Building the Data Foundation for Operational Flood Forecasting

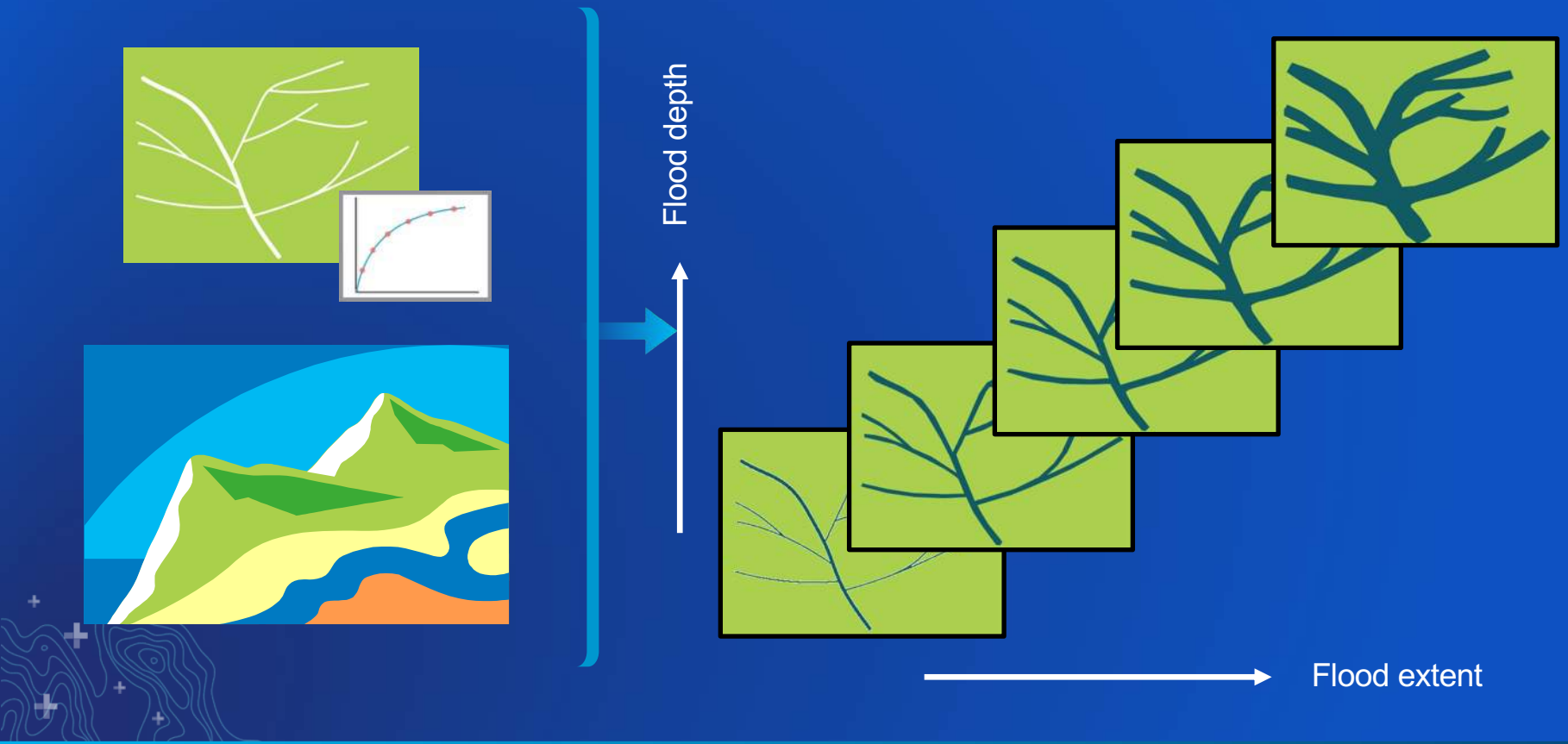
Dean Djokic, Esri

SEE WHAT OTHERS CAN'T

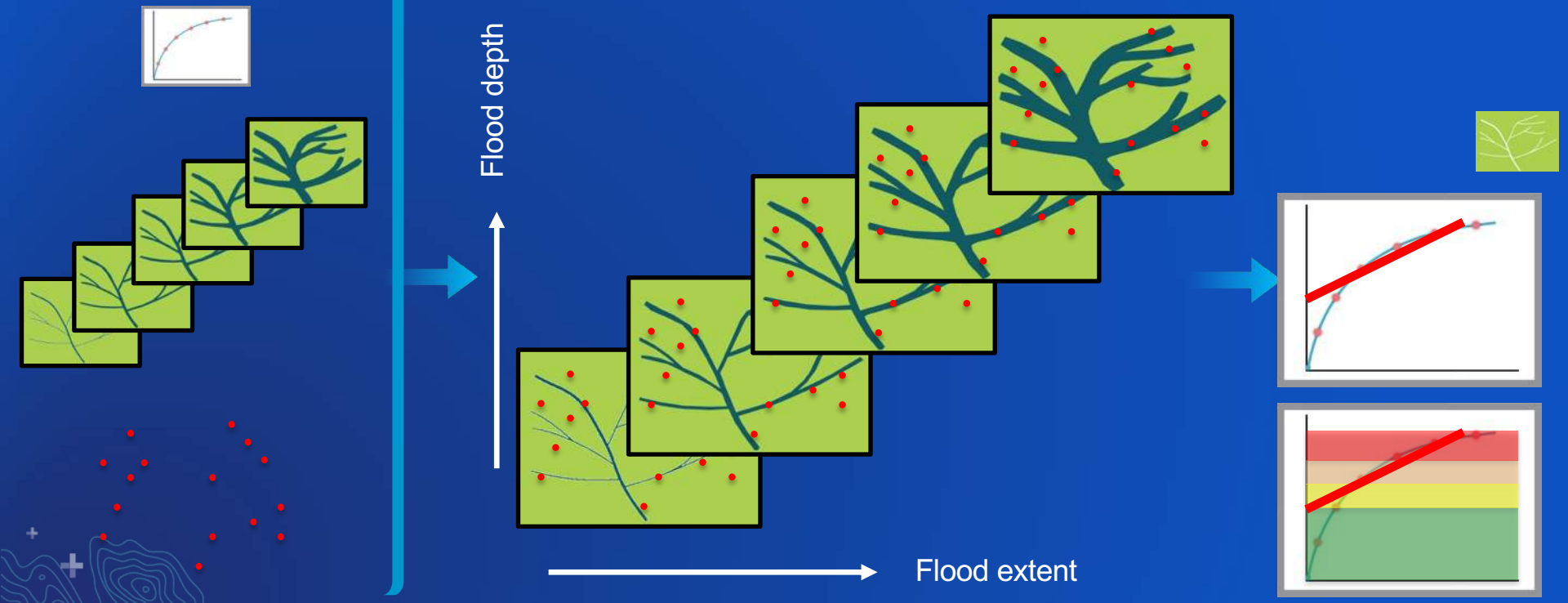
Topics

- Overview
- HAND principles
- Difference in NHDPlus HR and Lidar—derived DEM HAND processing
- Full flood stack processing
- Detailed walk-through (optional)

