Base Level Engineering (BLE)

Roger Mills, OK (MIP # 17-06-1169S)

STARR Strategic Alliance for Risk Reduction

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1. Introduction

1.1. Purpose of Study

As part of FEMA's Risk Mapping, Assessment, and Planning (Risk MAP) project, FEMA Region 6 is continuing to produce large-scale floodplain mapping efforts to provide quality flood and other natural hazard risk data to increase public awareness and achieve mitigation actions to reduce the risk to life and property. The primary of objectives of the Roger Mills County in OK Base Level Engineering (BLE) Analysis are as follows:

- Prepare base level engineering (map ready Zone A, no structures) for a complete stream network within the selected HUC4 basin area depicted in support of CNMS validation and non-regulatory product development throughout the study basin.
- Stream network modeling shall be produced in a manner to assist increase of technical creditability throughout the study area
- Grow partnerships and generate support for base level modeling throughout the Region

1.2. Scope of Work

The scope of work includes conduction Base Level Engineering Analysis of Roger Mills County in OK. Figure 1 depicts the study area and scope of work.

- Base level engineering analysis consistent with Guidance for Flood Risk Analysis and Mapping, First Order Approximation, November 2014 (and updates through the date of this report)
- Minimal model refinement to produce Zone A (no structures) analysis in accordance with SID #84
- Delivery of all network H&H models and shape files prepared for the study basin required for model refinement by future mapping partner.
- Produce seamless floodplain coverage of 1-percent and 0.2% annual chance floodplains, stream centerlines and study cross-section within the project area.

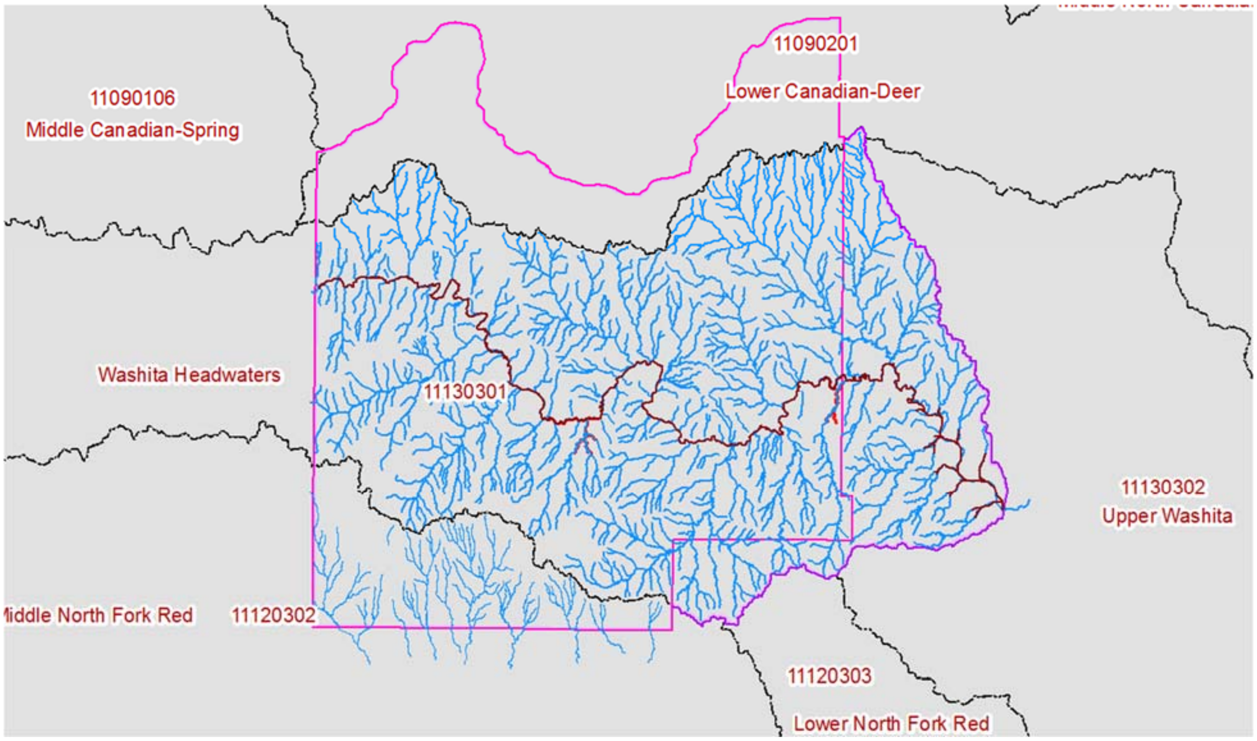


Figure 1: Location and Study Area Map of Roger Mills County, OK

2. Hydrology

STARR II's hydrology process is summarized in a work flow chart and is included as part of Appendix A. Following sections provide details of the hydrology process

The study area was divided into three watersheds for the hydrologic analysis (see Table 1 and Figure 1). These watersheds were extended beyond the study streams in order to capture the upstream drainage areas.

Peak flows for the 10%, 4%, 2%, 1%, 1% plus, 1% minus, and 0.2% events were computed utilizing the published USGS regression equations (Asquith and Roussel, 2009). For each watershed, a grid was generated for each of the regression parameters and each of the flow events described above. Each grid cell has a value for the drainage area and other regression parameters associated with the basin draining to that cell. Due to limited data and to be conservative, the effects of regulation on the flow rates were not included in this analysis.

The primary steps for the development of hydrologic data include:

1. Prepare stream network, hydrologic network, and delineate watersheds

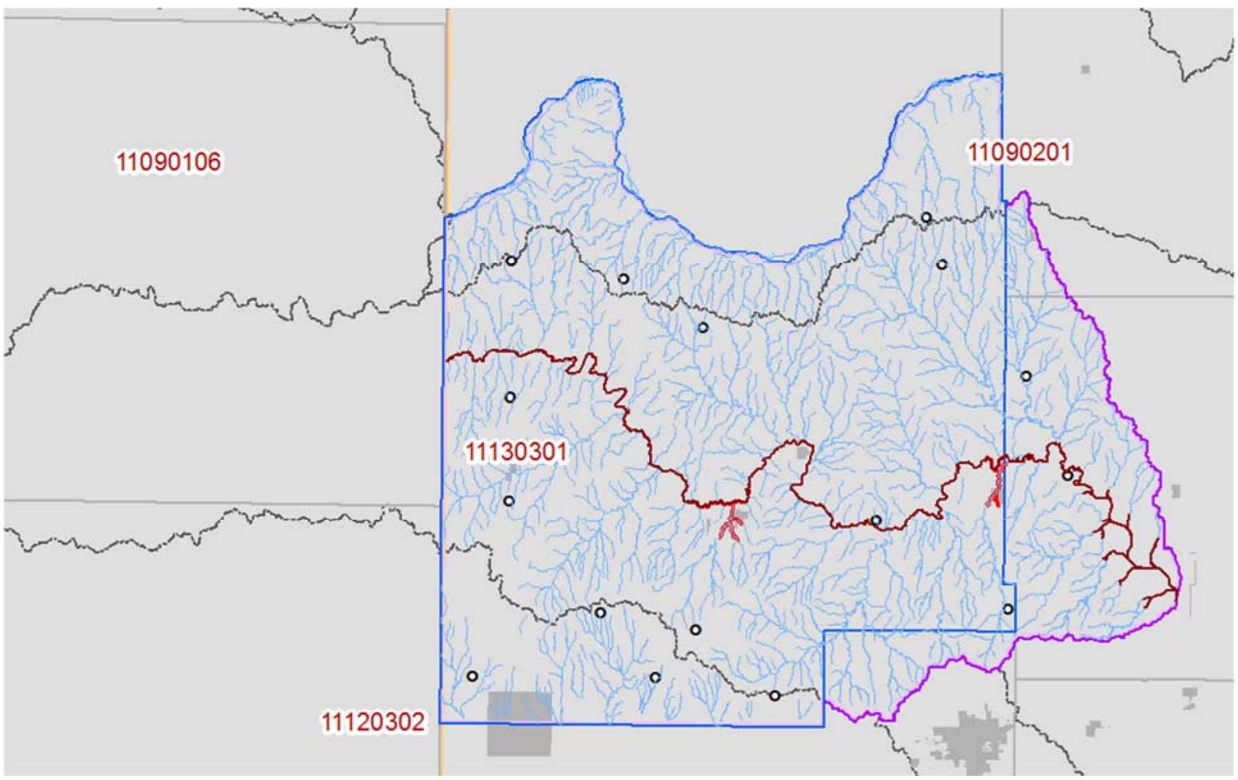
2. Develop gridded input parameters and peak flows from the rural regression equations

The details for each of these steps are included in the following sections.

Table 1.Description of watersheds defined for hydrologic analysis

Watershed Identifier	Description
11130301	Covers Washita Headwaters – both in Texas and Oklahoma.
11120302	Part of the HUC-8 watershed **11120302** (Middle North Fork Red) that is with in Roger Mills County Project Area
11090201	Part of the HUC-8 watershed **11090201** (Lower Canadian-Deer) that is with in Roger Mills County Project Area

Figure 2: Watersheds defined for hydrologic analysis



2.1. Stream Network Preparation and Watershed Delineation

The stream network was derived from the NHD high-definition flow lines for the watershed and used as a basis for stream centerlines and to develop hydrologic flow paths and drainage basins. The NHD lines are currently available at ftp://nhdftp.usgs.gov/DataSets/Staged/SubRegions/FileGDB/HighResolution/. These features are frequently updated, and the versions used for the project were from about May to August 2014.

The steps used to develop the stream network, delineate watersheds, and compute drainage areas are listed below:

1. Initially, the approximate contributing basins for those reaches for which hydraulic models are required were identified using NHD Plus (http://www.horizon-systems.com/nhdplus/) flow direction grids and watersheds derived from them. USGS stream gage locations that have drainage area information attached were also used to identify or confirm the size of contributing basins and to identify large streams with contributing flow outside the basin. The Washita Headwaters (11130301), which is upstream of the watersheds being studied), is included as a contributing basin to account for the total drainage area for the Washita River.
2. A 30-meter DEM topography sets for the approximate contributing basin was created. These DEMs were extracted from National Elevation Dataset 1/3 arcsecond (about 10 meter) rasters, downloaded from ftp://rockyftp.cr.usgs.gov/vdelivery/Datasets/Staged/Elevation/13/GridFloat. The National Elevation Dataset (NED) 1/3 data as it existed around mid-2014 was used. These were mosaiced as needed and re-projected into USGS Albers North American Datum of 1983 (NAD 83), 30 meter grids to cover the candidate contributing basin. The sampling method during re-projection was bilinear resampling. Note that this DEM is used only to develop hydrologic parameters and will not be used for hydraulic modeling.
3. All NHD high-definition lines that intersected the contributing basins were extracted and the lines classified as coastlines, if any, were deleted.
4. The NHD lines were joined to create the stream network with higher priority given to longer lengths.
5. The stream network was reviewed and modified as follows:
    - Split flow locations were reviewed and the primary flow path identified. The alternate flow paths were deleted from the network.
    - NHD lines classified as canals, underground conduits, and pipelines were removed from the network if they did not correspond to “natural” flow paths or scoped streams (CNMS lines).
    - Streamlines were added where there was no NHD flowline associated with a CNMS line.
6. All streamlines within 50 meters of CNMS lines were reviewed. At locations where the two alignments were noticeably different, the aerial photography and topography were reviewed to determine the correct alignment and the NHD flow line modified if appropriate.
7. The NHD stream network was then used as the basis for the “burn” layer. In the burn process, DEM cells that crossed burn lines were modified to have lower elevations.
8. There were no sinks in the watersheds. So, the DEM was filled to remove depressions so that there were continuous flow paths to the basin outlets.
9. A flow direction grid was created from the filled DEM, where each cell points to the next downstream cell.
10. Watershed delineation was performed (i.e., flowlines and basins are created from the flow direction grids). Basins were delineated up to a threshold of 0.1 square miles, and hydrologic flowlines were also created up the 0.1 square miles of drainage area, which is the threshold recommended for hydrologic computations.
11. The following quality checks were performed:

a. Delineated watersheds and flow lines were examined for consistency with the expected flow paths for the basin. The flow directions and alignments between the NHD stream network and the hydrologic network were checked. Differences were highlighted with automated tools. Generally, differences occurred when two burn lines were too close together and the flow direction grid was incorrect. At these locations, the stream line was not burned into the DEM in order to correct the direction.

b. A drainage area grid was computed along the flow paths and checked against stream gage drainage areas. If the flowlines or basins appeared to be in error, then the NHD stream network was modified.

c. If modifications were made, the fill / flow direction / watershed delineation steps were repeated and drainage areas recalculated and the flagged locations checked again.

During the review process, it was noted that the direction of a majority of the CNMS lines was reversed compared to the actual flow path and topography.

The delivered spatial files are described in the table 2 below. All files listed below are projected in USGS Albers NAD 1983.

Table 2: Spatial files delivered for stream network preparation and watershed delineation.

These files were generated for each of the watersheds described above. The "" refers to the watershed identifier.*

File Name	Type	Description
*_poly.shp	polygon	Polygon depicting estimated contributing drainage area
*_nhd.shp	polyline	NHD high-definition flow lines in the contributing drainage area
*_topo.bil	grid	Mosaiced 30-meter USGS DEM covering the contributing drainage area
*_burn_reaches.shp	polyline	Connected stream network derived from modified NHD flow lines. Attributes include names of major reaches that were in the NHD database.
*_topo_burn.bil	grid	30-meter topography with stream network (i.e., burn reaches) burned in
*_fd.bil	grid	Flow direction grid
*_fa.bil	grid	Flow accumulation grid
*_sqmi.tif	grid	Contributing drainage area (in square miles) for all drainage areas of 0.1 square miles or greater

File Name	Type	Description
*_basinpolys_0.1.shp	polygon	Basins delineated up to a threshold of 0.1 square miles of drainage area
*_basinpaths_0.1_join.shp	polyline	Hydrologic flow paths up to 0.1 square miles of drainage area
*_basinpolys_1.shp	polygon	Basins delineated up to a threshold of 1 square mile of drainage area
*_basinpaths_1_join.shp	polyline	Hydrologic flow paths up to 1 square mile of drainage area
*_basinpolys_10.shp	polygon	Basins delineated up to a threshold of 10 square miles of drainage area
*_basinpaths_10_join.shp	polyline	Hydrologic flow paths up to 10 square miles of drainage area
*_basinpolys_50.shp	polygon	Basins delineated up to a threshold of 50 square miles of drainage area
*_basinpaths_50_join.shp	polyline	Hydrologic flow paths up to 50 square miles of drainage area
*_basinpolys_100.shp	polygon	Basins delineated up to a threshold of 100 square miles of drainage area
*_basinpaths_100_join.shp	polyline	Hydrologic flow paths up to 100 square miles of drainage area
*_poly.shp	polygon	Polygon depicting estimated contributing drainage area

2.2. Peak Flows Computed from Unregulated Regression Equations Only

Peak flows for the 10%, 4%, 2%, 1%, 1% plus, 1% minus, and 0.2% events were computed utilizing the published USGS regression equations (Lewis, 2010). The contributing drainage area (*CONTDA*), mean-annual precipitation (*PRECIP*), and main channel slope (*CSL10_85fm*) were the basin characteristics used to estimate the flows. Flow grids were developed for each flow event and input parameters described above for drainage areas of 0.1 square mile or greater.

So for each hydrologic basin, a grid of contributing drainage (in square miles) was created, for all drainage areas of 0.1 square miles or greater. Note that 0.1 square mile corresponds to the lower limit of the drainage areas used in the development of the regression equations. For drainage areas exceeding the upper limit of 2,500 square miles, stream gages were used to estimate the flows (see Section 2.3).

