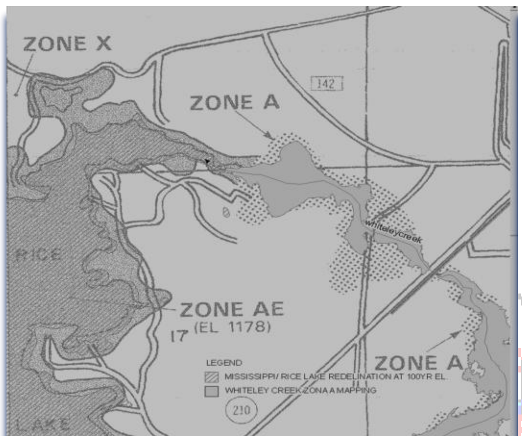
Rectifying approximate study hydraulic models



Presented by:
Laura M. Rightler, P.E, CFM
Paramjit Chibber, P.E, CFM

Overview:

- Definitions; Level of study
- Why rectify Zone A hydraulic models?
- Methods used to rectify hydraulic models
  - Hydraulic Calibration
  - Channel Modification
    - Arc GIS
    - HECRAS
- Conclusion: Pros & Cons

Level of study:

	ZONE A		ZONE AE
	Approximate Study	**Limited Detailed Study**	**Detailed Study**
Manning's "n"	Generalized	Generalized and calibrated	Determined from site reconnaissance
Structures	Estimated from topographic data and/or established from published sources	Estimated from topographic data, established from published sources, observed from field	Surveyed
Hydraulic Cross Sections	Sampled from topographic data	Sampled from topographic data, supplemented with field survey	Surveyed at specified spacing and location.
Channel	Estimated from topographic data	Determined from topographic data and calibrated for bathymetric data	Stream centerline and bank stations are surveyed
Boundary Conditions	Downstream condition: Normal depth, known water surface elevations	Downstream condition: Normal depth, known water surface elevations	Downstream, upstream and intermediate boundary conditions specified depending on model used.
Floodplains	Delineated	Delineated	Delineated/ redelineated /digitized
Floodway	Undefined	Undefined	Defined, tabulated in FDT
BFEs	Not determined	Available to community	Published in FIS and DFIRM

Level of Study Chart

Why rectify Zone A Models?

- Availability of new topographic data that is of higher accuracy and resolution
- Upgrades to hydraulic modeling techniques and software
- Physical and hydrologic changes to the watershed resulting in different discharge-frequency relations
- Redefinition of FEMA products to better meet community needs.

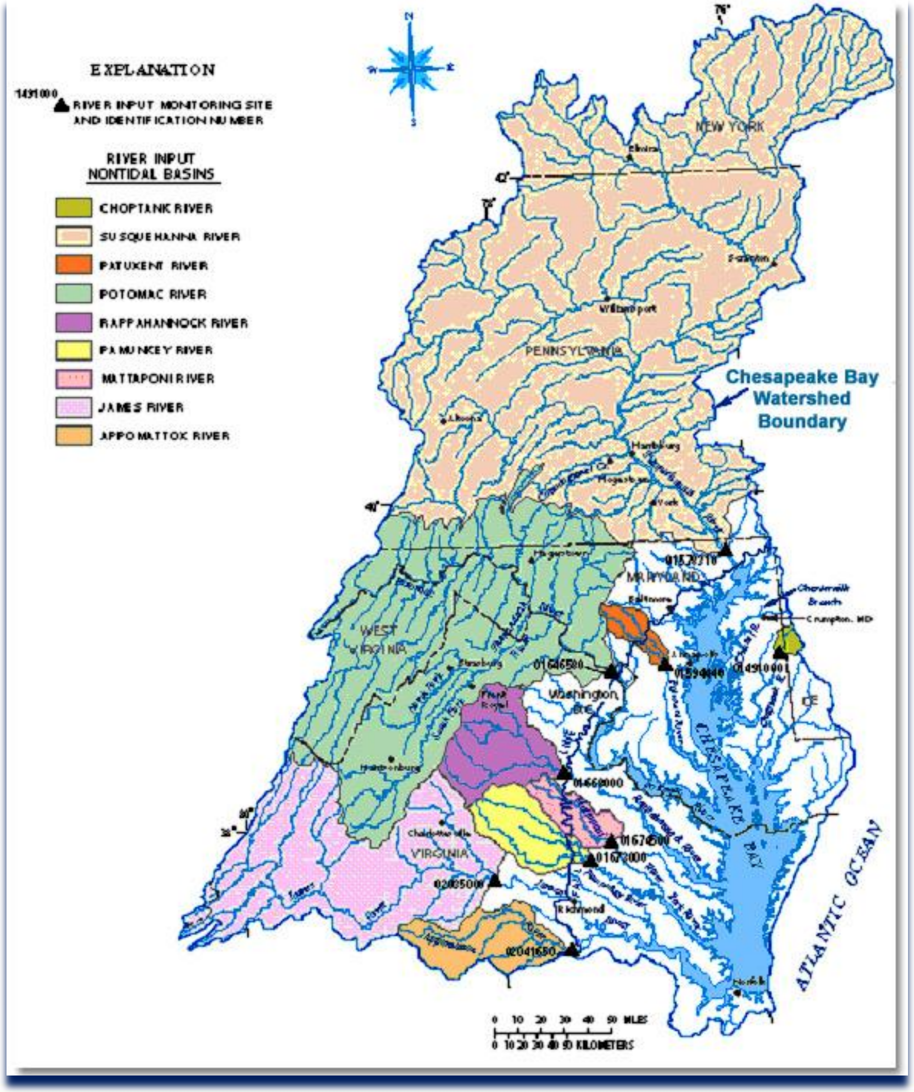
Why rectify Zone A Models?

Historically, FEMA has produced flood maps and flood insurance studies for communities designated by political boundaries and jurisdictions. Hence, a single flooding source may be depicted in several maps with varying levels of study both along and across its reach length.

Why rectify Zone A Models?

The Mississippi river watershed is a good example of how this may present mapping challenges.

Why rectify Zone A Models?



The Chesapeake Bay watershed

Methods used to rectify Zone A Models

Assumptions:

- Calibration of the hydrologic model if required has been completed. Performed by modeling major historic events/storms where rainfall and outflow data records are available, and comparing it to hydrologic model data. Parameters can then be adjusted and results checked against observed values.

Methods used to rectify Zone A Models

Assumptions:

- Hydraulic models discussed here are limited to one-dimensional steady flow models. The models represent a well defined channel with constant flow properties over time, with no reverse or multi-directional flow.

Methods used to rectify Zone A Models

Hydraulic Calibration

- Adjusting hydraulic input variables by comparison of model results with historic floods where flood flow and elevation data is known.
- The Manning "n" is more commonly the variable used to calibrate models.