Develop flood inundation dataset – geoenable runoff forecast

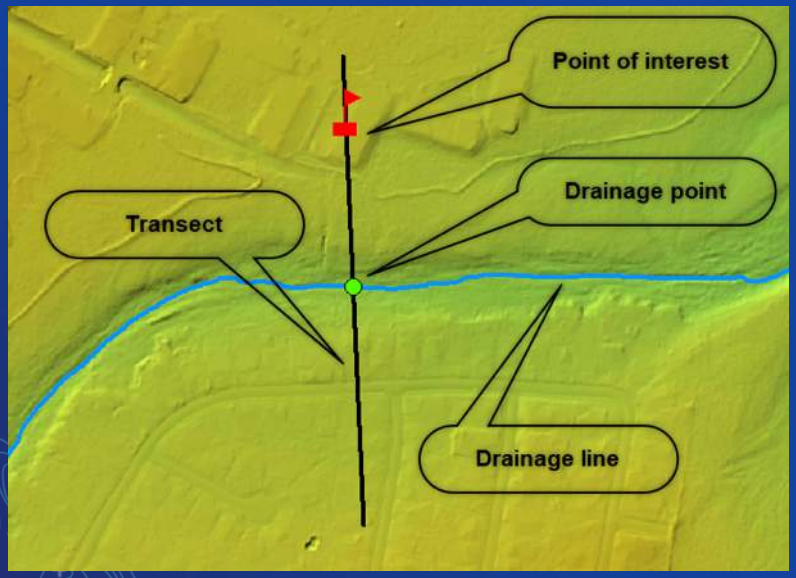


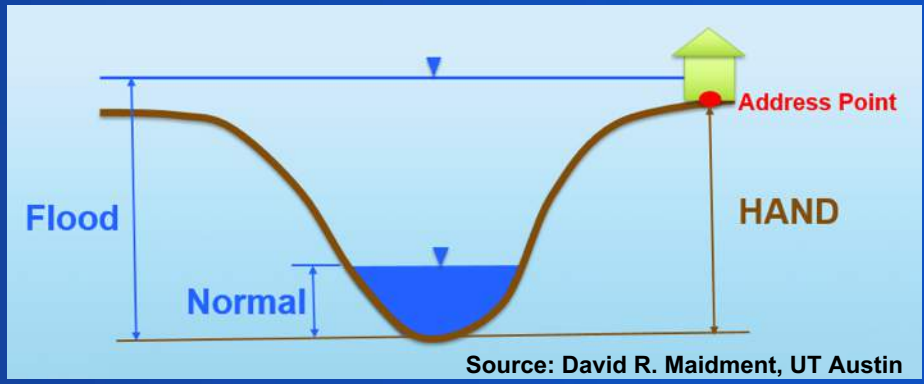
Develop flood impact dataset and rating curve



HAND definition

- HAND – Height Above Nearest Drainage: difference in elevation between a point in the landscape and a point on the drainage line "flooding" that point in the landscape.

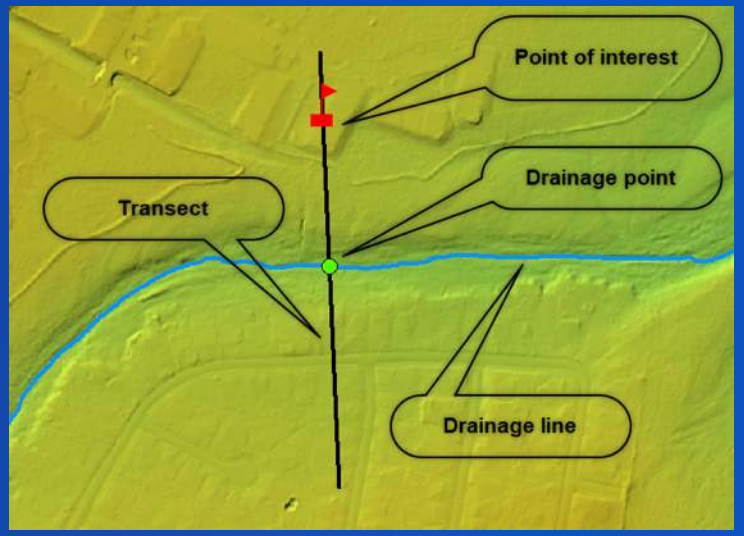




Source: David R. Maidment, UT Austin

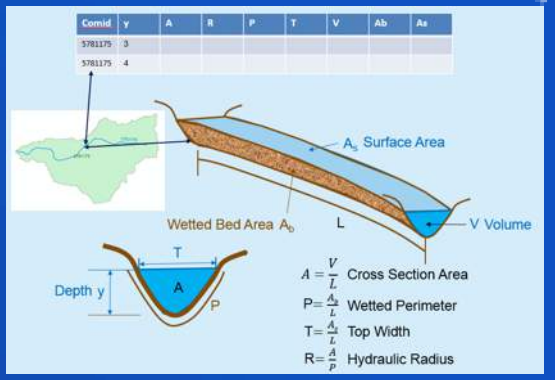
HAND principles

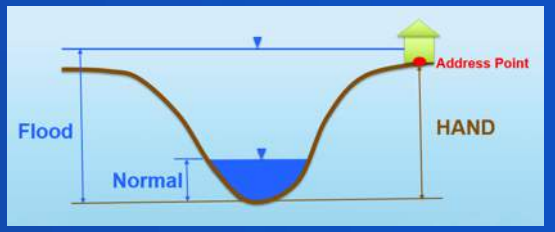
- Basic data requirements:
  - Elevation
  - Drainage (hydrography)
- Which point along drainage “floods” which point in the landscape
  - Different techniques are possible (Dinf, D8, NN)

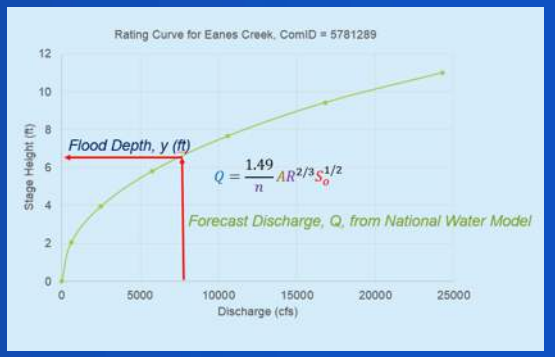


Landscape characterization

- **Streams**
  - DEM alignment and thalweg adjustment
  - Longitudinal WSE interpolation based on point values
- **Cross-sections/reach**
  - Characterization: h, A, B, P, R curve
  - Synthetic rating curve: Q-H relationship (based on normal depth with n and S_0 assumption)
  - Needed to related flow forecasts (NWM) to H forecasts
- **Address HAND attribution (impact assessment)**
  - Reach ID
  - HAND elevation