The mean annual precipitation (1971-2000) gridded spatial data was obtain from PRISM (http://www.prism.oregonstate.edu/). The precipitation values were converted to inches, clipped to the study area and re-projected to USAG Albers NAD 83. A grid of the area-weighted basin average precipitation was created for all of the drainage areas of 0.1 square mile or more. The lower and upper values in the regression analysis were 16.6 and 62.1 inches, respectively. All basin averaged precipitation values were within this range for the study area.

The main channel slope, feet per mile, is the slope of the stream between points that are 10 percent (E_{10}) and 85 (E_{85}) percent of the distance along the channel from the basin outlet to the basin divide (*DD*). The USGS 30-meter DEM, the flow accumulation, and flow direction grids were used to derive the grids for the elevations in meters and the distance to the divide in meters. The following equation was used to compute the main slope grid in feet per mile:

$$\mathrm{CSL10\_85fm} = \left(\frac{E_{85} - E_{10}}{0.75 \cdot DD}\right) \cdot 5280$$

The lower and upper limits of the slope in the regression analysis were 1.98 and 342 feet per mile, respectively. The computed flows are sensitive to the channel slope and unreasonable flows tend to be computed when slopes are outside of the range used in the regression analysis. Therefore, when the channel slope was less than 1.98 feet per mile, 1.98 feet per mile was used in place of the computed value; and similarly, when the channel slope exceeded 342 feet per mile, 342 feet per mile was used in place of the computed values.

The regression equations used to compute the gridded unregulated peak flows for the 10%, 4%, 2%, 1%, and 0.2% chance exceedances for basins with drainage areas of 0.1 square mile shown below:

$$Q_{10\%} = 1.74 \cdot \left(\mathrm{CONTDA}^{0.66}\right) \cdot \left(\mathrm{PRECIP}^{1.42}\right) \cdot \left(\mathrm{CSL10\_85fm}^{0.21}\right)$$

$$Q_{4\%} = 4.90 \cdot \left(\mathrm{CONTDA}^{0.66}\right) \cdot \left(\mathrm{PRECIP}^{1.24}\right) \cdot \left(\mathrm{CSL10\_85fm}^{0.23}\right)$$

$$Q_{2\%} = 13.18 \cdot \left(\mathrm{CONTDA}^{0.66}\right) \cdot \left(\mathrm{PRECIP}^{1.05}\right) \cdot \left(\mathrm{CSL10\_85fm}^{0.21}\right)$$

$$Q_{1\%} = 26.9 \cdot \left(\mathrm{CONTDA}^{0.65}\right) \cdot \left(\mathrm{PRECIP}^{0.92}\right) \cdot \left(\mathrm{CSL10\_85fm}^{0.21}\right)$$

$$Q_{0.2\%} = 126 \cdot \left(\mathrm{CONTDA}^{0.64}\right) \cdot \left(\mathrm{PRECIP}^{0.64}\right) \cdot \left(\mathrm{CSL10\_85fm}^{0.19}\right)$$

The average standard error of prediction for the 1% chance exceedance 35.72%. The 1% plus and 1% minus gridded flows were computed using the standard error of prediction as shown in the equations below:

$$Q_{1\%plus} = Q_{1\%} \cdot (1.3572)$$

$$Q1\%minus = \frac{Q_{1\%}}{1.3572}$$

The delivered spatial files are describe in the table below. All files listed below are projected in USGS Albers NAD 1983.

Table 3: These files were generated for each of the watersheds described above.

The "" refers to the watershed identifier*.

File Name	Type	Description
***_sqmi.tif**	grid	Contributing drainage area in square miles (A) for all drainage areas of 0.1 square miles or greater
***_precip.bil**	grid	PRISM precipitation grid clipped to the contributing drainage area, re-projected to USGS Albers NAD83, adjusted to 30-meter grid cells, and converted to inches
***_basinaverageprecip.tif**	grid	Area-weighted basin average precipitation (P) for all drainage areas of 0.1 square miles or greater
***_elevat100pcup.tif**	grid	Elevations in meters of the channels at the basin divide (Edivide) for all drainage areas of 0.1 square mile or greater
***_elevat85pcup.tif**	grid	Elevations in meters at 85 percent (E_{85}) of the distance along the channel from the basin outlet to the basin divide for all drainage areas of 0.1 square mile or greater
***_disttodivide_mtrs.tif**	grid	Distance along the channel from the basin outlet to the divide in meters (DD)

File Name	Type	Description
***_chanslope_final.tif**	grid	Dimensionless main channel slope (S) clipped to the upper and lower regression limits for all drainage areas of 0.1 square miles or greater
***_Q10_final.tif**	grid	Unregulated peak streamflows with 10% chance exceedance for all drainage areas of 0.1 square miles or greater
***_Q25_final.tif**	grid	Unregulated peak streamflows with 4% chance exceedance for all drainage areas of 0.1 square miles or greater
***_Q50_final.tif**	grid	Unregulated peak streamflows with 2% chance exceedance for all drainage areas of 0.1 square miles or greater
***_Q100_final.tif**	grid	Unregulated peak streamflows with 1% chance exceedance for all drainage areas of 0.1 square miles or greater
***_Q100_minus1_eqs_only.tif**	grid	Unregulated 1% minus peak stream flows
***_Q100_plus1_eqs_only.tif**	grid	Unregulated 1% plus peak stream flows

2.3. Gage Analysis for High Drainage Areas

The regression equations are not valid for drainage areas greater than 2,500 square miles. The Washita River is the only stream that has drainage areas exceeding 2,500 square miles. In the study area, this river is regulated by Foss Reservoir, which is the upstream limit of the hydraulic model. Since the entire length of the Washita River that the drainage area exceeds 2,500 miles is regulated, no adjustments were made for the high drainage area.

3. Hydrology Results

3.1. Comparison of Flows

Once the flow grids were computed for the 10%, 4%, 2%, 1%, 1% plus, 1% minus, and 0.2% events, the results were compared to StreamStats data. To compare the gridded flows to StreamStats outputs, the project team placed 80 points evenly distributed across the three study watersheds making sure to place points in a wide range of drainage areas, slopes, and precipitation values. The team submitted these points to the StreamStats Batch Processor and queried results for drainage area, channel slope, and mean-area precipitation. Using the StreamStats results, the project team calculated the peak flow for each event and then compared the StreamStats data to the gridded data computed by the project team.

For the first comparison, the mean-area precipitation obtained from StreamStats was compared to the gridded mean-area precipitation computed by the project team. Out of the 80 points analyzed, five points had a percent difference greater than 5.0%. The outlying point was found to be near a confluence where the StreamStats flow line differed from the flow line computed by the project team. Overall, the two data sets match very closely and the average of the absolute value percent difference between the data sets is only 0.7%.

The next data sets that were analyzed were the StreamStats output for drainage area and the gridded drainage area computed. Five points out of the 80 points analyzed resulted in a percent difference greater than 5.0%. The cause of these differences can be attributed to three factors:

1. The project team's 30-meter grid deviated from the StreamStats 10-meter grid,

2. Points with very small drainage areas are much more sensitive to small differences in results, which result in higher percent differences, and

3. The StreamStats drainage areas do not account for NRCS structures whereas the project team's grids account for these structures.

The underlying cause of much of the difference in the gridded analysis versus StreamStats is the use of the 30-meter topographic data. The project team concluded that using a smaller grid size would have alleviated some of the problem areas and given results closer to the StreamStats outputs; however, the average of the absolute value percent difference was only 4.0%, which is still within an acceptable range.

The next data sets studied were the main channel slopes. The main channel slopes had a percent difference of 5% or greater in approximately 26% of the 87 points analyzed. The source of the difference in these values is directly related to the use of a 30-meter grid size. Using a 30-meter grid results in shorter stream lengths because it doesn't capture small changes in stream sinuosity, and shorter stream lengths result in higher channel slopes. Channel slope in the Oklahoma regression equations has the least impact on peak flow of the three parameters included in the equations. Since the slopes calculated using the 30-meter grid are typically higher than the StreamStats slopes, this results in peak flows that are slightly more conservative.

The peak flows computed by the project team were compared to the StreamStats peak flows. The average percent difference was less than 5%. The points that have the highest percent difference in peak flow are all areas that were previously discussed due to discrepancies with the computed precipitation, drainage area, and/or slope.

Table 4: Spatial files and related data delivered for the final peak flows.

The "" refers to the watershed identifier.*

File Name	Type	Description
***_Q10_final.tif**	grid	Final peak streamflows with 10% chance exceedance for all drainage areas of 0.1 square miles or greater adjusted for regulation by large dams
***_Q25_final.tif**	grid	Final peak streamflows with 4% chance exceedance for all drainage areas of 0.1 square miles or greater adjusted for regulation by large dams
***_Q50_final.tif**	grid	Final peak streamflows with 2% chance exceedance for all drainage areas of 0.1 square miles or greater adjusted for regulation by large dams
***_Q100_final.tif**	grid	Final peak streamflows with 1% chance exceedance for all drainage areas of 0.1 square miles or greater adjusted for regulation by large dams
***_Q100_minus1_final.tif**	grid	Final 1% minus peak stream flows adjusted for regulation by large dams
***_Q100_plus1_final.tif**	grid	Final 1% plus peak stream flows adjusted for regulation by large dams

3.2. Digital Data Structure

Digital data delivered as part of the hydrology task is organized in the following structure

1. *_Stream_Hydrologic_Network: This folder contains data produced during stream network preparation and watershed delineation and are listed in Table 1.

3. *_Peak_Flows_From_Regression_Equations: This folder contains data before any adjustments to the Flow Retarding Structures within the project area are applied and includes regression equations input parameter calculations (drainage area, average annual precipitation and average slope) and 10%, 4%, 2%, 1%, 1% -, 1% + and 0.2% annual chance exceedance flows. All files included in this folder are listed in Table 3.

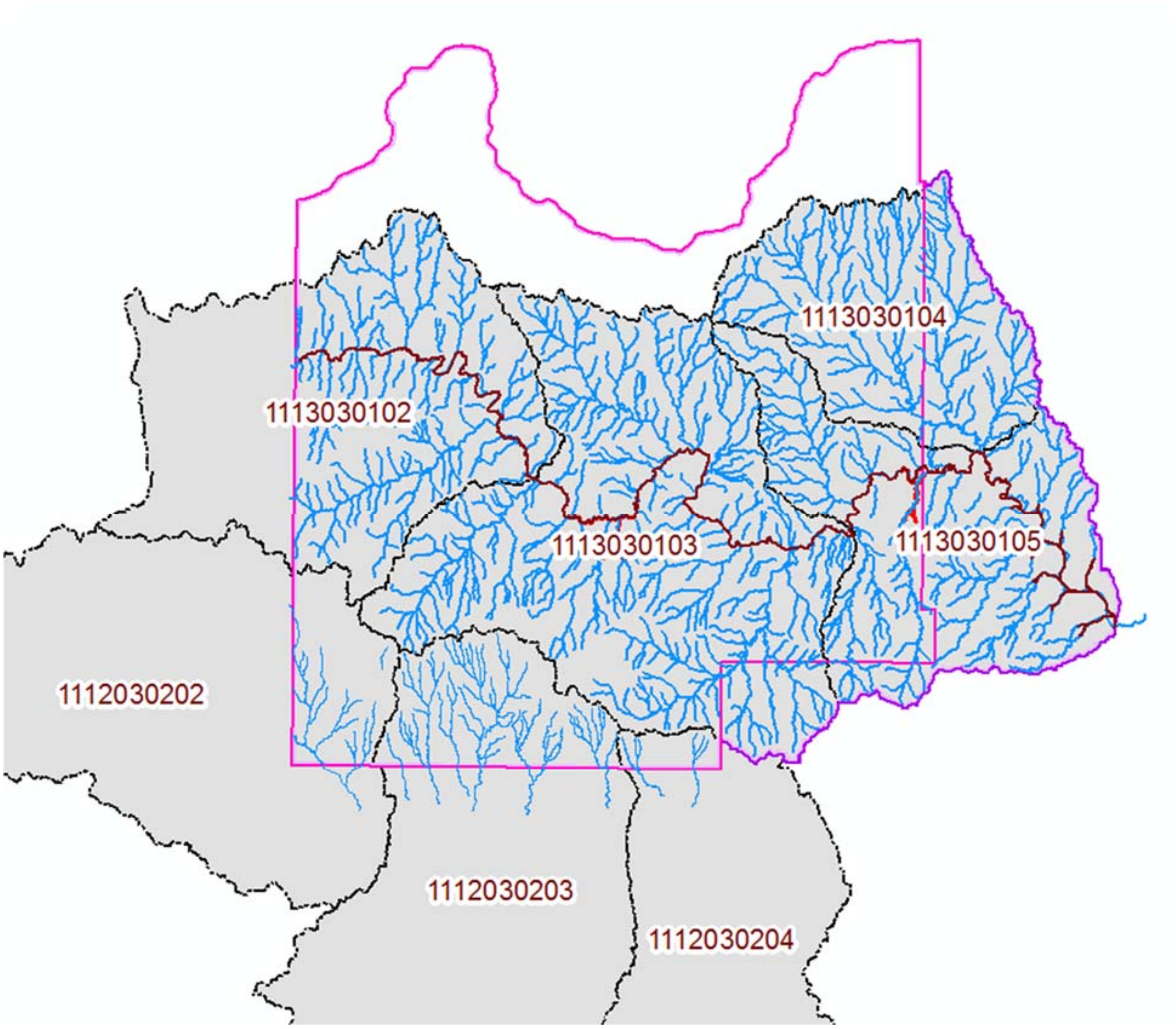
4. *_Final_Peak_Flows: This folder contains the final 10%, 4%, 2%, 1%, 1% -, 1% + and 0.2% annual chance exceedance flows adjusted for high drainage area and regulation by large dams along with gage location data, regulated streams. All files included in this folder are listed in Table 4.

*- represents HUC8 (11090201, 11120302, 11130301) within Roger Mills County

4. Hydraulics

For the hydraulic analysis, the Roger Mills County was divided into seven (7) HUC-10 watersheds as shown in Figure 3. A separate analysis is completed for Washita River main steam.

Figure 3: HUC-10 Watershed Boundaries that are within Roger Mills County



Steady flow HEC-RAS models were developed for the 10%, 4%, 2%, 1%, 1% plus, 1% minus, and 0.2% flood events. Model geometry and mapping were developed automatically using GIS tools and scripts and then refined as needed. Some common modeling practices not considered in this analysis are inclusion of bridges, culverts, or levees or split flow analysis.

The NHD high-definition streamlines were used to create the initial hydraulic centerlines for the models. These lines were then reviewed and modified to more closely follow the thalweg of the stream. A single conveyance area was used for each cross-section, e.g. bank stations were set at the outer limits of the cross-section. This method has been found to give good results, especially when Manning's n-values are set based on land-use coverage.

No supercritical flows were permitted in the models, so the lowest possible water surface elevation for any cross-section was critical depth.

After automated models were developed, the floodplains and cross-sections were visually reviewed. Cross sections with unusual changes in hydraulic parameters (water surface and energy grade slopes, water surface elevations, and velocity) were examined. In numerous cases cross-sections were deleted or modified, to improve the quality of the hydraulic model.

Water surface grids and floodplains (10% and 1% events) were processed once the models were finalized.

4.1. Discharges

Discharges for all events were imported into HEC-RAS using automated tools such that the corresponding computed USGS rural regression discharge was assigned for each cross-section location

4.2. Boundary Conditions

The downstream boundary condition for almost all models was set at critical depth. For areas of interest, where the streamline did not terminate at a confluence with another river, the reach was extended by about 3,200 feet downstream, to allow the water surface to stabilize, so that the area of interest was already outside the influence of the downstream limit of the model. Through confluences in most situations reaches were also extended downstream to parallel the main channel that they join. In the model extensions downstream of confluences the discharge applied was not increased to represent the increased discharge computed for the main channel, instead the highest computed discharge upstream of the confluence is used. This process allows for a smooth transition in water surface elevation and thus floodplains between tributaries and main channels

Typically "normal" depth is used for hydraulic models for the downstream boundary. However, the use of normal depth requires an estimate of the "normal slope," which depends on the method used to estimate it. Fully automated methods to estimate the normal slope for large numbers of reaches are not completely reliable, in particular there is a risk that the slope may be estimated too low, which can cause a significant and unrealistic backwater condition at the start of the model, which may perpetuate for a long distance upstream. When critical depth is used, the models will typically stabilize to a "normal" depth within just a few cross-sections.