Methods used to rectify Zone A Models

Hydraulic Calibration

Prior to modifying the Manning's "n" confirm that:

- Structure data is input correctly
    - National Bridge Inventory (NBI)_GIS data
    - Federal Highway Administration (FHWA) _ Technical Guidelines
    - Data available from the state or community
    - Energy loss coefficients are determined

Methods used to rectify Zone A Models

Hydraulic Calibration

Bridges	
Parameter	Assumption
Deck Thickness	3.5
Width	Approximate from Aerial Imagery
Pier Opening Width	Approximate as 90% of approximated Aerial opening width
Minimum Ground Elevation	*

Culverts	
Parameter	Assumption
Minimum Ground Elevation	*
Invert Elevations	Approximate from Topographic data
FHWA HDS-5 chart number	1 for circular/elliptical, 10 for box or rectangular
Nomograph Scale	1
Entrance loss coefficient	Estimated from HDS-5, Appendix D, Page 223, Table 12
Mannings n	0.014 for concrete, 0.016 for steel

Subcritical Flow Contraction and Expansion Coefficients

	Contraction	Expansion
No transition loss computed	0.0	0.0
Gradual transitions	0.1	0.3
Typical Bridge sections	0.3	0.5
Abrupt transitions	0.6	0.8

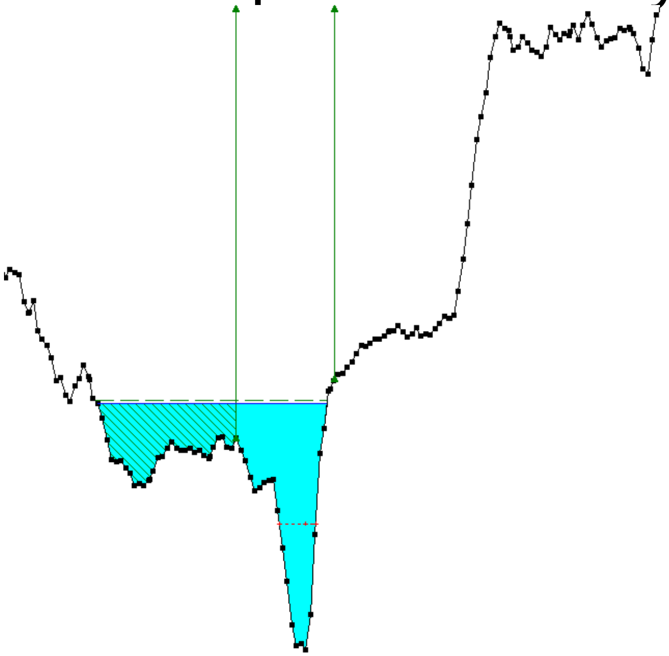
*Minimum ground elevation determined from spot elevation data provided by the State. If no data is available it is approximated as one half the contour interval above the lowest contour at the structure, or bridge elevation shown on quadrangle map.

Methods used to rectify Zone A Models

Hydraulic Calibration

- Ineffective flow areas are placed accurately

  Portions of the floodplain that are inundated by floodwaters but do not provide conveyance are defined



Methods used to rectify Zone A Models

PBS&J

Hydraulic Calibration

Manning's "n": categories:

- A-Natural Streams, applicable for most floodplain studies,
- B-Lined or Built-Up Channels, applicable for many manmade channels and storm water management projects and,
- C-Excavated or Dredged Channels often used with navigable waters improvement projects.

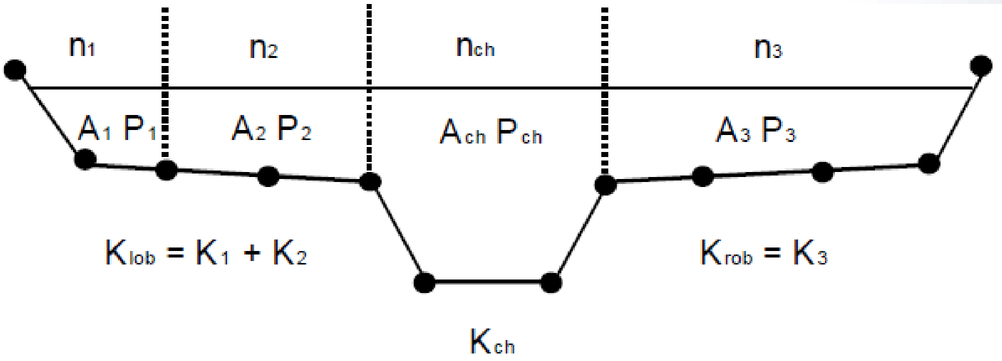
Methods used to rectify Zone A Models

Hydraulic Calibration

Manning's "n" & conveyance are related by the equation below:

$$Q = KS_f^{1/2}$$

$$K = \frac{1.486}{n} AR^{2/3}$$



where: K = conveyance for subdivision

n = Manning's roughness coefficient for subdivision

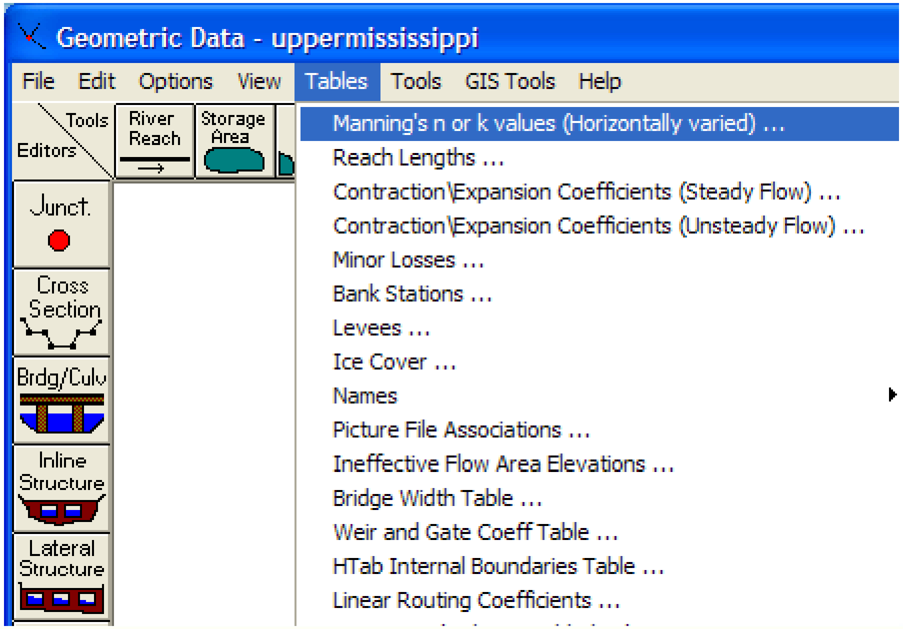
A = flow area for subdivision

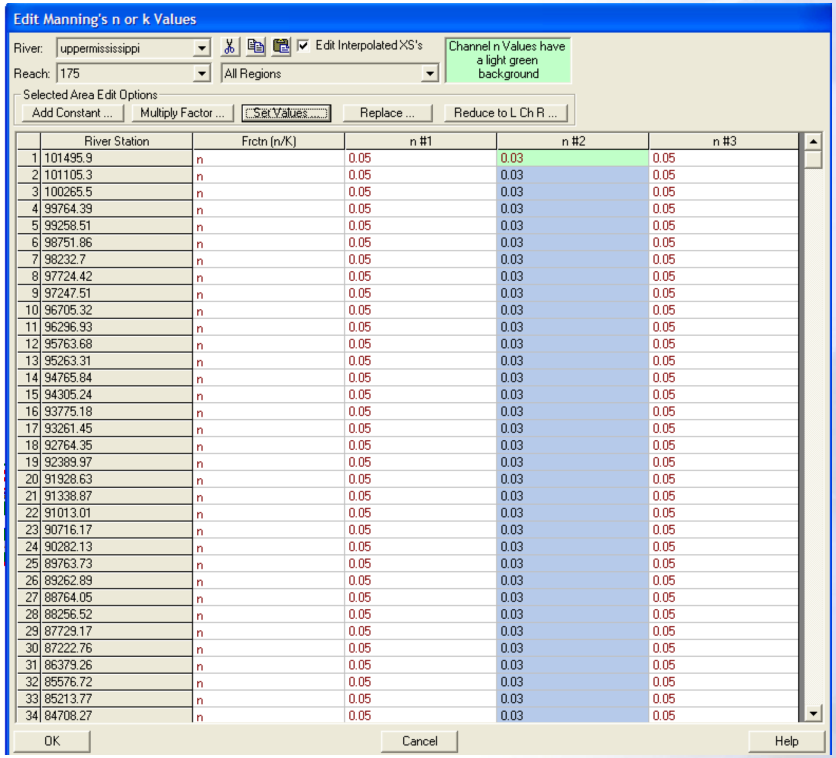
R = hydraulic radius for subdivision (area / wetted perimeter)

