



Hydrologic and Hydraulic Modeling with ArcGIS

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- **Water resources issues**
- **Core GIS tools for surface water analysis**
- **DEM data and processing**
- **Arc Hydro**
- **Application tools for Hydrologic and Hydraulic Modeling**
- **Q&A**

Water Resources Issues

The background features a dark blue gradient at the top, transitioning into a series of overlapping, semi-transparent geometric shapes in various shades of blue and green at the bottom. Faint, light-colored technical drawings or maps are visible in the lower right quadrant, partially obscured by the geometric shapes.

Water Resources Issues

- **Not enough (droughts)**
- **Too much (floods)**
- **Of wrong kind (water quality)**
- **In a wrong place (spatial distribution)**
- **At the wrong time (temporal distribution)**

Focus on Surface Water Quantity

- 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.

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)
 - “Physical” modeling (rainfall-runoff models)
 - HEC-HMS, SMS, etc.
- *GIS is used to summarize terrain and hydrologic characteristics of the watershed for input to a model.*

Hydraulic Modeling

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

GIS Data for Hydrologic and Hydraulic Modeling

- Check out Esri's Living Atlas (AGOL)
- Digital Elevation Model and land cover
 - <http://seamless.usgs.gov/>
 - <http://edna.usgs.gov/>
 - <http://www.horizon-systems.com/nhdplus/>
- Watershed boundaries
 - <http://www.ncgc.nrcs.usda.gov/products/datasets/watershed/>
- Hydrography
 - <http://nhd.usgs.gov/>
- Soils
 - <http://www.soils.usda.gov/survey/geography/statsgo/>

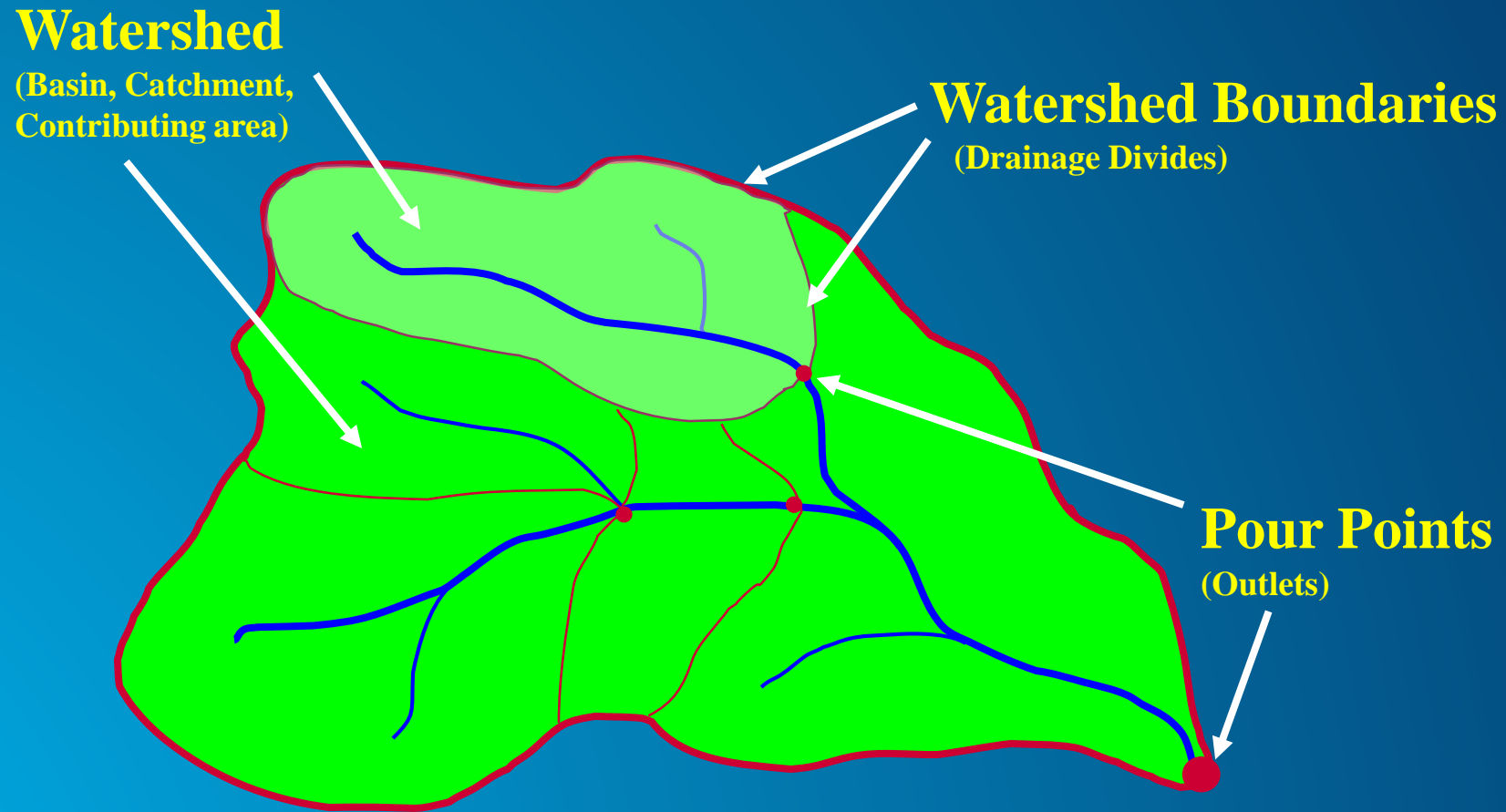
GIS Data for Hydrologic and Hydraulic Modeling

- **Current and historic water records**
 - <http://waterdata.usgs.gov/nwis>
 - <http://www.epa.gov/STORET/index.html>
 - <http://his.cuahsi.org/>
- **Climate and precipitation**
 - <http://www.weather.gov/gis/>
 - <http://www.ncdc.noaa.gov/oa/ncdc.html>
- **Channel geometry (cross sections)**
- **H&H data are very “local”**
 - “You have to be there when it rains!”

Core GIS Tools for Surface Water Analysis

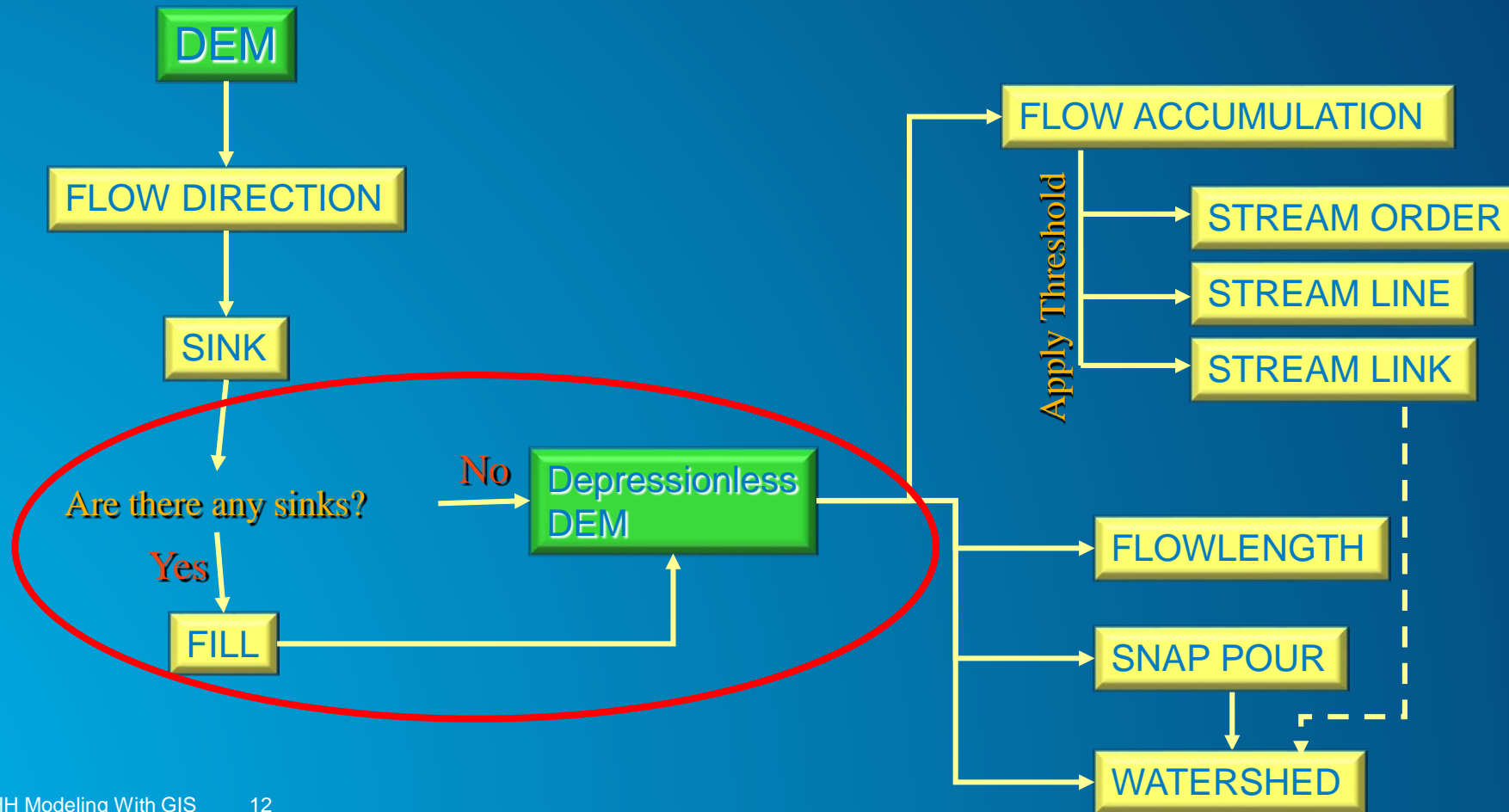
The background features a dark blue gradient at the top, transitioning into a series of overlapping, semi-transparent geometric shapes in shades of blue and green at the bottom. Faint, stylized maps or GIS data visualizations are visible within these shapes, including a grid pattern and a map with various lines and shapes.

Drainage System



GIS Tools for Describing Surface Water Movement

- Dendritic morphology – simple process



Flow Direction

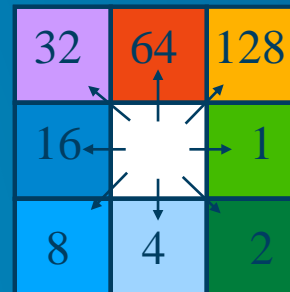
78	72	69	71	58	49
74	67	56	49	46	50
69	53	44	37	38	48
64	58	55	22	31	24
68	61	47	21	16	19
74	53	34	12	11	12

Elevation



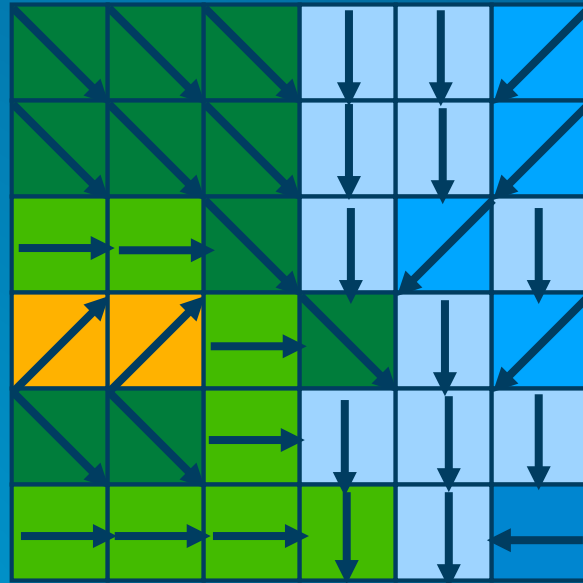
2	2	2	4	4	8
2	2	2	4	4	8
1	1	2	4	8	4
128	128	1	2	4	8
2	2	1	4	4	4
1	1	1	1	4	16

Flow Direction

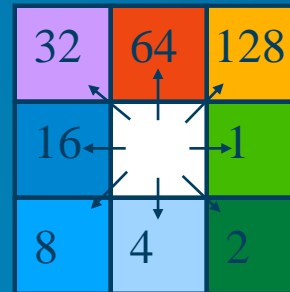


Direction Coding

Flow Accumulation

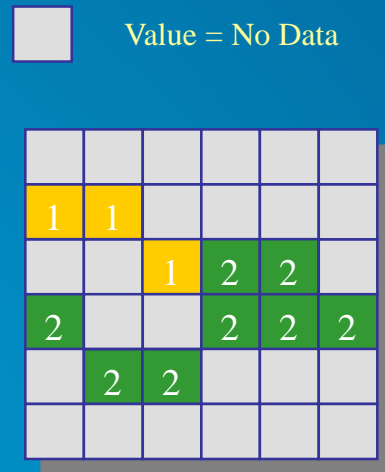


0	0	0	0	0	0
0	1	1	2	2	0
0	3	7	5	4	0
0	0	0	20	0	1
0	0	0	1	24	0
0	2	4	7	35	2

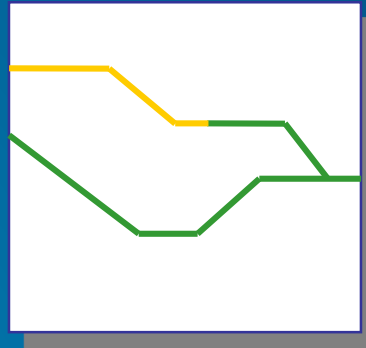


Direction Coding

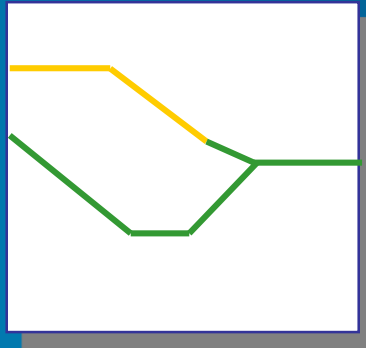
Creating Vector Streams



NET_GRID



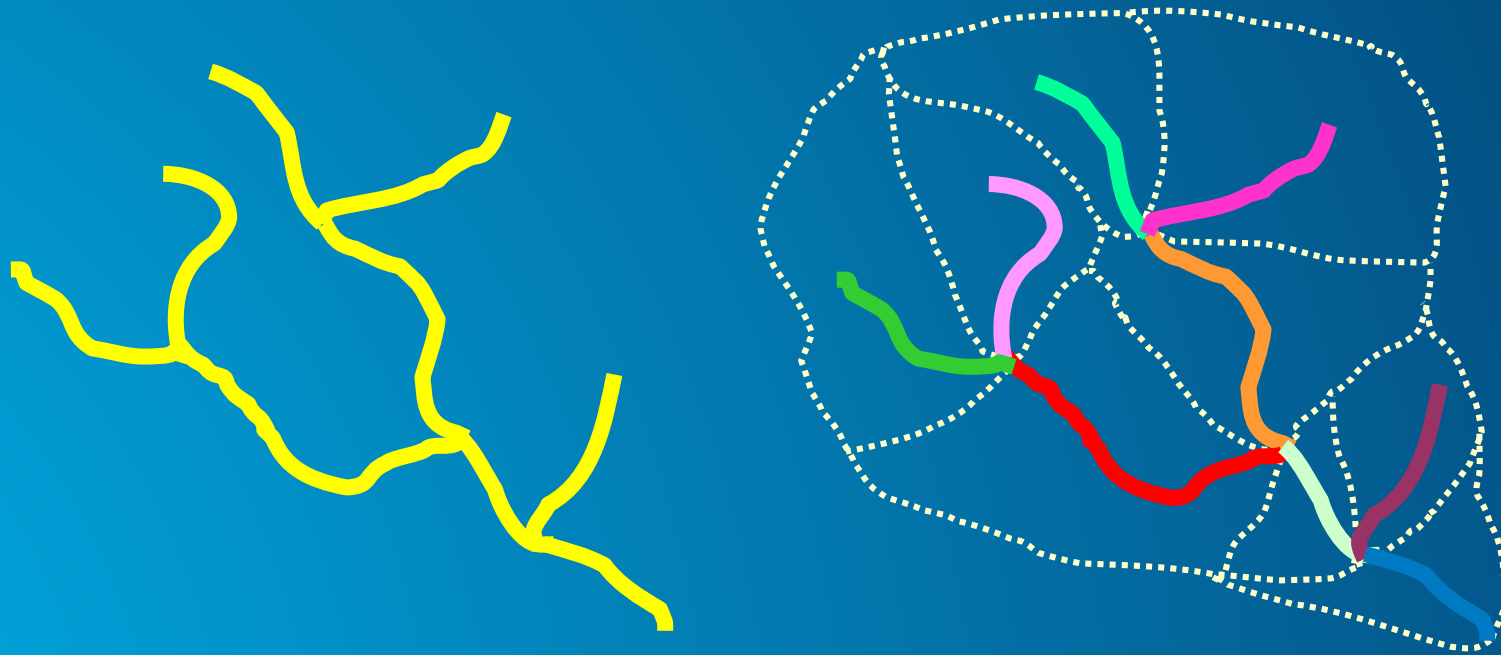
StreamToFeature



RasterToFeature

Stream Link

- Assign a unique value to each stream segment.
 - Can be used as input to Watershed tool



Watershed, subwatershed, drainage area

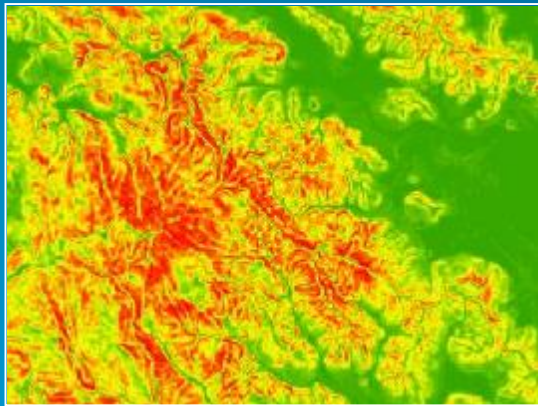
- Delineate the contributing area to a cell or group of cells.



