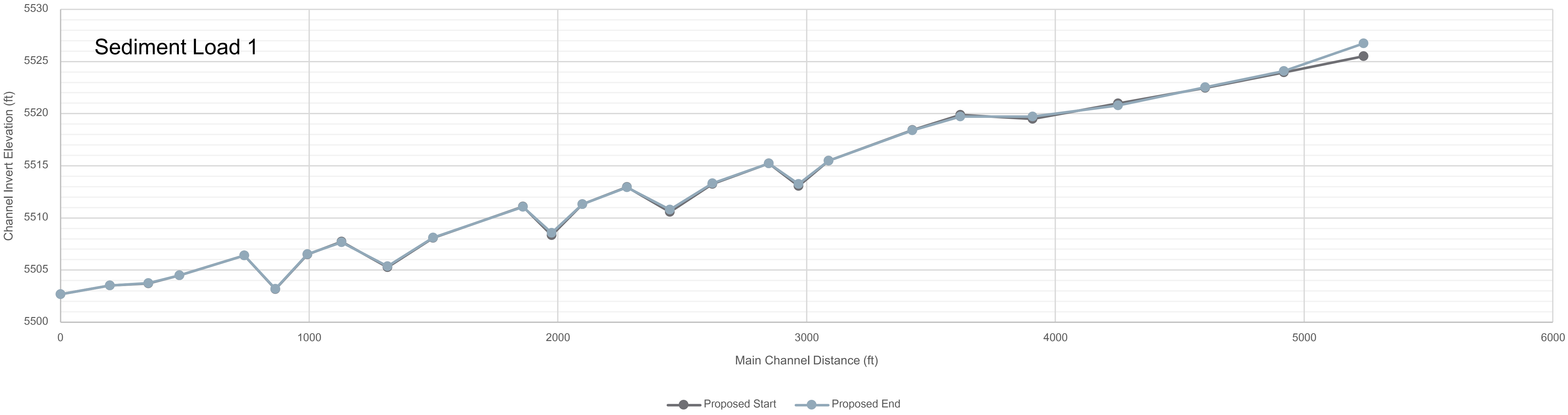
1,676 cfs

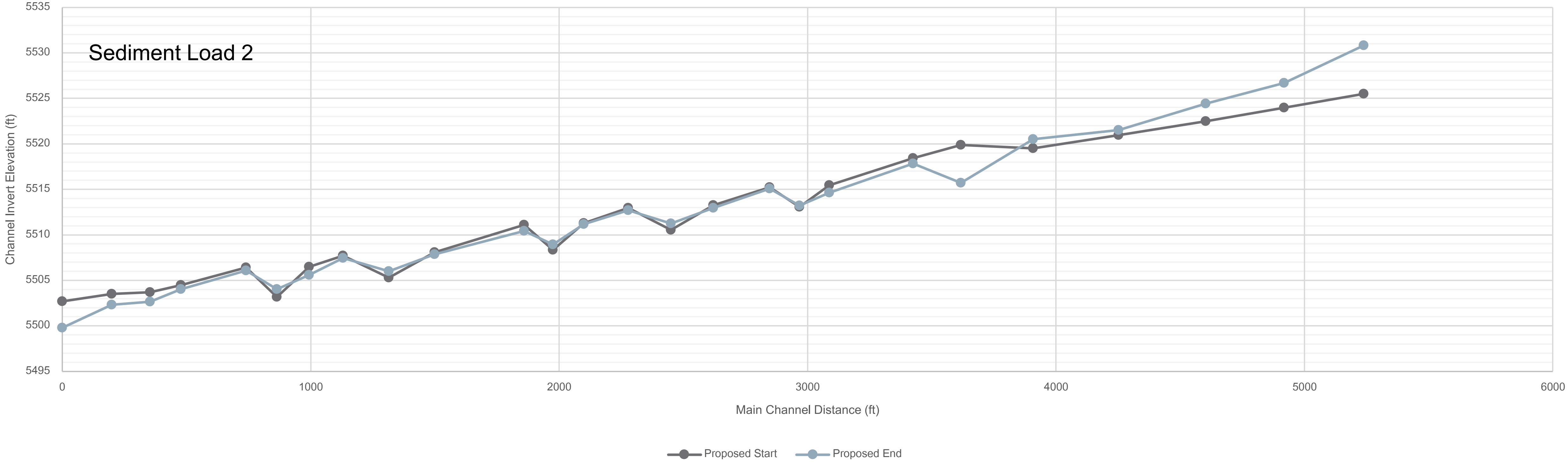


Velocity (ft/s)

