Partnering with Development: A Sterling Gulch Example

Colorado Association of Stormwater and Floodplain Managers
September 30, 2020
Data Source: U.S. Census Bureau

5.8 Million in 2020
Increase collaboration?

- Criteria - Develop Framework for High Functioning Low Maintenance Stream
- Training – Stream Management Academy
- Fee-In-Lieu Improvement Option
Resolution No. 38, Series of 2017:
Authorization to Establish a Development Services Enterprise (DSE)

The DSE may:

- Collect voluntary fees from land developers.

- Use fees to hire contractors to complete preliminary designs, final designs, cost estimates, and to construct regional infrastructure.

- District, Land Developer, and all affected Local Governments must agree in writing to proceed.
When to Consider FILI

- Create an Amenity
- Permit
- Schedule
When to Consider FILI

✔ Create an Amenity
  - Permit
✔ Schedule
Lessons Learned

- Project Partners
- Relationship based process
- Fast Tracking Trust
  - Assume the best
  - Stay positive
  - Open communication
Lessons Learned

- Communication Plan
  - Early coordination meetings
    - Design
    - Construction
Lessons Learned

Phase 2 limits
Lessons Learned

- Design Elements
  - Equestrian trail
  - Outfalls
Lessons Learned

- Trying new things
Lessons Learned
A perfect marriage...
An arranged marriage…
EXPECTATIONS

VS.

REALITY
It takes effort and training...

- Attitude
- Culture
- Expectations
A Project
Within a
Project
Staging

- Organized
- Signage
- No Trash
Safety

- Corporate Compliance
- Adaptation
- Teamwork
Takeaways

- Best intentions
- Open mind
- Early and often communication
- Build trust
- Be flexible
Naranjo Civil Constructors

20 years a Tier 1 Contractor with MHFD

10 Riverine Construction crews

38 Years in the Industry
A perfect marriage...
An arranged marriage…
It takes work...

Attitude
Culture
Expectations
Staging

Organized

Signage

No Trash
Safety

Corporate Compliance

Adaptation

Teamwork
A Project Within a Project
Lessons Learned

- Trying new things
A Project Within a Project
A Project Within a Project
## Presentation for 2020 CASFM Conference

### Presentation Web Link

<table>
<thead>
<tr>
<th>Full Presentation Web Link:</th>
<th>Presentation Abstract</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="https://youtu.be/ResfXj19nWc">https://youtu.be/ResfXj19nWc</a></td>
<td>As project teams have evolved to have more specialists at the table, collaboration between all team members becomes critical to a successful design and construction implementation. However, as ecologists who are not always in the driver’s seat when it comes to design or construction, it becomes difficult to voice concerns or speak in “engineer” talk to communicate what elements are necessary for ecology of the site to be successful. What is considered a success for geomorphology or sediment transport does not always equal success for wetland or riparian development – but how can we learn from these mistakes and improve communication between team members? This presentation will discuss the ecologist’s point of view and several example projects where communication or collaboration failed and construction of the projects resulted in a lack of wetland or riparian vegetation success. This includes discussion of the common failures observed, including the term “bankfull” compared to wetland elevations. How can we improve in communicating together to find project solutions that result in successful outcomes for all project goals? How can ecologists improve in discussing elevation and hydrology needs for successful vegetation outcomes? Some recently constructed Mile High Flood District high functioning low maintenance stream projects will be discussed where the different perspectives on the design, bankfull, and wetland development were apparent.</td>
</tr>
</tbody>
</table>

### Presenters

<table>
<thead>
<tr>
<th>Moneka Worah</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Resources Specialist/Principal</td>
</tr>
<tr>
<td>ERO Resources Corporation</td>
</tr>
<tr>
<td><a href="mailto:mworah@eroresources.com">mworah@eroresources.com</a></td>
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<table>
<thead>
<tr>
<th>Mary L. Powell</th>
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<tbody>
<tr>
<td>Environmental Manager</td>
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<tr>
<td>Mile High Flood District</td>
</tr>
<tr>
<td><a href="mailto:mpowell@udfcd.org">mpowell@udfcd.org</a></td>
</tr>
</tbody>
</table>

### Lessons Learned

- COMMUNICATE EARLY AND OFTEN
- ESTABLISH GOALS AND HOW TO MEET THEM
- SPEAK UP ON YOUR SUBJECT MATTER
- EQUAL VOICES ON A COLLABORATIVE TEAM
- USE GRAPHICS AND MAPS TO CONFIRM UNDERSTANDING
- RIGHT PEOPLE, RIGHT TIME FOR CONSTRUCTION INSPECTION
Why are the Wetlands Dry?
Lessons Learned When Ecologists Don’t Know How To Be Heard On Multidisciplinary Teams

Moneka Worah
ERO Resources Corporation

Mary L. Powell
Mile High Flood District
Why are the Wetlands Dry?
Lessons learned when ecologists don’t know how to be heard on multidisciplinary teams

Multidisciplinary Teams
Why are the Wetlands Dry?
Lessons learned when ecologists don’t know how to be heard on multidisciplinary teams

<table>
<thead>
<tr>
<th>Common Terms</th>
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<tbody>
<tr>
<td>Flood prone area</td>
</tr>
<tr>
<td>Bankfull elevation</td>
</tr>
<tr>
<td>Inner berm</td>
</tr>
<tr>
<td>Stream bed</td>
</tr>
<tr>
<td>Base flow</td>
</tr>
<tr>
<td>Channel forming flows</td>
</tr>
<tr>
<td>Channel toe</td>
</tr>
<tr>
<td>Rosgen stream type</td>
</tr>
<tr>
<td>Groundwater table</td>
</tr>
<tr>
<td>Wetland bench/terrace</td>
</tr>
<tr>
<td>Saturation zone</td>
</tr>
<tr>
<td>wetland fringe</td>
</tr>
<tr>
<td>Riparian overbank</td>
</tr>
<tr>
<td>Hydrogeomorphic Classification</td>
</tr>
<tr>
<td>Trickle flow</td>
</tr>
<tr>
<td>Top of channel bank</td>
</tr>
<tr>
<td>Mean annual flood</td>
</tr>
<tr>
<td>Below ordinary high water mark</td>
</tr>
</tbody>
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Why are the Wetlands Dry?
Lessons learned when ecologists don’t know how to be heard on multidisciplinary teams

Where Common Terms Intersect

- Flood prone area
- Bankfull elevation
- Inner berm
- Stream bed
- Base flow
- Channel forming flows
- Channel toe
- Rosgen stream type
- Groundwater table
- Wetland bench/terrace
- Saturation zone
- Wetland fringe
- Riparian overbank
- Hydrogeomorphic Classification
- Trickle flow
- Top of channel bank
- Mean annual flood
- Below ordinary high water mark
Why are the Wetlands Dry?
Lessons learned when ecologists don’t know how to be heard on multidisciplinary teams

Communication Successes

Plum Creek at Chatfield State Park
PLUM CREEK CROSS SECTION
(LOOKING DOWNSTREAM)

NOTES:
1. GROWING SEASON FOR GROUNDWATER ANALYSIS RANGES FROM APRIL TO OCTOBER.
2. SEE SITE PLAN (SHT. C-5) FOR SECTION LOCATIONS.
3. SUITABLE TOPSOIL WITHIN GRADING LIMITS SHALL BE STRIPPED, STOCKPILED, AND
   REPLACED AS SHOWN. THICKNESS AND AREA EXTENTS OF SUITABLE TOPSOIL STRIPPING
   WILL BE AS DIRECTED BY ENGINEER. IF INSUFFICIENT QUANTITIES OF SUITABLE TOPSOIL
   ARE AVAILABLE ALONG CHANNELS, THE UPPER PORTIONS OF WEST BENCH EXCAVATIONS
   SHALL BE USED AS SUPPLEMENTAL TOPSOIL.
MAIN CHANNEL WITH BENCH ON OUTSIDE BEND
(LOOKING DOWNSTREAM)
Why are the Wetlands Dry?
Lessons learned when ecologists don’t know how to be heard on multidisciplinary teams

Communication Successes

Sulphur Gulch at Riva Ridge
Why are the Wetlands Dry?
Lessons learned when ecologists don’t know how to be heard on multidisciplinary teams

Communication Challenges

Newlin Gulch at Chambers Road
SECTION A-A'

INNER BERM (TYP.)

BANKFULL

UNDISTURBED GROUND

SELECT RIFFLE MATERIAL

LOW POINT IN CHANNEL CENTER

SELECT RIFFLE MATERIAL SCOUR DEPTH 2.5*D100(mm) MINIMUM
Why are the Wetlands Dry?
Lessons learned when ecologists don’t know how to be heard on multidisciplinary teams

Communication Challenges

First Creek Upstream of Tower Road
Why are the Wetlands Dry?
Lessons learned when ecologists don’t know how to be heard on multidisciplinary teams

West Fork Second Creek

Communication Challenges
Why are the Wetlands Dry?
Lessons learned when ecologists don’t know how to be heard on multidisciplinary teams

Communication Successes

Cherry Creek at Iliff
Lessons Learned

- Communicate early and often
- Establish goals and how to meet them
- Speak up on your subject matter
- Equal voices on a collaborative team
- Use graphics and maps to confirm understanding
- Right people, right time for construction inspections
Why are the Wetlands Dry?
Lessons learned when ecologists don’t know how to be heard on multidisciplinary teams
The only mistake in life is the lesson not learned.

Albert Einstein
Learning from
Timbers Creek Douglas County
What not to do when you see this?
1. Buried concrete structures throughout reach.