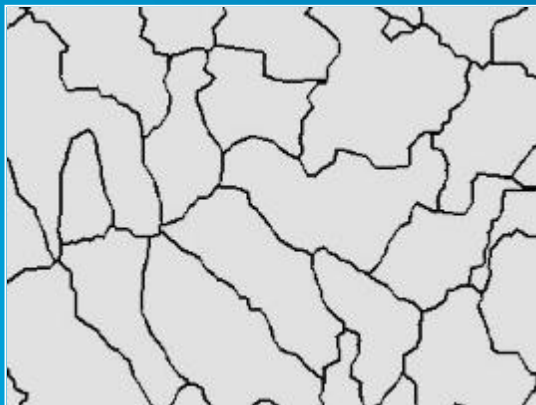
Summarizing Watershed Characteristics

- Using Zonal Statistics

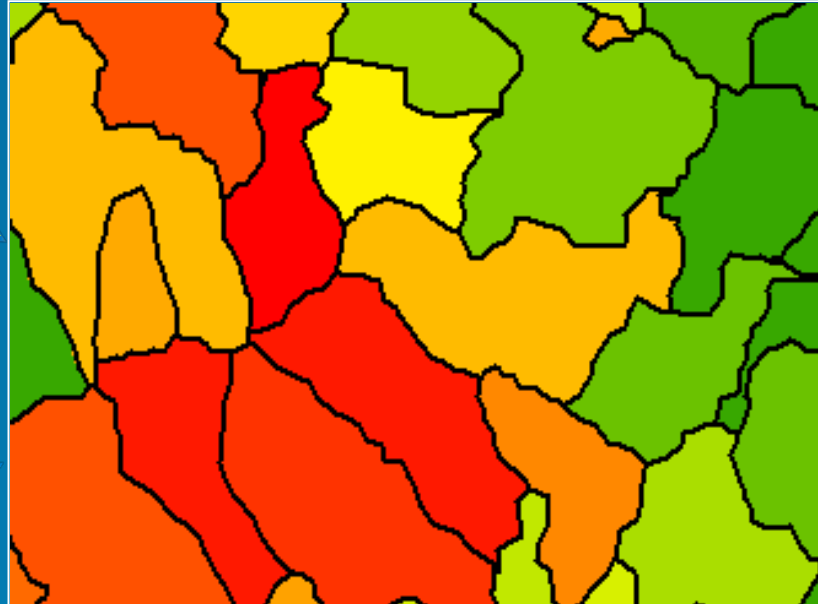
Slope



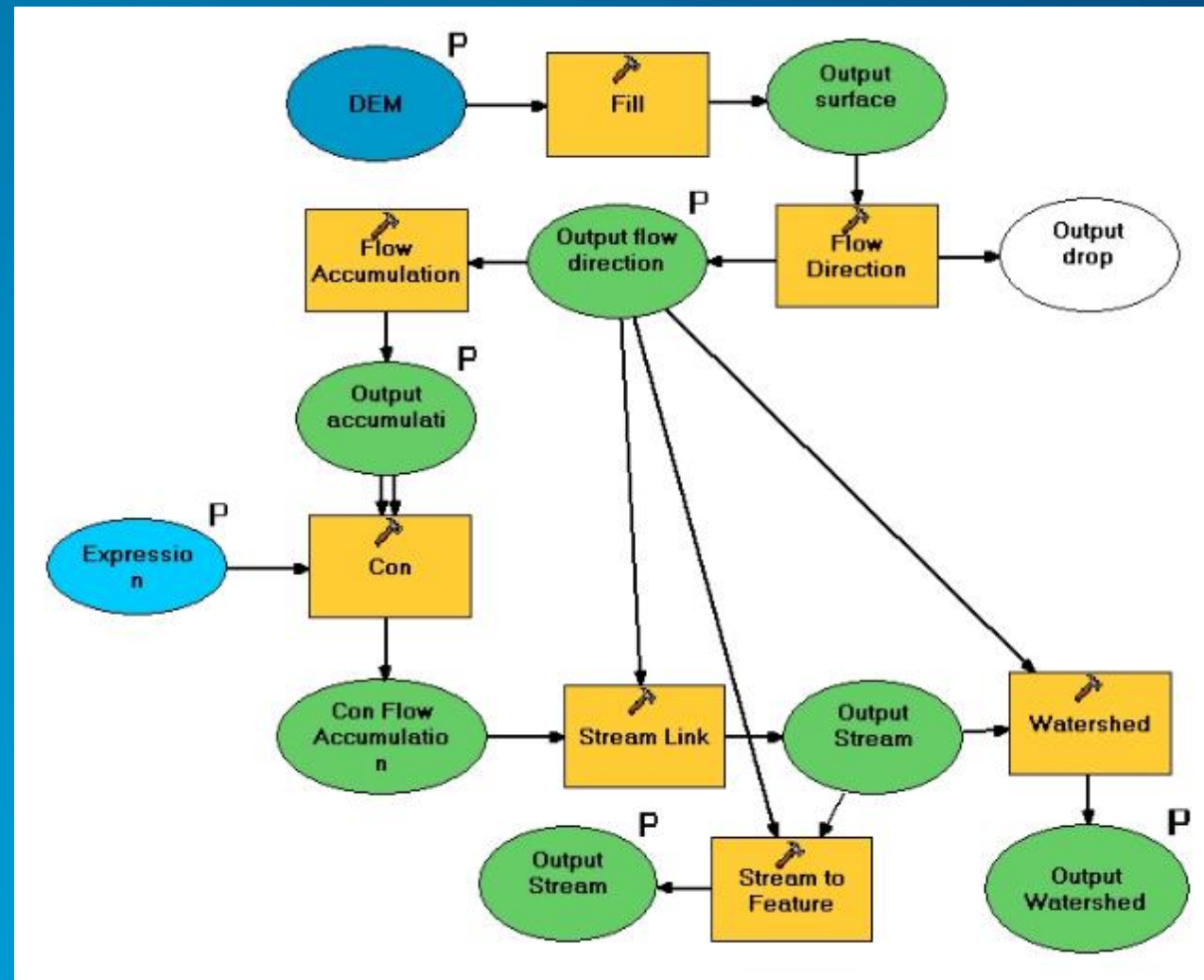
Watersheds



Mean Slope per Watershed



Using the Tools in the Model Builder

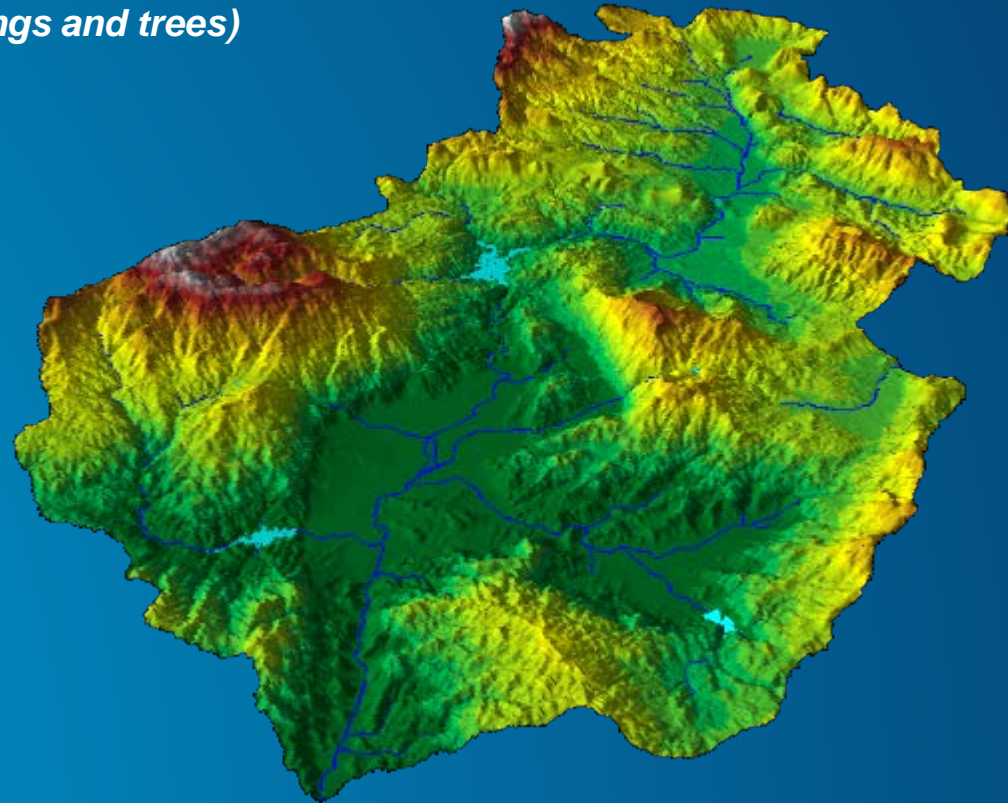


DEM Data and Processing

The background features a gradient from dark blue at the top to lighter blue and green at the bottom. The bottom portion is composed of overlapping, semi-transparent geometric shapes in shades of blue and green. Faint, light-colored outlines of a map or technical drawing are visible in the lower right quadrant.

Elevation Data – Key Dataset

- **Types**
 - **DEM: Digital Elevation Model** (*bare Earth*)
 - **DSM: Digital Surface Model** (*with buildings and trees*)
- **Data Structure**
 - Raster
 - TIN
 - Terrain dataset



Where Do You Get DEM Data?

- **Sources**

- Existing data: USGS DEM, NED, DTED, ETOPO30, SRTM
- LiDAR, IfSAR
- Generated photogrammetrically
- Interpolated from points and lines

- **What cell size and accuracy?**

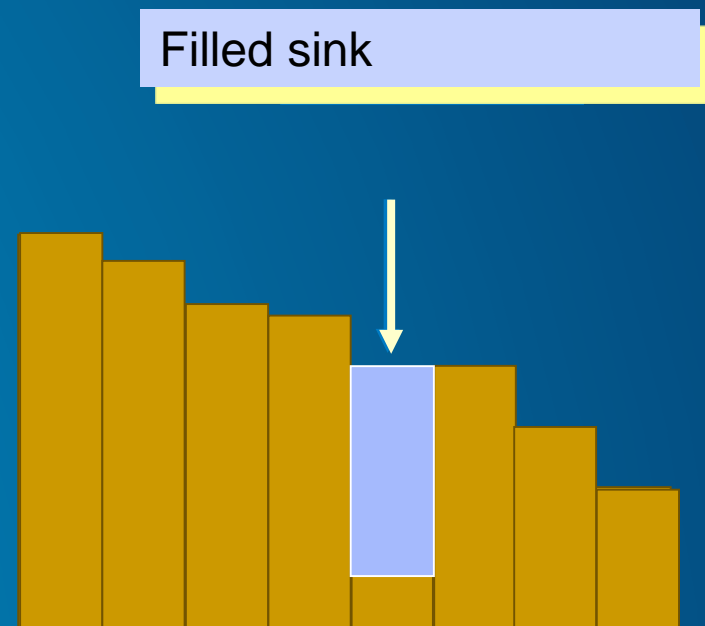
- Horizontal and Vertical resolution must be appropriate for the landscape and scale being modeled.

DEM Construction Considerations

- Resolution and extent
- Projection (for hydrology – use equal area)
- Source elevation data
- Interpolation techniques
 - For hydrologic applications, use **TopoToRaster**.
 - Avoids problems with contour input
 - Creates hydrologically correct DEM
 - Or specialized packages such as ANUDEM

DEM “Errors” – Sinks and Spikes

- Sinks: when sinks are (or are not) sinks – lakes, depressions,...
 - Global fill
 - Dealing with internal basins
 - Selective fill
 - Depth
 - Area
 - Volume
 - “you just know it”



DEM Editing

- **Streams: When streams are not where they “should” be**
 - Flat areas – Difficulty in determining the flow pattern
 - Barriers (roads) diverting the flow paths
 - How to “model” bridges and culverts in DEM
 - How to model dams
 - Imposing the flow pattern - to burn or not to burn (beware of the scale issues and artifacts – Saunders, 2000.)
 - Simple burn
 - AGREE
 - OMNR

DEM Editing (cont.)

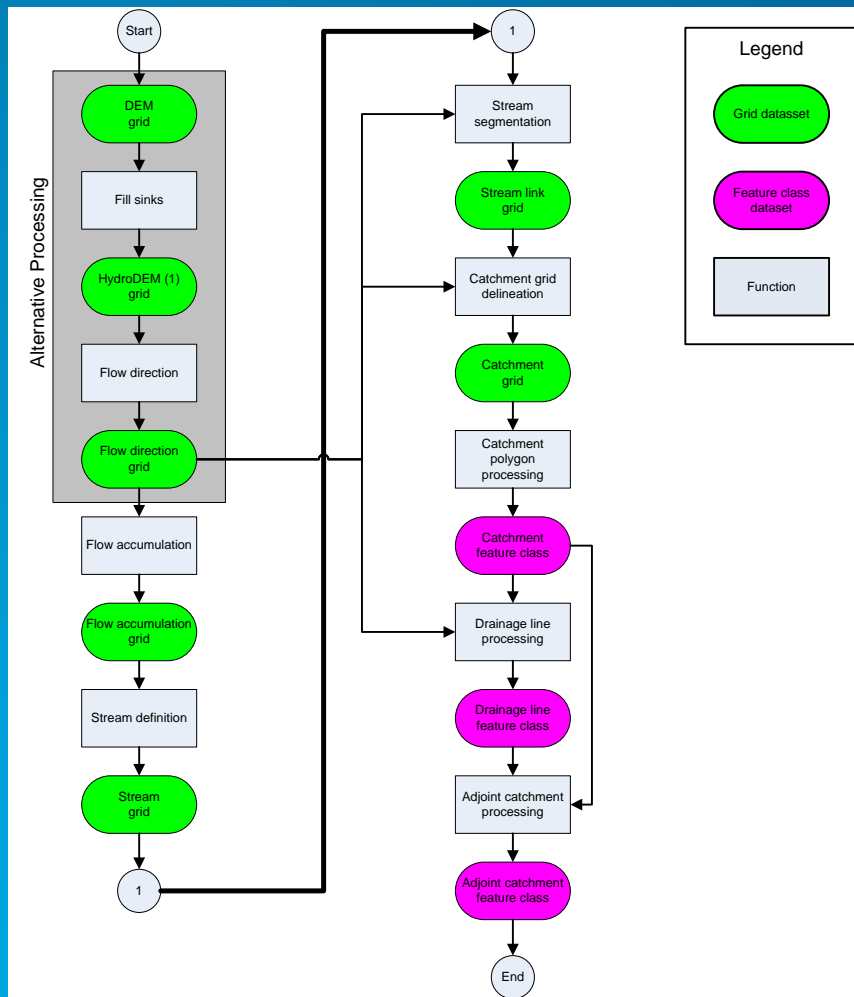
- **Watersheds—When watershed boundaries are not where they “should” be**
 - **To fence or not to fence**
 - **Ineffective flow areas**

What If You Do Not Have Dendritic Morphology?

- **Arc Hydro tools for terrain preprocessing:**
 - **Modified dendritic process**
 - **Burning streams**
 - **Fencing boundaries**
 - **Bowling lakes**
 - **Flow splits**
 - **Deranged terrains**
 - **Selective filling of sinks**
 - **Streams draining into sinks**
 - **Combined dendritic/deranged**

Workflows, Workflows, Workflows

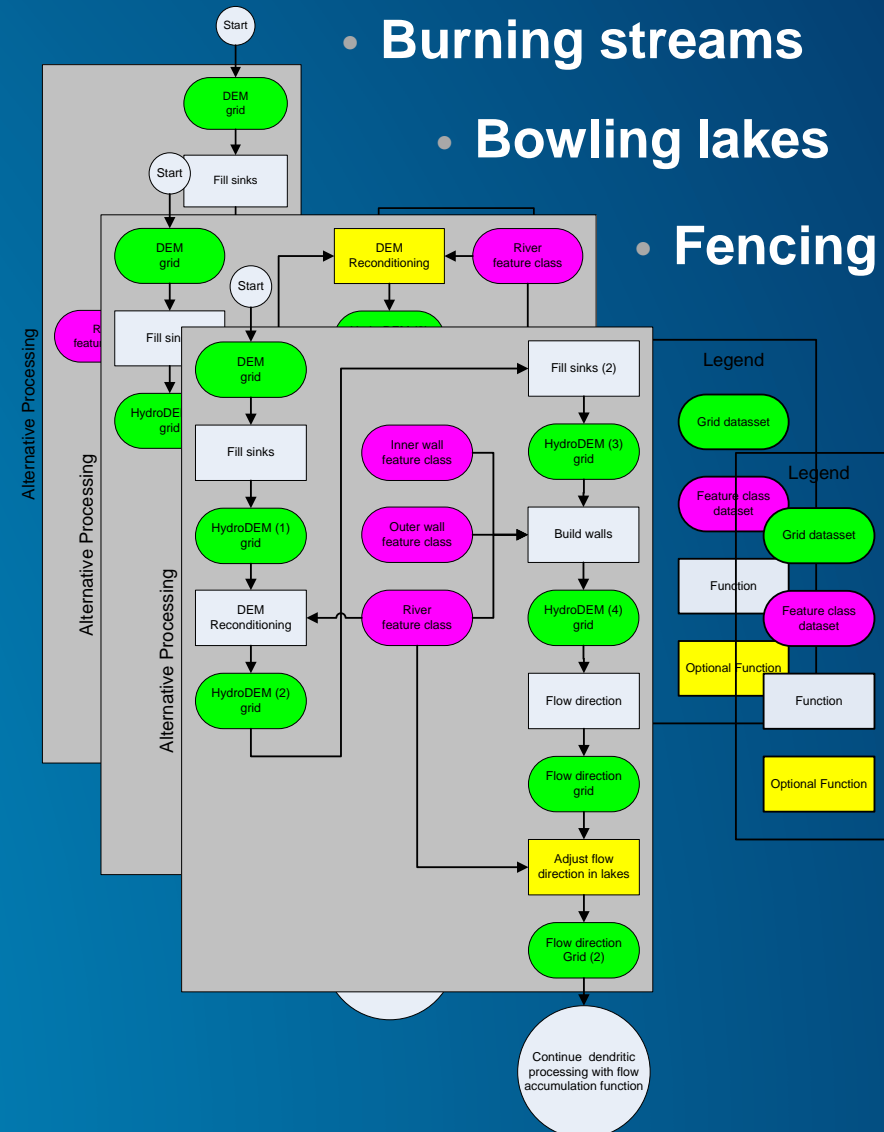
- “Basic” dendritic preprocessing



- Burning streams

- Bowling lakes

- Fencing



Where is this functionality?

- **ArcGIS Spatial Analyst**
 - Tools in the Spatial Analyst Toolbox
 - Sample Toolbar on ArcObjects Online
 - HydrologyOp containing ArcObjects methods
 - *Example ModelBuilder model on the Geoprocessing Center Web site*
- **Arc Hydro**
 - Tools in the Arc Hydro Toolbox
 - Arc Hydro Toolbar

Arc Hydro

Arc Hydro

- **Extension of geodatabase model for support of water resources applications (template data model)**
- **Culmination of a three-year process (1999–2002) led by D. R. Maidment through GIS in Water Resources Consortium (Arc Hydro book)**
- **Collection of tools for support of Arc Hydro geodatabase design and basic water resources functions**
- **Starting point for water resources database and application development**

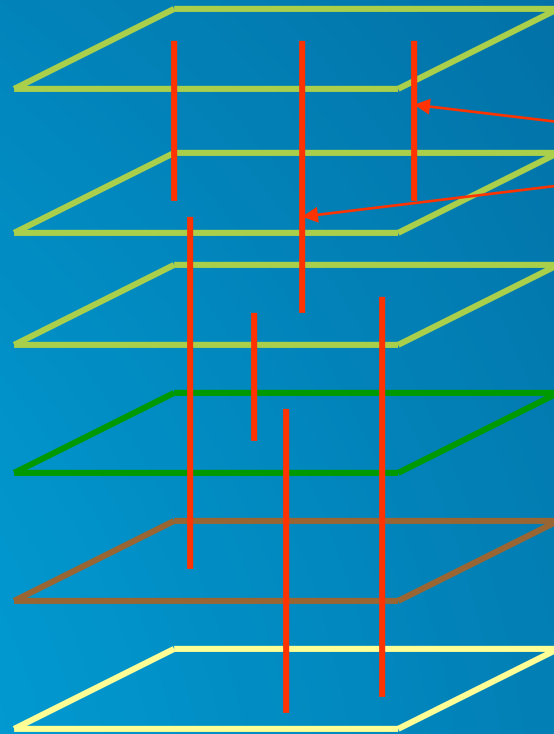
Data Model Purpose

- **Target audience: Water resources community interested in quick start in ArcGIS implementation**
- **Starting point for project model design**
- **Not a “do all” design**
- **Not implementation/application specific, but provides the key components to develop on top of**
 - **The user needs to add additional data structures for their specific requirements – there’s still work to be done!**

What makes Arc Hydro different?

ArcGIS: All features are labeled with a unique **ObjectID** within a feature layer.

Arc Hydro: All features are labeled with a unique **HydroID** across the geodatabase.



