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Watershed Modeling Using Arc Hydro Tools. Geo HMS, and HEC-HMS

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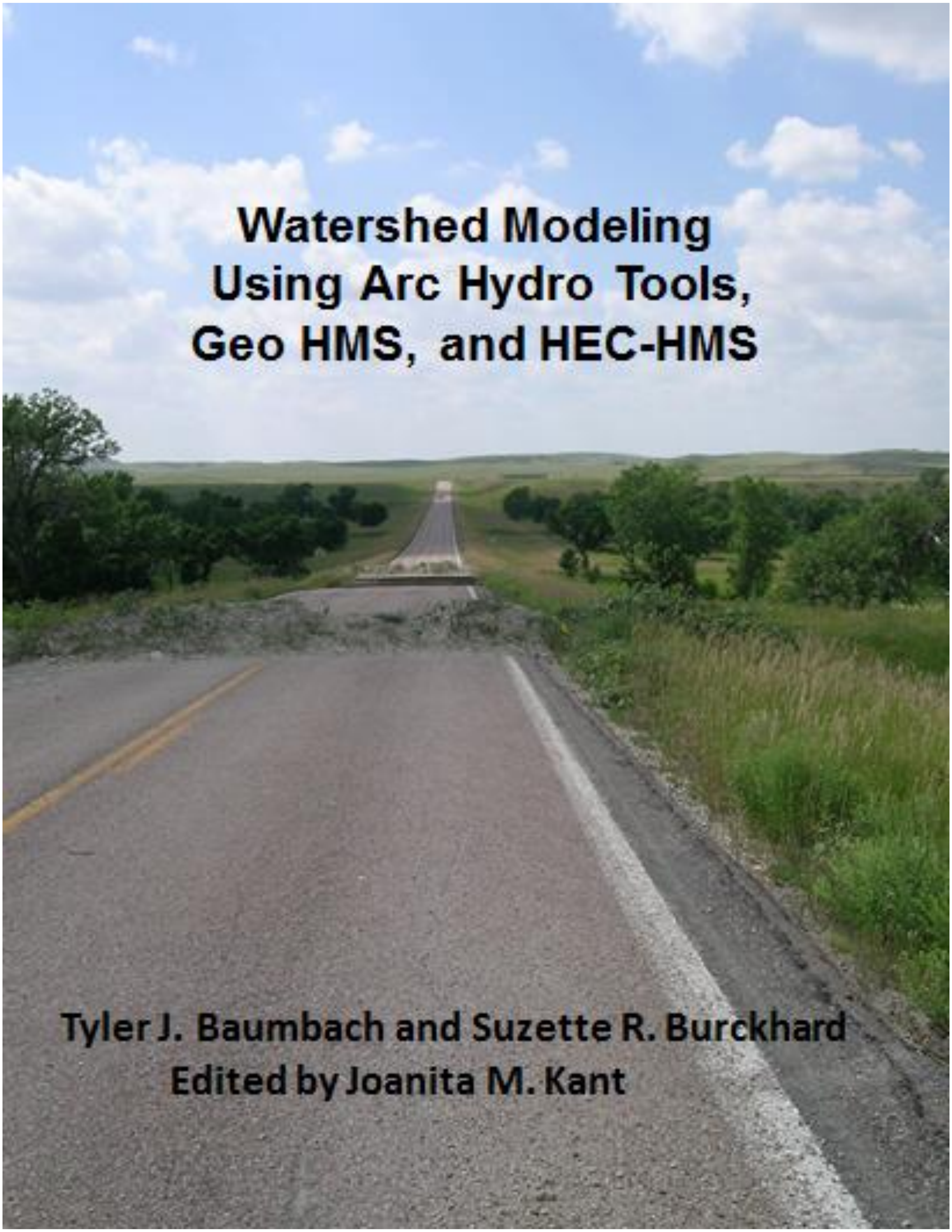

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Cover photo: Culvert and road washout on the White River, BIA Highway 32, southwestern South Dakota, 2013 (photo credit: Joanita M. Kant).

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Brookings, South Dakota

February 2015

A White Paper presented to Oglala Lakota College for use in pre-engineering class exercises.

This paper is meant to be used as a supplemental aid to the tutorials and user's manuals stated in the references. It is assumed that the user has basic knowledge of ArcGIS 10.

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Introduction

The purpose of this paper is to provide a real world example of how to develop and analyze a watershed. The watershed examined was the Upper White River Sub-basin Watershed which was recreated digitally with the aid of computer software and spatial data. Data links for needed files are provided throughout the paper. Computer software utilized was ArcGIS 10 (C ESRI, 2014), and HEC-HMS 4.0 (U. S. Army Corps of Engineers, 2013a) (Hydrologic Engineering Center – Hydrologic Modelling System). Screen shots of the Upper White River Sub-basin Watershed results are provide along with deviation of steps from referenced tutorials and user manuals.

Computer Programs

1. ArcGIS 10
2. Arc Hydro tools (toolbox package)
3. GeoHMS toolbar (toolbox package)
4. HEC-HMS 4.0

Data Requirements and Description

When starting a project, the data specifications should be thoroughly reviewed and stated. General specifications include but are not limited to: data, format, resolution, use, quality, accuracy, and price (e.g. time to survey, database fee, etc.). The user's discretion would be needed to select acceptable data if the dataset is not specified. This would mean, but not be limited to, considering the task's objective and budget, data storage size, resolution, and accuracy; and timeline for the overall project.

Arc Hydro Tools and GeoHMS

The following were the spatial data sources used to develop the Upper White River Sub-basin Watershed model. For this project there was no specified dataset; therefore, readily available government datasets were used. Table 1 provides a list of datasets and descriptions that were used to develop the watershed model in ArcGIS 10. For more information on specific HEC-GeoHMS processes, refer to the HEC- GeoHMS User's Manual (US Army Corps of Engineers, 2013a).

Table 1. Dataset sources and short descriptions

Data Type	**Description**	**Data Source**
Digital Elevation Model (DEM)	Resolution – 1/3 arc-sec Extracted by – 8 digit HUC Format – Arc Grid	USGS TNM 2.0 Viewer
Hydrography (NHD)	Resolution – Boundary Extracted by – 8 digit HUC Format – File GDB 10.1	USGS TNM 2.0 Viewer
Soil Types Data	Classification of soils	SSURGO Downloader
Land Use Land Cover (LULC)	Classification of coverage	MRLC (NLCD 2006 Land Cover – 2011 edition)

Note. Refer to Chapter 4, Table 4.1, for more data types (US Army Corps of Engineers, 2013a)

HEC-HMS

For an HEC-HMS model there are six components categorizing the data in the project: (1) Basin Models, (2) Meteorological Models, (3) Control Specifications, (4) Time-Series Data (5) Paired Data, and (6) Grid Data. The users must create inputs or upload inputs files for components (1) through (3) by using the tools within HEC-HMS or compatible software. For components (4) through (6), the user must select from a variety of data types for each individual component. This paper will focus on components (1) through (3). If more information is needed on components (1) through (3), or if the user would like to explore components (4) through (6), refer to the HEC-GeoHMS User's Manual (US Army Corps of Engineers, 2013a).

1. <u>Basin Models</u>

The user needs to build the watershed model. This can be done using another compatible program then importing the watershed or creating the watershed in HEC-HMS. For the purpose of this paper, the watershed was created in ArcGIS, then imported into HEC-HMS.

2. Meteorological Models

Create and use depth-duration-frequency curve (DDF-curve) data for the National Oceanic and Atmospheric Administration (NOAA) Atlas 14. For the purpose of this paper, I used the annual depth-duration-frequency curves for Pine Ridge, SD.

Data Source. http://hdsc.nws.noaa.gov/hdsc/pfds/ (NOAA, 2015).

3. Control Specifications

The user needs to set the time boundaries on stream monitoring. This can be done with an arbitrary time period or a specific time period representing a past storm or storms. For the purpose of this paper, I used an arbitrary time period of one month.

Watershed Modeling

This watershed modeling process incorporates an Upper White River Sub-basin Watershed model example. The assumption is that the user has working background knowledge of ArcGIS and how to develop working models. With this stated assumption, I provide a working model of the Upper White River Sub-basin Watershed. It is highly suggested that the user preform the tasks of obtaining the appropriate spatial data and creating the working model on his/her own. This paper is intended to be used with stated references.

Terrain Preprocessing

Terrain preprocessing is the delineation of watersheds by using existing DEMs and NHD data. Terrain preprocessing must be completed in sequential order before any HEC-GeoHMS processing functions can be processed. The terrain preprocessing processes can take anywhere from two minutes to several hours, depending on the size of the datasets. Not all terrain preprocessing processes are used for this example, because each watershed delineation is unique. For more information on any of the steps, refer to the HEC-GeoHMS User's Manual (US Army Corps of Engineers, 2013a).

Note. Datum must be set to projected coordinate system, specific for the watershed's region and appropriate units. This would have to be done, if the user chooses to download special data and create the working model on his/her own.

For the step-by-step procedure, refer to Merwade (2012b and c). This section entails screen shots from ArcGIS of the Upper White River Sub-basin Watershed model following Merwade (2012b and c). I explain any deviation from those steps in this section. For more detailed definitions or steps on terrain preprocessing, refer to Chapter 6 of the HEC-GeoHMS User's Manual (US Army Corps of Engineers, 2013a).

1. Load the data file given. Projected coordinate system. NAD_1983_HARN_StatePlane_SouthDakota_South_FIPS_4002_US_Meters

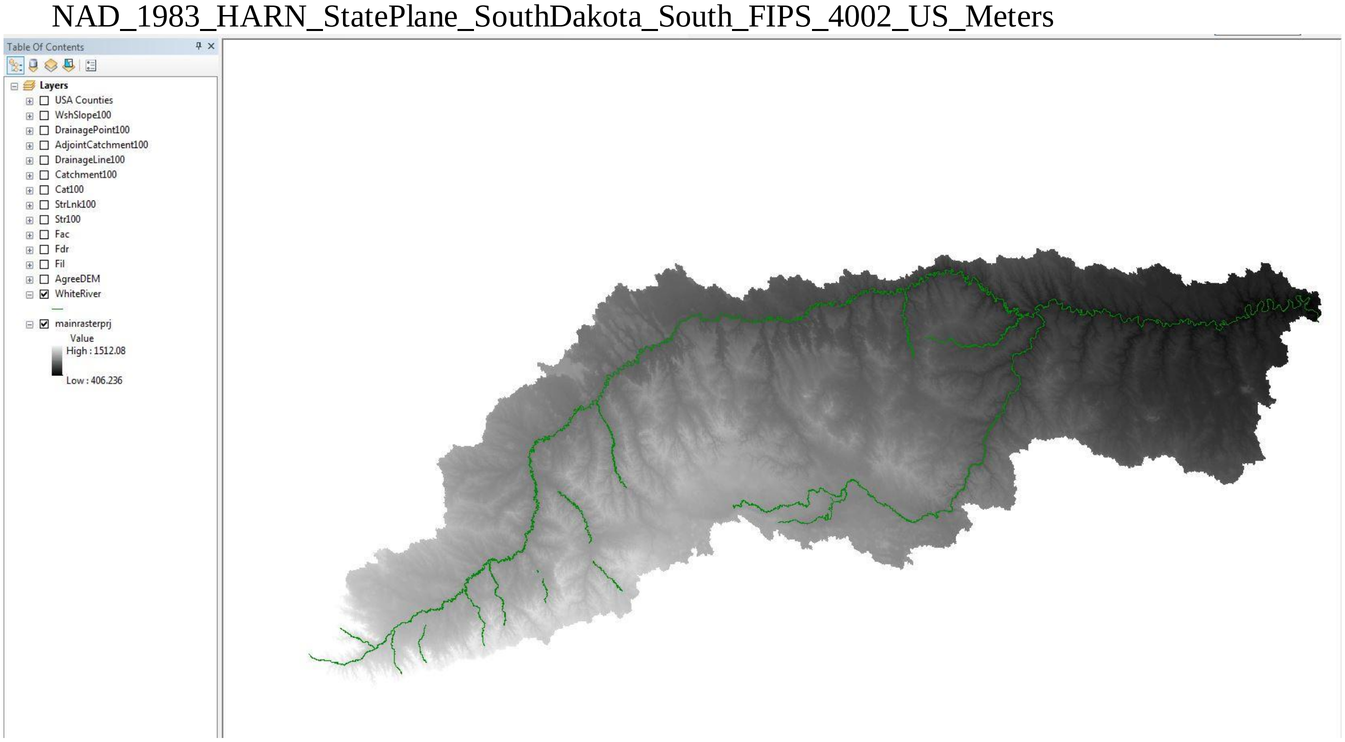

Figure 1. Starting point for terrain preprocessing with projected Mainraster and Whiter River datasets.

2. DEM Reconditioning

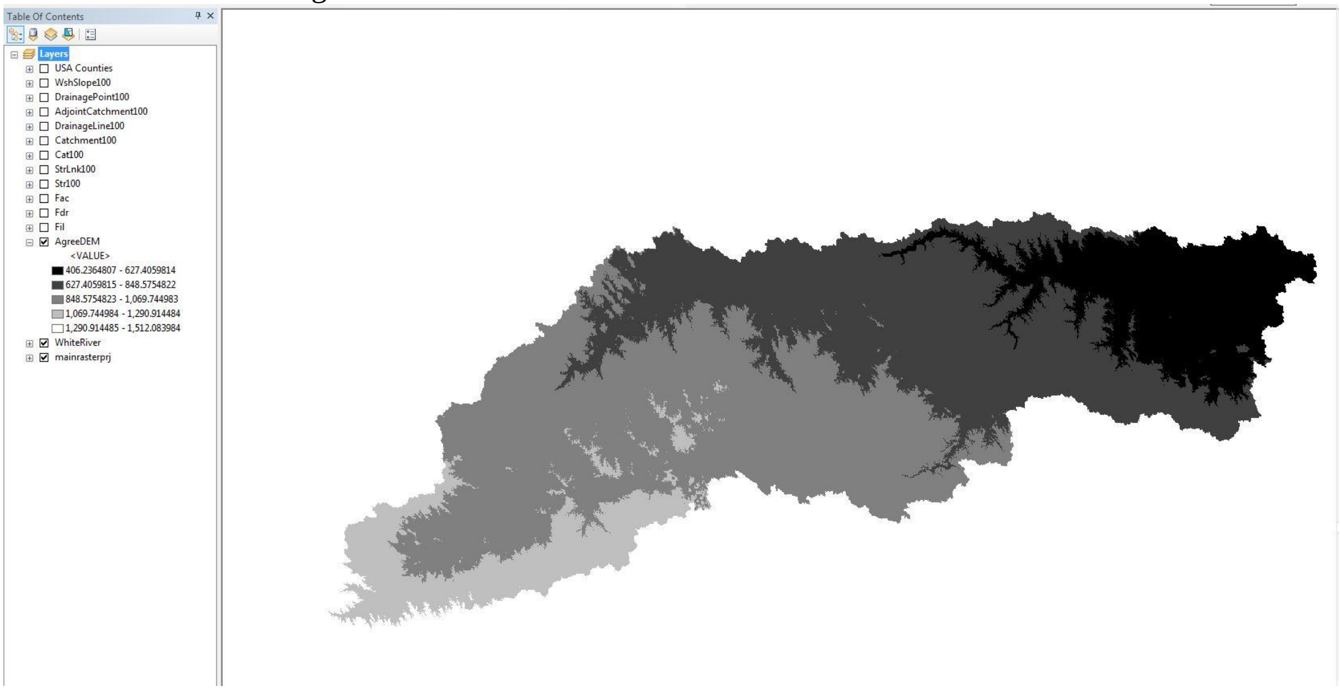

Figure 2. Reconditioned Agree DEM output with stream buffer, smooth drop/rise, and sharp drop/rise set at 5, 10, and 10, respectively.

