GIS Techniques for Floodplain Delineation

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- **How to get a floodplain?**
- **What can GIS do for floodplain modeling?**
- **Simple GIS techniques for floodplain delineation**
- **Summary**
- **Q&A**

What is it All About?

easy

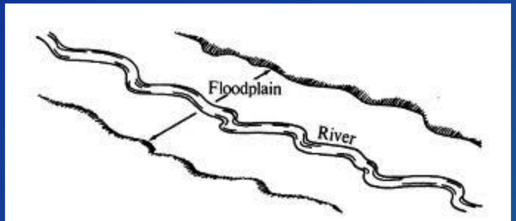
but, there is no “easy” button,
just hard work.

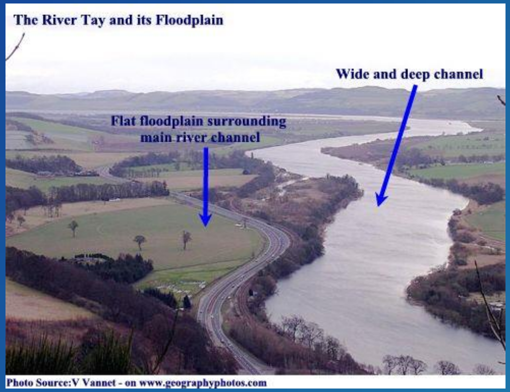
What is a Floodplain

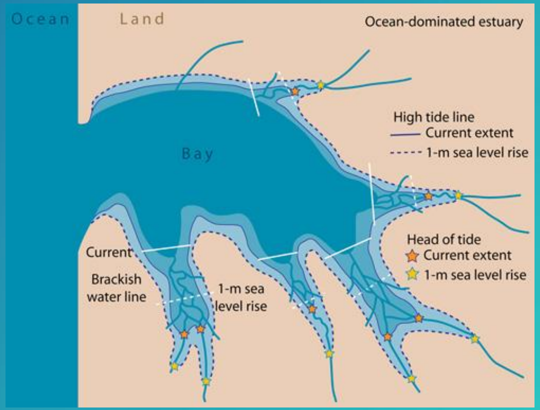
Floodplain Definitions

- “To define a floodplain depends somewhat on the goals in mind. As a topographic category it is quite flat and lies adjacent to a stream; geomorphologically, it is a landform composed primarily of unconsolidated depositional material derived from sediments being transported by the related stream; hydrologically, it is best defined as a landform subject to periodic flooding by a parent stream. A combination of these [characteristics] perhaps comprises the essential criteria for defining the floodplain" (Schmudde, 1968).
- “Any land area susceptible to being inundated by flood waters from any source” (FEMA).

Floodplain Definitions

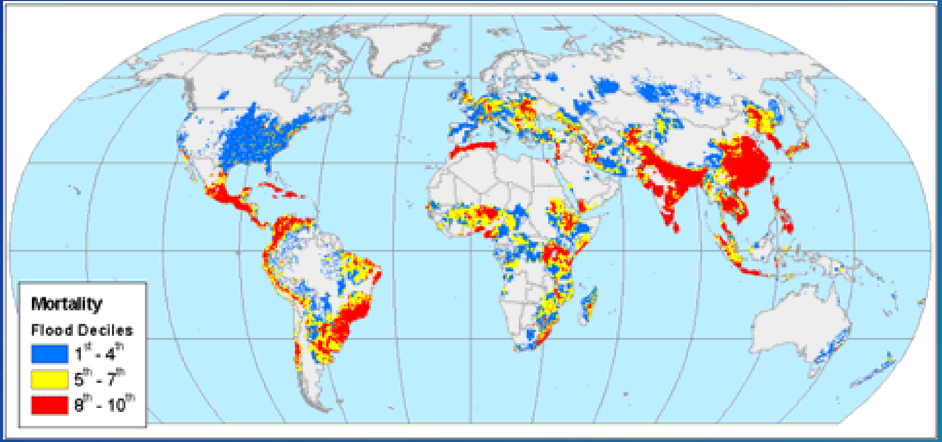






What’s so Important About Floodplains

- 82% of the world’s population lives in areas with high flood risk (UNDP, 2004).

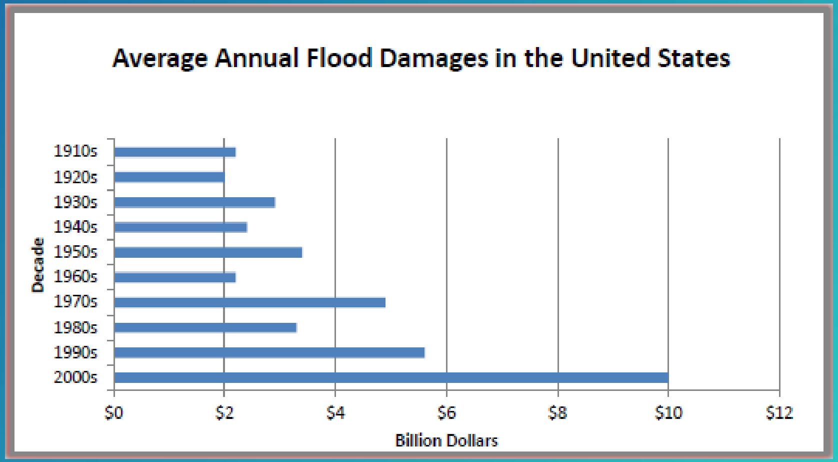


Mortality risk is expressed within a decile range with 10 being the most exposed (Decile 10= est. 300 people/sq. km and decile 9 is around 150 people/sq. km). Source: Mark Pelling, Visions of Risk, UNDP / ISDR, 2004

- ¾ of world population lives within coastal zone
  - USA – 16.5 million (5% population) within flood prone coast
- ½ billion people live within flood prone deltas