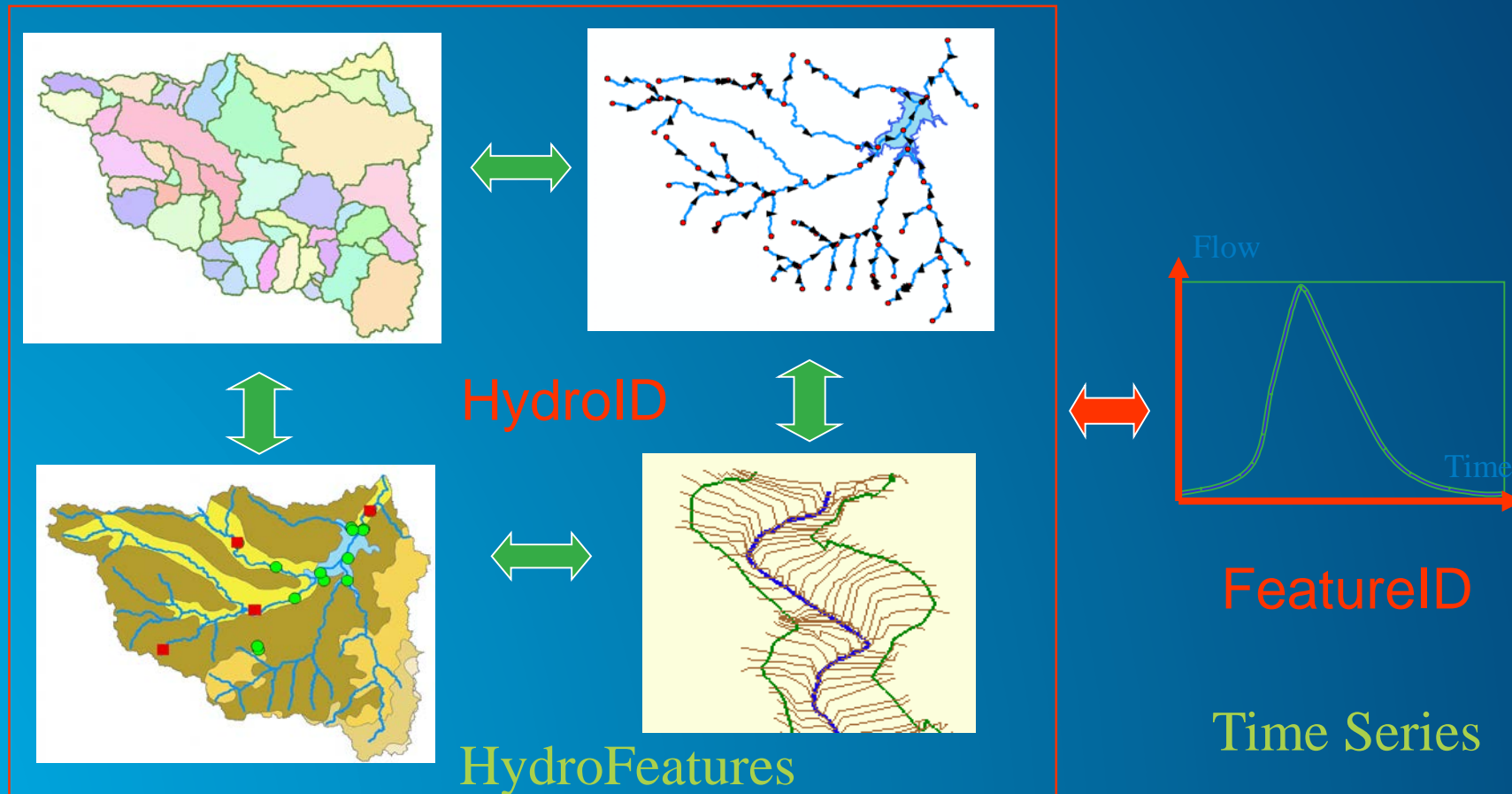
HydroID to ID relationships link neighboring features and help to trace water movement.



Arc Hydro is a unique “flavor” or style of doing GIS.

What makes Arc Hydro different?

Arc Hydro connects space and time:
HydroFeatures are linked to time series.



Arc Hydro Data Model Details

Complex edge feature class
HydroEdge

Geometry: Polyline
 Contains M-values: Yes
 Contains Z-values: No

Field name	Data type	Allow nulls	Default value	Domain	Precision	Scale	Length
OBJECTID	OID						
Shape	Geometry	Yes					
Enabled	Small Integer	Yes	1	EnabledDomain	0	0	2
HydroID	Integer	Yes			0		
HydroCode	String	Yes					30
ReachCode	String	Yes					30
Name	String	Yes					100
LengthKm	Double	Yes			0	0	
LengthDown	Double	Yes			0	0	
FlowDir	Integer	Yes	1	HydroFlowDirections	0		
FType	String	Yes					30
EdgeType	Integer	Yes	1	HydroEdgeType	0		
Shape_Length	Double	Yes			0	0	

Hydro edges are the network of lines describing map hydrography. There are two types: flowlines, which trace water movement, and shorelines, which form the interface between land and water.

Unique feature identifier in the geodatabase
 Permanent public identifier of the feature
 An identifier for a river or stream segment
 Geographic name
 Length of the edge in kilometers
 Length to nearest downstream sink (usually the basin outlet)
 Defines the direction of flow on the edge
 Descriptor of feature type
 Defines the edge as being either a flowline or a shoreline

Coded value domain
EnabledDomain

Description

Field type: Small Integer
 Split policy: Default Value
 Merge policy: Default Value

Code	Description
0	False
1	True

Coded value domain
HydroFlowDirections

Description

Field type: Integer
 Split policy: Default Value
 Merge policy: Default Value

Code	Description
0	Uninitialized
1	With Digitized
2	Against Digitized
3	Indeterminate

Coded value domain
HydroEdgeType

Description

Field type: Integer
 Split policy: Default Value
 Merge policy: Default Value

Code	Description
1	Flowline
2	Shoreline

Subtypes of HydroEdge

Subtype field: EdgeType
 Default subtype: 1

List of defined default values and domains for subtypes in this class

Subtype Code	Subtype Description	Field name	Default value	Domain
1	Flowline	Enabled	1	EnabledDomain
		FlowDir	1	HydroFlowDirections
		EdgeType	1	HydroEdgeType
2	Shoreline	Enabled	1	EnabledDomain
		FlowDir	1	HydroFlowDirections
		EdgeType	2	HydroEdgeType

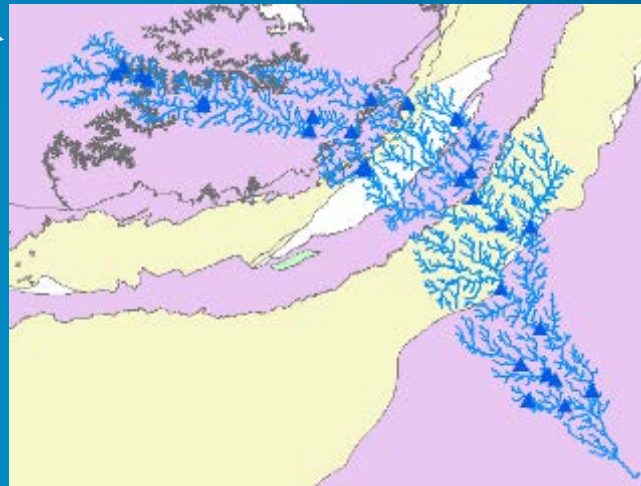
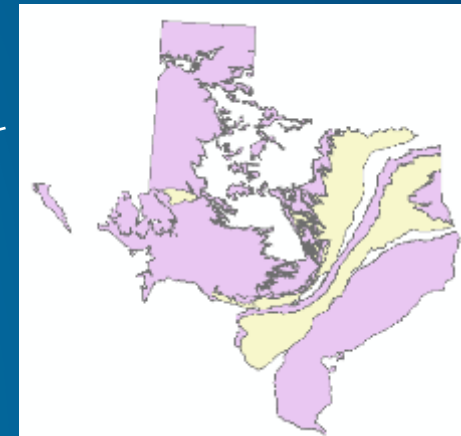
Integration of Surface Water and Groundwater Data

- Describe the relationship between surface water features (e.g., streams and water bodies) with groundwater features (aquifers, wells).

Hydro network



Aquifers



What are Arc Hydro Tools?

- **A set of freely available tools that are a companion to the Arc Hydro data model**
- **Developed and maintained by ESRI Water Resources Team (not a core product or a sample)**
- **Hundred (230) + tools organized in one main and several supporting toolbars in ArcMap**
 - **Geoprocessing (toolbox) implementation of most of the existing tools. All new tools are developed in gp environment.**

What do Arc Hydro Tools do?

- **“Exercise” Arc Hydro data model (manage key identifiers—HydroID, JunctionID, Next DownID, etc.)**
- **Provide functionality common to water resources analyses**
 - **Terrain analysis**
 - **Watershed delineation and characterization**
 - **Tracing and accumulation through networks**
 - **Schema (node-link) development**
 - **Specialized data I/O (XML, Excel, etc.)**
 - **Customizable**

“Why Should I Care” about Arc Hydro Tools?

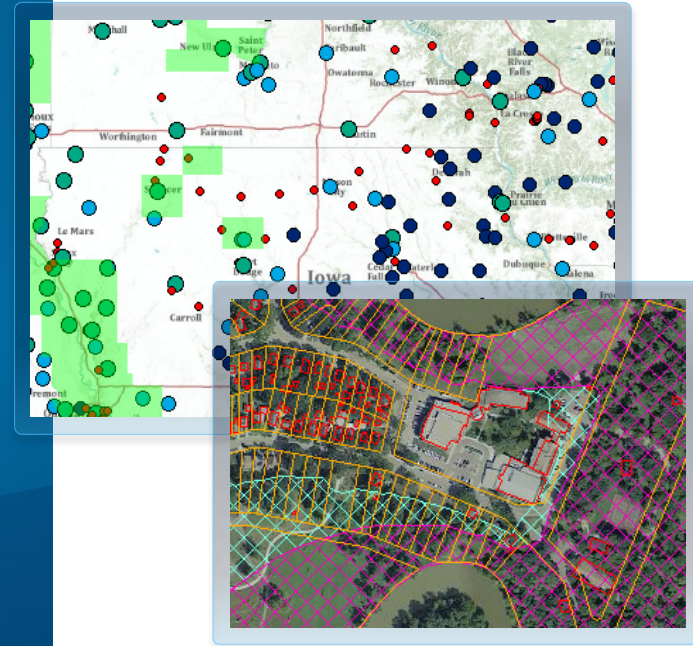
- **Economy of development**
 - Why reinvent the wheel?
 - Established configuration methodology
 - Established development framework
- **Industry “standard”**
 - Established techniques rolled into a publicly available utility
- **Training and support**
- **Free maintenance – ESRI’s commitment to the water resources community**
 - Bug fixes
 - Performance optimization
 - Release updates

Arc Hydro Tools Documentation

- **Online help**
- **Tutorial**
- **Various how-to documents**
- **Instructor-led training**

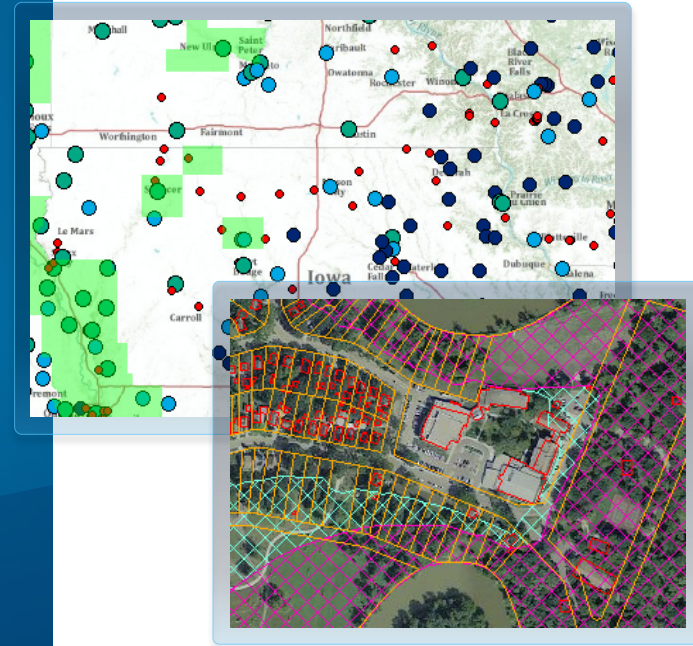
Demo

Arc Hydro



Demo

World Watershed Delineation and Tracing Services



Hydrologic and Hydraulic Modeling Support with GIS

The background features a dark blue gradient with abstract, overlapping geometric shapes in shades of green and light blue at the bottom. Faint, semi-transparent technical drawings, including a cross-section of a dam and a map-like layout, are visible in the lower right quadrant.

How “Things” Build Up

- Database design
 - Data preparation
 - Terrain preparation
 - “Watershed” delineation
 - “Watershed” characterization
-
- Parameterization
-
- Model pre- and post- processing
- Generic
(Arc Hydro)
- Semigeneric
- Model Specific

Section Overview

- **Stream statistics**
- **Hydrologic modeling (HEC-HMS, GeoHMS)**
- **Hydraulic modeling (HEC-RAS, GeoRAS)**
- **H&H integration considerations**
- **Integrated H&H modeling**

Hydrology: Stream Statistics

Regression Equations

- **Used to estimate streamflow statistics, both high and low flows, for ungaged sites (in uncontrolled flow environment)**
- **Relate streamflow statistics to measured basin characteristics**
- **Developed by all 48 USGS districts on a state-by-state basis through the cooperative program (usually sponsored by DOT)**

Example Regression Equation

- Regression equations take the form:

$$Q_{100} = 0.471A^{0.715}E^{0.827}SH^{0.472}$$

- Where

A is drainage area, in square miles

E is mean basin elevation, in feet

SH is a shape factor, dimensionless

Basin Characteristics Used for Peak Flows

Basin characteristic	# of States using this (including PR)
Drainage area or contributing drainage area (square miles)	51
Main-channel slope (feet per mile)	27
Mean annual precipitation (inches)	19
Surface water storage (Lakes, ponds, swamps)	16
Rainfall amount for a given duration (inches)	14
Elevation of watershed	13
Forest cover (percent)	8
Channel length (miles)	6
Minimum mean January temperature (degrees F)	4
Basin shape ((length) ² per drainage area)	4
Soils characteristics	3
Mean basin slope (feet per foot or feet per mile)	2
Mean annual snowfall (inches)	2
Area of stratified drift (percent)	1
Runoff coefficient	1
Drainage frequency (number of first order streams per sq. mi.)	1
Mean annual runoff (inches)	1
Normal daily May-March temp (degrees F)	1
Impervious Cover (percent)	1
Annual PET (inches)	1

... and many others

Role of GIS

- **Speed up the process (instead of hours, minutes).**
- **Provide a common (single) access to the methodology (for users and maintenance).**
- **Systematize methodology and datasets used in the process (repeatability).**
- **Provide better tools for deriving characteristics for regression equation determination.**
- **Provide a map-based user interface.**
- **Web and desktop implementation are based on Arc Hydro.**

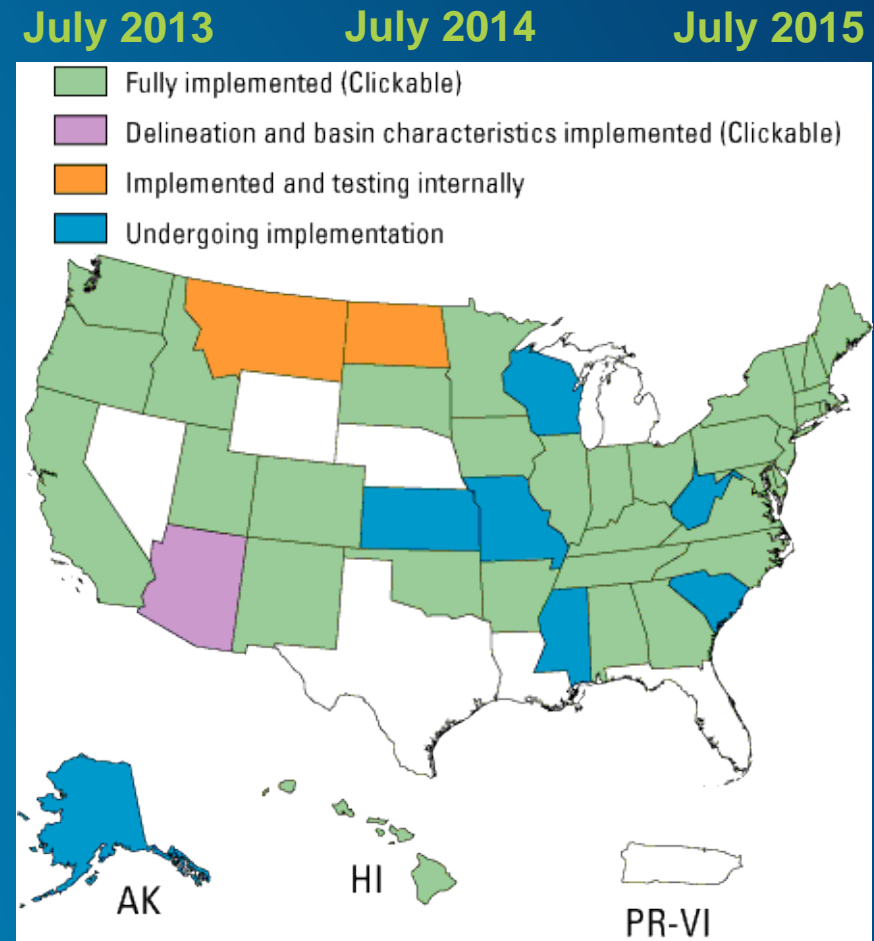
Arc Hydro Tools Role

- **StreamStats fully implemented within Arc Hydro environment**
 - **Terrain preprocessing**
 - **Local and global watershed delineation**
 - **Extracting local characteristics**
 - **Assembly of global characteristics**
- **Characteristics developed for StreamStats available to wider audience (e.g., hydrologic modeling support)**
- **Desktop and Web implementations**

StreamStats Implementation Activities

- USGS lead effort
- State-based
- ArcGIS Server technology
- Hosted in Denver
- Extended functionality

Source: <http://water.usgs.gov/osw/streamstats/ssonline.html>



H&H Integration Overview

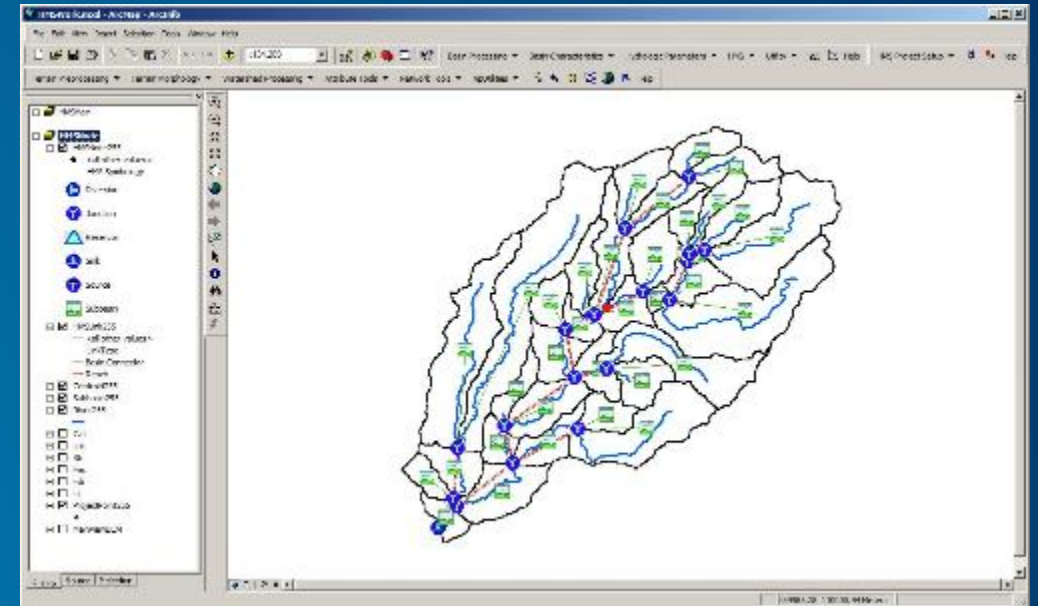
(HMS-RAS Focus)

Role of GIS

- **Develop hydrologically correct DEM and derivatives.**
- **Develop integrated drainage system.**
- **Summarize terrain and hydrologic characteristics of the watershed for input to a model.**
- **Summarize terrain and hydraulic characteristics of the channel for input to a model.**
- **Post process hydraulic modeling results (water surface determination).**
- **Visualization and mapping.**