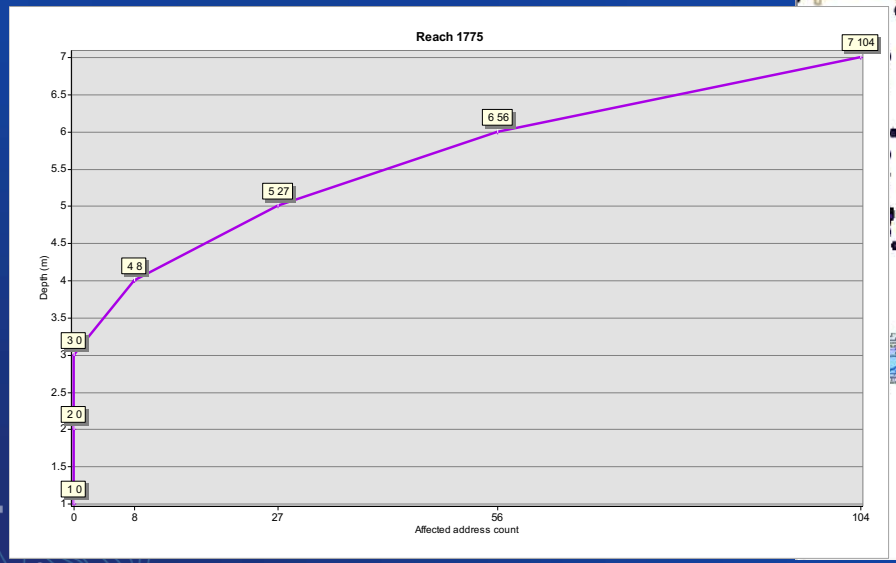


Source: David R. Maidment, UT Austin

Geoenable runoff forecast

Relate stages to local topography and impact

- Relating depth and extent of flooding to affected addresses



Differences in NHDPlus/Lidar processing

	NHDPlus HR	Lidar
NWM data	Same data (v1.2). Important for density and IDs	
Topo data	DEM, NHDBurnlines, NHDWaterbody (for sinks), NHDFlowline (for coastal reaches)	DEM, user provided sinks and streams
DEM Processing	• Derived from NWM origination points, NHDBurnlines. • Sinks based on “subnets”	• Derived from provided streams and sinks
Model reaches	Same for both: • Confluence to confluence • Limit to 2,000m	
HAND development	Same for both: • Create smooth 3D thalweg line based on minimal surrounding elevation • Enforce 3D thalweg into DEM • Derive HAND (D8 fdr approach)	

Differences in NHDPlus/Lidar processing

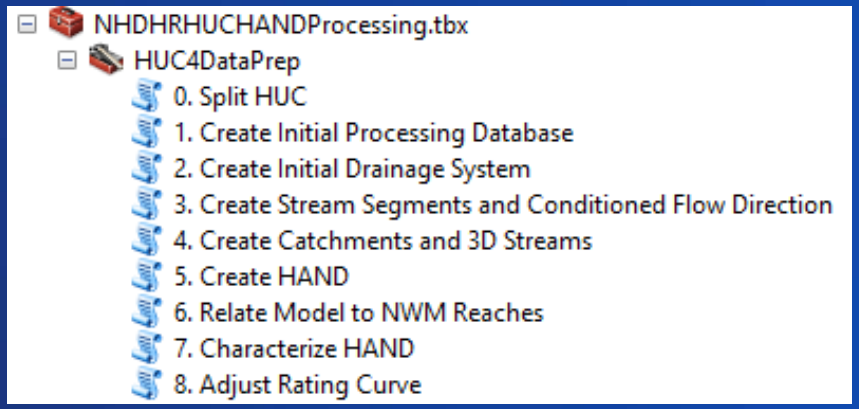
- Key difference is in the initial DEM processing:
  - Identifying sinks
  - Identifying streams to burn
- Once the DEM is conditioned, the rest of the steps are the same
  - Create 3D thalweg and enforce into DEM
  - Derive HAND (D8 fdr approach)
  - Characterize model reaches using HAND (reach characteristics – A,B,P,R)
    - 0-25m in 1ft increments (86 “slices”)
  - Derive rating curve based on assumed n and slope (per model reach)
  - Derive “flood stack” (polygon slices for each depth increment)

Differences from original HAND processing

- Key differences (original approach at CUAHSI):
  - No streams to burn – using synthetic streams (off filled DEM)
  - No sinks
  - Dinf (average stream flood point location)

Implementation (ArcGIS environment)

- Implemented as Arc Hydro tools (~100 individual processing steps)
- Keep tools coarse enough to:
  - Allow tweaks in data entry (starting point of analysis)
  - Allow tweaks/options in data processing techniques

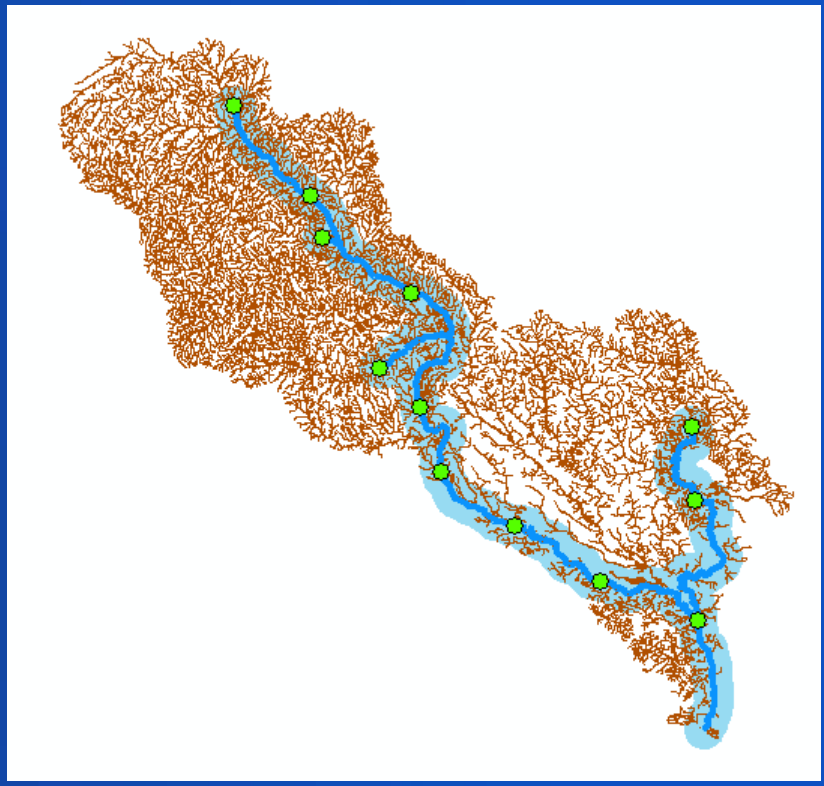


Version management

- Original tools (v0.5) implemented for NWC
- Current tools (v0.9) for 10.5.1 and 10.6.1/patch
- Added full slicing
- Inclusion into AH
- NHDPlusHR and HiRes DEM processing

RFC reach processing (replace and route)

- Methodology for DEM processing for reaches defined by gages (replace and route)
  - Tweak to existing process – applied to NC – HUC 0303
- Automate the process – build specific RR tools that fit into existing processing workflow
  - Initial starting points (gages instead of NWM channel initiation points)
  - Channel extent limit (buffer)