What's so Important About Floodplains

- Recurring
  - Lie, bigger lie, statistics
- Increase in % of aid from Feds due to hurricane/flooding (25% -> 70% since 2005)
  - Sandy (2nd most costly), Katrina (1st most costly) ~ $200B



If We Know Where the Floodplain Is …

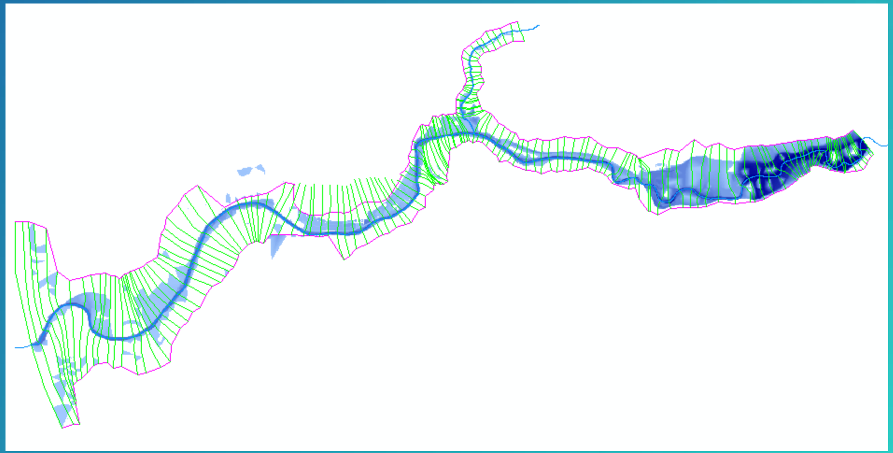
- Operations
  - Flood prevention (dam and levee operations)
  - Emergency management
  - Facility management
- Planning
  - Design
  - Insurance (not everywhere)
  - Emergency planning

How to Get a Floodplain

How to Get the Floodplain

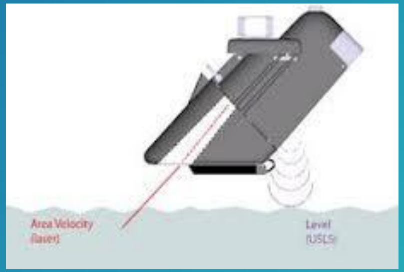
- Observations
  - Water surface elevations
  - Flows
  - Precipitation (rainfall, snow)
  - “Other” (temperature, soil moisture, E/T, …)

- Modeling (H&H)
  - Precipitation-runoff
    - Real-time
    - Planning (design)



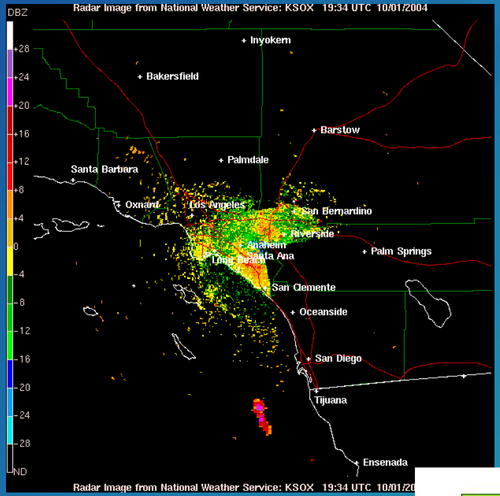
Observations (stage/flow)

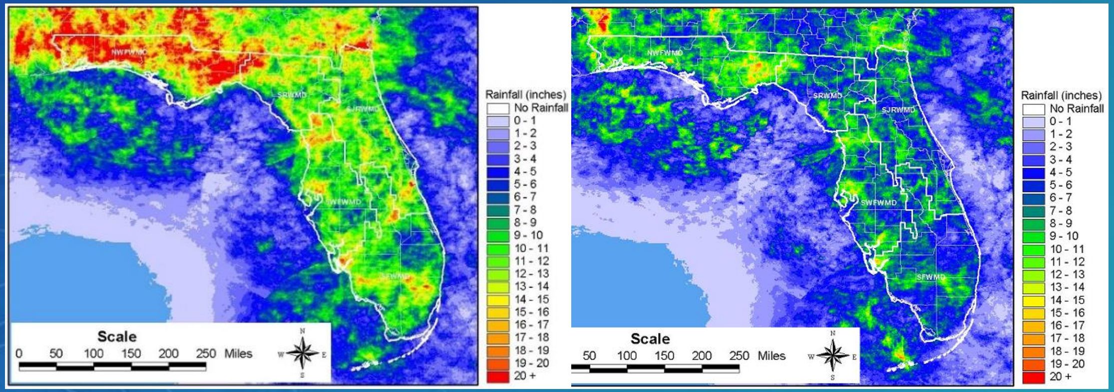
- Traditionally through gaging station
  - Problems with sensors during floods
- High water marks
  - Not real time
- Remote sensing – airborne/satellite
  - Problem with sensors and cloud cover, cost, timeliness
  - Some new options with UAVs

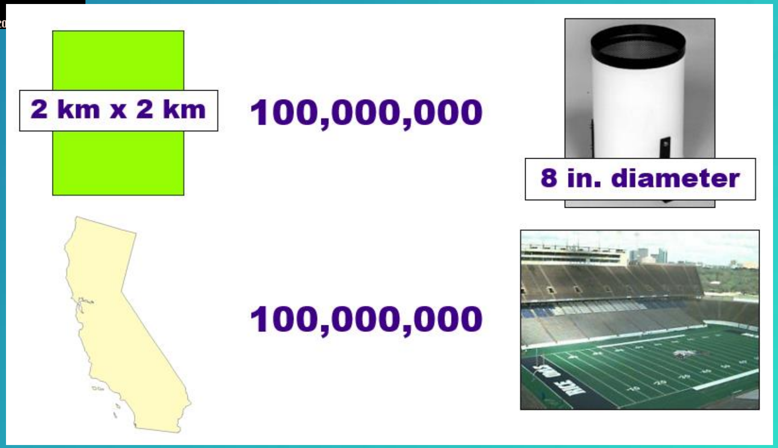


Observations (precipitation)

- Space and time distribution issues
- Traditional rain gages
- Nexrad
- Satellite
- Calibration!!!!