3. Fill Sinks

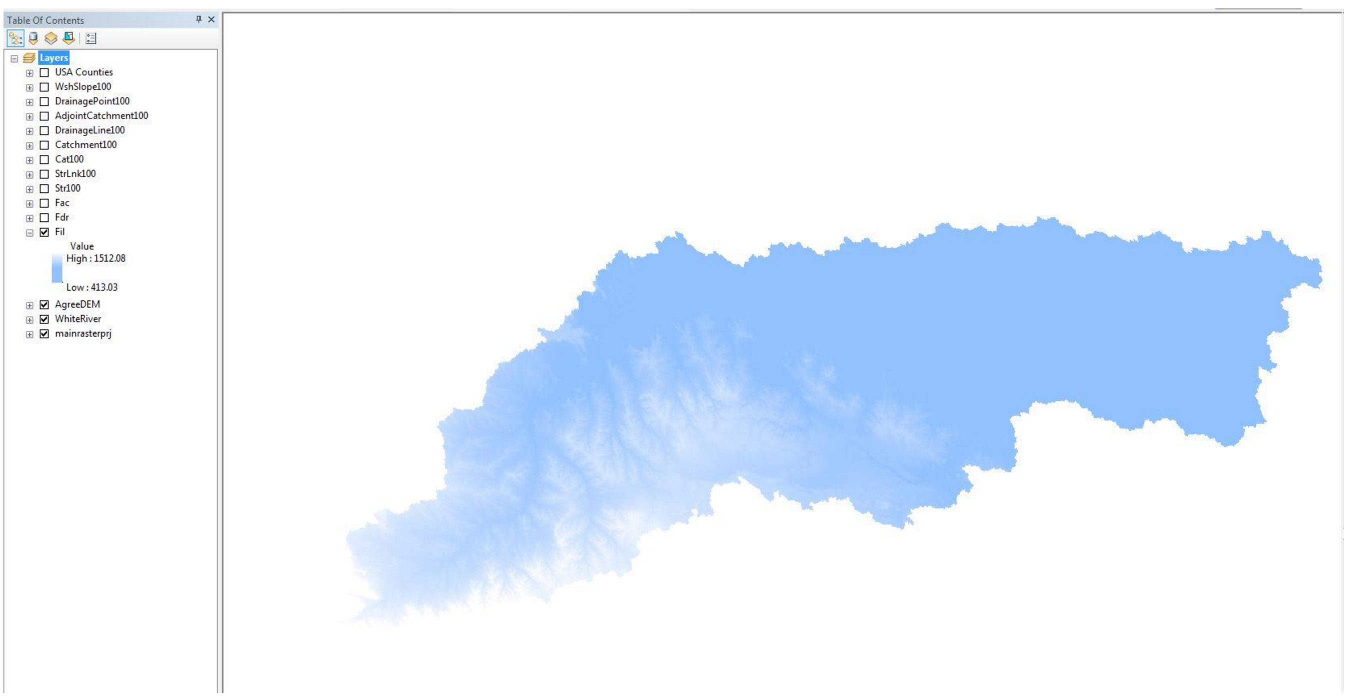

Figure 3. Fill sinks function modifies the elevation of the AgreeDEM smoothing cells which could inhibit water flow; used default settings.

4. Flow Direction

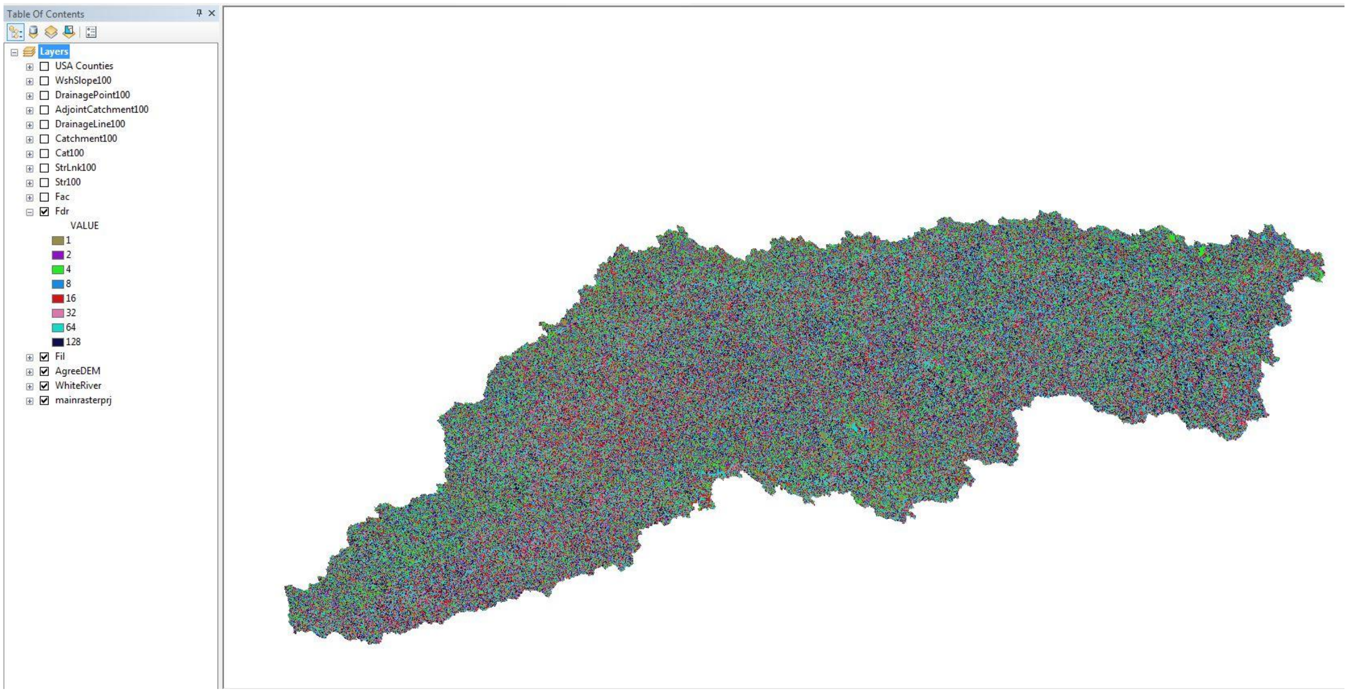

Figure 4. Flow direction computes each grid's flow direction based on an eight-point pour model, represented by a preselected color.

5. Flow Accumulation

Figure 5. Flow accumulation computes how many upstream cells drain to a given cell.

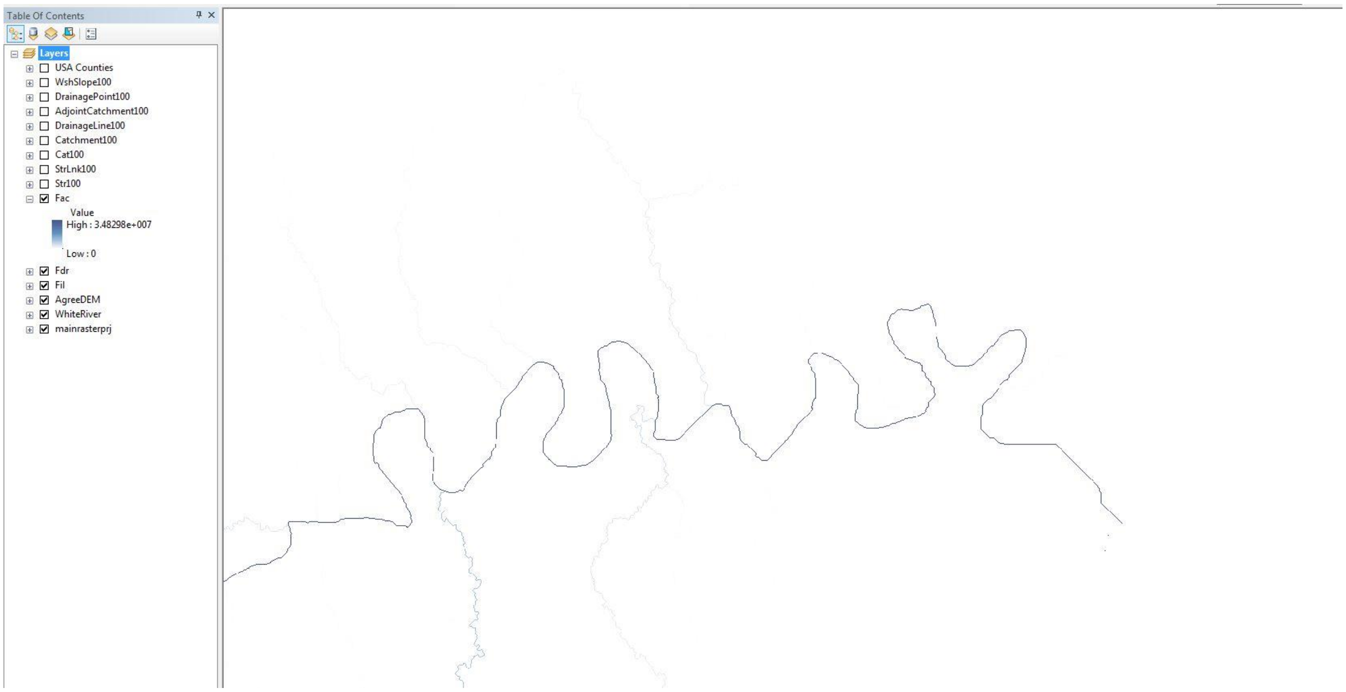

Figure 6. Zoomed in screen shot of the flow accumulation.

6. Stream Definition

Figure 7. Stream definition displays the river's threshold set for an area of 100 km^2.

Figure 8. Zoomed-in screen shot of the stream definition.

Typically the threshold value should be set at 1% of the maximum flow accumulation. Stream definition is used to break a large watershed up into smaller sub-basins or catchments. Hydrologic parameter estimations use the interpolated catchments to calculate basin lag times. One method used to calculate basin lag times is the CN Lag Method; which is based on the hydraulic length of the sub-basin, CN value, and basin slope. The CN Lag Method was developed for sub-basins less than 2,000 acres (approximately 8 km^2). Due to the size of Upper White River Sub-basin Watershed, it was impractical to choose an area of 8 km^2; therefore, the basin lag times will be skewed estimates. For a more precise estimate, select smaller areas. The following are the results from following steps 7 to 14.

7. Stream Segmentation

Figure 9. Stream segmentation breaks the waterway into stream segments which connect junctions to junctions, outlets, or drainage divide.

Figure 10. Zoomed-in screen shot of the stream segmentation.

8. Catchment Grid Delineation

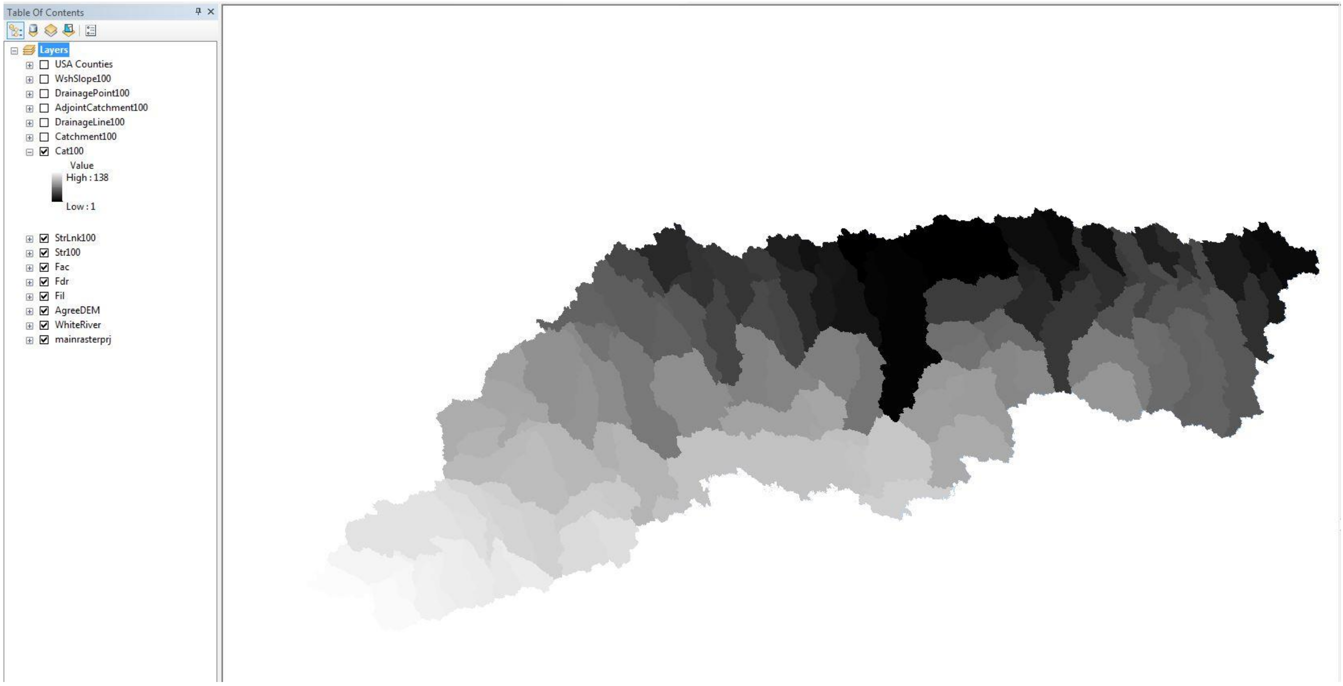

Figure 11. One hundred thirty-eight (138) catchments or sub-basins based on the stream segmentation results.