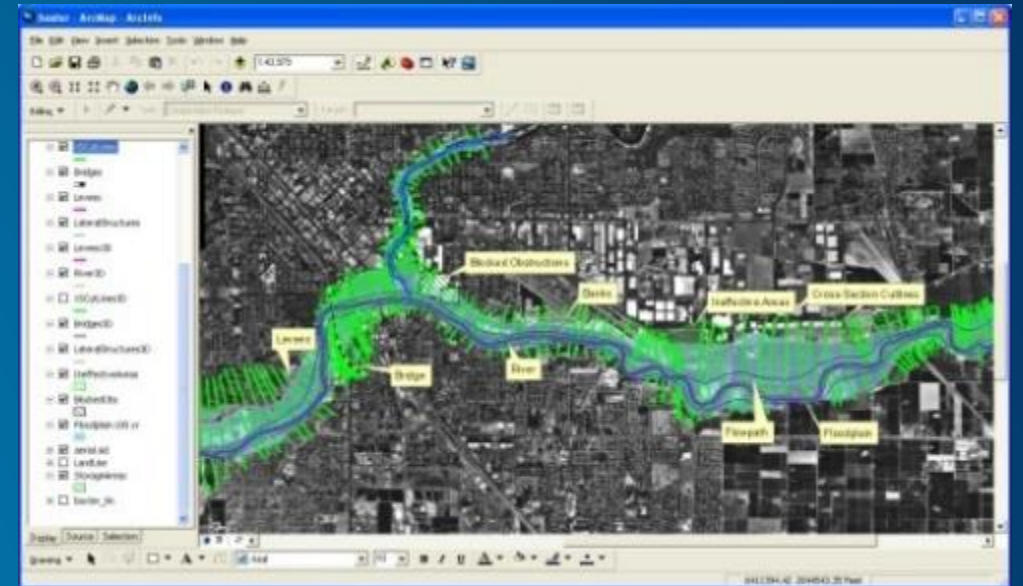
HEC-GeoHMS

- **HEC-HMS:** Hydrologic Engineering Center Hydrologic Modeling System: allows modeling of precipitation – runoff processes.
- **HEC-GeoHMS:**
 - ArcGIS preprocessor for HMS
 - Transforms the drainage paths and watershed boundaries based on DEM into a hydrologic data structure that can be used to model the watershed response to precipitation



HEC-GeoRAS

- HEC-RAS: Hydrologic Engineering Center River Analysis System: allows performing one-dimensional open channel steady and unsteady flow calculations.
- HEC-GeoRAS:
 - Prepare geometric data for import into HEC-RAS
 - Processes simulation results exported from HEC-RAS

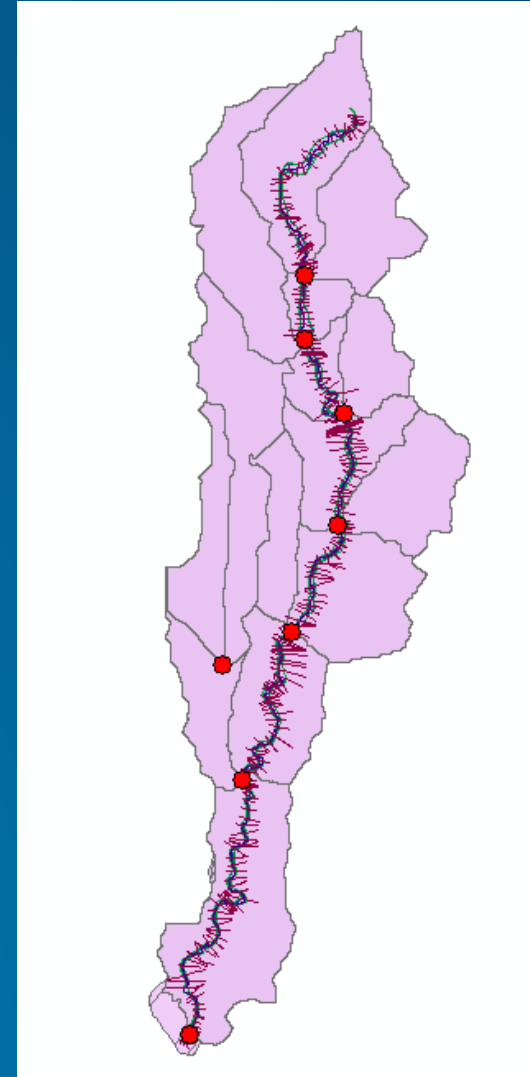


Integration Approach

- **Mix of planning, GIS, and H&H modeling operations (not a push-button operation)**
- **Types of integration**
 - **Modeling support (preparing data for model input)**
 - (e.g., land use/soils/CN or rainfall processing – Arc Hydro or general GIS data processing)
 - **Linked**
 - **GeoHMS**
 - **GeoRAS**
 - **Integrated**
 - **DSS**

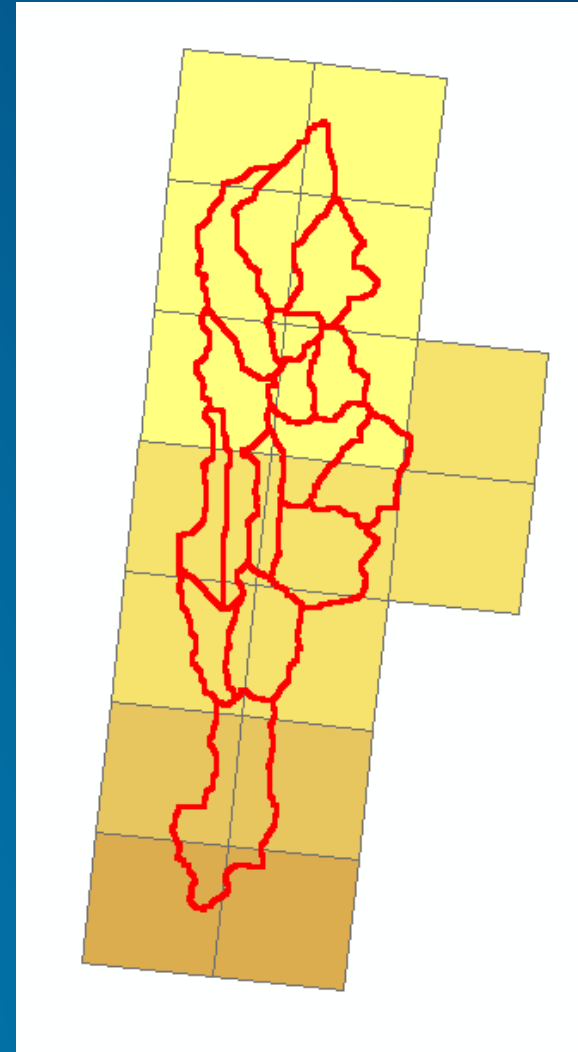
Integration Planning

- Identify where outputs from one model (HMS) become input to the second one (RAS).
 - Flow exchange points



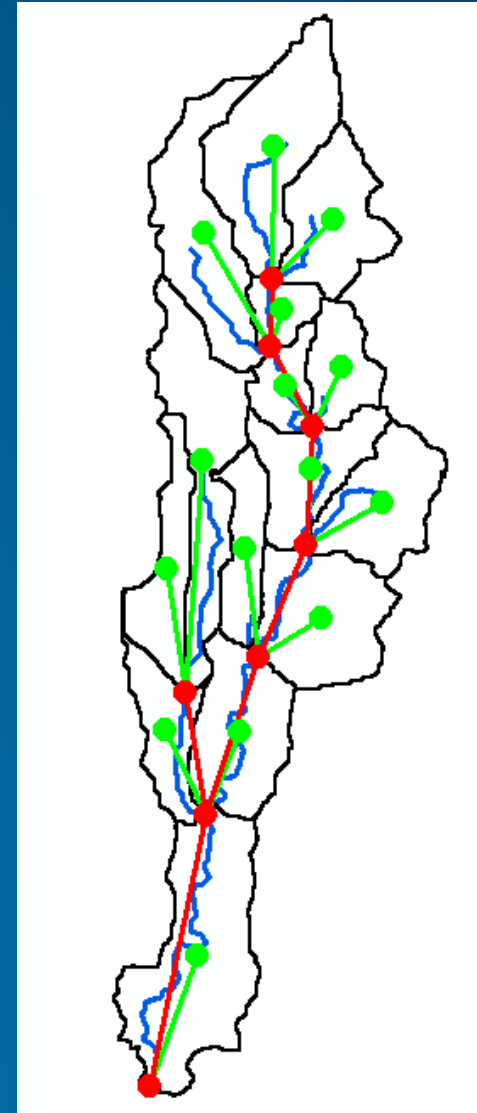
Precipitation Sources

- Identify sources of precipitation input into the hydrologic model and techniques for their incorporation into the dataset.
 - Point (rain gauge)
 - Polygon (Nexrad cells)
 - Surface (TIN/GRID)



Develop GeoHMS Model

- Follow all principles in development of a hydrologic model.
- In addition, take into consideration integration planning aspects developed earlier.
 - Placement of flow exchange points
 - Naming conventions



Meteorological Component

- Develop a custom rain “gauge” for each subbasin or for each rainfall observation element with corresponding weights for subbasins.

The image displays three software windows illustrating the meteorological component workflow:

- Attributes of TimeSeries1:** A data table showing rainfall observations for 22 subbasins. The columns are OBJECTID, FEATUREID, TSTYPEID, TSDATETIME, and TSVLUE.

OBJECTID	FEATUREID	TSTYPEID	TSDATETIME	TSVLUE
1	17	8	7/1/2002 4:00:0	0.03714
2	17	8	7/1/2002 5:00:0	0.28810
3	17	8	7/1/2002 6:00:0	1.21117
4	17	8	7/1/2002 7:00:0	0.79589
5	17	8	7/1/2002 8:00:0	0.69582
6	17	8	7/1/2002 9:00:0	0.31600
7	17	8	7/1/2002 10:00:0	0.80162
8	17	8	7/1/2002 11:00:0	0.50833
9	17	8	7/1/2002 12:00:0	0.34806
10	17	8	7/1/2002 1:00:0	0.33992
11	17	8	7/1/2002 2:00:0	0.15172
12	17	8	7/1/2002 3:00:0	0.04625
13	17	8	7/1/2002 4:00:0	0.01306
14	17	8	7/1/2002 5:00:0	0
15	17	8	7/1/2002 6:00:0	0.38137
16	17	8	7/1/2002 7:00:0	0.24416
17	17	8	7/1/2002 8:00:0	0.42312
18	17	8	7/1/2002 9:00:0	0.18495
19	17	8	7/1/2002 10:00:0	0.22027
20	17	8	7/1/2002 11:00:0	0.19340
21	17	8	7/2/2002	0
22	18	8	7/1/2002 4:00:0	0.04570

- Arc Hydro:** A map showing a watershed divided into subbasins, outlined in red. A green double-headed arrow indicates the transfer of data from the table to the map.
- HecDssVue:** A software window showing a list of pathnames for rainfall data. The file name is C:\hmspro\aaaa\RosWNexR.dss. The list includes paths for various subbasins (W17, W18, W19, W20, W21, W22, W23, W24, W25) and a summary path (W17 FROM NEXRAD).
- ROSILOBNEXT2/W17/PRECIP-INC/01 JUL 2002/1 HOUR/FROM NEXRAD/:** A precipitation hydrograph showing rainfall intensity (Precip (in)) over time (06:00 to 24:00) for subbasin W17. The graph shows a peak of approximately 1.2 inches at 06:00, followed by a gradual decrease with some fluctuations.

A red double-headed arrow labeled "Arc Hydro to DSS transfer" points from the Arc Hydro map to the HecDssVue window. A green double-headed arrow labeled "DSS" points from the HecDssVue window to the precipitation hydrograph.

Finalize and Run HMS

- Complete HMS model with any additional parameters including meteorological model and control specifications.

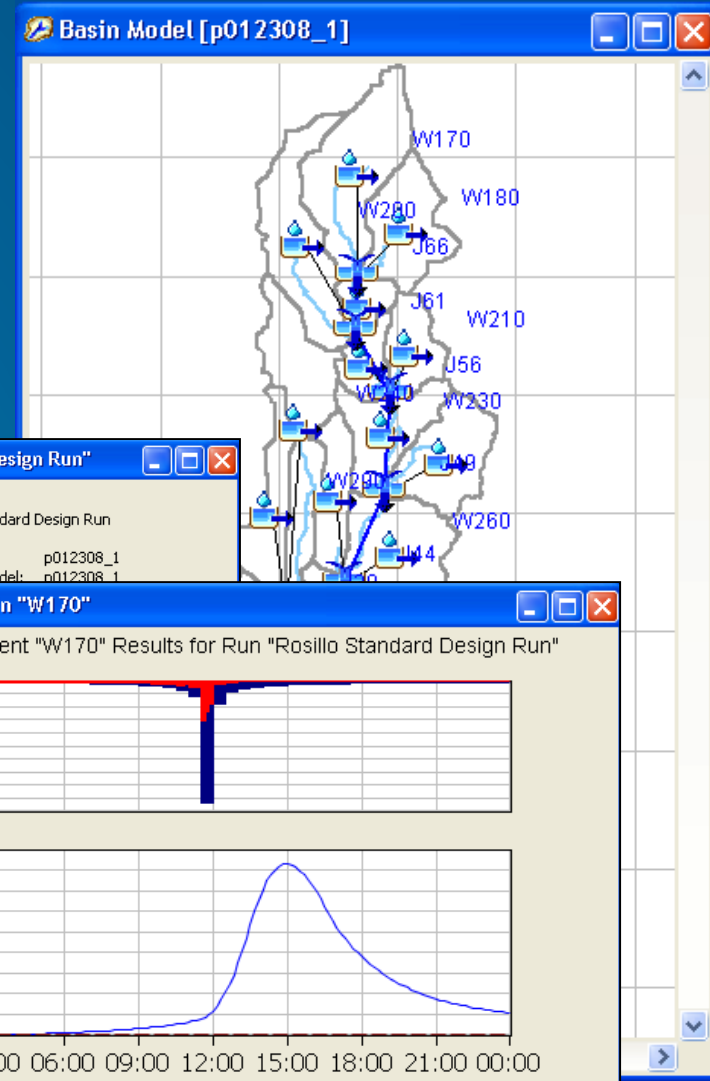
The screenshot displays the Basin Model software interface for project p012308_1. The main window shows a watershed map with subbasins labeled W170, W180, W190, W200, W210, W220, W230, W240, W250, W260, W270, W280, W290, W300, W310, W320, W330, W340, W350, W360, W370, W380, W390, W400, W410, W420, W430, W440, W450, W460, W470, W480, W490, W500, W510, W520, W530, W540, W550, W560, W570, W580, W590, W600, W610, W620, W630, W640, W650, W660, W670, W680, W690, W700, W710, W720, W730, W740, W750, W760, W770, W780, W790, W800, W810, W820, W830, W840, W850, W860, W870, W880, W890, W900, W910, W920, W930, W940, W950, W960, W970, W980, W990, W1000. The interface includes several configuration windows:

- Basin Model [p012308_1]**: Main window showing the watershed map.
- Subbasin List**: A table listing subbasins and their gages.

Subbasin Name	Gage
W170	WDNR
W180	WDNR
W190	WDNR
W200	WDNR
W210	WDNR
W220	WDNR
- Subbasin Configuration (Basin Name: p012308_1, Element Name: W170)**:
 - Initial Abstraction (IN): 0
 - Curve Number: 74.276
 - Impervious (%): 0.0
- Control Specifications (Name: Rosillo Standard)**:
 - Description: Standard Rosillo Design Run
 - Start Date (ddMMYYYY): 01Jan2000
 - Start Time (HH:mm): 00:00
 - End Date (ddMMYYYY): 02Jan2000
 - End Time (HH:mm): 00:00
 - Time Interval: 10 Minutes
- Subbasin Configuration (Basin Name: p012308_1, Element Name: W170)**:
 - Lag Time (MIN): 177.89
- Subbasin Configuration (Basin Name: p012308_1, Element Name: W170)**:
 - Description:
 - Downstream: J66
 - Area (MI2): 3.1678
 - Loss Method: SCS Curve Number
 - Transform Method: SCS Unit Hydrograph
 - Baseflow Method: --None--

Finalize and Run HMS (2)

- Do the final run and generate results (DSS).



HMS View

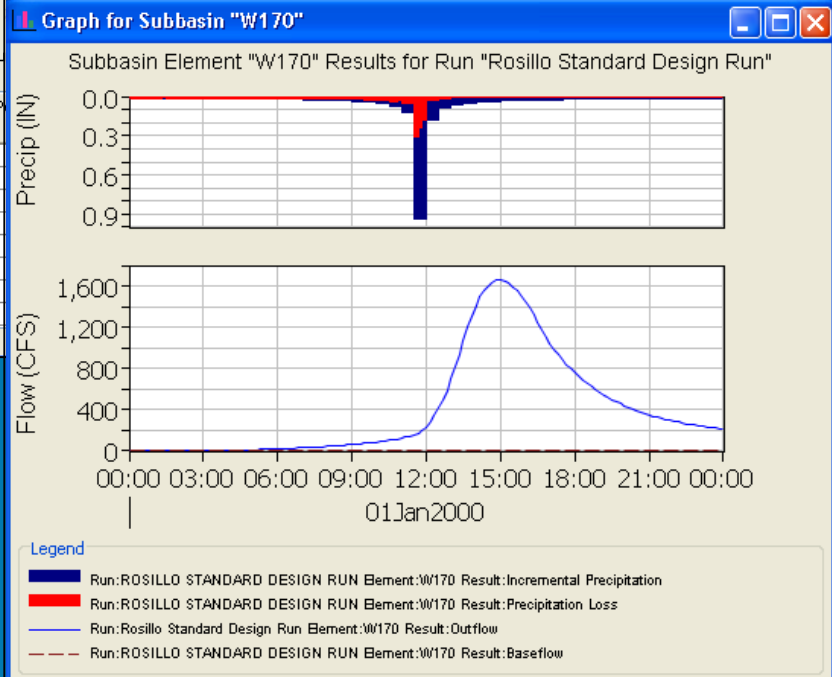
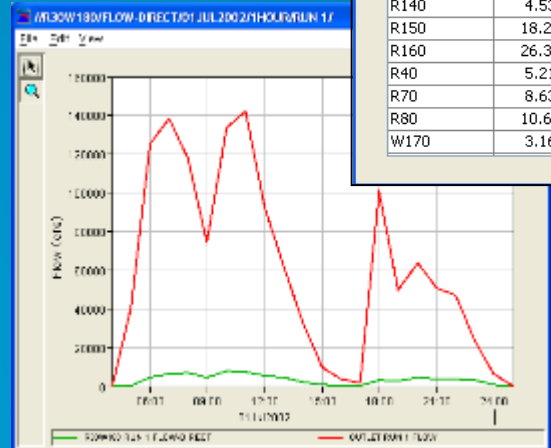
Global Summary Results for Run "Rosillo Standard Design Run"

Project: p012308_1 Simulation Run: Rosillo Standard Design Run

Start of Run: 01Jan2000, 00:00 Basin Model: p012308_1
End of Run: 02Jan2000, 00:00 Meteorologic Model: p012308_1
Compute Time: 23Jan2008, 00:00

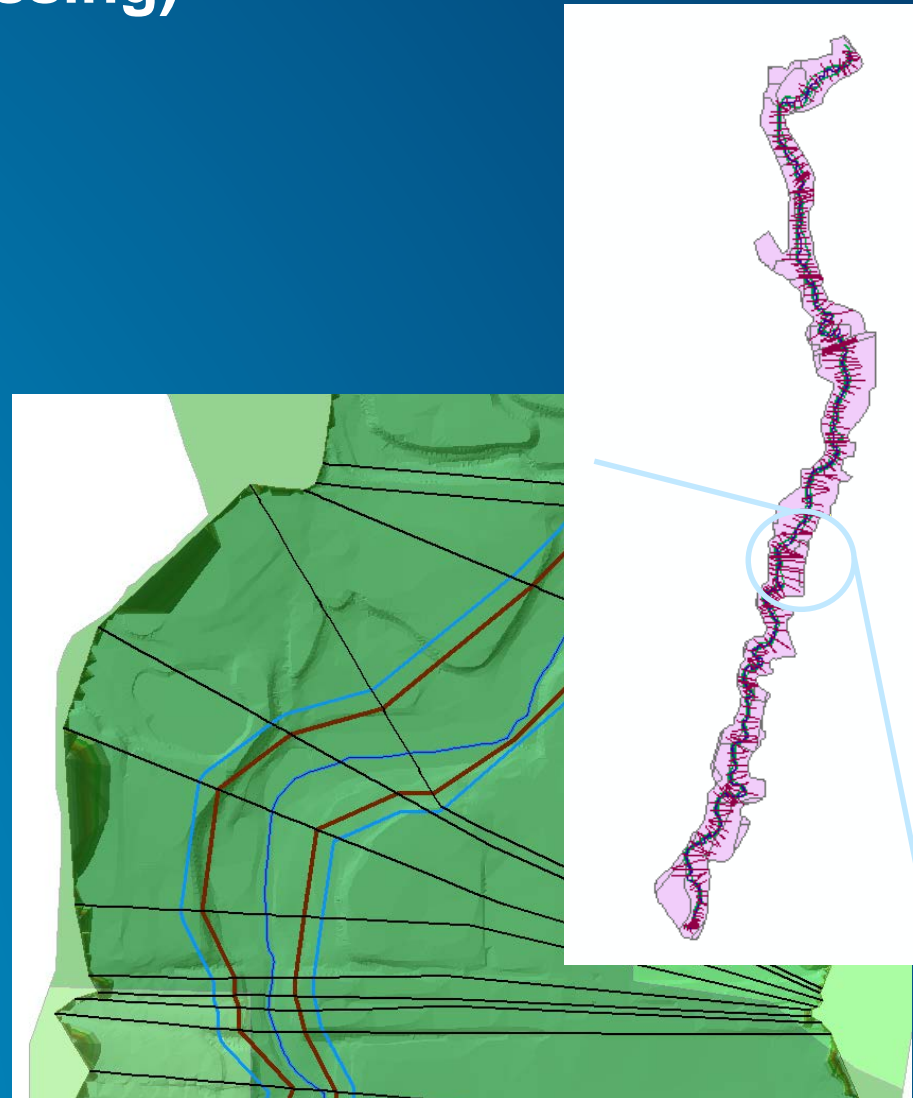
Hydrologic Element	Drainage Area (MI ²)	P
R110	14.39850	
R140	4.53340	
R150	18.20900	
R160	26.39950	
R40	5.21810	
R70	8.63036	
R80	10.60510	
W170	3.16780	

DSS View



Develop GeoRAS Model (preprocessing)

- Follow all principles in development of a hydraulic model for element placement (confluences, structures, ...).
- In addition, take into consideration integration planning aspects developed earlier.