Solution: Flow Duration & Sediment Load

- What will the flow duration curve look like in the future
- *What if* flows decrease
  - Contained within active channel
- *What if* flows increase
  - Sediment surplus→aggrading project reach
- Our solution
  - Designed reinforced riffles with screened, native alluvium and increased mat thickness
  - Enlarged pools and slightly flattened point bars to allow for storage of surplus sediment
  - Designed a forced deposition zone where excess sediment can be deposited prior to entering the project reach
  - Multiple sediment transport analyses
    - Capacity
    - Mobile bed
    - Competence


Sediment Load 1
Channel Invert Elevation (ft)
5530
5525
5520
5515
5510
5505
5500
0
1000
2000
3000
4000
5000
6000
Main Channel Distance (ft)
Proposed Start
Proposed End


Sediment Load 2
Channel Invert Elevation (ft)
5535
5530
5525
5520
5515
5510
5505
5500
5495
0
1000
2000
3000
4000
5000
6000
Main Channel Distance (ft)
Proposed Start
Proposed End

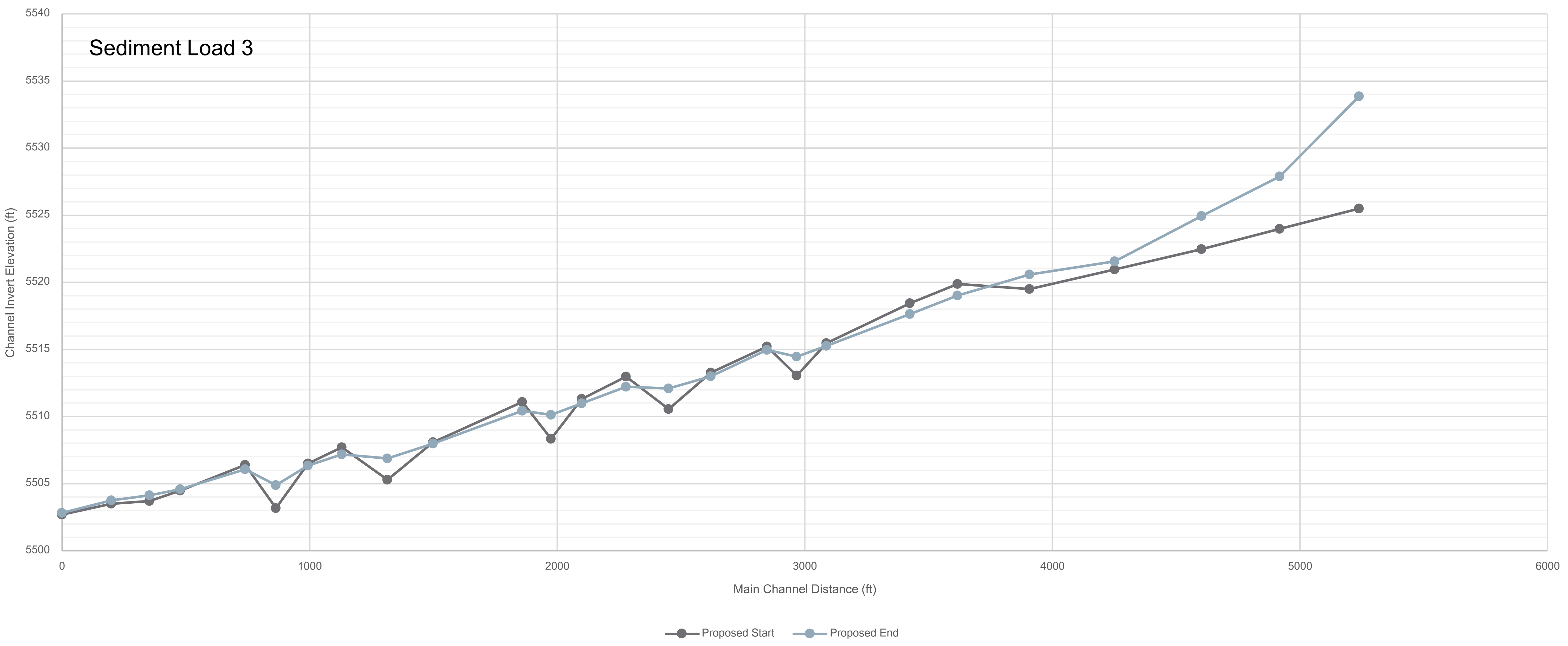


Table 8 - Sediment Competence Analysis Results for Proposed Design

Proposed Design		Required		Largest Available Particle (mm)	Largest Predicted Particle (mm)	Competent?
Depth (ft)	Slope (ft/ft)	Depth (ft)	Slope (ft/ft)			
2.33	0.0048	2.71	0.0056	130	116	Slightly Under-Competent