9. Catchment Polygon Processing

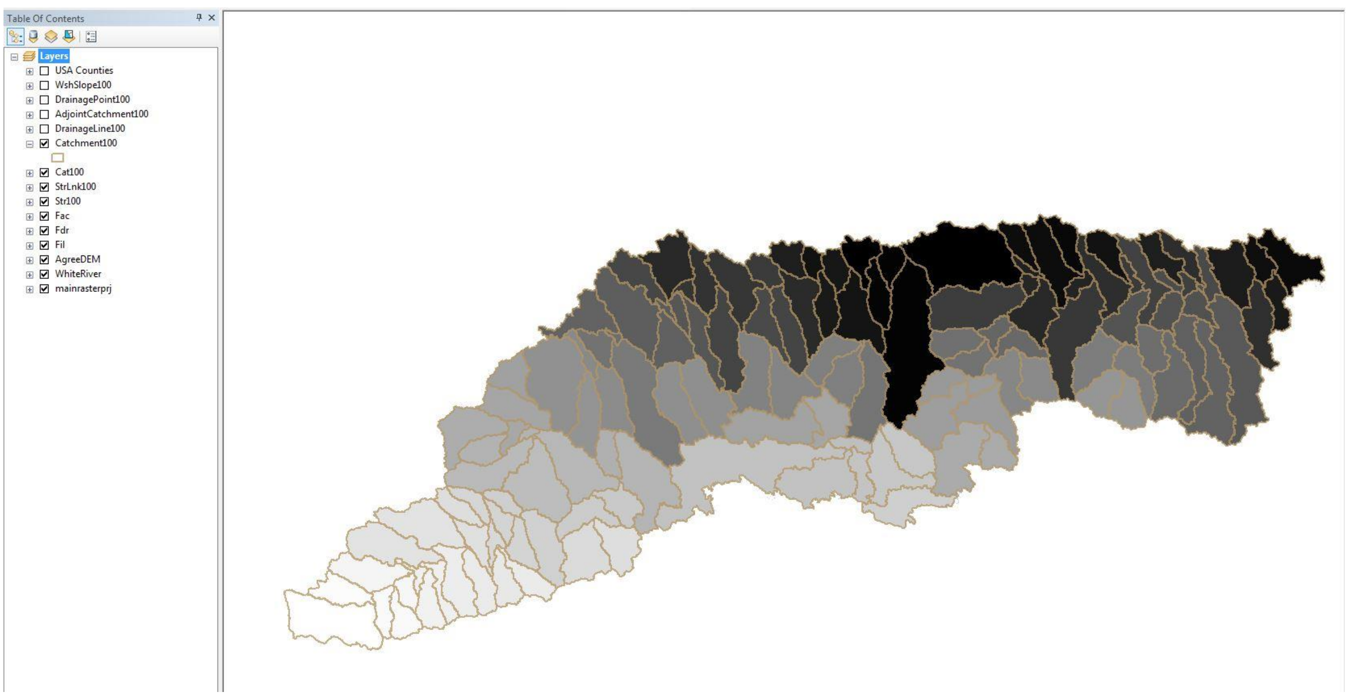

Figure 12. Catchment polygon processing converts the raster data to vector format.

10. Drainage Line Processing

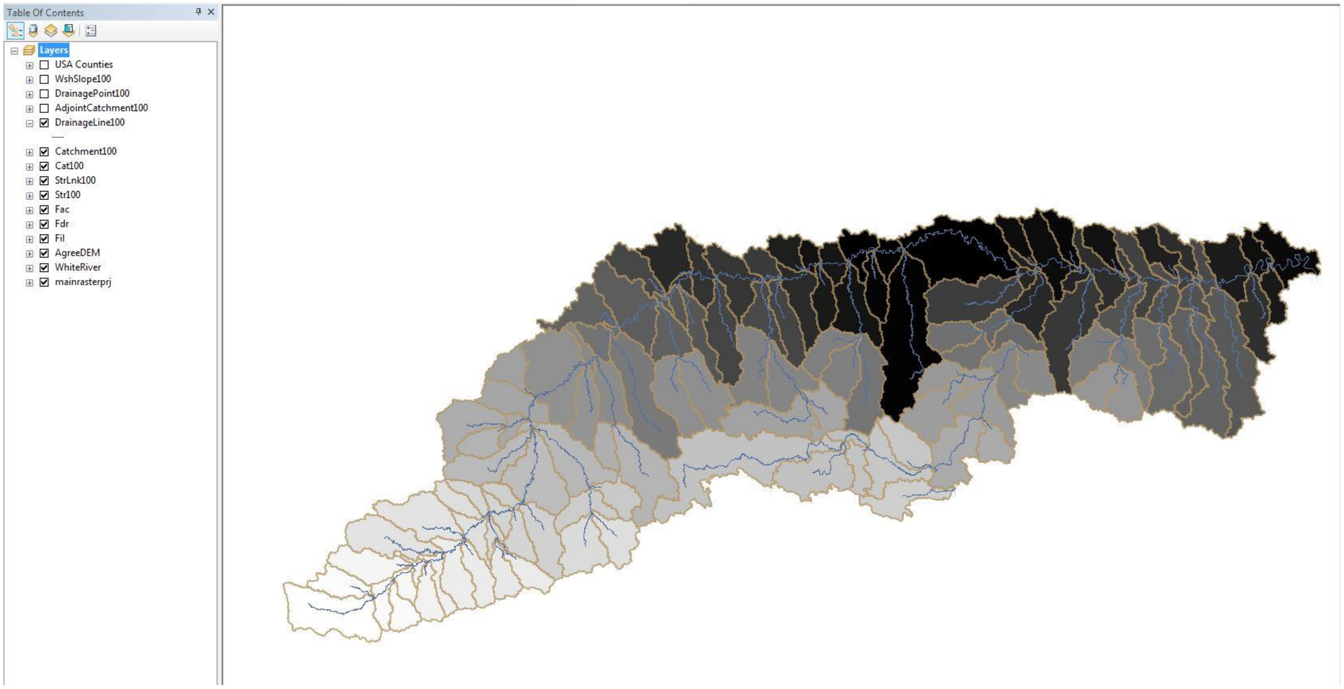

Figure 13. Drainage line processing converts the raster data for stream segments into a vector format.

11. Adjoint Catchment Processing

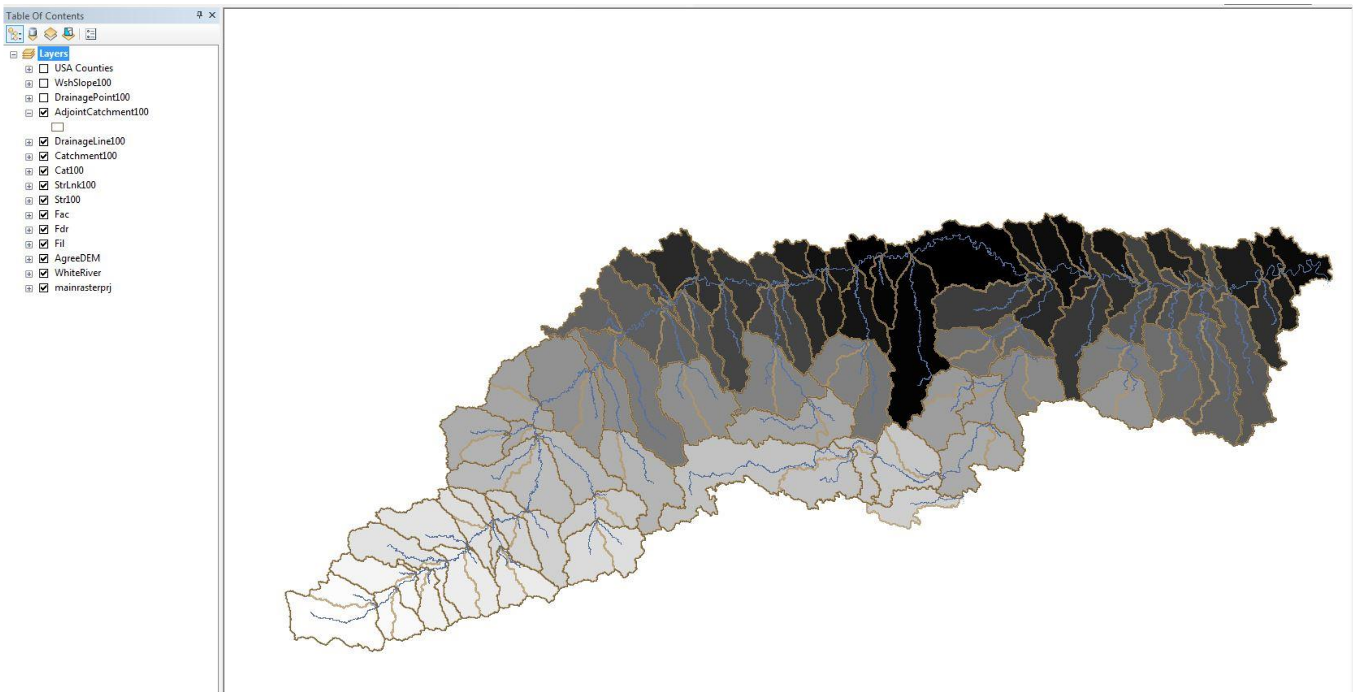

Figure 14. Adjoint catchment processing speeds up the point delineation process.

12. Drainage Point Processing

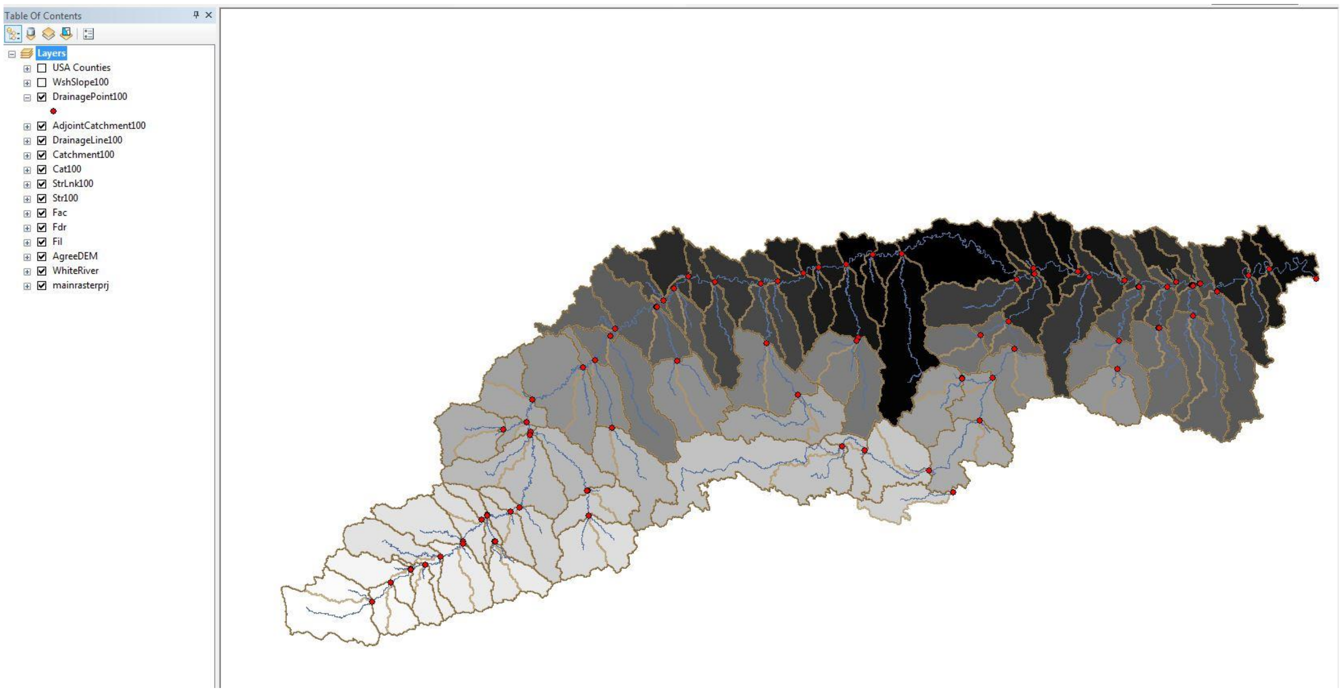

Figure 15. Drainage point processing calculates drainage outlets for each catchment.

13. Slope

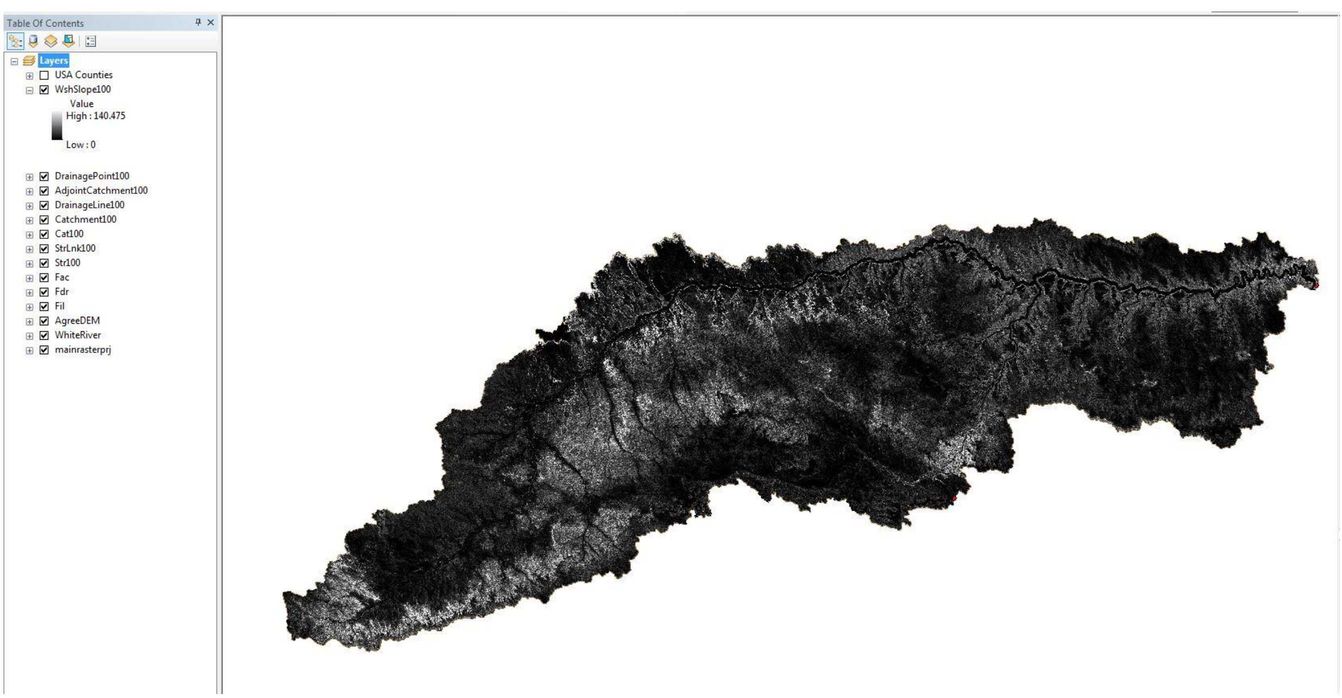

Figure 16. Slope processing interpolates a slope grid which will be used for HEC-GeoHMS processing.