The only place where the model results should be used in this stabilization region would be when the downstream end of a reach was in the confluence with another modeled stream. For most confluences, the downstream main channel was modeled also. Typically the higher water surface elevation (backwater) of the main channel would govern when the water surface grids and floodplains are merged, negating any inaccuracies associated with the critical depth boundary condition on the tributary stream.

4.3. Cross Sections

Although some cross sections were edited manually, cross section placement was primarily automated. Cross sections were placed perpendicular to the flow direction. Cross section spacing was typically at 250 feet or less. Cross section geometries were obtained by overlaying the cross-section on the DEM topography.

After automated placement, a series of checks was performed to look for unusual changes in water surface elevation, slope, or velocity between cross-sections for the water surface profile of the 1% plus annual chance exceedance event. Places flagged as exhibiting unusual behavior were examined, and cross-sections were sometimes modified (or deleted) in these areas. This process resulted in the final cross-sections location and orientation, however the cross-section extent or width was determined with a separate process based on the estimated limits of effective flow.

4.4. Ineffective Areas

Ineffective flow limits were not used. Instead, cross-sections were trimmed back to the extent of the estimated effective flow region. The cross-section extents were determined first using the 1% plus event such that under normal conditions the cross-section would be wide enough to contain the determined discharge for that cross-section. In some cases the cross-section width was limited based on an estimation of the allowable change in cross-section width for contraction or expansion of effective top width. Allowable ratios for flow contraction and expansion were set at 1:1 and 4:1, respectively.

The determined final cross-section orientation and width from review and hydraulic analysis using the 1% plus event were applied for all other events with the exception of the 10% or 10-year event. For the 10-year event a second pass was done to decrease the effective top width of cross-sections, this would force the flow to be contained mostly within the low flow channel if it has significant capacity to allow it. Because the previously determined cross-sections from the 1% plus event were used as the input sections for this process the cross-sections for the 10-year event can only be shorter and must be a section of the cross-section created from the 1% plus hydraulic model.

4.5. Channel Roughness Values

Manning's n values were assigned to each class in the National Land Cover Database 2011 (NLCD, http://www.mrlc.gov/nlcd11_data.php). The correspondence between land use codes and the Manning's n-values are provided in Appendix C. For each model cross-section, the n-value was computed by compositing the land cover Manning's n values along a cross section using the Lotter method (Chow, 1959, p. 136-137), which included an estimate of the 1% plus water surface elevation so the wetted extents could be used to perform the compositing. The compositing was done by each cross-section using the 1% plus discharges and estimated wetted extents. These composite n-values were then used for all other event simulations, including the 10% for which shorter cross sections are used to limit conveyance to the smallest overall width that may provide containment.

4.6. Expansion and Contraction

Default contraction and expansion coefficients (0.1 and 0.3) were used.

4.7. Special Issues

Flow was not decreased due to model breakouts, nor were models modified to take them into account.

4.8. Floodplain and Water Surface Elevation Grids

Floodplains were generated for the 1%, 10% and 0.2% annual chance exceedance events for the hydraulic model reaches. A GIS shapefile of streamlines are provided that show the actual reaches modeled. These floodplains were utilized to determine if the hydraulic model results looked reasonable, and if the models needed adjustment

The floodplains are based on water surfaces interpolated from the hydraulic model cross-sections. In most locations where flow containment was lost at the limits of the models, backwater conditions were considered and the floodplains adjusted with an automated post-processing step to include additional backwater areas. Figure 4 shows backwater that was added beyond the limits of the hydraulic model. Figure 5 shows an example of backwater that required additional area because the water surface elevations extend upstream beyond the upstream limits of most models.

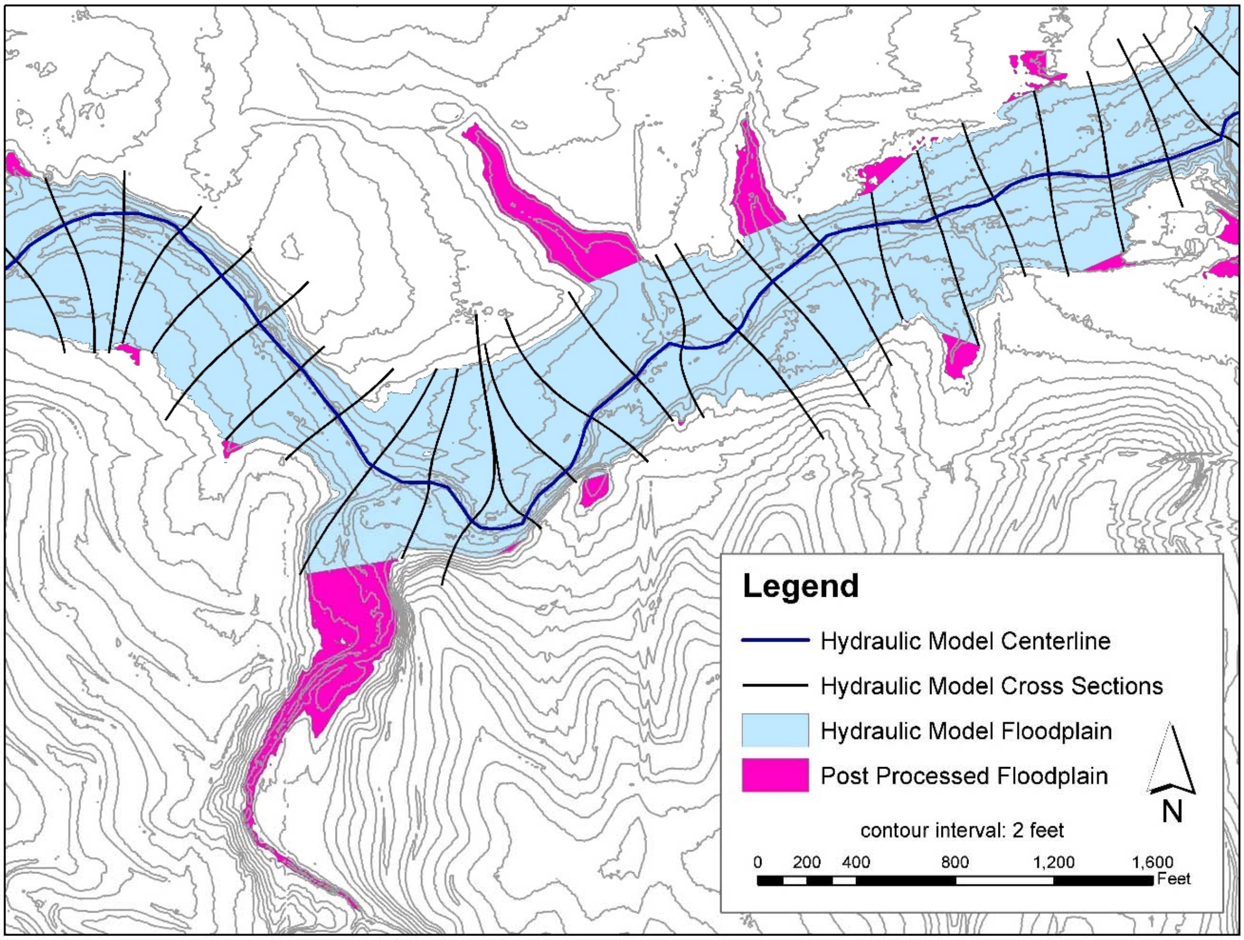


Figure 4: Post processed floodplain to add backwater areas along a modeled reach that would be flooded but were not reflected in the hydraulic model, typically these occur as small tributaries join a larger reach.

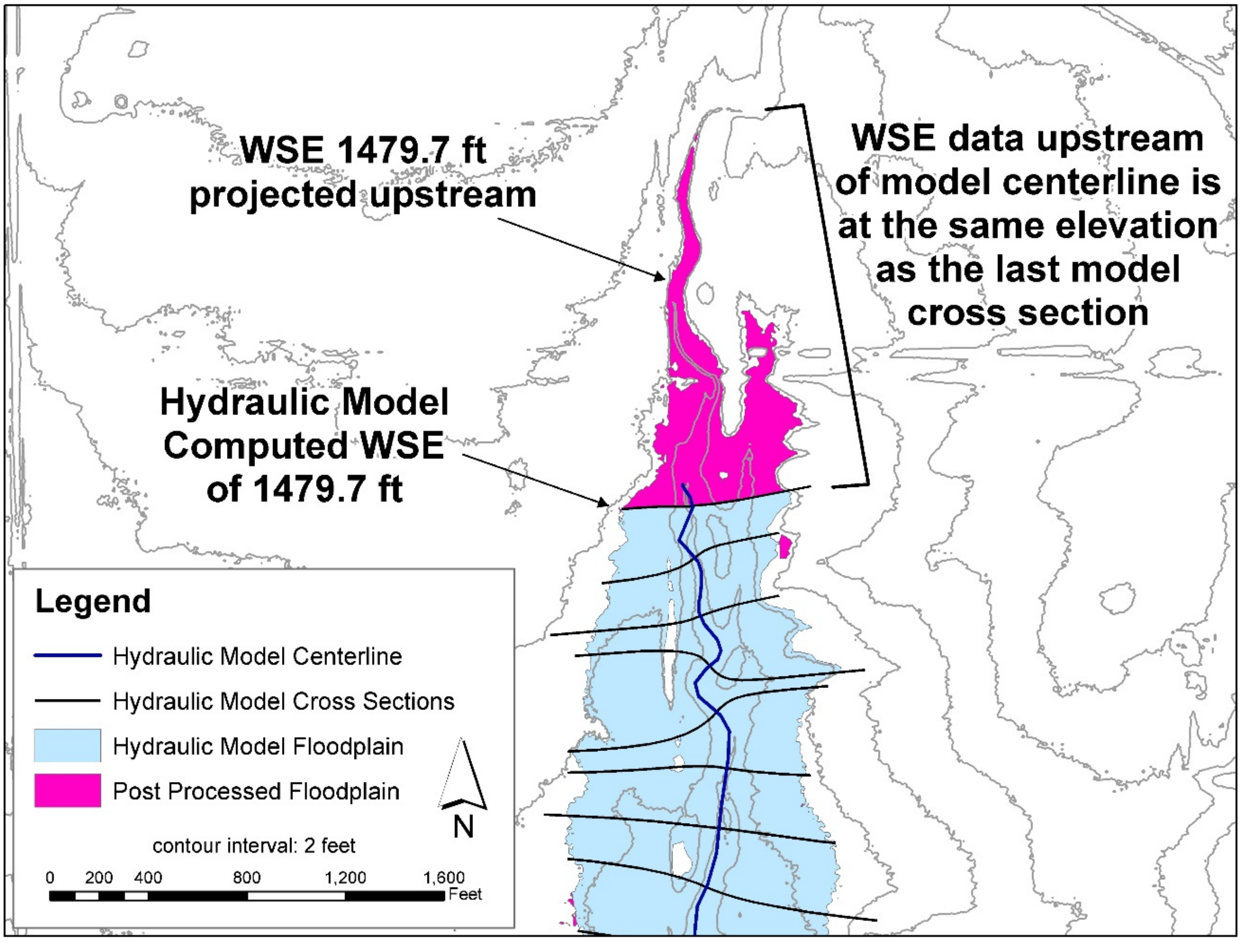


Figure 5: The post processing of floodplains also adds backwater areas upstream of the hydraulic model, these areas have the projected water surface from the most upstream cross section.

For locations where the models overlap, e.g. at confluences, the highest water surface elevation across all models dominates and results in the largest delineated floodplain by definition.

Dams and reservoirs are accounted for by simply placing a model cross-section along the upstream face of the dam at the same elevation as the emergency spillway

4.9. Deliverables

The HEC-RAS models have been created for the following flood profiles: 10-, 25-, 50-, 100-, and 500-year events. Two additional profiles the 100-year plus and 100-year minus have been created, that alter the 100-year profiles based on the standard error reported for applicable regression equations.

For all these profiles the same HEC-RAS geometries are used with the exception of the 10-year peak flow model.

Under HydraulicModels folder, 7 HUC10 folders along with Washita are include. Each of these 7 HUC10 folders contain individual hydraulic models for each stream. Streamline_model_Index spatial file provides the location of the streams and their corresponding model number. See Figure 6 below for the HUC10 Folder structure.

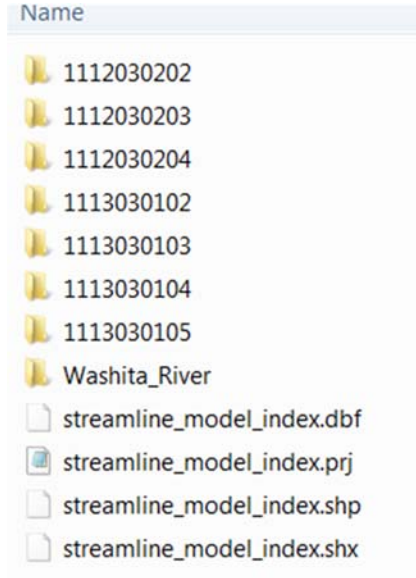


Figure 6: HEC-RAS HUC10 Folder structure

For the 10-year model the same cross-sections as the other events have been used but shortened or trimmed to limits that contain the 10-yr flow.

For all events an identical file and folder structure has been established and provided in the supplemental folder.

Inside each folder, for a given event, there are folders for each individual reach (each reach has been assigned a reach number that is assigned to the folder)

Each reach folder contains the following files as describe in the Table 5 below

Table 5: Data contents in each folder for various flood events

File Name	Type	Description
stream centerline (reach number).shp	Shape files	For example for reach number 35447 the stream centerline is 35447.shp
floodplain: (reach_number)_flood_00XX.shp	Shape files	for which the the XX represents the part number, large reaches are divided into multiple parts
cross sections: (reach_number)_xsecs_results.shp	Shape files	shapefile shows cross section locations and contains attributes with hydraulic model results

backwater floodplain: expand_(reach_number)_00XX_flood_redelin.shp	Shape files	floodplains expanded to include backwater areas beyond the cross section limits *Note: backwater processing has only been run for the 10-, 100-, and 500-year events
water surface grids	Grid format	similar naming convention to floodplains and backwater processed floodplains, provided as .tif files
Topo Grids	Grid format	similar naming convention to floodplains and backwater processed floodplains, provided as .tif files
HEC-RAS files: (reach_number)_ras.XXX	HEC-RAS	XXX represents all the HEC-RAS standard file and formats (flow -.f01, geometry - .g01, etc.)

For each event the individual model GIS files have been merged into the following files (where XX is the event name: 10yr, 25yr, etc).

5. Flood Risk Products and Datasets

The Flood Risk Database (FRD) is the key product that will support all other flood risk products and datasets. It is a database of non-regulatory flood risk data which contains the digital data used to prepare the Flood Risk Report (FRR) and Flood Risk Map (FRM), as well as other ancillary data generated during Base Level Engineering analysis.

As part of this project, Multi-Frequency Depth Grid and Water Surface Grids are produced. For BLE study areas, it is required to produce 1% and 0.2% annual chance profiles. However, as part of the project additional depth and water surface grids (including 10%, 4%, and 2%) are produced and delivered as part of the BLE deliverables, which are further discussed in section 9 of this report.

All depth and water surface grids (rasters) within the FRD are floating point with data rounded to the nearest tenth of a unit (i.e., 0.1 feet, 0.1 feet/second, or 0.1%) and have the same spatial reference, origin, resolution and rotation as one another. All elevation data in depth and water surface elevation rasters, are reference the North American Vertical Datum of 1988 (NAVD88) with units of US Survey Feet.