Observations (other)

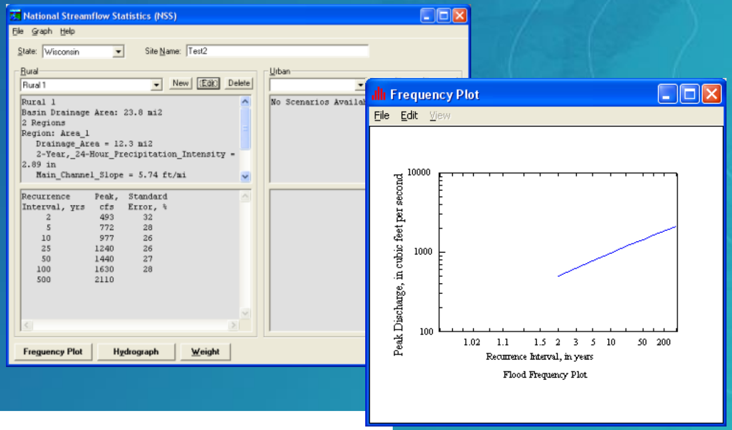
- **Space and time distribution issues**
- **Calibration!!!!**

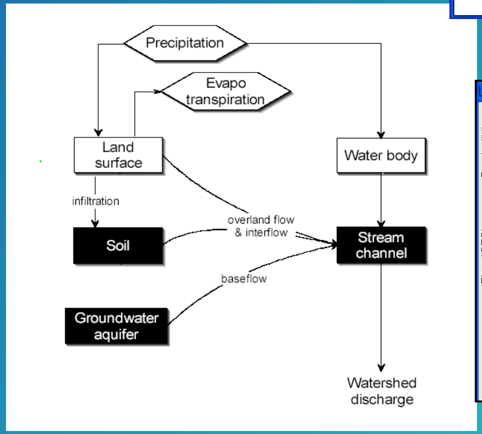
Modeling

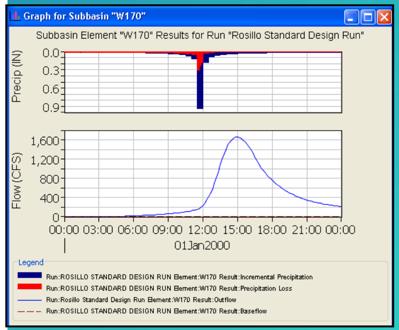
- How much water is there?
  - Hydrologic modeling (precipitation-runoff modeling), determines for a given storm on a landscape, how much water will become runoff.
- Where will it go?
  - Hydraulic modeling takes the quantity of water and the shape of the landscape and stream channel and determines how deep and fast the water will be, and what area it will cover.
- Types of modeling
  - Real-time (operations, forecasting)
  - Long term (planning, design)

Hydrologic Modeling

- Goal: Find stream discharge, Q, at a location for a given precipitation event.
- There are many ways to calculate Q.
  - Statistical methods
    - USGS regression equations (NFF, StreamStats)
  - Deterministic/physical modeling (“rainfall/runoff”)
    - HEC-HMS, SMS, …





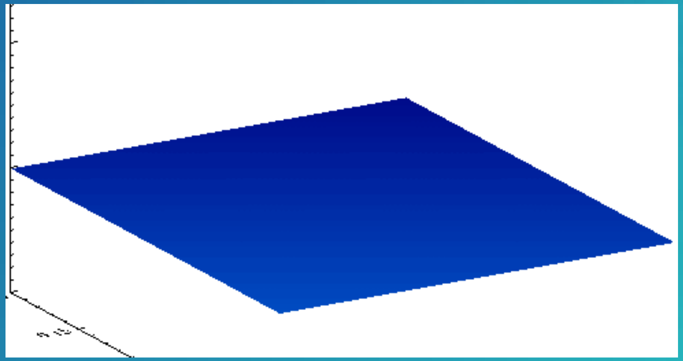


GIS is used to summarize terrain and hydrologic characteristics of the watershed for model input.

Hydraulic Modeling

- **Goal: Predict water surface elevations and velocities for a given discharge in space and time.**
- **Input: Terrain geometry with hydraulic characteristics, plus discharge Q and initial water surface level.**

$$
\begin{aligned}
\frac{\partial \eta}{\partial t} + \frac{\partial(\eta u)}{\partial x} + \frac{\partial(\eta v)}{\partial y} &= 0 \\
\frac{\partial(\eta u)}{\partial t} + \frac{\partial}{\partial x}\left(\eta u^2 + \frac{1}{2} g \eta^2\right) + \frac{\partial(\eta u v)}{\partial y} &= 0 \\
\frac{\partial(\eta v)}{\partial t} + \frac{\partial(\eta u v)}{\partial x} + \frac{\partial}{\partial y}\left(\eta v^2 + \frac{1}{2} g \eta^2\right) &= 0.
\end{aligned}
$$



St.Venant equations

GIS is used to summarize terrain and hydraulic characteristics of the channel for input to a model and post process hydraulic modeling results (water surface determination).

What Do You Need for H&H Analyses

- Definition of the landscape
  - Terrain
  - Known drainage structures (streams, sinks, lakes)
    - Constructed elements (dams, channels, tunnels, …)
  - Landscape characteristics
    - Land use, soils, vegetation cover, …
- Precipitation
  - Rainfall, snowfall, temperature, …
- Boundary conditions
  - Water levels, soil moisture content, …

Easy?

easy
???

but, there is no “easy” button,
just hard work.