14. Terrain Preprocessing Final

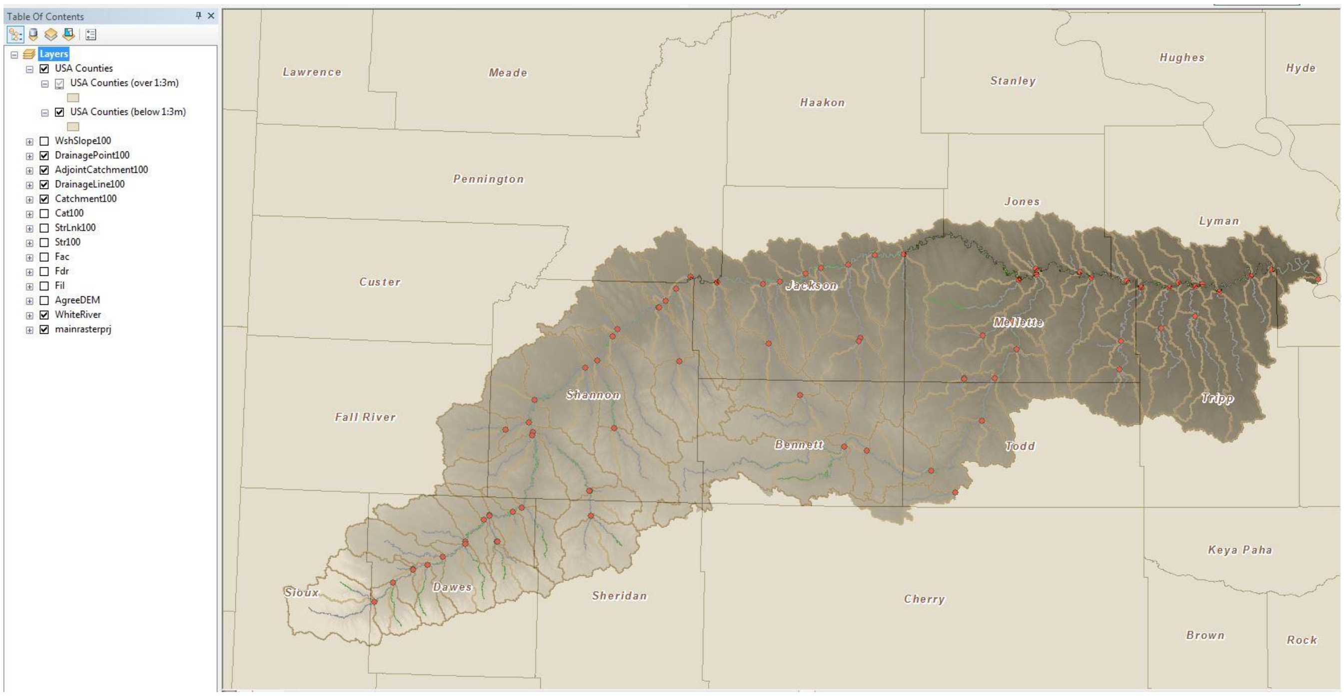

Figure 17. Result of terrain preprocessing overlays with a USA counties layer.

Figure 17 concludes the terrain preprocessing section, which will be used in the HEC-GeoHMS project setup. HEC-GeoHMS allows the data to be uploaded and processed by HEC-HMS. Make a copy of the final output of the terrain processing to be used as the starting point for the HEC-GeoHMS project setup. The next section will cover the steps for the HEC-GeoHMS project setup.

HEC-GeoHMS Project Setup

HEC-GeoHMS is a tool that helps the user to extract all necessary data to create the HEC-HMS project. To start the extraction process, the user must specify an outlet location on the river. HEC-GeoHMS will then use the terrain preprocessing dataset for the drainage area upstream specified outlet to run the flow analysis. The US Army Corps of Engineers (2013a) notes that “HEC-GeoHMS can be used to refine the sub-basin and stream delineations, extract physical characteristics of sub-basins and streams, estimate model parameters, and prepare input files for HEC-HMS.”

For the step-by-step procedure, refer to Merwade (2012b), since this section entails screen shots from ArcGIS of the Upper White River Sub-basin Watershed model. In this section, I explain any deviation from these steps. For more detailed definitions or steps on HEC-GeoHMS processes, refer to Chapter 7 - 11 of the HEC-GeoHMS User's Manual (US Army Corps of Engineers, 2013a).

1) Start New Project (Chapter 7)

- Use default names for "Project Area" and "Project Points"
- Project Name. PineRidgeRes2
- Specify outlet point coordinates. 399307, 56896 (rough estimate of the location of the new 12'x12' side-by-side box culvert)
- Point Name. Culvert
- Generate Project. Use the terrain preprocessing datasets

Note. The program may select an arbitrary number for the sub-basin, project point, and river (will be the same for all three). The reason for the numbers is because additional projects can be created using the same terrain preprocessed datasets.

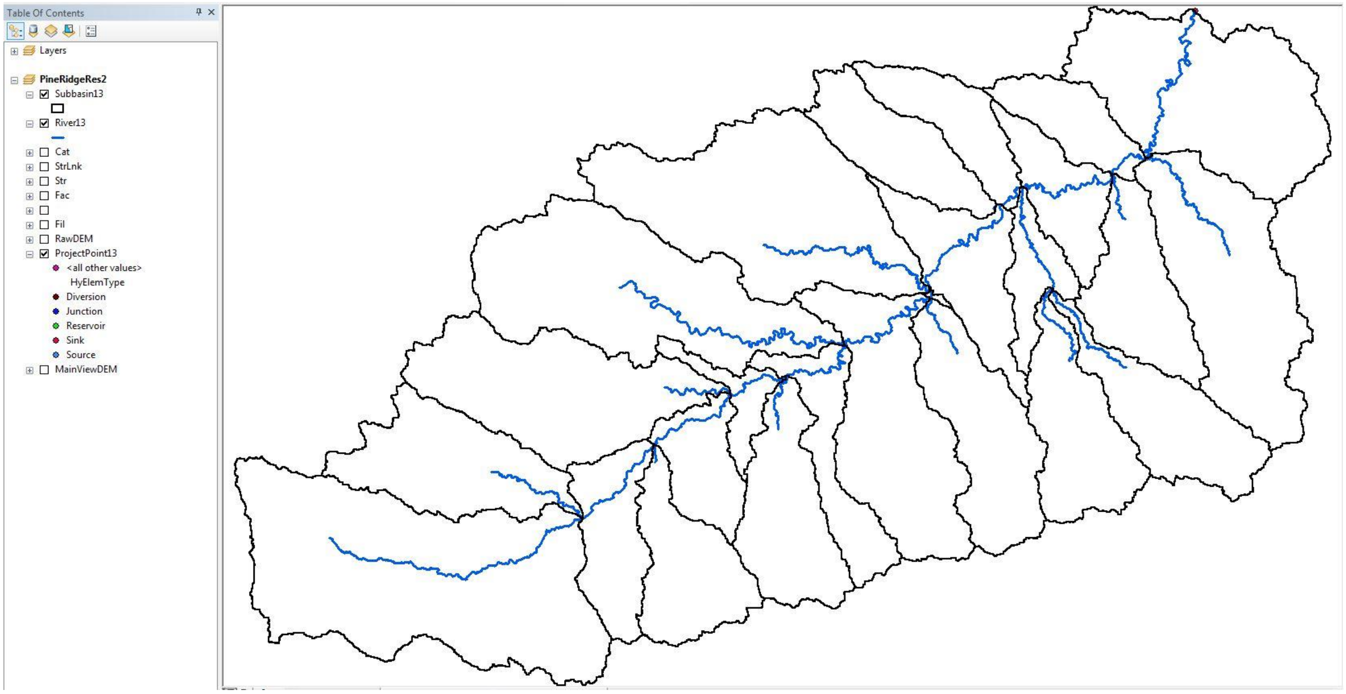

Figure 18. PineRidgeRes2 project with River13 and Subbasin13 datasets project set up.

2) Basin Processing (Chapter 8)

In basin processing the user has the option of modifying sub-basin delineations. This could be done by merging or dividing existing sub-basins based on method selected by the user. The result of merging or dividing existing sub-basins is the creation of new stream segments. New stream segments have to be added to existing stream segments by merging. In “PineRidgeRes2” basin processing was skipped due to the scope of the project.

Note. By choosing to modify the “PineRidgeRes2” project it will alter the outputs and numbers, therefore, future numbering systems will not match up.

3) Stream and Sub-basin Characteristics (Chapter 9)

Stream and sub-basin characteristics are used for estimating hydrologic parameters and are stored in attribute tables which can be edited by the user. Table 9-1 in the user manual summarized the list of extracted physical characteristics. It would be the user's responsibility to verify stream and sub-basin characteristics with recorded data.

Note. River length, river slope, and basin slope must be calculated before the longest flow path process.

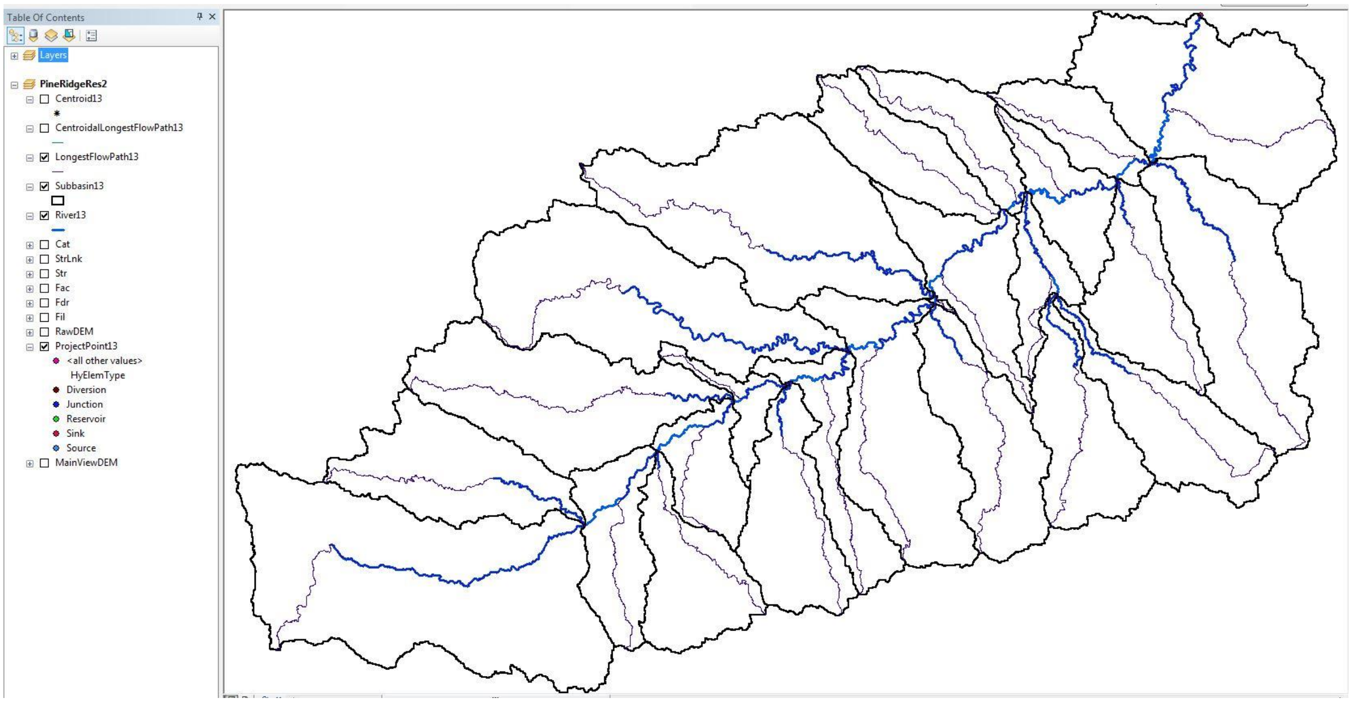

Figure 19. Longest flow path for each sub-basin represented by the light purple lines.

Note. Basin Centroid has four different methods which calculate each sub-basin's centroid location.