2. Large amounts of aggradation. No defined active channel.
Lesson Learned 1
Stable Stream Network
Hydrology

Stable Stream Network
Stable Stream Network

Hydrology
Hydraulics
Stable Stream Network

Hydrology

Hydraulics

Geomorphology
Stable Stream Network

Hydrology

Hydraulics

Geomorphology

Vegetation Community
Stable Stream Network

- Hydrology
- Hydraulics
- Geomorphology
- Vegetation Community
- Human Connection
Stable Stream Network

Hydrology
Hydraulics
Geomorphology
Vegetation Community
Human Connection
Lesson Learned 2
SILOED DESIGN APPROACH

- Project Begins
- 30% Plans
- 60% Plans
- 90% Plans
- LA/Env. Contractor Selection
- Construction Starts

*Slide Credit: Ryan Taylor/Muller
ENGAGE A MULTI-DISCIPLINE TEAM
Large Scale Geomorph Reaches Source Transport Response Geomorphic Zones
Bedrock Present eSEM Stages

1B – Bedrock Degrading

2B – Bedrock Uni-lateral Widening

3B – Bedrock Degrading + Widening
Single Thread eSEM Stages

3S – Degrading + Widening

4S – Aggrading + Widening

5S – Quasi-Equilibrium
Anastomosed eSEM Stages

AG – Anastomosed Grassland

AF – Anastomosed Forested
The Balance of Sediment and Water in Streams

- **Sediment size**
- **Bed-material discharge**
- **Bed slope**
- **Discharge**

- **D_{50}**
- **S**

- 500 coarse
- 0.01 fine
- 0.001 flat
- 0.1 steep

- **Degradation**
- **Aggradation**
Flow Variability

Bed Material Size

Stable Intermediate Flashy

Boulder Cobble Gravel Sand

Low Stream Response Potential

Our Reality High
Upstream Reach Sediment Transport Model

Figure 29: Sediment transport capacity balance plot using Brownlie (1981), 14 Reaches, and Version 1 (Orange) and Version 2 (Blue) data inputs for $Q_{50}$ event.
Stable Stream Network

Hydrology
Hydraulics
Geomorphology
Vegetation
Community
Floodplain - High Elevation

In the middle and lower reaches of the project area, a rare dry, semi-floodplain was observed adjacent to Timbers Creek. Typically the edges of stream systems have perennial riparian vegetation located along the edge of the channel, but this was not observed in these sections of the creek. Enrichment of riparian species in the floodplain typically occurs when riparian species inhabits a floodplain due to natural flows of water. This particular section of Timbers Creek, within the project area, has been altered by man-made interventions including grading of the stream bed, and the addition of permanent structures within the channel. These interventions have impacted the ecosystems within and adjacent to the channel.

Floodplain - Low Elevation

Wide floodplains were observed on site in multiple locations along Timbers Creek, with the two largest floodplains occurring upstream of major road crossings. Typically these floodplains would have provided habitat for many deciduous riparian trees and shrubs, but the wide floodplains observed on site had little diversity of this vegetation type. The floodplains on site were dominated by grasses, small shruberral wetland shrubland, and ponderosa pine ecosystems at the edges. Typically floodplain systems are continually changing as the stream channel fluctuates through the void areas of the floodplain. As the channel meanders across the floodplain, sand is deposited in bars and along the edge. Slowly these sandy areas are populated with willows, followed by cottonwood trees that help stabilize and hold the soil in place. As flash floods occur, vegetation is removed from the floodplain and the cycle begins again.

Riverine Wetlands

The channel, or the path of flowing water and sediment within a stream system, is present in any waterway with water flowing seasonally and/or year-round. Natural channels are constantly evolving and moving depending on the streamflow, sediment loads, floodplain slopes, and vegetation. Because this is generally the most consistent part of a stream system with water flowing within it, it is the channel zone. Natural channel systems typically do not have a straight and narrow path, but rather weave in and out of the landscape, changing course as water floods onto banks, and deposit on floodplains.

Upland - Shortgrass Prairie

The upland shortgrass prairie vegetation zone was present on the site in pockets within open areas of the ponderosa pine parkland zone, as well as reaching down to the channel in the lower elevations of Timbers Creek. Upland shortgrass prairie ecosystems are dry, warm, and sunny during the summer months, and much cooler during the winter months. Rainfall is relatively low, and vegetation in this zone is adapted to lower moisture and windy conditions. Shortgrass prairie ecosystems can thrive in a wide variety of landscapes, and were observed on the project site on flat areas, rolling hills, and steep-sided hillocks. The vegetation in this ecosystem is crucial in holding valuable soils in place when storm events and windy conditions occur on site. This soil-stabilizing aspect of shortgrass prairie systems is very important to maintain the stability of the varying slopes along Timbers Creek.

Upland - Ponderosa Pine Overstory

Upland - Ponderosa Pine Lowerstory

The upland ponderosa pine park vegetation zone includes areas above the floodplain and channel, and is entirely located within the woodland areas of the project site. The dominant vegetation within this ecological zone includes fire-adapted ponderosa pine (Pinus ponderosa) and shortgrass prairie grass species. This park-like ecosystem is characterized by large open areas of grasses, shrubs, and wildflowers. As the forest density increases the understory begins to lose diversity and becomes more sparse. These ponderosa pine ecosystems are found at elevations from 6000 to 9000 ft on dry mountain slopes and ridges. The large open areas present on site are remnants of historic, natural conditions where a fire regime managed the species diversity.

Off-Channel Wetlands

Off-channel wetlands are naturally found in stream systems in areas where the channel has been abandoned, such as oxbows, side channels, and ponds. These features are constantly being created and abandoned as the water migrates across the floodplain, and changes course. These ecosystems are predominately vegetated by bulrush (Schoenoplectus lacustris), broad-leaved cut-sedge (Syringa officinalis), sedges and rushes.

Floodplain Riparian Fringe

The edge between the channel and the upland areas is typically vegetated with riparian species. Within the project area, riparian vegetation located in the floodplain was observed only in small pockets in wet areas within the channel. Riparian fringes habitat is crucial for stream health, providing not only important habitat for birds, mammals, and reptiles, but this ecosystem also provides benefits to natural stream morphology.
Stable Stream Network

- Hydrology
- Hydraulics
- Geomorphology
- Vegetation Community
- Human Connection
Areas of Concern
Existing Channel
Spectrum of Urbanization

The transect. Duany Plater-Zyberk & Company
Log Grade Control Structure
Clay Cutoff Wall

TYPE 2 GRADE CONTROL STRUCTURE SECTION

- TCE ELEVATION
- CREST ELEVATION
- DROP HEIGHT VARIES, SEE PLAN
- SEE PLAN AND PROFILE SHOTS. FOR CHANNEL INVERT ELEVATIONS
- FLOW SEE PLAN AND PROFILE SHOTS. FOR CHANNEL INVERT ELEVATIONS
- 1" TAN HEAVYWEIGHT POLYPROPYLENE STRAP, 5' O.C.
- WASH IN NATIVE SOIL TO FILL IN VOIDS BETWEEN LOGS
- (3) 18" DIA. LOGS (TYP.)
- COMPACTED CLAY FILL
- WEAVE POLYPROPYLENE STRAPS IN FIGURE 8 PATTERN BETWEEN LOGS
- 6'-0" (MIN.)
- 7'-0" (MIN.)
- 1'-0" (MIN.)
- 2'-0"
Stable Stream Network

- Hydrology
- Hydraulics
- Geomorphology
- Vegetation Community
- Human Connection
ENGAGE A MULTI-DISCIPLINE TEAM

THE DESIGN PROCESS

1. Define the Problem
2. Collect Information
3. Brainstorm & Analyze Ideas
4. Develop Solutions/Build a Model
5. Present Your Ideas to Others for Feedback

Project Goals & Objectives

System Integration
System Collaboration
System Integration

80
$1100/ft

$50,000 Geomorphology/Vegetation for 2 miles

$850/ft
2D Collaboration without Borders

2D Technical Consistency & Recommendations

CASFM: September 30, 2020 – 10:30 to 11 am

Geoff Uhlemann – Michael Baker
Josh Hill - Wood
About the Presenters...

Geoff Uhlemann - PE, CFM, PMP
Michael Baker – Denver, CO
Water Resources Project Manager

Josh Hill - EIT, CFM
Wood – Denver, CO
Water Resources Engineer
2D Collaboration without Borders

2D Technical Consistency and Recommendations
Overview + Rain-on-Mesh Best Practices

2D Result Communication & Use
End products & their use

2D National Efforts
Floodway IPT
Benefits of Collaboration
Rain on Mesh
Best Practices Initiative

1) Consistency among contractors and teams
   Improved product, methodology, & reviews

2) Resources/info for training and reference
   (internal & external)
   Recommendations to FEMA for revised SIDS and refined guidance
Participants & Format

12-meeting series from Dec 2019 – Aug 2020
26 individuals from 7 states (CO, KS, KY, NJ, NY, UT, VA)
~350 hrs
Desired Session Outcomes

- Articulate importance and influence of each topic component
- Share common practice and agree on items that are best made consistent vs non-consequential differences
- Define principles, not processes – allowing flexibility in implementation but with guidance
- Document decisions & resources
1. Model Setup & Basin Delineation
2. Hydrology (Development & Application)
3. Model Detail & Refinements
4. Stormwater & Development Applications
5. Model Settings & Tolerances
6. Model Calibration & Validation
7. 2D Mapping & Rendering
8. Unsteady 2D Floodway
9. Updates to FEMA SIDs
Model Detail & Refinements

◊ Refinement Regions

Channel Refinement Regions

Floodplain Refinement Regions

Urban Refinement Regions

Automate generation of refinement regions by buffering flow accumulation grid lines or hydroflattened areas of DEM
Breaklines

Stream Banks/Centerline
- Mapped Streams → Use Stream Bank Breaklines
- Unmapped Streams → Can use Stream Centerline
- Ensure channel cell faces capture channel Manning’s n.

Roadways/Dams/Embarkments
- Multiple Sources → Review & Manually Edit.
- Use appropriate cell spacing along overtopping features to properly show continuous inundation.
Approximating Structures

- Offset Breaklines
  Not Recommended
- V-Notch Breaklines
- Hydroconnectors

Quickly approximate the hydraulics near structures without defining structure geometry/rating curves.
Terrain Modification

**Bathymetry**

- Depends on level of study
- Base Flow Considerations
  - Bathymetry Incorporated ➔ Add baseflow using lateral hydrographs (for wholly-contained tributaries)
  - No Bathymetry ➔ Remove baseflow from inflow hydrographs
Building Footprints

- Default Approach → Increase Manning’s n
- If flow direction matters, enforce building footprints.
  - Enforce footprints as breaklines
  - Plot floodplains through buildings
2D Floodway
2D Floodway

Flow Checkpoint
Lateral Inflow
Tributary Inflows
1. Mining Recent Events
   aerial coverage/lateral extent
   people capture notable events
   (examples later)

2. Gauge Data (stage & discharge)
   A) Replicate specific event (rain & flow)
   B) Matching Rating Curve
   C) X% NOAA ≈ X% LP-III
Model Calibration & Validation

Hierarchy of Sources

3. Effective Data (stage & discharge)
   A) Along a full reach
   B) Fixed Locations (crossings)

4. Regional Comparison
gauged unit discharges

5. Regression Eqns
   last resort - check within band
do not force to median

---

**Discharge** +

- Duration Distribution CN
- Mesh Alignment
- Restart Files
- Cell Size
- Normal Depth
- Manning’s N Crossing Types

**Knobs to turn**
Model Calibration & Validation
Aerial Validation with Social Media
2D Mapping & Rendering

Mapping Approaches

Figure 5-5: Comparison of Sloping and Horizontal water surface rendering for steep terrain.
Many thanks to MANY ENGINEERS!

