Interagency Flood Risk Management (InFRM)

Watershed Hydrology Assessment for the Trinity River Basin

Appendix C - Elliptical Frequency Storms in HEC-HMS

July 2021

InFRM
INTERAGENCY FLOOD RISK MANAGEMENT

Table of Contents

1. Elliptical Frequency Storms in HEC-HMS

1.1 INTRODUCTION TO ELLIPTICAL STORMS

Observations of actual storm events show that average precipitation intensity decreases as the area of a storm increases. The uniform rainfall method results (documented in a separate Appendix) use the depth-area analysis in HEC-HMS to produce frequency peak flow estimates (Version 4.2.1; USACE, 2014). The depth-area analysis in HEC-HMS applies the appropriate depth-area reduction factor to the given point rainfall depths based on the drainage area at a given evaluation point, which are derived from the published depth-area reduction factors from Figure 15 of the National Weather Service TP-40 publication (Hershfield, 1961), as shown in the figure below.

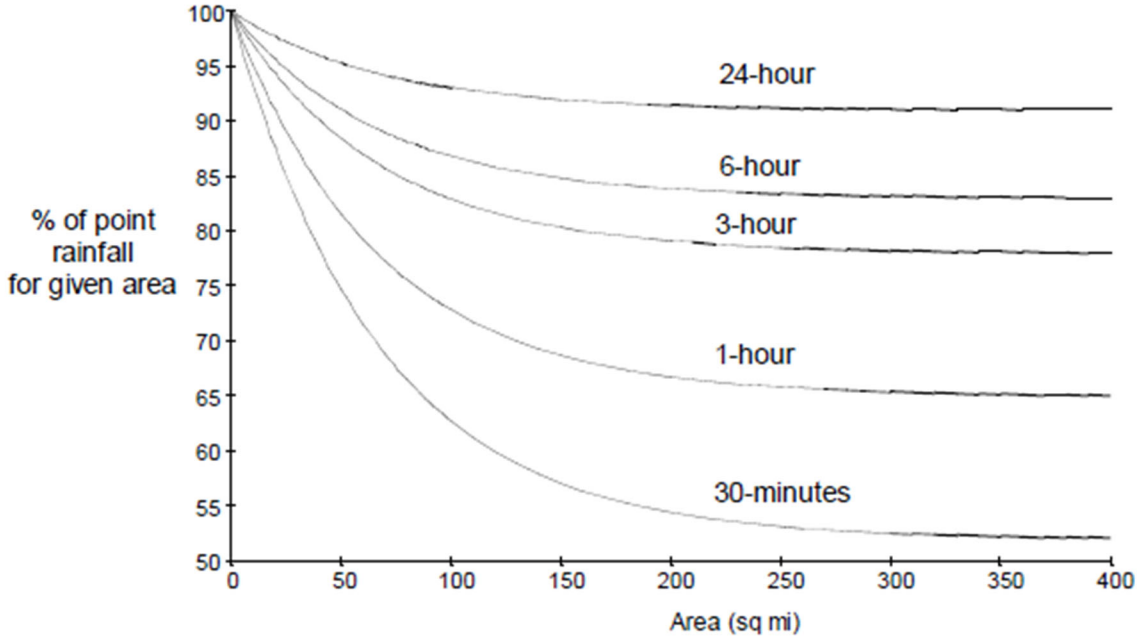


Figure 1: Published Depth-Area Reduction Curves from TP-40

When evaluating a point with a drainage area greater than 400 square miles, the HEC-HMS software issues a warning that the NWS depth-area reduction factors do not support storms beyond 400 square miles, as seen in the figure above. The program will still calculate the peak discharge, but the warning implies that the calculated volume of the storm may not be appropriate for larger drainage areas.

Since the Trinity hydrology study involves calculating frequency discharges for points with up to several thousand square miles of drainage area, the InFRM team developed elliptical frequency storms for points with drainage areas greater than 400 square miles. In these elliptical frequency storms, the same point rainfall depths and durations were applied as in the uniform rainfall method of Chapter 6, but the spatial distribution of the rainfall varied in an elliptical shaped pattern with higher rainfall amounts in the center of the ellipse and lesser amounts towards the outer fringes.

Elliptical shaped storms have been used in a variety of hypothetical design applications, including the Probable Maximum Precipitation (PMP) storms from Hydrometeorlogical Report No 52 (HMR 52) (Hansen, 1982). The elliptical frequency storms constructed for this study are similar to those of HMR 52 in that concentric ellipses are

used to construct the storm's spatial pattern, and the storm's location is optimized over the watershed by identifying the storm center location and the angle of its major axis that lead to a maximum peak flow at a downstream junction of interest. Figure 2 shows an example of an elliptical 1% annual exceedance probability (100-yr) storm that was centered over the watershed above the Trinity River at Dallas junction.

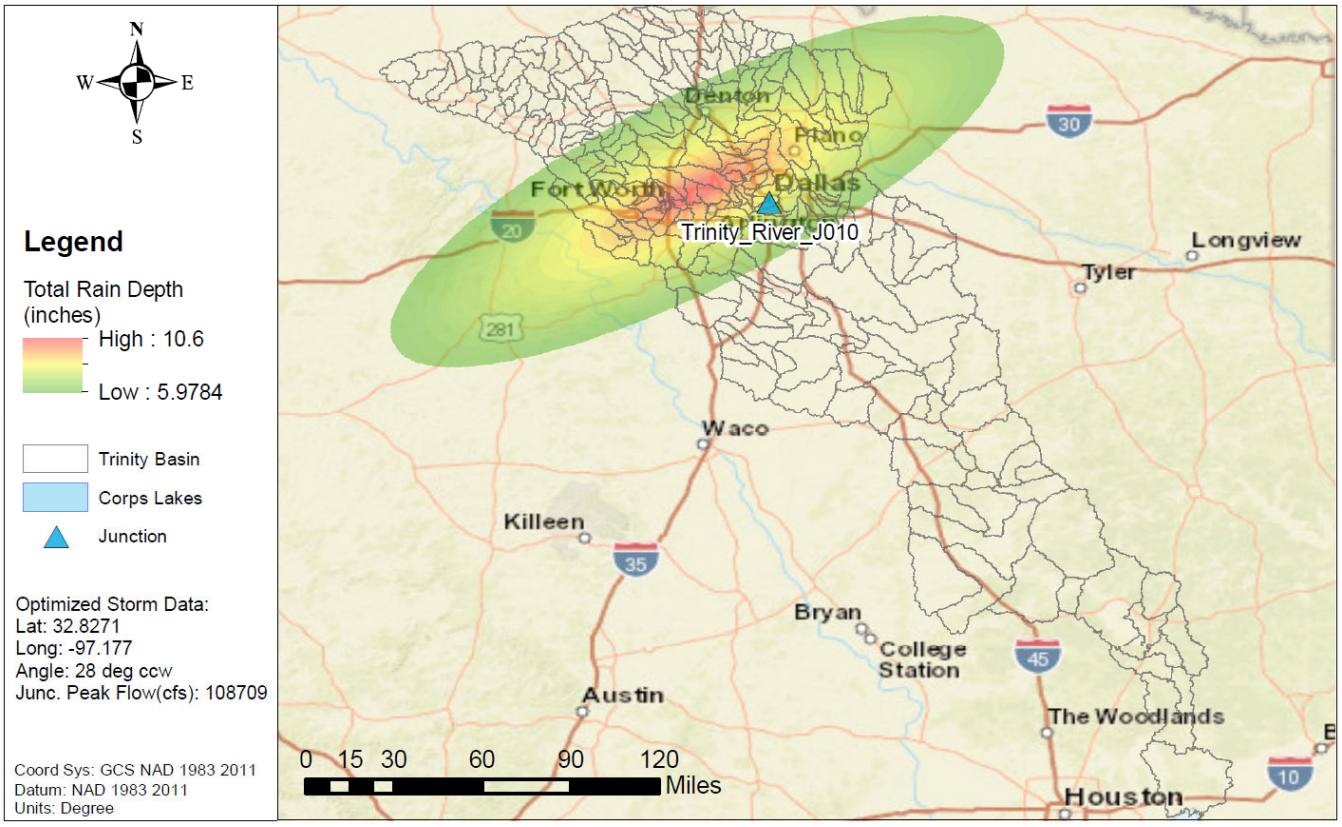


Figure 2: Example 1% AEP (100-yr) Elliptical Frequency Storm

1.2 ELLIPTICAL STORM PARAMETERS AND METHODOLOGY

The following elliptical storm parameters in sections 1.2.1 through 1.2.5 are relevant for the majority of the Trinity Basin. From the upper reaches of the Trinity Basin all the way downstream to the Trinity River near Crockett, TX USGS gage (128 junctions of interest), the orography and the meteorology remain relatively constant and these storm parameters worked well. However, for the 15 junctions of interest below the Crockett USGS gage, the meteorology rapidly changes and a few adjustments to the elliptical storm parameters and methodology were needed. The slightly different approach for the lower Trinity Basin is discussed in section 1.2.6.

Figure 3 below, summarizes the general approach used to create elliptical storms for the majority of the basin. The magnitude of the total storm is based off of one NOAA Atlas 14 point frequency depth queried from the storm center which is multipled by depth area reduction (DAR) factors.

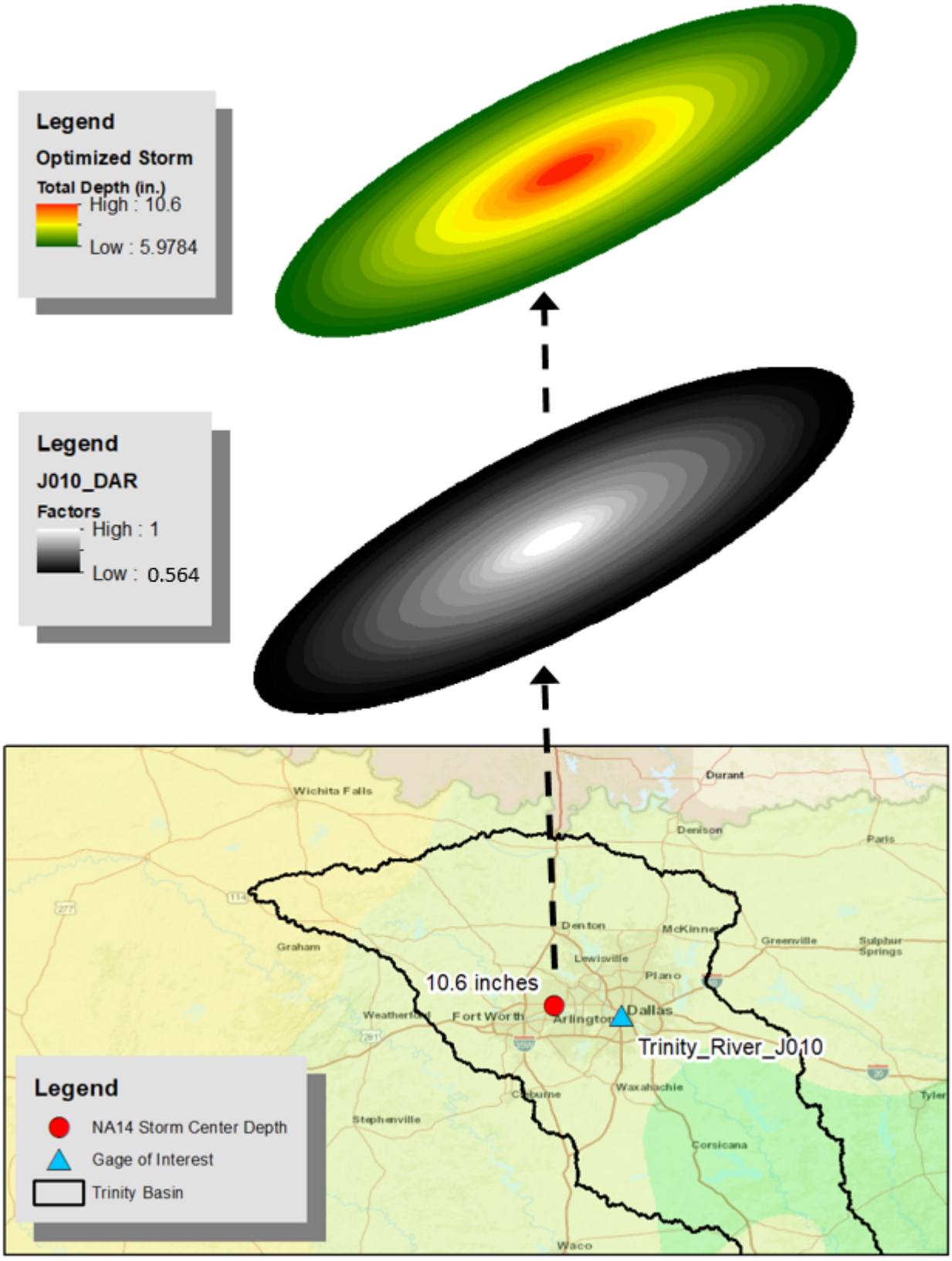


Figure 3: 100yr 48hr Elliptical Storm Generation – Upper Trinity Basin – Trinity River at Dallas

1.2.1 Elliptical Storm Area

This study uses a storm extent of 10,000 square miles. This is due to the historical rainfall studies rarely including data beyond 10,000 square miles (USACE, 1945). While this extent is somewhat arbitrary, testing was done to limit the storm extent to 3,000 square miles and the resulting peak discharges were slightly reduced. However the reduction in peak discharge was not significant because some of the rainfall beyond 3,000 square miles was falling outside the watershed and therefore not contributing to the runoff. Since there is no guidance or research on the subject, the storm extent of 10,000 square miles was used in this study.

1.2.2 Elliptical Storm Rainfall Depths

Elliptical storms were designed for each of the following annual exceedance probabilities (AEP): 1 in 2 years, 1 in 5 years, 1 in 10 years, 1 in 25 years, 1 in 50 years, 1 in 100 years, 1 in 200 years and 1 in 500 years. Point rainfall depths and durations were applied directly from NOAA Atlas 14 Volume 11 which contains depth duration frequency estimates of precipitation for Texas (NOAA, 2018). The point precipitation values that were applied to each elliptical storm were based on the storm center's location, not the location of the outlet of interest. For example, in Figure 3 above, the point precipitation values directly at the storm center (in red) were used to build the magnitude of the elliptical storm rather than the precipitation depths at the junction of interest (blue triangle).

1.2.3 Storm Ellipse Ratio

The HMR-52 study presents the option to design a storm with an ellipse ratio ranging from 2:1 to 3:1. For the Trinity basin, a 3:1 ellipse was used, as it better matched the long, narrow shape of the basin. A 2:1 ellipse was tested in several sections within the Trinity basin, and the optimized storm centerings, storm orientations, and resulting peak flows were generally similar to the results obtained from using a 3:1 ellipse.

1.2.4 Storm Temporal Pattern / Hyetograph

Historically, storms have varying intensities and temporal distributions and many studies have been done to document storm patterns. The six storm temporal distributions that were tested for a previous InFRM study on the Guadalupe Basin are shown in Figure 4. The Soil Conservation Service (1986) documented different distributions for the United States, and Type II is the distribution applicable to Texas and was included in the testing. Other distributions were also tested, including the Frequency Rainfall Distributions from HEC-HMS with the storm centroid occurring at the 25%, 33%, 50%, 67% and 75% of the total distribution. The HEC-HMS Frequency Rainfall Distributions maintain the appropriate storm intensity throughout the storm. In other words, the 100 year, 1 hour rainfall is maintained with the 100 year, 3 hour rainfall and so on all the way through the 100 year, 48 hour rainfall.

While varying the temporal pattern distribution of the storm did have a small effect on the peak discharge, the difference was generally less than 5%. As with the Guadalupe study, the 50% storm distribution was also selected for the Trinity study due to its simplicity and maintaining the proper intensity throughout the storm period. This is also consistent with the temporal distribution used for the uniform rainfall method.

The magnitude of the Frequency Rainfall Distributions in HEC-HMS are created with point rainfall input. The relative magnitude of each 1-hr alternating block within our base temporal pattern was determined with the NOAA Atlas 14 point rainfall frequency data pertinent to the centroid of Tarrant County (1-hr, 2-hr, 3-hr, 6-hr, 12-hr, 24-hr, and 48-hr rainfall data for Tarrant County was used as input). Tarrant County was chosen to establish a base temporal pattern because it is part of the Dallas – Fort Worth metropolitan region which is the primary economic hub within the Trinity Basin. Furthermore, it is meteorologically similar to the majority of the Trinity Basin. As the storm is translated over the basin during the optimization process, the temporal pattern is scaled up or down from the base temporal pattern depending only on the NOAA Atlas 14 point rainfall data at the storm's current centering.

Testing on the Trinity River basin was done for shorter and longer design storm durations (24hr, 48hr, 96hr, and 240hr). In general, it was found that the longer storm durations produced slightly larger peak discharges due to small increases in volume being added at the beginning (and end) of the storm hyetograph. These small volume increases eat away at the initial losses causing more runoff when the intense, central portion of the storm arrives. For this study, the 48 hour storm duration was used throughout the watershed. This storm duration more closely coincides with the duration of the storm events used to calibrate the HMS model, and it also coincides with the storm duration used for the uniform rainfall HMS runs.

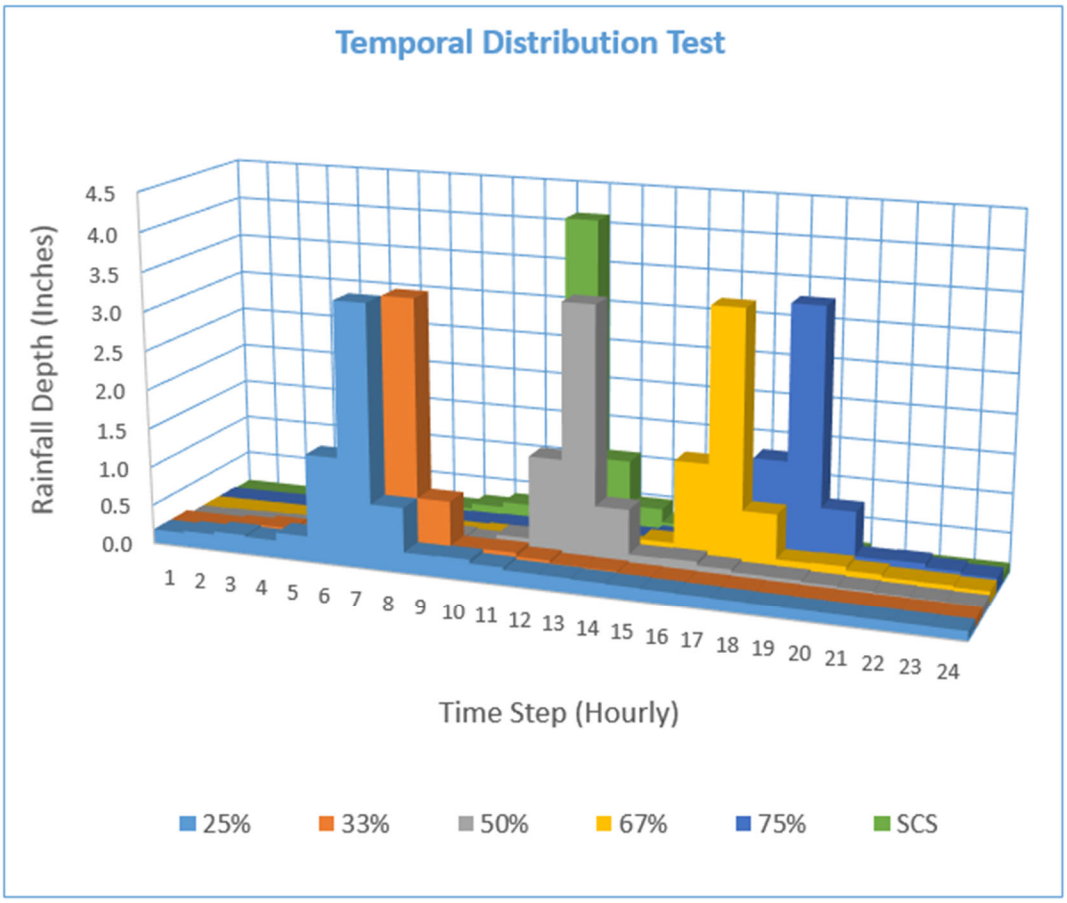


Figure 4: Tested Storm Temporal Distributions for the Guadalupe InFRM Study

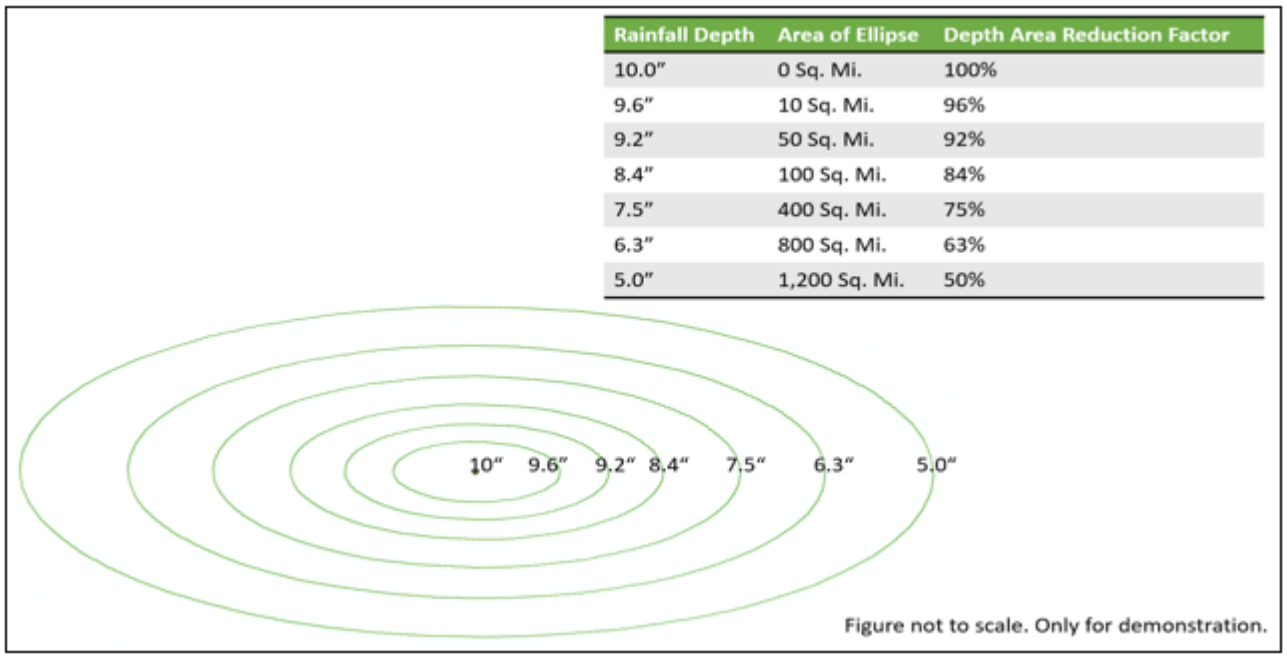
1.2.5 Storm Depth Area Reduction Factors

The term depth area reduction factor refers to a storm that has been spatially normalized to a unit depth at the storm center. Thus the remainder of the storm is a percentage of the storm center. A depth area duration table is a way to track the volume of the storm. All storms have varying spatial and temporal patterns and this affects the depth area duration table of the storm.