6. CNMS Validation

Under Title 42 of the Code of Federal Regulations, Chapter III, Section 4101(e), FEMA is to revise and update all floodplain areas and flood risk zones identified, delineated, or established, based on an analysis of all natural hazards affecting flood risks on a five-year cycle. To accomplish this goal, the Coordinated Needs Management Strategy (CNMS) establishes criteria by which to evaluate flood hazard studies and stores the study validation results and validation status in a database. Further, progress towards this goal is measured through the New, Valid, and Updated Engineering (NVUE) program metric.

As part of this project, CNMS validation of 640 miles was completed, which included 16 miles of detailed study miles and 624 miles of approximate study miles. Detailed studies were subjected to the complete validation processes as documented in the CNMS User's Guide Version 6.0 (FEMA, November 2016), which includes the review of 17 separate elements of a study's input data. The approximate studies were reviewed first for the A1 through A4 checks based on the November 2016 procedures. Base Level Engineering analysis (A5 check) was completed for those studies that failed at least one of the A1 through A4 checks.

6.1. Detailed Validation

Detailed study validation resulted in a x % revalidation rate calculated by mileage for all detailed miles that were part of this project. The following critical and secondary checks were evaluated based on the latest FEMA CNMS guidance.

- Critical Checks
    - (C1) Major change in gage record since effective analysis that includes major flood events
    - (C2) Updated and effective peak discharges differ significantly
    - (C3) Model methodology no longer appropriate
    - (C4) Addition/removal of a major flood control structure
    - (C5) Current channel reconfiguration outside effective SFHA
    - (C6) Five or more new or removed hydraulic structures that impact BFEs
    - (C7) Significant channel fill or scour

- Secondary Checks
    - (S1) Use of rural regression equations in urbanized areas
    - (S2) Repetitive losses outside the SFHA
    - (S3) Increase in impervious area in the sub-basin of more than 50 percent
    - (S4) One to four new or removed hydraulic structures that impact BFEs
    - (S5) Channel improvements / Shoreline changes
    - (S6) Availability of better topography/bathymetry
    - (S7) Changes to vegetation or land use
    - (S9) Significant storms with High Water Marks
    - (S10) New regression equations

6.2. Approximate Study Validation

The Zone A validation process begins with an assessment of three checks (A1-A3) which serve as an initial screening to efficiently categorize some Zone A studies as "Valid" or "Unverified" in the CNMS Inventory. Additional assessments include checking if the effective Zone A study is backed by technical data (A4) and the comparison of the effective Zone A study against a Refined Zone A

Engineering study (A5). For the purposes of these Zone A validation assessment procedures, either Large Scale Automated Engineering (LSAE) or Base Level Engineering (BLE) are appropriate sources for a Refined Zone A Engineering study. For regulatory FIRM production work, only Base Level Engineering would be appropriate. The following checks were evaluated based on the latest FEMA CNMS guidance.

- (A1) Check for Significant Topography Updates
- (A2) Check for Significant Hydrology Changes
- (A3) Check for Significant Development in the Watershed
- (A4) Check if Study was backed by Technical Data
- (A5) Comparison of Refined Zone A Engineering and Effective Zone A

7. Quality Assurance / Quality Control (QA/QC)

STARR II conducted a detailed review of the data utilized for this analysis at task level as part of STARR II Quality Management Plan (QMP). As part of QMP framework, STARR II maintains a consistent quality checklists and folder structure. Individual checklists and Technical review form are provided in Appendix D.

8. Base Level Engineering Deliverables

As described in the Regional BLE Submittal Guidance, dated June 2017, following datasets are included in the FRD as shown in the table below. Appendix E of this report provides additional details about Base Level Engineering Database.

Category	File Name	File Type	Description
Base Dataset	S_FRD_Pol_AR	Polygon	Political/Community Layer
	S_HUC_AR	Polygon	HUC8 Basin
EBFE Dataset	XS	Line	Hydraulic Cross-Sections
	WTR_LN	Line	Stream Centerline
	DTL_STUD_LN	Line	Stream Centerline – Detailed Study on FIRM
	DTL_STUD_AR	Polygon	Bounding Area – Detailed Study on FIRM
	FLD_HAZ_AR	Polygon	Seamless 1% and 0.2% floodplains included

Category	File Name	File Type	Description
	TENPCT_FP	Polygon	Seamless 10% floodplain
Mitigation Datasets	A_AOMI_PT	Point	Location of structures where information may refine H&H analysis
	S_CenBlk_AR	Polygon	Census Blocks within HUC8
CNMS Datasets	S_Studies_Ln	Line	CNMS validation status for streams included on current FIRMs
	S_UnMapped_Ln	Line	CNMS stream centerlines for streams not currently included on the FIRM
Hazus Dataset	LA_RA_Results	Table	Loss analysis results
Grids	BLE_WSE1PCT	Raster	Water Surface Elevation Grid – 1% annual chance
	BLE_WSE0_2PCT	Raster	Water Surface Elevation Grid – 0.2% annual chance
	BLE_DEP01PCT	Raster	Flood Depth Grid – 1% annual chance
	BLE_DEP0_2PCT	Raster	Flood Depth Grid – 0.2 % annual chance

9. References

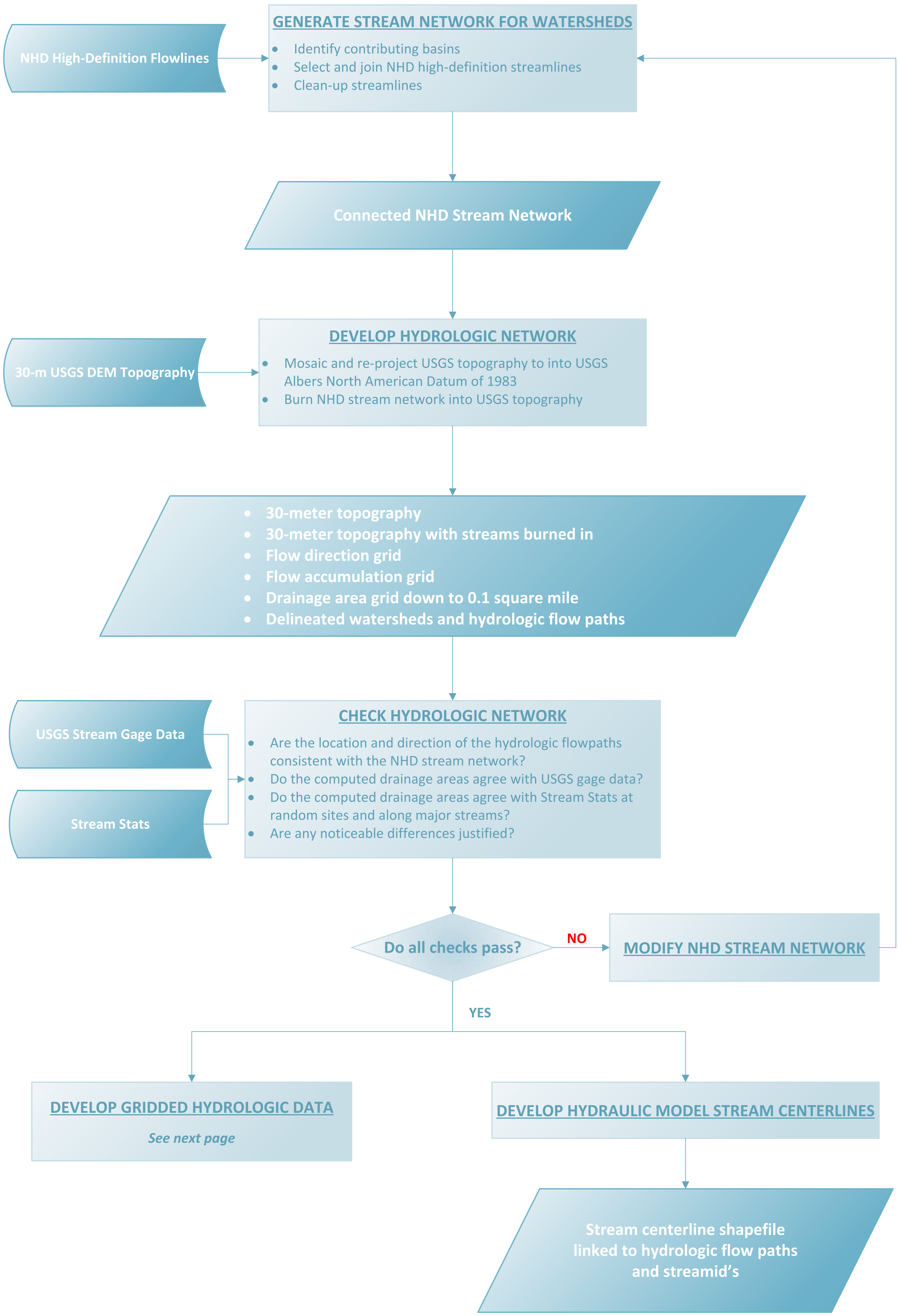
Asquith, W.H. and Roussel, M.C., 2009, Regression Equations for Estimation of Annual Peak-Streamflow Frequency for Undeveloped Watersheds in Texas Using an L-moment-Based, PRESS-Minimized, Residual-Adjusted Approach, U.S. Geological Survey Scientific Investigations Report 2009-5087 (Texas Department of Transportation Research Report 0-5521-1).

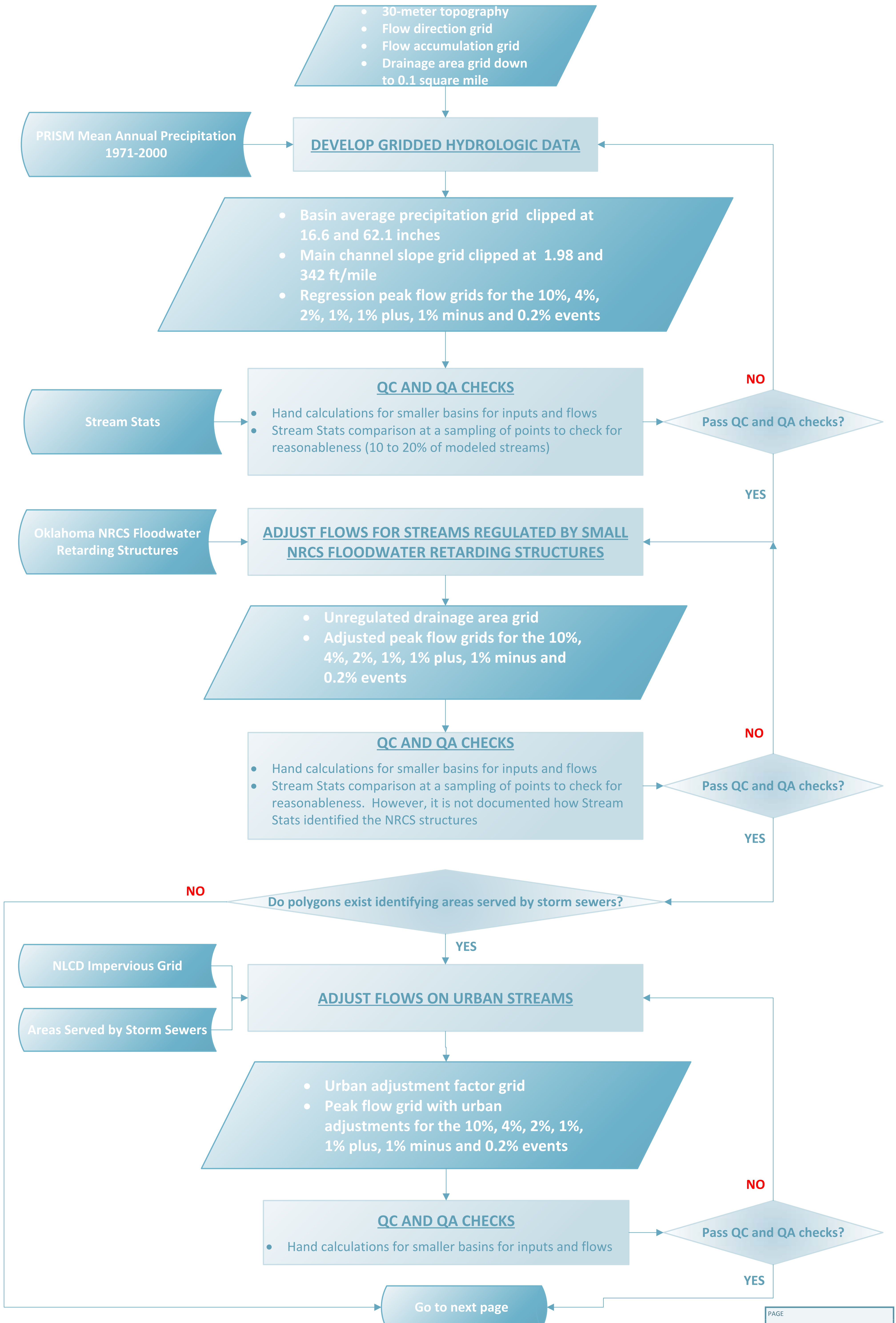
Federal Emergency Management Agency, First Order Approximation- Methodology, Validation, and Scalability Guidance Procedures, Verson 1.5, April 2014.

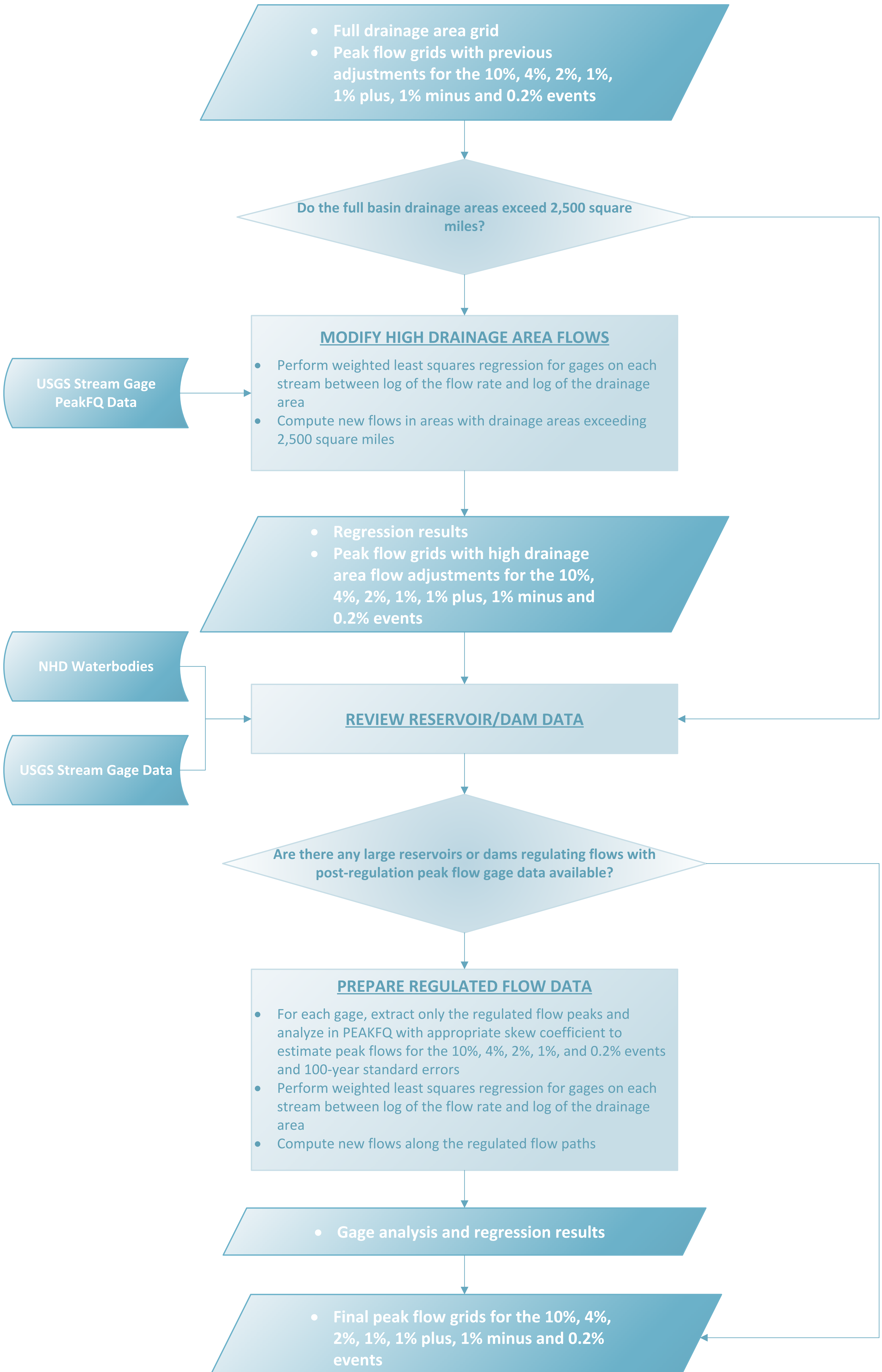
Hydrologic Engineering Center, HEC-RAS River Analysis System, Version 4.1, U.S. Army Corps of Engineers, Davis, California, March 2011.