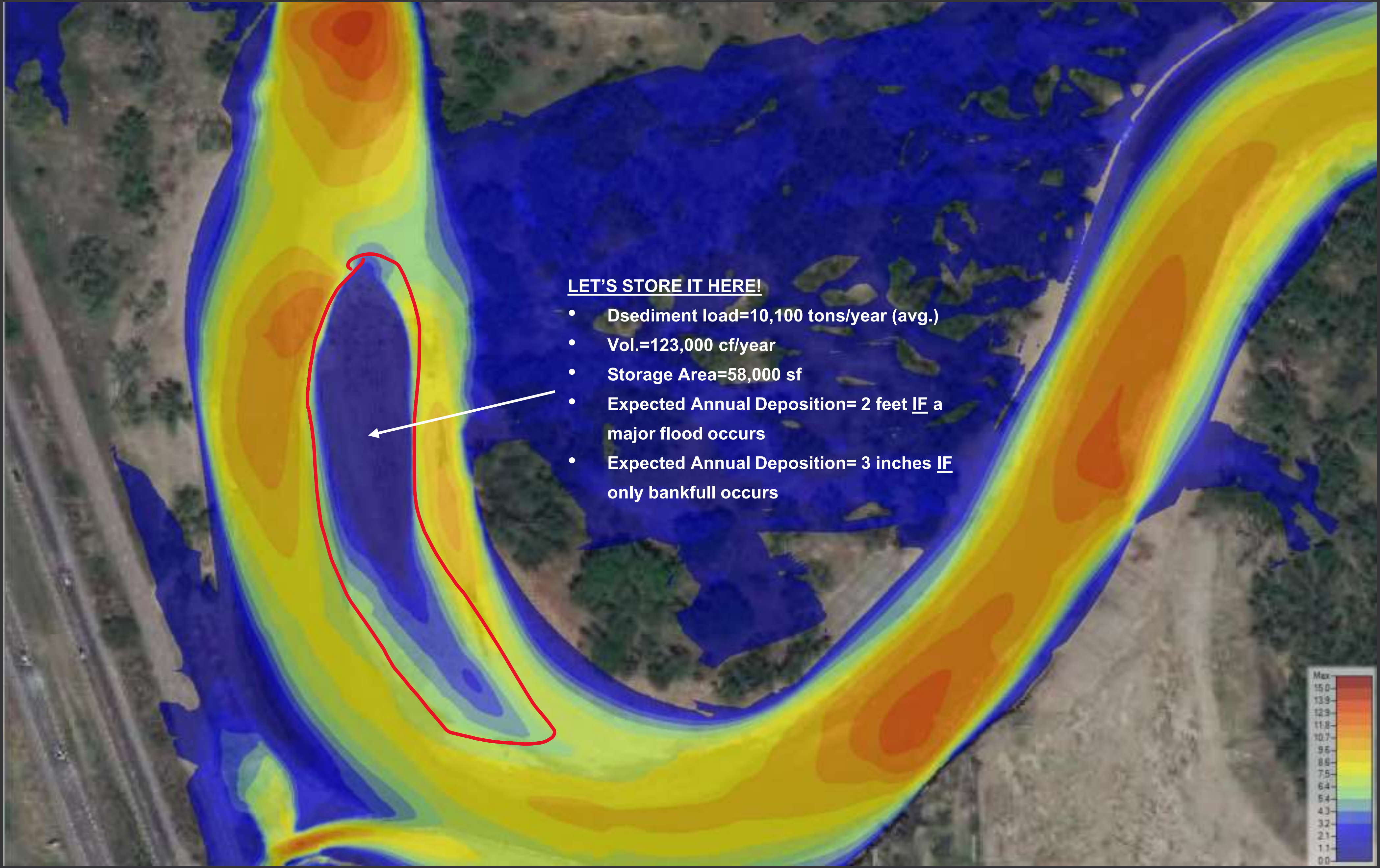
Makes sense given location in watershed

Sediment Supply = 40,100 Tons/Year (includes all flood flows)

Sediment Capacity = 30,000 Tons/Year (includes all flood flows)

Makes sense given location in watershed

We HAVE to store sediment!