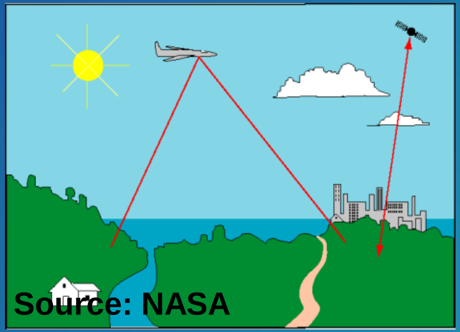
What Can GIS Do for Floodplain Modeling

What Can GIS Do for Floodplain Modeling?

- Centralized data storage
- Data preparation for multiple models
- Postprocessing of modeling results
- Integration of modeling results with other data
- Automation of operations (Map to Map)
- Mobilizing technology (once results are available):
  - Emergency management
  - Notifications
  - Vehicle routing
  - …

GIS Database Development

- **Develop digital representation of the landscape – one time process.**
  - **Quality**
  - **Precision**
  - **Labor Intensive**



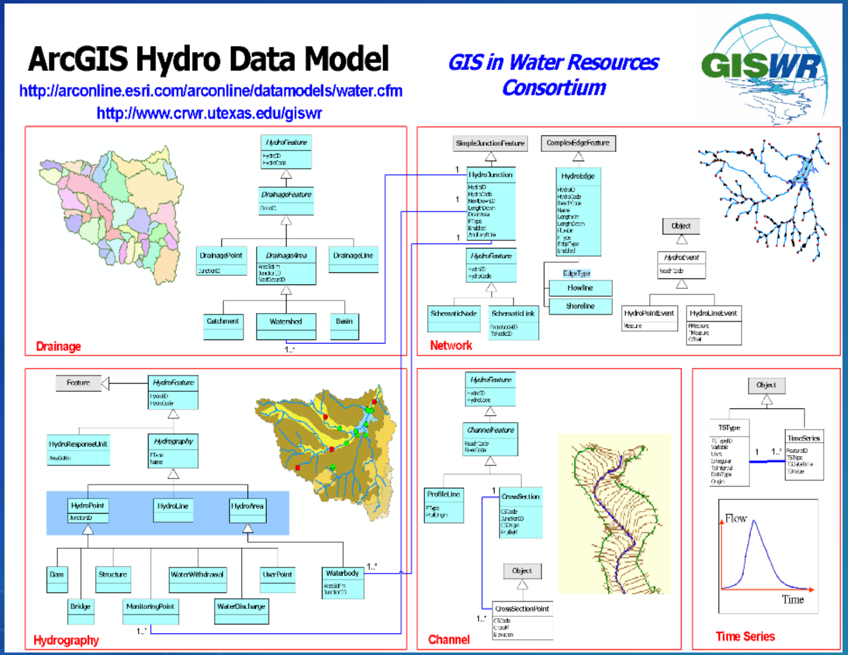
Remote Sensing

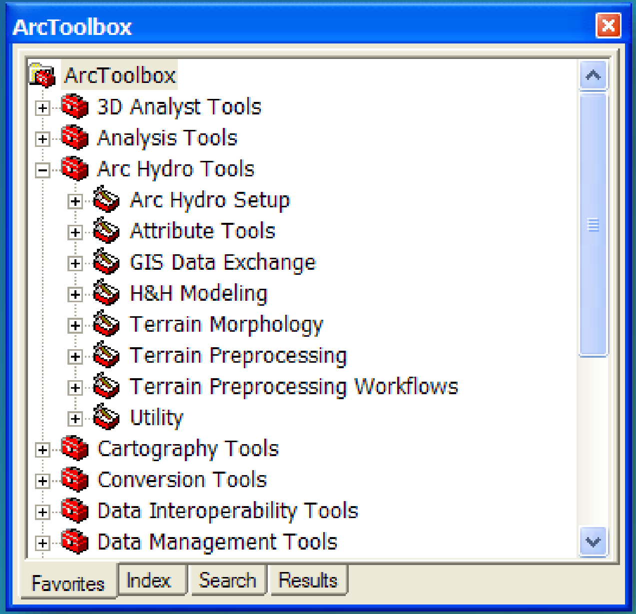
Heads-up digitizing

GIS Layers/Data

Arc Hydro: The Backbone

- **Arc Hydro data model and tools form the backbone for GIS WR implementation**





How “Things” Build Up

- Database design
- Data preparation
- Terrain preparation
- “Watershed” delineation
- “Watershed” characterization

Generic

(Arc Hydro)