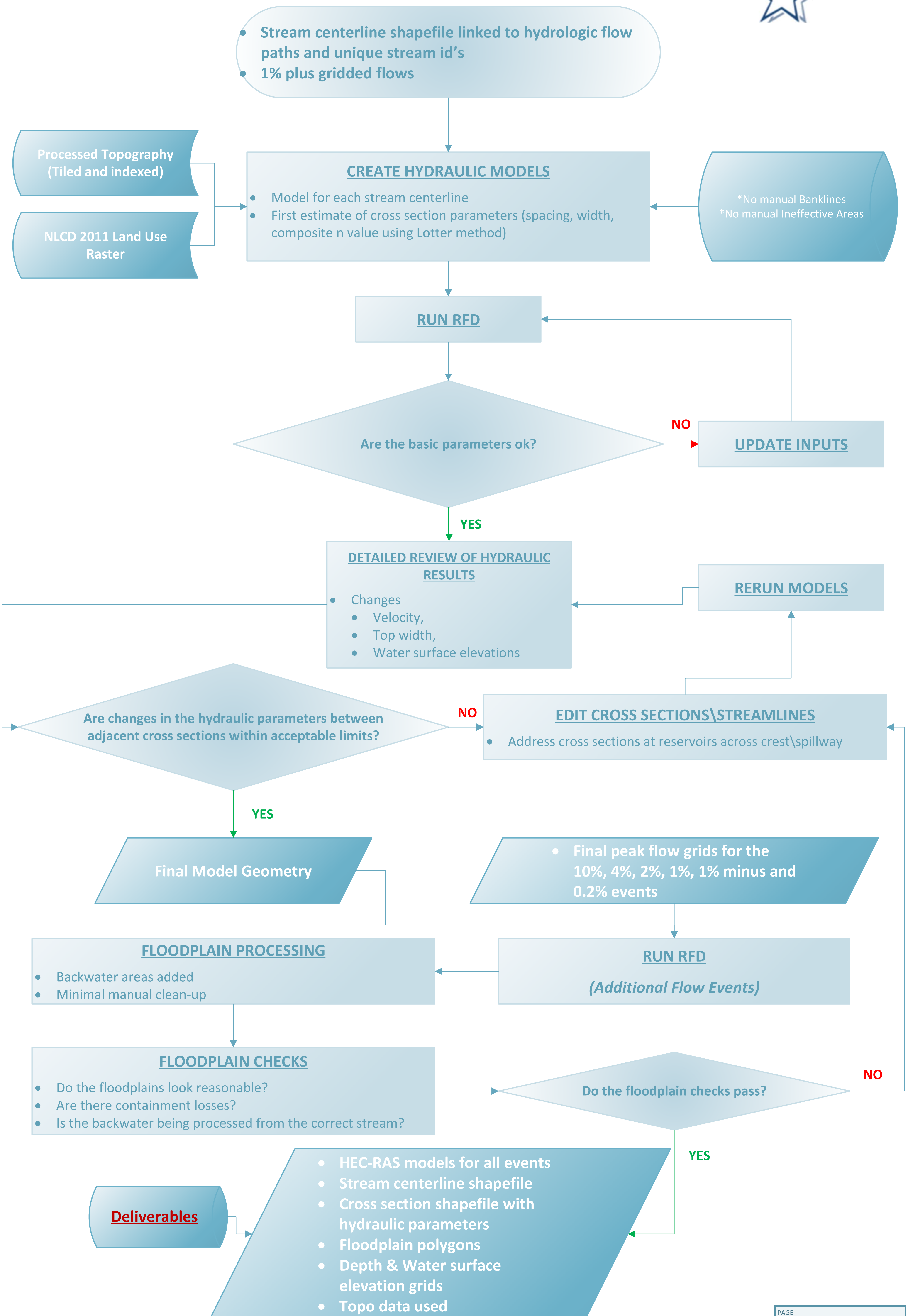
Water Resources Council, Hydrology Committee, Guidelines for Determining Flood Flow Frequencies, Bulletin #17B, U.S. Department of the Interior, September 1981.

Appendix A - STARR II Hydrology and Hydraulics Process Flow Chart


NHD High-Definition Flowlines
GENERATE STREAM NETWORK FOR WATERSHEDS
Identify contributing basins
Select and join NHD high-definition streamlines
Clean-up streamlines
Connected NHD Stream Network
30-m USGS DEM Topography
DEVELOP HYDROLOGIC NETWORK
Mosaic and re-project USGS topography to into USGS Albers North American Datum of 1983
Burn NHD stream network into USGS topography
30-meter topography
30-meter topography with streams burned in
Flow direction grid
Flow accumulation grid
Drainage area grid down to 0.1 square mile
Delineated watersheds and hydrologic flow paths
USGS Stream Gage Data
Stream Stats
CHECK HYDROLOGIC NETWORK
Are the location and direction of the hydrologic flowpaths consistent with the NHD stream network?
Do the computed drainage areas agree with USGS gage data?
Do the computed drainage areas agree with Stream Stats at random sites and along major streams?
Are any noticeable differences justified?
Do all checks pass?
NO
MODIFY NHD STREAM NETWORK
YES
DEVELOP GRIDDED HYDROLOGIC DATA
See next page
DEVELOP HYDRAULIC MODEL STREAM CENTERLINES
Stream centerline shapefile linked to hydrologic flow paths and streamid's


30-meter topography
Flow direction grid
Flow accumulation grid
Drainage area grid down to 0.1 square mile
PRISM Mean Annual Precipitation 1971-2000
DEVELOP GRIDDED HYDROLOGIC DATA
Basin average precipitation grid clipped at 16.6 and 62.1 inches
Main channel slope grid clipped at 1.98 and 342 ft/mile
Regression peak flow grids for the 10%, 4%, 2%, 1%, 1% plus, 1% minus and 0.2% events
Stream Stats
QC AND QA CHECKS
Hand calculations for smaller basins for inputs and flows
Stream Stats comparison at a sampling of points to check for reasonableness (10 to 20% of modeled streams)
NO
Pass QC and QA checks?
YES
Oklahoma NRCS Floodwater Retarding Structures
ADJUST FLOWS FOR STREAMS REGULATED BY SMALL NRCS FLOODWATER RETARDING STRUCTURES
Unregulated drainage area grid
Adjusted peak flow grids for the 10%, 4%, 2%, 1%, 1% plus, 1% minus and 0.2% events
QC AND QA CHECKS
Hand calculations for smaller basins for inputs and flows
Stream Stats comparison at a sampling of points to check for reasonableness. However, it is not documented how Stream Stats identified the NRCS structures
NO
Pass QC and QA checks?
YES
NO
Do polygons exist identifying areas served by storm sewers?
YES
NLCD Impervious Grid
Areas Served by Storm Sewers
ADJUST FLOWS ON URBAN STREAMS
Urban adjustment factor grid
Peak flow grid with urban adjustments for the 10%, 4%, 2%, 1%, 1% plus, 1% minus and 0.2% events
QC AND QA CHECKS
Hand calculations for smaller basins for inputs and flows
NO
Pass QC and QA checks?
YES
Go to next page


Full drainage area grid
Peak flow grids with previous adjustments for the 10%, 4%, 2%, 1%, 1% plus, 1% minus and 0.2% events
Do the full basin drainage areas exceed 2,500 square miles?
MODIFY HIGH DRAINAGE AREA FLOWS
Perform weighted least squares regression for gages on each stream between log of the flow rate and log of the drainage area
Compute new flows in areas with drainage areas exceeding 2,500 square miles
USGS Stream Gage PeakFQ Data
Regression results
Peak flow grids with high drainage area flow adjustments for the 10%, 4%, 2%, 1%, 1% plus, 1% minus and 0.2% events
NHD Waterbodies
USGS Stream Gage Data
REVIEW RESERVOIR/DAM DATA
Are there any large reservoirs or dams regulating flows with post-regulation peak flow gage data available?
PREPARE REGULATED FLOW DATA
For each gage, extract only the regulated flow peaks and analyze in PEAKFQ with appropriate skew coefficient to estimate peak flows for the 10%, 4%, 2%, 1%, and 0.2% events and 100-year standard errors
Perform weighted least squares regression for gages on each stream between log of the flow rate and log of the drainage area
Compute new flows along the regulated flow paths
Gage analysis and regression results
Final peak flow grids for the 10%, 4%, 2%, 1%, 1% plus, 1% minus and 0.2% events


Stream centerline shapefile linked to hydrologic flow paths and unique stream id's
1% plus gridded flows
Processed Topography (Tiled and indexed)
NLCD 2011 Land Use Raster
CREATE HYDRAULIC MODELS
Model for each stream centerline
First estimate of cross section parameters (spacing, width, composite n value using Lotter method)
*No manual Banklines
*No manual Ineffective Areas
RUN RFD
Are the basic parameters ok?
NO
UPDATE INPUTS
YES
DETAILED REVIEW OF HYDRAULIC RESULTS
Changes
Velocity,
Top width,
Water surface elevations
RERUN MODELS
Are changes in the hydraulic parameters between adjacent cross sections within acceptable limits?
NO
EDIT CROSS SECTIONS\STREAMLINES
Address cross sections at reservoirs across crest\spillway
YES
Final Model Geometry
Final peak flow grids for the 10%, 4%, 2%, 1%, 1% minus and 0.2% events
FLOODPLAIN PROCESSING
Backwater areas added
Minimal manual clean-up
RUN RFD
(Additional Flow Events)
FLOODPLAIN CHECKS
Do the floodplains look reasonable?
Are there containment losses?
Is the backwater being processed from the correct stream?
Do the floodplain checks pass?
NO
YES
Deliverables
HEC-RAS models for all events
Stream centerline shapefile
Cross section shapefile with hydraulic parameters
Floodplain polygons
Depth & Water surface elevation grids
Topo data used

Appendix B - Overview map

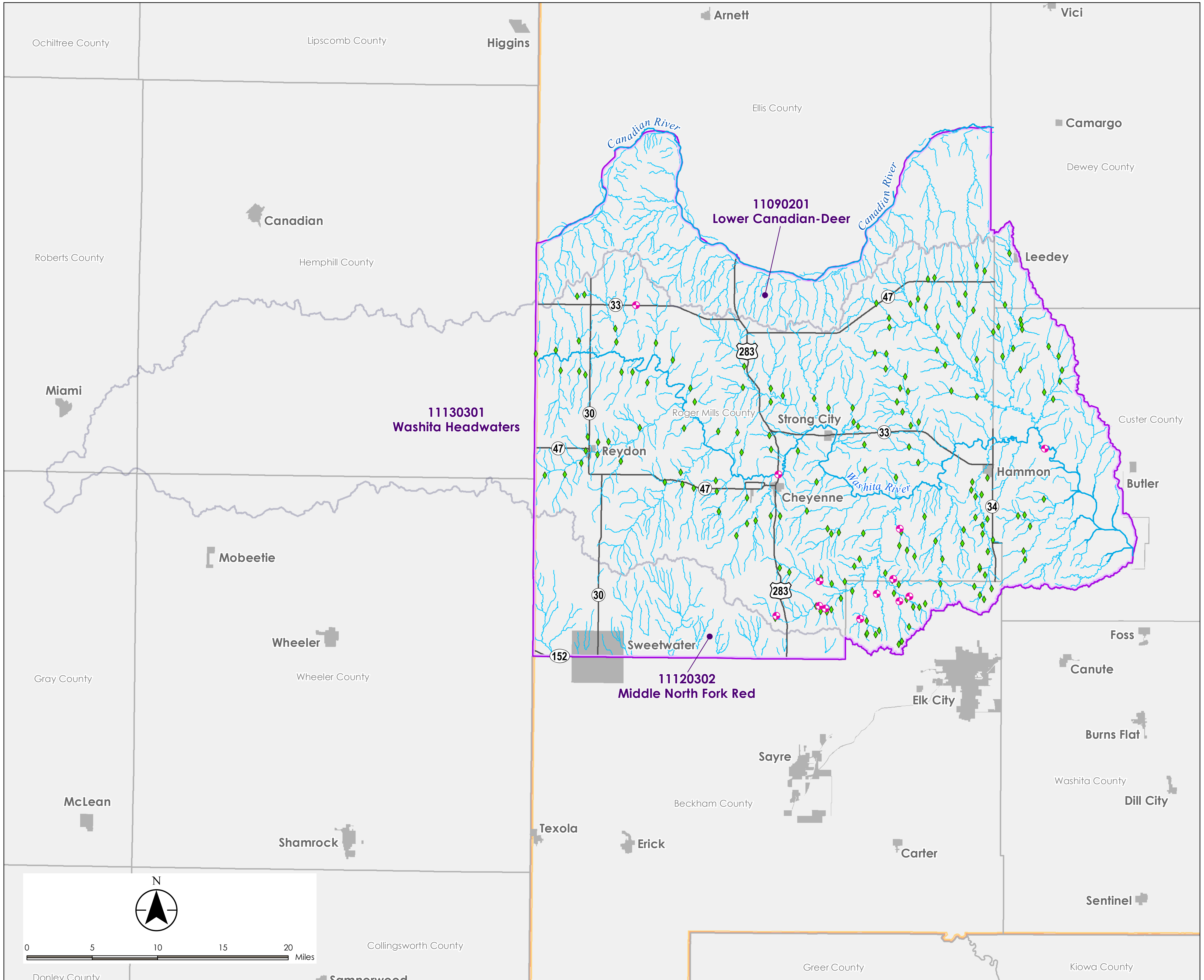


Figure No. 1 of 4

Project Area Overview

Title

Roger Mills County, Oklahoma
Base Level Engineering Analysis

Client/Project

FEMA Region 6

Project Location:

Prepared by MRW on 2017-01-30
Technical Review by SVK on 2017-01-30

HUC 8 Code:
- 11130301 - Washita Headwaters
- 11090201 - Lower Canadian-Deer
- 11120302 - Middle North Fork Red

Gage Stations
NRCS Flow Retarding Structures
Streams
Highways
Project Area
Watershed Boundary
Cities and Towns
County Boundaries
Cheyenne-Arapaho TSA

Text County Name
Text City or Town Name
Text Watershed Name (HUC 8)

1:500,000 (at original document size of 11" x 17")

Notes

1. Coordinate System: NAD 1983 2011 UTM Zone 14N
2. Drainage areas shown are for visualization purpose only. For detailed results, refer to hydrology grids.

