2-D Hydraulic Modeling
Theory & Practice

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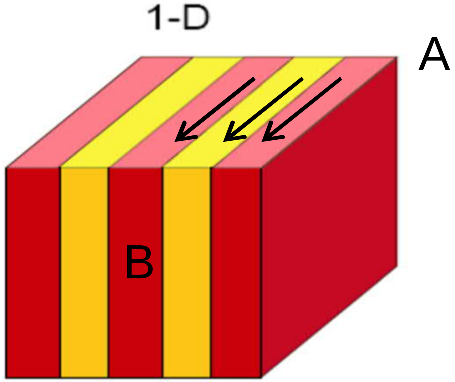
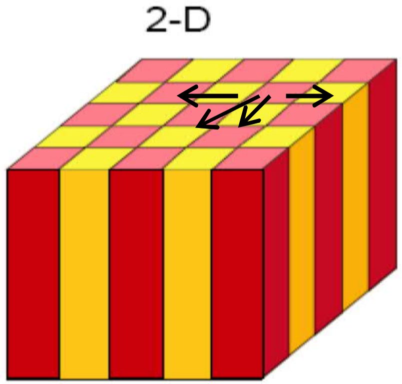
Presentation Outline

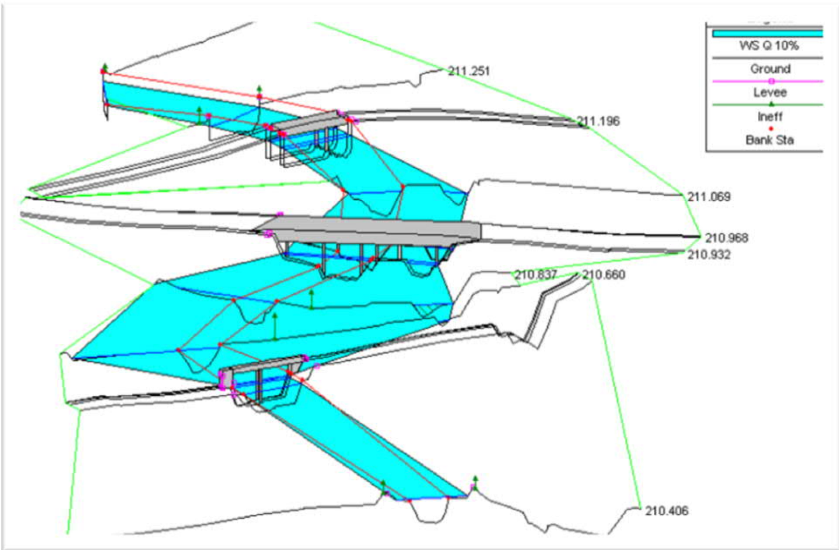
* 1-D vs. 2-D modeling
* Theory of 2-D simulation
* Commonly used and accepted software
* Real-life applications
* Conclusions
* Discussion