Methods used to rectify Zone A Models

Hydraulic Calibration

Adjusting Manning's "n" and roughness coefficients in HECRAS



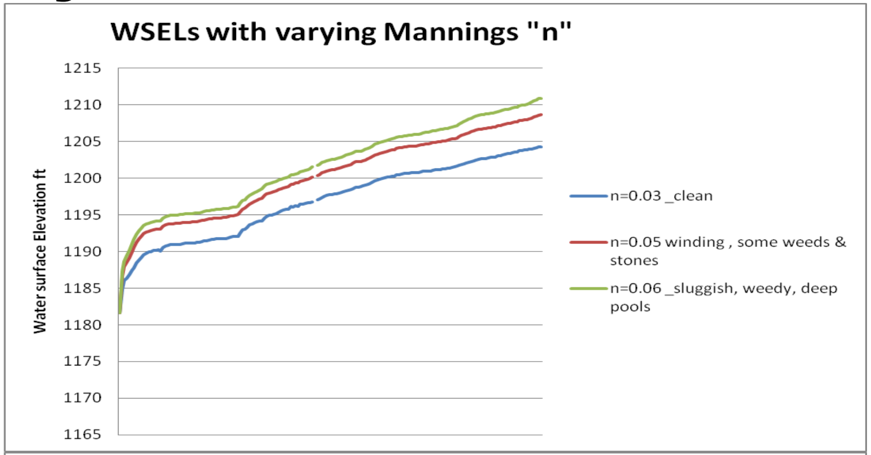


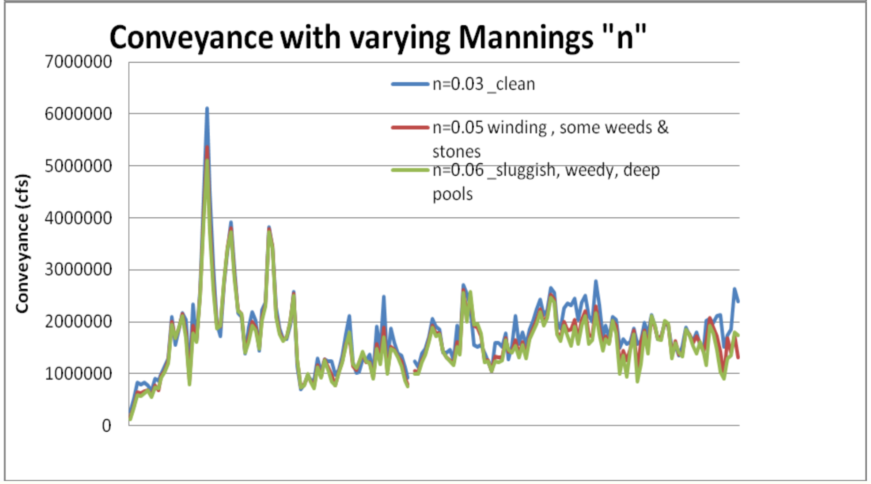
	River Station	Frctn (n/K)	n #1	n #2	n #3
1	101495.9	n	0.05	0.03	0.05
2	101105.3	n	0.05	0.03	0.05
3	100265.5	n	0.05	0.03	0.05
4	99764.39	n	0.05	0.03	0.05
5	99258.51	n	0.05	0.03	0.05
6	98751.86	n	0.05	0.03	0.05
7	98232.7	n	0.05	0.03	0.05
8	97724.42	n	0.05	0.03	0.05
9	97247.51	n	0.05	0.03	0.05
10	96705.32	n	0.05	0.03	0.05
11	96296.93	n	0.05	0.03	0.05
12	95763.68	n	0.05	0.03	0.05
13	95263.31	n	0.05	0.03	0.05
14	94765.84	n	0.05	0.03	0.05
15	94305.24	n	0.05	0.03	0.05
16	93775.18	n	0.05	0.03	0.05
17	93261.45	n	0.05	0.03	0.05
18	92764.35	n	0.05	0.03	0.05
19	92389.97	n	0.05	0.03	0.05
20	91928.63	n	0.05	0.03	0.05
21	91338.87	n	0.05	0.03	0.05
22	91013.01	n	0.05	0.03	0.05
23	90716.17	n	0.05	0.03	0.05
24	90282.13	n	0.05	0.03	0.05
25	89763.73	n	0.05	0.03	0.05
26	89262.89	n	0.05	0.03	0.05
27	88764.05	n	0.05	0.03	0.05
28	88256.52	n	0.05	0.03	0.05
29	87729.17	n	0.05	0.03	0.05
30	87222.76	n	0.05	0.03	0.05
31	86379.26	n	0.05	0.03	0.05
32	85576.72	n	0.05	0.03	0.05
33	85213.77	n	0.05	0.03	0.05
34	84708.27	n	0.05	0.03	0.05

Methods used to rectify Zone A Models

PBSJ®

Hydraulic Calibration





The figures illustrate the effects of varying the Manning's "n" along a sample river reach on the water surface elevation and conveyance.

The average difference in water surface elevation when the Manning's is increased from 0.03 to 0.05 and 0.06 was 3.33-ft and 4.76-ft respectively. For conveyance the corresponding reduction observed was 142842-cfs and 198625-cfs.

Methods used to rectify Zone A Models

Channel Modification

Applied where:

- Digital Elevation Models (DEMs) were developed from Light Detection and Ranging (LiDAR)
- Topographic data is obtained from the United States Geological Survey (USGS) National Elevation Datasets (NEDs) database