For the elliptical frequency storms, the storm, shape, temporal pattern, duration, and rainfall depth at the center have all been accounted for. All that remains is to apply a depth area reduction curve to the storm to find the depths at each concentric ellipse. An example of a depth area reduction curve applied to an elliptical storm is shown in Figure 5.

A large amount of research and analysis went into the determination of the appropriate depth area reduction curve for this study. A previous study of elliptical storms had been done by USACE in 2012 for the Dallas Floodway Extension project. This effort analyzed over 100 storms across Texas, Oklahoma, Arkansas and Louisiana. For this

study, 35 historical storms more local to the Trinity watershed with total precipitation depths ranging from 5 to 11 inches were analyzed. In the end, a DAR curve for the Upper Trinity was implemented that roughly equated to the median of the 35 observed storms. The DAR curve used for the Lower Trinity is slightly different as it was created predominantly from tropical storm observations. Both curves are presented in Figure 6 and Table 1 below.



Rainfall Depth	Area of Ellipse	Depth Area Reduction Factor
10.0"	0 Sq. Mi.	100%
9.6"	10 Sq. Mi.	96%
9.2"	50 Sq. Mi.	92%
8.4"	100 Sq. Mi.	84%
7.5"	400 Sq. Mi.	75%
6.3"	800 Sq. Mi.	63%
5.0"	1,200 Sq. Mi.	50%

Figure 5: Example of a Depth Area Reduction Curve Applied to an Elliptical Storm

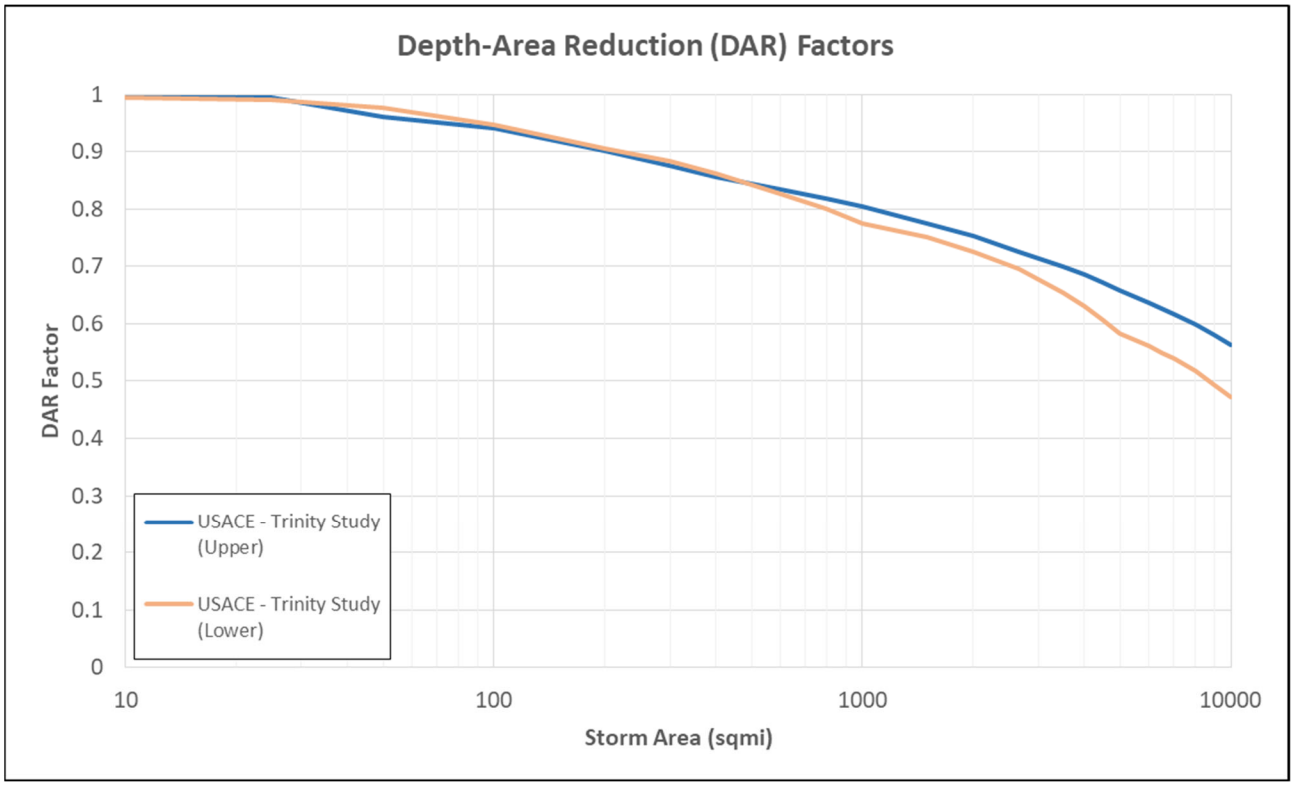


Figure 6: Adopted Depth Area Reduction Curves

Table 1: Adopted Depth Area Reduction Factors

Storm Area in Square Miles	DAR Factors – Trinity (Upper)	DAR Factors– Trinity (Lower)
1	1	1
10	1	1
25	0.997	0.991
50	0.96	0.976
100	0.94	0.946
200	0.902	0.906
300	0.875	0.884
400	0.855	0.862
600	0.834	0.827
800	0.818	0.801
1000	0.804	0.774
1500	0.775	0.75
2000	0.752	0.726
2667	0.726	0.695
3500	0.699	0.655
4000	0.685	0.631
4500	0.672	0.607
5000	0.658	0.583
6000	0.637	0.561
6500	0.626	0.55
7000	0.617	0.539
8000	0.599	0.517
9000	0.581	0.494
10000	0.564	0.472

1.2.6 Elliptical Storm Methodology - Lower Trinity Basin

The parameters listed above work well for the Upper Trinity Basin where the NOAA Atlas 14 precipitation gradient is, in general, spatially uniform and where the storms are largely convective. However, in the Lower Trinity Basin below the Trinity River near Crockett, TX USGS gage, the NOAA Atlas 14 precipitation gradient increases drastically as the basin approaches the Gulf of Mexico where tropical storms tend to drive larger precipitation events (Figure 7).

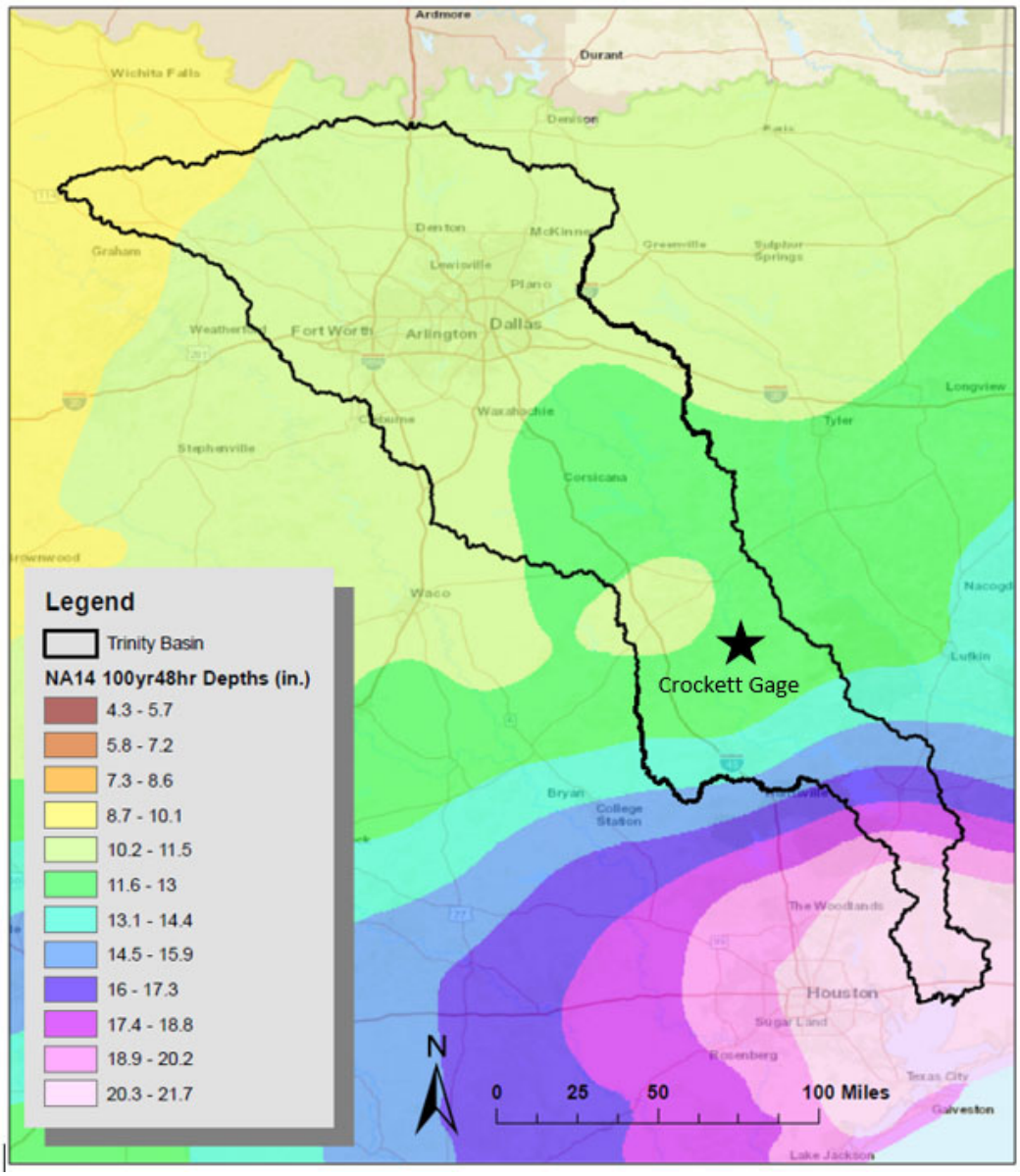


Figure 7: NOAA Atlas 14 100yr48hr Precipitation Gradient – Trinity Basin

The main change in methodology that was employed in the Lower Trinity Basin involves how the NOAA Atlas 14 precipitation data and the DAR curve were used to create the elliptical storm. In the Upper Trinity, only one precipitation depth coinciding with the storm center was used to determine the volume of the storm at the innermost, center ellipse. The DAR curve was then applied to the queried storm center precipitation depth to determine the reduced volumes in the outer ellipses up to 10,000 sqmi (Figure 3 above). Due to the rapidly varying precipitation gradient near the Gulf, determining the outer elliptical volume based off of one center precipitation depth led to volume overestimation in latitudes above the storm center. These upper latitude regions of the storm were not being reduced enough. To compensate for this, a new methodology was applied in which all of the precipitation depths that fell under the 10,000 sqmi elliptical storm positioning were queried instead of just the one depth at the storm center. Then all of the queried precipitation depths were reduced based off of which of the concentric, DAR ellipses they overlapped with (Figure 8 below). In regions where the precipitation depths vary greatly over a short distance, this method performs better since the precipitation gradient is reflected in the makeup of the elliptical storm.

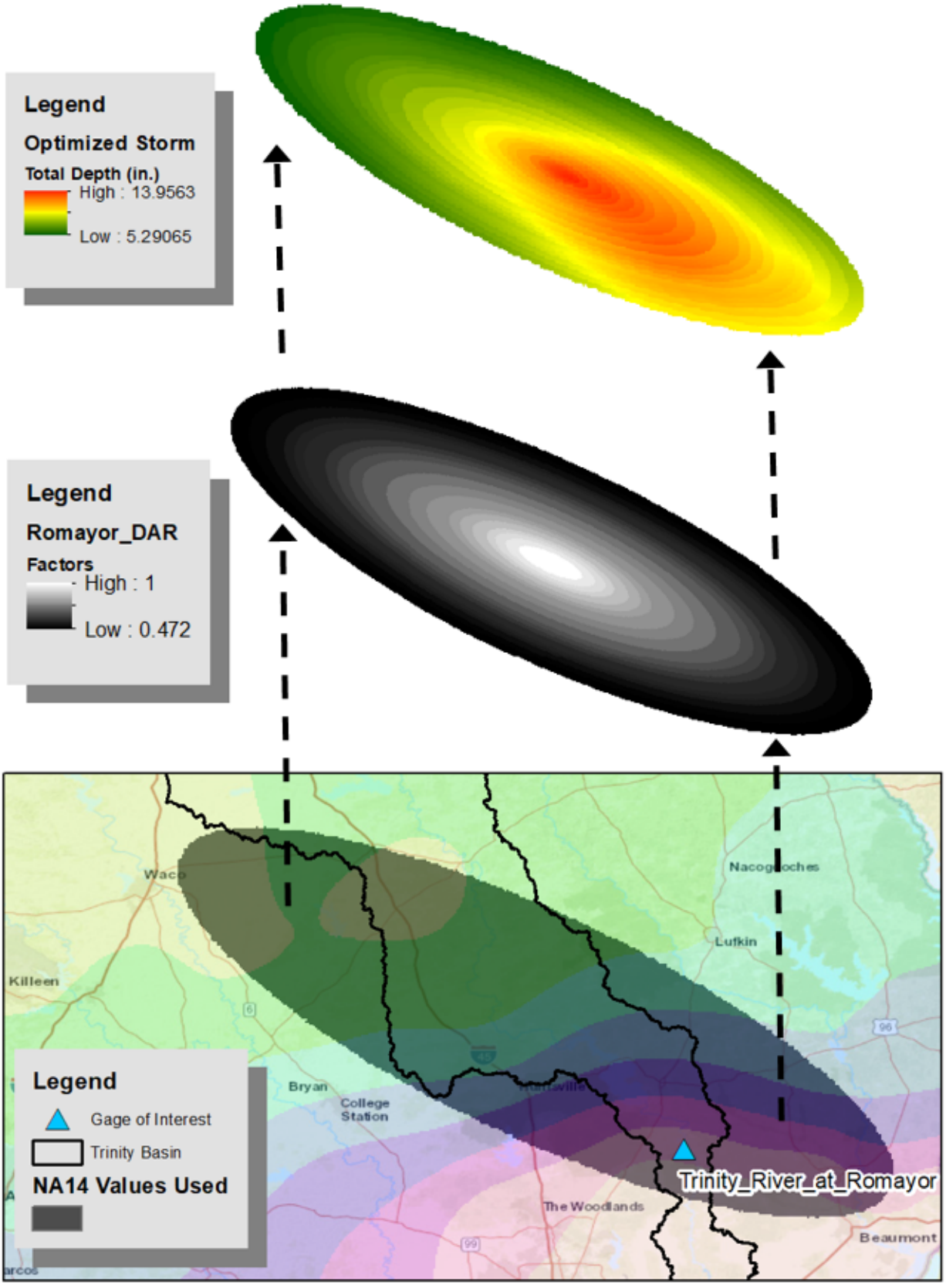


Figure 8: 100yr48hr Elliptical Storm Generation – Lower Trinity Basin – Trinity River at Romayor

A second, small deviation from the prior methodology involved changing the temporal pattern parameter. For the Upper Trinity Basin, a base temporal pattern derived from precipitation depth input specific to Tarrant County was used. For the Lower Trinity Basin, an improvement was made in the methodology that better accounts for potential differences in meteorology. Instead of manipulating a base temporal pattern, a customized temporal pattern unique to each storm centering was built. At each storm centering, the 1-hr, 2-hr, 3-hr, 6-hr, 12-hr, 24-hr, and 48-hr duration precipitation depths were queried and the alternating block method was applied to create a temporal pattern.

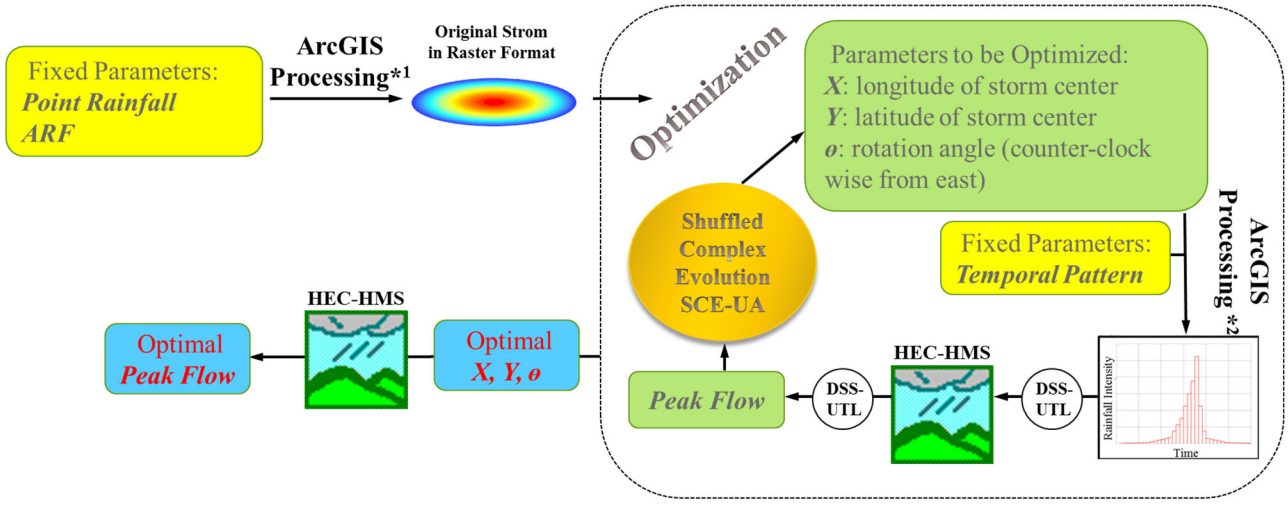
A third and final change involved the DAR curve that was used for the Lower Trinity Basin. A smaller, subset of observed storms that occurred in the Lower Trinity Basin were analyzed in an effort to better account for the potential meteorological differences near the Gulf. In the end, a slightly different DAR curve was adopted for this region (Lower) of the Trinity basin. Both the Upper and Lower Trinity Curves are shown in Figure 6.

1.3 OPTIMIZATION OF THE STORM CENTER LOCATION

For this study, a script was developed for the InFRM team that automatically locates optimal centering locations (x and y) and rotations (θ) of (spatially varied) elliptical frequency storms for a list of receiving junctions in a watershed. The script was expected to obtain the combination of the three parameters (x, y, and θ) that maximized peak flow at desired junctions while achieving the following objectives:

- To complete the task efficiently.
- To allow users to customize the scripts easily based on their needs.
- To generate reasonable results that can be validated manually.
- To outperform the manual grid search method in terms of precision, accuracy and efficiency.
- To function normally on any machine at USACE with the available software and hardware.