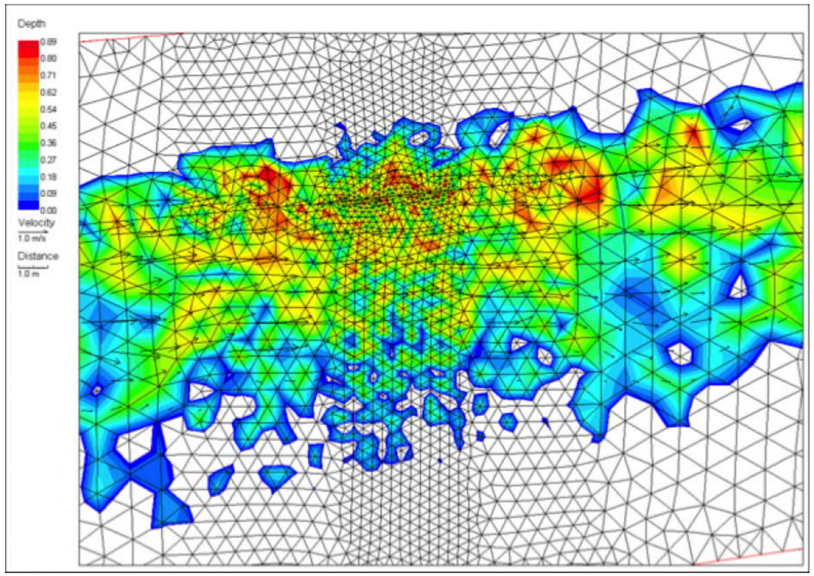
1-D vs. 2-D

1-D vs. 2-D





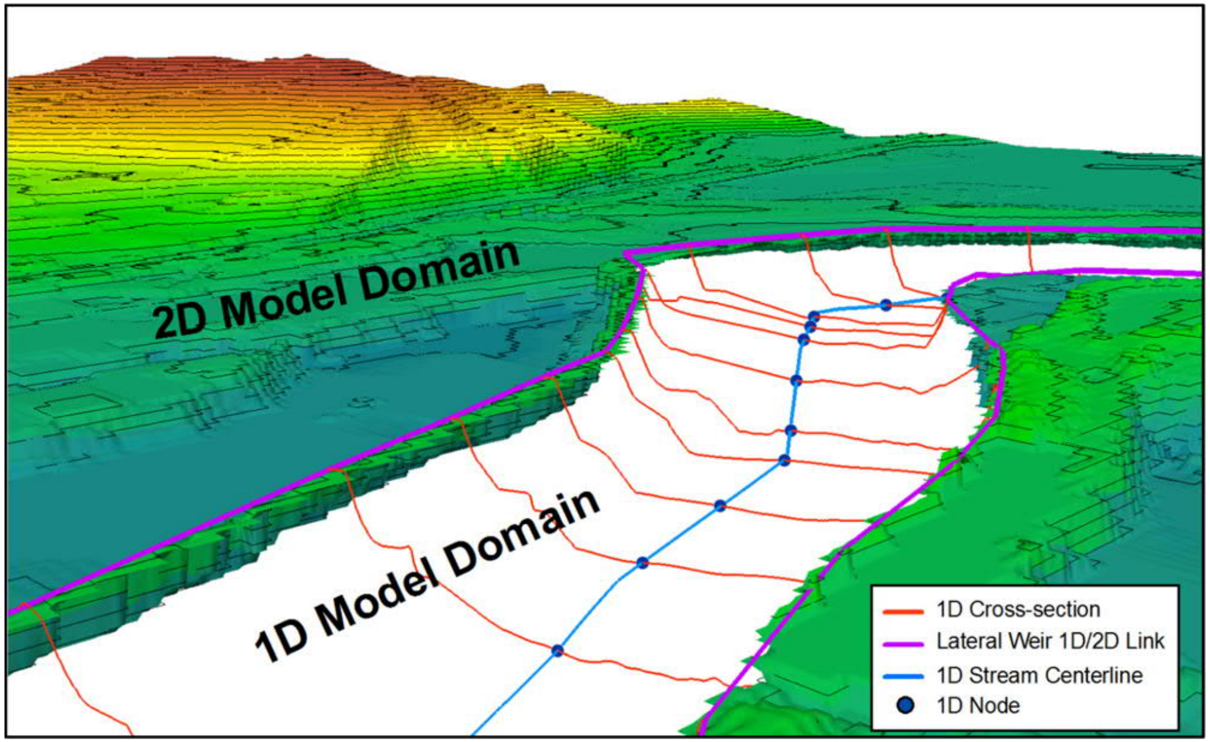




AECOM

1-D vs. 2-D

Hybrid Models



AECOM

1-D vs. 2-D

* When will a 1D model be suitable?

1. Locations where flow isn't required to 'spread' significantly (flow maintains primarily uni-directional flow patterns).
2. Well-defined channel/overbank systems (channel is bounded by steep slopes, constricting the lateral expansion of flows).
3. Simply-connected floodplains where flow in main channel is well connected to flow in the overbank and that flow in both is primarily uni-directional in nature.
4. When elevation data of only limited quality/quantity are available.

* When is a 2D model usually preferable?

1: Should be used when the engineer has great difficulty visualizing the flow patterns

2: Anywhere flow is expected to spread, such as urbanized areas, wide floodplains, downstream of levee/dam breaks, wetland studies, lake or estuary studies and alluvial fans

1-D Vs. 2-D

1-D

* Can overestimate depth and velocity due to 1D assumptions
* Requires engineering judgement
* Can't model dispersive flow

2-D

* Simple overland model construction
* More informative dynamic mapping
* Limited on hydraulic structures
* Heavy reliance on terrain quality

Other Considerations

- Run times. If your 2D area is very large and you have relatively small cells (i.e. a lot of cells), then run times can be long. By a lot of cells, say 100,000 to 1 million or more. Making your model 2D in areas where you need detail and 1D everywhere else can help solve this problem.

- Output. Getting output from 2D areas is a bit more cumbersome and limited. Still, you can get quite a bit of information out of your 2D areas, it just might take more time.

- Learning curve. Being new to 2D modeling, there will be some additional time for learning how to do 2D modeling.

- End-user may not be okay with it. Make sure the 2D modeling is acceptable to the end user. There is generally a perception that 2D modeling is more expensive. This is not (should not) always be the case.

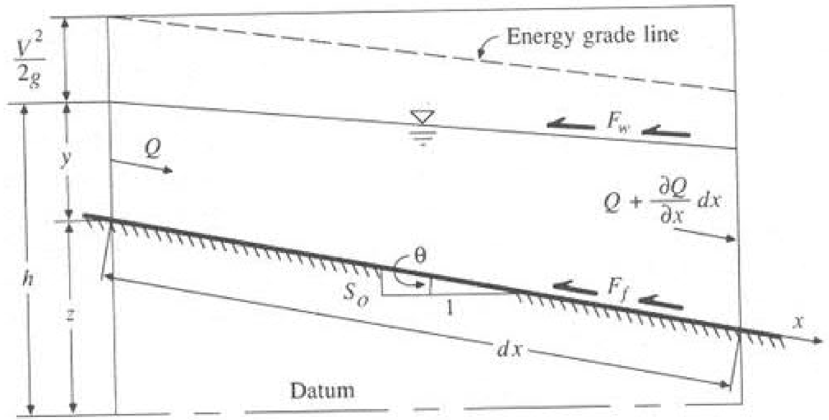
Theory

Saint-Venant Equation (Continuity Equation)

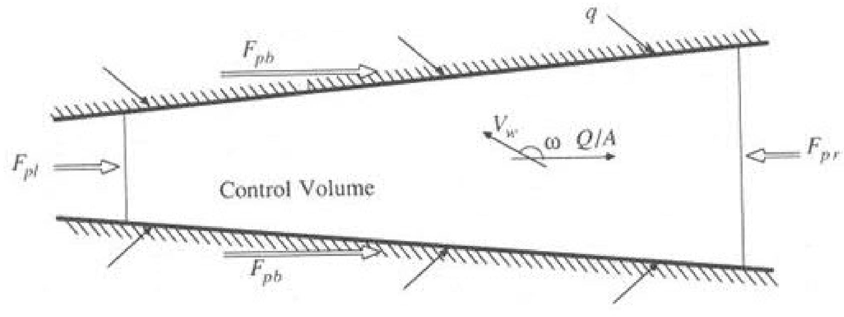
$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = 0$$

Change in flow

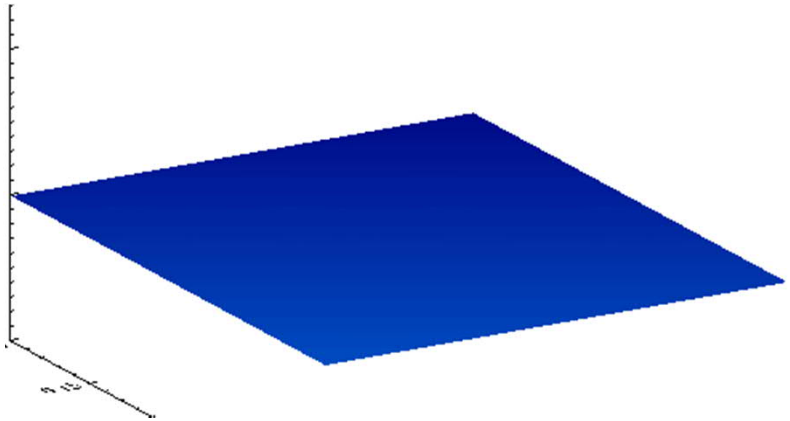
Change in storage



Elevation View



Plan View



https://en.wikipedia.org/wiki/Shallow_water_equations#/media/File:Shallow_water_waves.gif

