Expanding Our Knowledge of Climate Uncertainty – An Experimental Design at the American River Basin

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Climate Change and its Impact

According to California’s 4th Climate Change Assessment, Climate change is already impacting California:

- Rising Temperatures and Extreme Heat
- Changing Precipitation Patterns
- More Extreme Storm Events
- Sea Level Rise
- Wildfire
Flood Management Under Climate Change

- More extreme floods
- Greater floodplain vulnerability
- Pressure to expand flood control infrastructures
- Planning, modeling and design challenges
- Uncertainty quantification
Uncertainty in Hydraulic Modeling

Sources of Uncertainty:

- Model Geometry Uncertainty
  Simplified geometry representation; erosion; land subsidence

- Hydrology Uncertainty
  Poor knowledge in initial & boundary conditions; Climate Change

- Parameter Uncertainty
  Roughness coefficient, rating curve, etc.
Uncertainty In Modeling at Different Scales

- Uncertainty - Climate
- Model Complexity
- Computational Limit

Run time ?
Model Error ?

Run time ~ 6 hr
Model Error ~ 3 ft

Run time ~ 30 min
Model Error ~ 1 ft

Run time < 1 min
Model Error ~ 0.5 ft

Continental Scale
(1000 miles)

Basin Scale
(1 miles ~ 100 miles)

River Reach Scale
(100 ft~ 1 miles)

Hydrologic & Hydraulic Unit Scale
(1 ~ 100 ft)

Spatial & Temporal scale
Experimental Design

An experimental design for the American river to quantify uncertainty on hydraulic modeling:

- Base Condition – Well calibrated 1D HEC-RAS model (1997 event), assume that the model geometry, parameters and hydrology input are ‘stationary’ and therefore the stage profile along the river is ‘fixed’.

- Climate Uncertainty – Use downscaled climate projection to generate synthetic flow events, representing climate uncertainty

- Model Geometry Uncertainty – Varied streambed geometry to represent geometry uncertainty

- Parameter Uncertainty – Varied n value for river cross sections to represent parameter uncertainty
Climate Uncertainty – Base Hydrology

1997 Event

Flow (cfs)

12/28/1996 0:00 12/30/1996 0:00 1/1/1997 0:00 1/3/1997 0:00 1/5/1997 0:00 1/7/1997 0:00 1/9/1997 0:00 1/11/1997 0:00

0 20000 40000 60000 80000 100000 120000 140000
Climate Uncertainty – Climate Projection (RCP 4.5)

Dec-Jan-Feb Monthly Streamflow - American River at Fair Oaks

<table>
<thead>
<tr>
<th>Flow Observation</th>
<th>Flow Projection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below Normal</td>
<td>63 (33%)</td>
</tr>
<tr>
<td>Normal</td>
<td>64 (34%)</td>
</tr>
<tr>
<td>Above Normal</td>
<td>63 (33%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Future Projection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below Normal</td>
</tr>
<tr>
<td>Normal</td>
</tr>
<tr>
<td>Above Normal</td>
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</tbody>
</table>

Source: Cal-Adapt Streamflow Projection & California DWR
Climate Uncertainty – Synthetic Flow Generation

Synthetic monthly flow

99th Percentile
Climate Uncertainty – Synthetic Flow
Climate Uncertainty – Results
Climate Uncertainty – Results
Flooding causes river bank erosion, sediment deposition and channel migration, representing uncertainty in channel geometry.
Geometry Uncertainty – Example
Geometry Uncertainty – Results

Geometry Uncertainty Results

- Invert
- 1997 Event
- Upper Range
- Lower Range

River Mile
Elevation (ft, NAVD 88)
Parameter Uncertainty – Manning’s n value

- Base condition – 1997 events calibrated n value

- Uncertainty in n value due to changes in vegetation cover, erosion condition and channel geometry

- Tested upper bound and lower bound of n value changes along the American River against base condition
Parameter Uncertainty – Results
Conclusion

- Climate uncertainty dominates in hydraulic modeling and generates a much larger band of possible model outputs.
- Geometry uncertainty and parameter uncertainty have relatively smaller influences on model outputs.
- More study is needed to better quantify the uncertainty caused by climate change at different spatial scales.
- Future infrastructure planning and design should be guided by detailed climate studies.
LESSONS LEARNED

Given all sources of uncertainty, engineers/modelers have to

- Fully understand the scale & objectives of the modeling task;
- Know the limitations of the modeling tool used;
- Evaluate the quality of data provided;
- Investigate feasible modeling alternatives available; and most importantly
  - Make sound and logical engineering judgment
Thanks!
Questions?