Figure 9 illustrates the schematic flow of the storm optimization. The scheme begins with creating a spatially varied design storm in raster format using ArcGIS. Given the point rainfall (total rainfall at the storm centroid) and the areal reduction factor (ARF), a peak hour storm raster is digitized by creating a series of concentric ellipses and then converting them to raster format. An optimization stage is followed including two major components: 1) parameter update/optimization and 2) automatic simulation of the HEC-HMS hydrologic model. In each iteration of the optimization process, the peak hour storm raster is first shifted and rotated due to updated parameters (x, y, and θ); and then allocated into each subbasin as mean areal precipitation (MAP). Since the MAP value for each subbasin only represents the amount of rain during the peak hour (hour 25 of a 48 hour storm), the remaining 47 values are ratioed to create a time series. The time series MAP values, i.e. the hyetographs, are stored in DSS format and transmitted to the HMS model for simulations. After each simulation, the corresponding peak flow value at a desired junction is extracted from the output DSS file. Based on the extracted peak flow value, an optimization algorithm will update the parameters (x, y and θ) and then optimization proceeds into the next iteration. After all optimization iterations for a junction are complete, an optimized storm center (x and y) and orientation (θ) that leads to a peak flow at a given junction is determined. The optimization process can then be repeated for the next junction of interest.



*1. involves creating ellipse polygons and converting polygon to raster.
*2. involves shifting raster, rotating raster and calculating zonal statistics (for MAP).

Figure 9: Schematic Flowchart for the Storm Opimization Script

Originally, the scripts were designed to automate a grid search, where all possible combinations of parameters (i.e. the 'grids') are exhaustively tested and the optimal combination of the three parameters (x, y, and ϴ) can then be obtained. Although the approach of grid search seems straightforward, it does suffer from high computational cost because the computational run time depends on the number of grids, which is further constrained by the range and the interval of each parameter. Given the need of maintaining a certain level of precision or keeping constant intervals of the parameters, the UTA team found that the grid search approach might not be appropriate for this project since the computational run time was excessively lengthy – it increases exponentially with greater drainage area (more possible x and y values).

In order to overcome this issue, the UTA team selected a global optimization (GO) algorithm entitled shuffled complex evolution (SCE) (Duan et al., 1993) - a random sampling approach. Instead of exhausting all possible grids, the random sampling approach tests the objective function around some sampled grids in an iteration while learning about the structure of the objective function for improving the sampling of grids in the next iteration. More details about GO and SCE are included in the following sections.

1.3.1 Global Optimization

The objective of global optimization (GO) is to find the best solution of (possibly nonlinear) models globally, in the (possible or known) presence of multiple local optima. As an example, Figure 10 shows a 3-D plot of a continuous objective function of two bounded parameters x and y. Suppose the goal is to locate the minimal value globally instead of just locally (Note there are many local minimal values but with only one global minimum value in the chart), a global search in the two-dimensional box region is needed. The theory of GO has been applied to many engineering problems like model calibrations and optimal operations of "black-box" system. The storm optimization here is essentially a constrained GO problem, where the objective is to seek the combination of storm centering locations and rotations yielding the maximal peak flow within the constraints of the possible parameter values.

The level of difficulty in solving a GO problem depends on several major characteristics of the objective function. First, there may be multiple local minima in the parameter space. As illustrated in Figure 10, the search of global minimum can be easily "trapped" in the "valleys" of the objective function, depending on the starting point of the

search. Second, the objective function in the parameter space may not be smooth or even continuous. In addition, the parameters may exhibit varying degrees of highly nonlinear interaction. In order to deal with these difficulties, the UTA team employed the shuffled complex evolution algorithm (see the following section), which promises to be effective and efficient for the storm optimization task.

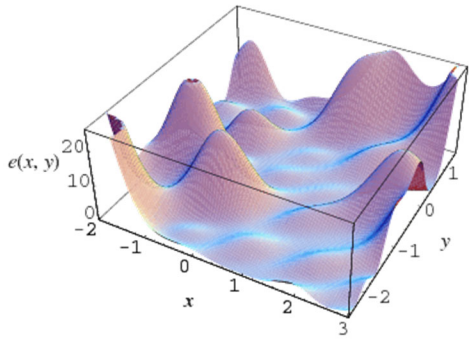


Figure 10: Example of a Global Optimization Problem

1.3.2 **Shuffled Complex Evolution**

The shuffled complex evolution works on the basis of four concepts: (1) combination of deterministic and probabilistic approaches; (2) systematic evolution of a complex of grids; (3) competitive evolution; and (4) complex shuffling. The algorithm begins with a randomly selected population of grids from the parameter space. The grids are sorted ascendingly so that the first point represents the smallest value of the objective function and the last point represents the largest. The initial population generated randomly is first partitioned into several complexes. Each complex is allowed to evolve independently to search the parameter space in different dimensions; and each individual grid in a complex has the potential to participate in the process of reproducing new grids. From each complex, some grids are selected to form a sub-complex, where the modified Nelder and Mead Simplex Method (NMSM) (Nelder and Mead, 1965) is applied for global improvement. The grids of higher fitness values have higher chance of getting selected to generate offspring. The NMSM performs reflection and inside contraction steps to get a better fit grid. This new offspring then replaces the grid with the worst performance in the complex. The grids in the evolved complexes are then pooled together and sorted again, shuffled, and finally reassigned to new complexes to enable information sharing. This process is repeated until some convergence criteria are satisfied.

1.4 ELLIPTICAL FREQUENCY STORM LOCATIONS

The final optimized storm center locations (x, y) and rotations (θ) for every node of interest in the Trinity watershed are listed in Table 2. Rotation angles are measured counter-clockwise from the positive x-axis. These location and rotation parameters were determined from 100yr frequency optimizations, and are assumed to be the same for all other frequency events (2yr – 500yr). Testing showed that, in general, optimized locations and orientations did not significantly change between frequency events. Once the optimum storm center location and rotation were determined for each location of interest, the elliptical frequency storms for the standard eight frequency events were constructed using the appropriate NOAA Atlas 14 point rainfall depths.

Table 2: Optimized Elliptical Storm Center Locations and Rotations for Each Model Junction

Location Description	HEC-HMS Element Name	Drainage Area (sq mi)	Longitude (X)	Latitude (Y)	Rotation of Major Axis (Theta)
West Fork Trinity River below Lost Creek	West Fork + Lost Ck	711.2	-98.2502	33.3773	3.1
West Fork Trinity River above Carroll Creek	West_Fork_abv_CarrollCk	750.8	-98.3463	33.3507	35.4
West Fork Trinity River below Carroll Creek	West_Fork_J090	792.1	-98.0781	33.2112	79.1
West Fork Trinity River above Beans Creek	WestFork_abv_Beans_Ck	827.7	-98.0621	33.2117	80.8
West Fork Trinity River below Beans Creek	WestFork_+_Beans_Ck	874.6	-98.0350	33.2125	85.1
Bridgeport Reservoir Inflow	Bridgeport Inflow	1095.7	-97.9452	33.1724	101.1
West Fork Trinity River above Dry Creek	West_Fork_abv_DryCk	1136.2	-98.0395	33.2249	157.5
West Fork Trinity River below Dry Creek	West_Fork_J100	1162.9	-97.7770	33.2180	95.2
West Fork Trinity River above Big Sandy Creek	WestFork_abv_Big_Sandy_Ck	1169.5	-97.7709	33.2139	113.9
Big Sandy Creek nr Bridgeport USGS Gage at Hwy 114 bridge	Big_Sandy_Ck_J030	334.3	-97.7448	33.4022	123.0
Big Sandy Creek above the West Fork Trinity River	Big_Sandy_Ck_abv_WestFork	353.9	-97.7170	33.3769	132.4
West Fork Trinity River below Big Sandy Creek	West Fork + Big Sandy Ck	1523.5	-97.7120	33.3202	69.2
West Fork Trinity River at FM 3259 near Paradise, TX	West_Fork_J110	1551.8	-97.7189	33.3196	75.8
West Fork Trinity River above Salt Creek	WestFork_abv_Salt_Ck	1573.7	-97.7191	33.3092	114.2
West Fork Trinity River below Salt Creek	West Fork + Salt Ck	1680.4	-97.7200	33.2084	71.8
West Fork Trinity River near Boyd, TX - USGS Gage at FM 730 bridge	West_Fork_J120	1710.8	-97.7184	33.2097	71.9
West Fork Trinity River about 0.8 miles upstream of FM 4757 in Wise County	West_Fork_J130	1751.9	-97.7291	33.2405	84.9
Eagle Mountain Reservoir Inflow	Eagle Mountain Inflow	1956.6	-97.5604	32.9617	26.3
Lake Worth Inflow	Lake Worth Inflow	2050.8	-97.5349	32.8183	166.7
West Fork Trinity River above the Clear Fork	WestFork_abv_Clear_Fork	2078.7	-97.5260	32.8308	176.4
Clear Fork above Marys Creek	Clear_Fork_abv_Marys_Ck	9.4	-97.4439	32.6760	127.6
Clear Fork below Marys Creek	Clear Fork + Marys Creek	63.6	-97.5399	32.7173	1.3
Clear Fork Trinity River at Fort Worth USGS gage	Clear_Fork_J020	89.0	-97.4252	32.7060	2.0
Clear Fork Trinity River above the West Fork	Clear_Fork_abv_WestFork	93.9	-97.4958	32.7139	162.3
West Fork Trinity River below the Clear Fork (West Fork at Fort Worth USGS gage)	West Fork + Clear Fork	2172.5	-97.3973	32.6971	165.2
West Fork Trinity River above Marine Creek	WestFork_abv_MarineCk	2173.7	-97.4590	32.7200	169.3
West Fork Trinity River below Marine Creek	West Fork + Marine Ck	2195.4	-97.4780	32.7187	169.4
West Fork Trinity River above Sycamore Creek	West_Fork_J140	2204.6	-97.4294	32.7200	178.2
West Fork Trinity River below Sycamore Creek (West Fork Trinity River at Beach Street USGS Gage)	West_Fork_J150	2243.8	-97.4221	32.7224	2.8
West Fork above Big Fossil	WestFork_abv_BigFossil	2256.8	-97.4350	32.7265	174.3

Location Description	HEC-HMS Element Name	Drainage Area (sq mi)	Longitude (X)	Latitude (Y)	Rotation of Major Axis (Theta)
West Fork Trinity River and Big Fossil Creek Confluence	West_Fork_J160	2333.4	-97.3372	32.7992	64.1
West Fork Trinity River below Village Creek	West Fork + Village Ck	2554.0	-97.3433	32.7642	19.3
West Fork Trinity River below Johnson Creek	West_Fork_J170	2618.6	-97.2700	32.7444	179.4
West Fork Trinity River at Grand Prairie USGS gage	West_Fork_J180	2623.4	-97.2783	32.7487	178.9
West Fork Trinity River above Big Bear Creek	West_Fork_abv_Big_Bear_Ck	2625.5	-97.2342	32.7375	178.2
West Fork Trinity River below Big Bear Creek	West Fork + Bear Ck	2718.8	-97.2794	32.7519	12.4
West Fork Trinity River above Mountain Creek	West_Fork_abv_Mountain_Ck	2727.4	-97.2575	32.7788	14.5
West Fork Trinity River below Mountain Creek	West Fork + Mountain Ck	2807.6	-97.1953	32.7685	179.9
West Fork Trinity River above the Elm Fork Trinity River	West_Fork_abv_Elm_Fork	2820.9	-97.2542	32.7774	11.6
Ray Roberts Lake Inflow	Ray Roberts Inflow	692.6	-97.0306	33.4809	21.5
Elm Fork Trinity River above Clear Creek	Elm_Fork_abv_Clear_Ck	36.9	-96.9954	33.3300	8.2
Elm Fork Trinity River below Clear Creek	Elm Fork + Clear Ck	388.1	-97.4056	33.4824	144.0
Lewisville Lake Inflow	Lewisville Inflow	968.2	-96.9318	33.2147	162.2
Elm Fork Trinity River above Indian Creek	Elm_Fork_abv_Indian_Ck	21.4	-96.9291	33.0539	8.0
Elm Fort Trinity River below Indian Creek	Elm Fork + Indian Ck	37.5	-96.8899	33.0543	23.0
Elm Fork Trinity River below Timber Creek	Elm Fork + Timber Ck	61.5	-96.8908	33.0101	173.1
Elm Fork Trinity River above Denton Creek	Elm_Fork_abv_Denton_Ck	79.9	-96.8993	33.0495	178.1
Denton Creek nr Justin, TX USGS gage	Denton_Ck_J030	400.0	-97.5137	33.3604	125.2
Denton Creek below Oliver Creek	Denton_Ck_J040	475.3	-97.4056	33.1625	167.0
Denton Creek above Elizabeth Creek	Denton_Ck_abv_Elizabeth_Ck	506.1	-97.4140	33.1664	157.5
Denton Creek below Elizaveth Creek	Denton_Ck_J050	599.7	-97.3828	33.1226	136.9
Grapevine Lake Inflow	Grapevine_Inflow	694.4	-97.3848	33.1218	149.9
Denton Creek above the Elm Fork Trinity River	Denton_Ck_abv_Elm_Fork	24.3	-97.0202	32.9735	19.5
Elm Fork Trinity River near Carrollton USGS gage	Elm Fork + Denton Ck	104.2	-96.8865	33.0146	175.2
Elm Fork Trinity River at Interstate 635	Elm_Fork_J060	143.4	-96.9106	32.9740	170.9
Elm Fork Trinity River above Hackleberry Creek	Elm_Fork_abv_Hackberry_Ck	143.4	-96.8948	33.0067	8.4
Elm Fk Trinity Rv at Spur 348 in Irving; TX USGS gage	Elm_Fork_J070	180.4	-96.8960	32.9943	20.3
Elm Fork Trinity River above Bachman Branch	Elm_Fork_abv_Bachman_Branch	202.6	-96.9488	32.9583	149.7
Elm Fork Trinity River below Bachman Branch (at Frasier Dam USGS gage)	Elm Fork + Bachman Branch	216.7	-96.9375	32.9720	159.5
Elm Fork Trinity River above the West Fork Trinity River	Elm_Fork_abv_West_Fork	222.8	-96.9183	32.9509	159.3
Trinity River below the West Fork and Elm Fork confluence	West Fork + Elm Fork	3043.7	-97.1951	32.8285	31.5

Location Description	HEC-HMS Element Name	Drainage Area (sq mi)	Longitude (X)	Latitude (Y)	Rotation of Major Axis (Theta)
Trinity River at Dallas, TX USGS gage	Trinity_River_J010	3056.1	-97.1770	32.8271	27.5
Trinity River at the Corinth Street bridge in Dallas, TX	Trinity_River_J020	3099.0	-97.1870	32.8280	29.2
Trinity River below White Rock Creek	Trinity River + White Rock	3233.9	-97.1262	32.8435	25.1
Trinity River below Honey Springs Branch (Trinity River below Dallas, TX USGS gage)	Trinity_Rv + Honey_Springs	3256.5	-97.1111	32.8539	26.3
Trinity River below Five Mile Ceek	Trinity_River + Five_Mile_Ck	3328.8	-97.1120	32.8517	23.4
Trinity River above Ten Mile Creek	Trinity_River_abv_Tenmile_Ck	3367.7	-97.0693	32.8368	18.3
Trinity River below Ten Mile Creek	Trinity River + Tenmile Ck	3469.8	-97.0427	32.8035	179.9
Trinity River above the East Fork Trinity River	Trinity_River_abv_East_Fork	3529.4	-97.0807	32.8068	10.9
Lavon Lake Inflow	Lavon Inflow	768.2	-96.4704	33.2165	75.3
Ray Hubbard Lake Inflow	Ray Hubbard Inflow	301.8	-96.5955	32.9947	138.4
East Fork Trinity River near Forney USGS gage	East_Fork_nr_Forney	349.9	-96.5877	32.9532	135.4
East Fork Trinity River above Buffalo Creek	East_Fork_abv_Buffalo_Ck	359.5	-96.5869	32.9530	132.5
East Fork Trinity River below Buffalo Creek	East_Fork + Buffalo_Ck	393.9	-96.5702	32.9448	134.1
East Fork Trinity River above South Mesquite Creek	East_Fork_abv_S_Mesquite_Ck	416.9	-96.5774	32.9445	130.8
East Fork Trinity River below South Mesquite Creek	East_Fork+South_Mesquite_Ck	446.4	-96.5561	32.9125	129.0
East Fork Trinity River above Mustang Creek	East_Fork_abv_Mustang_Ck	465.5	-96.5624	32.8935	124.0
East Fork Trinity River near Crandall, TX USGS gage	East_Fork_nr_Crandall	484.8	-96.5643	32.8874	123.4
East Fork Trinity River above the Trinity River	East_Fork_abv_Trinity_River	484.8	-96.5467	32.8542	120.4
Trinity River below the East Fork Trinity River	Trinity River + East Fork	4014.2	-96.9273	32.8541	11.8
Trinity River below Red Oak Creek	Trinity_River + Red_Oak_Ck	4245.5	-96.9348	32.8373	13.0
Trinity River near Rosser, TX USGS gage	Trinity_River_nr_Rosser	4349.6	-96.7872	32.8364	179.8
Trinity River above Cedar Creek	Trinity_River_abv_Cedar_Ck	4349.6	-96.6807	32.7993	6.0
Cedar Creek Reservoir Inflow	Cedar Creek Inflow	1010.8	-96.0991	32.3864	140.0
Trinity River below Cedar Creek	Trinity River + Cedar Creek	5360.4	-96.4942	32.6132	162.6
Trinity River at Trinidad, TX USGS gage	Trinity_River_at_Trinidad	5759.3	-96.1679	32.3623	166.3
Trinity River above Richland Creek	Trinity_Rv_abv_Richland_Ck	6042.8	-96.1413	32.3654	160.6
Bardwell Lake Inflow	Bardwell Inflow	174.4	-96.7069	32.3280	149.5
Chambers Creek below Mill Creek	Chambers_Ck_J020	511.9	-97.0574	32.2593	156.2
Chambers Creek below Waxahachie Creek	Chambers Ck + Waxahachie Ck	621.0	-97.0213	32.2515	161.0
Chambers Creek near Rice, TX USGS gage	Chambers_Ck_J030	650.1	-96.9728	32.2298	161.4
Richland Creek below Pin Oak Creek	Richland_Ck_J010	395.0	-96.5777	31.9717	58.6
Richland Chambers Reservoir Inflow	Richland-Chambers Inflow	1465.5	-96.4405	32.0129	28.0
Trinity River below Richland Creek	Trinity River + Richland Ck	7508.3	-96.2412	32.3753	15.6
Trinity River above Tehuacana Creek	Trinity_Rv_abv_Tehuacana_Ck	7508.3	-96.3369	32.3122	12.9
Trinity River below Tehuacana Creek	Trinity River + Tehuacana Ck	7894.7	-96.3620	32.0049	18.8

Location Description	HEC-HMS Element Name	Drainage Area (sq mi)	Longitude (X)	Latitude (Y)	Rotation of Major Axis (Theta)
Trinity River above Big Brown Creek	Trinity_Rv_abv_Big_Brown_Ck	7965.3	-96.3488	32.0055	14.4
Trinity River below Big Brown Creek	Trinity River + Big Brown Ck	8001.5	-96.3338	32.0086	14.3
Trinity River above Catfish Creek	Trinity_River_abv_Catfish_Ck	8306.6	-96.3441	32.0072	179.9
Trinity River below Catfish Creek	Trinity_River + Catfish_Ck	8353.0	-96.3206	31.9924	9.9
Trinity River near Oakwood, TX USGS gage	Trinity_River_nr_Oakwood	8593.0	-96.3193	32.1500	0.4
Trinity River above Upper Keechi Creek	TrinityRv_abv_UpperKeechi_Ck	8849.7	-96.3095	32.1515	0.6
Trinity River below Upper Keechi Creek	Trinity River + Upper Keechi	9358.9	-96.2930	32.1243	168.4
Trinity River above Big Elkhart Creek	Trinity_Rv_abv_Big_Elkhart	9359.5	-96.3196	32.1218	169.2
Trinity River below Big Elkhart Creek	Trinity River+ Big Elkhart	9502.5	-96.3748	32.1181	1.1
Trinity River near Crockett, TX USGS gage	Trinity_River_nr_Crockett	9615.0	-96.3470	32.1418	0.1
Trinity River above Lower Keechi Creek	Trinity_Rv_abv_LowerKeech_Ck	9791.7	-96.2470	32.0366	151.9
Trinity River below Lower Keechi Creek	Trinity_River+LowerKeechi_Ck	9979.3	-96.2909	32.0508	155.7
Trinity River above Bedias Creek	Trinity_River_abv_Bedias_Ck	10374.29	-96.2231	31.9926	145.9
Bedias Creek above the Trinity River	Bedias_Ck_abv_Trinity_River	604.3	-95.9526	30.9658	124.7
Trinity River below Bedias Creek	Trinity River + Bedias Ck	10978.5	-95.8797	30.9709	52.3
Trinity River at Riverside, TX USGS gage	Trinity River_at_Riverside	11306.7	-95.8826	31.0549	145.8
Lake Livingston Inflow	Lake Livingston Inflow	12301.1	-95.2801	30.8714	157.6
Trinity River above Long King Creek	Trinity_Rv_abv_Long_King_Ck	12340.5	-95.6283	31.0182	169.6
Trinity River at Goodrich, TX USGS gage	Trinity River + Long King Ck	12566.9	-95.6940	31.0571	173.2
Trinity River above Menard Creek	Trinity_River_abv_Menard_Ck	12628.0	-95.5939	30.9433	1.5
Trinity River below Menard Creek	Trinity River + Menard Ck	12776.2	-95.4685	30.9862	159.4
Trinity River at Romayor, TX USGS gage	Trinity_River_at_Romayor	12873.7	-95.4894	30.9636	155.9
Trinity River near Moss Hill, TX	Trinity_River_nr_MossHill_TX	12945.7	-95.4670	30.9793	154.9
Trinity River at Liberty, TX USGS gage	Trinity_River_at_Liberty	13176.5	-95.4456	30.9401	153.7
Trinity River at Wallisville, TX USGS gage	Trinity Bay	13618.4	-95.4915	30.9648	150.6

1.5 ELLIPTICAL FREQUENCY STORM LOSS RATES

The elliptical frequency storms were then applied to the final HEC-HMS basin model with the same frequency loss rates that were used for the uniform rainfall method which is discussed in a separate appendix. In some cases, the 2-yr through 10-yr losses had to be re-adjusted in order to maintain consistency with the frequent end of the statistical frequency curves at the USGS gages. This final adjustment was performed because of the increased level of confidence in the statistical frequency curve for the 2 through 10-yr recurrence intervals. The final 2-yr through 25-yr loss rates used for the elliptical frequency storm events are given in Table 3. The final 50-yr through 500-yr loss rates are the same as those used for the uniform rainfall method and are shown again in Table 4.