STARR II Strategic Alliance for Risk Reduction

FEMA

Appendix C - Manning's n Values by NLCD 2011 Land Use Code

Appendix 5: Manning n values

NLCD 2011 Land Use Code		Range of n values in literature	Utilized n-value
Water			
11	Open Water - areas of open water, generally with less than 25% cover of vegetation or soil.	0.001 - 0.06	0.013
12	Perennial Ice/Snow - areas characterized by a perennial cover of ice and/or snow, generally greater than 25% of total cover.	.01 - 0.027	0.020
Developed			
21	Developed, Open Space - areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.	0.01 -0.048	0.040
22	Developed, Low Intensity - areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units.	0.01 - 0.12	0.060
23	Developed, Medium Intensity – areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.	0.01 - 0.1	0.075
24	Developed High Intensity -highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.	0.01 - 0.12	0.100
Barren			
31	Barren Land (Rock/Sand/Clay) - areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.	0.011 - 0.09	0.030
Forest			
41	Deciduous Forest - areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.	0.07 - 0.36	0.120
42	Evergreen Forest - areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.	0.07 - 0.32	0.120
43	Mixed Forest - areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.	0.1 - 0.4	0.120

NLCD 2011 Land Use Code		Range of n values in literature	Utilized n-value
Shrubland			
51	Dwarf Scrub - Alaska only areas dominated by shrubs less than 20 centimeters tall with shrub canopy typically greater than 20% of total vegetation. This type is often co-associated with grasses, sedges, herbs, and non-vascular vegetation.	0.04	0.040
52	Shrub/Scrub - areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.	0.035 - 0.4	0.055
Herbaceous			
71	Grassland/Herbaceous - areas dominated by gramanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.	0.022 - 0.36	0.040
72	Sedge/Herbaceous - Alaska only areas dominated by sedges and forbs, generally greater than 80% of total vegetation. This type can occur with significant other grasses or other grass like plants, and includes sedge tundra, and sedge tussock tundra.	0.03	0.040
73	Lichens - Alaska only areas dominated by fruticose or foliose lichens generally greater than 80% of total vegetation.	0.027	0.035
74	Moss - Alaska only areas dominated by mosses, generally greater than 80% of total vegetation.	0.025	0.030
Planted/Cultivated			
81	Pasture/Hay – areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.	0.033 - 0.325	0.040
82	Cultivated Crops – areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.	0.035 - 0.04	0.040
Wetlands			
90	Woody Wetlands - areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.	0.037 - 0.14	0.090
95	Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.	0.045	0.045

Appendix D - Quality Assurance / Quality Control (QA/QC)

	Roger Mills County, OK- Base Level Engineering	Date: 07/20/2017			Date:		
		Technica Selena Foreman			QC Verif Michael Wilson		
	QC Check and Description	P/F/NA	Comments	Corr. By: Init/Date	P/F/NA	Comments	Corr. By: Init/Date
No.	General Requirements						
1	Is the metadata complete and correct?	P					
2	Are deliverables complete and consistent?	P					
3	Is the geodatabase in the proper projection?	P					
4	Does the geodatabase have the proper file structure?	P					

	Roger Mills County, OK- Base Level Engineering	Date: 07/20/2017 Technica Selena Foreman			Date: QC Verif Michael Wilson		
	QC Check and Description	P/F/NA	Comments	Corr. By: Init/Date	P/F/NA	Comments	Corr. By: Init/Date
No.	S_FRD_Pol_Ar						
5	Does the feature class follow the *Flood Risk Database Technical Reference* ?	P					
6	Are values in POL_AR_ID unique?	P					
7	Is DFIRM_ID populated for all records?	P					
8	Is CID populated for all records?	P					
9	Is POL_NAME1 populated for all records	P					
10	Is POL_NAME2 populated where necessary?	P					
11	Is CO_FIPS populated correctly for all records?	P					
12	Is ST_FIPS populated correctly for all records?	P					
13	Is COMM_NO populated for all records?	P					
14	Is POPULATION populated for all records?	P					
15	Is TOT_POP populated for all records?	P					
16	Is PCT_POP populated for all records?	P					
17	Is LND_AR_SM populated for all records?	P					
18	Is TOT_LND_AR populated for all records?	P					
19	Is PCT_LND_AR populated for all records?	P					
20	Is NFIPSTATUS populated for all records?	P					
21	Is CRS_RATING populated for all records?	P					
22	Is PASTDECLAR populated for all records?	P					
23	Is FLD_POLICY populated for all records?	P					
24	Is POLICY_COV populated for all records?	P					
25	Is HMP_STATUS populated for all records?	P					
26	Is HMP_NAME populated where HMP_STATUS is "T"?	P					
27	Is HMP_EXPIRE populated where HMP_STATUS is "T"?	P					
28	Is POL_TYPE populated for all records?	P					
29	Is HUC8_CODE populated for all records?	P					
30	Is CASE_NO populated for all records?	P					
31	Is VERSION_NO populated for all records?	P					
32	Is SOURCE_CIT populated for all records?	P					
33	Are source citations used recorded in L_SOURCE_CIT?	P					
34	Does the feature class appear free of spatial errors or irregularities?	P					
No.	S_HUC_Ar						

35	Does the feature class follow the *Flood Risk Database Technical Reference* ?	P					
36	Is HUC_CODE populated for all records?	P					
37	Is HUC_NAME populated for all records?	P					
38	Is DIGITS populated for all records?	P					
39	Is CASE_NO populated for all records?	P					
40	Is VERSION_NO populated for all records?	P					
41	Is SOURCE_CIT populated for all records?	P					
42	Are source citations used recorded in L_SOURCE_CIT?	P					
43	Does the feature class appear free of spatial errors or irregularities?	P					

	Roger Mills County, OK- Base Level Engineering	Date: 07/20/2017 Technica Selena Foreman			Date: QC Verif Michael Wilson		
	QC Check and Description	P/F/NA	Comments	Corr. By: Init/Date	P/F/NA	Comments	Corr. By: Init/Date
No.	EBLE_Dtl_Stud_Ar						
44	Is DTL_AR_ID populated for all records?	P					
45	Is VERSION_ID populated for all records?	P					
46	Is EFF_DATE populated for all records?	P					
47	Is SOURCE_CIT populated for all records?	P					
48	Are source citations used recorded in L_SOURCE_CIT?	P					
49	Is FIRM_PAN populated for all records?	P					
50	Is TYPE populated for all records?	P					
51	Is CD_YN populated for all records?	P					
52	Is CD_POC populated for all records?	P					
53	Is CD_ADD1 populated for all records?	P					
54	Is CD_ADD2 populated for all records?	P					
55	Is CD_CTY populated for all records	P					
56	Is CD_STATE populated for all records?	P					
57	Is CD_ZIP populated for all records?	P					
58	Is CD_PHONE populated for all records?	P					
59	Is CD_EMAIL populated for all records?	P					
60	Are hidden fields populated appropriately?	P					
61	Does the feature class appear free of spatial errors or irregularities?	P					
No.	EBLE_Dtl_Stud_Ln						
62	Is DTL_AR_ID populated for all records?	P					
63	Is VERSION_ID populated for all records?	P					
64	Is EFF_DATE populated for all records?	P					
65	Is SOURCE_CIT populated for all records?	P					
66	Are source citations used recorded in L_SOURCE_CIT?	P					
67	Is FIRM_PAN populated for all records?	P					
68	Is TYPE populated for all records?	P					
69	Is CD_YN populated for all records?	P					
70	Is CD_POC populated for all records?	P					
71	Is CD_ADD1 populated for all records?	P					
72	Is CD_ADD2 populated for all records?	P					
73	Is CD_CTY populated for all records	P					
74	Is CD_STATE populated for all records?	P					

75	Is CD_ZIP populated for all records?	P					
76	Is CD_PHONE populated for all records?	P					
77	Is CD_EMAIL populated for all records?	P					
78	Are hidden fields populated appropriately?	P					
79	Does the feature class appear free of spatial errors or irregularities?	P					
No.	**EBLE_Fld_Haz_Ar**						
80	Is EST_ID populated for all records?	P					
81	Is VERSION_ID populated for all records?	P					
82	Are values in EST_AR_ID unique?	P					
83	Is EST_FLD_ZONE populated for all records?	P					
84	Is EST_ZONE_SUBTY populated where necessary?	P					
85	Is V_DATUM populated for all records?	P					
86	Is LEN_UNIT populated for all records?	P					
87	Is SOURCE_CIT populated for all records?	P					
88	Are source citations used recorded in L_SOURCE_CIT?	P					
89	Are hidden fields populated appropriately?	P					
90	Does the feature class appear free of spatial errors or irregularities?	P					
No.	**EBLE_Wtr_Ar**						
91	Is EST_ID populated for all records?	P					
92	Is VERSION_ID populated for all records?	P					
93	Are values in WTR_AR_ID unique?	P					
94	Is WTR_NM populated where necessary?	P					
95	Is SOURCE_CIT populated for all records?	P					
96	Are source citations used recorded in L_SOURCE_CIT?	P					
97	Are hidden fields populated appropriately?	P					
98	Does the feature class appear free of spatial errors or irregularities?	P					
No.	**EBLE_Wtr_Ln**						
99	Is EST_ID populated for all records?	P					
100	Is VERSION_ID populated for all records?	P					
101	Are values in WTR_LN_ID unique?	F	Value "23" occurs twice.				
102	Is WTR_NM populated where necessary?	P					
103	Is SOURCE_CIT populated for all records?	P					
104	Are source citations used recorded in L_SOURCE_CIT?	P					
105	Is STATUS populated for all records?	P					
106	Is DT_AVAIL populated for all records?	P					
107	Is EST_MODEL_URL populated for all records?	P					
108	Are hidden fields populated appropriately?	P					

109	Does the feature class appear free of spatial errors or irregularities?	P						
No.	**EBLE_XS**							
110	Is EST_ID populated for all records?	P						
111	Is VERSION_ID populated for all records?	P						
112	Are values in XS_LN_ID unique?	P						
113	Is WTR_NM populated where necessary?	P						
114	Is STREAM_STN populated for all records?	P						
115	Is START_ID populated for all records?	P						
116	Is XS_LN_TYP populated where necessary?	P						
117	Is EST_WSEL_1PCT populated for all records?	P						
118	Is V_DATUM populated for all records?	P						
119	Is MODEL_ID populated for all records?	P						
120	Is EST_WSEL_10PCT populated for all records?	P						
121	Is EST_WSEL_4PCT populated for all records?	P						
122	Is EST_WSEL_2PCT populated for all records?	P						
123	Is EST_WSEL_1PCTPLUS populated for all records?	P						
124	Is EST_WSEL_1PCTMINUS populated for all records?	P						
125	Is EST_WSEL_0PT2PCT populated for all records?	P						
126	Is EST_Q_10PCT populated for all records?	P						
127	Is EST_Q_4PCT populated for all records?	P						
128	Is EST_Q_2PCT populated for all records?	P						
129	Is EST_Q_1PCT populated for all records?	P						
130	Is EST_Q_1PCTPLUS populated for all records?	P						
131	Is EST_Q_1PCTMINUS populated for all records?	P						
132	Is EST_Q_0PT2PCT populated for all records?	P						
133	Is SOURCE_CIT populated for all records?	P						
134	Are source citations used recorded in L_SOURCE_CIT?	P						
135	Are hidden fields populated appropriately?	P						
136	Does the feature class appear free of spatial errors or irregularities?	P						
No.	**EBLE_10YRFP**							
137	Is EST_ID populated for all records?	P						
138	Is VERSION_ID populated for all records?	P						
139	Are values in EST_AR_ID unique?	P						
140	Is EST_FLD_RISK populated as "Extreme" for all records?	P						
141	Is SOURCE_CIT populated for all records?	P						
142	Are source citations used recorded in L_SOURCE_CIT?	P						
143	Are all other fields populated with null values?	P						

144	Does the feature class appear free of spatial errors or irregularities?	P					

	Roger Mills County, OK- Base Level Engineering	Date: 07/20/2017			Date:		
		Technica Selena Foreman			QC Verif Michael Wilson		
	QC Check and Description	P/F/NA	Comments	Corr. By: Init/Date	P/F/NA	Comments	Corr. By: Init/Date
No.	S_AOMI_Pt						
145	Does the feature class follow the *Flood Risk Database Technical Reference* ?	NA					
146	Is AOMI_ID unique for all records?	NA					
147	Is CID populated where necessary?	NA					
148	Is POL_NAME1 populated where necessary?	NA					
149	Is AOMI_CLASS populated for all records?	NA					
150	Is AOMI_TYPE populated for all records?	NA					
151	Is AOMI_CAT populated for all recordS?	NA					
152	Is AOMI_SRCE populated for all records	NA					
153	Is AOMI_INFO populated where necessary?	NA					
154	Is NOTES populated where necessary?	NA					
155	Is HUC8_CODE populated for all records?	NA					
156	Is CASE_NO populated for all records?	NA					
157	Is VERSION_ID populated for all records?	NA					
158	Is SOURCE_CIT populated for all recordS?	NA					
159	Are source citations used recorded in L_SOURCE_CIT?	NA					
160	Does the feature class appear free of spatial errors or irregularities?	NA					
No.	S_CenBlk_Ar						
161	Does the feature class follow the *Flood Risk Database Technical Reference* ?	P					
162	Is CEN_BLK_ID populated for all records?	P					
163	Is POPULATION populated for all records?	P					
164	Is ARV_BG_TOT populated for all records?	P					
165	Is ARC_CN_TOT populated for all records?	P					
166	Is ARV_BG_RES populated for all records?	P					
167	Is ARV_CN_RES populated for all records?	P					
168	Is ARV_BG_COM populated for all records?	P					
169	Is ARV_CN_COM populated for all records?	P					
170	Is ARV_BG_OTH populated for all records?	P					
171	Is ARV_CN_OTH populated for all records?	P					
172	Is HUC8_CODE populated for all records?	P					

173	Is CASE_NO populated for all records?	P					
174	Is VERSION_ID populated for all records?	P					
175	Is SOURCE_CIT populated for all recordS?	P					
176	Are source citations used recorded in L_SOURCE_CIT?	P					
177	Does the feature class appear free of spatial errors or irregularities?	P	See Note 6 below.				

	Roger Mills County, OK- Base Level Engineering	Date: 07/20/2017			Date:		
		Technica Selena Foreman			QC Verif Michael Wilson		
	QC Check and Description	P/F/NA	Comments	Corr. By: Init/Date	P/F/NA	Comments	Corr. By: Init/Date
No.	L_AOMI_Summary						
178	Does the table follow the *Flood Risk Database Technical Reference* ?	NA	See Note 7 below.				
179	Is AOMISUMMID populated for all records?	NA	See Note 7 below.				
180	IS POL_NAME1 populated for all records?	NA	See Note 7 below.				
181	IS AOMI_CLASS populated for all records?	NA	See Note 7 below.				
182	IS AOMI_TYP populated for all records?	NA	See Note 7 below.				
183	IS AOMI_CAT populated for all records?	NA	See Note 7 below.				
184	Is AOMI_SRCE populated for all records?	NA	See Note 7 below.				
185	Is TOTAL populated for all records?	NA	See Note 7 below.				
186	Is HUC8_CODE populated for all records?	NA	See Note 7 below.				
187	Is CASE_NO populated for all records?	NA	See Note 7 below.				
188	Is VERSION_ID populated for all records?	NA	See Note 7 below.				
No.	L_RA_Results						
189	Does the feature class follow the *Flood Risk Database Technical Reference* ?	NA	See Note 8 below.				
190	Is CEN_BLK_ID populated for all records?	NA	See Note 8 below.				
191	Is HAZARD_TYP populated for all records?	NA	See Note 8 below.				
192	Is RETURN_PER populated for all records?	NA	See Note 8 below.				
193	Is SCENAR_ID populated where necessary?	NA	See Note 8 below.				
194	Is RA_SOURCE populated for all records?	NA	See Note 8 below.				
195	Is TOT_LOSSES populated for all records?	NA	See Note 8 below.				
196	Is BL_TOT populated for all records?	NA	See Note 8 below.				
197	Is CL_TOT populated for all records?	NA	See Note 8 below.				
198	Is BL_RES populated for all records?	NA	See Note 8 below.				
199	Is CL_RES populated for all records?	NA	See Note 8 below.				
200	Is BL_COM populated for all records?	NA	See Note 8 below.				
201	Is CL_COM populated for all records?	NA	See Note 8 below.				
202	Is BL_OTH populated for all records?	NA	See Note 8 below.				
203	Is CL_OTH populated for all records?	NA	See Note 8 below.				
204	Is BUS_DISRPT populated for all records?	NA	See Note 8 below.				
205	Is HUC8_CODE populated for all records?	NA	See Note 8 below.				
206	Is CASE_NO populated for all records?	NA	See Note 8 below.				