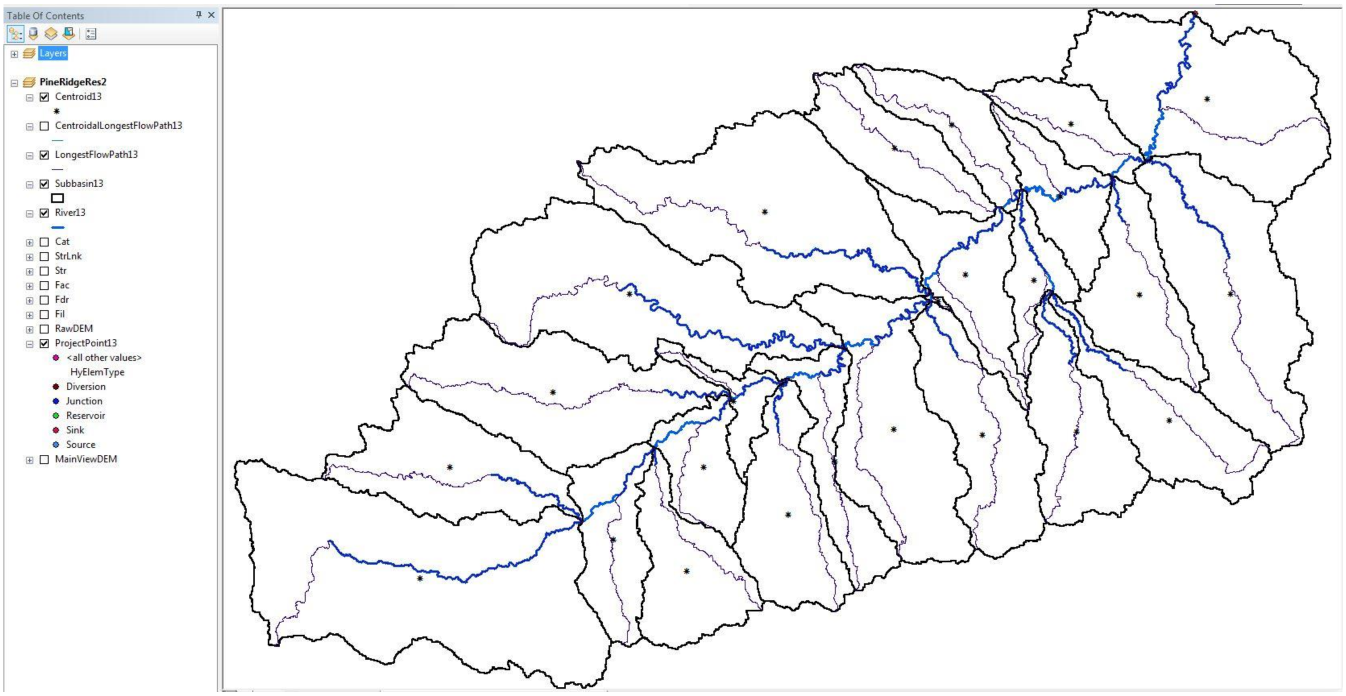

Figure 20. Center of gravity method (Method 1) basin centroid represented by the * symbol.

Note. Centroid elevation must be calculated before the centroidal flow path.

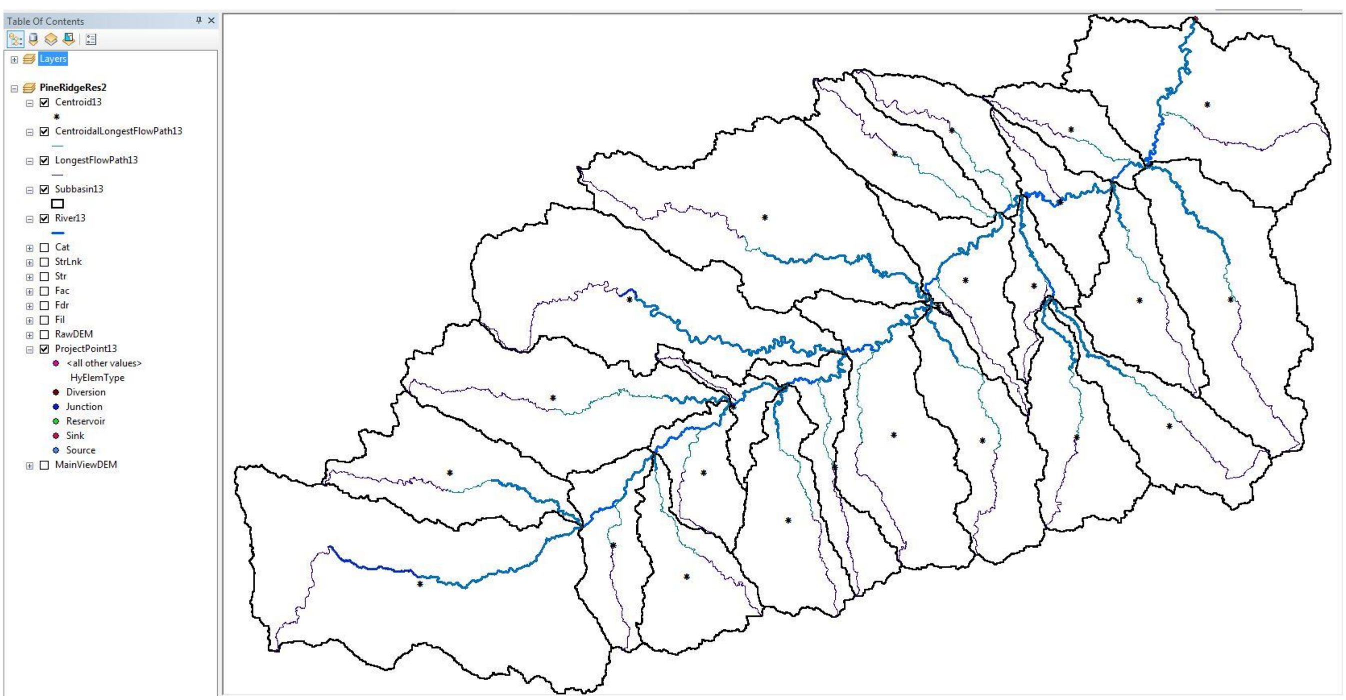

Figure 21. Centroidal flow path for each sub-basin represented by the light blue line.

4) Hydrologic Parameter Estimation (Chapter 10)

HMS inputs and parameters are assigned to the watershed model through the hydrologic parameter menu in HEC-GeoHMS. Chapter 10 in the HEC-GeoHMS User's Manual (U.S. Army Corps of Engineers, 2013a) and Merwade (2012c) have more detail about each parameter. Not all of the steps were followed to create the Upper White River Sub-basin Watershed model.

HMS processes were specified in HMS and not in the hydrologic parameter estimation chapter. River auto name and basin auto name assign names respectively for identification of river and basins in HMS. These two name steps are not shown with figures. The grid cell processing only needs to be performed if the user wants gridded precipitation data. For the Upper White River Sub-basin Watershed model, I created a grid cell to show the user what it should look like, but it was not used for future modeling processes.

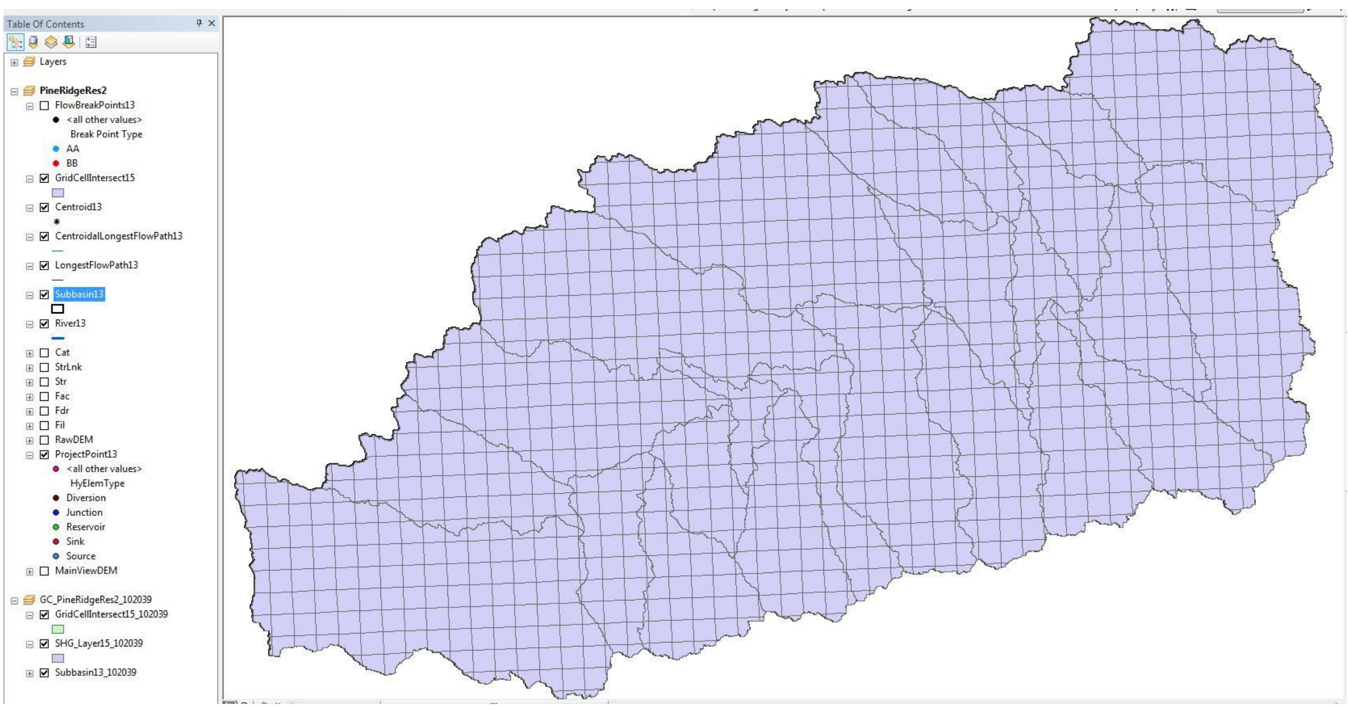

Figure 22. Upper White River Sub-basin Watershed grid cell processing output.

Note. Sub-basin parameters were estimated and added to sub-basins in HMS. Muskingum-Cunge and Kinematic Wave Parameters were not added to this watershed model.

Time of concentration estimates are processed using the TR-55 methodology; which breaks watershed flows into sheet, shallow concentration, and channel flows. TR55 flow path segments are created for each kind of break. The labels are as follows.

- AA – represent breaks between sheet flow and shallow concentration flow
- BB – represent breaks between shallow concentration flow and channel flow

Note. TR-55 provides accurate estimates of time of concentration up to 4,000 acres (McCuen, 2005, pp. 159).

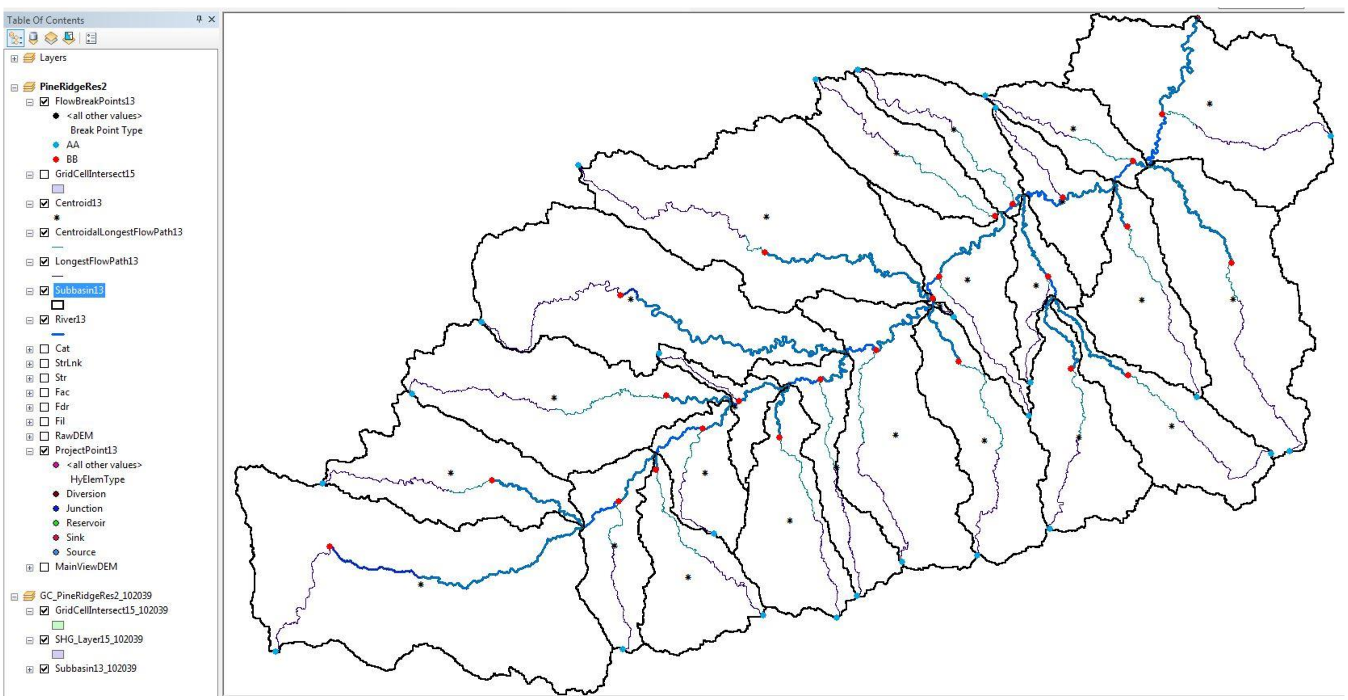

Figure 23. TR 55 mythology layer with blue dots = AA and red dots = BB breaks.

Time of concentration calculations need additional information on the two-year 24-hr rainfall amount. Rainfall amounts are manually entered into the Excel output file generated by HEC-GeoHMS. Figure 24 shows a screen shot of the time of concentration with the entered two-year 24-hr rainfall amount data.