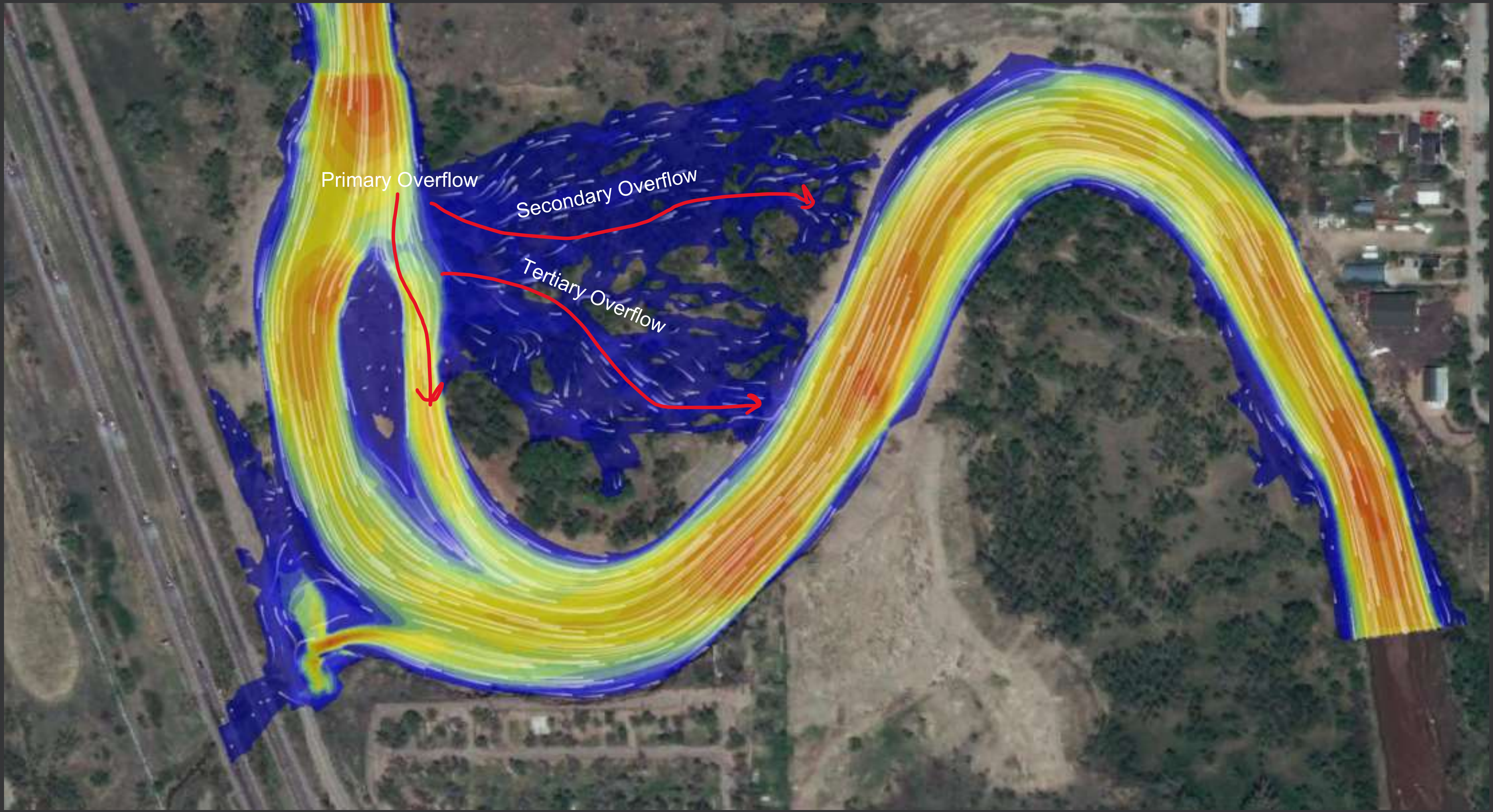

LET'S STORE IT HERE!
• Dsediment load=10,100 tons/year (avg.)
• Vol.=123,000 cf/year
• Storage Area=58,000 sf
• Expected Annual Deposition= 2 feet IF a major flood occurs
• Expected Annual Deposition= 3 inches IF only bankfull occurs
Max
15.0
13.9
12.9
11.8
10.7
9.6
8.6
7.5
6.4
5.4
4.3
3.2
2.1
1.1
0.0

AND LET'S TRY THIS!

Solution: 100-Year Flood Flow

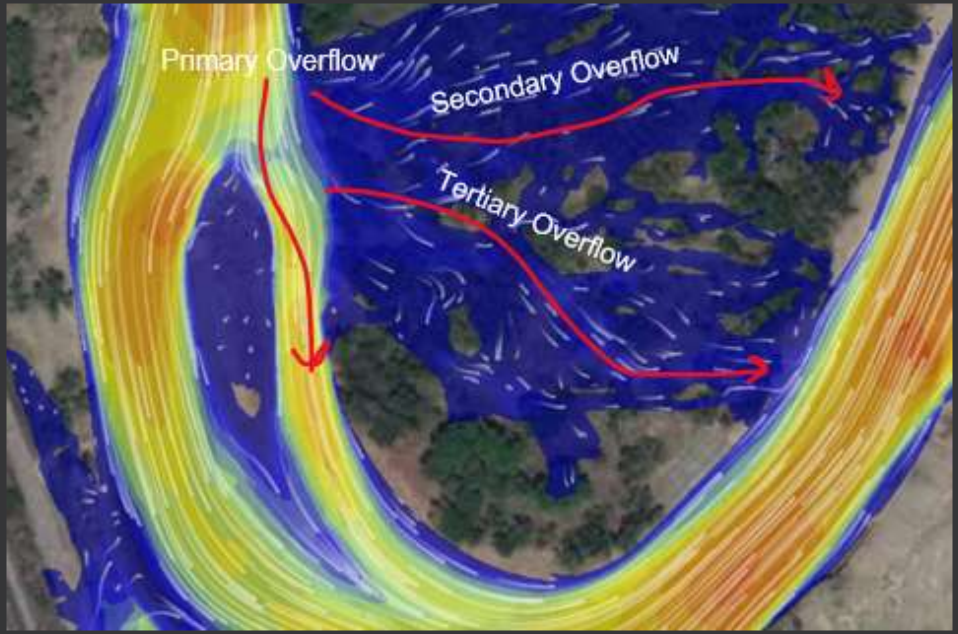
- What will the flow duration curve look like in the future
- *What if* flows are lower than expected
  - Great
- *What if* flows are greater than expected
  - Inundation of critical infrastructure
- Our solution
  - Designed a multi-stage bankfull channel, and flood prone bench, to efficiently convey base flows up to minor floods
  - Re-graded the low terrace to efficiently convey moderate flood flows
  - Designed a primary overflow channel to alleviate flood pressure within the bankfull channel
  - Designed floodplain grading to connect to relic secondary and tertiary overflow channels
  - Designed grading to direct flood flows away from critical infrastructure