Contact: Geoff.Uhlemann@mbakerintl.com
720.653.5928
THE START

• 2D Floodways are difficult to produce and manage
• New technology should be utilized if it creates a better understanding of risk
• FEMA’s Standards were cumbersome for 2D product development and effective use
• Needed more consistency with surcharge calculation approach
01 Water Surface Elevation Grids
02 Conversion to Digital FIRM
03 Interim Guidance for Managers and Engineers
04 Training
WATER SURFACE ELEVATION GRIDS

- Graphical representation of model results
- Benefits and needs for floodplain managers
  - One click for BFEs
  - Will need outreach and training on online viewers and data interpretation
  - Will allow cataloging of historic info
- Benefits and needs for FEMA and partners
  - Eliminate FIS Profiles, FWDT in most cases
  - Eliminates graphical BFEs/labeling, etc.
    (some may still be used for evaluation)
  - FIS becomes narrative, could be digital
  - Grids will need more detailed review process
  - Need LOMC Process
FULL CONVERSION TO DIGITAL FIRM

- FEMA converting would help with consistency
- Will eliminate need for paper FIRM products
  - Panel creation cost reduction
  - Can have draft/prelim/effective available on similar viewers
  - Move to a nationwide format
  - Reduce discrepancies between panels
- Make access easier and improve resolution
- Communities without web capabilities could be worked with one on one
INTERIM DIGITAL DATA FOR FLOODPLAIN MANAGERS AND ENGINEERS
RECOMMENDATIONS UNTIL NATIONAL DATASET DIGITAL

- WSE grids, Depth Grids, DxV Requested
  - Best on web viewer
  - Second Option Map Package
  - WSE Grid standalone for local GIS
- Floodway surcharge grid and floodplain changes for LOMR, and Effective method for 1D interface
- Comparison of pre and post project
- Model stability report

- Effective and revised model with versioning
- Typical spatial data
- GIS map packages
Depth grids were created for the 10%, 2%, 4%, 1%, 1.5%, and 0.2% annual chance flood analysis for all studied streams. These grids show the depth of flooding for an area.

- **1% Depth Grids**
  - Shows the anticipated depth of flooding during a 1% event.
  - Grids are color-coded with the following ranges:
    - 0 - 0.5 ft
    - 0.5 - 1 ft
    - 1 - 2 ft
    - 2 - 3 ft
    - 3 - 4 ft
    - 4 - 5 ft
    - 5 - 6 ft
    - 6 - 7 ft
    - 7 - 8 ft
    - 8 - 9 ft
    - 9 - 10 ft
    - > 10 ft

For related issues, contact ASCOM.
Flood Risk Products for Effective 1D Floodplain Studies

Flood Risk Product Guidelines
Guidance on Producing Flood Risk Products from FHADs

Prepared for:
Mile High Flood District

Prepared by:
Wood Environment and Infrastructure Solutions
2900 S. Quebec Blvd Suite 2-1000
Denver, CO 80222

Figure 1 – FHAD to Flood Risk Products

Figure 12 – Mapped Flood Severity Grid

Figure 15 – Percent Annual Chance Output - Example View

Legend
- High: 70.6
- Medium
- Low
- Very Low
- Extreme
DIGITAL DATA USE BY ENGINEERS

• Trainings for output manipulation of required grids.
• Ability to “check out” part of a large model still an issue.
• Transitioning from effective 1D models and floodways
SUGGESTED APPROACH
AND TRAINING

Recommendation
• WSE grids as regulatory products is recommended as an immediate step.
  - This change does not require a revision to current regulatory products, it is just an addition of a new one.
  - This will create a mandatory tool that will help with all of the items identified in the analysis above.
  - Will need to be generated in many areas.
  - C2DC asks that FEMA allow the publication of WSE grids in addition to or instead of water surface profiles based on floodplain manager preference.

• Move toward regulatory digital flood hazard layers instead of FIRMs.
  - Access to a universal platform, such as the NFHL, for information is recommended.
  - A method to view historic and superseded information is also recommended. Create revised quality standards, such as floodplain boundary standards, that can be applied to 2D results.

• Pursue outreach and develop training documentation and references related to the use of all digital products

• Develop a more effective check in/check out and quality assurance processes for model and map revisions. This needs to include storage and size considerations.
During floodplain mapping the raw hydraulic results are cleaned, filling small holes and connecting disconnected flow. During this process floodplains were also manually inspected comparing results with terrain.

**Preliminary Floodplains**
- Regulatory Floodway
- Administrative Floodway
- A (1% Annual Chance, 100 Year Floodplain)
- AE (1% Annual Chance, 100 Year Floodplain)
- AO (1% Annual Chance, 100 Year Floodplain)
- AH (1% Annual Chance, 100 Year Floodplain)
- 1% Depth < 1 ft
- X (0.2% Annual Chance, 500 Year Floodplain)
- Reduced Risk Due to Levee

**NFH Flood Hazard Zones**
- FEMA National Flood Hazard Layer
  - 1% Annual Chance
  - Regulatory Floodway
  - Special Floodway
  - Undetermined
  - 0.2% Annual Chance
  - Future Conditions 1% Annual Chance
  - Reduced Risk due to Levee
Best Practices for FPMs. Determine a BFE with no profile.

GIS data, use and symbology. Insurance.

Common pitfalls/issues to look for before signing MT2. Review of model stability/convergence.

When is 2D Beneficial? What to review for 2D?

What to request for 2D? What non-regulatory Products are used for?

How to read a BFE from 2D results? How to fill out elevation certs or permit using 2D results?

How to manage without a floodway. General Floodway Training. How effective data is filed.

How to transition or interface 2D with effective 1D models and floodways.

Trainings
Thank You!

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Thuy Patton, CFM
Thuy.patton@state.co.us

Rigel Rucker, PE, CFM
Rigel.rucker@aecom.com
Methods for Delineating and Evaluating Floodways in 2D Models

2020 CASFM Virtual Conference
Technical Session: 2D Modeling

September 30, 2020
Scott Hogan, P.E., Federal Highway Administration

Image by John Gussman
Background

• FHWA started using 2D modeling for complex bridge hydraulics in 1988
• In 2012 FHWA’s reference documents (HEC-18, HDS-7) recommended 2D modeling for bridge hydraulics and scour analysis
• FHWA partnered in 2013 with the US Bureau of Reclamation in the ongoing development of SRH-2D for transportation hydraulics and initiated a graphical user interface in SMS (by Aquaveo)
• The application of 2D models for floodway delineation and assessment was not clearly defined.
• In 2018, a Colorado floodway workgroup was initiated and ultimately provided recommendations to FEMA
• In 2019, FEMA formed an Interagency Project Team (IPT) to update the standards and guidelines for 2D modeling
Overview

• 1D versus 2D modeling assumptions that affect floodway development
• Evaluating surcharges in a 2D model
• Two methods for delineating floodways in 2D models
## 1D versus 2D Modeling Assumptions

<table>
<thead>
<tr>
<th>Hydraulic Variables</th>
<th>One-dimensional (1D) Modeling</th>
<th>Two-dimensional (2D) Modeling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow direction</td>
<td>Assumed by user</td>
<td>Computed</td>
</tr>
<tr>
<td>Flow paths</td>
<td>Assumed by user</td>
<td>Computed</td>
</tr>
<tr>
<td>Water surface elevation</td>
<td>Assumed constant across cross sections</td>
<td>Computed at each element</td>
</tr>
<tr>
<td>Flow velocity</td>
<td>Averaged at each cross section</td>
<td>Magnitude and direction Computed at each element</td>
</tr>
<tr>
<td>Flow distribution</td>
<td>Computed based on conveyance</td>
<td>Computed based on continuity</td>
</tr>
<tr>
<td>Channel roughness</td>
<td>Assumed constant between cross sections</td>
<td>Represented at each element</td>
</tr>
<tr>
<td>Ineffective (blocked) flow areas</td>
<td>Assumed by user</td>
<td>Computed</td>
</tr>
<tr>
<td>Flow contraction and expansion through bridges</td>
<td>Assumed by user</td>
<td>Computed</td>
</tr>
</tbody>
</table>
Case Study Project Example: Elkhorn River NE

- $Q_{100} = 86,000$ cfs
- ~9 mile reach
- Floodplain is 1.5 – 3 miles wide
- Project objective: US30 road/bridge improvements
Case Study Project Example: Elkhorn River NE

- $Q_{100} = 86,000$ cfs
- ~9 mile reach
- Floodplain is 1.5 – 3 miles wide
- Project objective: SR30 roadway/bridge improvements
- Mesh developed using new feature delineation tools in SMS
- ~87,000 elements (3 ft – 200 ft)
- Calibrated to HWM data
- Model runtime (CPU) = 12 minutes (20 hour steady state sim)
Evaluating Surcharges with Evaluation Lines

SMS Tools / Process

• Display linear WSEL Contours at desired spacing

• Save As .shp file (Mesh Contours -> Arc Shapefile)

• Open new shapefile and convert it to a 1D XS coverage

• Define a centerline (for stationing)

• Generate a Summary Table of average WSELs for each scenario

• Compare results
Current Effective 1D Floodway Modeled in 2D

Image Source: Nebraska Department of Highways / FEMA Flood Hazard Map
Current Effective 1D Floodway Modeled in 2D

SMS Tools / Process

- Floodway corridor defined in materials coverage
- The materials outside of floodway boundary are ‘disabled’ using an unassigned material type
- Simulation is rerun
- Results are compared
Current Effective 1D Floodway Modeled in 2D