	1	2	3	4	5	6	7	8	9	10	11	12
1	**Worksheet for computation of time of travel according to TR-55 methodology**											
2	Blue - GIS defined, Green - user specified, White and yellow - calculated, Red - final result											
3	**Watershed Name**	**W260**	**W270**	**W280**	**W290**	**W300**	**W310**	**W320**	**W330**	**W340**	**W350**	**W36**
4	**Watershed ID**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	
5	**Sheet Flow Characteristics**											
6	Manning's Roughness Coefficient	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	
7	Flow Length (ft)	100	100	100	100	100	100	99.9999	99.9999	100	99.9999	99.9
8	Two-Year 24-hour Rainfall (in)	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	
9	Land Slope (ft/ft)	0.0521	0.0385	0.1671	0.0464	0.0231	0.0198	0.2068	0.0196	0.0888	0.0366	
10	**Sheet Flow Tt (hr)**	0.22	0.25	0.14	0.23	0.30	0.32	0.13	0.32	0.18	0.25	
11	**Shallow Concentrated Flow Characteristics**											
12	Surface Description (1 - unpaved, 2 - paved)	1	1	1	1	1	1	1	1	1	1	
13	Flow Length (ft)	76151	66392	85077	42885	71733	92405.0585	43805.7811	90798.3983	61001.2122	102014.7308	84666.
14	Watercourse Slope (ft/ft)	0.0078	0.0067	0.0085	0.0083	0.0133	0.0056	0.0136	0.0056	0.0164	0.0054	0.0
15	Average Velocity - computed (ft/s)	1.42	1.32	1.49	1.47	1.86	1.21	1.88	1.21	2.07	1.19	
16	**Shallow Concentrated Flow Tt (hr)**	14.84	13.96	15.89	8.10	10.71	21.26	6.47	20.89	8.20	23.90	1
17	**Channel Flow Characterisitics**											
18	Cross-sectional Flow Area (ft2)	20	20	20	20	20	20	20	20	20	20	
19	Wetted Perimeter (ft)	20	20	20	20	20	20	20	20	20	20	
20	Hydraulic Radius - computed (ft)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
21	Channel Slope (ft/ft)	0.0013	0.0008	0.004	0.0007	0.0033	0.0022	0.0031	0.0059	0.0013	0.0017	0.0
22	Manning's Roughness Coefficient	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	
23	Average Velocity - computed (ft/s)	1.79	1.40	3.14	1.31	2.85	2.33	2.77	3.81	1.79	2.05	
24	Flow Length (ft)	58885	7922	60167	29588	19452	8420.3551	38125.6886	3161.63	45818.7629	91176.1179	132294.
25	**Channel Flow Tt (hr)**	9.13	1.57	5.32	6.25	1.89	1.00	3.83	0.23	7.11	12.37	1

Figure 23. Excel output document from HEC-GeoHMS (two-year 24-hr rainfall = 1.89 inches) (NOAA, Atlas 14 Point Precipitation Frequency Estimates, SD, website.)

The last hydrologic parameter calculated must be figured using a combination of ArcGIS and hand calculations. The following procedure is one way to manually calculate the curve number (CN) value for each sub-basin. CN is a runoff constant for a given soil type and is defined in the NRCS Curve Number Rainfall-Runoff method.

Note. Soil Viewer aids in compiling necessary soil information to calculate CN values in ArcGIS. This paper does not cover Soil Viewer and it would be the responsibility of the user to research the procedure.

1. Download the following datasets or use given mxd file.

Table 2. Datasets used to develop the CN numbers

Data Type	**Description**	**Data Source**
Soil Types Data	Classification of soils	SSURGO Downloader
Land Use Land Cover (LULC)	Classification of coverage	MRLC (NLCD 2006 Land Cover – 2011 edition)

Working Model. Tyler_Baumbach/Thesis/White River Watershed/UpperWhiteSubbasin/UpperWhite_CN.mxd (Baumbach, 2015)

2. Figures 24 and 25 are the Land Use/Land Cover (LULC) and soil layers respectively.

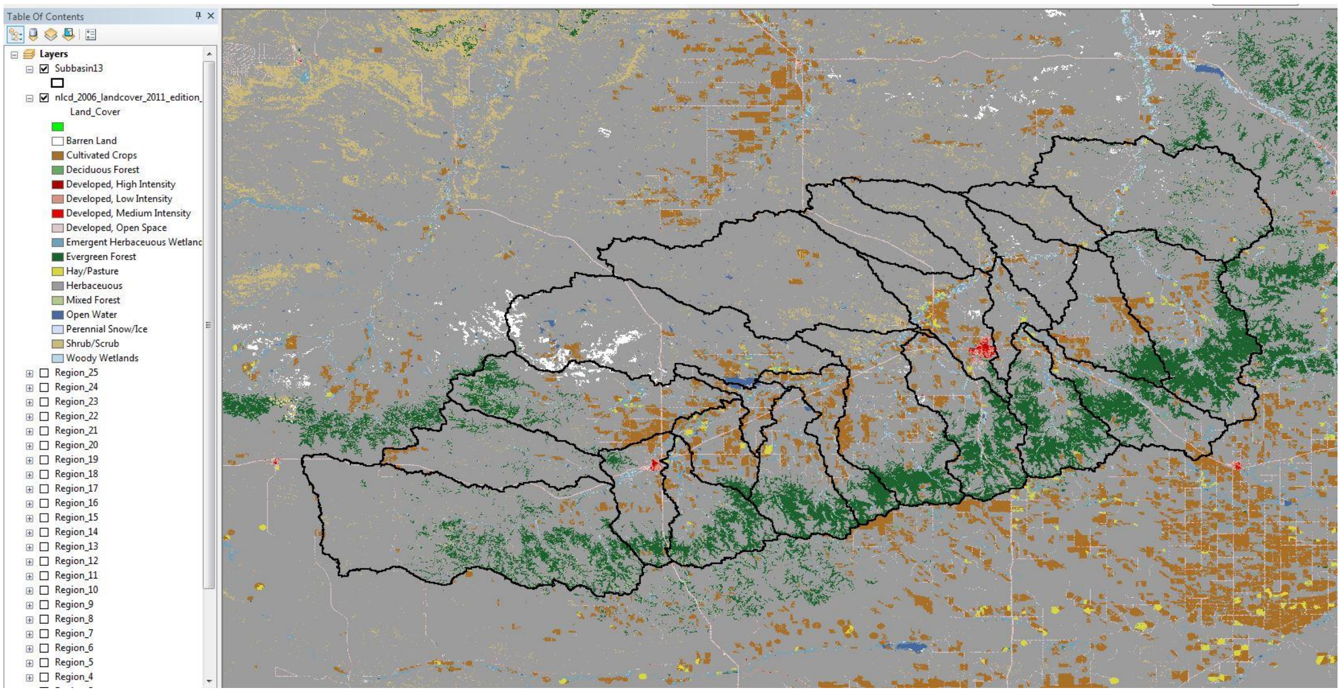

Figure 24. LULC layer

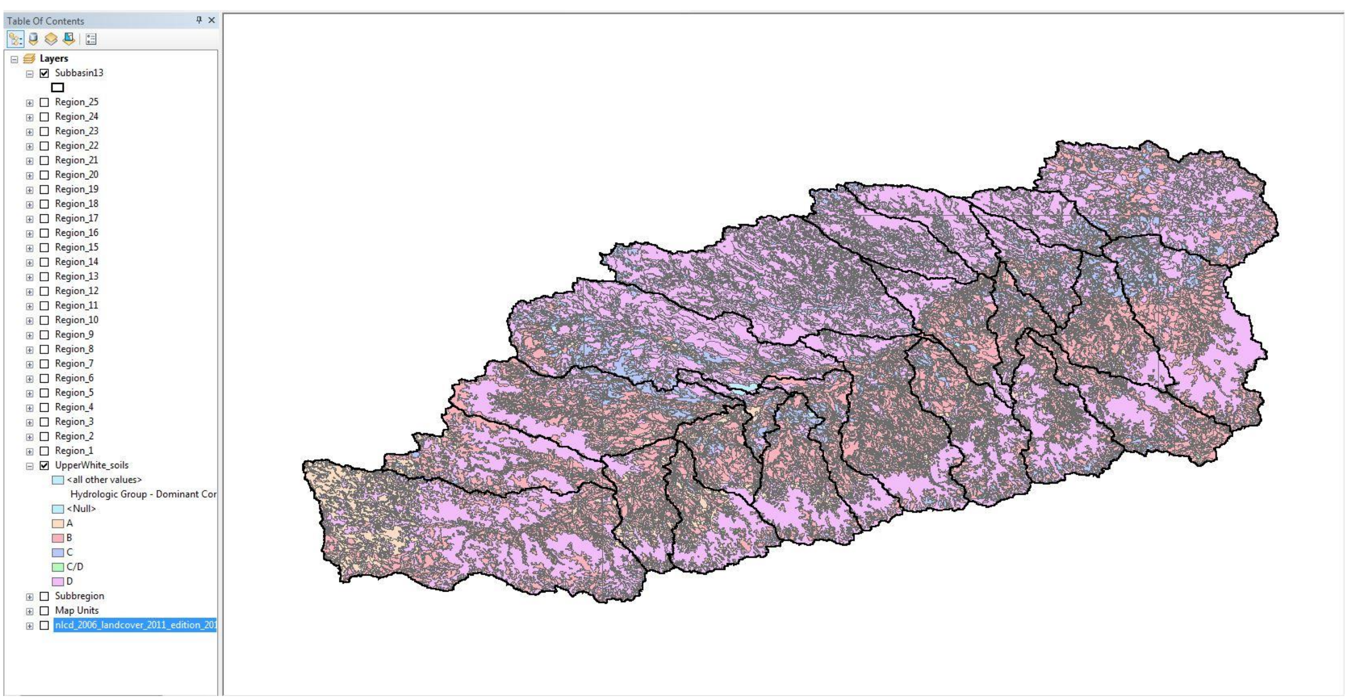

Figure 25. Hydrologic soil group layer

3. User will have to make as many copies of the hydrologic soil layer as sub-basins. For the Upper White River Sub-basin Watershed model there are 25 sub-basins. Next the user must cut out each sub-basin from the designated hydrologic soil layer copy. Figure 26 shows a screen shot of Region 22.

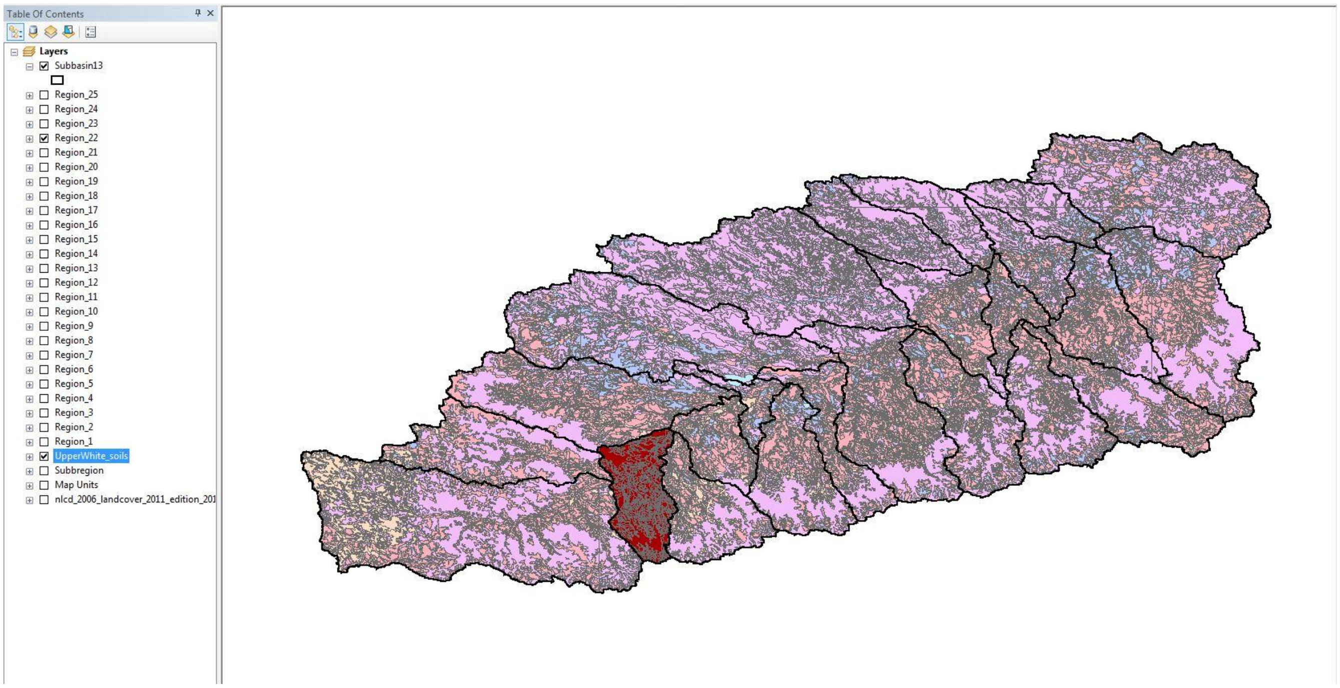

Figure 26. Region 22 hydrologic soil layer shown in red.

4. Create reports for each sub-basin region of the attribute table and copy the reports to Excel. A weighted per cent of the area per hydrologic soil group must be calculated.

	FID	hydgrpdcd	Shape_Area	runoff
2	624	A	0.000002	Very low
3	625	A	0.000001	Very low
4	6	B	0.000305	
5	8	B	0.000012	
6	11	B	0	
7	12	B	0.00002	
8	15	B	0.000006	
9	17	B	0.000004	
10	18	B	0.000025	
11	20	B	0.000012	
12	21	B	0.000024	
13	22	B	0.000023	
14	23	B	0.000012	
15	24	B	0.000037	
16	25	B	0.000007	
17	26	B	0.000007	
18	28	B	0.000006	
19	29	B	0.000013	
20	30	B	0.000026	
21	31	B	0.000015	
22	33	B	0.000026	
23	34	B	0.000016	

	Hydrologic Soil Group				
	A	B	C	D	Total
Count	2	292	78	423	795
Area (m^2)	0.000003	0.007155	0.002479	0.018515	0.028152
Weight (%)	0.010656	25.4156	8.805769	65.76797	100

Summary | Region_1 | Region_2 | Region_3 | Region_4 | Region_5 | Region_6 | Region_7 | Region_8 | Region_9 | Region_10 | Region_11 | Region_12 | Regi

Figure 27. Region on report presented in Excel with weighted per cent of hydrologic soil groups.

$$weighted\ percent = \frac{\sum hydrologic\ soil\ group\ area}{subbasin\ area} * 100\%$$

5. Calculate the weighted CN for each region.

Region	Weighted Percent				Total Area	Land Use	Hydrologic Condition	Curve Number				Weighted Curve Numbers	
	A	B	C	D				A	B	C	D		
1	0.011	25.416	8.806	65.768	0.0282	Herbaceous	Fair	62	71	81	89	84	W260
2	0.070	6.921	10.131	82.878	0.0086	Herbaceous	Fair	62	71	81	89	87	W270
3	0.000	41.715	11.062	47.224	0.0256	Herbaceous	Fair	62	71	81	89	81	W280
4	0.995	27.105	18.483	53.417	0.0074	Herbaceous	Fair	62	71	81	89	82	W290
5	2.263	51.532	10.170	36.035	0.0136	Herbaceous	Fair	62	71	81	89	78	W300
6	0.000	1.813	2.954	95.233	0.0088	Herbaceous	Fair	62	71	81	89	88	W310
7	5.024	62.125	10.234	22.618	0.0054	Herbaceous	Fair	62	71	81	89	76	W320
8	0.156	0.220	10.229	89.395	0.0109	Herbaceous	Fair	62	71	81	89	88	W330
9	4.032	41.917	6.502	47.548	0.0132	Herbaceous	Fair	62	71	81	89	80	W340
10	0.145	0.000	8.764	91.090	0.0358	Herbaceous	Fair	62	71	81	89	88	W350
11	1.380	9.776	20.804	68.040	0.0306	Herbaceous	Fair	62	71	81	89	85	W360
12	0.000	100.000	0.000	0.000	0.0004	Herbaceous	Fair	62	71	81	89	71	W370
13	1.470	16.688	1.341	80.501	0.0409	Herbaceous	Fair	62	71	81	89	85	W380
14	1.074	81.013	3.630	14.283	0.0105	Herbaceous	Fair	62	71	81	89	74	W390
15	1.274	10.943	1.104	86.679	0.0752	Herbaceous	Fair	62	71	81	89	87	W400
16	0.759	27.357	2.550	69.334	0.0525	Herbaceous	Fair	62	71	81	89	84	W410
17	0.610	26.073	3.017	70.301	0.0481	Herbaceous	Fair	62	71	81	89	84	W420
18	11.839	21.236	12.347	54.579	0.0146	Herbaceous	Fair	62	71	81	89	81	W430
19	3.351	19.615	4.308	72.727	0.0455	Herbaceous	Fair	62	71	81	89	84	W440
20	3.308	28.620	13.019	55.053	0.0531	Herbaceous	Fair	62	71	81	89	82	W450
21	6.431	14.809	1.963	76.797	0.0419	Herbaceous	Fair	62	71	81	89	84	W460
22	4.058	7.439	0.074	88.428	0.0940	Herbaceous	Fair	62	71	81	89	87	W470
23	8.253	13.552	0.626	77.569	0.0419	Herbaceous	Fair	62	71	81	89	84	W480
24	24.866	28.651	3.147	43.335	0.0434	Herbaceous	Fair	62	71	81	89	77	W490
25	13.579	22.014	1.069	63.338	0.1026	Herbaceous	Fair	62	71	81	89	81	W500

Figure 28. Summary table of regions' weighted CN values.