Methods used to rectify Zone A Models

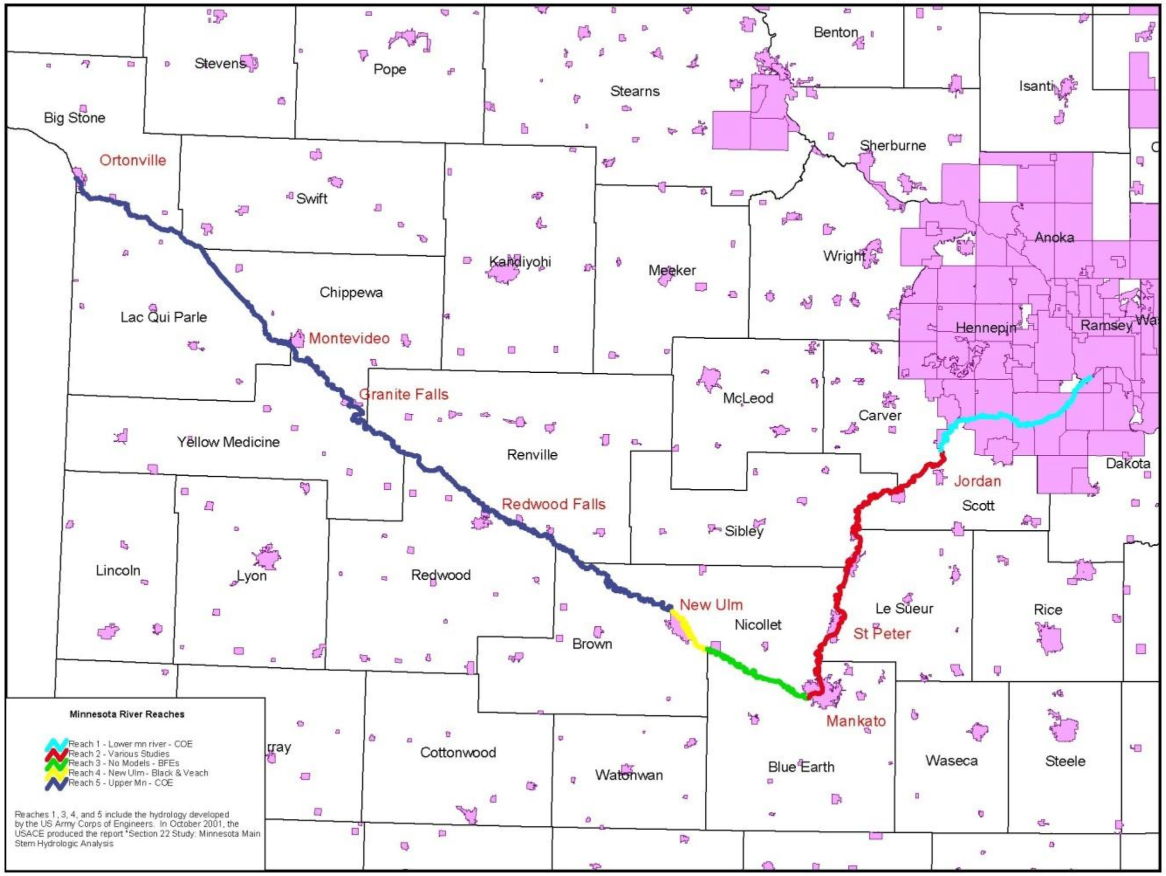
Channel Modification

Limitations of the topographic data:

- LiDAR returns over water surfaces are not accurate
- Stream centerline, shorelines and ridge line are not accurately delineated
- Water surfaces elevations computed using these data tend to be higher when checked against models developed from actual survey ground data, due to a loss in channel conveyance.

Methods used to rectify Zone A Models

Channel Modification- Arc GIS



Case Study
Nicollet County, MN

Stream Minnesota River

Study Type Limited Detail

Reach Length (miles) 24.5

Reach Description From approximately 1.25 miles upstream of its confluence with Blue Earth River to just upstream of Blue Earth/Brown County Line.

Methods used to rectify Zone A Models

Channel Modification- Arc GIS

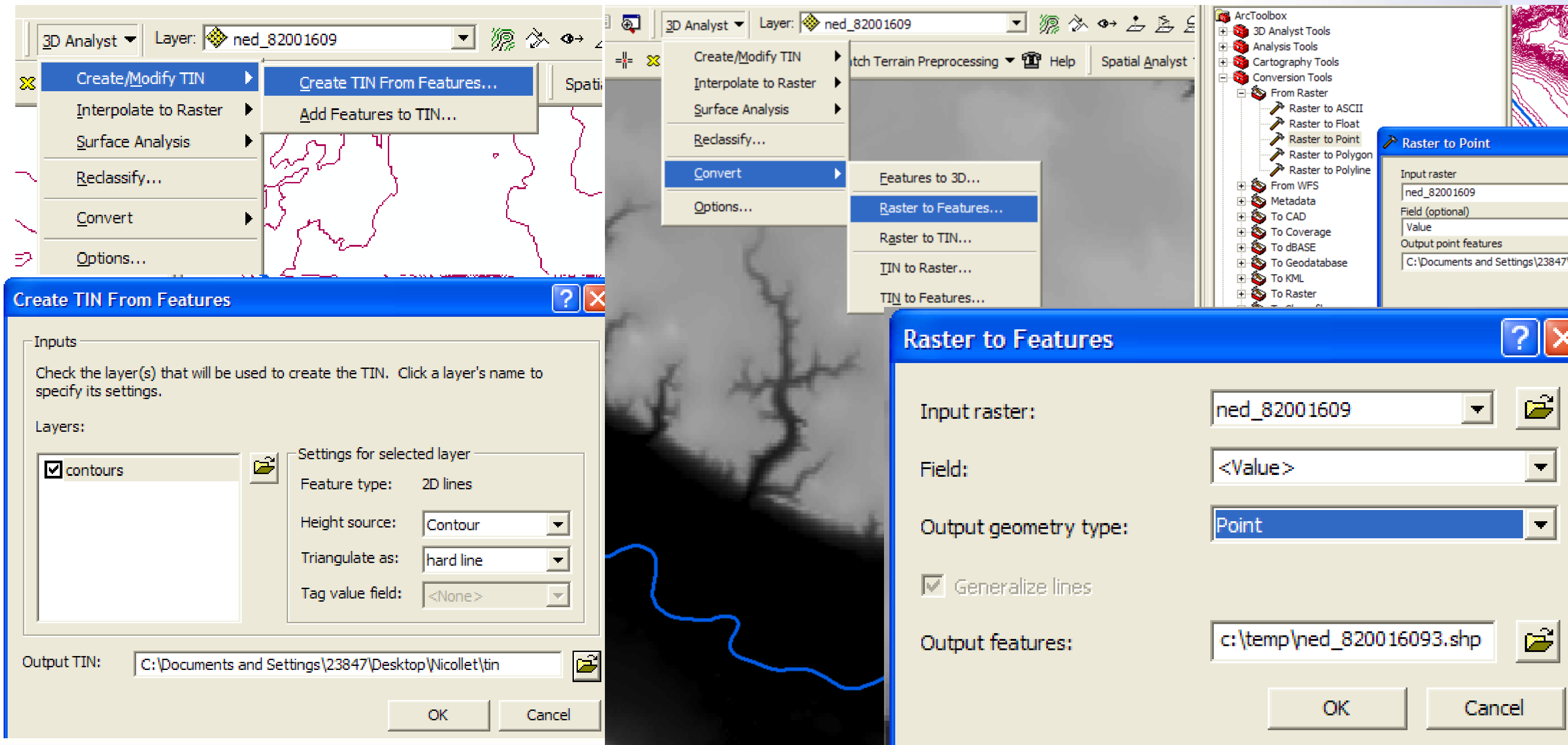
Building surfaces from existing data

- Create Triangular Irregular Network (TIN) datasets from LiDAR contours
- Convert supplemental data, USGS NED raster datasets to a point shapefile
- Correct for units meters to feet
- Add point data to TIN