Finalize and Run RAS

- Complete RAS model with any additional parameters including initial and boundary conditions.

The screenshot displays the HEC-RAS software interface. The main window shows a river reach with a grid of cross-sections. Overlaid on this are three dialog boxes:

Steady Flow Data - NormalDepth Run 1

Enter/Edit Number of Profiles (2000 max): 1 Reach Boundary Conditions Apply Data

Locations of Flow Data Changes

River: Rosillo Reach: Upper River Sta.: 96270.05 Add A Flow Change Location

Flow Change Location			Profile Names and Flow Rates	
River	Reach	RS	Peak Flows	
1	Rosillo	Upper	96270.0E	19443.55
2	Rosillo	Upper	79446.8E	19443.55
3	Rosillo	Upper	74689.1E	32777.76
4	Rosillo	Upper	64156.1E	41599.27
5	Rosillo	Upper	55586.7E	59869.55
6	Rosillo	Upper	44931.4	80382.88
7	Rosillo	Upper	28705.8E	121592.4
8	Rosillo	Upper	3.67378E	142012

DSS Set Locations for DSS Connections

River: Rosillo Delete row from table

Reach: Upper River Sta.: 96270.05 Add selected location to table

	River	Reach	RS	DSS File	Part A
1	Rosillo	Upper	79446.88	C:\hmsproj\aaaa\	
2	Rosillo	Upper	74689.13	C:\hmsproj\aaaa\	
3	Rosillo	Upper	64156.13	C:\hmsproj\aaaa\	
4	Rosillo	Upper	55586.71	C:\hmsproj\aaaa\	
5	Rosillo	Upper	44931.4	C:\hmsproj\aaaa\	

DSS File: C:\hmsproj\aaaa\aaaa.dss Update Catalog

Filter	Part A	Part B	Part C	Part D	Part E	Part F
1		J36	FLOW	01JUL2002	1HOUR	RUN 1
2		J39	FLOW	01JUL2002	1HOUR	RUN 1
3		J44	FLOW	01JUL2002	1HOUR	RUN 1
4		J49	FLOW	01JUL2002	1HOUR	RUN 1
5		J56	FLOW	01JUL2002	1HOUR	RUN 1
6		J61	FLOW	01JUL2002	1HOUR	RUN 1
7		J66	FLOW	01JUL2002	1HOUR	RUN 1
8		OUTLET	FLOW	01JUL2002	1HOUR	RUN 1

Select DSS Pathname << Previous Next >>

Plot Selected Pathname OK Cancel

NormalRun Flow: Run 1 with normal depth 3/3/2005

Plot showing flow rate (cfs) vs. Station (ft). The plot displays a series of peaks and troughs, with a legend indicating 'EG Peak Flows', 'DSS Table Flows', 'DSS Peak Flows', 'Flow', and 'Bank Sta.'.

Finalize and Run RAS (2)

- Do the final run and generate results (export to .sdf file).

The screenshot displays the HEC-RAS software interface. The main window shows a 'Profile Plot' of the water surface elevation (W.S. Elev) versus 'Main Channel Distance (ft)'. The plot shows a steady increase in elevation from approximately 500 ft at 0 ft distance to over 600 ft at 10,000 ft. A cyan shaded area represents the flow depth. Two windows are overlaid on the plot:

Cross Section Output

Plan: plan1 Rosillo Upper RS: 96270.05 Profile: Peak Flows					
		Element	Left OB	Channel	Right OB
E.G. Elev (ft)	769.97		0.035	0.040	0.040
Vel Head (ft)	4.78				
W.S. Elev (ft)	765.19	Reach Len. (ft)	294.20	272.74	243.54
Crit W.S. (ft)	765.19	Flow Area (sq ft)	48.55	737.52	332.43
E.G. Slope (ft/ft)	0.025348	Area (sq ft)	48.55	737.52	332.43
Q Total (cfs)	19443.55	Flow (cfs)	610.05	13466.30	5367.19
Top Width (ft)	114.99	Top Width (ft)	9.66	66.60	38.73
Vel Total (ft/s)	17.38	Avg. Vel. (ft/s)	12.57	18.26	16.15
Max Ch Dpth (ft)	15.19	Hydr. Depth (ft)	5.02	11.07	8.58
Conv. Total (cfs)	122123.6	Conv. (cfs)	3831.7	84581.0	33711.0
Length Wtd. (ft)	264.90	Wetted Per. (ft)	29.25	135.97	93.77
Min Ch El (ft)	750.00	Shear (lb/sq ft)	2.63	8.58	5.61
Alpha	1.02	Stream Power (lb/ft s)	33.01	156.73	90.58
Ficth Loss (ft)	3.06	Cum Volume (acre-ft)	12436.43	8097.76	8851.39
C & E Loss (ft)	0.97	Cum SA (acres)	1054.24	576.89	753.63

Errors, Warnings and Notes

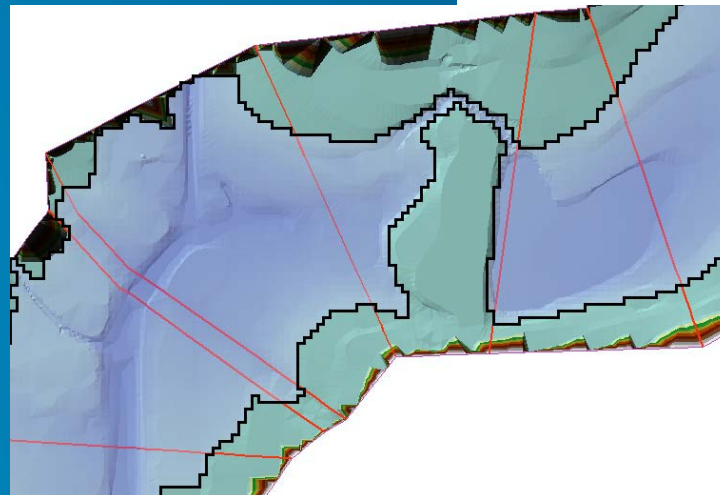
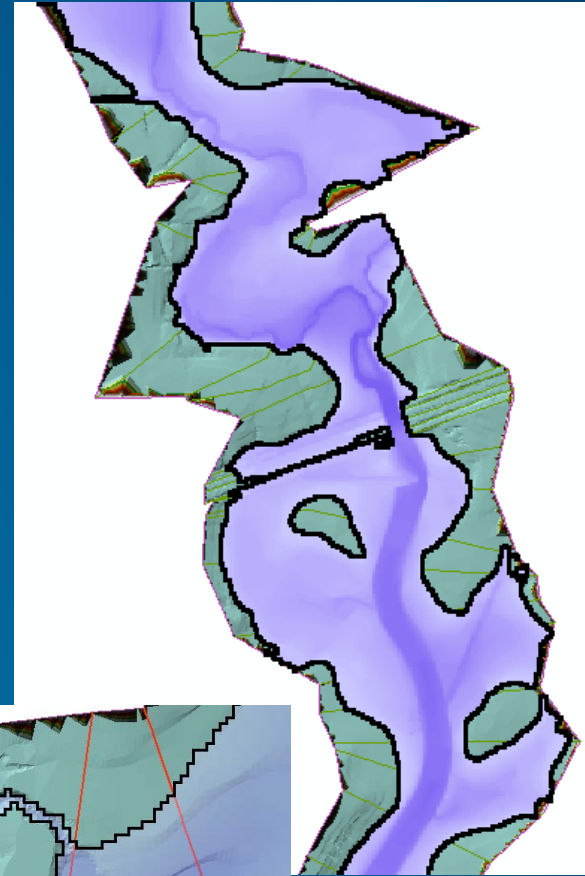
- Warning: The energy equation could not be balanced within the specified number of iterations. The program used critical depth for the water surface and continued on with the calculations.
- Warning: Divided flow computed for this cross-section.
- Warning: The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross sections.
- Warning: The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than

Profile Output Table - Standard Table 1

Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)
Upper	75626.59	Peak Flows	19443.55	666.00	674.09		674.45
Upper	75251.3	Peak Flows	19443.55	666.00	673.66		673.93
Upper	74771.74	Peak Flows	19443.55	665.15	672.89		673.35
Upper	74689.13 J61	Peak Flows	32777.76	663.75	672.62		673.20
Upper	74204.02	Peak Flows	32777.76	662.00	671.81		672.44
Upper	73943.38	Peak Flows	32777.76	662.00	671.06		671.85
Upper	73599.31	Peak Flows	32777.76	660.64	669.83		670.85

Process RAS Results in GeoRAS

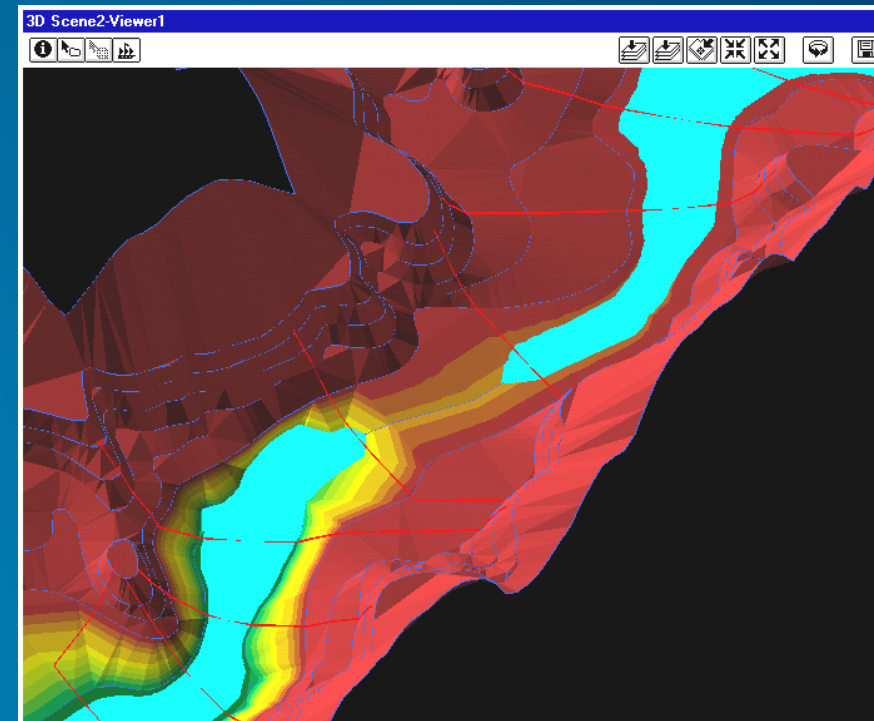
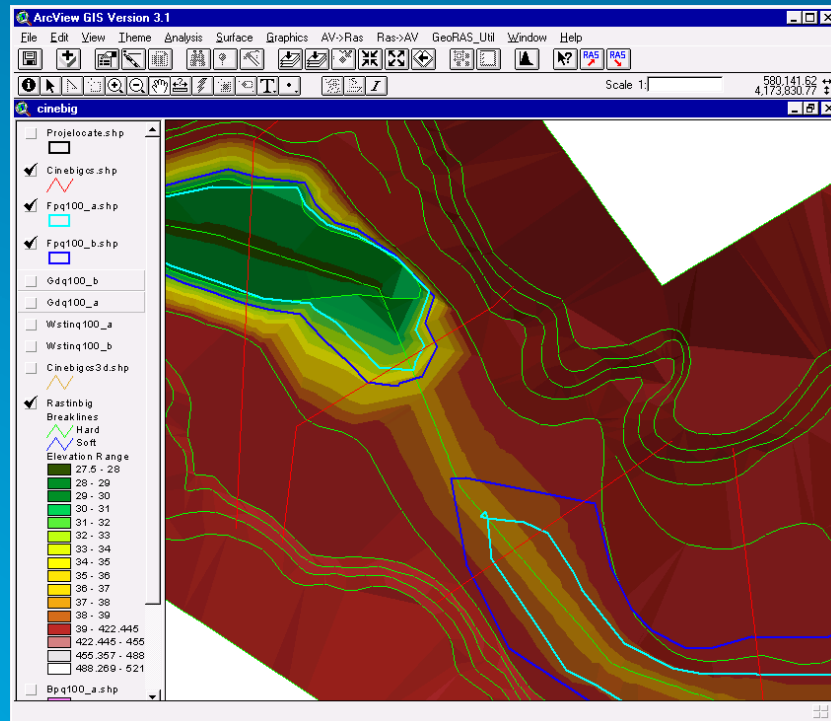
- Construct the floodplain based on the results in the .sdf.
- Review the results with respect to spatial integrity (extents of cross sections, ineffective flow areas, disconnected flood areas, etc.).
- Clean results.
- Revisit RAS.



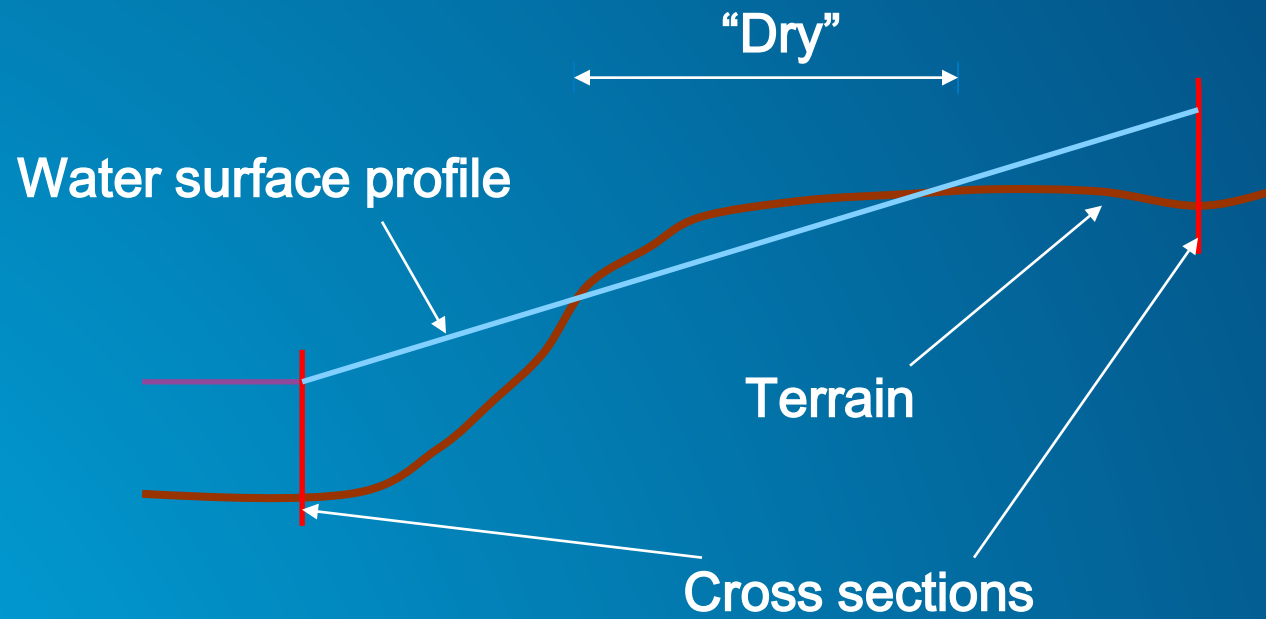
GIS–HMS–RAS Feedback

- **At present, it is manual and at the discretion of the modeler.**
 - GIS–H&H interaction
 - H–H interaction
- **Visualization in both pre- and postprocessing is not just a “pretty picture.”**
 - **Flyover in preprocessing (GeoHMS and GeoRAS)**
 - Identification of data problems
 - Modeling element placement
 - **Postprocessing (GeoRAS)**
 - Validity of element placement