Saint-Venant Equation (Momentum Equation)

Local acceleration | Convective acceleration | Pressure force | Gravity force | Friction force

$$\frac{\partial V}{\partial t} + V\frac{\partial V}{\partial x} + g\frac{\partial y}{\partial x} - g\left(S_0 - S_f\right) = 0$$

Kinematic wave

Diffusion wave

Dynamic wave

Steady, uniform flow

Steady, non-uniform flow

Unsteady, non-uniform flow

https://en.wikipedia.org/wiki/Shallow_water_equations

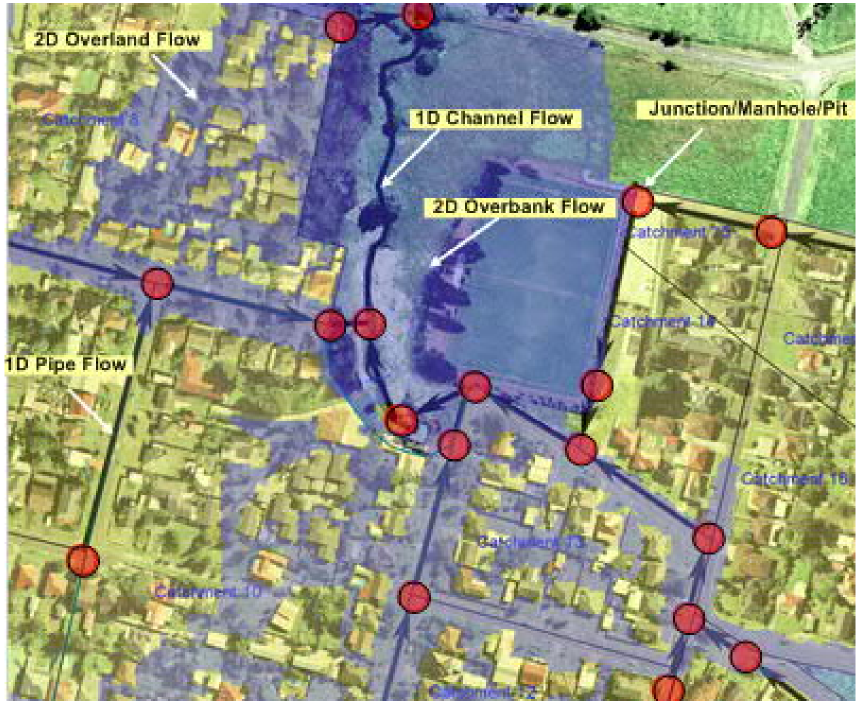
Software

2-D Hydraulic Software

- FLO-2D
  - FEMA approved
  - Free of charge(Basic Model)
  - Combined 1-D and 2-D
  - Storm drain system
  - Scour analysis
  - Dam and levee breach
  - Mud flow

2-D Hydraulic Software

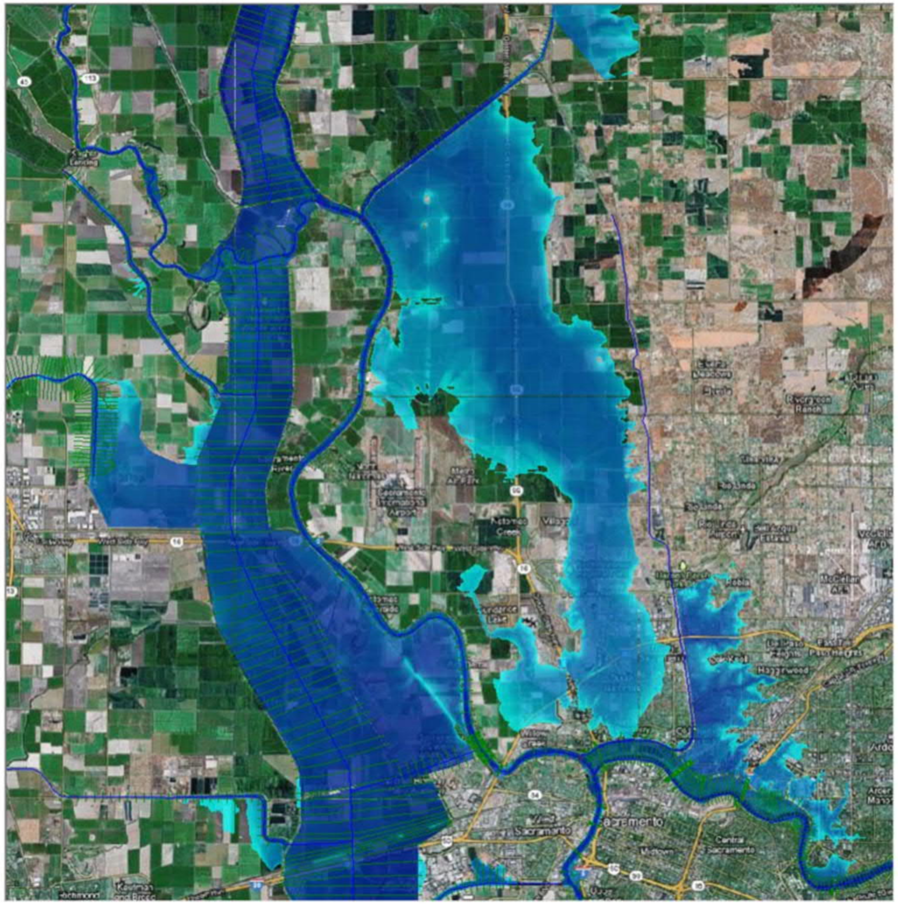
- XP-SWMM 2D
  - FEMA approved
  - Hydrologic Model
  - Combined 1-D, 2-D, and Storm drain system
  - Plume and sediment transport
  - Real-time control



2-D Hydraulic Software

US Army Corps of Engineers

- HEC-RAS 5.0.3 2D
  - FEMA approved
  - Free of charge
  - Combined 1-D and 2-D
  - Dam and levee breach
  - Plume and sediment transport
  - RAS Mapper