- In many cases the floodway surcharges estimated with a 2D model for current effective 1D floodways are higher than predicted with the 1D model.
Evaluating Surcharges in a 2D Model (1D Floodway)

Floodway Surcharge Summary

<table>
<thead>
<tr>
<th>Q100 Base Flood Evaluation Lines</th>
<th>Current Effective 1D Floodway in 2D</th>
</tr>
</thead>
<tbody>
<tr>
<td>WSEL Ave (ft)</td>
<td>WSEL Ave (ft)</td>
</tr>
<tr>
<td>1158.00</td>
<td>1159.82</td>
</tr>
<tr>
<td>1160.00</td>
<td>1162.08</td>
</tr>
<tr>
<td>1162.00</td>
<td>1163.28</td>
</tr>
<tr>
<td>1164.00</td>
<td>1165.72</td>
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<td>1166.00</td>
<td>1166.96</td>
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<tr>
<td>1168.00</td>
<td>1168.75</td>
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<td>1170.00</td>
<td>1170.45</td>
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<td>1172.00</td>
<td>1172.27</td>
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<td>1174.00</td>
<td>1174.42</td>
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<td>1176.00</td>
<td>1177.36</td>
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<td>1179.13</td>
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<td>1180.00</td>
<td>1180.89</td>
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<td>1182.79</td>
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<tr>
<td>1184.00</td>
<td>1185.44</td>
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<td>1186.00</td>
<td>1188.25</td>
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<td>1188.00</td>
<td>1190.62</td>
</tr>
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<td>1190.00</td>
<td>1191.75</td>
</tr>
<tr>
<td>1192.00</td>
<td>1193.80</td>
</tr>
</tbody>
</table>

Image Source: Nebraska Department of Highways
Two Methods for Delineating 2D Floodways

1. Equal Discharge Reduction
2. Unit Discharge (Depth x Velocity)
Equal Discharge Reduction Floodway Delineation

- Most consistent with 1D Equal Conveyance method
- Flow area is removed from either floodplain limit, based on equal discharge reduction, until a target rise is achieved
- Cross sections are required for evaluation, but alignment is not critical

SMS/SRH-2D Tools and Process
- Define channel centerline and banks
- Add reference cross sections
- Select Encroachment Method and appropriate data set and target surcharge
- An initial FW boundary and materials coverage are automatically generated
- Run encroachment simulation
- Review/compare results

Image Source: Nebraska Department of Highways
Equal Discharge Reduction Method Results

Floodway Surcharge Summary

<table>
<thead>
<tr>
<th>Q100 Base Flood Evaluation Lines</th>
<th>Equal Discharge Reduction Floodway</th>
</tr>
</thead>
<tbody>
<tr>
<td>WSEL Ave (ft)</td>
<td>WSEL Ave (ft)</td>
</tr>
<tr>
<td>1158.00</td>
<td>1158.70</td>
</tr>
<tr>
<td>1160.00</td>
<td>1160.55</td>
</tr>
<tr>
<td>1162.00</td>
<td>1161.92</td>
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<td>1188.77</td>
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<td>1190.00</td>
<td>1190.76</td>
</tr>
<tr>
<td>1192.00</td>
<td>1192.80</td>
</tr>
</tbody>
</table>
Unit Discharge Floodway Delineation

- Based on a user specified depth*velocity (DxV) threshold
- A specific unit discharge does not correspond to a specific rise
- Internal DxV ‘Islands’ are excluded
- An iterative process is needed to identify the unit discharge that corresponds with the desired rise

SMS Tools / Process
- Select Unit Discharge Method and appropriate data sets
- Set target Unit Discharge threshold
- An initial FW boundary and materials coverage are automatically generated
- Run encroachment simulation
- Review/compare results

Image Source: Nebraska Department of Highways
Unit Discharge Floodway Delineation Method

Resulting Surcharge for 2D Unit Discharge FW (5 cfs/ft)

Evaluation Lines

FW Unit Discharge Boundary (5 cfs/ft)

Floodway Surcharge Summary

<table>
<thead>
<tr>
<th>Q100 Base Flood Evaluation Lines</th>
<th>Unit Discharge 2D Floodway (q=5cfs/ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WSEL Ave (ft)</td>
<td>WSEL Ave (ft)</td>
</tr>
<tr>
<td>1158.00</td>
<td>1158.73</td>
</tr>
<tr>
<td>1160.00</td>
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<td>1173.97</td>
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<tr>
<td>1176.00</td>
<td>1176.26</td>
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<td>1182.06</td>
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<td>1184.07</td>
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<td>1188.14</td>
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<tr>
<td>1190.00</td>
<td>1190.08</td>
</tr>
<tr>
<td>1192.00</td>
<td>1192.08</td>
</tr>
</tbody>
</table>

Image Source: Nebraska Department of Highways
Comparison of Floodway Delineation Methods

- FEMA Current Effective 1D Floodway
- Equal Discharge Reduction FW Boundary
- Unit Discharge FW Boundary (5 cfs/ft)

Image Source: Nebraska Department of Highways
Please contact me if you are interested in the following resources:

- 2D hydraulic modeling bi-monthly webinars on 2D modeling best practices
- Floodway modeling updates
- Training resources
- Tutorials and videos

www.fhwa.dot.gov/engineering/hydraulics/bridgehyd/bridge.cfm
2D NATIONAL EFFORTS

CASFM Virtual Conference
September 30th, 2020
Two-Dimensional Floodway Updates

FEMA Updates
Integrated Project Team (IPT)

**Membership**

**Executive Sponsor:**
Luis Rodriguez, FEMA Risk Management Directorate

**Executive Sponsor:**
Rachel Sears, FEMA Mitigation Directorate

**Vice-Chair:**
Laura Algeo, FEMA Risk Management Directorate

**Membership:**
Production and Technical Services (PTS)
Cooperating Technical Partners (CTP)
FEMA Regions
Federal Highway Administration (FHWA)
Colorado 2-Dimensional Consortium (C2DC)
United States Army Corps of Engineers (USACE)
Community Engagement and Risk Communication (CERC)

**Purpose**

- Define how FEMA will evaluate regulatory compliance for floodways developed from 2D models.

**Outcome**

- Define recommendations for short-term changes and additions to existing standards and guidance.
- Define additional recommendations in the long-term for senior leadership on CFR changes.

Slide Source: FEMA, Two-Dimensional Floodway Modeling Presentation, ASFPM 2020
# IPT Goals

## Short-Term (Phase 1)

- **Allowable Approaches**
  
  Determine allowable approaches to define floodway when base analysis has been performed in 2D (1D floodway, steady state equivalent, 2D unsteady only, etc.)

- **Surcharge Compliance Criteria**
  
  Identify floodway surcharge compliance criteria (new floodways and no-rise) that will ensure we meet regulatory descriptions of compliance

- **Guidance & Standards**
  
  Other 2D guidance/standards updates needed for how to display the results; such as profiles, Floodway Data Tables (FDT), Base Flood Elevation (BFE) on Flood Insurance Rate Maps (FIRM), etc.

- **Training Needs**
  
  Identify training needs for floodplain managers to effectively administer and manage floodplains and floodways developed from 2D models

## Long-Term (Phase 2)

- **Revisiting Encroachment-Based Floodway**
  
  Alternatives to encroachment-based floodway that still help effectively manage floodplain development

- **Code of Federal Regulations (CFR)**
  
  Definition of path to accomplish CFR changes
The monthly FEMA Engineering and Mapping Community of Practice meetings will announce the Public Review Periods to highlight internal/external comment collection on proposed revisions to identified Guidance & Standards.
IPT Future Considerations

- Testing Floodway Alternatives
- Pushing New Tools to Expedite 2D Floodway Analysis
- Continue identifying needed long term updates and best practices

Slide Source: FEMA, Two-Dimensional Floodway Modeling Presentation, ASFPM 2020
THANK YOU!

QUESTIONS?

Isaac Allen
Water Resources Engineer
AECOM, a member of the Compass PTS JV
Isaac.allen@aecom.com
LAFAYETTE-LOUISVILLE BOUNDARY AREA DRAINAGE IMPROVEMENTS
SEPTEMBER 21, 2017

CASFM
2017 Project Awards Presentation

OLSSON ASSOCIATES | STREAM DESIGN LANDSCAPE ARCHITECTURE | UDFCD | CITY OF LOUISVILLE | CITY OF LAFAYETTE
Sharing what we learned about trying to “naturalize” a confined system, and an interesting comparison of two contractors working side by side on the same project.

• Going to share a pair of stories from a project that was up for the CASFM Award back in 20XX. During this project we had to present to the various open space advisory boards, and a common concern we heard was that we were going to build a bunch of concrete lined channels. I’m not sure where they would ever get the idea that I like concrete lined channels. No idea where that comes from….and yes, for those of you that haven’t seen me present before….that was a joke.

• Although we try and mimic natural stream processes wherever we can, we can’t be ignorant of the contexts we’re working in. There is still a time and a place for sticking pipes in the ground – hopefully only in urban retrofit situations, but if that’s one end of the spectrum then a full HFLMS design is on the other end of the spectrum. [example photos Dahlia, First Creek] AND there are situations in between these two extremes. I’m going to talk about a project where we might’ve tried too hard to be on the naturalized end of the spectrum, given the context we were working in.

Context and Problem Statement

• Funny video of me caressing a concrete baffle block

• 6 to 8 feet thick topsoil

• Boulders with gingivitis

• Two Contractors

• Construction Lessons Learned – the audience will care about this topic because we have some fuel for the fire if they are looking for arguments about why lowest bid isn’t always the best way to go. Providing them with backup to use if they want to improve their own processes, to better control who gets to bid on their work.

• We measured some aspects of construction that don’t often get measured (Mark’s contractor comparison table). Convert table into infographics (Stephanie).

• Ball valves on water services – not the right type of valve.

• Tightening the bolts on megalugs – when we dug up a water line they had installed, the bolts weren’t even broken off like they should’ve been.

• Redesign because of a misaligned sanitary sewer line.

• How long Short Street was torn up versus how long residents were told it would be torn up.

Post Construction Lessons Learned

• Steepness

• Confinement

• Loose rock structures – shouldn’t be 2’ tall

• Lack of water – all soaked in without any other pitfalls for 2 miles.