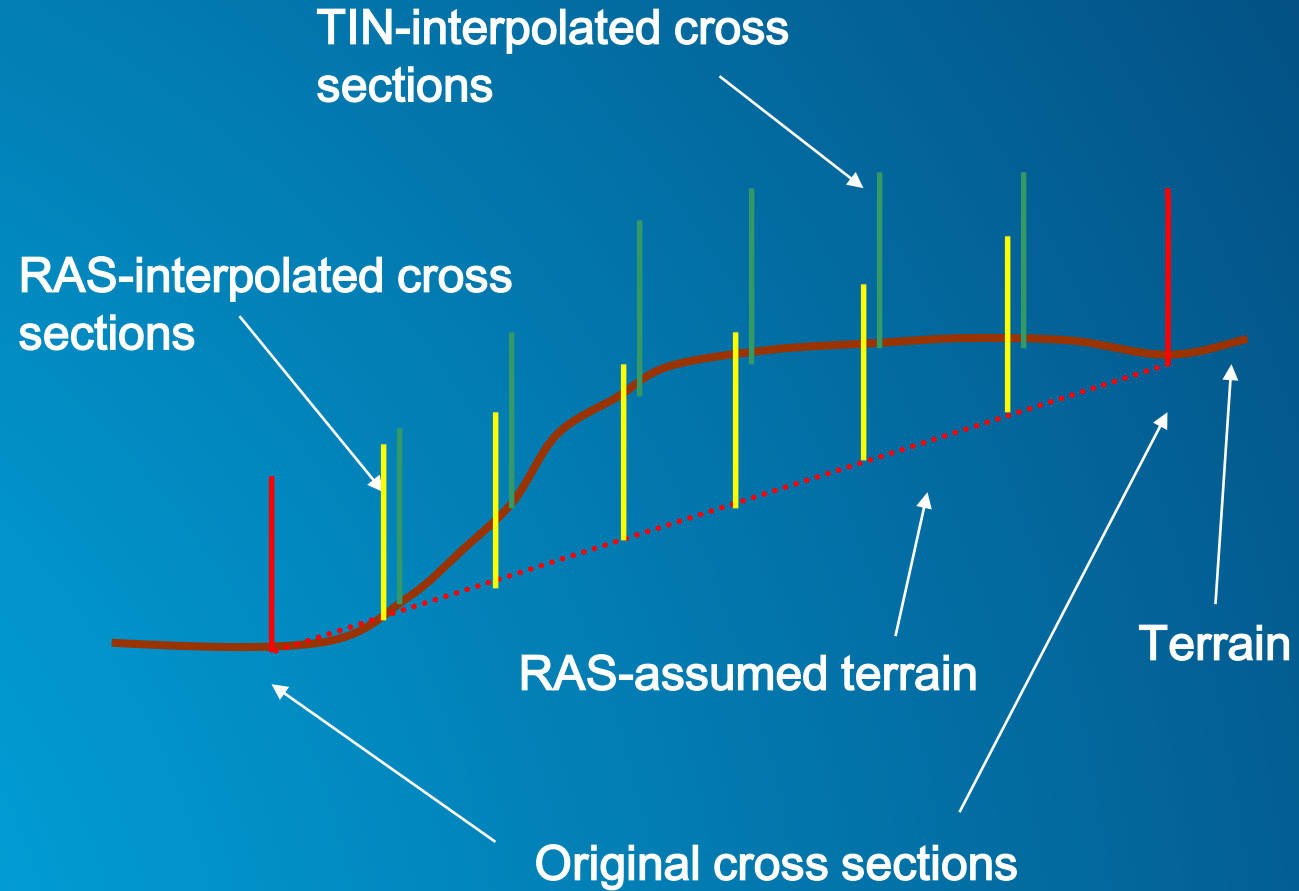
Floodplain Discontinuity



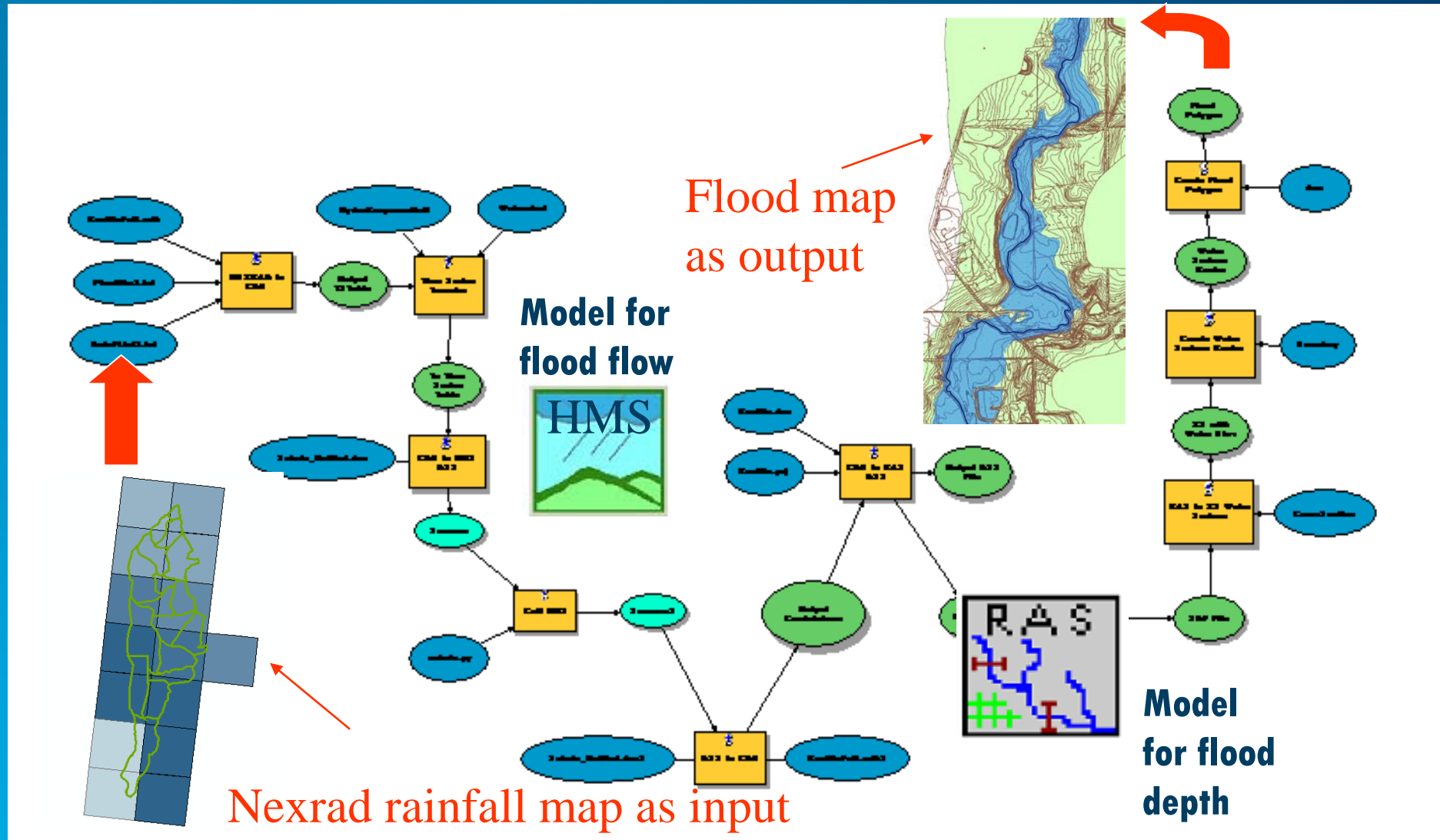
Floodplain Discontinuity (cont.)



Cross-Section Interpolation



Map2Map (rainfall to floodplain)



Integrated H&H

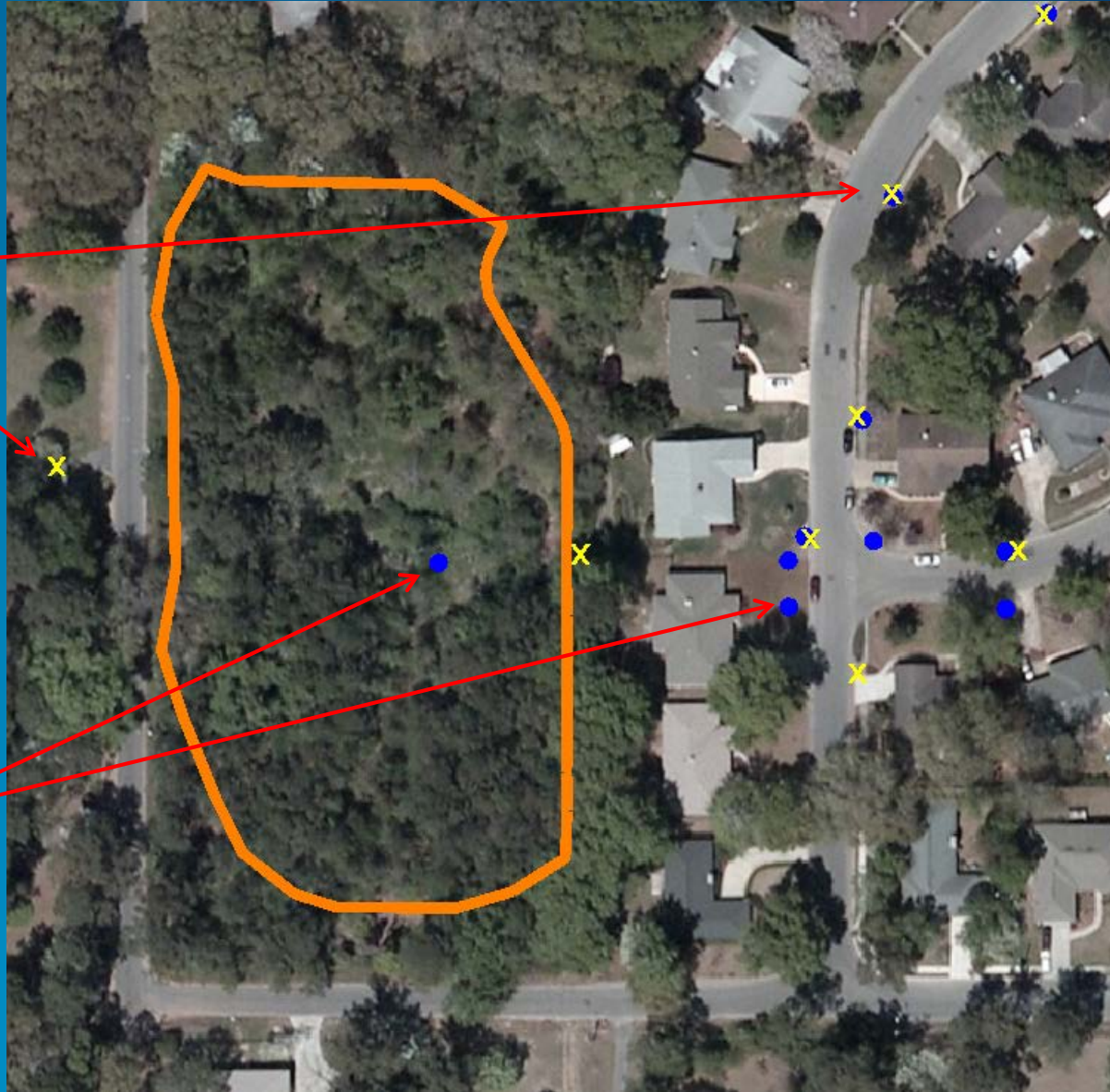
(ICPR^{4G} - shape of the things to come)

ICPR^{4G} interface

- Transition from ICPR 3 (1-D, node-link model) to full 2.5-D, spatially distributed, process integrated, H&H model.
- Interface fully integrated within AH.
- Model structure and results I/O (XML for model structure, TBD for results).

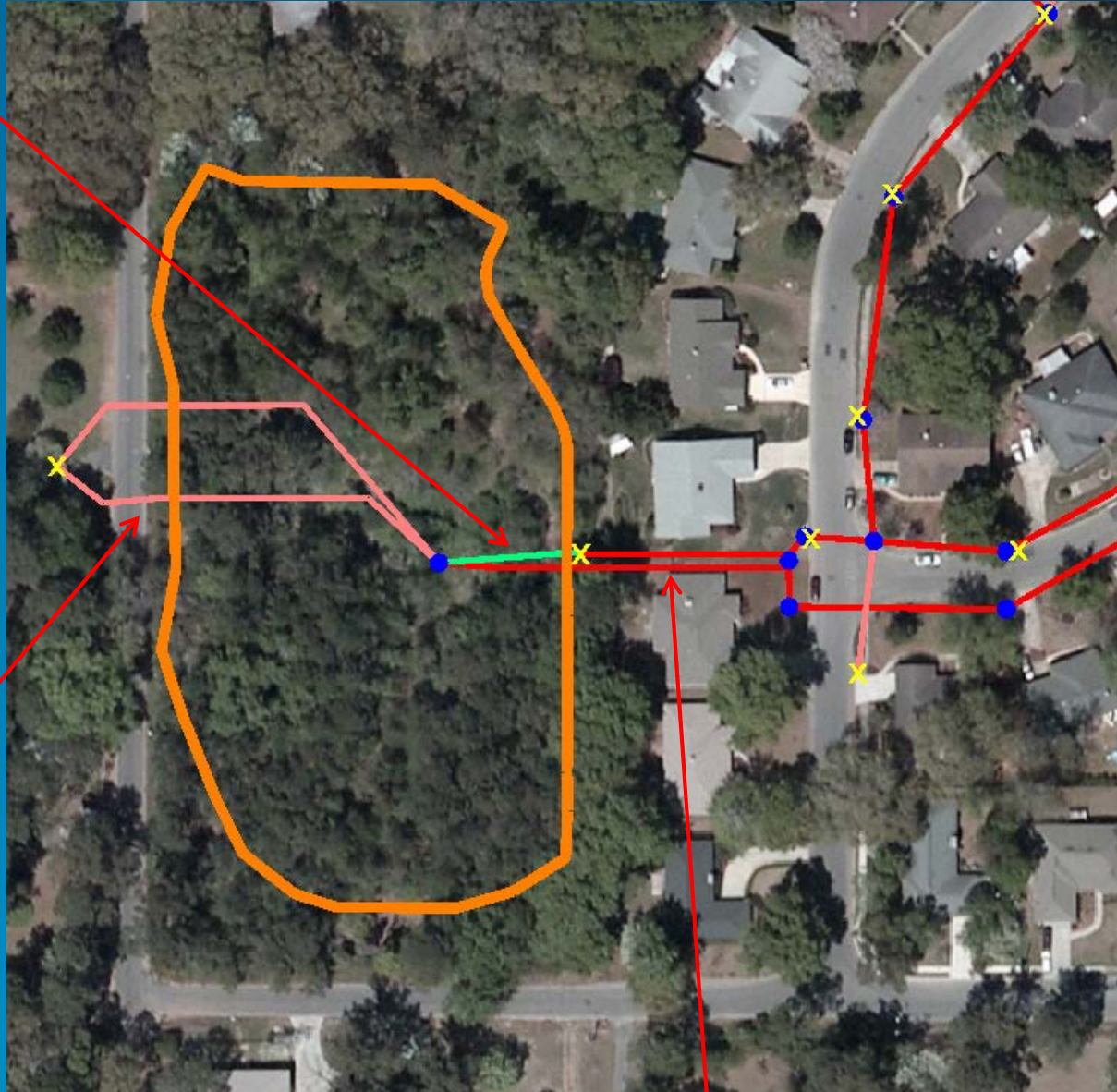
1D/2D Interface
(Storm Inlets)

1D Nodes
(Pond, Manholes)