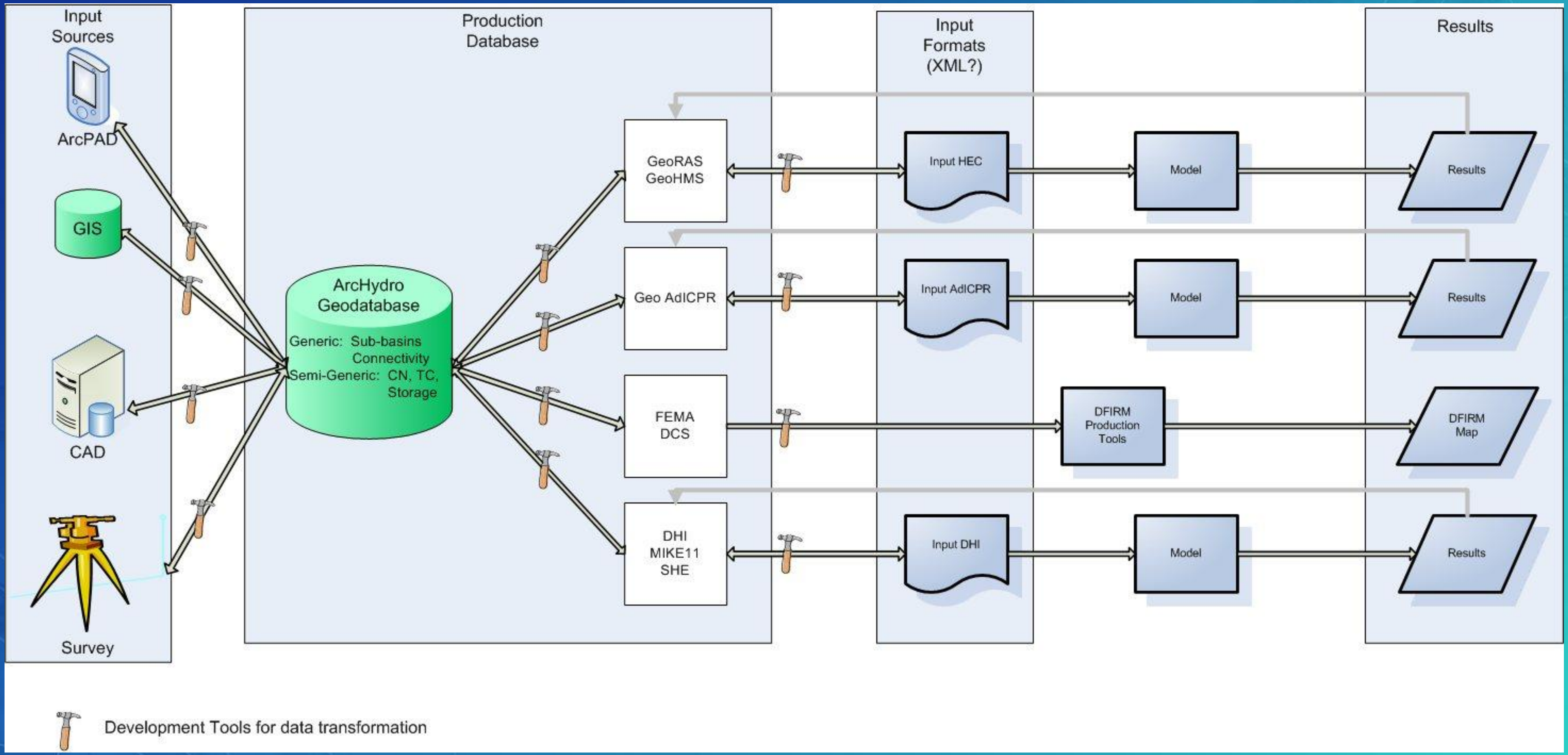
- Parameterization

Semi-generic

- Model pre- and post- processing

Model Specific

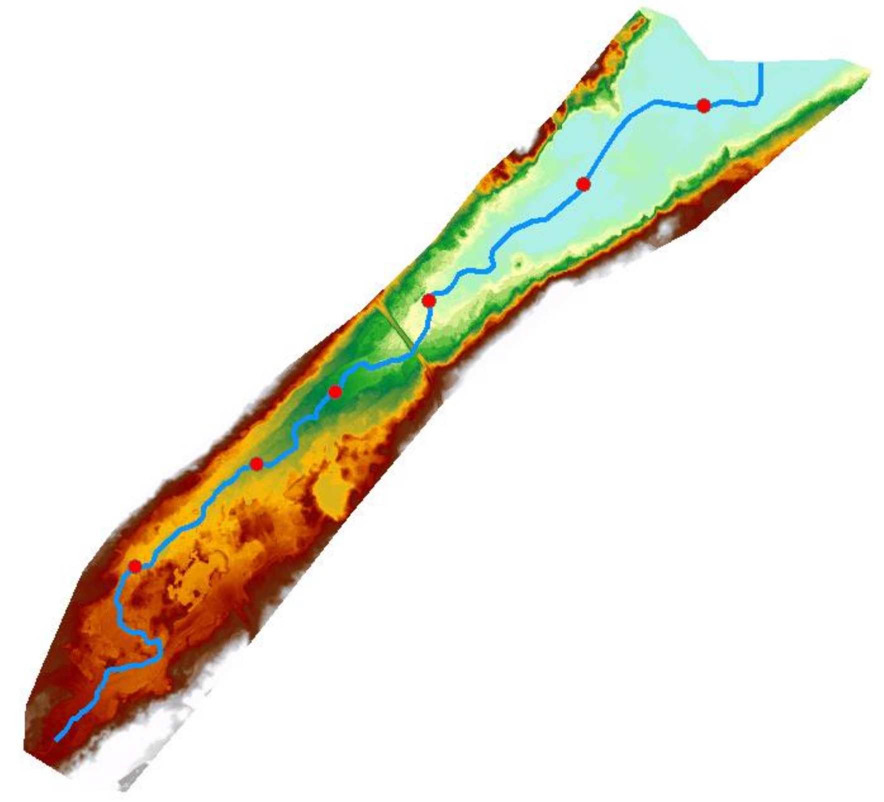
Arc Hydro as Centralized Data Repository Integrates Model Databases