• There wasn’t even enough water for any of the channel but the very end to be jurisdictional. With a fully built out watershed, at least what would get built out, this ended up mattering.
Pre-Project
2.2 FT HIGH GROUTED BOULDER DROP STRUCTURE
SEE SHEET DT8 FOR DETAILS

2.2 FT HIGH GROUTED BOULDER DROP STRUCTURE
SEE SHEET DT9 FOR DETAILS

1 FT HIGH DROP STRUCTURE
SEE DETAILS ON SHEET DT5
2.2 FT HIGH GROUTED BOULDER DROP STRUCTURE
SEE SHEET DT8 FOR DETAILS

1 FT HIGH DROP STRUCTURE
SEE DETAILS ON SHEET DT5
Over 1 mile
LOUISVILLE
Gaps
HighEST Functioning and LowEST Maintenance given the CONTEXT

What’s realistic?

Confinement, lack of water, fine material, channel slope
A Tale of Two Contractors: Lessons Learned from a $9 Million Drainage Project

Introduction
The City of Louisville, along with the Lousiville Drainage and Flood Control District (LDFCD) and City of Louisville, undertook a drainage improvement project with the purpose of significantly reducing the '100 year Rainfall' in downtown Louisville. Olsson constructed the design and construction engineering services for the drainage improvement project. The project consisted of three separate sections in downtown Louisville: Consulting drainage engineers to assess the risk of flooding and design solutions. To ensure the project was completed within the allocated budget and timeline, Olsson collaborated closely with the client and other stakeholders.

Phase I: Construction
- Construction of approximately 12,000 linear feet of new drainage improvements, including the installation of 1,000 linear feet of new pipe along the banks of the Ohio River.
- Installation of new drainage systems to manage stormwater runoff and prevent flooding.

Phase II: Construction
- Construction of approximately 12,000 linear feet of new drainage improvements, including the installation of 1,000 linear feet of new pipe along the banks of the Ohio River.
- Installation of new drainage systems to manage stormwater runoff and prevent flooding.

Results
During the project, Contractor I lived up to the expectations, completing the work within the scheduled time frame and staying within budget. Contractor II, on the other hand, faced difficulties in meeting the project requirements and incurred additional costs.

Notable Observations
- Contractor I was proactive in communicating with the clients and stakeholders, ensuring smooth project progress.
- Contractor II had difficulty managing the project scope and encountered unexpected challenges, leading to extra costs.

Contractor Comparison Summary

<table>
<thead>
<tr>
<th></th>
<th>Contractor I</th>
<th>Contractor II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Bid</td>
<td>$3,569,146</td>
<td>$3,434,558</td>
</tr>
<tr>
<td>Next closest bidder</td>
<td>$3,983,111</td>
<td>$3,632,942</td>
</tr>
<tr>
<td>Increase in Cost from Change Orders</td>
<td>$96,381</td>
<td>$143,889</td>
</tr>
<tr>
<td>Total Cost After Contract Changes</td>
<td>$3,664,527</td>
<td>$3,578,247</td>
</tr>
<tr>
<td>Final Cost</td>
<td>$3,664,527</td>
<td>$3,122,921</td>
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<td>Value of Removed and Uncompleted Work</td>
<td>0</td>
<td>($455,326)</td>
</tr>
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<td>Notice to Proceed</td>
<td>1/20/2016</td>
<td>2/8/2016</td>
</tr>
<tr>
<td>Original number of contract work days</td>
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<td>130</td>
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<td>Number of days contract was extended</td>
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<td>31</td>
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<td>Weather Days</td>
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<tr>
<td>Field Orders</td>
<td>5</td>
<td>11</td>
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<tr>
<td>Overtime Requests</td>
<td>0</td>
<td>2</td>
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<tr>
<td>Requests for Information</td>
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<td>20</td>
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<tr>
<td>Submittals</td>
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<td>Avg. Reviews/Submittals</td>
<td>1.2</td>
<td>1.6</td>
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<tr>
<td>Change Orders/Work Change Directives</td>
<td>10</td>
<td>34</td>
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<td>Average Cost/Contract Change</td>
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<td>$2,307</td>
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<td>Pay Applications</td>
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<td>Avg. Reviews/Pay Application</td>
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<td>Number of Project Manager Changes</td>
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<td>Number of Superintendent Changes</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Number of Foreman Changes</td>
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<td>3</td>
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<td>Number of Email Correspondence</td>
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<td>Number of Emails per day</td>
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<td>14.0</td>
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<td>Public Complaints</td>
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<tr>
<td>Safety Concerns</td>
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<td>13</td>
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<td>Quality Issues</td>
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<td>17</td>
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<tr>
<td>Punchlist Items</td>
<td>57</td>
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<tr>
<td>Total Engineer's Time Spent</td>
<td>1,318</td>
<td>1,739</td>
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<tr>
<td>Average Engineer's Time Spent/Day</td>
<td>4</td>
<td>8</td>
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<tr>
<td>Total Value of Engineer's Time</td>
<td>$135,348</td>
<td>$175,235</td>
</tr>
<tr>
<td>Average Value of Engineer's Time/Day</td>
<td>$403</td>
<td>$776</td>
</tr>
</tbody>
</table>
Personnel Changes

2 Project Manager Changes

I'M NOT QUITTING
I'M JUST NOT GOING TO GO ANYMORE
Change Order Requests

10

Contractor I

34

Contractor II
Contractor Requests

- Contractor I: 5
- Contractor II: 11

Field Orders
Reviews per Pay App

1.5  
Contractor I

4.1  
Contractor II
Emails per Day

- Contractor I: 6.4
- Contractor II: 14.0
Engineering Cost per Day

- Contractor I: $403
- Contractor II: $776
$455,326
Value of removed and uncompleted work for Contractor II
A Tale of Two Contractors: Lessons Learned from a $9 Million Drainage Project

Introduction
The City of Louisville, along with the Urban Drainage and Flood Control District (UDFCD) and City of Louisville, undertook a drainage improvement project with the purpose of significantly reducing the 100-year floodplains in downtown Louisville. Olson Construction provided design and construction engineering services for the drainage improvement project. The project included the sheet drain system in downtown Louisville, constructed in a single-phase approach on 2.5 acres of property. The sheet drain system consists of 12-inch, 15-inch, and 18-inch diameter vertical cleanout pipes. Due to the anticipated timing of revenue by neighboring utilities, the project was split into two phases for bidding and construction.

Phase I: Construction I - First Contract
- Construction of 7,500 linear feet of sheet drain system from downtown Louisville to Old Creek, including three separate trench improvements.
- Construction of sheet drain system in downtown Louisville and Old Creek, including five separate trench improvements.
- Construction of three separate trench improvements in downtown Louisville.
- Construction of 10-inch sheet drain in downtown Louisville and Old Creek.
- Construction of 12-inch, 15-inch, and 18-inch diameter vertical cleanout pipes.

Phase II: Construction II - Second Contract
- Construction of 1,500 linear feet of sheet drain system from downtown Louisville to Old Creek, including three separate trench improvements.
- Construction of sheet drain system in downtown Louisville and Old Creek, including five separate trench improvements.
- Construction of three separate trench improvements in downtown Louisville.
- Construction of 10-inch sheet drain in downtown Louisville and Old Creek.
- Construction of 12-inch, 15-inch, and 18-inch diameter vertical cleanout pipes.

RISKS
During the last process, Contractor I stood out as the top choice for Phase I. Contractor I was the low bidder, ran a history of quality work in Colorado, and the sponsors were familiar with their past work. Not for their low price but a higher than expected, with Contractor I being the only bidder over the engineer's estimate for Phase I. Neither the project sponsors nor Olson staff were aware of any other Colorado projects completed by Contractor I. Despite the lack of history of successful work, Contractor I was selected as the low bidder.

Contractor Comparison Summary

<table>
<thead>
<tr>
<th>Contractor</th>
<th>Initial Bid</th>
<th>Next closest bidder</th>
<th>Increase in Cost from Change Orders</th>
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<th>Final Cost</th>
<th>Value of Remote Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contractor I</td>
<td>$3,569,146</td>
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<td>$3,664,527</td>
<td>($455,326)</td>
</tr>
<tr>
<td>Contractor II</td>
<td>$3,434,558</td>
<td>$3,632,942</td>
<td>$143,889</td>
<td>$3,578,247</td>
<td>$3,578,247</td>
<td></td>
</tr>
</tbody>
</table>

Notice to Proceed Date: 2/20/2016
Date of Completion: 2/28/2016

The Effective Client
Why Being a Good Client Is Smart Business in the Architecture, Engineering, and Construction Industries
David Skuodas

Average Value of Engineer's Time/Day: $403
Total Value of Engineer's Time: $175,235

Lessons Learned from a “Small Project”

House flooded seven times in 17 years, records show house was built 12” lower than it should have been based on the original drainage study.

Crawl space constructed below grade but with vapor barrier, garage and living room slab on grade and less than required 18” inches above gutter flow line.

Nearly 100 acres drained to a single inlet and 24” pipe.
Project designed street-width gallery inlets and new 34” elliptical pipe threaded between other utilities.

Design took just a few months and construction took just over seven weeks including several weather days.

After a large rain in early July, the homeowner called us to say how pleased she was with the improvements and the project.
An afternoon storm on August 10th brought 1.5” rain in the first 15 minutes, 2” overall

Floatable debris at fence, high water line in garage and homeowner stated water in living room. Neighbors said water knee/thigh deep in street and they cleared debris from inlets.

I shifted to forensic engineer mode, trying to gather information and determine cause. Neighbors and homeowners were upset and needed to vent.
Further investigation found construction per plan except for fence, bottom designed 18” above grade, constructed at 6”. Homeowner request to fence sub, City inspector and prime may have known, no engineers were aware

One design flaw was exposed in the review, the back fence should have also had an opening to allow water to continue to flow and not pond in the yard.

Post-storm flow modeling showed changes to fence would allow a 10-year flow in pipe, and up to 100-year flow in swale through yard before water would impact the house. This was the original level of protection intended.

Design engineering firm, prime contractor and City each paid 1/3 of cost to repair damages.
Takeaways

- Take the time to explain design to ALL who are impacted long term, and ALWAYS get an agreement in writing.

- Don’t forget your sympathy/empathy, be able to take some venting and still be kind.