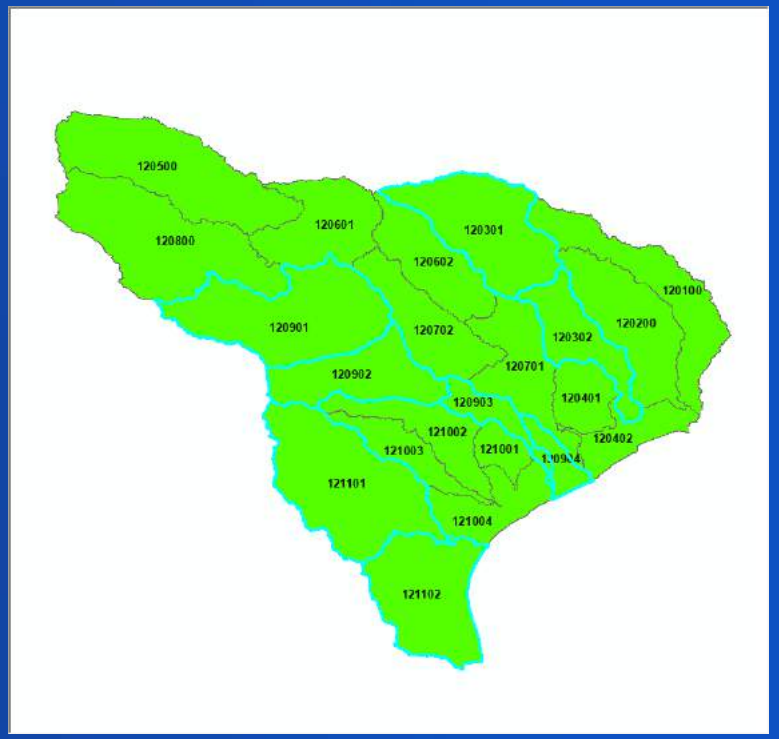
Processing improvements (need/desire)

- Better/automated stream identification (2D alignment)
- Better 3D thalweg definition
- HAND technique (Dinf, D8, NN)?
- Reduction in size of outputs
  - Delete intermediate layers (mostly rasters)
  - Fewer slices
  - Visualization
    - Reduce accuracy of vectors
    - Generalization

Review Region 12 processing (NHDPlus HR)

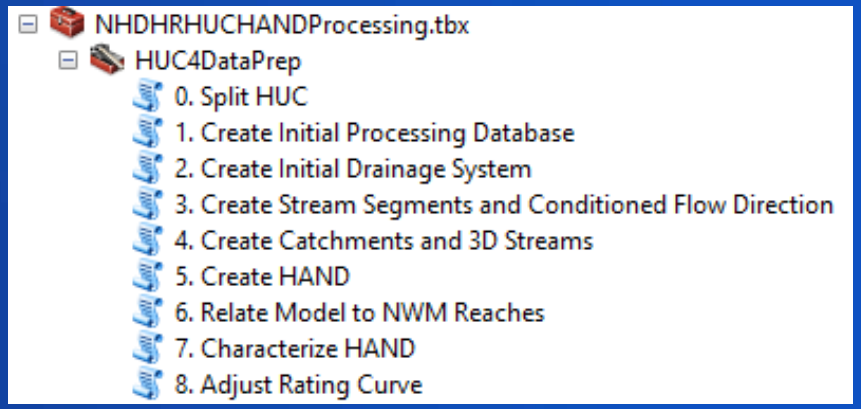
- 22 HUC 6

Region	Fdr cells	Area (km2)	Folder size (GB)	# reaches
1201	31,797 by 38,946	25,502.7362	168	10,456
1202	21,159 by 29,648	26,031.5152	86	10,611
1203				
120301	27,178 by 22,658	30,506.7151	88	11,115
120302	19,269 by 27,479	15,868.1533	75	7,509
1204	23,636 by 22,024	18,931.1502	69	5,238
1205	36,725 by 24,773	37,558.8948	119	4,336
1206	37,784 by 27,359	40,429.6079	140	13,993
1207	36,774 by 42,216	40,246.3904	213	15,329
1208	35,191 by 26,432	41,643.6554	109	4,705
1209	66,338 by 44,230			
120901	35,453 by 19,848	38,938.4067	100	11,140
120902	27,921 by 15,303	21,344.9594	62	7,829
120903	17,547 by 21,250	7,506.4249	53	3,055
120904	10,882 by 14,373	4,675.3477	21	1,483
1210	36,959 by 28,619	44,158.2992	141	15,540
1211	34,770 by 49,025			
121101	29,051 by 29,174	43,319.2045	123	15,098
121102	19,420 by 24,269	27,083.6400	61	2,326



Review Region 12 processing

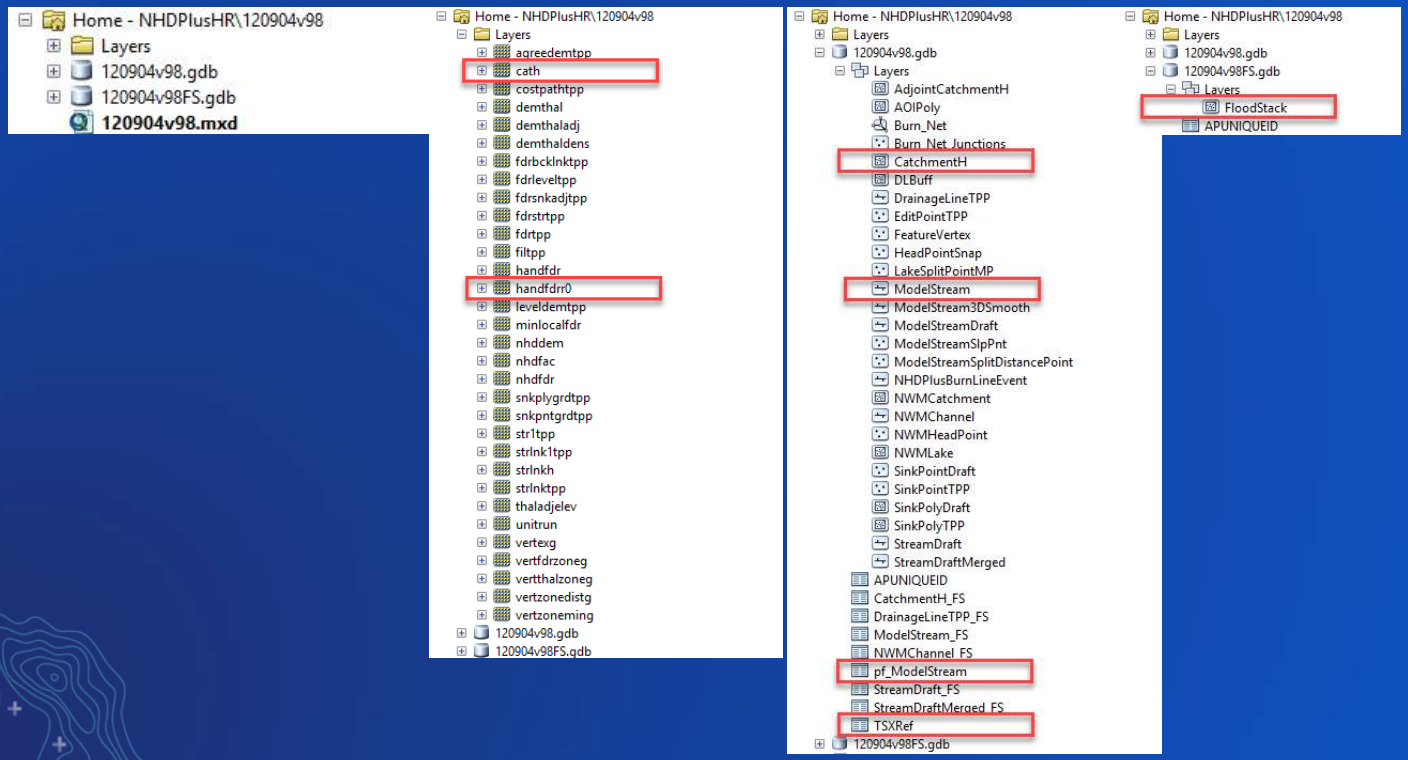
- **Review Region 12 NHDPlus HR HAND processing – “8” step process**
  - Split HUC 4
  - Create initial processing database
  - Create initial drainage system
  - Create stream segments and conditioned flow direction
  - Create catchments and 3D streams
  - Create HAND
  - Relate model to NWM reaches
  - Characterize HAND
  - Adjust Rating Curve