Table 3: Final Initial and Constant Losses for the 2-yr through 25-yr Elliptical Frequency Storms

Subbasin Name	2-yr Initial (in)	2-yr Constant (in/hr)	5-yr Initial (in)	5-yr Constant (in/hr)	10-yr Initial (in)	10-yr Constant (in/hr)	25-yr Initial (in)	25-yr Constant (in/hr)
West_Fork_S020	1.53	0.22	1.50	0.17	1.27	0.16	1.18	0.14
West_Fork_S010	1.55	0.22	1.59	0.17	1.41	0.16	1.37	0.14
West_Fork_S030	1.54	0.22	1.52	0.18	1.29	0.16	1.20	0.14
West_Fork_S040	1.53	0.22	1.51	0.17	1.28	0.16	1.19	0.14
West_Fork_S050	1.54	0.22	1.51	0.17	1.28	0.16	1.19	0.14
West_Fork_S060	1.53	0.22	1.50	0.17	1.27	0.16	1.18	0.14
West_Fork_S070	1.55	0.22	1.53	0.18	1.29	0.16	1.20	0.14
West_Fork_S080	1.52	0.22	1.49	0.17	1.26	0.16	1.17	0.14
West_Fork_S090	1.56	0.22	1.54	0.18	1.30	0.16	1.21	0.14
West_Fork_S100	1.50	0.22	1.47	0.17	1.25	0.15	1.16	0.14
West_Fork_S120	1.73	0.22	2.24	0.17	2.37	0.16	2.64	0.14
West_Fork_S110	1.58	0.23	1.55	0.18	1.31	0.16	1.22	0.14
Big_Cleveland_S010	1.86	0.22	2.73	0.17	3.12	0.16	3.63	0.14
Big_Cleveland_S020	1.71	0.22	2.18	0.17	2.28	0.16	2.52	0.14
West_Fork_S130	1.51	0.22	1.48	0.17	1.26	0.15	1.17	0.14
Lost_Ck_S010	1.78	0.22	1.50	0.17	1.27	0.16	1.18	0.14
Lost_Ck_S020	2.27	0.24	2.13	0.19	1.25	0.15	1.16	0.14
West_Fork_S140	2.47	0.24	2.76	0.19	1.94	0.16	2.06	0.14
West_Fork_S150	2.28	0.24	2.16	0.19	1.26	0.16	1.17	0.14
West_Fork_S160	2.34	0.24	2.20	0.20	1.29	0.16	1.20	0.14
Beans_Ck_S010	2.32	0.24	2.22	0.19	1.30	0.16	1.22	0.14
Beans_Ck_S020	2.35	0.24	2.22	0.20	1.29	0.16	1.20	0.14
Big_Ck_S010	2.39	0.25	2.27	0.20	1.34	0.16	1.25	0.14
Big_Ck_S030	2.46	0.25	2.31	0.20	1.35	0.16	1.25	0.15
Big_Ck_S020	2.40	0.25	2.25	0.20	1.32	0.16	1.23	0.14
Bridgeport_S030	2.51	0.26	2.35	0.21	1.37	0.17	1.27	0.15
Bridgeport_S010	2.08	0.22	1.96	0.17	1.16	0.14	1.07	0.13
Bridgeport_S040	2.48	0.25	2.34	0.20	1.36	0.17	1.26	0.15
Bridgeport_S020	2.38	0.25	2.24	0.20	1.31	0.16	1.21	0.14
West_Fork_S170	2.41	0.25	2.27	0.20	1.32	0.16	1.23	0.14
Dry_Ck_S010	2.52	0.26	2.43	0.21	1.45	0.17	1.38	0.15
West_Fork_S180	2.56	0.26	2.40	0.21	1.39	0.17	1.30	0.15
Amon_G_Carter_S030	1.71	0.20	1.68	0.17	1.66	0.15	1.79	0.14
Amon_G_Carter_S010	1.91	0.21	2.28	0.17	2.59	0.15	3.07	0.14
Amon_G_Carter_S020	1.68	0.21	1.54	0.17	1.43	0.15	1.48	0.14
Big_Sandy_Ck_S010	1.52	0.21	1.55	0.17	1.60	0.15	1.71	0.14
Big_Sandy_Ck_S020	1.49	0.22	1.33	0.18	1.20	0.16	1.39	0.15

Subbasin Name	2-yr Initial (in)	2-yr Constant (in/hr)	5-yr Initial (in)	5-yr Constant (in/hr)	10-yr Initial (in)	10-yr Constant (in/hr)	25-yr Initial (in)	25-yr Constant (in/hr)
Brushy_Ck_S010	1.48	0.22	1.35	0.18	1.26	0.16	1.42	0.15
Brushy_Ck_S020	1.56	0.22	1.51	0.18	1.50	0.16	1.63	0.15
Brushy_Ck_S030	1.66	0.22	1.85	0.18	2.03	0.16	2.07	0.15
Big_Sandy_Ck_S030	1.57	0.22	1.52	0.18	1.50	0.16	1.63	0.15
Big_Sandy_Ck_S040	1.52	0.22	1.39	0.18	1.30	0.16	1.46	0.15
Big_Sandy_Ck_S050	2.58	0.26	2.51	0.21	1.50	0.17	1.44	0.15
West_Fork_S190	2.56	0.26	2.48	0.21	1.49	0.17	1.43	0.15
West_Fork_S200	2.52	0.26	2.36	0.21	1.37	0.17	1.28	0.15
Garrett_Ck_S020	2.71	0.25	2.76	0.20	2.27	0.17	2.48	0.15
Garrett_Ck_S010	2.75	0.26	2.76	0.21	2.34	0.17	2.57	0.15
Garrett_Ck_S030	2.53	0.26	2.37	0.21	1.37	0.17	1.29	0.15
Salt_Ck_S010	2.81	0.26	2.76	0.21	3.29	0.17	3.82	0.15
Salt_Ck_S020	2.80	0.26	2.76	0.21	2.27	0.17	2.45	0.15
West_Fork_S210	2.55	0.26	2.39	0.21	1.38	0.17	1.29	0.15
West_Fork_S220	2.29	0.22	2.26	0.18	2.37	0.17	1.75	0.15
Eagle_Mountain_S010	2.19	0.21	2.02	0.18	2.01	0.16	1.25	0.15
Eagle_Mountain_S020	2.05	0.20	1.90	0.17	1.92	0.15	1.14	0.14
Walnut_Ck_S020	1.54	0.20	1.66	0.17	1.79	0.15	1.29	0.15
Walnut_Ck_S010	1.54	0.20	1.66	0.17	1.78	0.15	1.28	0.15
Walnut_Ck_S030	2.25	0.22	2.15	0.18	2.06	0.17	1.29	0.15
Eagle_Mountain_S040	2.07	0.20	2.00	0.17	1.94	0.15	1.16	0.14
Eagle_Mountain_S030	2.21	0.21	2.11	0.18	2.02	0.17	1.26	0.15
Silver_Ck_S020	2.19	0.21	2.18	0.18	2.18	0.16	1.48	0.14
Silver_Ck_S010	2.27	0.22	2.25	0.18	2.23	0.17	1.54	0.15
Lake_Worth_S010	2.17	0.21	2.08	0.18	2.00	0.16	1.23	0.14
Lake_Worth_S020	2.11	0.20	2.02	0.17	1.95	0.16	1.18	0.14
West_Fork_S230	2.03	0.20	2.04	0.17	1.96	0.15	1.32	0.15
Lk_Weatherford_S010	1.69	0.21	2.64	0.17	2.39	0.16	1.69	0.14
Lk_Weatherford_S020	1.49	0.20	2.09	0.17	1.75	0.15	1.71	0.15
Clear_Fork_S010	1.76	0.20	2.02	0.16	2.27	0.15	2.73	0.15
Clear_Fork_S020	1.54	0.20	1.36	0.16	1.22	0.15	1.23	0.14
Bear_Ck_S010	1.58	0.20	1.46	0.16	1.38	0.15	1.46	0.14
Bear_Ck_S020	1.50	0.19	1.32	0.15	1.19	0.15	1.19	0.14
Benbrook_S010	1.46	0.19	1.29	0.15	1.17	0.14	1.17	0.14
Benbrook_S020	1.41	0.18	1.25	0.15	1.14	0.14	1.13	0.14
Benbrook_S030	1.40	0.18	1.23	0.14	1.12	0.14	1.12	0.13
Clear_Fork_S030	1.50	0.19	1.53	0.15	1.57	0.15	1.19	0.14
Marys_Ck_S010	1.87	0.20	1.92	0.19	2.03	0.18	1.21	0.14
Clear_Fork_S040	1.72	0.20	1.76	0.17	1.87	0.15	2.00	0.15

Subbasin Name	2-yr Initial (in)	2-yr Constant (in/hr)	5-yr Initial (in)	5-yr Constant (in/hr)	10-yr Initial (in)	10-yr Constant (in/hr)	25-yr Initial (in)	25-yr Constant (in/hr)
Clear_Fork_S050	2.07	0.21	2.08	0.18	2.00	0.16	1.35	0.15
West_Fork_S240	2.06	0.20	1.95	0.16	1.88	0.15	1.26	0.15
Marine_Ck_S020	2.27	0.20	2.38	0.16	2.56	0.15	2.52	0.15
Marine_Ck_S010	1.37	0.18	1.21	0.14	1.10	0.14	1.10	0.13
West_Fork_S250	2.11	0.21	1.99	0.17	1.93	0.15	1.29	0.15
West_Fork_S260	1.92	0.20	1.90	0.15	1.94	0.14	1.35	0.14
West_Fork_S270	3.28	0.31	3.00	0.22	2.36	0.15	1.76	0.15
Big_Fossil_Ck_S010	2.17	0.24	2.46	0.18	2.17	0.12	2.91	0.13
LittleFossil_Ck_S010	3.22	0.27	2.28	0.20	1.72	0.13	1.07	0.13
West_Fork_S280	3.28	0.29	2.53	0.21	1.96	0.15	1.18	0.14
Village_Ck_S010	1.82	0.25	1.65	0.19	1.15	0.13	1.29	0.14
Village_Ck_S020	1.98	0.25	1.56	0.19	1.04	0.13	1.13	0.14
Lake_Arlington_S010	1.94	0.25	1.53	0.18	1.03	0.13	1.11	0.13
Village_Ck_S030	3.28	0.31	2.64	0.22	2.04	0.15	1.23	0.14
West_Fork_S290	3.28	0.31	2.64	0.22	2.04	0.15	1.23	0.14
West_Fork_S300	3.28	0.28	2.46	0.21	1.88	0.14	1.15	0.14
West_Fork_S310	3.28	0.28	2.36	0.20	1.84	0.14	1.11	0.13
West_Fork_S320	1.27	0.16	1.12	0.13	1.00	0.12	1.26	0.15
Big_Bear_Ck_S010	1.21	0.15	1.13	0.12	1.09	0.12	1.43	0.14
Big_Bear_Ck_S020	1.25	0.16	1.10	0.13	0.99	0.12	1.24	0.15
West_Fork_S330	1.25	0.16	1.09	0.13	0.98	0.12	1.24	0.14
Joe_Pool_S020	1.33	0.16	1.36	0.14	1.43	0.13	1.60	0.13
Joe_Pool_S030	1.40	0.18	1.42	0.18	1.51	0.16	1.13	0.14
Joe_Pool_S040	1.37	0.18	1.21	0.14	1.10	0.14	1.10	0.13
Joe_Pool_S010	1.19	0.16	1.05	0.13	0.97	0.12	0.96	0.12
Joe_Pool_S050	1.24	0.16	1.10	0.14	1.01	0.13	1.00	0.12
Mountain_Ck_S010	1.27	0.16	1.14	0.14	1.05	0.13	1.04	0.13
Mountain_Ck_S020	1.29	0.16	1.14	0.14	1.04	0.13	1.04	0.13
Mountain_Ck_S030	1.33	0.17	1.34	0.17	1.29	0.15	1.07	0.13
West_Fork_S340	1.14	0.14	1.01	0.12	0.92	0.11	1.14	0.14
Elm_Fork_S020	1.55	0.17	1.86	0.14	2.16	0.14	2.62	0.13
Elm_Fork_S010	1.77	0.18	2.50	0.15	3.15	0.14	4.03	0.14
Brushy_Elm_Ck_S010	1.44	0.17	1.61	0.14	1.78	0.13	2.09	0.13
Brushy_Elm_Ck_S020	1.37	0.17	1.33	0.14	1.33	0.13	1.44	0.13
Elm_Fork_S030	1.47	0.17	1.69	0.14	1.91	0.13	2.27	0.13
Elm_Fork_S040	1.37	0.17	1.39	0.14	1.44	0.13	1.60	0.13
Elm_Fork_S050	1.49	0.18	1.50	0.15	1.52	0.14	1.69	0.14
Elm_Fork_S070	1.44	0.18	1.36	0.14	1.32	0.14	1.40	0.13
Elm_Fork_S060	1.26	0.16	1.11	0.14	1.02	0.13	1.02	0.13

Subbasin Name	2-yr Initial (in)	2-yr Constant (in/hr)	5-yr Initial (in)	5-yr Constant (in/hr)	10-yr Initial (in)	10-yr Constant (in/hr)	25-yr Initial (in)	25-yr Constant (in/hr)
Spring_Ck_S010	1.32	0.17	1.17	0.14	1.07	0.13	1.06	0.13
Spring_Ck_S020	1.32	0.17	1.17	0.14	1.07	0.13	1.06	0.13
Ray_Roberts_S010	1.52	0.17	1.78	0.14	2.04	0.14	2.45	0.13
Timber_Ck_S010	1.58	0.20	1.39	0.16	1.26	0.15	1.26	0.15
Timber_Ck_S030	1.44	0.18	1.27	0.15	1.15	0.14	1.15	0.14
Timber_Ck_S020	1.57	0.20	1.38	0.16	1.24	0.15	1.25	0.15
Ray_Roberts_S030	1.47	0.19	1.30	0.15	1.18	0.15	1.19	0.14
Range_Ck_S010	1.83	0.23	1.88	0.22	1.94	0.22	1.00	0.12
Range_Ck_S020	1.22	0.16	1.08	0.13	1.00	0.12	0.98	0.12
Lake_Kiowa_S020	1.55	0.20	1.36	0.16	1.23	0.15	1.23	0.14
Lake_Kiowa_S010	1.62	0.20	1.42	0.17	1.28	0.15	1.29	0.15
Ray_Roberts_S020	1.23	0.16	1.10	0.14	1.01	0.13	1.00	0.12
Range_Ck_S030	1.29	0.17	1.14	0.14	1.05	0.13	1.04	0.13
Buck_Ck_S010	1.22	0.16	1.09	0.14	1.00	0.12	0.99	0.12
Ray_Roberts_S050	1.24	0.16	1.10	0.14	1.01	0.13	1.00	0.12
Ray_Roberts_S040	1.38	0.17	1.34	0.14	1.32	0.13	1.42	0.13
Ray_Roberts_S060	1.37	0.18	1.21	0.14	1.10	0.14	1.10	0.13
Timber_Ck_S040	1.42	0.18	1.25	0.15	1.14	0.14	1.13	0.14
Elm_Fork_S080	1.83	0.23	1.75	0.21	1.17	0.15	1.17	0.14
Clear_Ck_S010	1.65	0.18	2.27	0.16	2.67	0.15	3.31	0.15
Clear_Ck_S020	1.61	0.18	2.06	0.17	2.31	0.15	2.78	0.15
Clear_Ck_S030	1.65	0.18	2.29	0.16	2.70	0.15	3.34	0.15
Clear_Ck_S040	1.58	0.17	2.30	0.15	2.80	0.14	3.50	0.14
Clear_Ck_S050	1.44	0.16	1.92	0.15	2.21	0.14	2.68	0.14
Clear_Ck_S070	1.30	0.16	1.50	0.14	1.57	0.14	1.76	0.13
Clear_Ck_S060	1.34	0.17	1.31	0.15	1.19	0.15	1.19	0.14
Clear_Ck_S080	1.44	0.16	1.93	0.15	2.24	0.14	2.72	0.14
Clear_Ck_S090	1.30	0.16	1.62	0.14	1.81	0.13	2.13	0.13
Clear_Ck_S110	1.29	0.17	1.14	0.14	1.05	0.13	1.04	0.13
Clear_Ck_S100	1.39	0.17	1.44	0.14	1.51	0.13	1.70	0.13
Clear_Ck_S120	1.37	0.17	1.24	0.14	1.17	0.14	1.20	0.13
Little_Elm_Ck_S010	1.58	0.18	1.81	0.14	2.17	0.12	2.66	0.12
Little_Elm_Ck_S020	1.46	0.17	1.49	0.13	1.66	0.12	1.94	0.12
Little_Elm_Ck_S030	1.19	0.16	1.06	0.13	0.98	0.12	0.97	0.12
Pecan_Ck_S010	1.44	0.19	1.27	0.15	1.15	0.14	1.15	0.14
Doe_Branch_S010	1.22	0.16	1.10	0.14	1.02	0.12	1.02	0.12
Doe_Branch_S020	1.25	0.16	1.10	0.14	1.01	0.13	1.01	0.12
Lewisville_S030	1.39	0.18	1.23	0.14	1.12	0.14	1.12	0.13
Hickory_Ck_S020	1.36	0.17	1.32	0.14	1.32	0.13	1.42	0.13

Subbasin Name	2-yr Initial (in)	2-yr Constant (in/hr)	5-yr Initial (in)	5-yr Constant (in/hr)	10-yr Initial (in)	10-yr Constant (in/hr)	25-yr Initial (in)	25-yr Constant (in/hr)
Hickory_Ck_S010	1.35	0.17	1.31	0.14	1.32	0.13	1.42	0.13
Hickory_Ck_S030	1.29	0.16	1.18	0.14	1.10	0.13	1.12	0.13
Hickory_Ck_S040	1.56	0.17	1.88	0.14	2.18	0.14	2.66	0.13
Hickory_Ck_S050	1.63	0.20	1.58	0.16	1.57	0.15	1.71	0.15
Lewisville_S010	1.47	0.19	1.34	0.15	1.26	0.14	1.30	0.14
Lewisville_S040	1.20	0.16	1.07	0.13	0.99	0.12	0.97	0.12
Lewisville_S050	1.24	0.16	1.10	0.14	1.01	0.13	1.00	0.12
Lewisville_S020	1.47	0.19	1.34	0.15	1.26	0.14	1.30	0.14
Elm_Fork_S090	2.34	0.23	2.20	0.21	2.24	0.18	1.08	0.13
Elm_Fork_S110	2.34	0.21	2.20	0.20	2.24	0.18	1.03	0.13
Elm_Fork_S100	2.34	0.24	2.20	0.22	2.24	0.21	1.26	0.14
Elm_Fork_S120	2.34	0.21	2.20	0.20	2.24	0.18	1.83	0.13
Denton_Ck_S010	1.81	0.25	2.04	0.19	2.20	0.17	2.64	0.15
Denton_Ck_S020	1.79	0.24	2.02	0.18	2.19	0.16	2.62	0.15
Denton_Ck_S030	1.74	0.24	1.95	0.18	2.09	0.16	2.48	0.14
Denton_Ck_S040	1.76	0.22	1.67	0.17	1.66	0.15	1.68	0.13
Denton_Ck_S050	1.47	0.17	1.62	0.14	1.76	0.14	2.05	0.13
Denton_Ck_S060	1.33	0.17	1.18	0.14	1.08	0.13	1.07	0.13
Denton_Ck_S070	1.34	0.17	1.20	0.14	1.11	0.13	1.12	0.13
Grapevine_S010	1.53	0.19	1.51	0.15	1.52	0.15	1.68	0.14
Denton_Ck_S080	2.34	0.23	2.38	0.22	2.55	0.19	1.13	0.14
Elm_Fork_S130	1.10	0.14	1.12	0.11	1.16	0.10	1.61	0.13
Hackberry_Ck_S010	1.07	0.12	1.24	0.10	1.42	0.10	2.10	0.12
Hackberry_Ck_S020	0.95	0.12	0.84	0.10	0.78	0.10	0.97	0.12
Hackberry_Ck_S030	0.98	0.13	0.87	0.11	0.80	0.10	0.99	0.12
Elm_Fork_S140	1.11	0.14	0.98	0.12	0.89	0.11	1.11	0.13
Elm_Fork_S150	1.12	0.14	0.99	0.12	0.89	0.11	1.12	0.13
Bachman_Branch_S010	1.19	0.15	1.04	0.12	0.94	0.12	1.18	0.14
Bachman_Branch_S020	1.12	0.14	0.99	0.12	0.90	0.11	1.13	0.14
Elm_Fork_S160	1.13	0.14	1.00	0.12	0.91	0.11	1.13	0.14
Trinity_River_S010	1.11	0.14	1.04	0.12	1.18	0.11	1.30	0.13
Trinity_River_S020	1.67	0.20	1.29	0.13	1.11	0.10	1.18	0.09
White_Rock_Ck_S010	1.58	0.18	1.38	0.12	1.30	0.09	1.46	0.08
White_Rock_Ck_S020	1.57	0.20	1.06	0.12	0.81	0.10	0.77	0.09
White_Rock_Ck_S030	1.54	0.20	1.04	0.12	0.80	0.09	0.75	0.09
White_Rock_Ck_S040	1.52	0.19	1.03	0.12	0.78	0.09	0.75	0.09
Trinity_River_S030	1.63	0.21	1.10	0.13	0.84	0.10	0.80	0.09
Fivemile_Ck_S010	1.53	0.19	0.94	0.10	0.87	0.09	0.99	0.09
Trinity_River_S040	1.38	0.17	0.80	0.10	0.71	0.08	0.75	0.09