Methods used to rectify Zone A Models

Channel Modification- Arc GIS

Building surfaces from existing data

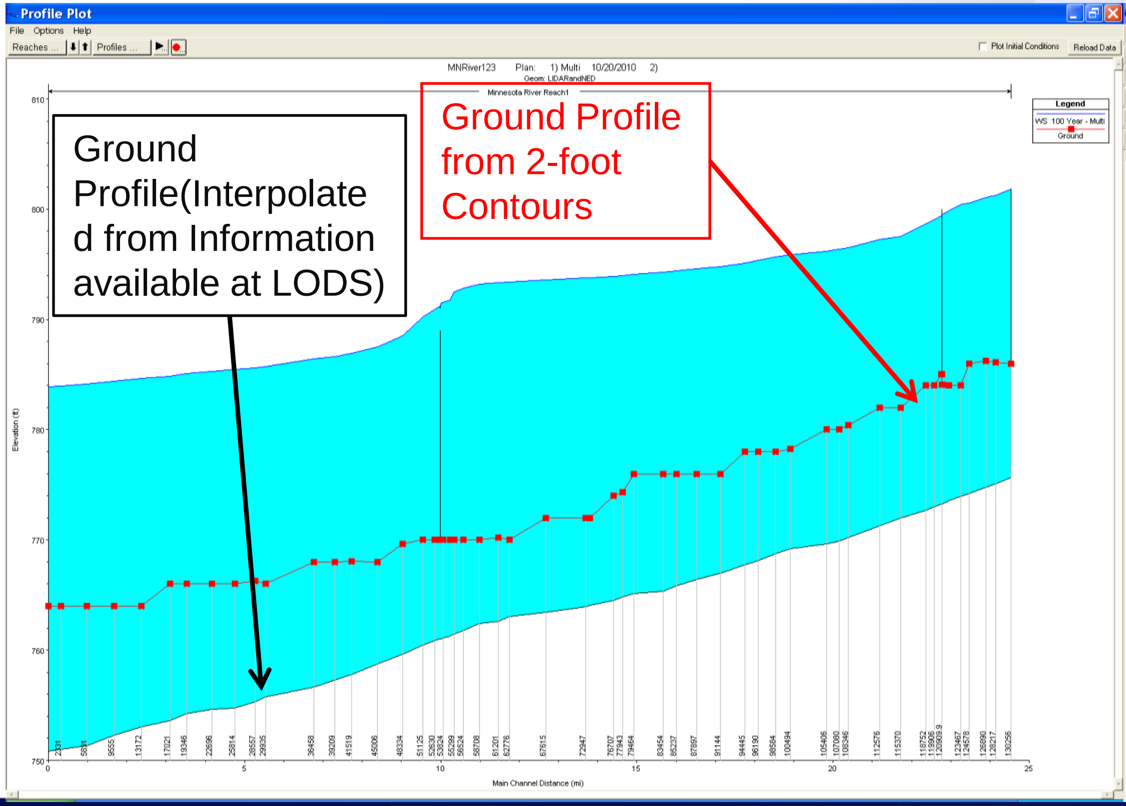


Methods used to rectify Zone A Models

Channel Modification- Arc GIS

Augmenting TIN data for channel information

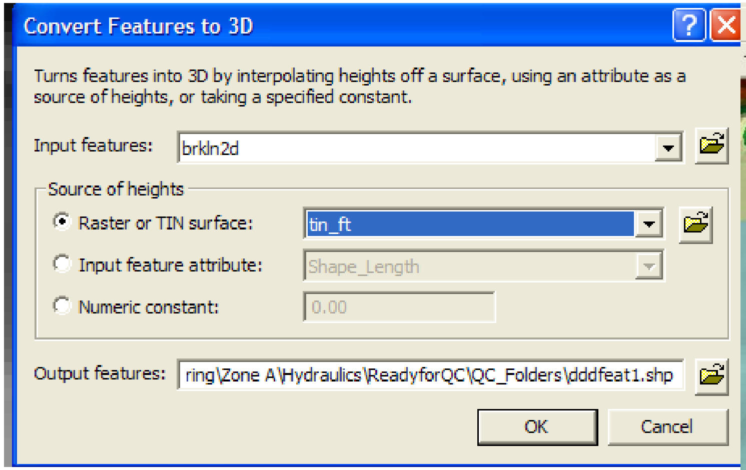
- Add channel information using 3d-breaklines
- Linearly interpolate centerline elevations between surveyed data; Limit of Detailed Study cross sections & structures