Flood stack database design (1)

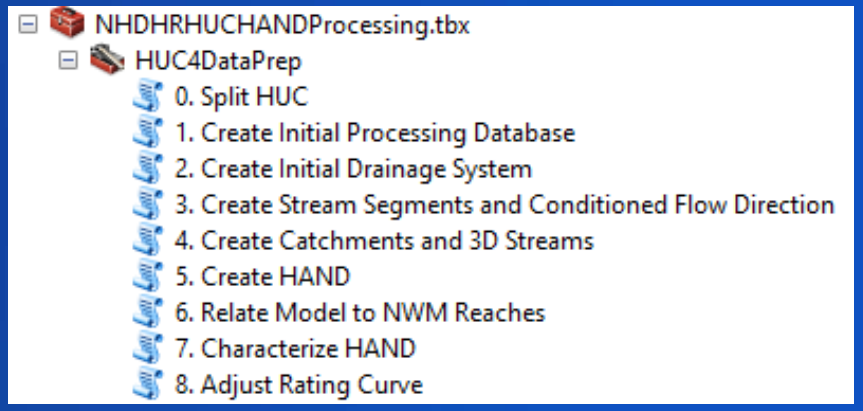
- The process generates rich dataset (~80GB per processing unit).
- It is a mix of raster and vector layers and tabular data.
- Resulting dataset is fully Arc Hydro compliant and can be used with other Arc Hydro tools to support other hydro analyses besides flooding.
- Final flood stack needed for immediate flood applications are not complex:
  - Raster: HAND and catchment
  - Vector: model stream and catchment and corresponding flood extents
  - Tabular: channel characteristics/rating curve and channel/NWM V1.2 cross-reference

Flood stack database design (2)

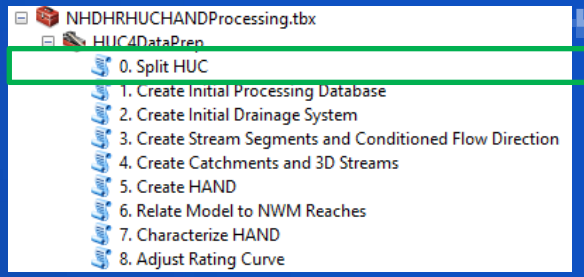


NHDPlus HR HAND processing - walkthrough

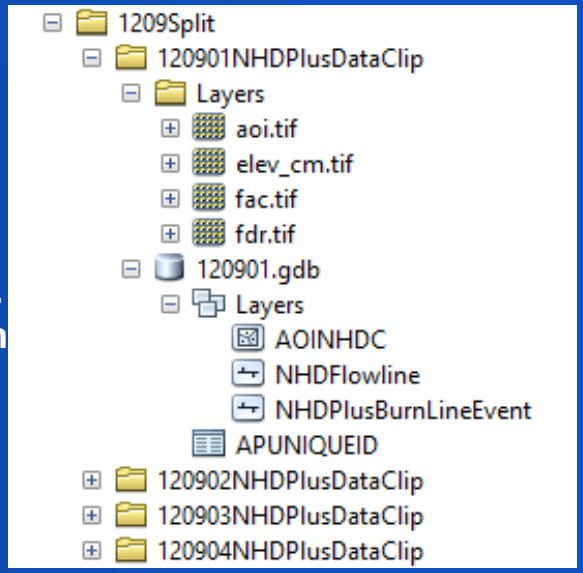
- Split HUC
- Create initial processing database
- Create initial drainage system
- Create stream segments and conditioned flow direction
- Create catchments and 3D streams
- Create HAND
- Relate model to NWM reaches
- Characterize HAND
- Adjust rating curve



NHDPlus HR HAND processing

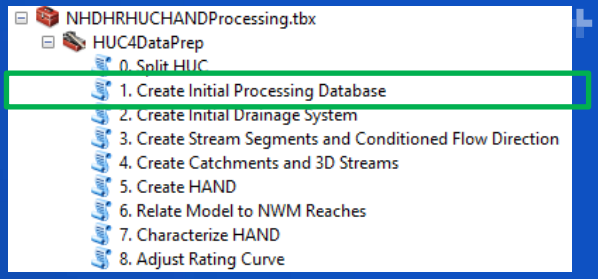


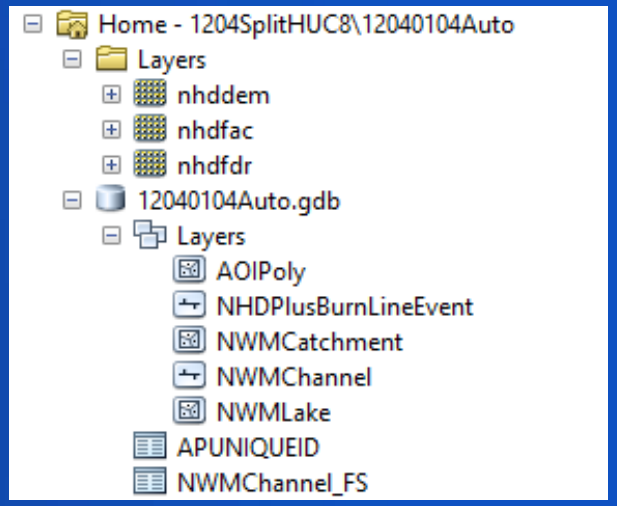
- **Split HUC**
  - Extracts a subset of NHDPlus data defined by smaller HUC boundaries into subfolders for each selected smaller HUC.
  - Used only when HUC 4 is too big to be processed as a single processing unit.
  - Organizes base NHDPlus data needed in later processing.
  - No “real” processing – just data clipping.
  - Can take any HUC boundary polygons as input for clipping (e.g. HUC 8 or HUC 10). This can help with performance optimization and when processing higher resolution DEMs (e.g. Lidar-derived).