Solution: 100-Year Flood Flow



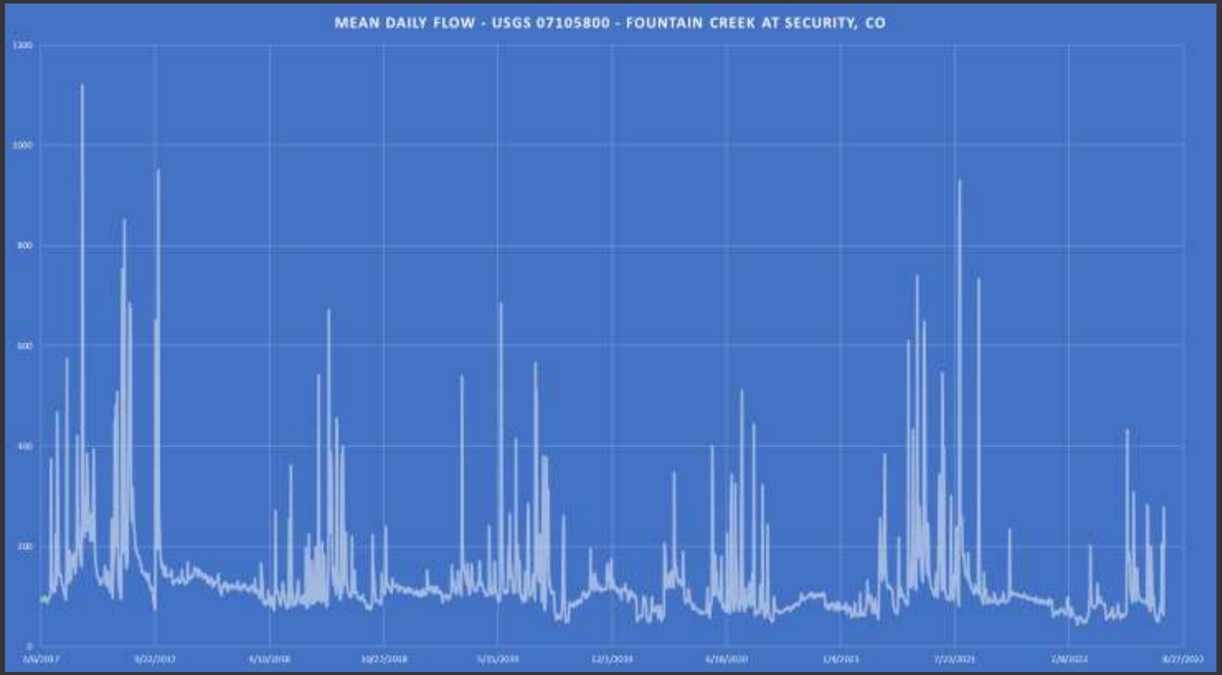
Solution: Natural Stream Tendency

- Where will the next flood deposit excess sediment?
- What will be the resulting downstream impact?
- We do know where we don’t want the stream to go.
- Our solution
  - Designed a forced deposition zone where excess sediment can be deposited prior to entering the project reach.
  - Designed buried floodplain protection in the primary overflow channel to prevent avulsion.
  - Minimized the use of in-stream structure.
  - Design focused on adding boundary and floodplain roughness for stability.