Simple GIS Techniques for Floodplain Delineation

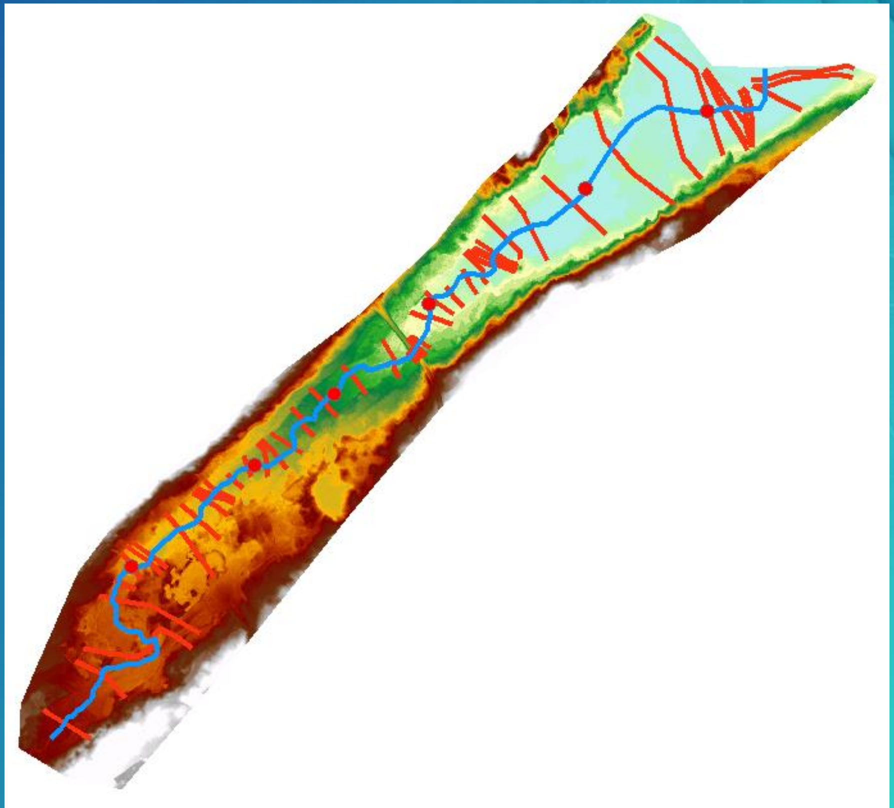
Floodplain Delineation Solutions Matrix

- Different levels of complexity are possible/needed to determine flood extents
- Simple:
  - "Flooding out" based on DEM, stream centerline, and point data (fixed depth, incremental depth, observed measurements, modeled flows at points and conversion to WSE)
    - HAND approach (constant depth of flooding per reach)



Floodplain Delineation Solutions Matrix

- **Less simple:**
  - **Same as above, but using cross-sections to control lateral distribution of water surface elevations along the stream centerline**

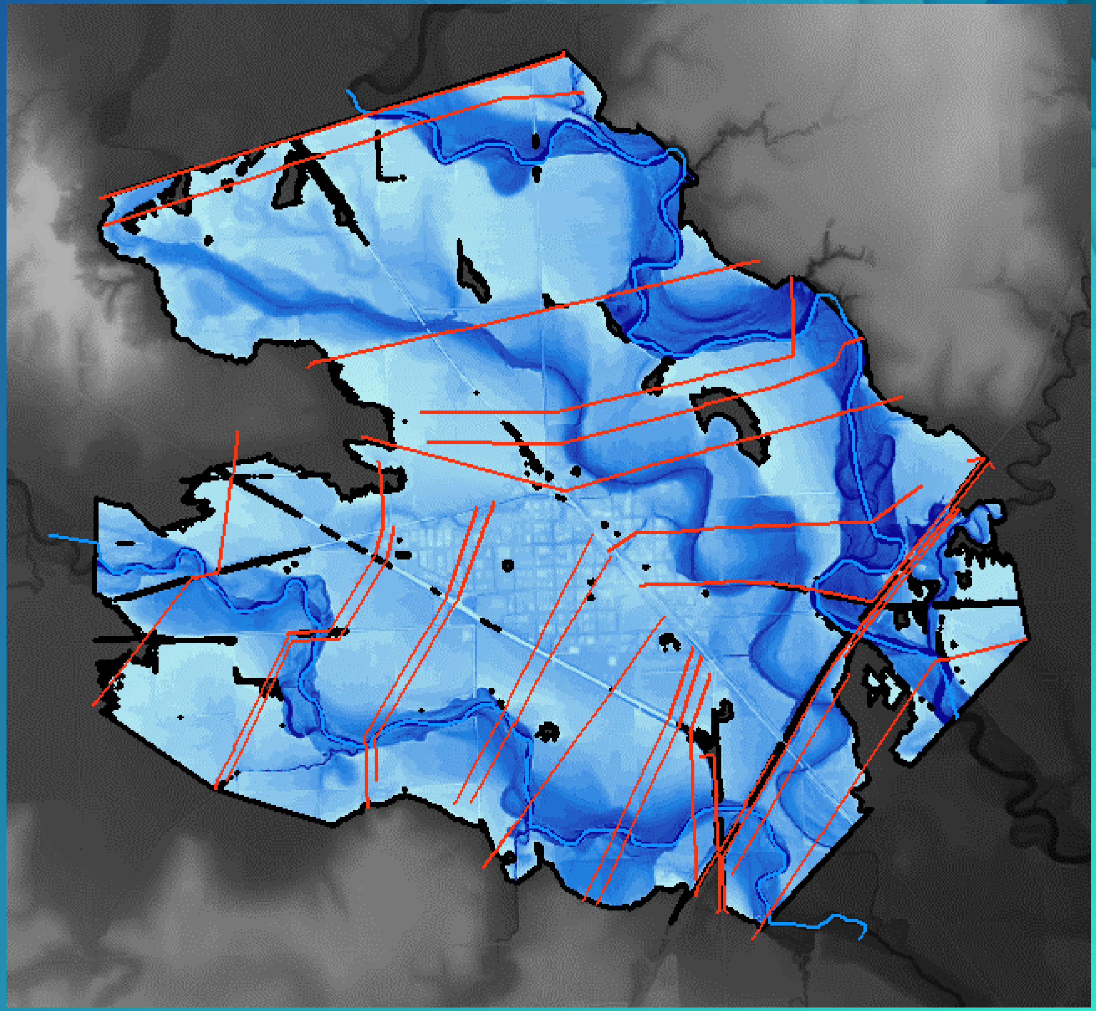


Floodplain Delineation Solutions Matrix

- More complex:
  - 1-D hydraulic modeling in operational mode (complexity in data collection)
  - 1-D hydraulic modeling in design mode (for fixed flood frequency – design discharges derived using statistical methods)
  - 1-D hydraulic modeling in design mode (for fixed flood frequency – design discharges derived using deterministic methods)
- Most complex:
  - Fully integrated 2-D hydrologic and hydraulic modeling