Note. Land use, keep constant for the whole watershed and assumed to be fair conditions. CN values for Herbaceous are from Table 3.18 (McCuen pp. 163, 2005). CN for hydrologic soil group A for Herbaceous was linearly interpolated from the Table 3.18(McCuen, 2005, Equation 3.53, pp. 168).

$$Weighted\ CN = \sum_{i=1}^{n} w_i CN_i \qquad\qquad Equation\ (3.53) from\ McCuen$$

Did not use the CN Lag Method tool to calculate basin lag time, because the sub-basins were greater then 2,000 acres. For that reason, the Upper White River Sub-basin Watershed model uses the TR-55 Method basin lag times. The user could choose to average the CN Lag Method and TR-55 Method for the basin lag time. Both the CN values and basin lag times are important parameters for the HMS model.

5) Hydrologic Modeling System (Chapter 11)

The final steps convert the HEC-GeoHMS data into HEC-HMS input formats. The user must convert the HEC-GeoHMS maps into HMS units (English units) and preform a data check. These steps are in either Merwade (2012c) or Chapter 11 in the HEC-GeoHMS User's Manual (U. S. Army Corps of Engineers, 2012a). The user must also create a watershed schematic and add coordinates to the features before exporting the model. Figures 29 and 30 are screen shots of what the schematic should look like. Once the schematic is drawn, the user will have to prepare the data for export as directed in Merwade (2012c) or Chapter 11 in the HEC-GeoHMS User's Manual (U. S. Army Corps of Engineers, 2013a). The exported data will include sub-basin and river files, background shape file, and basin model file.

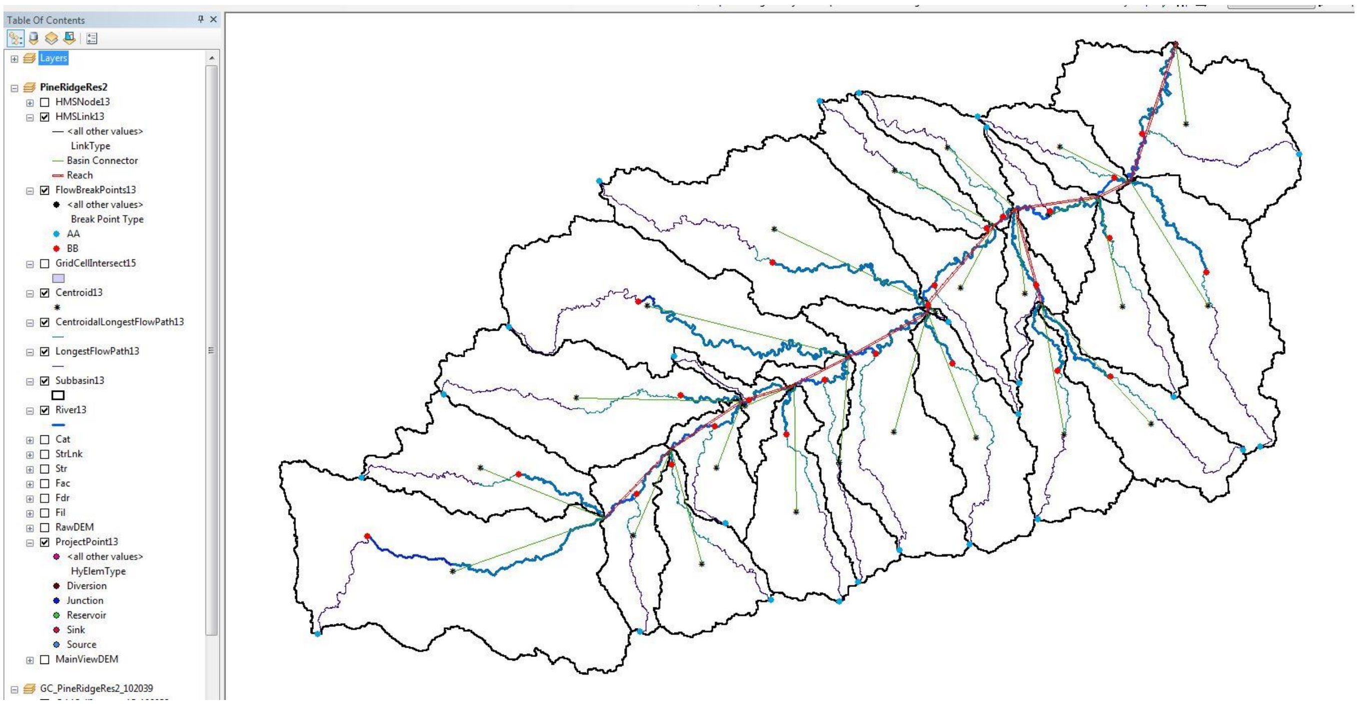

Figure 29. Upper White River Sub-basin Watershed schematic.

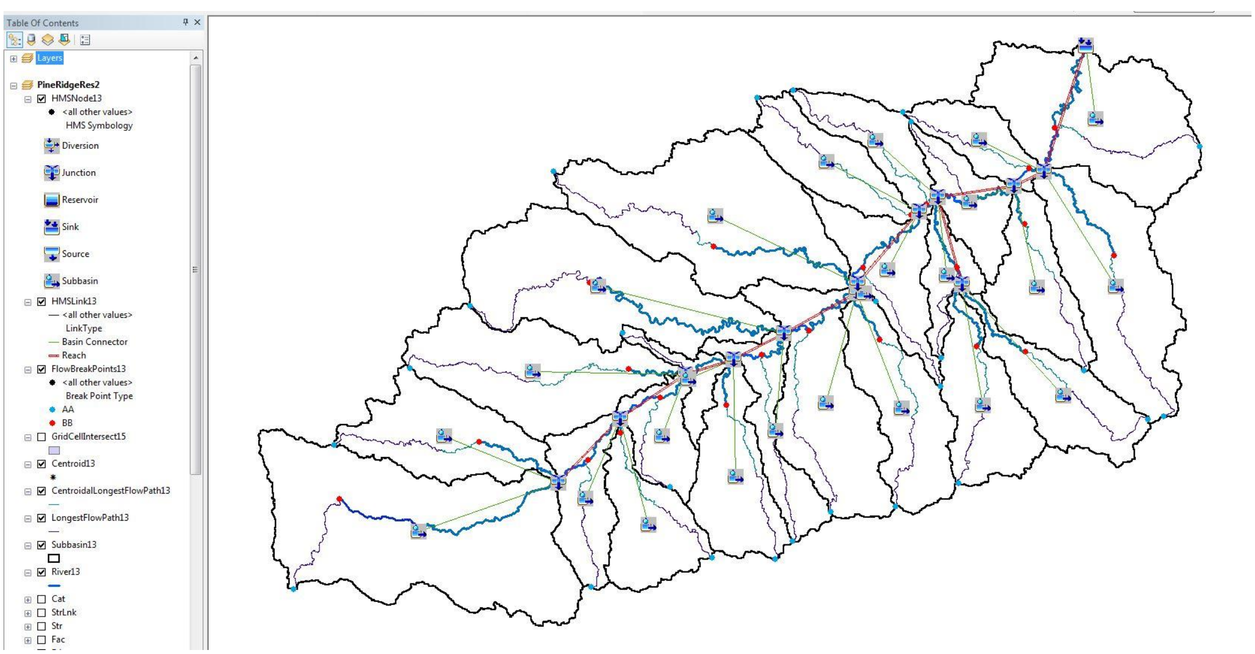

Figure 30. Upper White River Sub-basin Watershed schematic with HEC-HMS symbols.

HEC-HMS

HEC-HMS is a modeling tool that helps the user to analyze a watershed for a number of parameters. For the Upper White River Sub-basin Watershed HEC-HMS was used to analyze river levels as rain events are applied to the watershed. To start, the user must create or upload a basin model, meteorological model, and control specifications. HEC-HMS has three other components that the user can choose to perform, but these were not used for the Upper White River Sub-basin Watershed model.

For the step-by-step procedure, refer to McCuen (2005) or Merwade (2012a). This section entails screen shots from HEC-HMS of the Upper White River Sub-basin Watershed model that were obtained by following McCuen and Merwade. Any deviation from those steps are noted and explained in this section. For more detailed definitions or steps on HEC-HMS processes, refer to the HEC-HMS User's Manual (US Army Corps of Engineer, 2013b).

1. Create a new project and import the Upper White River Sub-basin Watershed basin model.

Basin Model.

Tyler_Baumbach/Thesis/White River Watershed/PineRidgeRes/PineRidgeRes2/PineRidgeRes2.basin (Baumbach, 2015)

Backgrounds.

Tyler_Baumbach/Thesis/White River Watershed/PineRidgeRes/PineRidgeRes2/subbasin13 (Baumbach, 2015)

AND

Tyler_Baumbach/Thesis/White River Watershed/PineRidgeRes/PineRidgeRes2/River13 (Baumbach, 2015)

Note. The units are U.S. Customary (feet, seconds, cubic feet per second)

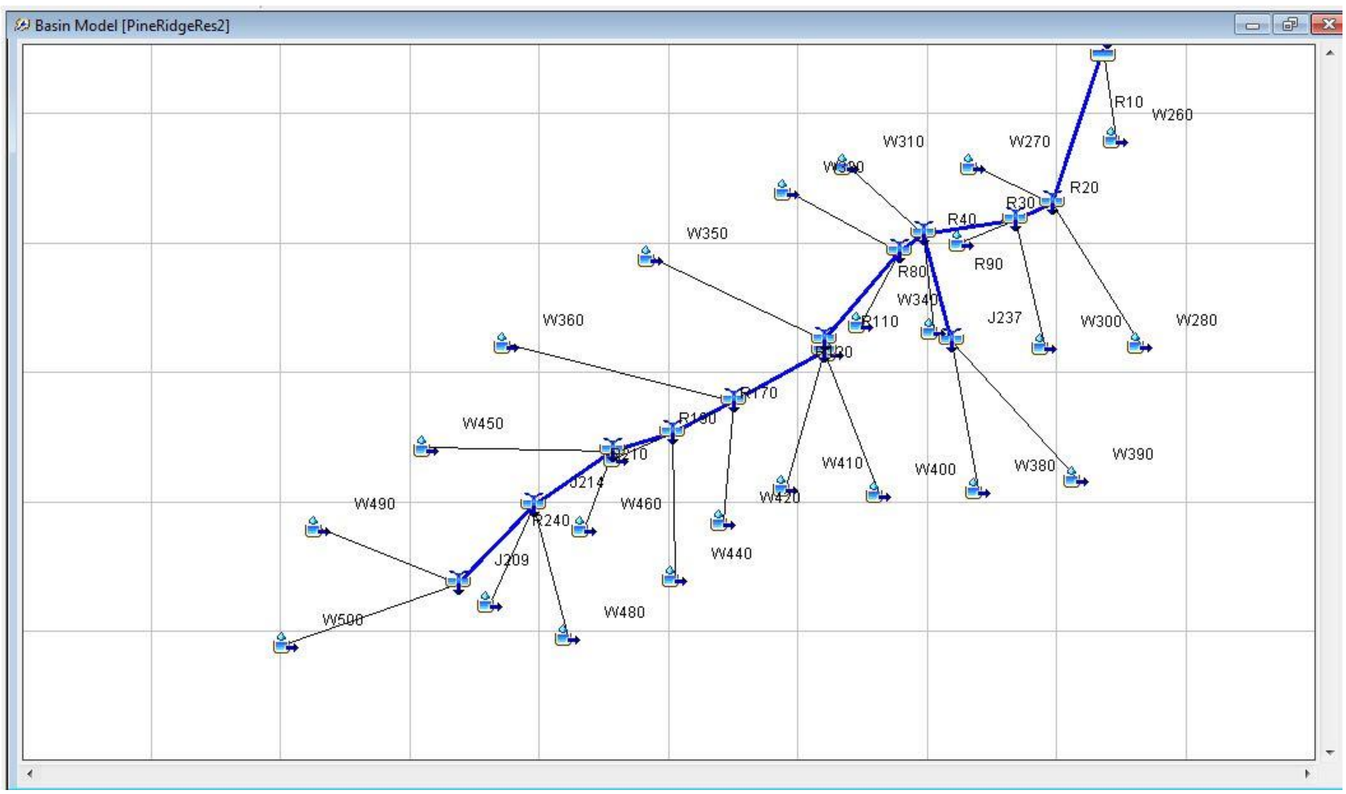

Figure 31. Upper White River Sub-basin Watershed schimate loaded in HEC-HMS.