Subbasin Name	2-yr Initial (in)	2-yr Constant (in/hr)	5-yr Initial (in)	5-yr Constant (in/hr)	10-yr Initial (in)	10-yr Constant (in/hr)	25-yr Initial (in)	25-yr Constant (in/hr)
Trinity_River_S050	1.34	0.17	0.77	0.09	0.69	0.08	0.73	0.08
Tenmile_Ck_S010	1.40	0.17	0.82	0.10	0.75	0.08	0.81	0.09
Tenmile_Ck_S020	1.25	0.17	0.72	0.09	0.64	0.08	0.68	0.08
Trinity_River_S060	1.42	0.18	0.86	0.10	0.80	0.08	0.88	0.09
Indian_Ck_S010	1.36	0.16	1.28	0.10	1.48	0.09	1.63	0.08
Indian_Ck_S030	1.37	0.17	1.07	0.11	1.09	0.10	1.10	0.08
Indian_Ck_S020	1.16	0.15	0.79	0.09	0.71	0.09	0.63	0.08
Indian_Ck_S040	1.31	0.16	1.15	0.10	1.27	0.09	1.35	0.08
Sister_Grove_S010	1.52	0.17	1.42	0.11	1.63	0.10	1.79	0.08
Sister_Grove_S020	1.37	0.17	1.16	0.10	1.26	0.09	1.33	0.08
East_Fork_S020	1.45	0.17	1.33	0.11	1.52	0.09	1.66	0.08
East_Fork_S010	1.58	0.17	1.64	0.11	2.00	0.09	2.27	0.08
East_Fork_S030	1.33	0.17	1.00	0.11	0.99	0.09	0.97	0.08
East_Fork_S040	1.27	0.17	0.86	0.11	0.77	0.09	0.69	0.08
Wilson_Ck_S010	1.45	0.17	1.29	0.11	1.43	0.09	1.53	0.08
Lavon_S010	1.18	0.15	0.86	0.09	0.83	0.09	0.79	0.08
Lavon_S020	1.19	0.16	0.81	0.10	0.73	0.09	0.65	0.08
Rowlett_Ck_S010	1.73	0.19	1.27	0.12	1.12	0.11	0.77	0.08
Ray_Hubbard_S010	1.30	0.07	1.02	0.06	1.21	0.07	1.40	0.08
Ray_Hubbard_S020	0.60	0.07	0.47	0.06	0.56	0.07	0.65	0.08
East_Fork_S050	0.62	0.08	0.49	0.06	0.58	0.07	0.68	0.08
East_Fork_S070	0.86	0.11	0.61	0.08	1.54	0.07	0.64	0.08
East_Fork_S060	1.10	0.11	1.23	0.08	0.64	0.07	2.03	0.08
East_Fork_S080	0.86	0.11	0.61	0.08	0.64	0.07	0.64	0.08
East_Fork_S090	0.86	0.11	0.63	0.08	0.65	0.07	0.67	0.08
East_Fork_S110	0.91	0.11	0.74	0.09	0.69	0.08	0.76	0.08
East_Fork_S100	1.14	0.11	1.32	0.08	1.68	0.07	2.21	0.08
Trinity_River_S070	1.08	0.14	0.75	0.09	0.70	0.08	0.75	0.08
East_Fork_S120	1.12	0.13	0.98	0.09	1.09	0.08	1.37	0.08
Kings_Ck_S020	1.06	0.13	0.86	0.08	0.91	0.07	1.10	0.08
Kings_Ck_S010	1.15	0.13	1.00	0.09	1.09	0.08	1.37	0.08
Kings_Ck_S030	1.19	0.13	1.15	0.09	1.34	0.08	1.76	0.08
Cedar_Ck_S040	1.31	0.15	1.07	0.10	1.11	0.09	1.35	0.09
Cedar_Ck_S010	0.74	0.08	0.58	0.07	0.63	0.07	0.85	0.08
New_Terrell_City_Lake_S010	0.63	0.14	0.43	0.08	0.38	0.08	0.40	0.08
Cedar_Ck_S020	1.11	0.14	0.79	0.09	0.74	0.08	0.82	0.08
Cedar_Ck_S030	1.35	0.15	1.19	0.10	1.32	0.09	1.68	0.09
Trinity_River_S080	1.11	0.13	0.87	0.09	0.89	0.08	1.05	0.08

Subbasin Name	2-yr Initial (in)	2-yr Constant (in/hr)	5-yr Initial (in)	5-yr Constant (in/hr)	10-yr Initial (in)	10-yr Constant (in/hr)	25-yr Initial (in)	25-yr Constant (in/hr)
Trinity_River_S090	1.21	0.15	0.92	0.09	0.92	0.09	1.07	0.08
Chambers_Ck_S010	1.29	0.18	1.13	0.12	1.24	0.10	1.40	0.08
Chambers_Ck_S020	1.34	0.18	1.34	0.11	1.59	0.10	1.81	0.08
Chambers_Ck_S040	1.36	0.18	1.33	0.12	1.55	0.10	1.77	0.08
Chambers_Ck_S030	1.41	0.19	1.31	0.12	1.48	0.11	1.66	0.08
Waxahachie_Ck_S010	2.27	0.22	2.08	0.18	2.26	0.15	2.31	0.09
Waxahachie_Ck_S020	1.70	0.20	1.38	0.13	1.43	0.12	1.35	0.09
Waxahachie_Ck_S030	1.38	0.17	1.01	0.11	0.98	0.10	0.85	0.08
Mustang_Ck_S010	1.30	0.17	0.97	0.10	0.95	0.10	0.84	0.08
Bardwell_S010	1.34	0.17	1.05	0.10	1.07	0.10	0.97	0.08
Chambers_Ck_S050	1.25	0.17	1.25	0.10	1.49	0.10	1.70	0.08
Chambers_Ck_S060	1.21	0.17	1.04	0.11	1.12	0.10	1.25	0.08
Chambers_Ck_S070	1.25	0.17	1.24	0.10	1.47	0.10	1.68	0.08
Chambers_Ck_S080	1.12	0.14	0.92	0.09	0.98	0.08	1.18	0.08
Post_Oak_Ck_S010	1.14	0.14	0.97	0.09	1.05	0.08	1.29	0.08
Lake_Halbert_S010	1.07	0.13	0.87	0.08	0.92	0.07	1.09	0.08
Navarro_Mills_S020	1.10	0.14	0.89	0.09	0.93	0.08	1.11	0.08
Navarro_Mills_S030	1.35	0.14	1.39	0.09	1.68	0.08	2.22	0.08
Navarro_Mills_S010	1.34	0.15	1.24	0.10	1.41	0.09	1.80	0.09
Navarro_Mills_S040	1.04	0.14	0.71	0.09	0.63	0.08	0.66	0.08
Richland_Ck_S010	1.16	0.14	1.01	0.09	1.12	0.08	1.39	0.08
Richland_Ck_S020	1.19	0.14	1.15	0.09	1.34	0.08	1.72	0.08
Richland-Chambers_S010	1.04	0.14	0.71	0.09	0.64	0.08	0.66	0.08
Richland-Chambers_S020	1.02	0.14	0.70	0.09	0.62	0.08	0.65	0.08
Tehuacana_Ck_S020	1.48	0.15	1.43	0.10	1.66	0.09	2.15	0.09
Tehuacana_Ck_S010	0.77	0.14	0.81	0.09	1.13	0.09	1.38	0.08
Trinity_River_S100	1.17	0.15	0.79	0.10	0.70	0.09	0.73	0.09
Fairfield_Lake_S010	1.60	0.15	1.79	0.10	2.24	0.09	3.04	0.09
Trinity_River_S110	1.48	0.18	1.01	0.11	0.90	0.10	0.98	0.10
Big_Brown_Ck_S010	1.74	0.17	1.82	0.11	2.20	0.10	2.94	0.10
Trinity_River_S120	1.43	0.17	1.14	0.11	1.16	0.10	1.39	0.10
Trinity_River_S130	1.40	0.17	0.98	0.11	0.95	0.11	0.94	0.10
Upper_Keechi_Ck_S030	1.53	0.18	1.07	0.12	1.02	0.11	1.02	0.10
Upper_Keechi_Ck_S010	1.53	0.18	1.19	0.12	1.18	0.12	0.94	0.10
Upper_Keechi_Ck_S020	1.64	0.19	1.22	0.12	1.24	0.12	1.30	0.10
Upper_Keechi_Ck_S040	1.43	0.18	0.96	0.11	0.89	0.11	0.85	0.10
Trinity_River_S140	1.05	0.14	0.72	0.09	0.68	0.08	0.64	0.08
Little_Elkhart_S010	1.50	0.18	1.01	0.12	0.93	0.11	0.89	0.10
Houston_County_Lake_S010	1.92	0.19	2.01	0.12	2.57	0.11	3.12	0.10

Subbasin Name	2-yr Initial (in)	2-yr Constant (in/hr)	5-yr Initial (in)	5-yr Constant (in/hr)	10-yr Initial (in)	10-yr Constant (in/hr)	25-yr Initial (in)	25-yr Constant (in/hr)
Trinity_River_S150	1.32	0.16	0.90	0.11	0.84	0.10	0.81	0.09
Trinity_River_S160	1.54	0.20	0.99	0.12	0.80	0.10	0.79	0.09
Trinity_River_S170	1.76	0.21	1.14	0.13	0.92	0.11	0.92	0.10
Trinity_River_S180	1.54	0.20	0.99	0.12	0.80	0.10	0.79	0.09
Bedias_Ck_S010	1.46	0.19	1.32	0.11	1.41	0.09	1.70	0.09
Bedias_Ck_S020	1.52	0.19	0.98	0.12	0.79	0.10	0.78	0.09
Trinity_River_S190	1.50	0.19	0.97	0.11	0.79	0.10	0.78	0.09
Livingston_S010	1.17	0.14	0.94	0.11	0.88	0.11	0.80	0.09
Livingston_S030	1.12	0.14	0.90	0.11	0.84	0.10	0.75	0.09
Livingston_S020	1.10	0.14	0.88	0.11	0.82	0.10	0.74	0.09
Trinity_River_S200	0.99	0.12	0.92	0.11	0.86	0.11	0.77	0.09
Long_King_Ck_S010	1.16	0.14	0.93	0.11	0.86	0.11	0.78	0.09
Long_King_Ck_S020	1.09	0.12	1.02	0.11	1.00	0.11	0.96	0.09
Trinity_River_S210	1.40	0.15	1.09	0.12	1.00	0.11	0.94	0.10
Menard_Ck_S010	1.65	0.20	1.30	0.12	1.31	0.11	1.34	0.10
Trinity_River_S220	1.28	0.15	1.00	0.12	0.89	0.11	0.80	0.09
Trinity_River_S230	1.10	0.15	0.87	0.11	0.78	0.09	0.70	0.08
Trinity_River_S240	1.13	0.15	0.89	0.11	0.79	0.10	0.71	0.08
Trinity_River_S250	1.43	0.16	1.36	0.10	1.58	0.09	1.75	0.08

Table 4: Final Initial and Constant Losses for the 50-yr through 500-yr Elliptical Frequency Storms

Subbasin Name	50-yr Initial (in)	50-yr Constant (in/hr)	100-yr Initial (in)	100-yr Constant (in/hr)	250-yr Initial (in)	250-yr Constant (in/hr)	500-yr Initial (in)	500-yr Constant (in/hr)
West_Fork_S020	1.01	0.12	0.85	0.09	0.69	0.08	0.57	0.07
West_Fork_S010	1.21	0.12	1.05	0.09	0.89	0.08	0.57	0.07
West_Fork_S030	1.02	0.12	0.86	0.09	0.69	0.08	0.57	0.07
West_Fork_S040	1.02	0.12	0.85	0.09	0.69	0.08	0.57	0.07
West_Fork_S050	1.02	0.12	0.85	0.09	0.69	0.08	0.57	0.07
West_Fork_S060	1.01	0.12	0.85	0.09	0.69	0.08	0.57	0.07
West_Fork_S070	1.03	0.12	0.86	0.09	0.70	0.08	0.57	0.07
West_Fork_S080	1.01	0.12	0.85	0.09	0.69	0.08	0.56	0.07
West_Fork_S090	1.03	0.12	0.86	0.09	0.70	0.08	0.57	0.07
West_Fork_S100	1.00	0.12	0.84	0.09	0.68	0.08	0.56	0.07
West_Fork_S120	2.58	0.12	2.41	0.09	2.25	0.08	0.57	0.07
West_Fork_S110	1.04	0.12	0.87	0.09	0.70	0.08	0.58	0.07
Big_Cleveland_S010	3.66	0.12	3.49	0.09	3.33	0.08	0.57	0.07
Big_Cleveland_S020	2.46	0.12	2.29	0.09	2.13	0.08	0.57	0.07
West_Fork_S130	1.00	0.12	0.84	0.09	0.68	0.08	0.56	0.07
Lost_Ck_S010	1.01	0.12	0.85	0.09	0.69	0.08	0.57	0.07
Lost_Ck_S020	1.00	0.12	0.84	0.09	0.68	0.08	0.56	0.07
West_Fork_S140	1.97	0.12	1.81	0.09	1.65	0.08	0.56	0.07
West_Fork_S150	1.01	0.12	0.85	0.09	0.69	0.08	0.56	0.07
West_Fork_S160	1.02	0.12	0.86	0.09	0.69	0.08	0.57	0.07
Beans_Ck_S010	1.05	0.12	0.89	0.09	0.73	0.08	0.57	0.07
Beans_Ck_S020	1.03	0.12	0.86	0.09	0.69	0.08	0.57	0.07
Big_Ck_S010	1.08	0.12	0.90	0.09	0.74	0.08	0.58	0.07
Big_Ck_S030	1.07	0.13	0.88	0.10	0.71	0.08	0.59	0.08
Big_Ck_S020	1.04	0.12	0.87	0.09	0.70	0.08	0.58	0.07
Bridgeport_S030	1.08	0.13	0.89	0.10	0.72	0.09	0.59	0.08
Bridgeport_S010	0.93	0.11	0.80	0.08	0.65	0.07	0.53	0.06
Bridgeport_S040	1.07	0.13	0.88	0.10	0.72	0.09	0.59	0.08
Bridgeport_S020	1.04	0.12	0.86	0.09	0.70	0.08	0.58	0.07
West_Fork_S170	1.05	0.12	0.87	0.09	0.70	0.08	0.58	0.07
Dry_Ck_S010	1.20	0.13	1.01	0.10	0.84	0.09	0.59	0.08
West_Fork_S180	1.10	0.13	0.90	0.10	0.73	0.09	0.60	0.08
Amon_G_Carter_S030	1.67	0.12	1.50	0.09	1.34	0.08	0.57	0.07
Amon_G_Carter_S010	3.04	0.12	2.87	0.09	2.70	0.08	0.58	0.07
Amon_G_Carter_S020	1.32	0.12	1.15	0.09	0.98	0.08	0.58	0.07
Big_Sandy_Ck_S010	1.56	0.12	1.37	0.09	1.21	0.08	0.58	0.07
Big_Sandy_Ck_S020	1.19	0.13	1.00	0.10	0.83	0.09	0.60	0.08
Brushy_Ck_S010	1.24	0.13	1.05	0.10	0.88	0.09	0.59	0.08
Brushy_Ck_S020	1.46	0.13	1.26	0.10	1.09	0.09	0.60	0.08

Subbasin Name	50-yr Initial (in)	50-yr Constant (in/hr)	100-yr Initial (in)	100-yr Constant (in/hr)	250-yr Initial (in)	250-yr Constant (in/hr)	500-yr Initial (in)	500-yr Constant (in/hr)
Brushy_Ck_S030	1.94	0.13	1.74	0.10	1.57	0.09	0.60	0.08
Big_Sandy_Ck_S030	1.46	0.13	1.26	0.10	1.09	0.09	0.60	0.08
Big_Sandy_Ck_S040	1.28	0.13	1.08	0.10	0.91	0.09	0.60	0.08
Big_Sandy_Ck_S050	1.26	0.13	1.06	0.10	0.89	0.09	0.60	0.08
West_Fork_S190	1.25	0.13	1.05	0.10	0.88	0.09	0.60	0.08
West_Fork_S200	1.09	0.13	0.89	0.10	0.72	0.09	0.59	0.08
Garrett_Ck_S020	2.39	0.13	2.20	0.10	2.03	0.09	0.59	0.08
Garrett_Ck_S010	2.48	0.13	2.29	0.10	2.12	0.09	0.59	0.08
Garrett_Ck_S030	1.09	0.13	0.89	0.10	0.72	0.09	0.60	0.08
Salt_Ck_S010	3.82	0.13	3.62	0.10	3.45	0.09	0.60	0.08
Salt_Ck_S020	2.35	0.13	2.14	0.10	1.97	0.09	0.60	0.08
West_Fork_S210	1.09	0.13	0.90	0.10	0.73	0.09	0.60	0.08
West_Fork_S220	1.60	0.13	1.41	0.10	1.24	0.09	0.59	0.08
Eagle_Mountain_S010	1.06	0.13	0.88	0.10	0.71	0.08	0.59	0.08
Eagle_Mountain_S020	0.98	0.12	0.83	0.09	0.67	0.08	0.56	0.07
Walnut_Ck_S020	1.09	0.13	0.90	0.10	0.73	0.09	0.60	0.08
Walnut_Ck_S010	1.09	0.13	0.89	0.10	0.72	0.09	0.60	0.08
Walnut_Ck_S030	1.09	0.13	0.90	0.10	0.73	0.09	0.60	0.08
Eagle_Mountain_S040	0.99	0.12	0.84	0.09	0.68	0.08	0.56	0.07
Eagle_Mountain_S030	1.07	0.13	0.88	0.10	0.71	0.09	0.59	0.08
Silver_Ck_S020	1.32	0.12	1.15	0.09	0.98	0.08	0.58	0.07
Silver_Ck_S010	1.37	0.13	1.17	0.10	1.00	0.09	0.59	0.08
Lake_Worth_S010	1.05	0.12	0.87	0.09	0.70	0.08	0.58	0.07
Lake_Worth_S020	1.01	0.12	0.85	0.09	0.69	0.08	0.57	0.07
West_Fork_S230	1.11	0.13	0.91	0.10	0.74	0.09	0.60	0.08
Lk_Weatherford_S010	2.81	0.13	2.61	0.10	2.44	0.09	0.60	0.08
Lk_Weatherford_S020	1.87	0.12	1.70	0.09	1.54	0.08	0.57	0.07
Clear_Fork_S010	2.66	0.13	2.48	0.10	2.31	0.08	0.59	0.08
Clear_Fork_S020	1.05	0.12	0.87	0.09	0.70	0.08	0.58	0.07
Bear_Ck_S010	1.29	0.12	1.11	0.09	0.95	0.08	0.58	0.07
Bear_Ck_S020	1.02	0.12	0.85	0.09	0.69	0.08	0.57	0.07
Benbrook_S010	1.00	0.12	0.84	0.09	0.68	0.08	0.56	0.07
Benbrook_S020	0.98	0.12	0.83	0.09	0.67	0.07	0.55	0.07
Benbrook_S030	0.96	0.11	0.82	0.08	0.67	0.07	0.55	0.06
Clear_Fork_S030	1.02	0.12	0.85	0.09	0.69	0.08	0.57	0.07
Marys_Ck_S010	1.04	0.12	0.86	0.09	0.70	0.08	0.58	0.07
Clear_Fork_S040	1.86	0.13	1.66	0.10	1.49	0.09	0.60	0.08
Clear_Fork_S050	1.13	0.13	0.92	0.10	0.74	0.09	0.61	0.08
West_Fork_S240	1.07	0.13	0.88	0.10	0.71	0.09	0.59	0.08
Marine_Ck_S020	2.43	0.13	2.24	0.10	2.08	0.09	0.59	0.08
Marine_Ck_S010	0.95	0.11	0.81	0.08	0.66	0.07	0.54	0.06