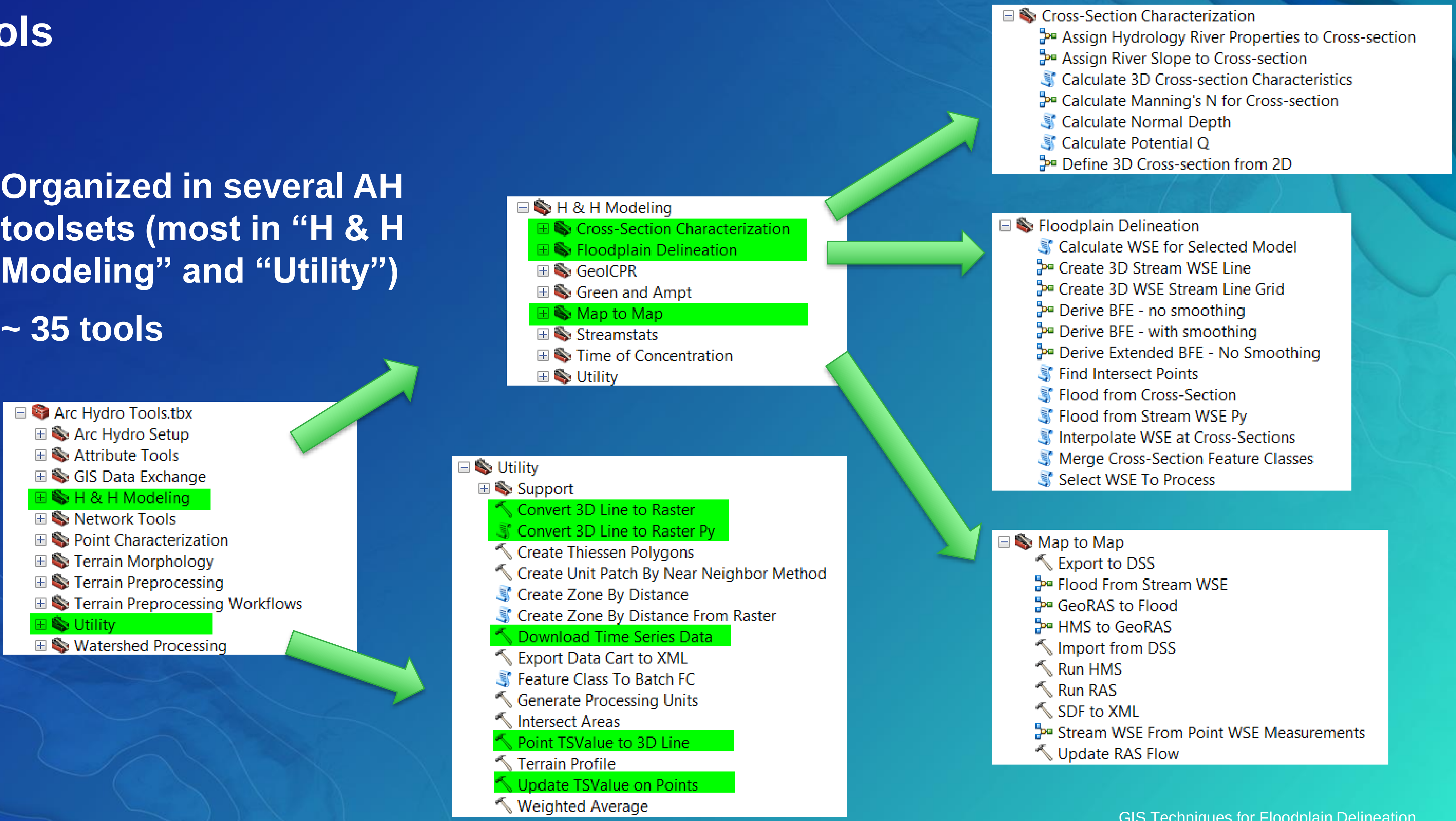
Simplified Floodplain DelineationTools

- **Support for floodplain analysis**
  - **Real-time (observed, forecasted flows)**
  - **Planning (flood frequency)**
- **Facilitate landscape characterization for floodplain analysis**
  - **Streams**
  - **Cross-sections**
  - **Floodplain**
- **Floodplain delineation**
  - **Points**
  - **Cross-sections**
  - **From models**