- Solutions don’t have to be perfect, know when to say good enough.
Thanks for sending me an email asking me to do something for you that it would have taken less time for you to do than it took for you to send me an email.
Long email so I included a couple summary comments at the start. We definitely are sensitive to the costs and inconvenience of excessive routine maintenance so it is being considered as we go through the design. While it is impossible to entirely eliminate some types of maintenance that are connected to a multi-purpose facility such as the Little Dry Creek Park. It’s also unrealistic to compare the required level of maintenance to a park that is located entirely outside of 100 year floodplains. Additionally, there are recreational benefits to consider that can be achieved in multi-purpose facilities that can’t be achieved elsewhere. We have an intelligent and experienced design team that is supported by intelligent and experienced City, County, and USFCD staff. I suggest we schedule a few meetings over the next 3 months to specifically discuss operations and maintenance so we can collectively identify the specific concerns and develop solutions which minimize the anticipated level of maintenance. Let us know how we can help to get those discussions started.

I also provided some detailed responses to Item 4 of Item 4 that have identified. Ultimately, we recognize that you get to a place where the staff responsible for maintenance is comfortable with the design that is being proposed. I just wanted to assure you that many of the problems Item 4 and Item 4 are dealing with are already being evaluated by our design team and we continue to work towards acceptable solutions.

- High water events result in a debris field. Within landscaped areas it will require raking, removal, and disposal. Within native areas you may be able to selectively decide where to remove the debris and when to leave it in place. We view this as a minor level of maintenance effort.
- Routine trash and debris. We’ve seen several storms pass through the site over the last few summers and it results in a high level of trash and debris. This debris will attach to trees, shrubs, railings, structure grates, etc. and will occur even if the debris pond is not storm water. There is very little that can be done to correct the problem outside of controlling the trash and debris at the source or upstream of the project. Within our design we are trying to incorporate storm water collection systems through a water quality treatment system. This will isolate the trash to specific locations within the park for collection and removal. It will not address trash and debris from the upstream portion of Little Dry Creek itself. On both Federal Boulevard culverts we are not installing trash rails subsequently less trash and debris will be retained on site as the current condition of the pond is too low to fill due to the result of clogging or siltation in the maintenance ditches on the vegetation should be avoided. Again, reestablishing and disposing of trash and debris after a storm event is a minor level of maintenance.
- With regard to structures, we know that all structures within the lower pond will be subjected to bentonite fines and will need special design attention. Most will need to be fixed, including trash cans, benches, and irrigation boxes, and so on. We should be able to address many of these concerns with proper design.
- Landscape materials. We aren’t planning to propose widespread use of floating surface cover treatments within the lower portions of the ponding limits. Especially with the low flow rates. We recognize it floats and will not wash away. There may be a few isolated areas where we may recommend the use of mulch around the station but we could design those to be relatively small and high within the ponding limits and design channel flows. The majority of these concerns can be minimized or eliminated through proper design.
- Sediment on trails. Most trails are designed to run parallel to the Creek and be higher on the banks. In locations were direct flows pass over the trails we will incorporate a low wall design along the edge of the trail to reduce the potential of trail erosion during larger events. We also are designing major cuts within the trail layout where large amounts of sediment could accumulate. That said, some sediment deposition should be anticipated during ponding events.
- Lower Network adjacent to the station. We think it is important to include design elements that provide access to the Creek. In the case around the station this means that after larger flow events, portions of the Network will need to be swept or washed clean. We don’t view this to be a high level of maintenance as compared to the recreational value provided, but if City staff believe otherwise we can easily eliminate the access near the lower portions of the Creek.
- Irrigated turf maintenance. The concern is tough to quantify. A couple of things, we have been doing. We should be able to achieve good infiltration within the turf grass areas. The sodros indicate the turf grass elevations are within the range of 6 to 12 inches from established and seeds are good. During construction if we encounter more than 6 inches we can easily over sow the area by 1 1/2 inches and replace it with new sods and seeds. Also consider that the lower elevations of the turf grass are 6 to 12 inches above the normal permanent pool water surface level of the ponding so frequent ponding over the turf grass connected to smaller storm events won’t be an issue. The sediment deposition connected to flows that breach the channel banks need to be considered. The area will be irrigated so we could incorporate quick contacts into the system so that manageable levels of sediment can be easily washed into the turf grass. Some sediment loading shouldn’t be harmful. It’s deep deposits over poor draining soils that could cause problems. Again, we believe there are things we can do to minimize the level of maintenance of these turf zones and still be able to provide the desired recreational value.
- With regard to bank stabilization and erosion control, we’ll do the best we can to design a reliable system that is generally free erosion.
- Finally, the lower Network area within the pond limits such as parking lots, Creekside trails and the pedestrian pathways. It is true that if this ponding reaches the 100 year and above level, sediment deposition will occur in these areas and need to be removed. For this level of storm, this is minor maintenance that would have to be performed compared to the anticipated much larger flood damage to respond to elsewhere in the basin.
GROUTED RIPRAP

Wait...that is not what I designed!
• Client:
  • Municipal Maintenance Division
  • Self Perform the work
  • Desires Hard Improvement
• Problem
  • Sediment Accumulation
  • Floodplain issues
• Vegetated Void-filled Riprap lining
• NOT Vegetated VFR Lining
August, 2011
Thunderstorm
August, 2011
Thunderstorm
Stuck in the details! ✭
Missed the big picture.

Keep it simple.
Missed the big picture.

Keep it simple.
Missed the big picture.

Keep it simple.
Lessons Learned

- Design:
  - Step back
  - Evaluate the Big Picture

- Project Management:
  - Get team buy-in
  - Ownership in “new” approach
  - Manage for success
LEGAL ACTIONS

LESSONS LEARNED
EXAMPLE CASE

BACKGROUND

IT WILL FEEL PERSONAL

LEGAL PROCESS

FOCUS ON THE FACTS
CDOT REGION 4 2D MODELING REVIEW AND THE D-27-G BRIDGE REPLACEMENT

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970-350-2338

Anthony Alvarado, PE, CFM
Ayres, Hydraulics
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970-797-3501
TOUR OF COMING ATTRACTIONS

- History of 2D Models
- 2D Advantages
- 2D Challenges
- Common Pitfalls and the QC Review process
- Case Study – Wray, CO
HISTORY OF HYDRAULIC MODELING

SOURCE: FHWA TWO-DIMENSIONAL HYDRAULIC MODELING FOR HIGHWAYS IN THE RIVER ENVIRONMENT
## THE 2D ADVANTAGE

<table>
<thead>
<tr>
<th>Hydraulic Variables</th>
<th>1D Modeling</th>
<th>2D Modeling</th>
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</thead>
<tbody>
<tr>
<td>Flow direction</td>
<td>Assumed by user</td>
<td>Computed</td>
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<tr>
<td>Flow paths</td>
<td>Assumed by user</td>
<td>Computed</td>
</tr>
<tr>
<td>Channel roughness</td>
<td>Assumed constant between cross sections</td>
<td>Roughness values at individual elements used in computations.</td>
</tr>
<tr>
<td>Ineffective flow areas</td>
<td>Assumed by user</td>
<td>Computed</td>
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<tr>
<td>Flow contraction and expansion through bridges</td>
<td>Assumed by user</td>
<td>Computed</td>
</tr>
<tr>
<td>Flow velocity</td>
<td>Averaged at each cross section</td>
<td>Computed at each element</td>
</tr>
<tr>
<td>Flow distribution</td>
<td>Approximated based on conveyance</td>
<td>Computed based on continuity and momentum</td>
</tr>
<tr>
<td>Water Surface Elevation</td>
<td>Assumed constant across entire cross section</td>
<td>Computed at each element</td>
</tr>
</tbody>
</table>
THE PROBLEM

Powerful New Tech

+ New Users

+ New Reviewers

= What Could Go Wrong?
COMMON PITFALLS!

WOODY STREAM ROUGHNESS N=0.011…RIGHT?

BAD TOPO!

COARSE TIMESTEP!

WHERE ARE THE PIERS!?

NON-CONVERGING SOLUTION OF PAIN!

SPECTACULAR HAPPY 2D SOLUTION!
# REVIEW GUIDE TO COMMON MISTAKES

<table>
<thead>
<tr>
<th>Input Review</th>
<th>Review Item</th>
<th>QC Comments</th>
<th>Designer Response</th>
<th>Follow Up Review Item</th>
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<tr>
<td>QC</td>
<td>Boundary Conditions</td>
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<tr>
<td>QC</td>
<td>Upstream Boundary Condition</td>
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<tr>
<td>1</td>
<td>Does the location of the inflow boundary condition seem appropriate?</td>
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<td>2</td>
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<tr>
<td>3</td>
<td>Are the flowrate units correct?</td>
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</tbody>
</table>

**Project (Sub-Account and Description):** 29010 Eastern Timber BR

**Model Run:** 100 yr Existing

**Str # and/or Reach:** G-21-A, Sand Creek

**Review Date:** Nov 11, 2019

**Reviewer:** Steven Griffin, CDOT

**SMS Version:** 13.010

---

**Region 4 Hydraulics Unit**

SMS / SRH-2D Quality Check

Original Form (credit): Clark Barlow, Atkins

Form Revision Number: 1.0

Form Revision Date: November 2019 by Steven Griffin
UPSTREAM BOUNDARY

- Where water enters
- Location
- Data source
- Correct numbers
- Impacts to results
DOWNSTREAM BOUNDARY

- Where water exits
- Location
- Data source
- Elevation Datum
- Correct number
- Impact to results
• Complete coverage
• Reasonable values
• Mesh sampling frequency
TERRAIN

- Elevation Datum
- Merging data sources
- Necessary resolution
- Dealing with missing data
- Check min/ max
MESH

• Extents
  • Upstream / downstream
  • Inundation
• Resolution
• Number of elements
• Mesh quality
  • Size transitions
  • Angles
• Maximum slope
• Holes in the mesh
STRUCTURES

- Vertical faces
- Snapping pressure flow to grid
- Representing piers:
  - Mesh holes (best)
  - Obstructions (ok-ish)
  - Roughness (kind of bad)
  - Neglect (Not OK)
- Culverts and HY-8
DO RESULTS EQUAL ANSWERS?