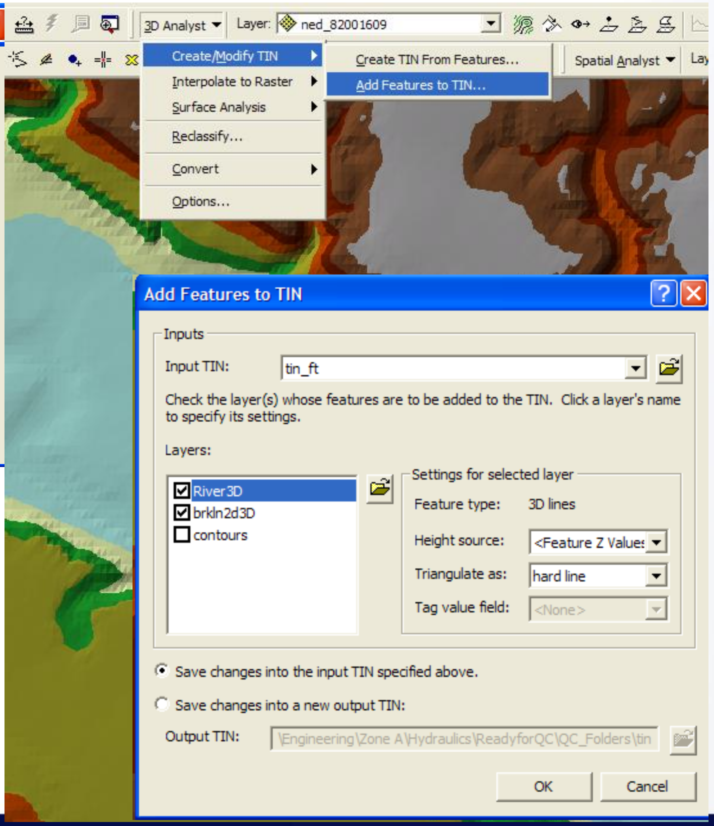


Methods used to rectify Zone A Models

Channel Modification- Arc GIS

Augmenting TIN data…

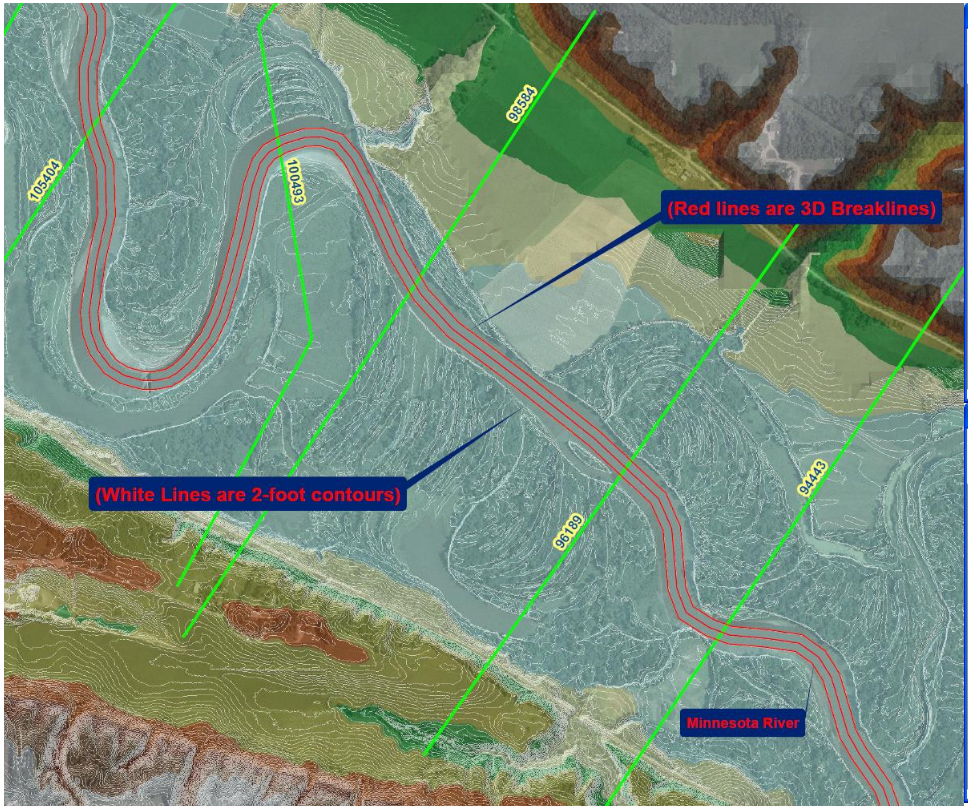


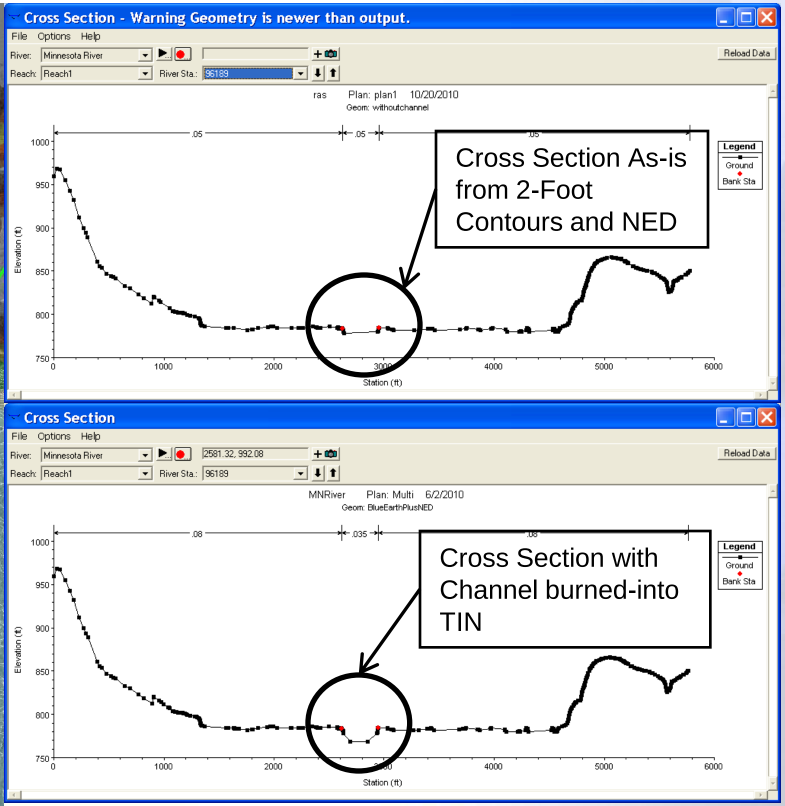


Methods used to rectify Zone A Models

Channel Modification- Arc GIS

Augmenting TIN data…





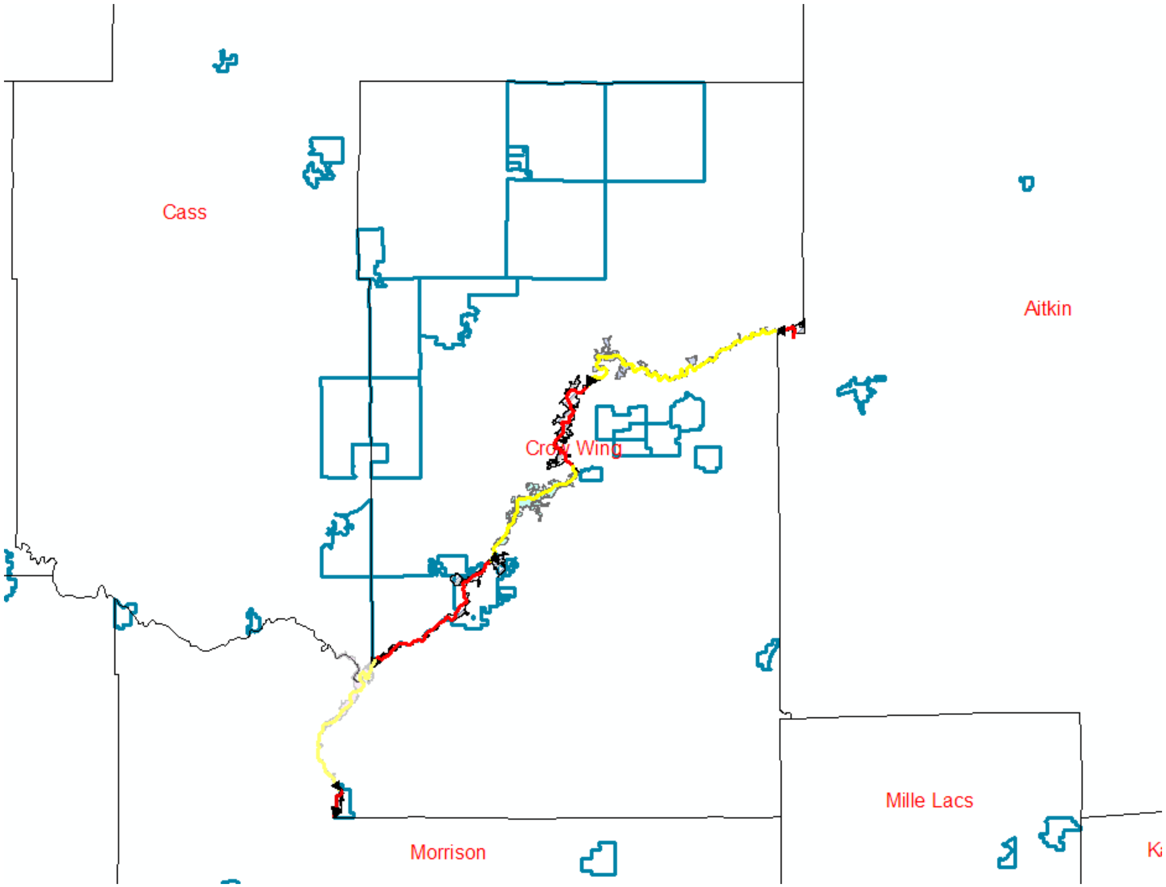
Methods used to rectify Zone A Models

Channel Modification- Arc GIS

Inter-phase with HECRAS by importing or exporting SDF (Spatial Data File)using Geo-RAS, to run the model and complete mapping.

Methods used to rectify Zone A Models

Channel Modification- HECRAS



Case Study
Crow Wing County, MN

Stream Mississippi River

Study Type Approximate

Reach Length (miles) 41

Reach Description Alternating Approximate study reaches from the northeastern county boundary with Aitkin County to the southwestern county boundary with Morrison County.