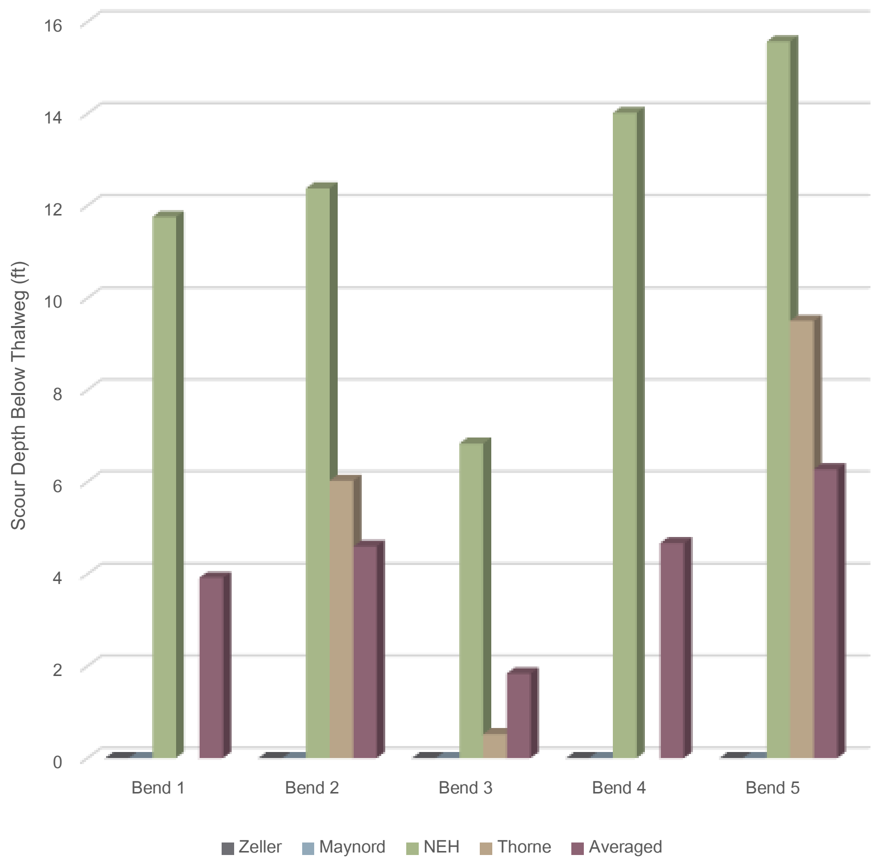


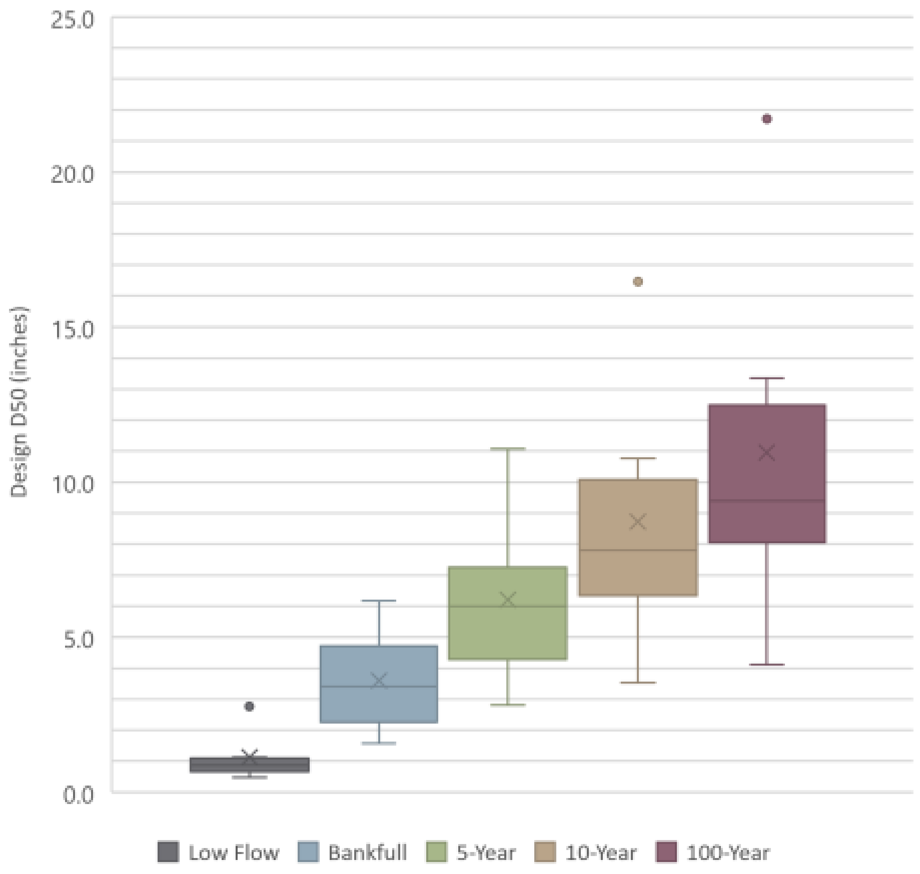
Solution: Stream Flashiness

- Need to critically and thoroughly evaluate
- Our solution
  - Evaluated design using a variety of hydraulic design equations
  - Detailed force analysis on all large wood structures



Multi-Point Hydraulic Calculations





Before & After *(3 flood events)*

Looking Downstream at Start of Project

Looking Upstream at Bend #1

Looking Upstream at West Bank Trib. Confluence

Looking Upstream at Bend #2

Looking Downstream at Riffle #2

Thank You!

WATERVATION

Questions?