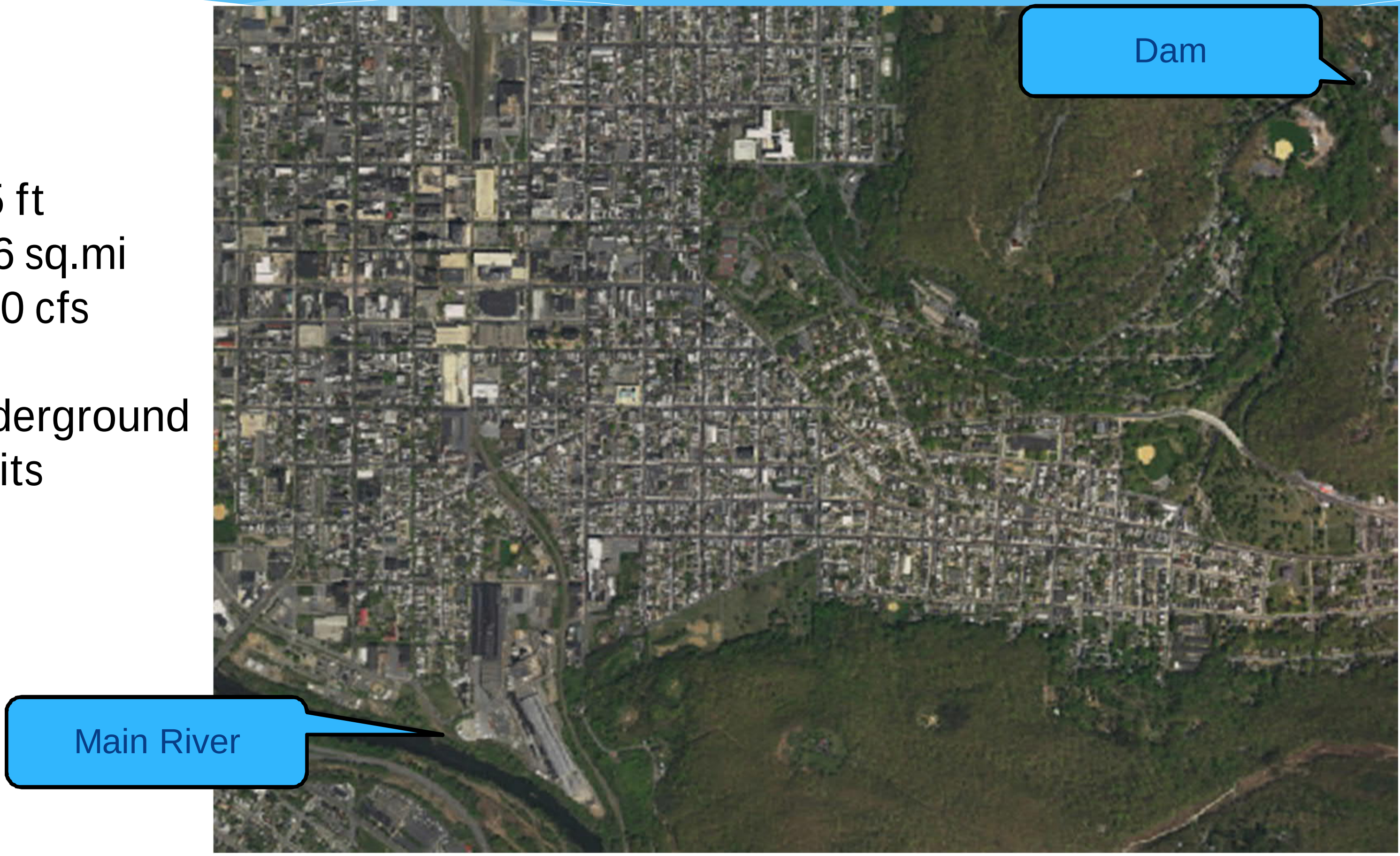


Applications

2D Modeling for Dam Break Analysis

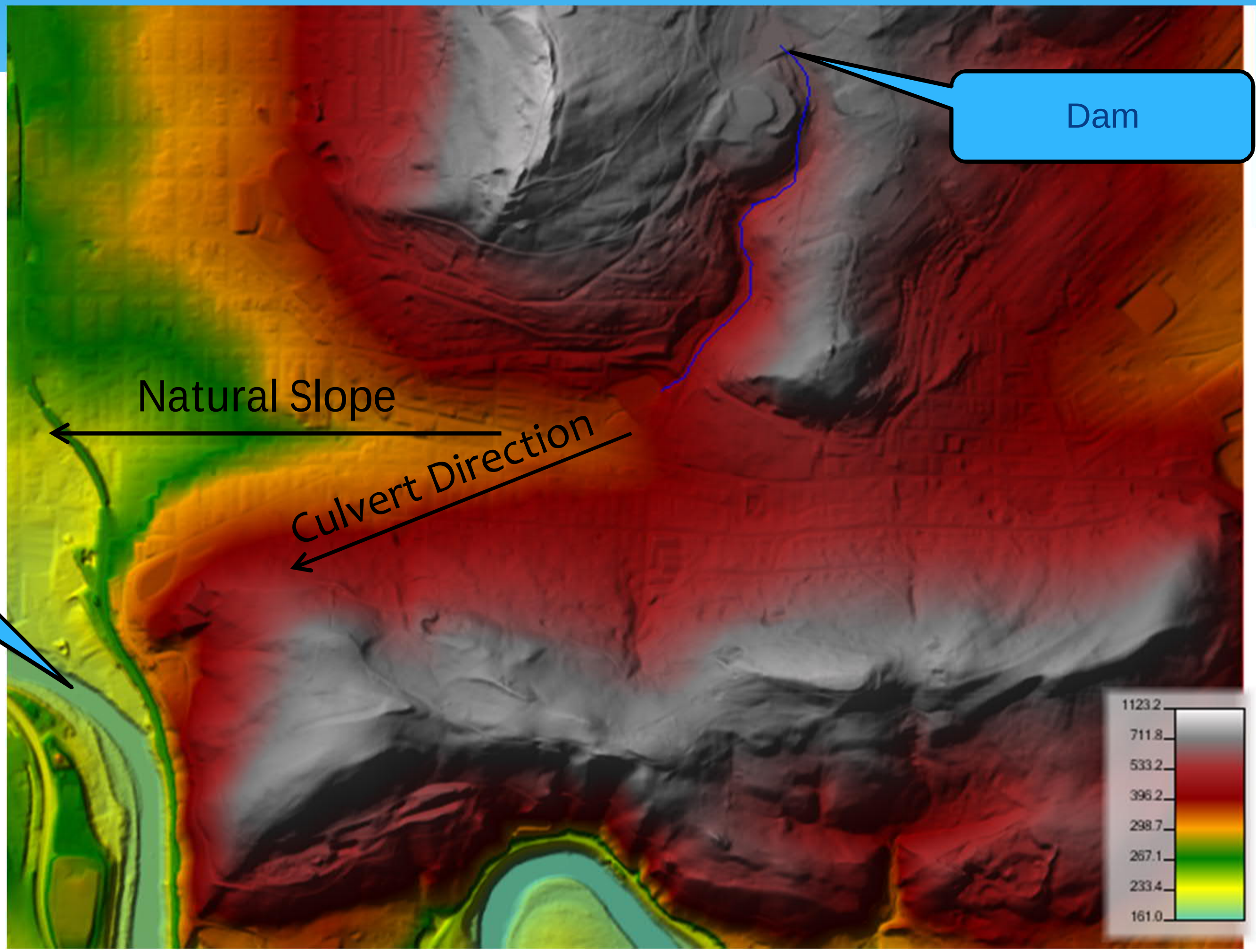
Dam height 15 ft
Watershed 0.6 sq.mi
PMF flow 3,100 cfs