- Stability and Convergence
- Monitor points
- Monitor Line
- Continuity
- Steady state
RESOURCES

- CDOT Region 4 SRH-2D QC Checklist
- FHWA SRH-2D QC Checklist
- NHI Course 135095
- Bi-Monthly Webinars – Scott Hogan, FHWA
  - https://www.fhwa.dot.gov/engineering/hydraulics/
CASE STUDY: D-27-G

- Timber Bridge replacement
- Wray, CO (Eastern Colorado)
- Assumed Design: Two Span bridge
US 34 BRIDGES OF WRAY
EXISTING CONDITIONS

• Timber Bridge
• Three 24-foot spans
• Wall piers
CDOT MODEL REVIEW

- Questioned source of terrain data
- Minor mesh quality issue
- Water touched model extents
- Questioned roughness
- **Duration of 2.5-hour insufficient**
  > Caught additional overtopping in 500-year event → 8-hour simulation
- Recommended additional monitor lines
2D MODEL RESULTS

- Passes the QA Checklist
- No adverse impact
- The 112ft Two span bridge works!
- So what’s wrong?

Velocity Map of 112ft, two span bridge
2D MODEL RESULTS

- Single Span, 80ft bridge
- Passes the QA Checklist
- No adverse impact
- $400k Lower Cost

Velocity Map: 80ft single span bridge
SUMMARY

• Review checklist
• Avoid mistakes
• Save money
## 2-D Hydraulic Model Review Checklist

<table>
<thead>
<tr>
<th>#</th>
<th>Item</th>
<th>Comment</th>
<th>Action Needed</th>
<th>Screen Shot</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
<td><strong>Data</strong></td>
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<tr>
<td>1</td>
<td>Project Vertical Datum</td>
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<td>X</td>
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<tr>
<td>2</td>
<td>Project Horizontal Datum</td>
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<td>X</td>
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<tr>
<td>3</td>
<td>Does final surface accurately represent site (are hydraulic controls represented)</td>
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<td><strong>5</strong></td>
<td><strong>Topography</strong></td>
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<tr>
<td>6</td>
<td>Source/Date</td>
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<td>7</td>
<td>Stated Accuracy</td>
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<tr>
<td>8</td>
<td>Datums verified</td>
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<tr>
<td><strong>9</strong></td>
<td><strong>Bathymetry</strong></td>
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<td>9</td>
<td>Source/Date</td>
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<td>10</td>
<td>Datums verified</td>
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<td><strong>12</strong></td>
<td><strong>Additional Survey</strong></td>
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<td>12</td>
<td>Source/Date</td>
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<td>13</td>
<td>Datums verified</td>
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<tr>
<td><strong>15</strong></td>
<td><strong>Bridge/Culvert/Structure Data</strong></td>
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<td>14</td>
<td>Source/Date</td>
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<td>15</td>
<td>Datums verified</td>
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<td><strong>18</strong></td>
<td><strong>Mesh</strong></td>
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<td>16</td>
<td>Is the upstream mesh limit sufficient</td>
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<td>17</td>
<td>Is the downstream mesh limit sufficient</td>
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<td>18</td>
<td>Are the lateral extents sufficient</td>
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<td>19</td>
<td>Does mesh accurately represent the site (are hydraulic controls represented)</td>
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<td>20</td>
<td>Is mesh quality sufficient</td>
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<td>21</td>
<td>Source of material types (imagery)</td>
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<td>22</td>
<td>Are material types correctly assigned</td>
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<td>23</td>
<td>Are appropriate n values used</td>
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<td>24</td>
<td>Is mesh size reasonable (element count)</td>
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<td>25</td>
<td>Appropriate monitor lines (# and location)</td>
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<td>Upstream Boundary - Verify correct inflow(s) amount and type</td>
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<td>Downstream Boundary - Verify correct stage and type</td>
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<td><strong>Bridge</strong></td>
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<td>28</td>
<td>Is bridge geometry correct</td>
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<td>29</td>
<td>Are pier locations correct</td>
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<td>30</td>
<td>Are piers modeled correctly</td>
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<td>31</td>
<td>Is pressure flow accounted for correctly</td>
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<td><strong>Culvert</strong></td>
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<tr>
<td>32</td>
<td>Is culvert correctly represented</td>
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<td><strong>40</strong></td>
<td><strong>Other Structures</strong></td>
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<tr>
<td>33</td>
<td>Is structure correctly represented</td>
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<td><strong>Hydraulic Analysis</strong></td>
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<td>Are simulation settings reasonable</td>
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<td>Verify steady state conditions</td>
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<td>Verify continuity</td>
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<td>37</td>
<td>Do results contain any oddity’s</td>
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<td>Does model calibrate to known data</td>
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<td><strong>Input Review</strong></td>
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<td>Are the flowrate units correct?</td>
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<td>4</td>
<td>Do the upstream boundary conditions in the BC coverage match the computed flowrates in the model as evidenced by monitoring lines, monitoring points, etc.?</td>
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<td>Downstream Boundary Condition</td>
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<td>5</td>
<td>Does the location of the outflow boundary condition seem appropriate?</td>
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<td>6</td>
<td>Does the input downstream water level match the event being modeled?</td>
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<td>7</td>
<td>Are the water level elevation units correct?</td>
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<td>8</td>
<td>Does the downstream boundary condition in the BC coverage match the water surface elevation shown in the model at the model boundary? (As evidenced by the output data)</td>
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<tr>
<td>9</td>
<td>Are the locations of the Monitor Lines and Monitor Points sufficient and appropriate?</td>
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<td>10</td>
<td>Is the correct hot start file being used?</td>
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<tr>
<td>11</td>
<td>Is the hot start file working?</td>
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<tr>
<td>12</td>
<td>Are the correct scatter sets or terrain image data being interpolated to the mesh?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>13</td>
<td>Are there any outliers in the scatter data (e.g. zero value elevations, high or low values relative to surroundings)?</td>
<td></td>
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</tr>
<tr>
<td>Comment Number</td>
<td>Review Item</td>
<td>QC Comments</td>
<td>Designer Response</td>
<td>Follow Up Review Item</td>
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<td>------------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>14</td>
<td>Does the scatter set triangulation seem reasonable?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>15</td>
<td>Have breaklines been employed where necessary?</td>
<td></td>
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<tr>
<td>16</td>
<td>Was the correct priority assigned when merging scatter sets (if applicable)?</td>
<td></td>
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</tr>
<tr>
<td>17</td>
<td>Does the merged surface contain any artificial artifacts from the merge? Significant &quot;ledges&quot; or drops in elevation across the merging boundary, etc.?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>18</td>
<td>Is the terrain extent sufficient to cover the modeling domain?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>19</td>
<td>Are the elevation units in the terrain data correct?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Mesh/Geometry</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>20</td>
<td>Are all significant mesh quality checks satisfied?</td>
<td></td>
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</tr>
<tr>
<td>Comment Number</td>
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<td>QC Comments</td>
<td>Designer Response</td>
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</tr>
<tr>
<td>21</td>
<td>Are minimum and maximum element sizes appropriate throughout the model?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Is the model domain sufficiently large to contain the computational extent and the desired reach?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Are the roadway toes of slope, centerlines, edge of pavement, and other pertinent features correctly captured by the mesh?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td><strong>Roughness</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Do manning’s roughness values seem reasonable?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>25</td>
<td>Do the boundaries and extent of material polygons seem reasonable?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td><strong>Model Control Inputs</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>26</td>
<td>Do model control settings, particularly the time step, seem reasonable?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Have other settings been introduced to maximize model run efficiency? Setting the Inflow BC to “steady” if a steady simulation etc.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comment Number</td>
<td>Review Item</td>
<td>QC Comments</td>
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<tr>
<td></td>
<td><strong>Structures</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>28</td>
<td>Is the bridge deck included, and pressurized if necessary?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>Are bridge abutments, retaining walls, and other bridge features represented appropriately?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>30</td>
<td>Are the bridge piers correctly represented in the mesh and materials coverage?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Are all pertinent insurable structures blocked out within the mesh and unassigned via the materials coverage?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>Are all culverts accounted for in the model, and has the culvert definition (arcs, HY-8 input) been verified?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Have other hydraulic structures (irrigation ditches, offtake gates or weirs, other features) been appropriately modeled?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td><strong>Model Calibration</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>34</td>
<td>Are any external references to aid in calibration and tie-ins present? Cross-section locations, previous model results, observed WSE, etc.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td><strong>Output Review</strong></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td><strong>Numerical Health</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>35</td>
<td>Are there any warnings/messages in the SRH-2D output file?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>Has a steady state solution been reached? Do the INF file, monitor line/point files, HY output file, demonstrate convergence of the model?</td>
<td></td>
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</tr>
<tr>
<td></td>
<td><strong>Depths/Water Surface Elevations</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comment Number</td>
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<tr>
<td>37</td>
<td>Are there any abnormally high or negative depth values?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>Are extracted water surface elevations accurate?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>Are extracted flowrates accurate?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>Are there any abnormally high velocities? Any negative velocities?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>Do Froude Numbers appear reasonable?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>Is there good &quot;data hygiene&quot; in the model? (Are different data sets easily distinguished from one another, are there old model runs that need to be cleaned up or deleted, etc.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>Are pertinent data sets (i.e. Existing vs. Proposed) able to be directly compared via the data calculator or other appropriate method?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Region 4 Hydraulics Unit**

**SMS / SRH-2D Quality Check**

**Comment Number**

- **37**: Are there any abnormally high or negative depth values?
- **38**: Are extracted water surface elevations accurate?
- **39**: Are extracted flowrates accurate?
- **40**: Are there any abnormally high velocities? Any negative velocities?
- **41**: Do Froude Numbers appear reasonable?
- **42**: Is there good "data hygiene" in the model? (Are different data sets easily distinguished from one another, are there old model runs that need to be cleaned up or deleted, etc.)
- **43**: Are pertinent data sets (i.e. Existing vs. Proposed) able to be directly compared via the data calculator or other appropriate method?
<table>
<thead>
<tr>
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<th>Designer Response</th>
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</tr>
</thead>
<tbody>
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</tbody>
</table>

**Model Run**: 100 yr Existing  
**Str # and/or Reach**: G-21-A Sand Creek  
**Review Date**: Nov 11, 2019  
**Reviewer**: Steven Griffin, CDOT  
**SMS Version**: 13.0.10  
**Original Form (credit)**: Clark Barlow, Atkins  
**Form Revision Number**: 1.0  
**Form Revision Date**: November 2019 by Steven Griffin
HEC-HMS + HEC-RAS 2D for Rain-on-Snow-on-Grid with Uplands, too!