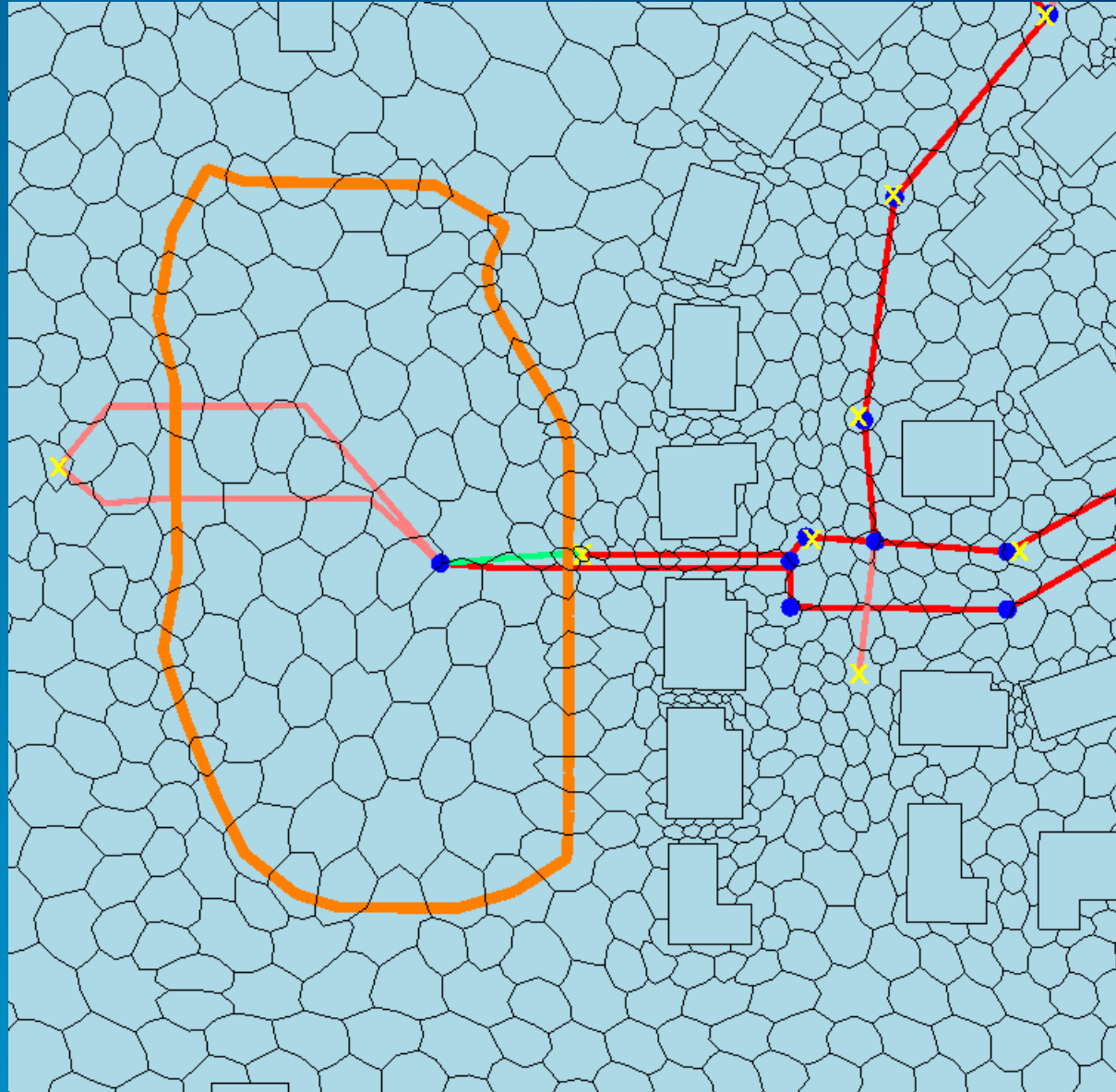
1D Weir Link

1D Drop
Structure
Link

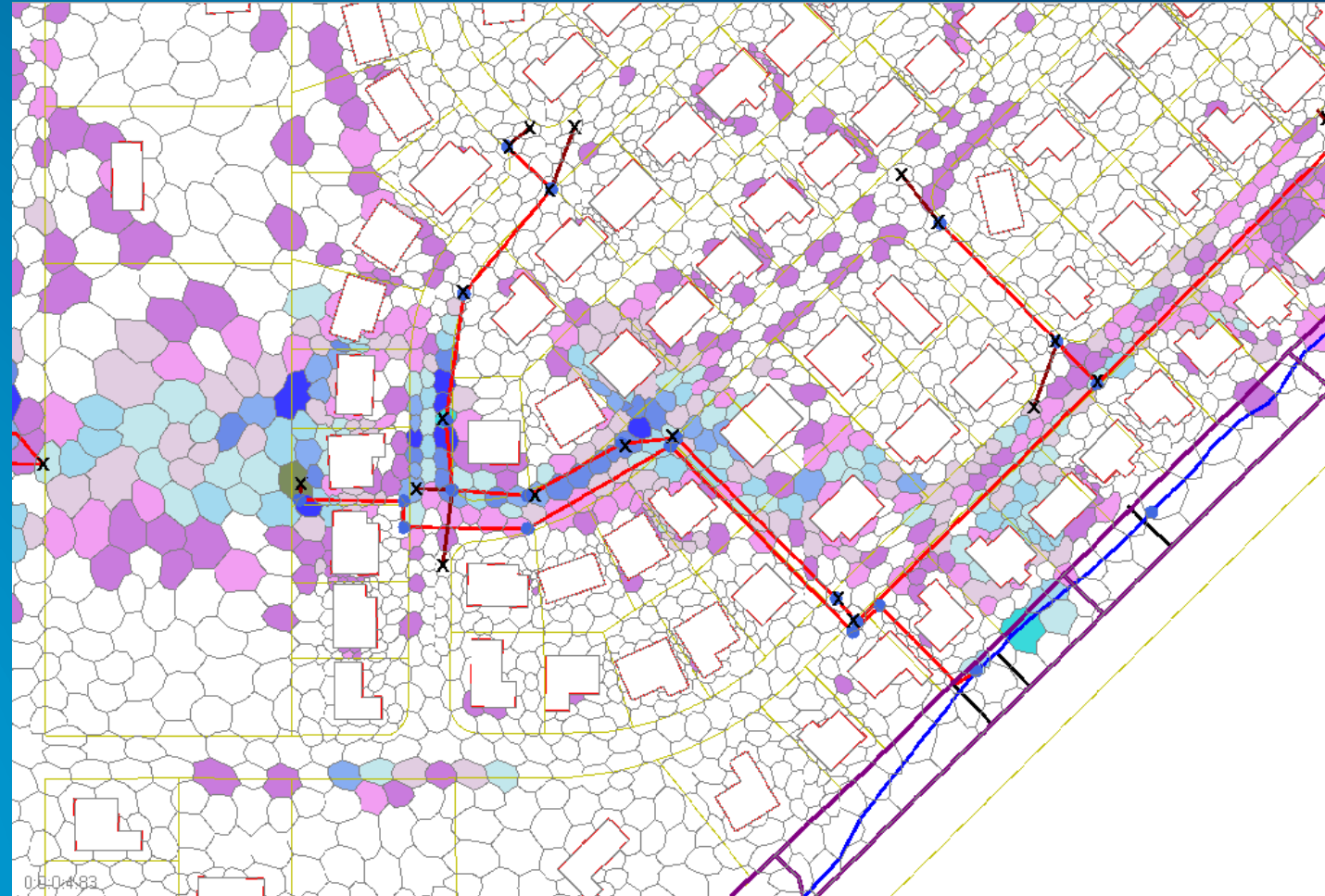


1D Pipe Link

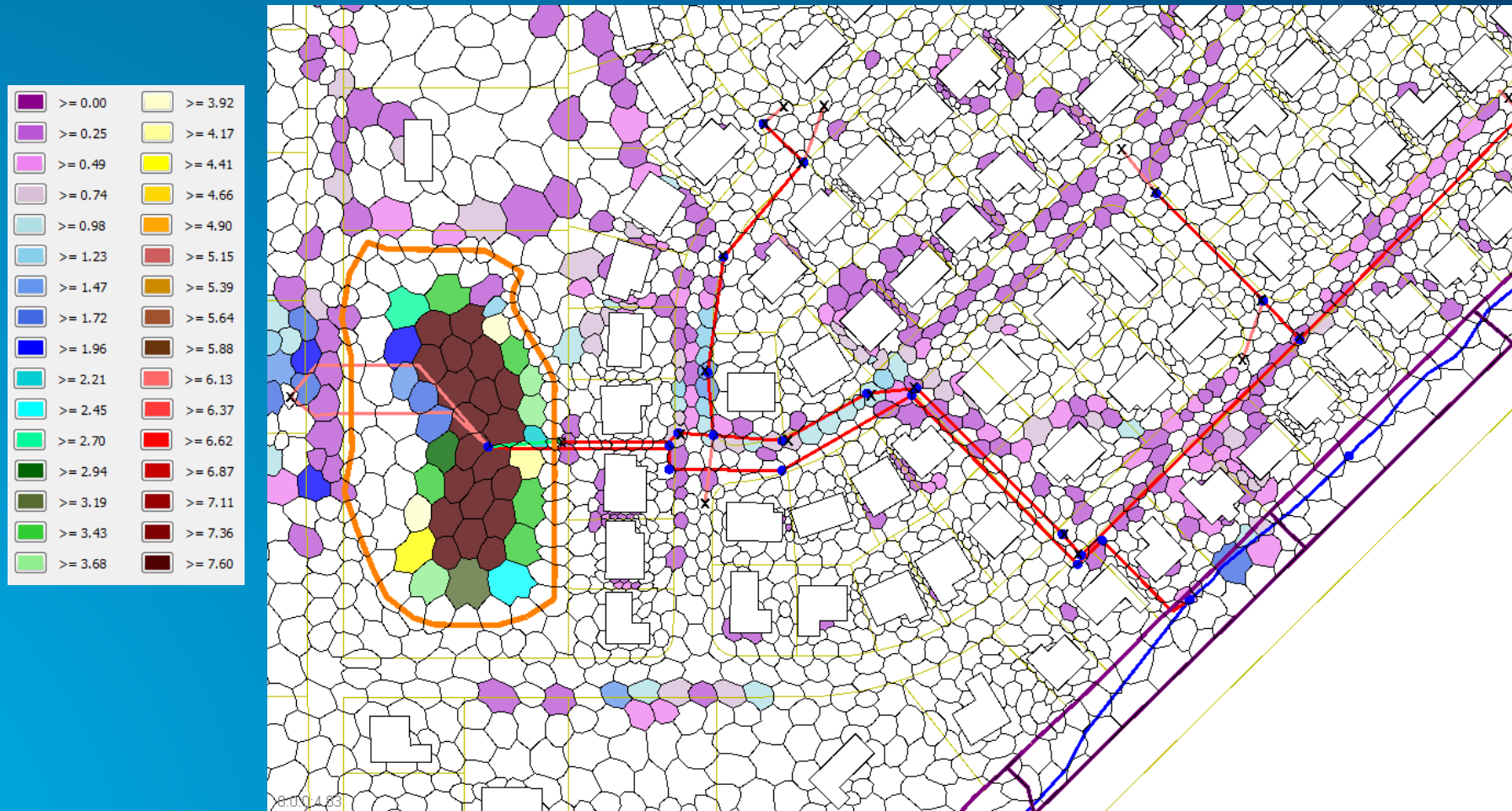
2D Honeycomb with 1D Elements



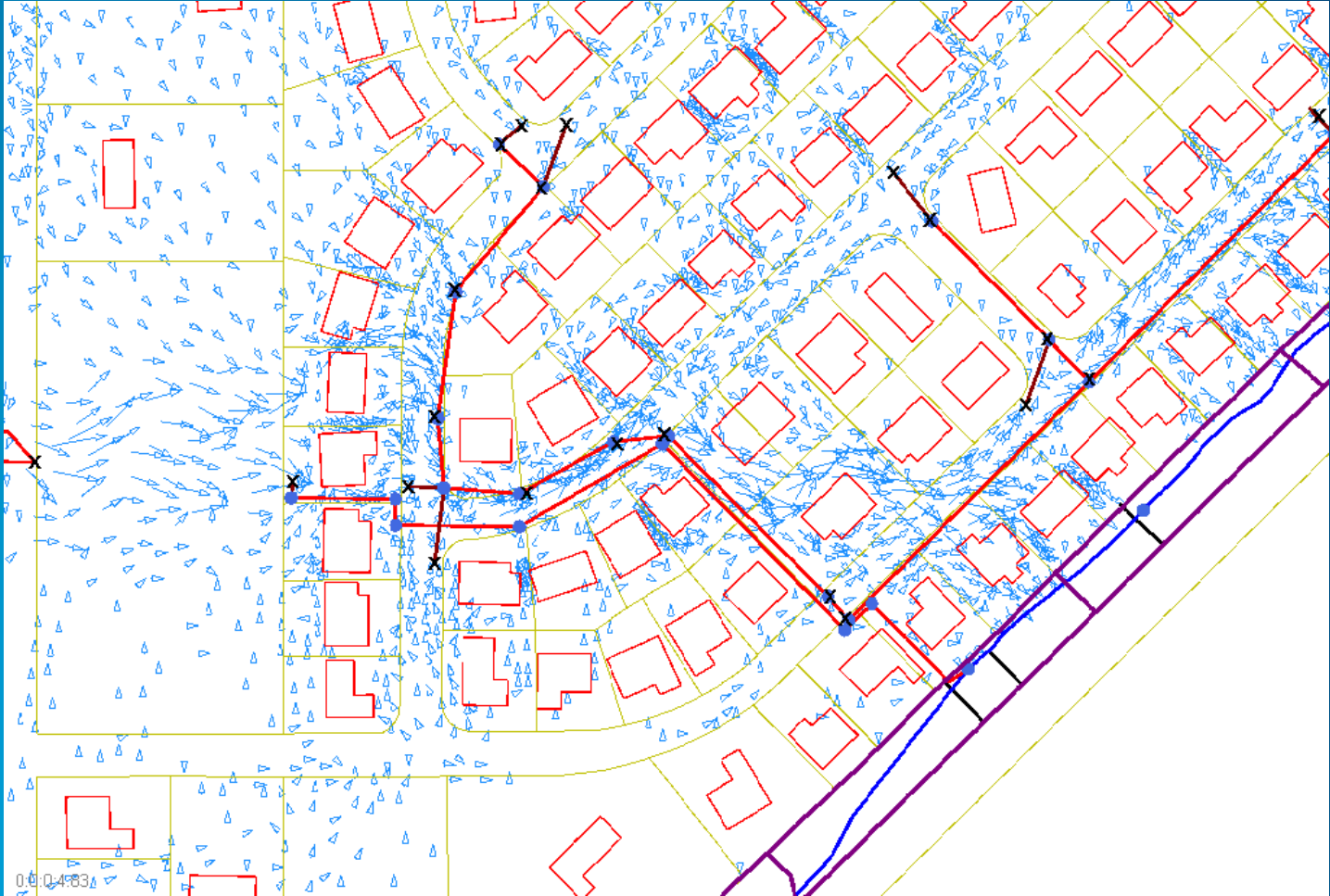
Flood Depths, Existing Condition



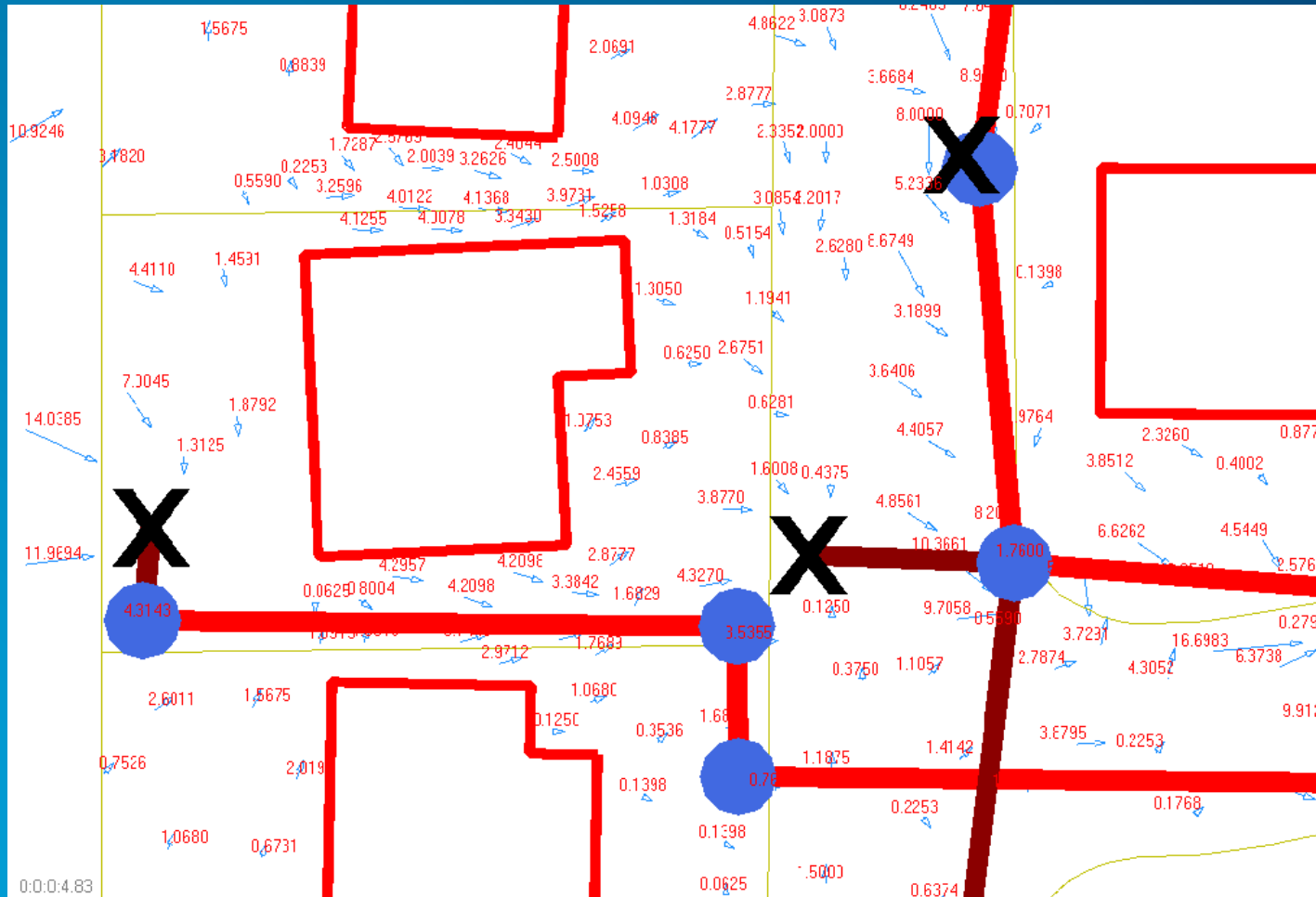
Flood Depths, Alternative 4




Flow Vectors, Existing Conditions



Flow Vectors with Labels, Existing Conditions

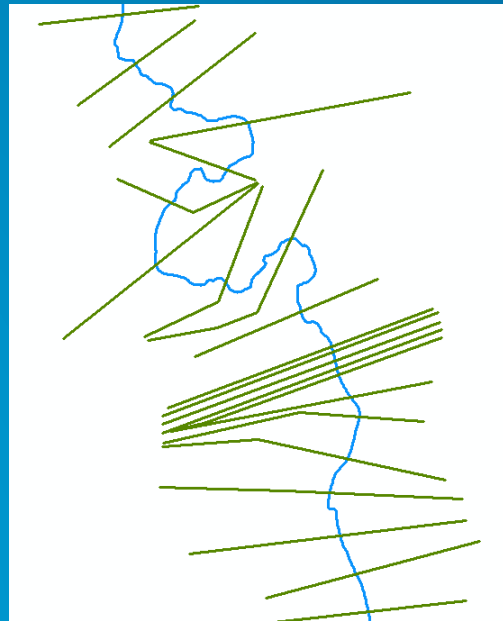
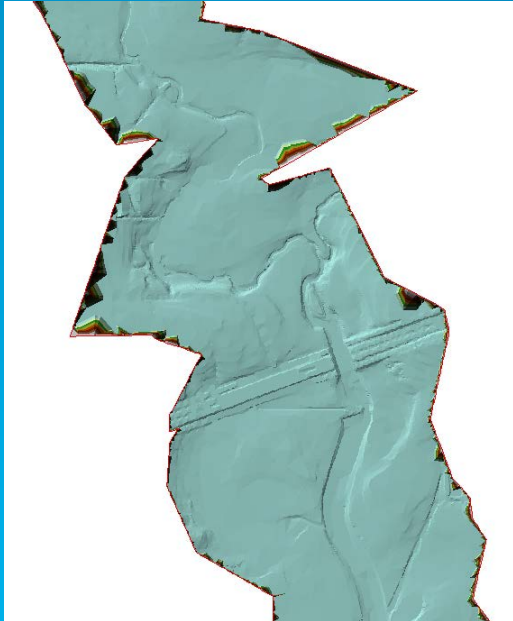
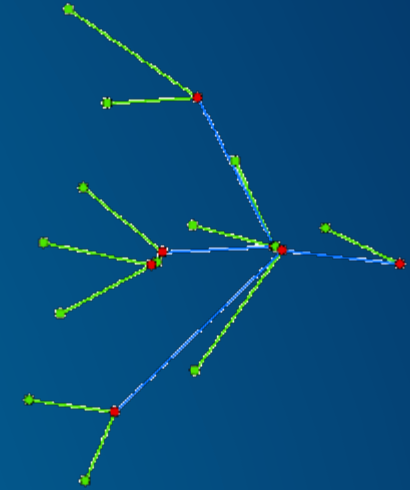


Overview of GIS techniques for H&H modeling support data simplification



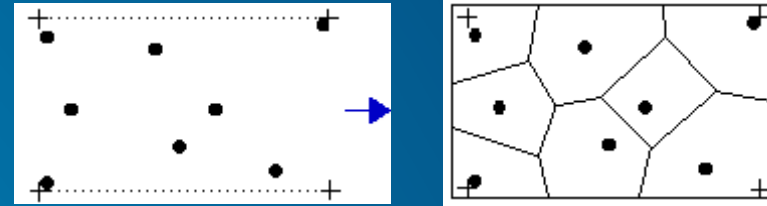
Schematization – 1D

- Node – link representation
- Wireframe representation

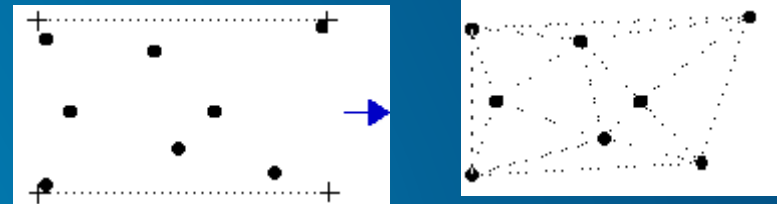


Schematization – 2D

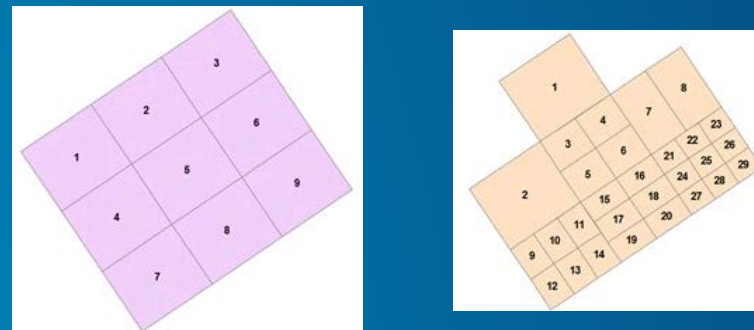
- Thiessen polygon



- TIN



- Fish Net



- Can get tricky – need to understand solvers for optimal tessellation!


Schematization – 2D

- Topology to ensure spatial consistency within and across layers

Polygon

Must not overlap


Polygons must not overlap unless a feature class is using a topology that allows overlapping polygons. Use this rule to ensure that polygons do not overlap.



Polygon

Area boundary must be covered by boundary of

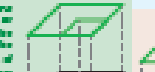
This is a variation of the topology rule that requires a polygon's area to be covered by the boundary of another polygon. Use this rule to ensure that the area of a polygon is covered by the boundary of another polygon.



Line

Must be covered by boundary of

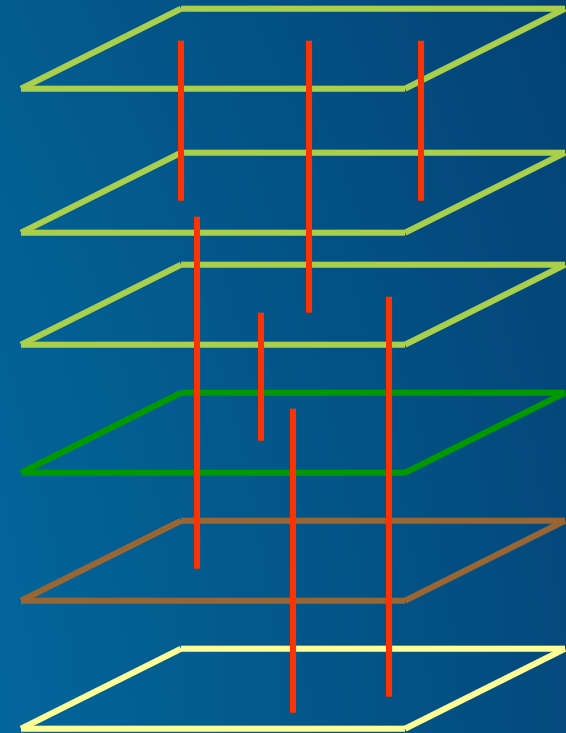
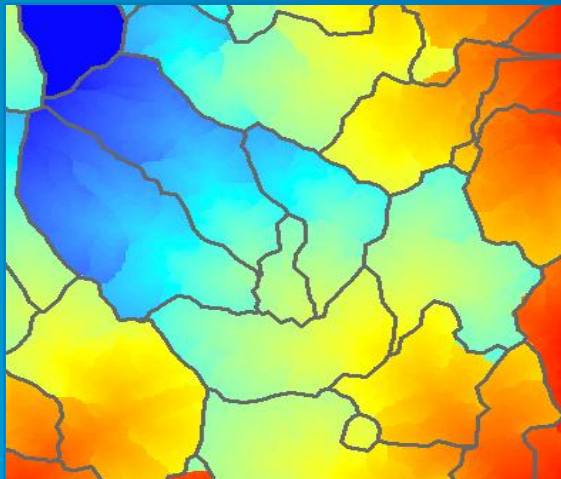
This is a variation of the topology rule that requires a line's area to be covered by the boundary of a polygon. Use this rule when you want to ensure that the area of a line is covered by the boundary of a polygon.