Flow goes underground within city limits



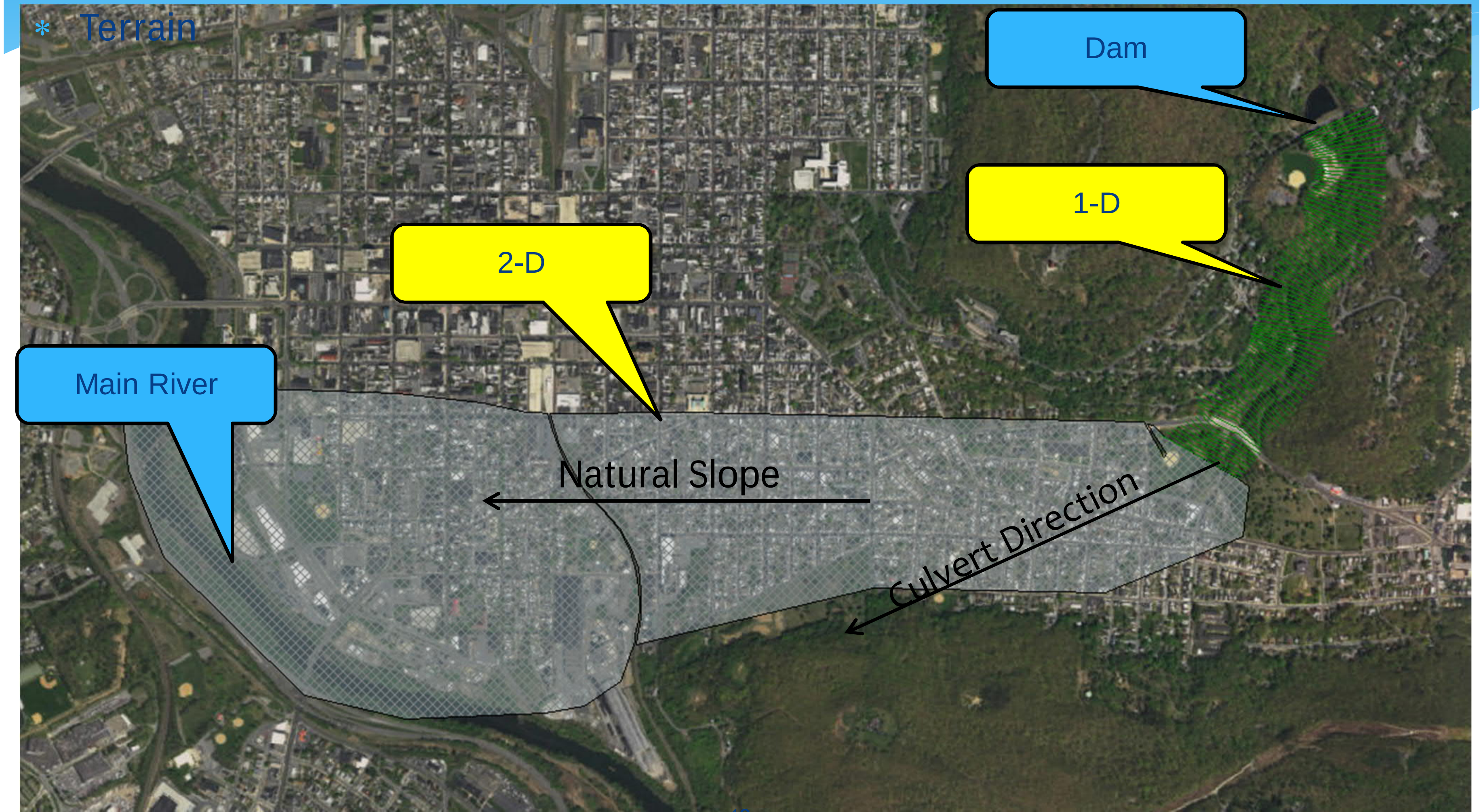
2D Modeling for Dam Break Analysis

- Terrain



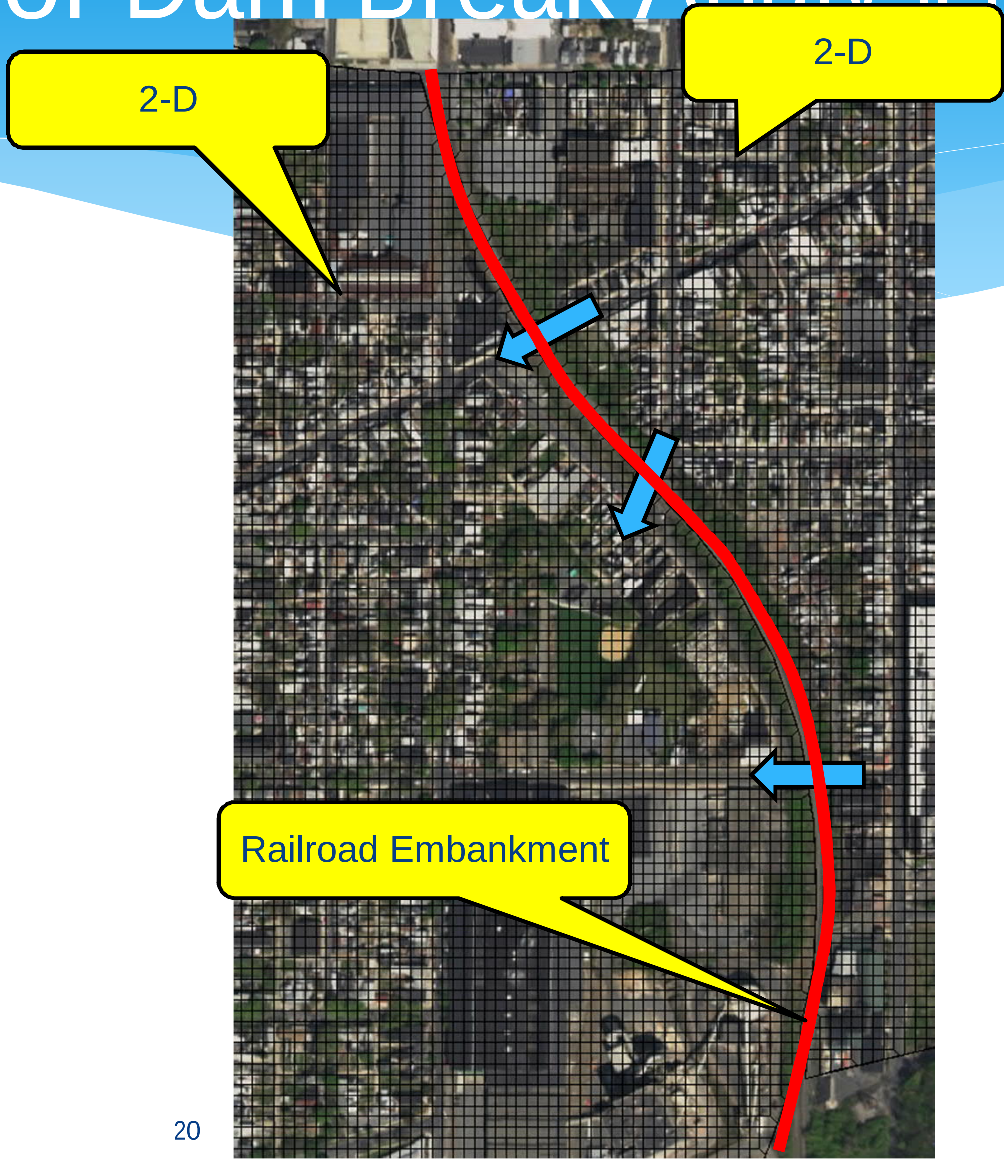
2D Modeling for Dam Break Analysis

* Terrain



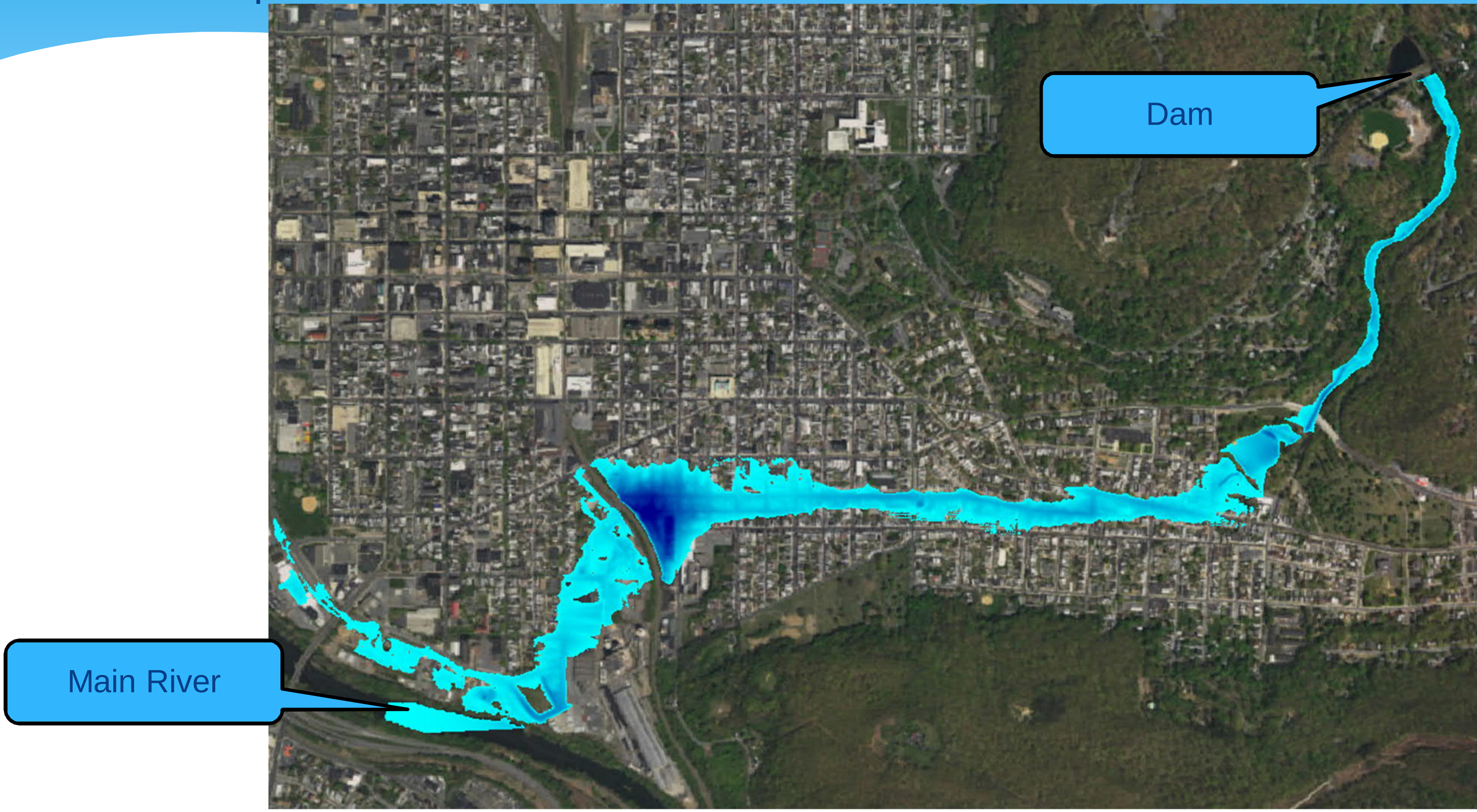