Case Study in the Sierra Valley, CA

September 30, 2020
Sierra Valley?

- Approximately 50 miles NW of Reno, NV & 140 miles NE of Sacramento, CA
- Leeward slope of the Sierra Nevada range, mountains on all sides
- Surrounded by National Forests
- Headwaters of the Middle Fork Feather River
- 586 sq. mile watershed
Flooding History

- Driven by rain-on-snow from atmospheric rivers during Pineapple Express events from the Pacific Ocean
- Flood of record: February 10, 2017

### Annual Peak Flows for Middle Fork Feather River
CDWR Gage MFP at Portola, CA

<table>
<thead>
<tr>
<th>Water Year</th>
<th>Date</th>
<th>Peak Flow (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>February 10, 2017</td>
<td>12,891</td>
</tr>
<tr>
<td>2007</td>
<td>November 16, 2006</td>
<td>6,918</td>
</tr>
<tr>
<td>2018</td>
<td>March 23, 2018</td>
<td>6,108</td>
</tr>
<tr>
<td>2019</td>
<td>March 1, 2019</td>
<td>5,652</td>
</tr>
<tr>
<td>2011</td>
<td>March 17, 2011</td>
<td>4,851</td>
</tr>
<tr>
<td>2016</td>
<td>March 15, 2016</td>
<td>1,649</td>
</tr>
<tr>
<td>2008</td>
<td>March 16, 2008</td>
<td>1,382</td>
</tr>
<tr>
<td>2012</td>
<td>March 19, 2012</td>
<td>1,342</td>
</tr>
<tr>
<td>2013</td>
<td>December 5, 2012</td>
<td>942</td>
</tr>
<tr>
<td>2009</td>
<td>March 5, 2009</td>
<td>881</td>
</tr>
<tr>
<td>2010</td>
<td>February 28, 2010</td>
<td>775</td>
</tr>
<tr>
<td>2015</td>
<td>February 10, 2015</td>
<td>706</td>
</tr>
<tr>
<td>2014</td>
<td>February 12, 2014</td>
<td>394</td>
</tr>
</tbody>
</table>
Restudy Need

Significant Community Feedback:

– “Rain-on-snow assessment in earlier study did not sufficiently represent observed floods of record.”
– SNODAS predictive snow data could not be calibrated.
– Outdated Rainfall
Hydrology – HEC-HMS Parameters
Uplands Hydrology

- 86 Sub-Basins
- 36% above 6,000 feet
- NOAA Atlas 14, 24-hour Gridded Rainfall
- Initial & Constant Loss
- SCS Lag transform
- Constant baseflow
- Temperature Index Snowmelt
- Muskingum-Cunge Channel Routing
- 2 Reservoirs
Valley Floor Hydrology

- 3 Subareas
- Very Flat topography
- NOAA Atlas 14 24-hour Gridded Rainfall
- Initial & Constant Loss
- Constant Baseflow
- Temperature Index Snowmelt
- No Routing
<table>
<thead>
<tr>
<th>Gage Name</th>
<th>Gage ID</th>
<th>Elevation (feet)</th>
<th>Rain, Incremental (inches, daily)</th>
<th>Rain, Accumulated (inches, hourly)</th>
<th>Snow, Depth (inches, monthly)</th>
<th>Snow, Water Content (inches, monthly)</th>
<th>Reservoir Storage (acre-feet, hourly &amp; daily)</th>
<th>Reservoir Elevation (feet, hourly &amp; daily)</th>
<th>Air Temperature (deg. F, hourly)</th>
<th>Flow River Discharge (cfs, 15 minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abbey</td>
<td>ABY</td>
<td>5,560</td>
<td>--</td>
<td>--</td>
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<td>--</td>
<td>--</td>
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</tr>
<tr>
<td>Lake Davis (DWR)</td>
<td>DAV</td>
<td>5,768</td>
<td>1987-1984, Present</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1984-1984, Present</td>
<td>--</td>
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</tr>
<tr>
<td>Frenchman Cove</td>
<td>FCV</td>
<td>5,800</td>
<td>1963-1963, Present</td>
<td>--</td>
<td>--</td>
<td>--</td>
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<td>--</td>
</tr>
<tr>
<td>Independence Creek</td>
<td>INN</td>
<td>6,500</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
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</tr>
<tr>
<td>Portola</td>
<td>PRT</td>
<td>4,850</td>
<td>1987-1989, Present</td>
<td>--</td>
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<td>--</td>
<td>--</td>
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<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Rowland Creek</td>
<td>RWL</td>
<td>6,700</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1950-1950, Present</td>
<td>1950-1950, Present</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Vinton</td>
<td>VNT</td>
<td>4,944</td>
<td>1987-1989, Present</td>
<td>--</td>
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<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Yuba Pass</td>
<td>YBP</td>
<td>6,700</td>
<td>--</td>
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</tr>
</tbody>
</table>

Source Data – 13 CDWR Gages!
Rainfall Temporal Distribution

100-year, 24-hour Precipitation from NOAA Atlas 14, Volume 6.
Baseflow

- Field observations and review of stream gage record showed baseflow in the watershed
- Earlier study included it, but provided no source info
- Middle Fork Portola gage included 15-minute data
- Average baseflow visually interpreted from Late Winter record.
- Unit Baseflow = Average baseflow/watershed area = 0.17 cfs/mi$^2$
**Snowmelt Inputs**

**Average March Snow Depth and Water Content and Dominant Aspect**

<table>
<thead>
<tr>
<th>Gage Name</th>
<th>Gage ID</th>
<th>Elevation (feet)</th>
<th>Average March Snow Depth (inches)</th>
<th>Average March Snow Water Content (inches)</th>
<th>Dominant Aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abbey</td>
<td>ABY</td>
<td>5,560</td>
<td>31.3</td>
<td>10.1</td>
<td>North</td>
</tr>
<tr>
<td>Yuba Pass</td>
<td>YBP</td>
<td>6,700</td>
<td>68.1</td>
<td>24.8</td>
<td>North</td>
</tr>
<tr>
<td>Grizzly Ridge</td>
<td>GRZ</td>
<td>6,900</td>
<td>69.9</td>
<td>24.4*</td>
<td>North</td>
</tr>
<tr>
<td>Frenchman Cove</td>
<td>FCV</td>
<td>5,800</td>
<td>14.6</td>
<td>4.6</td>
<td>South</td>
</tr>
<tr>
<td>Independence Creek</td>
<td>INN</td>
<td>6,500</td>
<td>35.5</td>
<td>12.0</td>
<td>South</td>
</tr>
<tr>
<td>Rowland Creek</td>
<td>RWL</td>
<td>6,700</td>
<td>46.2</td>
<td>14.5</td>
<td>South</td>
</tr>
</tbody>
</table>

*Manually adjusted to 24.8 inches for use in the analysis to provide for a consistently increasing interpolation curve.

- 6 gages evenly distributed around watershed, over the elevation range, and across the dominant aspects
- Observed Average March SWE and Depth used to develop rating curves across bands
- GIS methods used to
  - Estimate Snow Water Equivalent by Elevation & Aspect, composited to each band by aspect
  - Locate Basin Centroid
- Initial Liquid Water = 0.4*Initial SWE
- Diurnal temperature series taken from 5-day period in March with widest range
Hydraulics – HEC-RAS 2D Parameters
Mesh, Connections, Flows…

- **Mesh**
  - Initial 200-ft grid
  - Breaklines placed to refine mesh at channels, ridges, roadways
- **Region Connections**
  - Physical feature (roadway)
  - Dummy storage areas (to resolve instabilities for direct connections)
- **Flows/Boundary Conditions**
  - Rain-on-grid on Valley Floor
  - 68 Hydrographs from Upland basins
  - Used DSS file to connect HMS to RAS (Pro tip!)
- Adaptive timestep based on Courant number, 20 iterations
- Diffusion Wave Equation
Calibration Parameters
Calibration Events

February 10, 2017
- 12,891 cfs @ MFP
- 4-12 inches total rain over 11 days
- 151-208% of February Average Snowpack
- Max temp above freezing for few days

March 23, 2018
- 6,108 cfs @ MFP
- 5-15 inches total rain over 16 days
- 17-70% of March Average Snowpack
- Max temp above freezing for 8 days
Calibration Rainfall – Unit Hyetographs

- Grizzly Ridge and Sierraville
- Accumulated data converted to incremental

- Selected storm for each calibration event
- Converted to unit hyetograph
- Used NOAA NEXRAD historical radar to review storm tracks and assign basins to gages
Apply Observed Gage Data

- Rainfall
  - Theissen Polygons used to spatially distribute gages to basins (GIS tool!)
  - Estimate total basin rainfall
  - Develop basin-specific hyetographs
- SWE, temperature applied directly using same methods as frequency events
- Baseflow event unit flow calculated and applied
- Reservoir storage; no outflow
Run the models! Both of them! Iterate!

- Calibrating to observed flow at MFP Portola
- Use Constant Infiltration, the land-use and soil-based parameter to calibrate
  (Everything else from observed info!)

Ultimately.....
- Reduced Constant Infiltration to 20% of original value
- Consistent with literature review for winter conditions

<table>
<thead>
<tr>
<th>Calibration Storm</th>
<th>Middle Fork Feather River near Portola (MFP)</th>
<th>Hydraulic Model</th>
<th>Percent Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>February 2017</td>
<td>12,891</td>
<td>12,255</td>
<td>4.9</td>
</tr>
<tr>
<td>March 2018</td>
<td>6,108</td>
<td>5,728</td>
<td>6.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Calibration Storm</th>
<th>Middle Fork Feather River near Portola (MFP)</th>
<th>Hydraulic Model</th>
<th>Percent Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>February 2017</td>
<td>113,320</td>
<td>103,501</td>
<td>8.7</td>
</tr>
<tr>
<td>March 2018</td>
<td>44,963</td>
<td>44,431</td>
<td>1.2</td>
</tr>
</tbody>
</table>
Validation

Flooding at the A-23 Bridge Over the Middle Fork Feather River

Widespread Flooding at along Harriet Lane
What’s next?

Possible Post-Fire Analysis…

20 sq. miles burned in the Loyalton fire in August
Questions?
Thank you!

Kimberley.Pirri@aecom.com
Lead Hydrologist