Subbasin Name	50-yr Initial (in)	50-yr Constant (in/hr)	100-yr Initial (in)	100-yr Constant (in/hr)	250-yr Initial (in)	250-yr Constant (in/hr)	500-yr Initial (in)	500-yr Constant (in/hr)
West_Fork_S250	1.09	0.13	0.89	0.10	0.72	0.09	0.60	0.08
West_Fork_S260	1.20	0.12	1.04	0.09	0.88	0.08	0.56	0.07
West_Fork_S270	1.62	0.13	1.44	0.10	1.27	0.08	0.58	0.08
Big_Fossil_Ck_S010	2.92	0.11	2.80	0.08	2.65	0.07	0.53	0.06
LittleFossil_Ck_S010	0.93	0.11	0.80	0.08	0.65	0.07	0.53	0.06
West_Fork_S280	1.01	0.12	0.85	0.09	0.69	0.08	0.57	0.07
Village_Ck_S010	1.14	0.12	0.99	0.09	0.83	0.08	0.55	0.07
Village_Ck_S020	0.97	0.12	0.83	0.09	0.67	0.07	0.55	0.07
Lake_Arlington_S010	0.96	0.11	0.82	0.08	0.66	0.07	0.55	0.06
Village_Ck_S030	1.05	0.12	0.87	0.09	0.71	0.08	0.58	0.07
West_Fork_S290	1.05	0.12	0.87	0.09	0.70	0.08	0.58	0.07
West_Fork_S300	0.99	0.12	0.84	0.09	0.68	0.08	0.56	0.07
West_Fork_S310	0.96	0.11	0.82	0.08	0.66	0.07	0.54	0.06
West_Fork_S320	1.07	0.13	0.88	0.10	0.72	0.09	0.59	0.08
Big_Bear_Ck_S010	1.28	0.12	1.12	0.09	0.96	0.08	0.84	0.07
Big_Bear_Ck_S020	1.06	0.13	0.88	0.10	0.71	0.08	0.58	0.08
West_Fork_S330	1.05	0.12	0.87	0.09	0.71	0.08	0.58	0.07
Joe_Pool_S020	1.52	0.11	1.41	0.08	1.26	0.06	1.15	0.06
Joe_Pool_S030	0.97	0.12	0.83	0.09	0.67	0.07	0.55	0.07
Joe_Pool_S040	0.95	0.11	0.81	0.08	0.66	0.07	0.54	0.06
Joe_Pool_S010	0.85	0.10	0.75	0.07	0.61	0.06	0.50	0.05
Joe_Pool_S050	0.88	0.10	0.77	0.07	0.63	0.06	0.52	0.05
Mountain_Ck_S010	0.92	0.11	0.80	0.08	0.66	0.06	0.54	0.06
Mountain_Ck_S020	0.90	0.11	0.79	0.08	0.64	0.07	0.52	0.06
Mountain_Ck_S030	0.93	0.11	0.80	0.08	0.65	0.07	0.53	0.06
West_Fork_S340	0.98	0.12	0.83	0.09	0.67	0.08	0.56	0.07
Elm_Fork_S020	2.59	0.11	2.46	0.08	2.30	0.07	2.19	0.06
Elm_Fork_S010	4.11	0.12	3.96	0.09	3.80	0.07	3.68	0.07
Brushy_Elm_Ck_S010	2.04	0.11	1.91	0.08	1.76	0.07	1.65	0.06
Brushy_Elm_Ck_S020	1.33	0.11	1.21	0.08	1.06	0.07	0.95	0.06
Elm_Fork_S030	2.23	0.11	2.11	0.08	1.96	0.07	1.84	0.06
Elm_Fork_S040	1.51	0.11	1.39	0.08	1.24	0.07	1.13	0.06
Elm_Fork_S050	1.58	0.12	1.43	0.09	1.27	0.07	1.15	0.07
Elm_Fork_S070	1.27	0.11	1.12	0.08	0.97	0.07	0.85	0.06
Elm_Fork_S060	0.89	0.11	0.78	0.08	0.63	0.06	0.52	0.06
Spring_Ck_S010	0.92	0.11	0.80	0.08	0.65	0.07	0.53	0.06
Spring_Ck_S020	0.92	0.11	0.80	0.08	0.65	0.07	0.53	0.06
Ray_Roberts_S010	2.41	0.11	2.28	0.08	2.13	0.07	2.01	0.06
Timber_Ck_S010	1.07	0.13	0.88	0.10	0.72	0.09	0.59	0.08
Timber_Ck_S030	0.99	0.12	0.84	0.09	0.68	0.08	0.56	0.07
Timber_Ck_S020	1.06	0.13	0.88	0.10	0.71	0.08	0.59	0.08

Subbasin Name	50-yr Initial (in)	50-yr Constant (in/hr)	100-yr Initial (in)	100-yr Constant (in/hr)	250-yr Initial (in)	250-yr Constant (in/hr)	500-yr Initial (in)	500-yr Constant (in/hr)
Ray_Roberts_S030	1.02	0.12	0.86	0.09	0.70	0.08	0.58	0.07
Range_Ck_S010	0.88	0.10	0.77	0.07	0.63	0.06	0.51	0.05
Range_Ck_S020	0.86	0.10	0.76	0.07	0.62	0.06	0.51	0.05
Lake_Kiowa_S020	1.05	0.12	0.87	0.09	0.71	0.08	0.58	0.07
Lake_Kiowa_S010	1.09	0.13	0.90	0.10	0.73	0.09	0.60	0.08
Ray_Roberts_S020	0.88	0.10	0.77	0.07	0.62	0.06	0.51	0.05
Range_Ck_S030	0.91	0.11	0.79	0.08	0.64	0.07	0.53	0.06
Buck_Ck_S010	0.87	0.10	0.77	0.07	0.62	0.06	0.51	0.05
Ray_Roberts_S050	0.88	0.10	0.77	0.07	0.62	0.06	0.51	0.05
Ray_Roberts_S040	1.31	0.11	1.18	0.08	1.02	0.07	0.91	0.06
Ray_Roberts_S060	0.95	0.11	0.81	0.08	0.66	0.07	0.54	0.06
Timber_Ck_S040	0.98	0.12	0.83	0.09	0.67	0.07	0.55	0.07
Elm_Fork_S080	1.00	0.12	0.84	0.09	0.68	0.08	0.56	0.07
Clear_Ck_S010	3.29	0.13	3.10	0.10	2.94	0.08	2.81	0.08
Clear_Ck_S020	2.71	0.13	2.52	0.10	2.35	0.09	2.22	0.08
Clear_Ck_S030	3.32	0.13	3.13	0.10	2.96	0.08	2.84	0.08
Clear_Ck_S040	3.53	0.12	3.37	0.09	3.21	0.08	3.09	0.07
Clear_Ck_S050	2.65	0.12	2.50	0.09	2.34	0.07	2.22	0.07
Clear_Ck_S070	1.67	0.11	1.53	0.08	1.38	0.07	1.26	0.06
Clear_Ck_S060	1.02	0.12	0.85	0.09	0.69	0.08	0.57	0.07
Clear_Ck_S080	2.69	0.12	2.55	0.09	2.39	0.07	2.27	0.07
Clear_Ck_S090	2.08	0.11	1.95	0.08	1.80	0.07	1.69	0.06
Clear_Ck_S110	0.91	0.11	0.79	0.08	0.64	0.07	0.53	0.06
Clear_Ck_S100	1.62	0.11	1.50	0.08	1.35	0.07	1.23	0.06
Clear_Ck_S120	1.06	0.11	0.93	0.08	0.78	0.07	0.66	0.06
Little_Elm_Ck_S010	2.68	0.10	2.57	0.07	2.43	0.06	2.32	0.05
Little_Elm_Ck_S020	1.90	0.10	1.80	0.07	1.66	0.06	1.55	0.05
Little_Elm_Ck_S030	0.85	0.10	0.76	0.07	0.61	0.06	0.51	0.05
Pecan_Ck_S010	0.99	0.12	0.84	0.09	0.68	0.08	0.56	0.07
Doe_Branch_S010	0.91	0.10	0.80	0.07	0.66	0.06	0.55	0.05
Doe_Branch_S020	0.88	0.10	0.77	0.07	0.63	0.06	0.52	0.05
Lewisville_S030	0.96	0.11	0.82	0.08	0.67	0.07	0.55	0.06
Hickory_Ck_S020	1.31	0.11	1.19	0.08	1.04	0.07	0.93	0.06
Hickory_Ck_S010	1.31	0.11	1.19	0.08	1.04	0.07	0.93	0.06
Hickory_Ck_S030	0.99	0.11	0.88	0.08	0.73	0.07	0.61	0.06
Hickory_Ck_S040	2.64	0.11	2.50	0.08	2.35	0.07	2.23	0.06
Hickory_Ck_S050	1.56	0.13	1.38	0.10	1.21	0.08	1.09	0.08
Lewisville_S010	1.15	0.12	0.99	0.09	0.83	0.08	0.71	0.07
Lewisville_S040	0.86	0.10	0.76	0.07	0.62	0.06	0.51	0.05
Lewisville_S050	0.88	0.10	0.77	0.07	0.62	0.06	0.51	0.05
Lewisville_S020	1.15	0.12	0.99	0.09	0.83	0.08	0.71	0.07

Subbasin Name	50-yr Initial (in)	50-yr Constant (in/hr)	100-yr Initial (in)	100-yr Constant (in/hr)	250-yr Initial (in)	250-yr Constant (in/hr)	500-yr Initial (in)	500-yr Constant (in/hr)
Elm_Fork_S090	0.93	0.11	0.80	0.08	0.65	0.07	0.54	0.06
Elm_Fork_S110	0.90	0.11	0.78	0.08	0.63	0.07	0.52	0.06
Elm_Fork_S100	1.11	0.12	0.95	0.09	0.79	0.08	0.67	0.07
Elm_Fork_S120	1.77	0.11	1.65	0.08	1.50	0.07	1.39	0.06
Denton_Ck_S010	2.78	0.13	3.08	0.10	2.91	0.09	2.78	0.08
Denton_Ck_S020	2.76	0.13	3.07	0.10	2.90	0.08	2.77	0.08
Denton_Ck_S030	2.61	0.12	2.89	0.09	2.72	0.08	2.60	0.07
Denton_Ck_S040	1.58	0.11	1.44	0.08	1.29	0.07	1.17	0.06
Denton_Ck_S050	1.99	0.11	1.85	0.08	1.70	0.07	1.58	0.06
Denton_Ck_S060	0.93	0.11	0.80	0.08	0.65	0.07	0.53	0.06
Denton_Ck_S070	0.98	0.11	0.85	0.08	0.70	0.07	0.58	0.06
Grapevine_S010	1.55	0.12	1.40	0.09	1.24	0.08	1.11	0.07
Denton_Ck_S080	0.97	0.12	0.83	0.09	0.67	0.07	0.55	0.07
Elm_Fork_S130	1.52	0.11	1.40	0.08	1.25	0.07	1.14	0.06
Hackberry_Ck_S010	2.08	0.10	1.98	0.07	1.84	0.06	1.73	0.05
Hackberry_Ck_S020	0.85	0.10	0.76	0.07	0.61	0.06	0.50	0.05
Hackberry_Ck_S030	0.87	0.10	0.77	0.07	0.62	0.06	0.51	0.05
Elm_Fork_S140	0.96	0.11	0.82	0.08	0.66	0.07	0.55	0.06
Elm_Fork_S150	0.97	0.11	0.82	0.08	0.67	0.07	0.55	0.06
Bachman_Branch_S010	1.01	0.12	0.85	0.09	0.69	0.08	0.57	0.07
Bachman_Branch_S020	0.97	0.12	0.83	0.09	0.67	0.07	0.55	0.07
Elm_Fork_S160	0.98	0.12	0.83	0.09	0.67	0.07	0.55	0.07
Trinity_River_S010	1.17	0.11	1.03	0.08	0.88	0.07	0.76	0.06
Trinity_River_S020	1.26	0.09	1.51	0.09	1.35	0.08	1.23	0.07
White_Rock_Ck_S010	1.64	0.08	2.06	0.08	1.91	0.07	1.79	0.06
White_Rock_Ck_S020	0.76	0.09	0.85	0.09	0.69	0.08	0.57	0.07
White_Rock_Ck_S030	0.75	0.09	0.84	0.09	0.68	0.08	0.56	0.07
White_Rock_Ck_S040	0.74	0.09	0.83	0.09	0.68	0.08	0.56	0.07
Trinity_River_S030	0.79	0.09	0.87	0.09	0.70	0.08	0.58	0.07
Fivemile_Ck_S010	1.02	0.09	1.18	0.09	1.02	0.08	0.89	0.07
Trinity_River_S040	0.74	0.09	0.84	0.09	0.68	0.08	0.56	0.07
Trinity_River_S050	0.73	0.08	0.82	0.08	0.67	0.07	0.55	0.06
Tenmile_Ck_S010	0.82	0.09	0.94	0.09	0.78	0.08	0.66	0.07
Tenmile_Ck_S020	0.68	0.08	0.79	0.08	0.64	0.07	0.53	0.06
Trinity_River_S060	0.90	0.09	1.05	0.09	0.89	0.08	0.77	0.07
Indian_Ck_S010	1.88	0.08	2.41	0.07	2.26	0.06	2.15	0.05
Indian_Ck_S030	1.20	0.08	1.47	0.08	1.31	0.07	1.2	0.06
Indian_Ck_S020	0.65	0.08	0.76	0.07	0.62	0.06	0.51	0.05
Indian_Ck_S040	1.54	0.08	1.94	0.07	1.8	0.06	1.69	0.05
Sister_Grove_S010	2.06	0.08	2.61	0.08	2.46	0.07	2.34	0.06
Sister_Grove_S020	1.49	0.08	1.86	0.08	1.71	0.07	1.6	0.06

Subbasin Name	50-yr Initial (in)	50-yr Constant (in/hr)	100-yr Initial (in)	100-yr Constant (in/hr)	250-yr Initial (in)	250-yr Constant (in/hr)	500-yr Initial (in)	500-yr Constant (in/hr)
East_Fork_S020	1.91	0.08	2.42	0.08	2.27	0.07	2.15	0.06
East_Fork_S010	2.66	0.08	3.42	0.08	3.26	0.07	3.15	0.06
East_Fork_S030	1.04	0.08	1.26	0.08	1.11	0.07	0.99	0.06
East_Fork_S040	0.69	0.08	0.8	0.08	0.65	0.07	0.53	0.06
Wilson_Ck_S010	1.74	0.08	2.19	0.08	2.04	0.07	1.92	0.06
Lavon_S010	0.84	0.08	1.02	0.07	0.88	0.06	0.77	0.05
Lavon_S020	0.65	0.08	0.77	0.07	0.62	0.06	0.51	0.05
Rowlett_Ck_S010	0.79	0.08	0.93	0.08	0.78	0.07	0.66	0.06
Ray_Hubbard_S010	1.61	0.08	2.04	0.07	1.9	0.06	1.79	0.05
Ray_Hubbard_S020	0.66	0.08	0.77	0.07	0.62	0.06	0.51	0.05
East_Fork_S050	0.68	0.08	0.8	0.08	0.65	0.06	0.54	0.06
East_Fork_S070	0.65	0.08	0.76	0.07	0.62	0.06	0.51	0.05
East_Fork_S060	2.39	0.08	3.09	0.07	2.94	0.06	2.83	0.05
East_Fork_S080	0.65	0.08	0.76	0.07	0.62	0.06	0.51	0.05
East_Fork_S090	0.68	0.08	0.82	0.07	0.67	0.06	0.56	0.05
East_Fork_S110	0.80	0.08	0.96	0.07	0.81	0.06	0.7	0.05
East_Fork_S100	2.61	0.08	3.39	0.07	3.24	0.06	3.13	0.05
Trinity_River_S070	0.77	0.08	0.91	0.08	0.76	0.07	0.65	0.06
East_Fork_S120	1.55	0.08	1.96	0.07	1.82	0.06	1.71	0.05
Kings_Ck_S020	1.22	0.08	1.53	0.07	1.38	0.06	1.28	0.05
Kings_Ck_S010	1.54	0.08	1.94	0.08	1.79	0.07	1.68	0.06
Kings_Ck_S030	2.03	0.08	2.6	0.07	2.46	0.06	2.35	0.05
Cedar_Ck_S040	1.49	0.09	1.82	0.09	1.66	0.08	1.53	0.07
Cedar_Ck_S010	1.60	0.08	1.99	0.08	1.84	0.07	1.72	0.06
New_Terrell_City_Lake_S010	0.68	0.08	0.79	0.08	0.64	0.07	0.53	0.06
Cedar_Ck_S020	0.86	0.08	1.01	0.08	0.86	0.07	0.74	0.06
Cedar_Ck_S030	1.90	0.09	2.37	0.09	2.21	0.08	2.09	0.07
Trinity_River_S080	1.16	0.08	1.42	0.08	1.27	0.07	1.16	0.06
Trinity_River_S090	1.15	0.08	1.38	0.08	1.23	0.07	1.11	0.06
Chambers_Ck_S010	1.58	0.08	1.97	0.08	1.82	0.07	1.71	0.06
Chambers_Ck_S020	2.09	0.08	2.67	0.08	2.51	0.07	2.41	0.06
Chambers_Ck_S040	2.03	0.08	2.59	0.08	2.43	0.07	2.32	0.06
Chambers_Ck_S030	1.90	0.08	2.39	0.08	2.23	0.08	2.12	0.06
Waxahachie_Ck_S010	2.67	0.09	3.39	0.09	3.22	0.09	3.1	0.07
Waxahachie_Ck_S020	1.48	0.09	1.8	0.09	1.64	0.08	1.52	0.07
Waxahachie_Ck_S030	0.90	0.08	1.09	0.08	0.94	0.07	0.83	0.06
Mustang_Ck_S010	0.90	0.08	1.11	0.07	0.96	0.06	0.86	0.05
Bardwell_S010	1.07	0.08	1.32	0.07	1.17	0.06	1.07	0.05
Chambers_Ck_S050	1.97	0.08	2.53	0.07	2.38	0.06	2.27	0.05
Chambers_Ck_S060	1.41	0.08	1.76	0.08	1.61	0.07	1.5	0.06

Subbasin Name	50-yr Initial (in)	50-yr Constant (in/hr)	100-yr Initial (in)	100-yr Constant (in/hr)	250-yr Initial (in)	250-yr Constant (in/hr)	500-yr Initial (in)	500-yr Constant (in/hr)
Chambers_Ck_S070	1.95	0.08	2.5	0.07	2.35	0.06	2.25	0.05
Chambers_Ck_S080	1.31	0.08	1.64	0.08	1.49	0.07	1.38	0.06
Post_Oak_Ck_S010	1.46	0.08	1.83	0.08	1.67	0.07	1.57	0.06
Lake_Halbert_S010	1.22	0.08	1.52	0.07	1.37	0.06	1.27	0.05
Navarro_Mills_S020	1.23	0.08	1.53	0.07	1.38	0.07	1.27	0.05
Navarro_Mills_S030	2.60	0.08	3.33	0.08	3.16	0.07	3.06	0.06
Navarro_Mills_S010	2.06	0.09	2.6	0.09	2.44	0.08	2.33	0.07
Navarro_Mills_S040	0.67	0.08	0.78	0.08	0.62	0.07	0.52	0.06
Richland_Ck_S010	1.58	0.08	1.99	0.08	1.84	0.07	1.73	0.06
Richland_Ck_S020	2.00	0.08	2.56	0.07	2.41	0.07	2.3	0.05
Richland-Chambers_S010	0.67	0.08	0.78	0.08	0.63	0.07	0.52	0.06
Richland-Chambers_S020	0.66	0.08	0.77	0.07	0.62	0.07	0.51	0.05
Tehuacana_Ck_S020	2.48	0.09	3.13	0.09	2.97	0.08	2.85	0.07
Tehuacana_Ck_S010	1.55	0.08	1.94	0.08	1.79	0.07	1.67	0.06
Trinity_River_S100	0.73	0.09	0.83	0.09	0.67	0.07	0.55	0.07
Fairfield_Lake_S010	3.59	0.09	4.62	0.09	4.45	0.08	4.33	0.07
Trinity_River_S110	0.96	0.11	1.05	0.11	0.87	0.1	0.74	0.09
Big_Brown_Ck_S010	3.44	0.10	4.37	0.1	4.19	0.09	4.06	0.08
Trinity_River_S120	1.51	0.10	1.81	0.1	1.64	0.09	1.51	0.08
Trinity_River_S130	0.95	0.10	1.08	0.1	0.91	0.09	0.78	0.08
Upper_Keechi_Ck_S030	1.03	0.11	1.14	0.11	0.97	0.09	0.83	0.09
Upper_Keechi_Ck_S010	0.95	0.10	1.07	0.1	0.9	0.09	0.77	0.08
Upper_Keechi_Ck_S020	1.36	0.11	1.56	0.11	1.38	0.1	1.24	0.09
Upper_Keechi_Ck_S040	0.83	0.10	0.9	0.1	0.73	0.09	0.6	0.08
Trinity_River_S140	0.65	0.08	0.77	0.07	0.62	0.06	0.51	0.05
Little_Elkhart_S010	0.86	0.11	0.93	0.11	0.75	0.09	0.62	0.09
Houston_County_Lake_S010	3.64	0.11	4.62	0.11	4.44	0.1	4.3	0.09
Trinity_River_S150	0.80	0.09	0.9	0.09	0.73	0.08	0.61	0.07
Trinity_River_S160	0.78	0.09	0.86	0.09	0.7	0.08	0.58	0.07
Trinity_River_S170	0.89	0.11	0.97	0.11	0.79	0.1	0.66	0.09
Trinity_River_S180	0.78	0.09	0.87	0.09	0.7	0.08	0.58	0.07
Bedias_Ck_S010	2.30	0.09	2.91	0.09	2.75	0.08	2.63	0.07
Bedias_Ck_S020	0.77	0.09	0.86	0.09	0.69	0.08	0.57	0.07
Trinity_River_S190	0.77	0.09	0.87	0.09	0.71	0.08	0.59	0.07
Livingston_S010	0.79	0.09	0.88	0.09	0.72	0.08	0.59	0.07
Livingston_S030	0.75	0.09	0.84	0.09	0.68	0.08	0.56	0.07
Livingston_S020	0.74	0.09	0.83	0.09	0.67	0.08	0.55	0.07
Trinity_River_S200	0.76	0.09	0.85	0.09	0.69	0.08	0.57	0.07
Long_King_Ck_S010	0.77	0.09	0.86	0.09	0.7	0.08	0.57	0.07
Long_King_Ck_S020	0.99	0.09	1.15	0.09	0.99	0.08	0.86	0.07
Trinity_River_S210	0.96	0.10	1.09	0.1	0.92	0.09	0.79	0.08

Subbasin Name	50-yr Initial (in)	50-yr Constant (in/hr)	100-yr Initial (in)	100-yr Constant (in/hr)	250-yr Initial (in)	250-yr Constant (in/hr)	500-yr Initial (in)	500-yr Constant (in/hr)
Menard_Ck_S010	1.45	0.10	1.74	0.1	1.57	0.09	1.44	0.08
Trinity_River_S220	0.79	0.09	0.87	0.09	0.71	0.08	0.58	0.07
Trinity_River_S230	0.70	0.08	0.8	0.08	0.65	0.07	0.53	0.06
Trinity_River_S240	0.71	0.08	0.81	0.08	0.66	0.07	0.54	0.06
Trinity_River_S250	2.03	0.08	2.59	0.08	2.44	0.06	2.33	0.06

1.6 ELLIPTICAL FREQUENCY STORM RESULTS FROM HMS

The frequency peak flow values were then calculated in HEC-HMS by applying the appropriate, optimized elliptical frequency storms for each junction of interest in the final HEC-HMS basin model. These results will later be compared to the uniform rain results from HEC-HMS along with other methods from this study.