2D Modeling for Dam Break Analysis

* 2D Areas Connectors



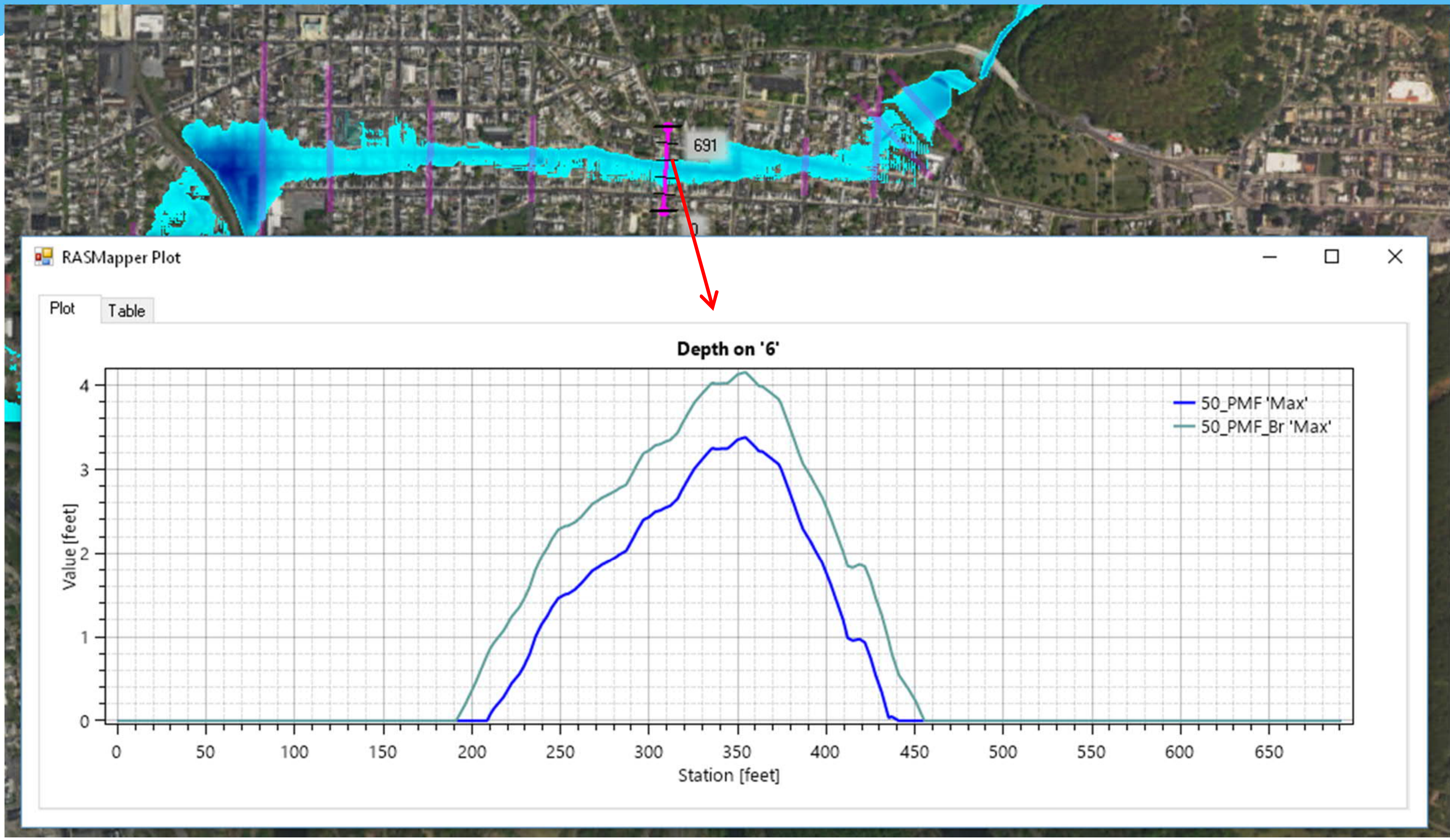
2D Modeling for Dam Break Analysis

* Maximum Depth



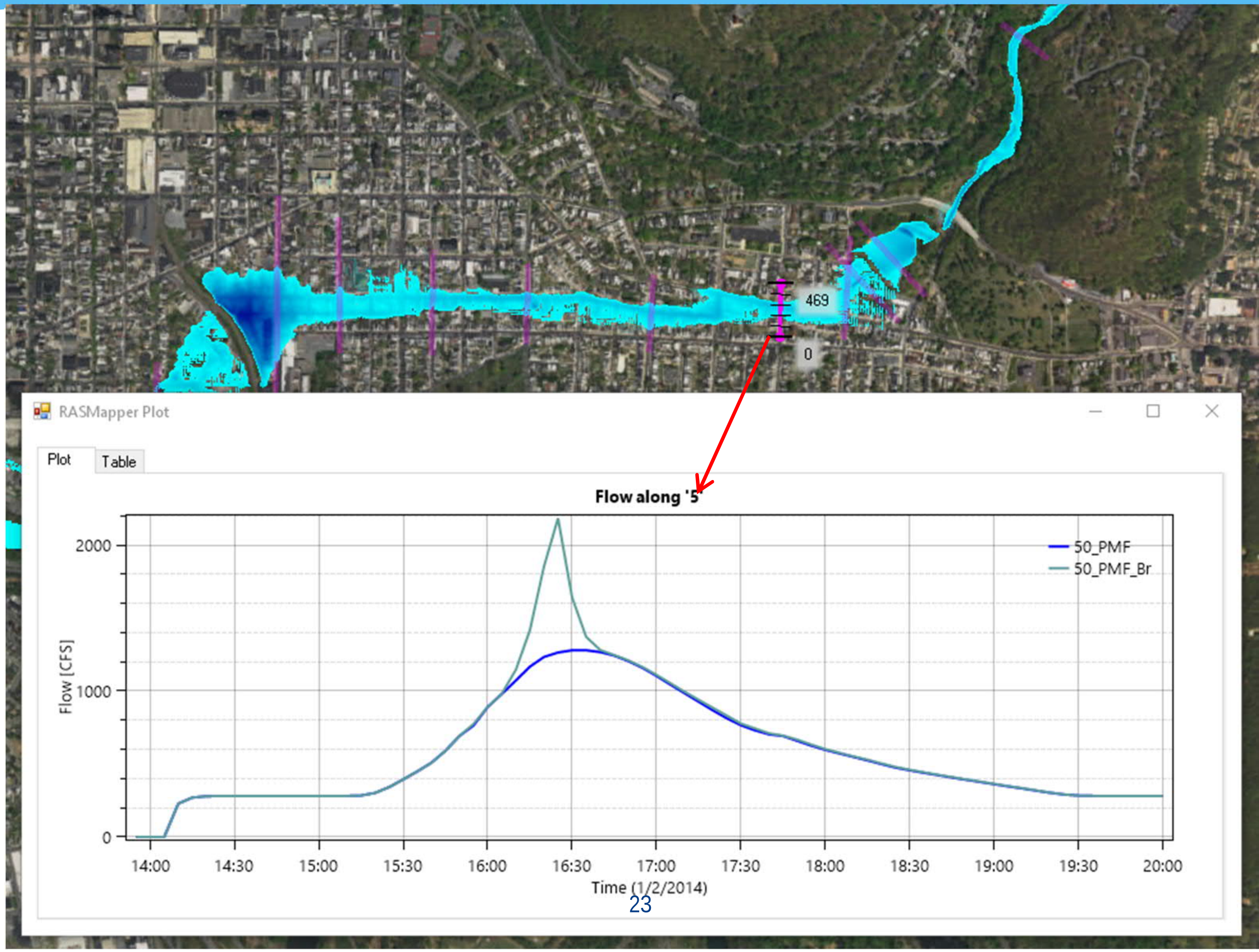
2D Modeling for Dam Break Analysis

* Profile Depth Plot

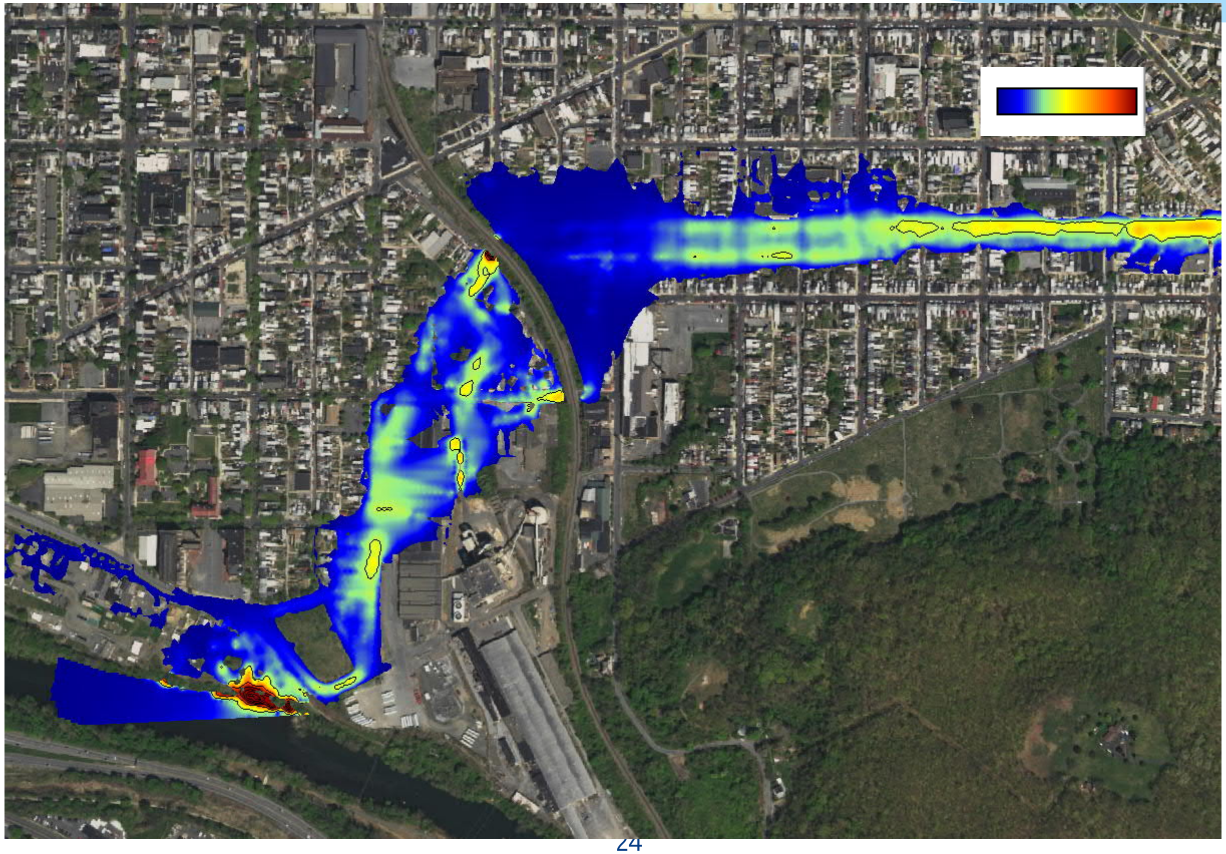


2D Modeling for Dam Break Analysis

* Time Series Flow Plot



2D Modeling for Dam Break Analysis– velocity grid



Conclusions

* 2D or 1D/2D models offer significant gains
  * in accuracy of flood modeling (flow path, depressions, diversions)
  * risk and flood impact predictions
  * in stakeholder understanding and acceptance
* Slow in comparison to 1D only
* Models need to be
  * Calibrated where possible
  * Quality Controlled: Garbage In / Garbage Out

Discussion

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