Methods used to rectify Zone A Models

Channel Modification- HECRAS

Initial study using standard Zone A modeling procedures;

Water Surface Elevations, Model vs. Effective FIS

Mississippi River (Modeled Reach Name)	"Modeled" 1-percent-annual-Chance Elevation (Feet, NGVD 29)		"Effective" 1-percent-annual-Chance Elevation (Feet, NGVD 29)		Difference in WSEL at Upstream Tie-in Locations (Feet)
	Downstream	Upstream	Downstream	Upstream	
Lower Mississippi	1151.5	1166.18	1151.5	1157.6	+8.58
Upper Mississippi	1177.8	1190.23	1177.8	1182.3	+7.93
Upper Mississippi Trib1	1187.9	1208.641	1187.9	1201.3	+7.34

Methods used to rectify Zone A Models

Channel Modification- HECRAS

Thalweg, Effective FIS Profile vs. County DEM

Modeled Reach Name	Community/Cross Section	Thalweg from Published profile (Feet)	Thalweg approximated from DEM (Feet)	Differences in Thalweg (Feet)
Lower Mississippi				
	downstream City of Fort Ripley/G	1132.7 (01P)	1137.29	4.59
	upstream Crow Wing County/0A*	1141(01P)	1146.594	5.594
Upper Mississippi				
	downstream City of Brainerd/W, X*	1152.0 (03P)	1172.247	20.247
	upstream Crow Wing County/V	1160.0 (04P)	1172.855	12.855
Upper Mississippi Trib 1				
	downstream Crow Wing County/AJ	1163.5 (06P)	1174.045	10.545
	upstream Aitkin County/A	1176.5 (01P)	1185.194	8.694

The FIS Profile sheet number is included in brackets ()

* Read from profile, not included in Floodway Data Table (FDT)

Methods used to rectify Zone A Models

Channel Modification- HECRAS

Pilot Channel

- Smooth out irregularities
- Adjust main channel invert elevations to increase the depth of flow

Methods used to rectify Zone A Models

Channel Modification- HECRAS

Pilot Channel Parameters

- Slope- straight line interpolation from the FIS thalweg elevation

Channel Slope Approximation

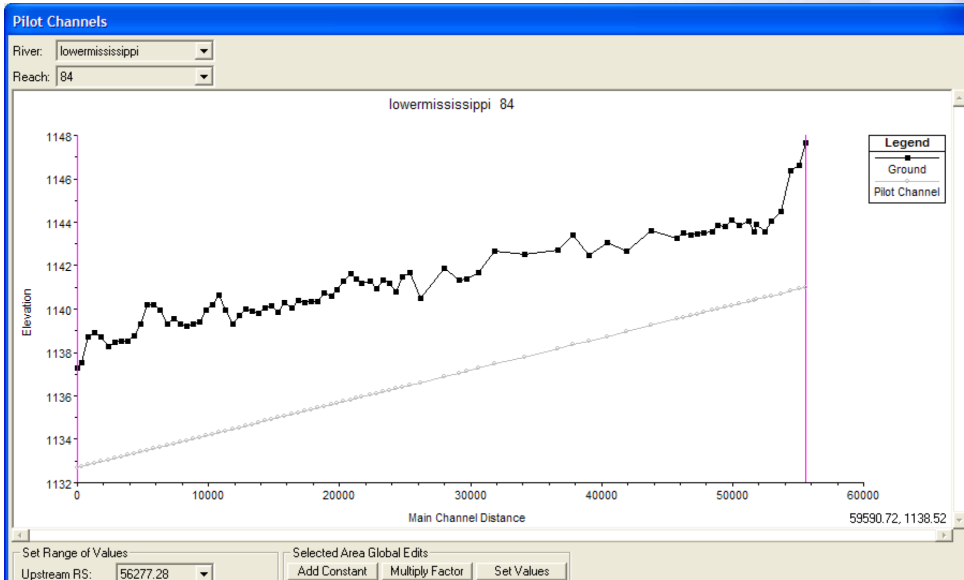
Modeled Reach	Downstream Thalweg Elevation from effective FIS (FT)	Upstream Thalweg Elevation from effective FIS (FT)	Length of Channel (FT)	Slope used for Pilot Channel (FT/FT)
Lower Mississippi	1132.7	1141.0	55,582	0.015%
Upper Mississippi	1152.0	1160.0	42,755	0.019%
Upper Mississippi Trib 1	1163.5	1177.5	94,611	0.015%

Methods used to rectify Zone A Models

Channel Modification- HECRAS

Pilot Channel Parameters

- Invert elevations - Developed by projecting a cut from the effective FIS upper cross section elevation at the slope determined over the entire reach cross section range
- Pilot Channel Width- Estimated from FIRMs and orthophotos
- Manning’s n- A weighted Manning’s n of 0.05 was used for the channel and overbanks



	RS	Invert (ft)	Pilot Invert (ft)	Pilot Width (ft)	Mann n
1	56277.28	1147.632	1141	580	0.05
2	55752.14	1146.594	1140.922	580	0.05
3	55089.24	1146.367	1140.823	580	0.05
4	54376.62	1144.502	1140.716	580	0.05
5	53636.89	1144.057	1140.606	580	0.05
6	53134.43	1143.563	1140.531	580	0.05
7	52537.27	1143.891	1140.441	580	0.05
8	52309.72	1143.56	1140.407	580	0.05
9	51945.7	1144.049	1140.353	580	0.05
10	51206.54	1143.874	1140.243	580	0.05

Methods used to rectify Zone A Models

Channel Modification- HECRAS

Cross Section Template Information

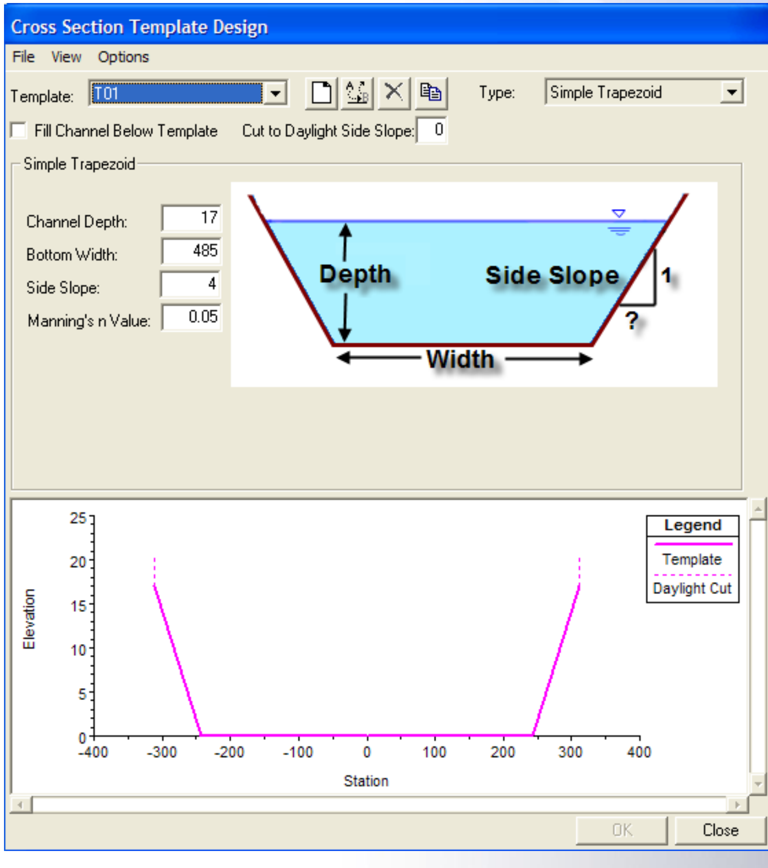
- Permanently defines changes made in the pilot channel geometric data
- Multiple templates may be used for a single reach