Polygon Must not overlap	Polygon Must not have gaps	Line or Polygon Must be larger than cluster tolerance	Line Must not have pseudo nodes
Polygon Covers a point	Polygon Covers a one-point	Line Must not have slivers	Line Must not self-overlap
Polygon Must be covered by feature class of	Polygon Must be covered by	Line Must not overlap	Line Must not self-intersect
Polygon Must not overlap with	Polygon Must be covered by	Line Must not intersect	Line Must be single part
Polygon Area boundary must be covered by boundary of	Polygon Must cover each other	Line Must not intersect with	Line Must be covered by feature class of
Point Must coincide with	Point Must be disjoint	Line Must not intersect or touch interior	Line Must be covered by boundary of
Point Must be covered by endpoint of	Point Point must be covered by line	Line Must not intersect or touch interior with	Line Must be properly inside
Point Must be properly inside	Point Must be covered by boundary of	Line Must not overlap with	Line Endpoint must be covered by

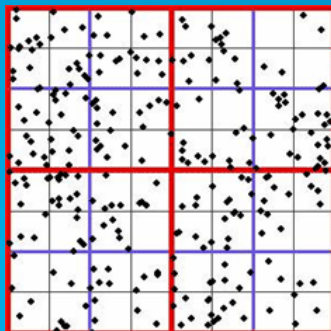
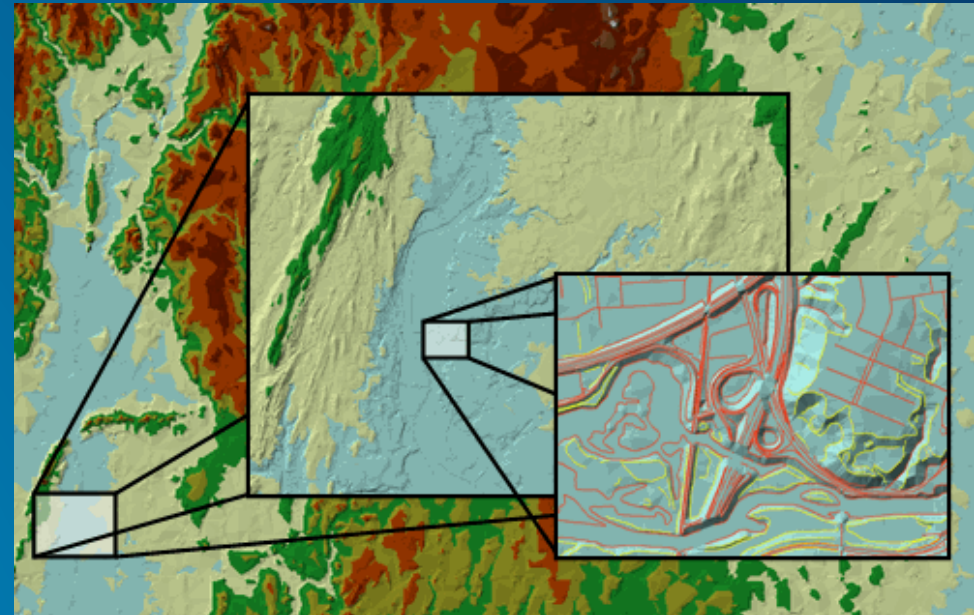
“Lumping”/characterization

- Push-pin (not much to do unless it needs “vertical” aggregation)
- “Lumping”/characterization
 - Zonal stats operations
 - Can do interpolation first, then stats

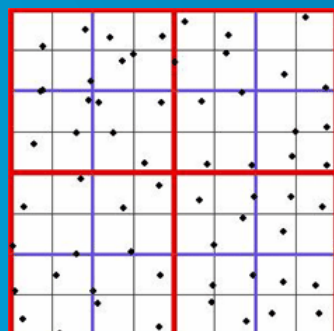


“Weeding”/VIP identification

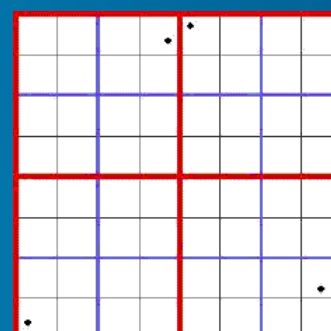
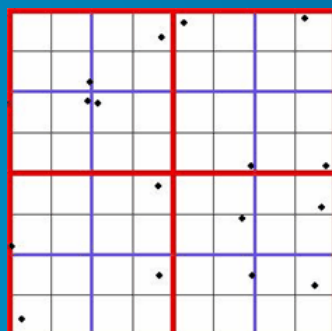
- 2D (terrain/surface)
 - Terrain dataset (terrain pyramids)
 - Window size
 - Z-tolerance



HH Modeling With GIS



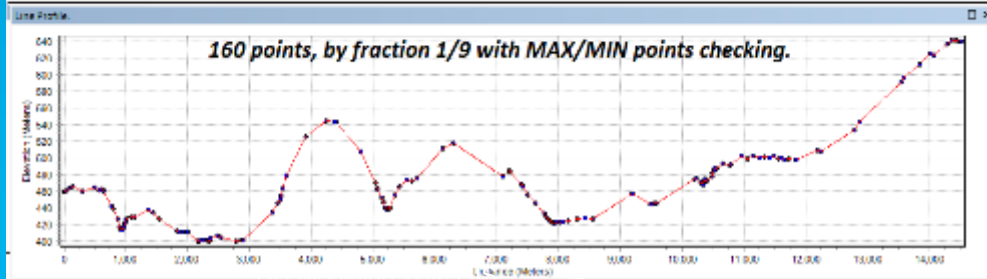
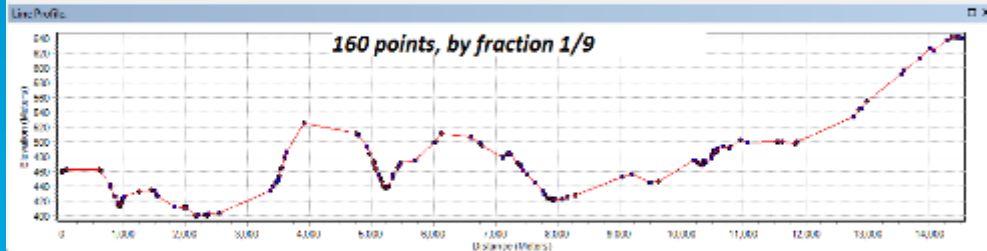
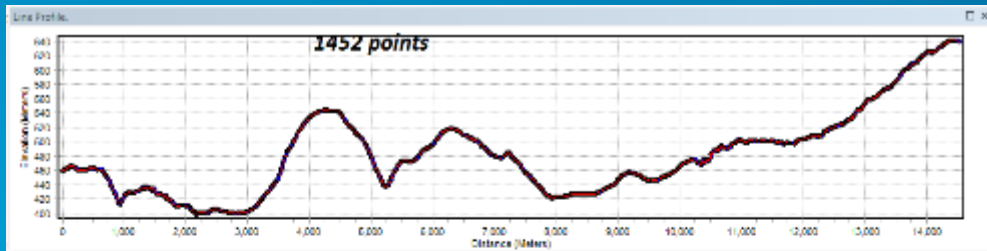
93



“Weeding”/VIP identification

• “1D”

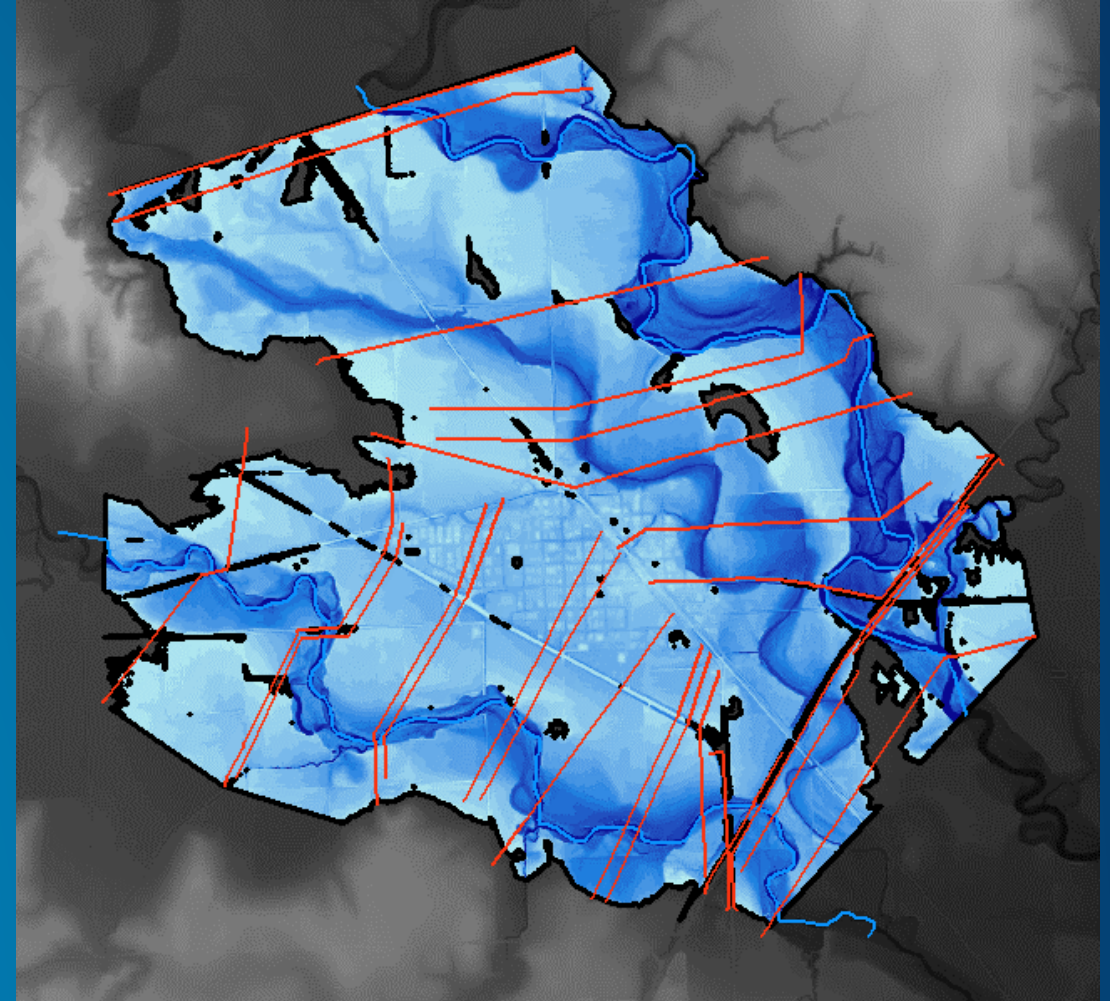
OBJECTID *	Shape *	Shape_Length	HydroID	FEATUREID	AREAPCT	LENGTHPCT	PNTCOUNT0	PNTCOUNT1
1	Polyline Z	14507.643301	<Null>	1	100.01038	99.996045	1452	435
2	Polyline Z	19955.248114	<Null>	2	99.953482	99.988502	1998	598



OBJECTID *	FEATUREID	POINTINDEX	INCLUDED	AREAIMPACT	ACCAREA0	ACCAREA1
1406	1	1405	0	1	2310814.828507	<Null>
1407	1	1406	1	0.001729	2310991.917979	2306996.725614
1408	1	1407	1	0.001729	2311169.305129	2307174.112764
1409	1	1408	1	0.001729	2311336.235132	2307341.042767
1410	1	1409	0	1	2311520.519762	<Null>
1411	1	1410	0	1	2311683.678762	<Null>
1412	1	1411	1	0.001729	2311830.374621	2307833.249336
1413	1	1412	0	1	2311991.113774	<Null>
1414	1	1413	0	1	2312125.293854	<Null>
1415	1	1414	0	1	2312261.224304	<Null>
1416	1	1415	1	0.001729	2312383.575964	2308336.015759
1417	1	1416	0	1	2312517.511936	<Null>
1418	1	1417	0	1	2312635.399086	<Null>
1419	1	1418	0	1	2312740.766844	<Null>
1420	1	1419	0	1	2312854.552255	<Null>
1421	1	1420	0	1	2312947.592206	<Null>
1422	1	1421	0	1	2313039.938006	<Null>
1423	1	1422	1	0.00173	2313121.378782	2309120.581018
1424	1	1423	0	1	2313208.758361	<Null>
1425	1	1424	0	1	2313284.238011	<Null>
1426	1	1425	0	1	2313350.427389	<Null>
1427	1	1426	0	1	2313420.511842	<Null>
1428	1	1427	0	1	2313476.13634	<Null>
1429	1	1428	1	0.001733	2313528.05224	2309517.921595
1430	1	1429	1	0.001733	2313573.752638	2309563.621993
1431	1	1430	0	1	2313611.114938	<Null>
1432	1	1431	0	1	2313641.858638	<Null>
1433	1	1432	1	0.001733	2313665.041467	2309655.433497
1434	1	1433	0	1	2313685.759199	<Null>
1435	1	1434	1	0.001733	2313699.483755	2309689.781308
1436	1	1435	0	1	2313710.081905	<Null>
1437	1	1436	1	0.001733	2313717.661702	2309708.290516
1438	1	1437	0	1	2313723.184152	<Null>
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1450	1	1449	1	0.001734	2313761.924789	2309748.912162
1451	1	1450	1	0.001734	2313772.536135	2309759.523508

Simplified Floodplain Delineation Tools

- **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

- [-] Arc Hydro Tools.tbx
 - [+] Arc Hydro Setup
 - [+] Attribute Tools
 - [+] GIS Data Exchange
 - [+] **H & H Modeling**
 - [+] Network Tools
 - [+] Point Characterization
 - [+] Terrain Morphology
 - [+] Terrain Preprocessing
 - [+] Terrain Preprocessing Workflows
 - [+] **Utility**
 - [+] Watershed Processing

- [-] **H & H Modeling**
 - [+] **Cross-Section Characterization**
 - [+] **Floodplain Delineation**
 - [+] GeolCPR
 - [+] Green and Ampt
 - [+] **Map to Map**
 - [+] Streamstats
 - [+] Time of Concentration
 - [+] Utility

- [-] **Utility**
 - [+] Support
 - [+] **Convert 3D Line to Raster**
 - [+] **Convert 3D Line to Raster Py**
 - [-] Create Thiessen Polygons
 - [-] Create Unit Patch By Near Neighbor Method
 - [-] Create Zone By Distance
 - [-] Create Zone By Distance From Raster
 - [+] **Download Time Series Data**
 - [-] Export Data Cart to XML
 - [-] Feature Class To Batch FC
 - [-] Generate Processing Units
 - [-] Intersect Areas
 - [+] **Point TSValue to 3D Line**
 - [-] Terrain Profile
 - [+] **Update TSValue on Points**
 - [-] Weighted Average

- [-] **Cross-Section Characterization**
 - [+] Assign Hydrology River Properties to Cross-section
 - [+] Assign River Slope to Cross-section
 - [-] Calculate 3D Cross-section Characteristics
 - [+] Calculate Manning's N for Cross-section
 - [-] Calculate Normal Depth
 - [-] Calculate Potential Q
 - [+] Define 3D Cross-section from 2D

- [-] **Floodplain Delineation**
 - [-] Calculate WSE for Selected Model
 - [+] Create 3D Stream WSE Line
 - [+] Create 3D WSE Stream Line Grid
 - [+] Derive BFE - no smoothing
 - [+] Derive BFE - with smoothing
 - [+] Derive Extended BFE - No Smoothing
 - [-] Find Intersect Points
 - [-] Flood from Cross-Section
 - [-] Flood from Stream WSE Py
 - [-] Interpolate WSE at Cross-Sections
 - [-] Merge Cross-Section Feature Classes
 - [-] Select WSE To Process

- [-] **Map to Map**
 - [-] Export to DSS
 - [+] Flood From Stream WSE
 - [+] GeoRAS to Flood
 - [+] HMS to GeoRAS
 - [-] Import from DSS
 - [-] Run HMS
 - [-] Run RAS
 - [-] SDF to XML
 - [+] Stream WSE From Point WSE Measurements
 - [-] Update RAS Flow

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

Summary

Summary

- **GIS provides many capabilities for support of H&H**
- **Integrated, multi-purpose database for storage of H&H and related data.**
- **Consistent methodology for spatial data processing and analytical functionality, such as terrain processing, watershed delineation and characterization.**
- **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**

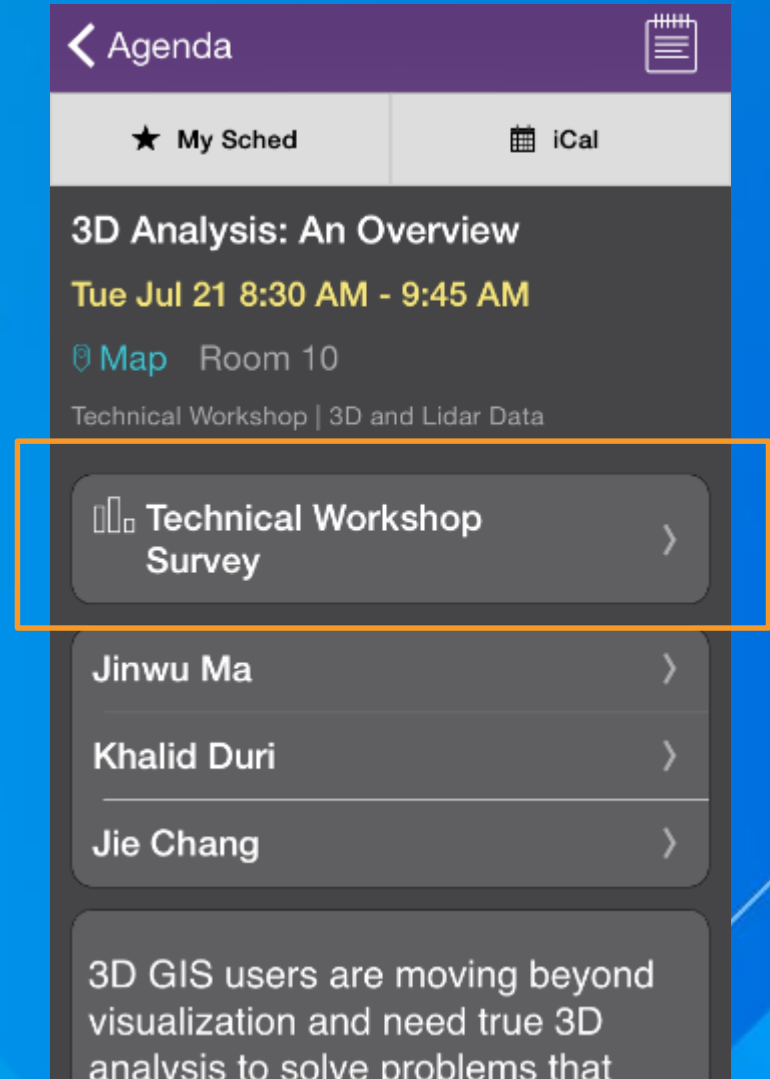
Summary

- **Easy evaluation of alternatives**
- **H&H model integration and automation**
 - Operational and change in conditions
- **Environment for integrated solution management:**
 - Emergency management
 - Design
 - Decision support
- **Leverage existing online templates for information augmentation and result publishing**
 - E.g. identify affected people in a floodplain and present the information through operations dashboard or story map

Q & A

Thank you...

- Please fill out the session survey in your mobile app
- Select “Hydrologic and Hydraulic Modeling” in the Mobile App
 - Use the Search Feature to quickly find this title
- Click “Technical Workshop Survey”
- Answer a few short questions and enter any comments





Understanding our world.