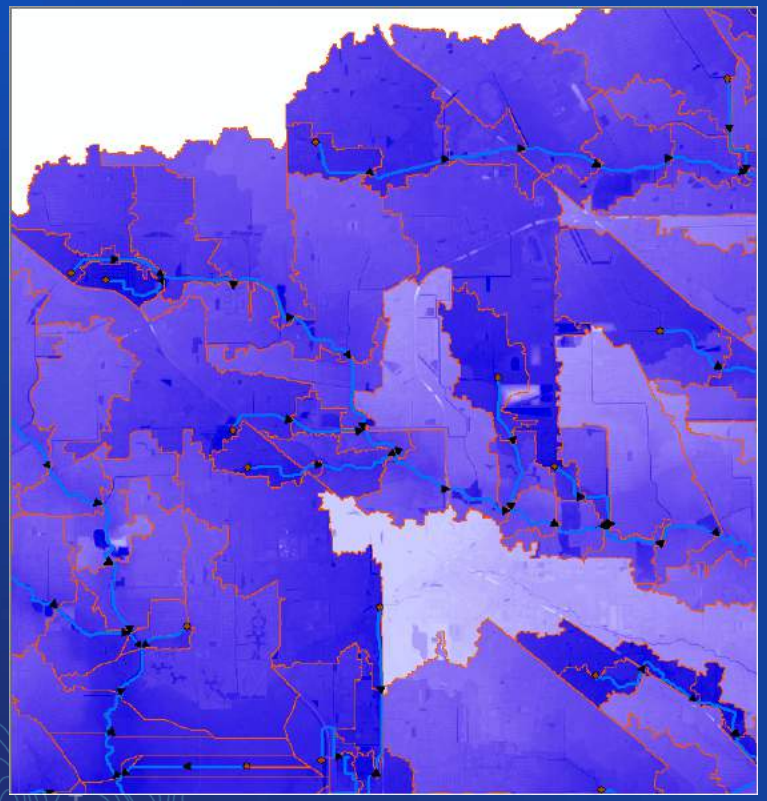
NHDPlus HR HAND processing

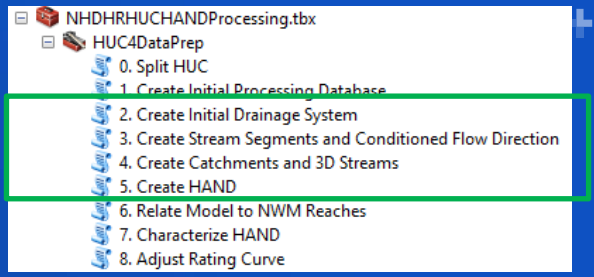
- Create initial processing database
  - Organize necessary processing raster (NHDPlus) and vector (NHDPlus and NWM) layers into a standard Arc Hydro data processing structure.
  - Project all vector data into the same (National Albers) projection as rasters are in.
  - Clip NWM data to the local processing extent.
  - Convert raster data into GRID format.
  - Basic attribution (Arc Hydro, NHD)





NHDPlus HR HAND processing

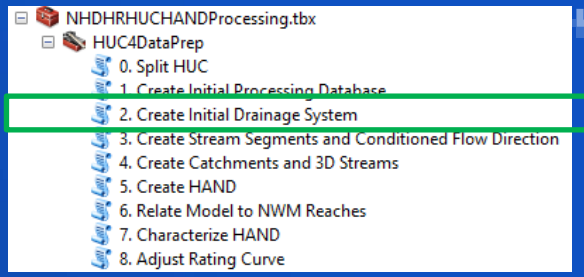


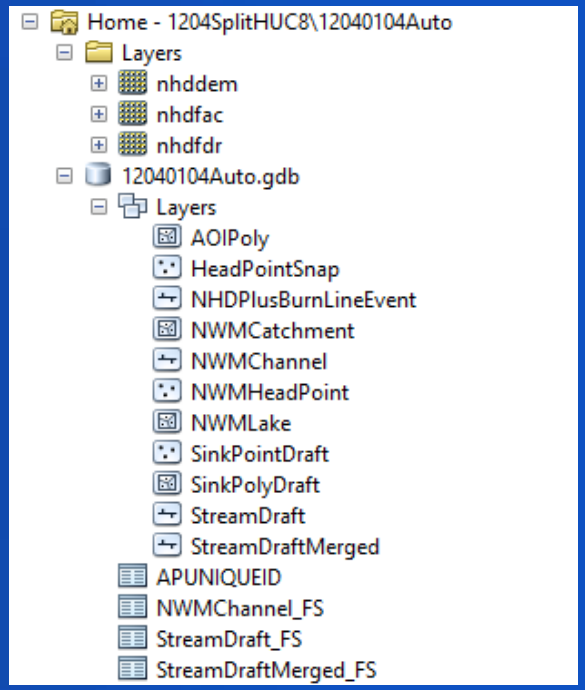


- Green – NWM reaches
- Thin blue – NHDPlus HR
- Red point – NWM head points
- Black – merged HR “channels” based on NWM
- Thick blue – model reaches
- Polygons – model catchments
- HAND

NHDPlus HR HAND processing

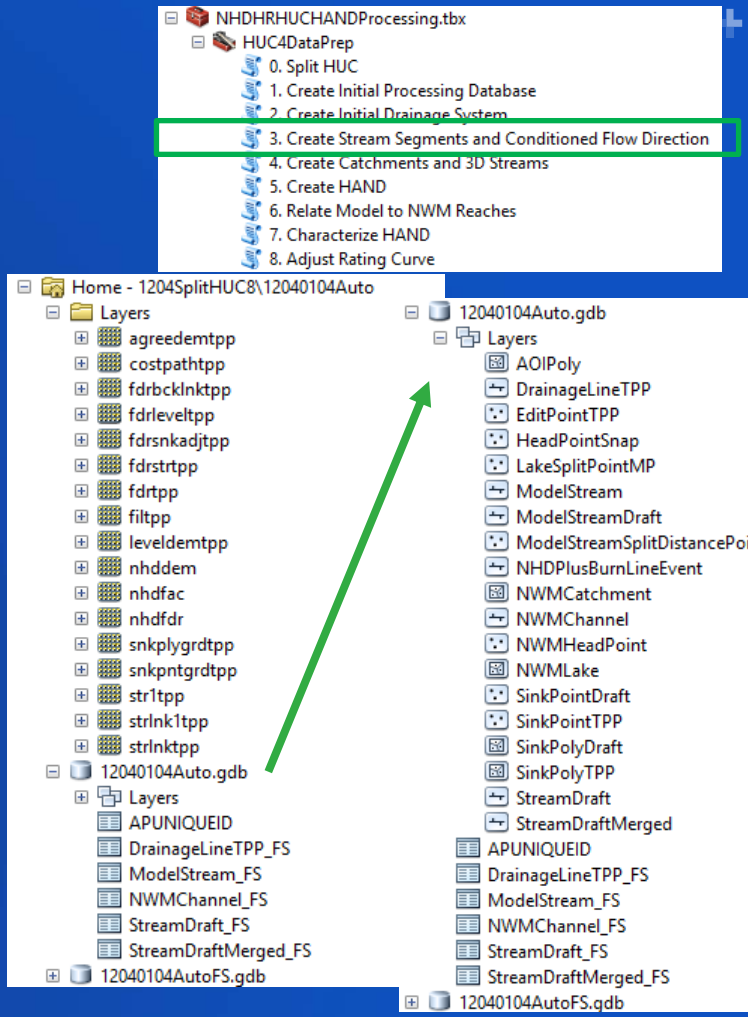
- **Create initial drainage system**
  - Establish relevant high resolution NHD flowlines based on NWM stream origination points.
  - Identify sinks.
  - No raster processing.