In some cases, one may observe that the simulated peak discharge decreases in the downstream direction. It is not an uncommon phenomenon to see decreasing frequency peak discharges for some river reaches as flood waters spread out into the floodplain and the hydrograph becomes dampened as it moves downstream. This can be due to a combination of peak attenuation due to river routing as well as the difference in timing between the peak of the main stem river versus the runoff from the local tributaries and subbasins.

1.6.1 **Tabular Results**

The final HEC-HMS frequency flows for the locations of interest throughout the watershed model using the NOAA Atlas 14 rainfall depths can be seen below in Table 5.

Table 5: Summary of Discharges (cfs) from the HEC-HMS Elliptical Frequency Storm Method

Location Description	HEC-HMS Element Name	Drainage Area*	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
West Fork Trinity River above Turkey Creek	West_Fork_abv_TurkeyCk	403.1	2,000	7,200	13,300	22,500	32,700	47,800	62,500	83,300
West Fork Trinity River below Turkey Creek	West_Fork_J050	439.2	2,100	7,500	13,800	23,300	34,100	50,000	65,400	88,000
West Fork Trinity River above Big Cleveland Creek	WestFork_abv_Big_Cleveland	549.4	1,900	6,200	11,100	18,500	27,200	41,300	55,800	76,800
West Fork Trinity River below Big Cleveland Creek	West_Fork_J070	648.1	2,800	6,200	11,100	18,600	27,500	42,800	59,200	83,100
West Fork Trinity River near Jacksboro, TX USGS gage	West_Fork_J080	668.7	1,900	5,900	10,600	17,800	26,300	40,700	56,200	79,500
West Fork Trinity River below Lost Creek	West Fork + Lost Ck	711.2	2,000	6,100	11,000	18,600	27,300	41,800	57,500	81,700
West Fork Trinity River above Carroll Creek	West_Fork_abv_CarrollCk	750.8	1,900	5,900	10,700	18,300	26,800	41,000	56,500	80,100
West Fork Trinity River below Carroll Creek	West_Fork_J090	792.1	2,100	9,500	20,500	29,000	36,600	45,800	54,500	69,700
West Fork Trinity River above Beans Creek	WestFork_abv_Beans_Ck	827.7	1,900	10,000	22,100	31,700	40,400	51,100	61,100	78,000
West Fork Trinity River below Beans Creek	West Fork + Beans Ck	874.6	1,700	11,600	26,900	38,900	49,700	62,900	74,300	93,300
Bridgeport Reservoir Inflow	Bridgeport Inflow	1095.7	3,700	24,500	58,400	83,000	105,500	132,300	157,200	192,200
Bridgeport Reservoir Outflow	Bridgeport Reservoir	1095.7	2,600	5,400	11,600	12,400	13,200	21,100	29,300	39,000
West Fork Trinity River above Dry Creek	West_Fork_abv_DryCk	1136.2	2,200	5,500	11,500	12,400	13,300	21,100	29,500	39,200
West Fork Trinity River below Dry Creek	West_Fork_J100	1162.9	1,800	5,900	12,600	17,500	21,800	26,700	31,400	37,800
West Fork Trinity River above Big Sandy Creek	WestFork_abv_Big_Sandy_Ck	1169.5	1,800	5,300	11,800	17,200	22,300	27,600	32,500	39,200
Big Sandy Creek nr Bridgeport USGS Gage at Hwy 114 bridge	Big_Sandy_Ck_J030	334.3	3,600	7,900	12,300	18,800	26,200	36,600	47,000	64,600
Big Sandy Creek above the West Fork Trinity River	Big_Sandy_Ck_abv_WestFork	353.9	3,500	7,900	11,900	18,900	26,400	36,700	47,300	64,500

Location Description	HEC-HMS Element Name	Drainage Area*	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
West Fork Trinity River below Big Sandy Creek	West Fork + Big Sandy Ck	1523.5	4,400	11,200	19,700	28,200	36,600	49,000	61,100	78,400
West Fork Trinity River at FM 3259 near Paradise, TX	West_Fork_J110	1551.8	4,200	10,500	17,500	26,600	36,400	49,300	61,800	80,000
West Fork Trinity River above Salt Creek	WestFork_abv_Salt_Ck	1573.7	3,600	9,700	15,300	22,800	31,700	44,500	56,600	74,800
West Fork Trinity River below Salt Creek	West Fork + Salt Ck	1680.4	3,300	9,400	17,000	27,000	38,600	55,600	71,700	95,600
West Fork Trinity River near Boyd, TX - USGS Gage at FM 730 bridge	West_Fork_J120	1710.8	3,000	9,300	16,800	26,700	38,200	54,700	71,500	96,400
West Fork Trinity River about 0.8 miles upstream of FM 4757 in Wise County	West_Fork_J130	1751.9	3,200	9,800	16,700	26,300	37,400	53,300	69,000	92,900
Eagle Mountain Reservoir Inflow	Eagle Mountain Inflow	1956.6	9,300	28,800	43,300	66,800	83,600	102,700	120,300	143,600
Eagle Mountain Reservoir Outflow	Eagle Mountain Reservoir	1956.6	3,800	7,300	13,800	17,200	21,500	27,100	33,000	42,500
Lake Worth Inflow	Lake Worth Inflow	2050.8	4,800	11,800	16,500	25,400	31,200	37,800	43,500	51,500
Lake Worth Outflow	Lake Worth	2050.8	3,000	7,300	13,900	17,400	21,600	27,400	33,400	42,800
West Fork Trinity River above the Clear Fork	WestFork_abv_Clear_Fork	2078.7	3,200	8,200	11,700	18,200	21,300	25,000	29,700	36,100
Benbrook Lake Inflow	Benbrook Inflow	429.2	24,900	47,500	61,800	79,500	94,800	111,900	128,800	154,600
Clear Fork above Marys Creek	Clear_Fork_abv_Marys_Ck	9.4	3,200	4,900	5,900	7,300	8,500	9,700	10,900	12,800
Clear Fork below Marys Creek	Clear Fork + Marys Creek	63.6	5,200	14,800	25,800	39,500	47,400	56,700	68,300	79,800
Clear Fork Trinity River at Fort Worth USGS gage	Clear_Fork_J020	89.0	7,600	18,200	29,100	46,900	55,100	64,000	73,000	82,300
Clear Fork Trinity River above the West Fork	Clear_Fork_abv_WestFork	93.9	8,100	19,200	30,600	45,300	53,300	62,100	71,000	80,900
West Fork Trinity River below the Clear Fork (West Fork at Fort Worth USGS gage)	West Fork + Clear Fork	2172.5	10,700	23,600	36,600	54,300	64,300	75,200	86,400	100,000
West Fork Trinity River above Marine Creek	WestFork_abv_MarineCk	2173.7	10,700	24,000	36,900	53,500	63,400	73,700	86,500	100,200

Location Description	HEC-HMS Element Name	Drainage Area*	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
West Fork Trinity River below Marine Creek	West Fork + Marine Ck	2195.4	11,000	24,700	37,900	54,900	65,200	76,000	89,000	103,300
West Fork Trinity River above Sycamore Creek	West_Fork_J140	2204.6	11,300	24,000	37,800	53,900	62,600	73,700	88,000	104,400
West Fork Trinity River below Sycamore Creek (West Fork Trinity River at Beach Street USGS Gage)	West_Fork_J150	2243.8	11,500	23,700	36,900	56,100	66,700	77,200	90,400	108,400
West Fork above Big Fossil	WestFork_abv_BigFossil	2256.8	10,200	21,400	34,600	53,200	64,400	76,000	89,000	107,100
West Fork Trinity River and Big Fossil Creek Confluence	West_Fork_J160	2333.4	12,300	23,700	38,000	60,600	76,400	92,700	108,500	130,200
West Fork Trinity River below Village Creek	West Fork + Village Ck	2554.0	11,700	21,100	36,400	55,000	70,200	89,200	108,600	138,800
West Fork Trinity River below Johnson Creek	West_Fork_J170	2618.6	8,600	17,200	27,000	44,000	58,300	78,100	96,800	129,200
West Fork Trinity River at Grand Prairie USGS gage	West_Fork_J180	2623.4	8,500	17,200	27,100	44,200	58,400	78,000	96,500	128,100
West Fork Trinity River above Big Bear Creek	West_Fork_abv_Big_Bear_Ck	2625.5	8,400	16,500	26,400	42,600	56,700	73,200	93,000	124,500
West Fork Trinity River below Big Bear Creek	West Fork + Bear Ck	2718.8	10,000	17,600	29,700	50,000	66,800	85,300	107,200	143,000
West Fork Trinity River above Mountain Creek	West_Fork_abv_Mountain_Ck	2727.4	10,000	17,500	29,100	46,200	62,600	81,600	101,600	134,400
West Fork Trinity River below Mountain Creek	West Fork + Mountain Ck	2807.6	14,100	22,900	30,300	47,300	63,900	82,900	103,100	137,000
West Fork Trinity River above the Elm Fork Trinity River	West_Fork_abv_Elm_Fork	2820.9	13,100	21,700	29,900	46,800	63,600	83,000	103,100	136,100
Ray Roberts Lake Inflow	Ray Roberts Inflow	692.6	59,500	95,900	120,600	153,100	182,400	216,100	249,700	296,000
Elm Fork Trinity River above Clear Creek	Elm_Fork_abv_Clear_Ck	36.9	2,500	5,400	8,300	11,000	13,200	15,900	18,300	21,700
Elm Fork Trinity River below Clear Creek	Elm Fork + Clear Ck	388.1	8,500	14,000	20,000	28,300	41,700	59,900	77,500	100,300
Lewisville Lake Inflow	Lewisville Inflow	968.2	42,500	69,000	88,200	112,500	135,100	159,700	182,700	215,000

Location Description	HEC-HMS Element Name	Drainage Area*	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
Elm Fork Trinity River above Indian Creek	Elm_Fork_abv_Indian_Ck	21.4	1,600	3,200	4,400	6,500	7,700	9,100	10,400	12,200
Elm Fort Trinity River below Indian Creek	Elm Fork + Indian Ck	37.5	3,600	6,800	9,100	13,200	15,500	18,100	20,600	24,200
Elm Fork Trinity River below Timber Creek	Elm Fork + Timber Ck	61.5	4,200	7,700	9,800	14,000	16,600	20,200	23,600	28,200
Elm Fork Trinity River above Denton Creek	Elm_Fork_abv_Denton_Ck	79.9	5,800	10,400	13,300	18,700	22,200	26,700	31,000	36,900
Denton Creek nr Justin, TX USGS gage	Denton_Ck_J030	400.0	4,500	11,300	17,400	26,000	35,700	46,800	62,700	82,600
Denton Creek below Oliver Creek	Denton_Ck_J040	475.3	9,400	18,900	26,500	36,000	45,200	55,300	64,500	77,600
Denton Creek above Elizabeth Creek	Denton_Ck_abv_Elizabeth_Ck	506.1	9,800	18,600	25,800	35,600	45,800	57,100	69,500	85,200
Denton Creek below Elizaveth Creek	Denton_Ck_J050	599.7	15,800	29,300	39,500	53,400	68,400	85,300	102,000	123,900
Grapevine Lake Inflow	Grapevine_Inflow	694.4	16,000	28,200	38,600	52,200	66,900	84,800	101,600	124,500
Denton Creek above the Elm Fork Trinity River	Denton_Ck_abv_Elm_Fork	24.3	2,300	4,300	5,800	8,800	10,400	12,200	14,000	16,300
Elm Fork Trinity River near Carrollton USGS gage	Elm Fork + Denton Ck	104.2	7,500	13,400	17,700	25,600	30,100	35,600	41,500	49,300
Elm Fork Trinity River at Interstate 635	Elm_Fork_J060	143.4	12,300	17,500	21,400	29,300	34,900	41,300	47,400	56,400
Elm Fork Trinity River above Hackleberry Creek	Elm_Fork_abv_Hackberry_Ck	143.4	8,900	14,700	19,200	28,000	33,700	40,200	46,600	54,800
Elm Fk Trinity Rv at Spur 348 in Irving; TX USGS gage	Elm_Fork_J070	180.4	10,800	15,400	20,000	28,800	35,000	42,400	49,400	59,100
Elm Fork Trinity River above Bachman Branch	Elm_Fork_abv_Bachman_Branch	202.6	10,000	14,400	18,700	26,100	32,000	39,500	45,900	54,700
Elm Fork Trinity River below Bachman Branch (at Frasier Dam USGS gage)	Elm Fork + Bachman Branch	216.7	10,700	15,000	19,100	26,600	32,700	40,400	46,900	55,900
Elm Fork Trinity River above the West Fork Trinity River	Elm_Fork_abv_West_Fork	222.8	8,800	14,600	19,000	25,900	32,000	40,000	46,400	55,700

Location Description	HEC-HMS Element Name	Drainage Area*	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
Trinity River below the West Fork and Elm Fork confluence	West Fork + Elm Fork	3043.7	19,300	31,100	41,900	67,100	89,600	113,800	140,200	182,800
Trinity River at Dallas, TX USGS gage	Trinity_River_J010	3056.1	19,000	31,000	42,100	66,200	88,500	113,100	138,900	181,500
Trinity River at the Corinth Street bridge in Dallas, TX	Trinity_River_J020	3099.0	19,000	31,000	42,200	66,300	88,500	113,500	139,100	182,300
Trinity River below White Rock Creek	Trinity River + White Rock	3233.9	21,800	35,500	48,000	68,200	90,000	116,800	143,700	185,500
Trinity River below Honey Springs Branch (Trinity River below Dallas, TX USGS gage)	Trinity_Rv + Honey_Springs	3256.5	21,900	35,700	48,300	68,400	90,000	116,700	143,800	185,700
Trinity River below Five Mile Ceek	Trinity_River + Five_Mile_Ck	3328.8	21,100	34,600	47,300	67,600	88,000	114,100	140,200	180,300
Trinity River above Ten Mile Creek	Trinity_River_abv_Tenmile_Ck	3367.7	20,100	29,900	40,700	59,400	78,800	104,000	125,700	161,300
Trinity River below Ten Mile Creek	Trinity River + Tenmile Ck	3469.8	20,200	30,800	40,600	59,300	78,500	103,700	124,800	160,400
Trinity River above the East Fork Trinity River	Trinity_River_abv_East_Fork	3529.4	19,500	28,400	37,700	56,700	74,900	99,500	122,800	156,000
Lavon Lake Inflow	Lavon Inflow	768.2	24,100	42,300	53,600	69,400	79,900	90,700	106,400	128,700
Ray Hubbard Lake Inflow	Ray Hubbard Inflow	301.8	31,100	50,600	62,300	78,800	90,500	103,200	119,000	141,400
East Fork Trinity River near Forney USGS gage	East_Fork_nr_Forney	349.9	14,000	25,700	35,100	47,200	55,900	65,900	89,500	113,800
East Fork Trinity River above Buffalo Creek	East_Fork_abv_Buffalo_Ck	359.5	12,300	23,200	29,700	44,300	53,700	63,800	85,100	111,700
East Fork Trinity River below Buffalo Creek	East_Fork + Buffalo_Ck	393.9	13,000	24,500	31,700	47,000	56,900	67,900	90,600	119,000
East Fork Trinity River above South Mesquite Creek	East_Fork_abv_S_Mesquite_Ck	416.9	9,500	19,700	28,000	39,600	49,100	59,300	76,000	105,300
East Fork Trinity River below South Mesquite Creek	East_Fork+South_Mesquite_Ck	446.4	10,000	20,500	29,000	41,100	51,000	61,700	79,400	110,600
East Fork Trinity River above Mustang Creek	East_Fork_abv_Mustang_Ck	465.5	9,400	19,000	25,900	35,100	43,700	52,900	66,700	88,800
East Fork Trinity River near Crandall, TX USGS gage	East_Fork_nr_Crandall	484.8	9,600	19,400	26,500	35,800	44,600	53,900	68,100	90,700

Location Description	HEC-HMS Element Name	Drainage Area*	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
East Fork Trinity River above the Trinity River	East_Fork_abv_Trinity_River	484.8	9,200	17,100	22,800	30,500	37,200	44,700	55,500	70,600
Trinity River below the East Fork Trinity River	Trinity River + East Fork	4014.2	27,000	41,600	54,200	80,400	104,100	134,200	166,200	210,600
Trinity River below Red Oak Creek	Trinity_River + Red_Oak_Ck	4245.5	27,100	43,400	55,300	81,000	105,000	135,200	167,700	212,700
Trinity River near Rosser, TX USGS gage	Trinity_River_nr_Rosser	4349.6	25,600	38,900	51,000	74,000	98,700	131,500	164,600	207,300
Trinity River above Cedar Creek	Trinity_River_abv_Cedar_Ck	4349.6	24,700	38,000	50,000	68,300	76,700	105,600	150,100	196,600
Cedar Creek Reservoir Inflow	Cedar Creek Inflow	1010.8	45,200	82,100	106,000	135,000	158,200	182,100	219,900	274,400
Cedar Creek Reservoir Outflow	Cedar Creek Reservoir	1010.8	32,400	55,600	70,000	88,300	105,900	123,700	129,800	140,500
Trinity River below Cedar Creek	Trinity River + Cedar Creek	5360.4	27,600	41,300	53,400	71,600	79,200	112,300	162,400	220,600
Trinity River at Trinidad, TX USGS gage	Trinity_River_at_Trinidad	5759.3	33,300	51,200	68,000	89,100	106,800	125,100	155,800	188,200
Trinity River above Richland Creek	Trinity_Rv_abv_Richland_Ck	6042.8	31,300	48,100	63,500	83,100	99,900	117,300	149,800	187,500
Bardwell Lake Inflow	Bardwell Inflow	174.4	10,400	18,700	23,400	30,700	35,700	41,300	48,500	59,200
Chambers Creek below Mill Creek	Chambers_Ck_J020	511.9	13,600	29,100	40,900	62,200	75,900	88,300	114,200	148,800
Chambers Creek below Waxahachie Creek	Chambers Ck + Waxahachie Ck	621.0	12,800	28,300	39,500	60,200	74,300	86,700	113,500	152,700
Chambers Creek near Rice, TX USGS gage	Chambers_Ck_J030	650.1	12,500	28,000	39,000	59,200	73,300	88,100	110,500	148,800
Richland Creek below Pin Oak Creek	Richland_Ck_J010	395.0	19,000	37,800	50,100	64,800	76,300	87,600	106,900	135,300
Richland Chambers Reservoir Inflow	Richland-Chambers Inflow	1465.5	33,300	64,300	85,700	112,000	133,000	154,500	188,200	237,200
Richland Chambers Reservoir Outflow	Richland-Chambers Reservoir	1465.5	9,500	26,700	42,700	65,800	86,000	107,400	143,200	193,900
Trinity River below Richland Creek	Trinity River + Richland Ck	7508.3	36,200	64,300	88,100	122,800	150,100	177,200	234,800	304,000
Trinity River above Tehuacana Creek	Trinity_Rv_abv_Tehuacana_Ck	7508.3	35,300	63,300	87,600	122,400	149,500	178,100	234,200	306,200