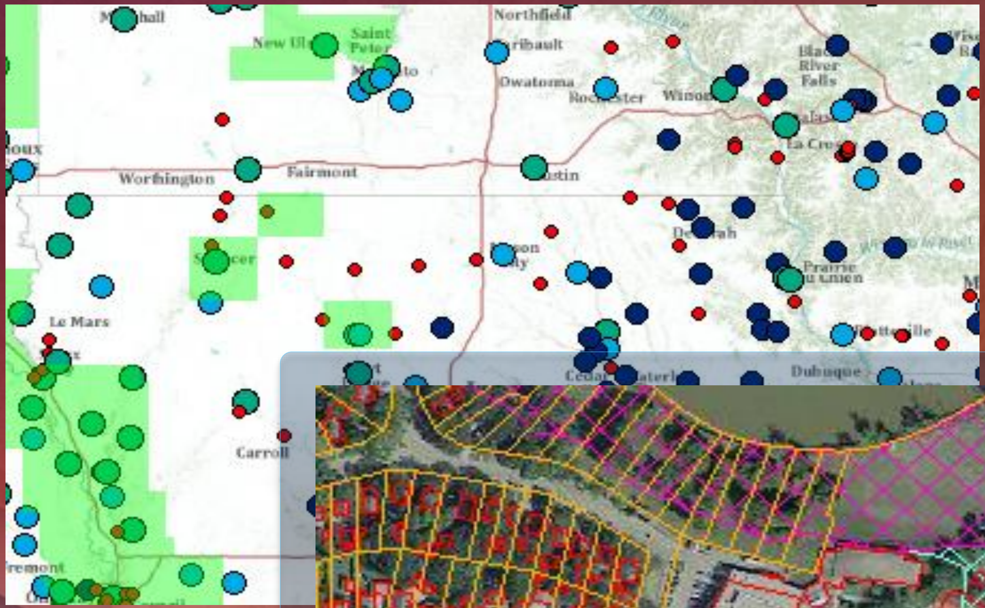
Tools

- Organized in several AH toolsets (most in “H & H Modeling” and “Utility”)
- ~ 35 tools



Sample Implementation Use Cases

- DEM only:
  - Create synthetic streams from DEM
  - “Flood out” WSE along streams in incremental steps
- DEM + cross-sections:
  - Use TIN technique for WSE at c-s in incremental steps
- DEM + stream + observed points:
  - “Flood out” observed WSE along streams
- DEM + stream + modeled Q at points:
  - Build c-s and develop synthetic rating curve at modeled points
  - Use synthetic rating curve to get WSE from modeled Q
  - Alt 1 – use flood out technique at points
  - Alt 2 – use TIN technique at c-s



Arc Hydro

Demo

Summary

Summary

- GIS provides many capabilities to support floodplain delineation.
- Integrated, multi-purpose database for storage of H&H and related data.
- Consistent methodology for spatial data processing and analytical functionality.
- Pre- and post-processing for H&H models significantly reduces time for data preparation for modeling support.
- Needs approach to GIS as an analytical technology.
- Easy evaluation of alternatives
- H&H model integration and automation
  - Operational and change in conditions

Q & A

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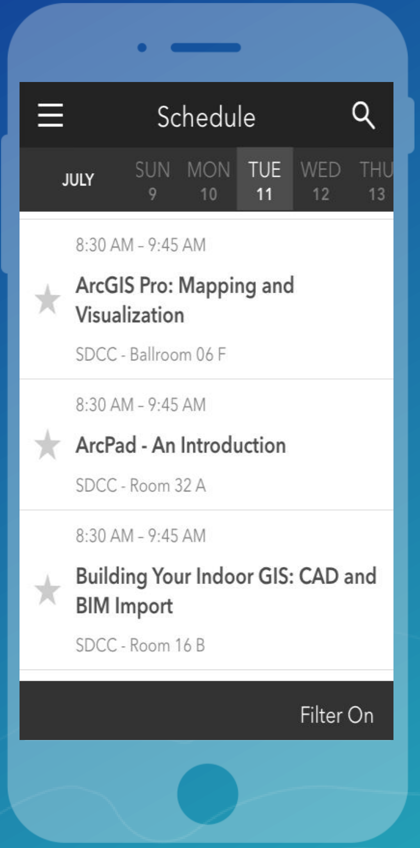
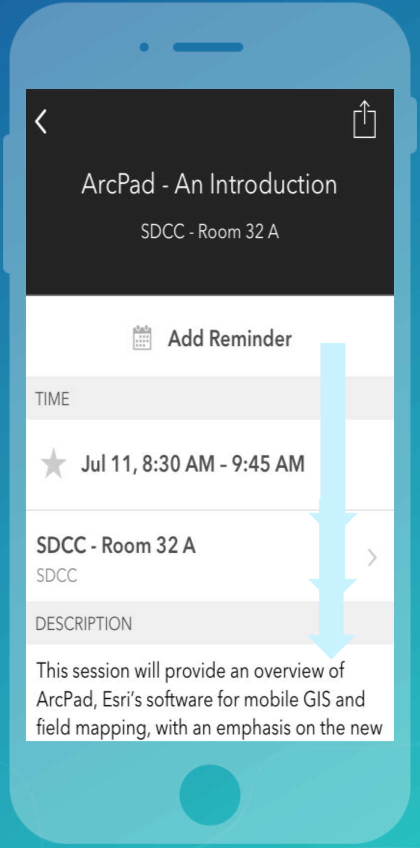
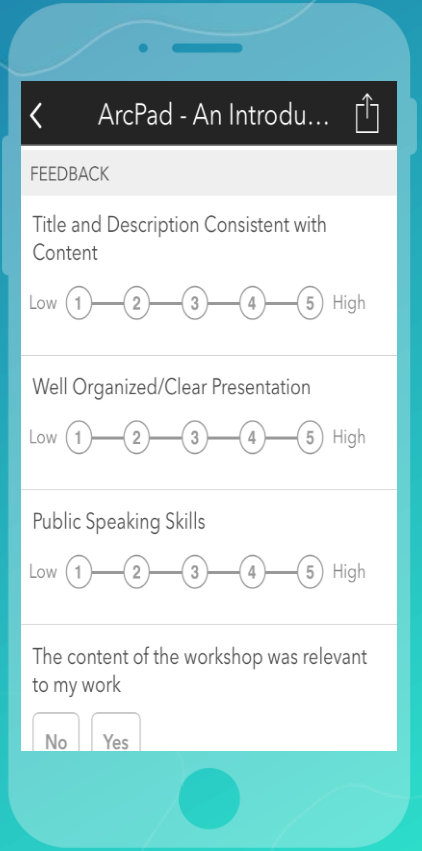


Scroll down to find the survey



Complete Answers and Select "Submit"



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