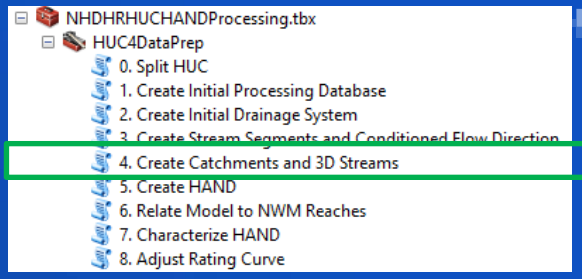
NHDPlus HR HAND processing

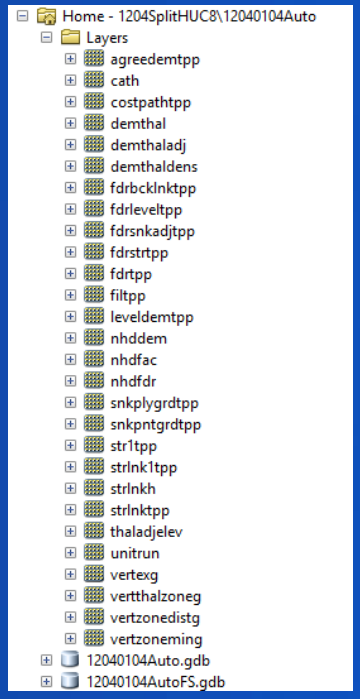
- Create stream segments and conditioned flow direction
  - Core Arc Hydro combined terrain preprocessing.
  - Establish hydro-conditioned flow direction.
    - Remove most sinks
    - Enforce streams
  - Establish model reaches based on lake and distance threshold.

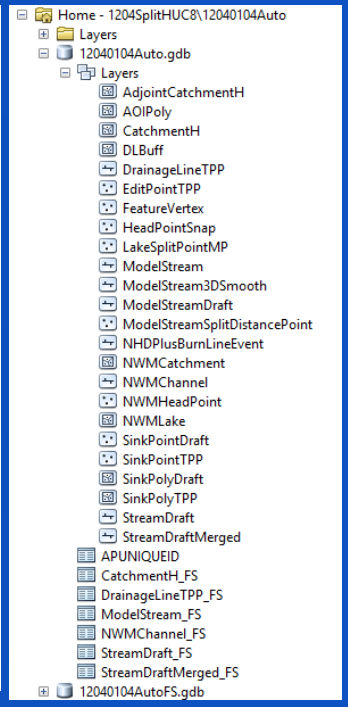


NHDPlus HR HAND processing

- Create catchments and 3D streams
  - Finalize Arc Hydro processing using new model reaches as basis (derive catchments and adjoint catchments).
  - Derive 3D thalweg representation and create thalweg-adjusted DEM.

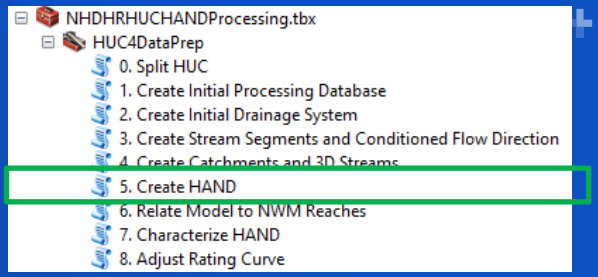


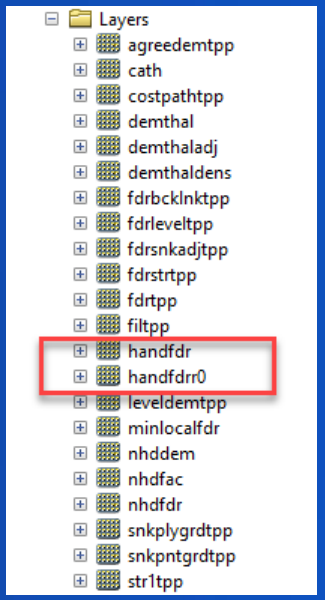




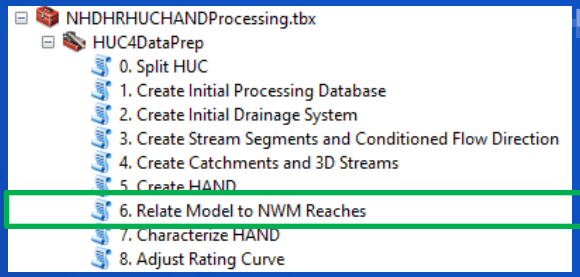
NHDPlus HR HAND processing

- Create HAND
  - Creates HAND surface based on D8 method.
    - Limit to H>0.





NHDPlus HR HAND processing

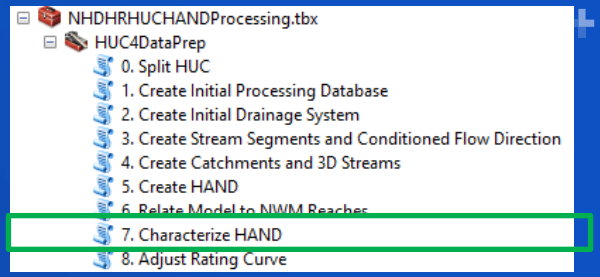


- Relate model to NWM reaches
  - Finalize model reach attribution.
    - LengthKm, AreaSqKm, TotalAreaSqKm, River order, ManningN, S_0
  - Creates a table relating local modeling reaches to the NWM reaches. Based on maximum percent area contribution.
    - KeyTo – local modeling reach
    - KeyFrom – NWM reach ID
    - PctTo - % of NWM catchment with most contribution in the local modeling reach catchment.