207	Is VERSION_ID populated for all records?	NA	See Note 8 below.				
No.	**L_Source_Cit**						
208	Is SOURCE_CIT populated for all records?	P					
209	Is DFIRM_ID populated for all records?	P					
210	Is CITATION populated for all records?	P					
211	Is PUBLISHER populated for all records?	P					
212	Is TITLE populated for all records?	P					
213	Is AUTHOR populated where necessary?	P					
214	Is PUB_PLACE populated where necessary?	P					
215	Is PUB_DATE populated for all records?	P					
216	Is WEBLINK populated where necessary?	P					
217	Is SRC_SCALE populated where necessary?	P					
218	Is MEDIA populated for all records?	P					
219	Is CASE_NO populated for all records?	P					
220	Is VERSION_ID populated for all records?	P					

Note 7: This feature class was not checked because AOMI data was not collected for this study.

Note 8: The tables **L_RA_AAL**, **L_RA_Composite**, and **L_RA_Refined** are deprecated and were officially removed from the *Flood Risk Database Technical Reference* in May 2016, and replaced with **L_RA_Results**. Thus, the *Base Level Engineering Guidance* is outdated, but is in the process of being revised and updated. I've reviewed these tables against an older, superseded version of the *Flood Risk Database Technical Reference* , included as a separate section below.

	QC Check and Description	P/F/NA	Comments	Corr. By: Init/Date	P/F/NA	Comments	Corr. By: Init/Date
No.	**L_RA_AAL**						
A	Not Checked	NA	See Note A below.				
No.	**L_RA_Composite**						
B	Is CEN_BLK_ID populated for all records?	P	See Note B below.				
C	Is HAZARD_TYP populated for all records?	P					
D	Is RETURN_PER populated for all records?	P					
E	Is RA_SOURCE populated for all records?	P					
F	Is TOT_LOSSES populated for all records?	P					
G	Is BL_TOT populated for all records?	P					
H	Is CL_TOT populated for all records?	P					
I	Is BL_RES populated for all records?	P					
J	Is CL_RES populated for all records?	P					
K	Is BL_COM populated for all records?	P					
L	Is CL_COM populated for all records?	P					
M	Is BL_OTH populated for all records?	P					
N	Is CL_OTH populated for all records?	P					
O	Is BUS_DISRPT populated for all records?	P					

P	Is HUC8_CODE populated for all records?	P					
Q	Is CASE_NO populated for all records?	P					
R	Is VERSION_ID populated for all records?	P					
No.	**L_RA_Refined**						
S	Is CEN_BLK_ID populated for all records?	P	See Note B below.				
T	Is HAZARD_TYP populated for all records?	P					
U	Is RETURN_PER populated where necessary?	P					
V	Is SCENAR_ID populated where necessary?	P					
W	Is TOT_LOSSES populated for all records?	P					
X	Is BL_TOT populated for all records?	P					
Y	Is CL_TOT populated for all records?	P					
Z	Is BL_RES populated for all records?	P					
AA	Is CL_RES populated for all records?	P					
BB	Is BL_COM populated for all records?	P					
CC	Is CL_COM populated for all records?	P					
DD	Is BL_OTH populated for all records?	P					
EE	Is CL_OTH populated for all records?	P					
FF	Is BUS_DISRPT populated for all records?	P					
GG	Is HUC8_CODE populated for all records?	P					
HH	Is CASE_NO populated for all records?	P					
II	Is VERSION_ID populated for all records?	P					

Note A: This table was not checked because no records were included.
Note B: This table includes the SOURCE_CIT field not included in the supersed version of the *Flood Risk Database Technical Reference* I'm using as a guide. Since this table is deprecated and has been replaced with **L_RA_Results**, I'm not marking this as an error.

	Roger Mills County, OK- Base Level Engineering	Date: 07/20/2017			Date:		
		Technica Selena Foreman			QC Verif Michael Wilson		
	QC Check and Description	**P/F/NA**	**Comments**	**Corr. By: Init/Date**	**P/F/NA**	**Comments**	**Corr. By: Init/Date**
No.	**Depth Grids**						
221	Are there any non-spatial issues with the grids?	P					
222	Do the grids appear free of spatial errors or irregularities?	P					
No.	**Water Surface Elevation Grids**						
223	Are there any non-spatial issues with the grids?	P					
224	Do the grids appear free of spatial errors or irregularities?	P					

Appendix E - Base Level Engineering Database

1.0 BASE LEVEL ENGINEERING GEODATABASE

1.1 OVERVIEW

The BLE geodatabase consists of three types of data: spatial data (feature classes), tabular data (database tables), and gridded data (rasters). Additionally, the spatial data is grouped into four themes (feature datasets) based on function and interconnectivity with other related FEMA datasets in this study, such as the Flood Risk Database (FRD) and the DFIRM Database, as well as the Coordinated Needs Management Strategy (CNMS) program.

The BLE Database does not represent a flood risk study, but is intended to serve as a data- and model-based foundation for future flood risk studies as well as to assist communities in better determining their flood risk by providing *estimated* base flood elevations (BFEs). The primary means of achieving this goal is through the *Estimated Base Flood Elevation Viewer* (https:\\apps.femadata.com\estbfe).

Some of the data files in the geodatabase exactly match corresponding data files in other related FEMA datasets, while others are based on corresponding data files in other related FEMA datasets but have been modified for use with the *Estimated Base Flood Elevation Viewer*. These modifications are necessary since the automated processes create a foundational dataset for future studies, but do not meet minimum requirements themselves. For example, it is inappropriate to label a flood zone delineated by automated processes as Zone A, rather it can be described by its relative risk. These data files are described below.

1.2 BASE LAYERS

1.2.1. S_FRD_POL_AR

Flood Risk Database Political Areas: This polygon feature class is the combination of the S_Pol_Ar feature class from all FIRM databases in the project area. It shows political area boundaries and includes community-specific data. This feature class matches the S_FRD_Pol_Ar feature class in the FRD. For additional information, see the *Flood Risk Database (FRD) Technical Reference*.

1.2.2. S_HUC_AR

Hydrologic Unit Code Areas: This polygon feature class depicts the watersheds in and around the project area. It shows watershed boundaries and includes identifying information about these watersheds. This feature class matches the S_HUC_Ar feature class in the FRD. For additional information, see the *Flood Risk Database (FRD) Technical Reference*.

1.3 CNMS LAYERS

1.3.1. S_STUDIES_LN

Studies Lines: This polyline feature class depicts stream reaches recorded and assessed as part of the CNMS program. This feature class matches the S_Studies_Ln feature class in the CNMS database. For additional information, see the *Coordinated Needs Management Strategy (CNMS) Technical Reference*.

1.3.2. S_UNMAPPED_LN

Unmapped Lines: This polyline feature class depicts stream reaches known to FEMA but which have not been assessed or mapped on a FIRM. This feature class matches the S_Unmapped_Ln feature class in the CNMS database. For additional information, see the *Coordinated Needs Management Strategy (CNMS) Technical Reference*.

1.4 EBFE LAYERS

1.4.1. DTL_STUD_AR

Detailed Studies Areas: This polygon feature class was created for the purposes of the *Estimated Base Flood Elevation Viewer*, and identifies areas that have detailed study depicted on the current effective Flood Insurance Rate Map (FIRMs) that may be available in portions of the study area. Additionally, it can also show areas of new detailed study that are currently in process and not yet effective, and which will be shown on updated FIRMs which may also be updated based on studies launched from the BLE dataset. It includes FIRM panel numbers where detailed studies are located, effective dates of the detailed study, the production stage of the detailed study (*e.g.* Preliminary, Effective, *etc*.), contact information for inquiries about the detailed study, and LOMR information for areas revised by Letters of Map Revision. Its purpose is to indicate to users of the *Estimated Base Flood Elevation Viewer* that flood data more detailed than the estimated base flood elevations produced by the automated processes are available.

1.4.2. DTL_STUD_LN

Detailed Studies Lines: This polyline feature class was created for the purposes of the *Estimated Base Flood Elevation Viewer*, and identifies stream reaches that have detailed study depicted on the current effective Flood Insurance Rate Map (FIRMs) that may be available in portions of the study area. Additionally, it can also show reaches of new detailed study that are currently in process and not yet effective, and which will be shown on updated FIRMs which may also be updated based on studies launched from the BLE dataset. It includes FIRM panel numbers where detailed studies are located, effective dates of the detailed study, the production stage of the detailed study (*e.g.* Preliminary, Effective, *etc*.), contact information for inquiries about the detailed study, and LOMR information for areas revised by Letters of Map Revision. Its purpose is to indicate to users of the *Estimated Base Flood Elevation Viewer* that flood data more detailed than the estimated base flood elevations produced by the automated processes are available.

1.4.3. FLD_HAZ_AR

Flood Hazard Areas: This polygon feature class is based on the S_Fld_Haz_Ar feature class (*q.v.*) in the DFIRM database, but has been modified for use with the *Estimated Base Flood Elevation Viewer*. It contains information about flood risks in the study area and their geographic extents. This feature class includes an additional field EST_RISK (Estimated Risk) which substitutes in the *Estimated Base Flood Elevation Viewer* for the Flood Zone. Values in the EST_RISK field include:

- High, which corresponds to areas of 1 Percent Annual Chance Flood Hazard
- Moderate, which corresponds to areas of 0.2 Percent Annual Chance Flood Hazard; and
- Low, which corresponds to Areas of Minimal Flood Hazard.

Twelve fields, while populated in the database, are hidden in the *Estimated Base Flood Elevation Viewer*. For complete details on modifications to this feature class and which fields are visible to users, see the *Base Level Engineering, Region 6 Submittal Guidance*.

1.4.4. SUBBASINS

Subbasins: This polygon feature class is based on the S_Subbasins feature class (*q.v.*) in the DFIRM database, but has been modified for use with the *Estimated Base Flood Elevation Viewer*. It collects data and calculations used in the preparation of Base Level Engineering hydrology, which uses the Regional Regression Equations to calculate the flow volumes expected throughout study reaches. This feature class includes several additional fields:

- US_1 (Upstream Basin 1)
- US_2 (Upstream Basin 2)
- US_3 (Upstream Basin 3)
- US_4 (Upstream Basin 4)
- PRECIP_IN (Precipitation in Inches)
- MAINCHSL (Main Channel Slope)
- E_Q_10PCT (Estimated Discharge of the 10-percent-annual-chance Event)
- E_Q_04PCT (Estimated Discharge of the 4-percent-annual-chance Event)

- E_Q_02PCT (Estimated Discharge of the 2-percent-annual-chance Event)
- E_Q_01PCT (Estimated Discharge of the 1-percent-annual-chance Event)

- E_Q_01PLUS (Estimated Discharge of the 1-percent-plus-annual-chance Event)
- E_Q_01MIN (Estimated Discharge of the 1-percent-minus-annual chance Event), and
- E_Q_0_2PCT (Estimated Discharge of the 0.2-percent-annual-chance Event).

Four fields, while populated in the database, are hidden in the *Estimated Base Flood Elevation Viewer*. For complete details on modifications to this feature class and which fields are visible to users, see the *Base Level Engineering, Region 6 Submittal Guidance*.

1.4.5. TENPCT_FP

Ten Percent Floodplain: This polygon feature class is based on the S_Fld_Haz_Ar feature class (*q.v.*) in the DFIRM database, but has been modified for use with the *Estimated Base Flood Elevation Viewer*. It contains information about the 10-percent-annual-chance-flood event flood risks in the study area and their geographic extents. This feature class includes an additional field EST_RISK (Estimated Risk) which substitutes in the *Estimated Base Flood Elevation Viewer* for the Flood Zone. Values in the EST_RISK field include:

- Extreme.

Thirteen fields, while populated in the database, are hidden in the *Estimated Base Flood Elevation Viewer*. However, since the 10-percent-annual-chance flood event is not reflected in any established flood zone, most fields are populated with null values. For complete details on modifications to this feature class and which fields are visible to users, see the *Base Level Engineering, Region 6 Submittal Guidance*.

1.4.6. WTR_AR

Water Areas: This polygon feature class is based on the S_Wtr_Ar feature class (*q.v.*) in the DFIRM database, but has been modified for use with the *Estimated Base Flood Elevation Viewer*. It contains information about and depicts the locations of waterbodies throughout the study area and/or those included in the automated hydrologic and hydraulic modeling. Two fields, while populated in the database, are hidden in the *Estimated Base Flood Elevation Viewer*.

1.4.7. WTR_LN

Water Lines: This polyline feature class is based on the S_Wtr_Ln feature class (*q.v.*) in the DFIRM database, but has been modified for use with the *Estimated Base Flood Elevation Viewer*. It contains information about and depicts the locations of streams and stream reaches throughout the study area and/or those included in the automated hydrologic and hydraulic modeling. Two fields, while populated in the database, are hidden in the *Estimated Base Flood Elevation Viewer*.

1.4.8. XS

Cross Sections: This polyline feature class is based on the S_XS feature class (*q.v.*) in the DFIRM database, but has been modified for use with the *Estimated Base Flood Elevation Viewer*. It contains information about and depicts the locations of streams and stream reaches throughout the study area and/or those included in the automated hydrologic and hydraulic modeling. Two fields, while populated in the database, are hidden in the *Estimated Base Flood Elevation Viewer*.

1.5 MITIGATION LAYERS

1.5.1. S_AOMI_PT

Areas of Mitigation Interest Points: This point feature class depicts the location of hydraulic structures (inline structures, dams, weirs, culverts, bridges, *etc*.) and other types of locations that may be used to refine future hydraulic models and mapping efforts. This feature class matches the S_FRD_Pol_Ar feature class in the FRD. For additional information, see the *Flood Risk Database (FRD) Technical Reference*.

1.5.2. S_CENBLK_AR

Census Block Areas: This polygon feature class contains the sptial location of census blocks intersecting the study area. It contains basic inventory and population data that is used as the basis for flood risk assessments in Hazus or similar software. This feature class matches the S_FRD_Pol_Ar feature class in the FRD. For additional information, see the *Flood Risk Database (FRD) Technical Reference*.

1.6 GRIDS

1.6.1. BLE_DEP01PCT

Depth 1 Percent: This raster dataset depicts the estimated flood water depth for the 1-percent-annual-chance flood event within the 1-percent-annual-chance floodplain as determined by the automated methods of the Base Level Engineering assessment.

1.6.2. BLE_DEP0_2PCT

Depth 0.2 Percent: This raster dataset depicts the estimated flood water depth for the 0.2-percent-annual-chance flood event within the 0.2-percent-annual-chance floodplain as determined by the automated methods of the Base Level Engineering assessment.

1.6.3. BLE_WSE01PCT

Water Surface Elevation 1 Percent: This raster dataset depicts the estimated water surface elevation (or *estimated base flood elevation*) for the 1-percent-annual-chance flood event within the 1-percent-annual-chance floodplain as determined by the automated methods of the Base Level Engineering assessment.