Methods used to rectify Zone A Models

Channel Modification- HECRAS

Template Parameters:

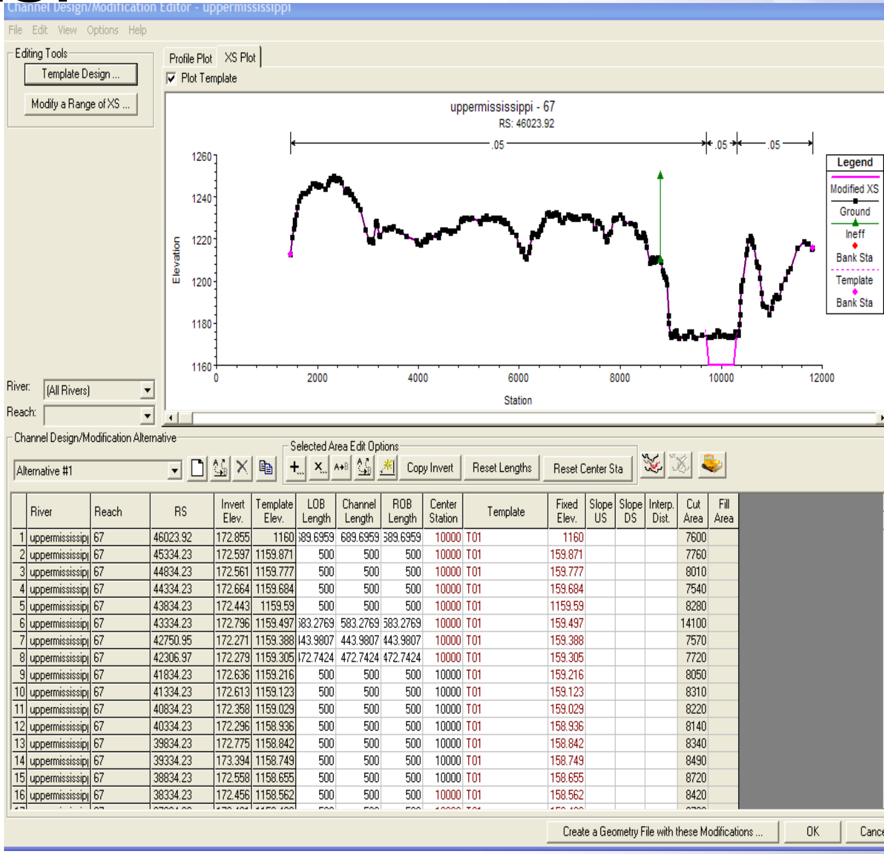
- Bank slope is estimated from County DEM topography and cross sections (4:1)
- Initial depth -average difference in elevation between the effective FIS thalweg and the thalweg estimated from the DEMs
- Channel top width is measured from FIRMs and orthophotos.
- Bank slope is projected downwards at the average depth, assuming a trapezoidal channel. The channel bottom width is determined by subtracting the bank/slope widths from the top width.



Methods used to rectify Zone A Models

Channel Modification- HECRAS Computational Iterations:

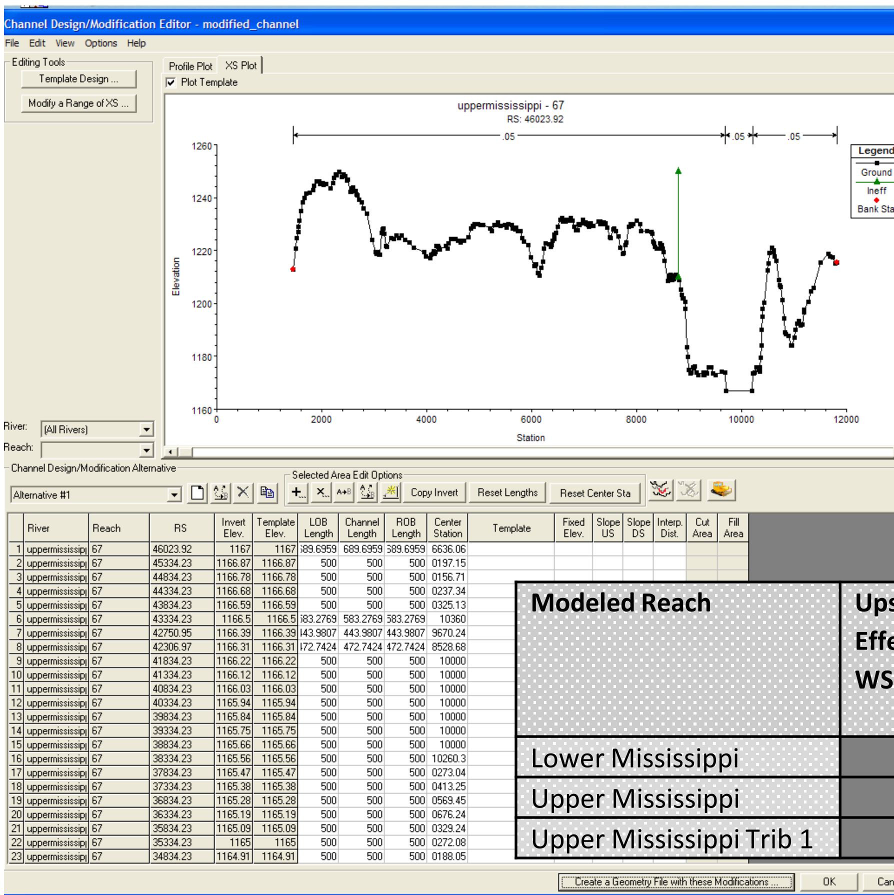
- Centerline station is adjusted to the channel thalweg
- Copy invert elevations from the Pilot Channel to the “Fixed Elev” column in the Channel Design/ Modification Editor
- The bottom of the cross section template is coincident with the invert el.
- Final template design is determined by running several iterations and comparing results to effective FIS WSEL upstream.



Methods used to rectify Zone A Models

Channel Modification- HECRAS

Modified Channel



Template Parameters

Modeled Reach	Cross Section Width (FT)	Bank Slope (FT)	Initial Estimate Average Depth (FT)	Final Average Depth (FT)
Lower Mississippi	580	4:1	6	5
Upper Mississippi	485	4:1	17	16
Upper Mississippi Trib 1	195	4:1	9	8

Elevations at upstream tie-in locations

Modeled Reach	Upstream Effective FIS WSEL (Feet)	Unmodified Channel WSEL (Feet)	Upstream Pilot Channel WSEL (Feet)	Upstream Modified Channel WSEL (Feet)
Lower Mississippi	1157.6	1166.18	1166.18	1160.28
Upper Mississippi	1182.3	1190.23	1185.2	1182.67
Upper Mississippi Trib 1	1201.3	1208.641	1208.67	1203.30

Methods used to rectify Zone A Models

Channel Modification- HECRAS

Attribute cross section data with computed water surface elevations or export SDF (Spatial Data File)using Geo-RAS to complete mapping.

Conclusion:

Pros:

- Easily modified interactively
- Can be calibrated for hydraulic parameters on the fly
- Varying cross section templates can be applied along the stream reach
- revised topography can be stored as digital format and may be used as source data for other applications.

Cons:

- This is still approximate, and actual survey data is required for detailed study.

Note: FEMA now recommends that hydraulic analysis be completed on a watershed basis to reconcile mapping between City, County and State boundaries (FEMA 2009).