KeyTo *	KeyFrom *	PctTo
3448	1605150	1
3449	1605172	0.3155
3450	1605156	1
3451	1605162	1
3452	1605444	1
3453	1605212	0.4141
3454	1605236	1
3455	1605438	1
3456	1605308	1
3457	1606654	1
3458	1606678	1
3459	1606868	1
3460	1606718	1
3461	<Null>	1
3462	<Null>	0.7647
3463	1607440	1
3464	1607442	1
3465	1607498	1
3466	1607498	0.3014
3467	1606772	1
3468	1606778	1
3469	1606784	0.9196

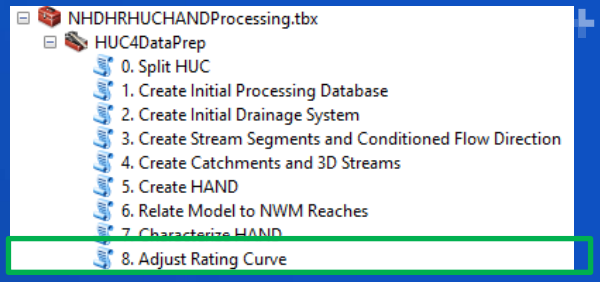
NHDPlus HR HAND processing

- **Characterize HAND**
  - **"Slice" through HAND in elevation increments and define:**
    - **Reach characteristics (area, perimeter, hydraulic radius, …).**
    - **Discharge (using Manning's equation with fixed n and S_0).**
    - **Flood extent polygon.**



RiverID *	Length_M	H *	B	R	A	P	Q *
3448	1433.259018	0	0.209313	0	0	0.20932	0
3448	1433.259018	0.3048	4.256035	0.143466	0.610763	4.257204	0.088217
3448	1433.259018	0.6096	20.163836	0.201077	4.055823	20.170456	0.733674
3448	1433.259018	0.9144	45.351189	0.317881	14.421331	45.367055	3.540223
3448	1433.259018	1.2192	61.468303	0.496539	30.534065	61.493798	10.091032
3448	1433.259018	1.524	77.166792	0.669374	51.67887	77.204726	20.842085
3448	1433.259018	1.8288	89.934895	0.857598	77.169941	89.983867	36.712949
3448	1433.259018	2.1336	103.261168	1.032361	106.667184	103.323558	57.424942
3448	1433.259018	2.4384	117.006067	1.196033	140.031697	117.08016	83.157955
3448	1433.259018	2.7432	133.262723	1.335189	178.047951	133.350387	113.783912
3448	1433.259018	3.048	150.077549	1.473643	221.30581	150.175963	151.043889
3448	1433.259018	3.3528	171.287951	1.574751	269.910263	171.39874	192.549618
3448	1433.259018	3.6576	195.63805	1.667899	326.502537	195.756774	242.018454
3448	1433.259018	3.9624	215.732115	1.803155	389.227884	215.859375	303.907474
3448	1433.259018	4.2672	226.965256	2.01159	456.830461	227.099243	383.674895
3448	1433.259018	4.572	237.570457	2.219708	527.650779	237.711829	473.215753
3448	1433.259018	4.8768	246.082526	2.442199	601.344356	246.230677	574.76817
3448	1433.259018	5.1816	255.292306	2.653364	677.796274	255.447877	684.666658
3448	1433.259018	5.4864	264.362544	2.861609	756.967342	264.525049	804.142073
3448	1433.259018	5.7912	274.200263	3.057984	839.017599	274.369531	931.629604
3448	1433.259018	6.096	284.456609	3.246759	924.132383	284.6323	1067.946779
3448	1433.259018	6.4008	294.503641	3.435503	1012.394179	294.68583	1214.857426
3448	1433.259018	6.7056	307.062432	3.593268	1104.034564	307.250847	1365.079067

NHDPlus HR HAND processing



- **Adjust rating curve**
  - **Modifies the rating curve for “short” reaches.**
    - **These are usually reaches between two confluences.**
    - **Short reaches are those with length < 0.5 km and direct contributing area < 0.25 km2.**
    - **Rating curve from the largest directly connected upstream reach is applied to the short reach.**

Short reach rating curve adjustment

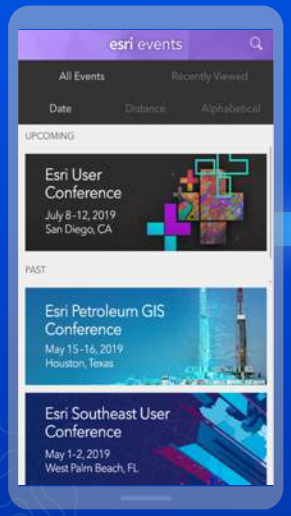
- Length and contributing area thresholds to determine short reach (0.5 km and 0.25 km2).
- Q adjustment – tool 8.
  - Use Q of the larger of the two upstream tribs (implemented in version 0.9).
  - Alternatives (later versions):
    - Use “weighted” sum of the two upstream Qs.
    - Area based (Manning’s equation) weighting.

Questions / Discussion

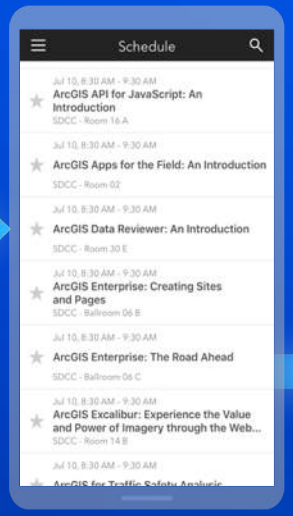
Section Subhead

Please Share Your Feedback in the App

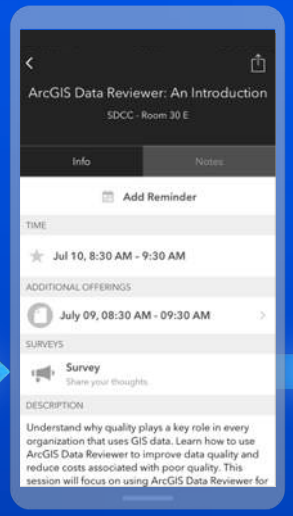
Download the Esri Events app and find your event



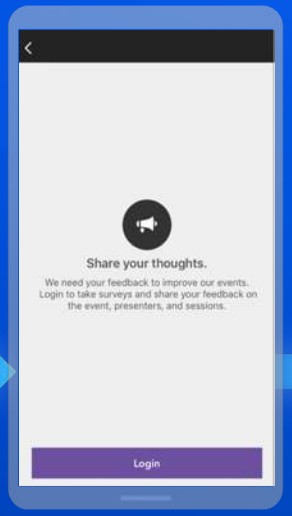
Select the session you attended



Scroll down to "Survey"



Log in to access the survey



Complete the survey and select "Submit"

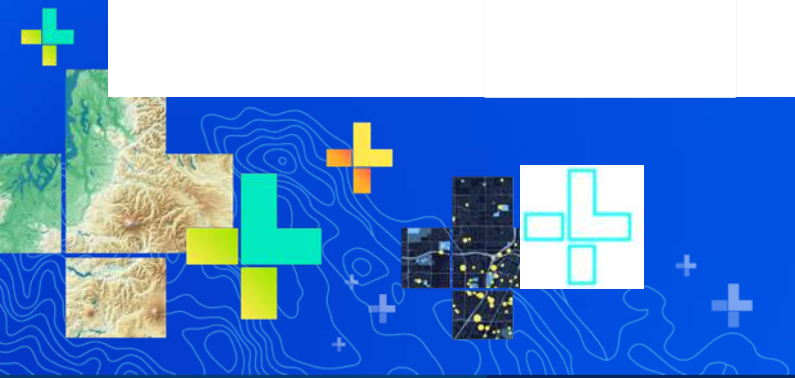
Presentation Title

Presenter Names

SEE
WHAT
OTHERS
CAN'T

Section Header

Section Subhead



Demo Title

Presenter(s)