1.6.4. BLE_WSE0_2PCT

Water Surface Elevation 0.2 Percent: This raster dataset depicts the estimated water surface elevation (or *estimated base flood elevation*) for the 0.2-percent-annual-chance flood event within the 0.2-percent-annual-chance floodplain as determined by the automated methods of the Base Level Engineering assessment.

1.7 TABLES

1.7.1. L_RA_RESULTS

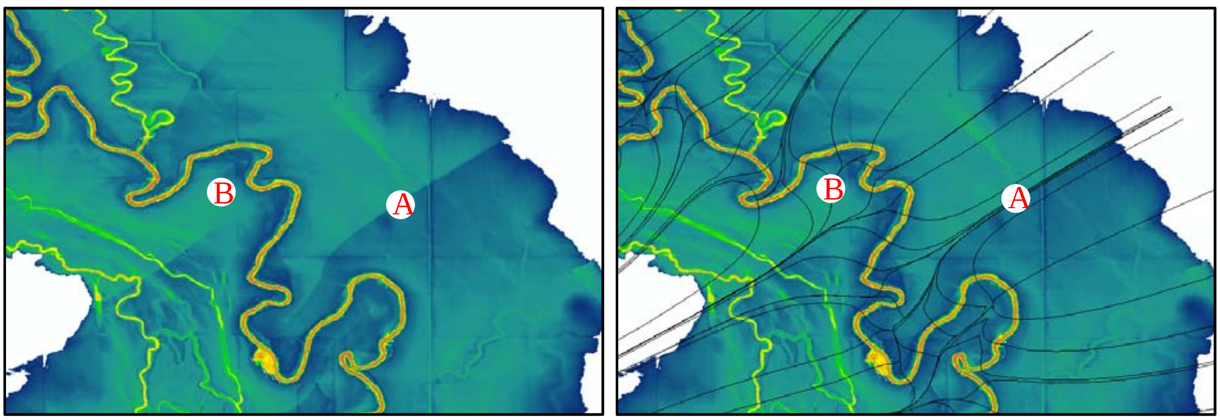
Risk Assessment Results: This table includes results from a flood risk assessment conducted in Hazus or similar software and are reported at the census block level. It is used in conjunction with the S_CenBlk_Ar feature class. This table matches the L_RA_Results table in the FRD. For additional information, see the *Flood Risk Database (FRD) Technical Reference*.

1.7.2. L_SOURCE_CIT

Source Citations: This table includes bibliographic data for references and data sources used in the compilation of the Base Level Engineering database. This table matches the L_Source_Cit table in the FIRM database and the FRD. For additional information, see the *Flood Insurance Rate Map (FIRM) Database Technical Reference* or the *Flood Risk Database (FRD) Technical Reference.*

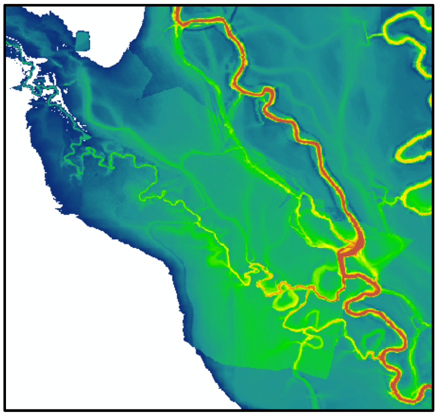
2.0 KNOWN ISSUES

Irregularities in depth values may appear in the depth grids due to parameters within the automated modeling. In most cases, these are caused by the orientation of cross sections as they were automatically created by the processing software. Per the rules of hydraulic modeling, cross sections must intersect the stream channel perpendicularly. And no irregularities are observed along or near the stream channel. However, in the overbank areas, which are sensitive to the orientation of cross sections, these irregularities appear. This is likely because in the overbank areas, flood waters are not flowing along the channel, but the cross sections are modeled as if they are. This becomes an issue in areas where the perpendicular requirement of cross sections along a highly meandering stream inside a wide floodplain causes cross sections to "bunch up" together. There are several possible ways to address this situation, but these may not be applicable for a low-level (base level) analysis and instead may be applicable for a full FIRM-level analysis or even a detailed analysis.



The image at left shows the depth grid without cross sections, so that these irregularities are easier to see. The image at right shows the depth grid with cross sections superimposed on it. Note that a Location A, the bunched up cross sections create an irregularity in the depth where the values change rather abruptly. Note that at Location B, where the cross sections near the channel and are no longer bunched up, these irregularities disappear.

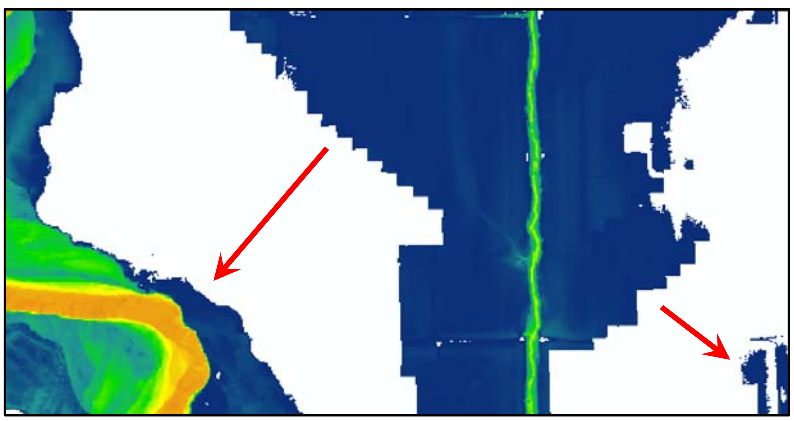
In other cases, irregularities appear at stream confluences. Generally, in hydraulic modeling, the main receiving stream has higher flows than tributary streams, and therefore exert backwater effects on these tributaries. However, in some portions of these watersheds, tributary streams have higher flows at their confluences with the main receiving stream than the main receiving stream itself. This is likely due to various factors such as geology, climate, contributing watershed area, floodplain geometry, and so on.



In this example, the tributary stream has a higher water surface elevation than the main receiving stream, and therefore backwater effects do not eliminate a “cliff” or “waterfall” in the water surface calculated by automated modeling. It appears here that this result may be influenced by the shared floodplain of the tributary and the main receiving streams.

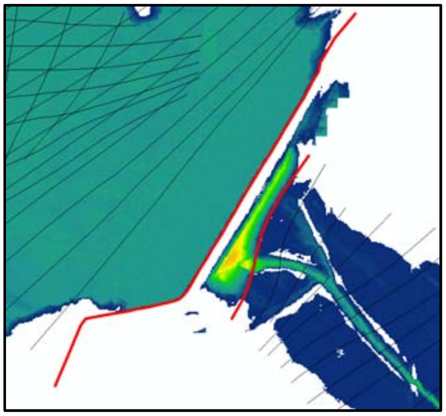
Efforts have been made to account for all manner backwater effects in the automated modeling, but the possibility still exists that this issue remains.

Next, in some areas, the automated modeling was unable to “close” a floodplain and determine a boundary. In most cases this appears to be the results of the limitations of automated 1D modeling that cannot account for split flows or areas of low topographic relief causing weir flow or sheet flow of water outside of a floodplain into another. These particular examples mentioned require 2D modeling to accurately determine flood prone areas subject to these conditions, which is usually reserved for detailed study areas, and is beyond the scope of low-level (base level) automated engineering methods. Other situations may also exist. In places where the model could not “close” a floodplain, usually because the water surface elevation did not intersect the ground on one side, the program eventually chose a location and stopped processing. This causes “stair step” boundaries to appear in the dataset, revealing which grid sectors were processed by the program and which were not.



“Stair step” boundaries caused by the program’s inability to “close” the floodplain. Note that the depths here are very shallow, usually less than six inches. It is possible that there may be weir flow or sheet flow into adjacent floodplains (indicated by red arrows), which is not in included in basic 1D modeling.

Finally, values in the depth grids at dams are another irregularity. At some identified dam sites, automatically generated cross sections were not used, and instead an engineer manually added cross sections at the top and bottom of the dam structure. Depth values at dams between these two cross sections represent waterfall-type conditions and may show water depth deeper than it may actually occur. Again, at structures like dams, modeling the flow of water over or around das and spillways is usually conducted for detailed studies and is beyond the scope of low-level (base level) analysis.



The cross sections at the top and bottom of this dam are indicated by heavy red lines. All others are indicated by thin black lines. Note that the water depths between the two dam cross sections, especially at the head of the channel at the foot of the dam, have higher depth values than elsewhere in the flood plain. These values may be erroneous. The cross sections do manage to pick up two tiny portions of the unmodeled spillway, located in the lower center portion of this image.

3.0 EXCEPTIONS AND SPECIAL CONSIDERATIONS

S_FRD_Pol_Ar: Some fields, such as those relating to hazard declarations, flood policies, and hazard mitigation plans, are populated with null values since information for those fields is not available at this time.

S_HUC_Ar: No comments.

S_Studies_Ln: This feature class has no records since conducting a CNMS assessment is not included in the scope for this study.

S_Unmapped_Ln: This feature class has no records since conducting a CNMS assessment is not included in the scope for this study.

Dtl_Stud_Ar: Fields relating to point-of-contact information are populated with null values since this information is not available. Fields relating to LOMRs are populated with null values since no applicable LOMRs exist within the study area. Additionally, polygons covering the two HUC8 watersheds of the Canadian River and outside the BLE data area were added since this area is being studied separately by the United States Army Corps of Engineers. Their results are expected to be combined with the BLE assessment when the next map revision is made. Thus, to indicate this future detailed study, these polygons have been attributed with FIRM panel numbers with the next (future) suffix and a null value for the effective date.

Dtl_Stud_Ln: Fields relating to point-of-contact information are populated with null values since this information is not available. Fields relating to LOMRs are populated with null values since no applicable LOMRs exist within the study area. Additionally, polylines extracted from the National Hydrography Dataset and representing the Canadian River were added, since this area is being studied separately by the United States Army Corps of Engineers. Their results are expected to be combined with the BLE assessment when the next map revision is made. Thus, to indicate this future detailed study, these polylines have been attributed with FIRM panel numbers with the next (future) suffix and a null value for the effective date.

Fld_Haz_Ar: Automated processing usually produces “dirty” areas and “noise”, such as including small, low-lying areas adjacent to a flood zone as being in the flood zone even if they are not hydrologically connected to it. Additionally, it can generate polygons that are near-microscopic in size. To correct for these issues, to “clean” the dataset, and to conform to general FEMA mapping standards, polygons smaller than 1 acre in size (43,560 square feet) have been eliminated. Additionally, the largest polygon representing the area of “low” flood risk and analogous to “Area of Minimal Flood Hazard” could not be shown as a single polygon due to exceeding the vertex limit in ArcGIS. Thus, it has been divided into smaller polygons at HUC8 boundaries, and along major streams that divide the study area into approximate quadrants. Finally, the area within the Canadian River drainage and that is being studied by the United States Army Corps of Engineers is shown as Zone D *only for BLE database purposes*. However, in the *Estimated Base Flood Elevation Viewer*, flood zone designations are not shown and users will only see this area as “low” flood risk.

Subbasins: This feature class has no records since the automated processes used do not generate subbasins as part of its hydrologic modeling.

TenPct_FP: Automated processing usually produces “dirty” areas and “noise”, such as including small, low-lying areas adjacent to a flood zone as being in the flood zone even if they are not hydrologically connected to it. Additionally, it can generate polygons that are near-microscopic in size. To correct for these issues, to “clean” the dataset, and to conform to general FEMA mapping standards, polygons smaller than 1 acre in size (43,560 square feet) have been eliminated

Wtr_Ar: This feature class has no records since waterbodies with static elevations were not used in the hydraulic modeling.

Wtr_Ln: Water line features were taken directly from the profile base lines in the hydraulic modeling. These lines were previously refined to the terrain data as described in Section 2.3 above. However, for hydraulic modeling purposes it was necessary for these profile base lines to extend for some distance beyond the downstream confluence (mouth) of the stream. This creates overlapping features for most streams in the study area. For the Wtr_Ln feature class, these polylines were edited to remove these overlaps, and stream lines end at their downstream confluences. Stream names were taken from the National Hydrography Dataset or from published FIRMs. Name identifiers were not generated for unnamed streams. However, each stream, whether named or unnamed, has a unique Model ID, which is recorded in the corresponding XS file.

XS: Cross sections were extracted directly from the hydraulic modeling. Start ID points and cross sections letters were not identified for the Base Level Engineering database. Due to the density of the cross sections generated by the automated processes, not every cross section is attributed as “Mapped” (it will be visible in the *Estimated Base Flood Elevation Viewer*). Any cross section affected by backwater effects in the modeling (where the water surface elevation value in the cross section is different from the value in the water surface elevation grid at that location) is attributed as “Not Mapped” (it will not be visible in the *Estimated Base Flood Elevation Viewer*). Thereafter, every fourth cross section on a stream is shown as “Mapped” and the intervening three cross sections are shown as “Not Mapped”.

S_AOMI_Pt: Dam features within this feature class were obtained from the Oklahoma Water Resources Board. The source metadata indicates the spatial accuracy of the data “is low” and a reference scale value is not provided. Thus, the scale value for this reference is not populated in the L_Source_Cit table. Where possible the dam points were snapped to the water line at the top of the dam structure as it is visible in the terrain data. If a dam was located elsewhere not on a modeled stream, its location was placed at the top of the dam where the thalweg would otherwise intersect it. If a dam was not visible in the terrain data (*e.g.* dams located in the Canadian River drainage), it was refined in the same way using aerial photography. Road crossing locations were not generated within the Canadian River drainage basin because the extents of the Canadian River model being developed by the United States Army Corps of Engineers is unknown at this time.

S_CenBlk_Ar: No comments.

BLE_Dep01Pct: Per FEMA Region 6 guidance, the BLE database uses a geographic projection system, but grid data are to be in Universal Transverse Mercator projection. Grid data, therefore are in the UTM projection. The 1-percent-annual-chance event depth grid has been clipped to match the cleaned 1-percent-annual-chance event boundaries shown in the Fld_Haz_Ar feature class. Per FEMA guidance, cell values have been rounded to the nearest 0.1 foot. Cell values that rounded down to 0.0 feet were rounded up to 0.1 feet instead.

BLE_Dep0_2Pct: Per FEMA Region 6 guidance, the BLE database uses a geographic projection system, but grid data are to be in Universal Transverse Mercator projection. Grid data, therefore are in the UTM projection. The 0.2-percent-annual-chance event depth grid has been clipped to match the cleaned 0.2-percent-annual-chance event boundaries shown in the Fld_Haz_Ar feature class. Per FEMA guidance, cell values have been rounded to the nearest 0.1 foot. Cell values that rounded down to 0.0 feet were rounded up to 0.1 feet instead.

BLE_WSE01Pct: Per FEMA Region 6 guidance, the BLE database uses a geographic projection system, but grid data are to be in Universal Transverse Mercator projection. Grid data, therefore are in the UTM projection. The 1-percent-annual-chance event water surface elevation grid has been clipped to match the cleaned 1-percent-annual-chance event boundaries shown in the Fld_Haz_Ar feature class. Per FEMA guidance, cell values have been rounded to the nearest 0.1 foot. Cell values that rounded down to 0.0 feet were rounded up to 0.1 feet instead.

BLE_WSE0_2Pct: Per FEMA Region 6 guidance, the BLE database uses a geographic projection system, but grid data are to be in Universal Transverse Mercator projection. Grid data, therefore are in the UTM projection. The 0.2-percent-annual-chance event water surface elevation grid has been clipped to match the cleaned 0.2-percent-annual-chance event boundaries shown in the Fld_Haz_Ar feature class. Per FEMA guidance, cell values have been rounded to the nearest 0.1 foot. Cell values that rounded down to 0.0 feet were rounded up to 0.1 feet instead.

L_RA_Results: This table has no records since conducting a flood risk assessment is not included in the scope for this study. This assessment is scheduled to be conducted at a later time.

L_Source_Cit: No comments.

4.0 REFERENCES

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