Sub-basin

For each sub-basin, the user must manually enter in the canopy method, surface method, loss method, transform method, and baseflow method, unless it was entered in the HEC-GeoHMS process. Refer to Chapter 7 in the HEC-HMS User's Manual (U. S. Army Corps of Engineers, 2013a) for detailed definitions or steps for sub-basin elements. No canopy, surface, or baseflow information was entered for the Upper White River Sub-basin Watershed model in the provided database.

- Loss Method – SCS Curve Number

  The loss method computes the actual infiltration. Here the CN values are entered for each sub-basin and 0.0% was entered in for impervious. The SCS cucurve number loss method was selected, based on data inputs. By entering 0.0%, all of the rain that falls becomes direct runoff.

- Transformed Method – SCS Unit Hydrograph

  The transform method computes acutal surface ruoff for each sub-basin. The graph type should be left at its default (standard) and a lag time must be entered (in minutes). Lag time, $T_{L,}$ has to be manually computed, using sub-basin time of travel from the TR-55 Excel file. The US Army Corps of Engineers noted that, "Studies by the SCS found that in general the lag time can be approximated by taking 60% of the time of concentration" (2013b). Table 3 displays the time of concentration and calculated lag times for each sub-basin.

Table 3. Time of concentration and lag time for each sub-basin

Watershed	T_c (hr)	T_L (hr)	T_L (min)	Watershed	T_c (hr)	T_L (hr)	T_L (min)
W260	24.20	14.52	871	W390	20.51	12.31	738
W270	15.78	9.47	568	W400	16.96	10.18	611
W280	21.34	12.80	768	W410	21.69	13.01	781
W290	14.59	8.75	525	W420	16.73	10.04	602
W300	12.90	7.74	464	W430	10.41	6.25	375
W310	22.58	13.55	813	W440	13.50	8.10	486
W320	10.42	6.25	375	W450	21.64	12.98	779
W330	21.44	12.86	772	W460	7.95	4.77	286
W340	15.48	9.29	557	W470	10.34	6.20	372
W350	36.52	21.91	1315	W480	12.15	7.29	437
W360	32.18	19.31	1158	W490	16.36	9.82	589
W370	1.78	1.07	64	W500	17.96	10.78	647
W380	14.19	8.51	511				

Note. T_C = Time of concentration

T_L = Lag time

Culvert

- Description – 12 foot CMP
- Downstream – Left blank

Junction

- Description – Default (Generic Junction)
- Downstream – Automaticaly filled

Reach

Reaches are the river segments that carry the water from junction to junction and eventually to the culvert. Each reach has constants that have to be manually entered. Refer to Chapter 8 in the HEC-HMS User's Manual (U. S. Army Corps of Engineers, 2013a) for detailed definitions or steps on reach elements.

- Downstream – Default
- Routing Method – Lag Routing

The assumpiton made for the reaches was constant flow depths over the total travel time. With more detailed information about the river's cross sections throughout the model, a different routhing method could be selected to give a better estimate. The lag routing method only requires an estimated lag time in minutes for the channel. Lag time was calculated using equation 3.43 and 3.45 (McCuen, 2005, pp. 148) and Table 5.4 for the k function of the landcover (Ward and Trimble, 2004, pp.138). Table 4 displays the values used to calculate the lag routing times and the lag times for each reach.

$$T_t = \frac{L}{60V} \qquad Equation\ (3.43) from\ McCuen$$

$$V = kS^{0.5} \qquad Equation\ (3.46) from\ McCuen$$

Variables.

L = Length of flow (HEC-GeoHMS River13 attribute table), ft

V = Velocity, ft/s

k = function of landcover with the effect measeare by the value manning's number and hydrologic radius

S = Slope (HEC-GeoHMS River13 attribute table), ft/ft

Table 4. Lag routing variables and lag times for each reach.

Reach	Slope (ft/ft)	Velocity, V (ft/s)	Length, L (ft)	Lag Time, T_t (min)
R10	0.035	0.94	87319	1548
R20	0.002	0.22	17850	1352
R30	0.001	0.16	51784	5394
R40	0.002	0.22	13249	1004
R80	0.001	0.16	55181	5784
R90	0.003	0.27	45589	2814
R110	0.003	0.27	3273	202
R120	0.001	0.16	58533	6097
R170	0.002	0.22	40281	3052
R190	0.003	0.27	26505	1636
R210	0.004	0.32	38974	2030
R240	0.004	0.32	40403	2104

Note. *Assumed river bed was composed mainly of sand and gravel, therefore, k = 5*

- Loss/Gain Method – Left blank

2. Create one or multiple meteorologic model(s) depending on how many rain events the user chooses to run. Table 5 displaces all of the meteorologic models used in the Upper White River Sub-basin Watershed model. Frequency storm was set as the type of precipitation and U.S. Customary for the unit system. Refer to Chapter 11 in the HEC-HMS User's Manual (U.S. Army Corps of Engineers, 2013a) for detailed definitions or steps on meteorological elements.

Note. Set "Include Subbasins" to YES under the "Basins" tab for each meteorologic model created.

Frequency Storm

- Probability – Varies see Table 5

- Input Type – Annual Duration
- Output Type – Annual Duration
- Intesnity Duration – Varies, See Table 5
- Storm Duration – 1 hour (assumption made for an average storm, may vary)
- Intensity Position – 50% (default, may vary)
- Storm Area – Left blank (will use the whole watershed)
- Curve – Uniform For All Sub-basins

Table 5. Meteorologic models processed for the Upper White River Sub-basin Watershed model.

Probability (%)	Intensity Duration (min)	Duration (min)	Annual-Duration Depth (in)
1	5	5	0.863
		15	1.54
		60	2.51
	15	15	1.54
		60	2.51
	60	60	2.51
2	5	5	0.759
		15	1.36
		60	2.2
	15	15	1.36
		60	2.2
	60	60	2.2
4	5	5	0.658
		15	1.18
		60	1.91
	15	15	1.18
		60	1.91
	60	60	1.91
10	5	5	0.529
		15	0.945
		60	1.54
	15	15	0.945
		60	1.54
	60	60	1.54

Note. Annual-Duration Depth – Data Source. http://hdsc.nws.noaa.gov/hdsc/pfds/

3. Create control specifications for the watershed model. The purpose of the control specifications is to set the model's time limits. Figure 32 is a screen shot of what the control specifications could be. For the Upper Whiter River Sub-basin Watershed model the control specifications were arbitrary dates and times. The only stipulation is that the time period has to contain all of the runoff effects on the river.

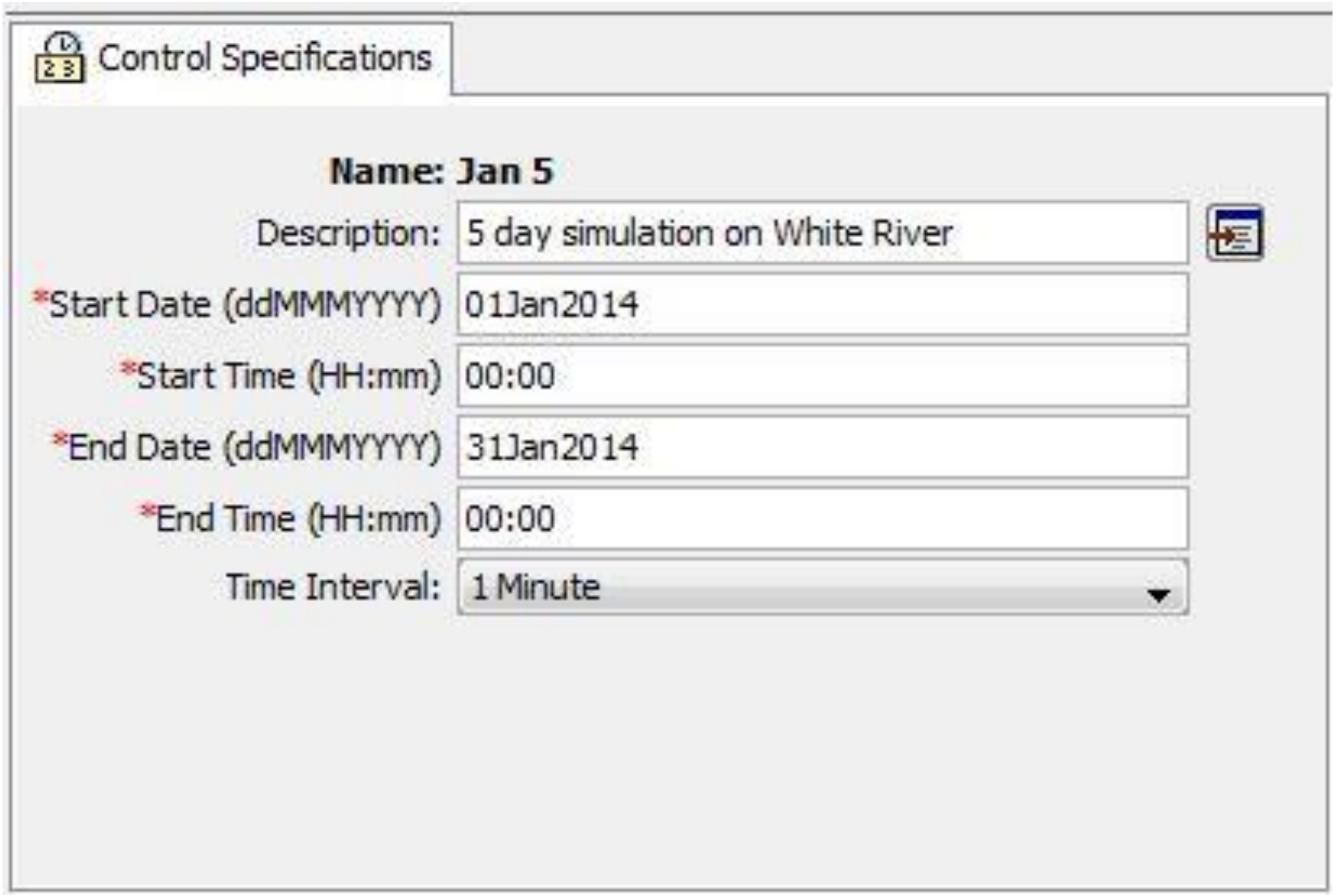

Figure 32. Control specifications set at one month time limit measured every one minute.

4. Develop results by running simulations on the watershed basin model. For the steps used to obtain results, refer to Chapter 13 in the HEC-HMS User's Manual (U. S. Army Corps of Engineers, 2013a), or Maidment and Espinoza (2011) and Merwade (2012a-c). In Figure 33, I estimated outflow for the culvert after running a simulation, using a frequency = 1% and intensity duration = 5 min.

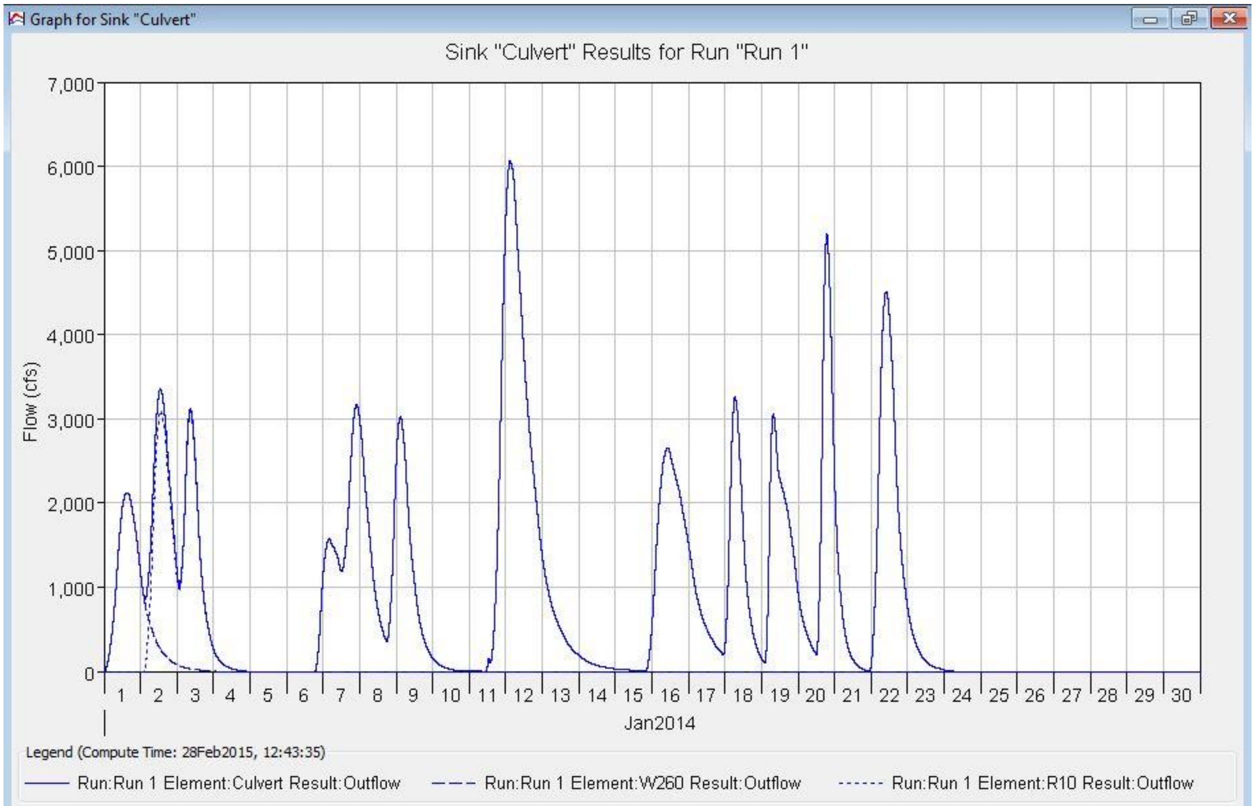

Figure 33. Estimated river levels for a 100 year event at the 12' CMP culvert without any baseflow.

The same watershed basin model can be used to run multiple meteorological model simulations to produce comparable data sets. In order to export graphs, the user must copy data tables to Excel for reconstruction of HEC-HMS graphs. Once the data is exported, the user can edit data sets and form conclusion on set graphs. One application would be to use meteorological model simulations to compare current rain events against future rain events on a current hydrologic structure.

Acknowledgements

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