Location Description	HEC-HMS Element Name	Drainage Area*	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
Trinity River below Tehuacana Creek	Trinity River + Tehuacana Ck	7894.7	38,700	59,000	81,700	124,000	157,800	192,800	259,200	349,800
Trinity River above Big Brown Creek	Trinity_Rv_abv_Big_Brown_Ck	7965.3	37,900	58,600	80,900	120,000	148,400	189,000	254,100	345,000
Trinity River below Big Brown Creek	Trinity River + Big Brown Ck	8001.5	38,200	59,100	81,600	121,000	154,000	190,100	255,900	348,700
Trinity River above Catfish Creek	Trinity_River_abv_Catfish_Ck	8306.6	39,500	60,800	85,300	122,200	153,300	190,100	264,300	367,200
Trinity River below Catfish Creek	Trinity_River + Catfish_Ck	8353.0	39,800	61,400	86,000	123,200	154,200	191,500	266,400	370,700
Trinity River near Oakwood, TX USGS gage	Trinity_River_nr_Oakwood	8593.0	36,300	59,500	81,100	107,400	129,000	152,400	223,500	308,900
Trinity River above Upper Keechi Creek	TrinityRv_abv_UpperKeechi_Ck	8849.7	33,000	54,300	71,800	99,000	121,800	139,500	160,100	235,500
Trinity River below Upper Keechi Creek	Trinity River + Upper Keechi	9358.9	33,700	54,900	72,200	99,700	122,900	140,900	163,700	243,300
Trinity River above Big Elkhart Creek	Trinity_Rv_abv_Big_Elkhart	9359.5	33,600	54,300	72,000	99,500	122,800	140,700	163,600	241,800
Trinity River below Big Elkhart Creek	Trinity River+ Big Elkhart	9502.5	33,100	53,300	70,100	98,000	121,600	139,300	160,600	233,700
Trinity River near Crockett, TX USGS gage	Trinity_River_nr_Crockett	9615.0	33,300	53,900	71,500	98,700	121,900	139,800	160,600	235,000
Trinity River above Lower Keechi Creek	Trinity_Rv_abv_LowerKeech_Ck	9791.7	32,900	48,100	56,600	72,500	96,400	114,900	145,300	181,300
Trinity River below Lower Keechi Creek	Trinity_River+LowerKeechi_Ck	9979.3	32,700	48,200	56,600	72,600	96,700	115,200	145,500	181,500
Trinity River above Bedias Creek	Trinity_River_abv_Bedias_Ck	10374.286	32,600	47,200	54,300	68,600	92,800	110,200	140,400	175,800
Bedias Creek above the Trinity River	Bedias_Ck_abv_Trinity_River	604.3	13,100	32,500	46,800	64,300	76,800	90,800	114,400	147,300
Trinity River below Bedias Creek	Trinity River + Bedias Ck	10978.5	44,300	69,800	96,100	128,000	150,400	172,300	205,200	251,400
Trinity River at Riverside, TX USGS gage	Trinity River_at_Riverside	11306.7	41,000	61,500	71,800	109,300	133,800	158,700	194,300	249,200
Lake Livingston Inflow	Lake Livingston Inflow	12301.1	77,000	111,100	144,000	193,600	233,400	278,700	333,900	413,400
Lake Livingston Outflow	Lake Livingston	12301.1	38,900	65,700	81,100	100,400	120,700	158,200	210,400	281,800

Location Description	HEC-HMS Element Name	Drainage Area*	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
Trinity River above Long King Creek	Trinity_Rv_abv_Long_King_Ck	12340.5	39,600	67,000	82,800	102,100	123,700	159,400	208,300	277,000
Trinity River at Goodrich, TX USGS gage	Trinity River + Long King Ck	12566.9	40,000	69,000	84,400	104,700	126,400	162,200	211,200	282,700
Trinity River above Menard Creek	Trinity_River_abv_Menard_Ck	12628.0	39,400	59,900	73,600	89,400	101,100	118,200	148,200	207,300
Trinity River below Menard Creek	Trinity River + Menard Ck	12776.2	40,700	64,000	77,400	94,100	107,700	127,500	159,500	220,900
Trinity River at Romayor, TX USGS gage	Trinity_River_at_Romayor	12873.7	40,700	62,900	76,500	93,100	107,000	126,200	157,100	218,100
Trinity River near Moss Hill, TX	Trinity_River_nr_MossHill_TX	12945.7	39,600	59,200	73,800	91,300	104,600	122,000	152,200	208,800
Trinity River at Liberty, TX USGS gage	Trinity_River_at_Liberty	13176.5	34,800	54,500	70,800	90,200	103,700	120,900	151,100	205,300
Trinity River at Wallisville, TX USGS gage	Trinity Bay	13618.4	32,300	45,700	62,400	84,000	98,700	115,300	141,800	188,300

*Drainage area is uncontrolled area downstream of USACE dams

1.6.2 **Map Results**

The following ‘a’ figures represent the 100yr48hr heatmap results for the optimization of each junction of interest in the Elliptical Storm HMS model. For each junction of interest, the optimization script ran 300+ times recording the junction flow rate for various storm centerings and orientations. Each of the recorded storm centerings (x,y) and resulting flow rates (z) at the junction of interest were recorded and used to create a rasterized heat map. The red shading represents storm locations that led to relatively high flow rates at the junction whereas the green shading represents storm locations that led to relatively low flow rates.

The following ‘b’ figures show the final, total storm depths and optimized storm configurations for each junction. Note that the peak flow values recorded in the ‘a’ figures may differ slightly from the final peak flow values recorded in the ‘b’ figures and in Table 5 above. This is due to a couple of small tweaks to the HMS model parameters that were done after the 100yr48hr storm centerings were determined.

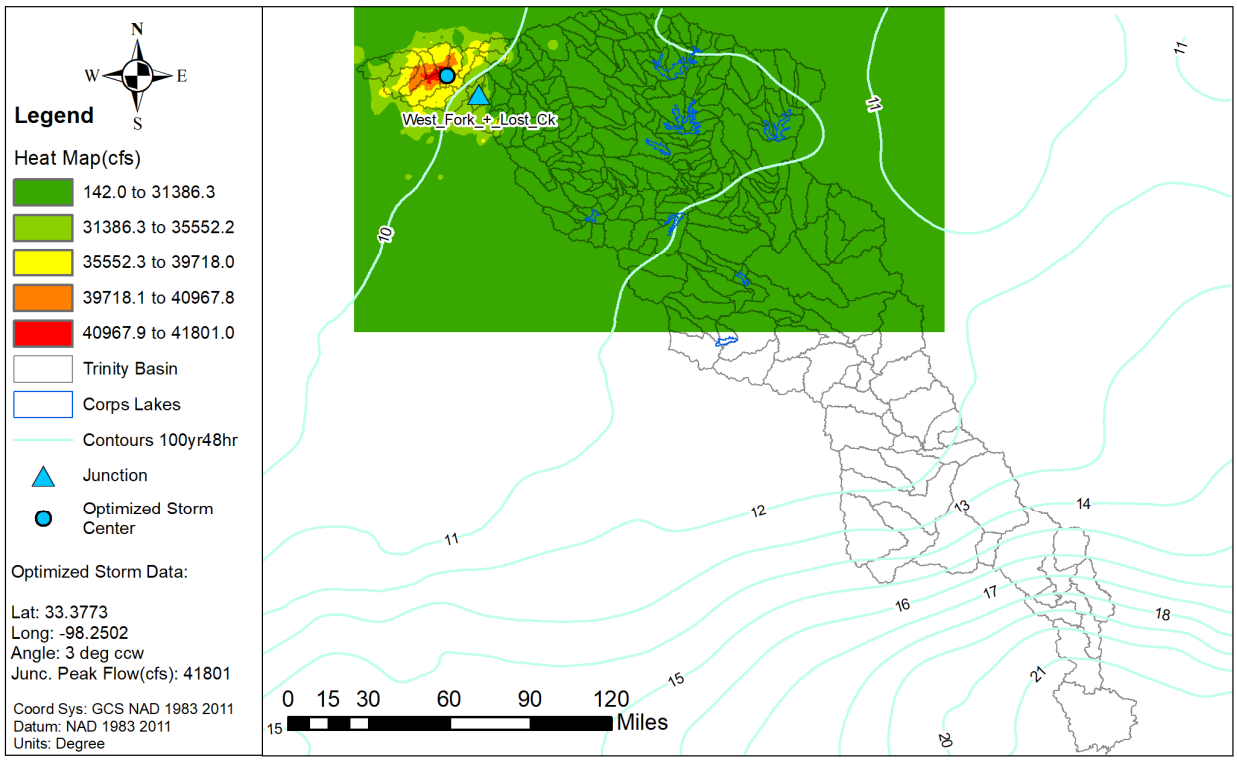


Figure 11a: Elliptical Storm Heat Map for the West Fork Trinity River below Lost Creek

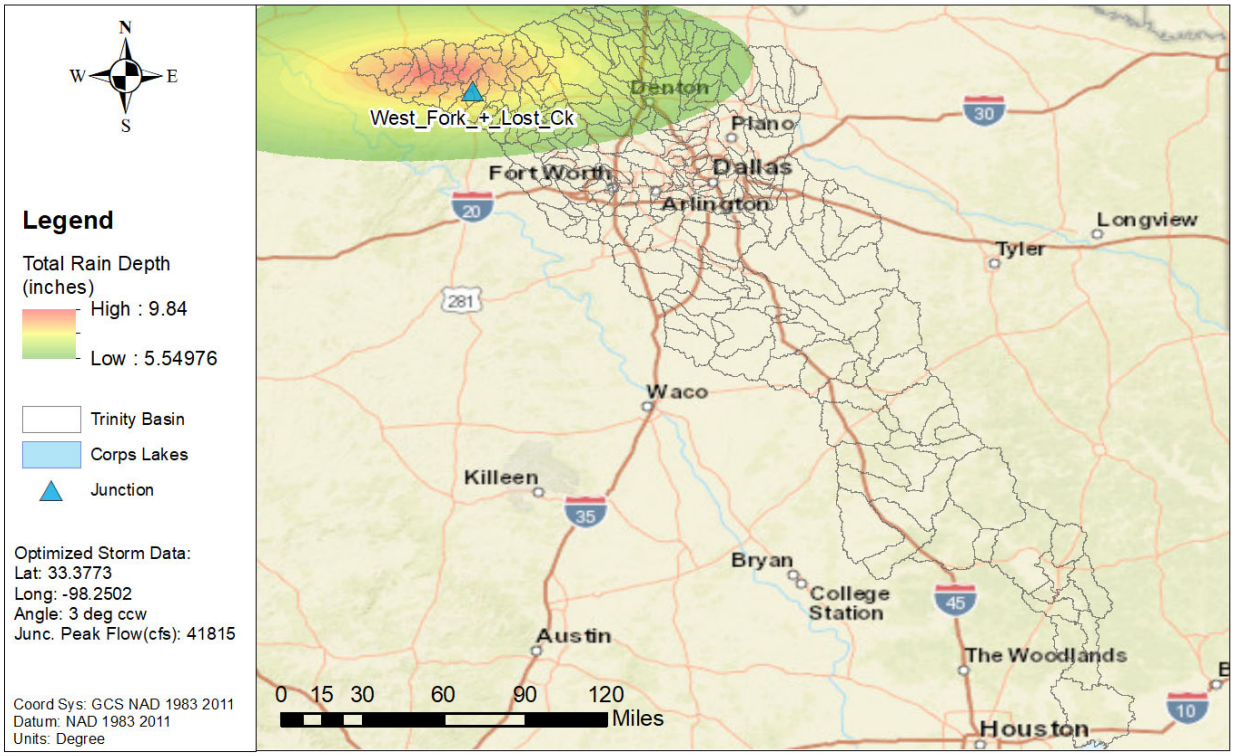


Figure 11b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below Lost Creek

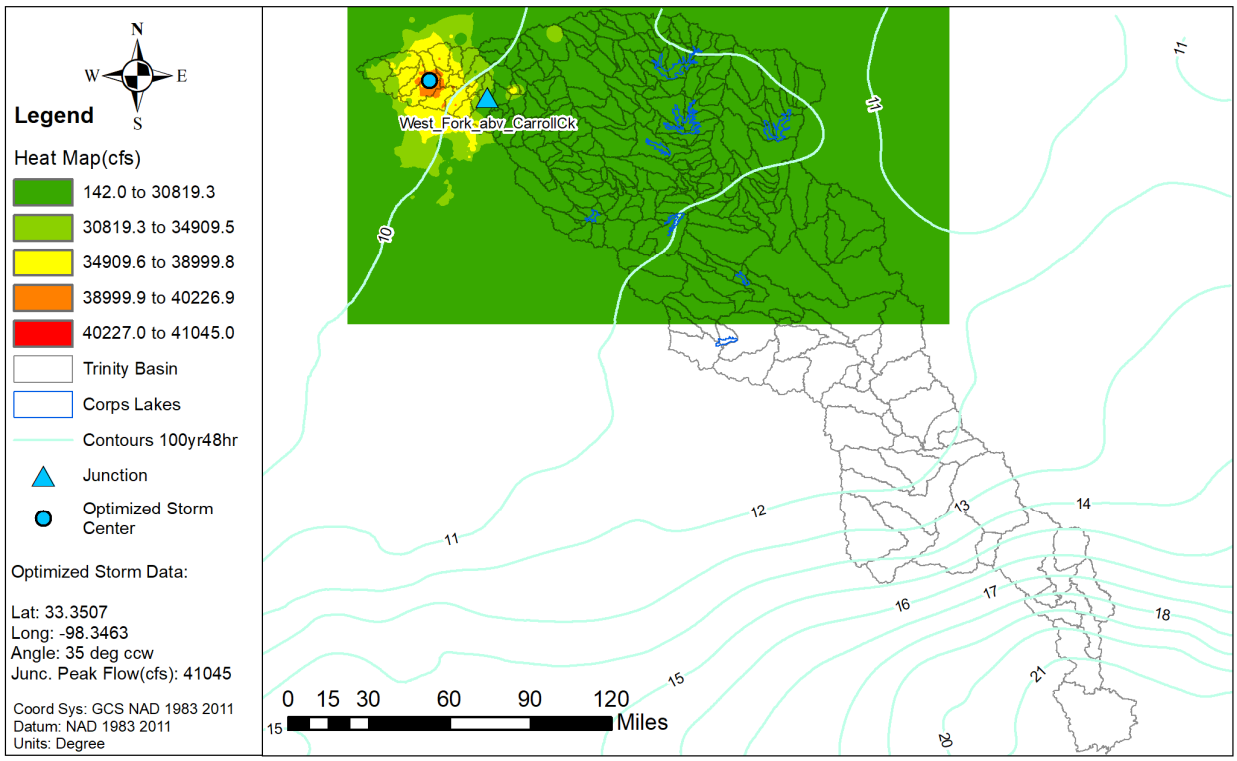


Figure 12a: Elliptical Storm Heat Map for the West Fork Trinity River above Carroll Creek

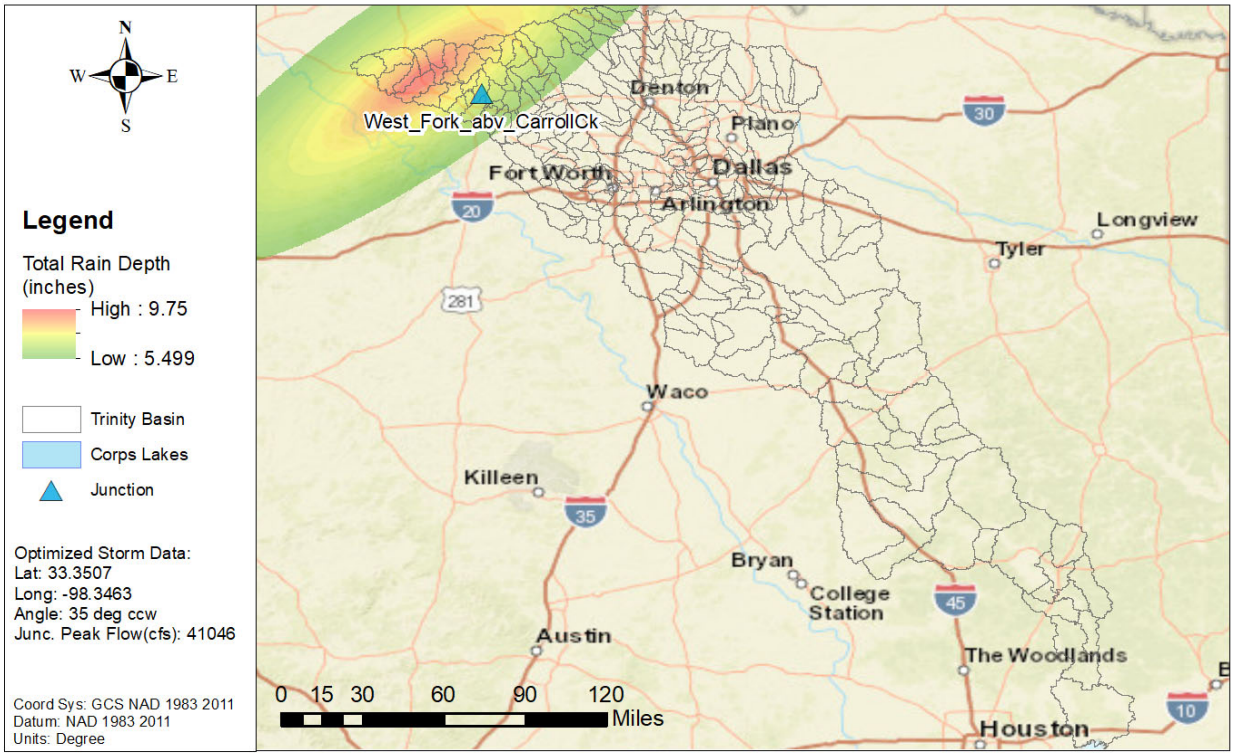


Figure 12b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River above Carroll Creek

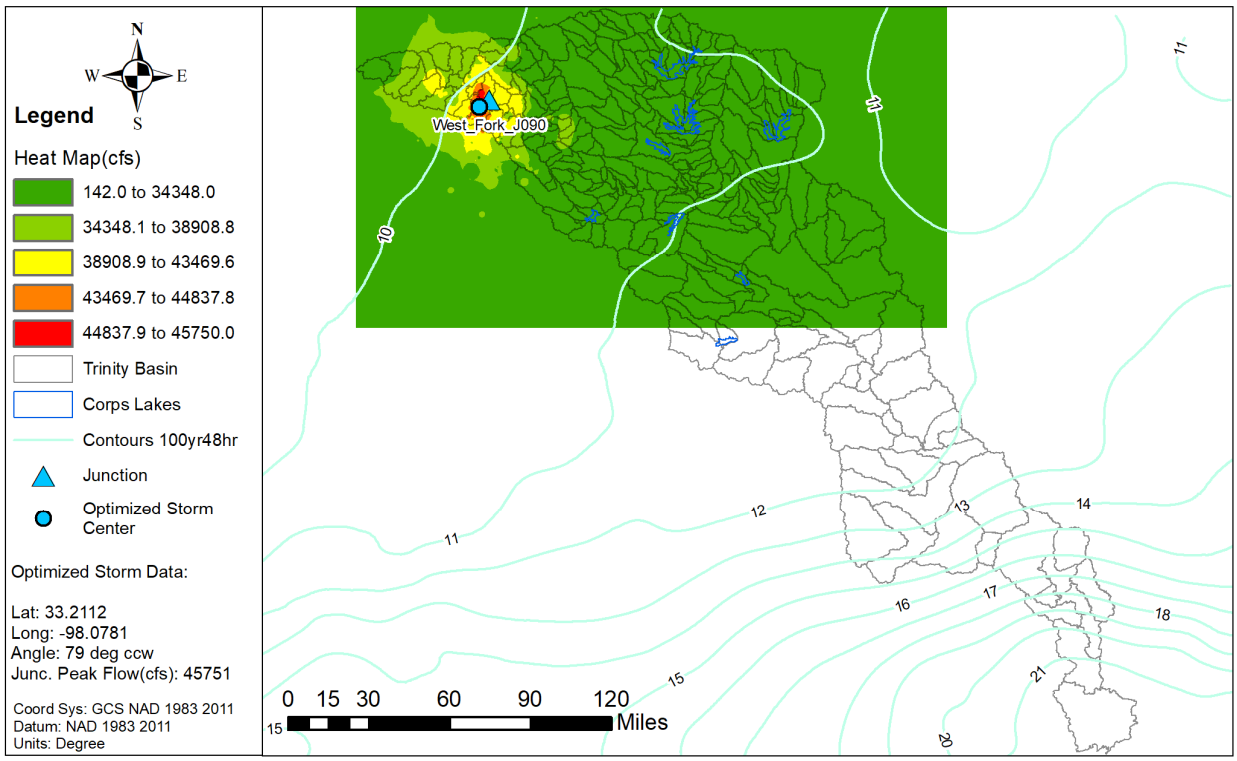


Figure 13a: Elliptical Storm Heat Map for the West Fork Trinity River below Carroll Creek

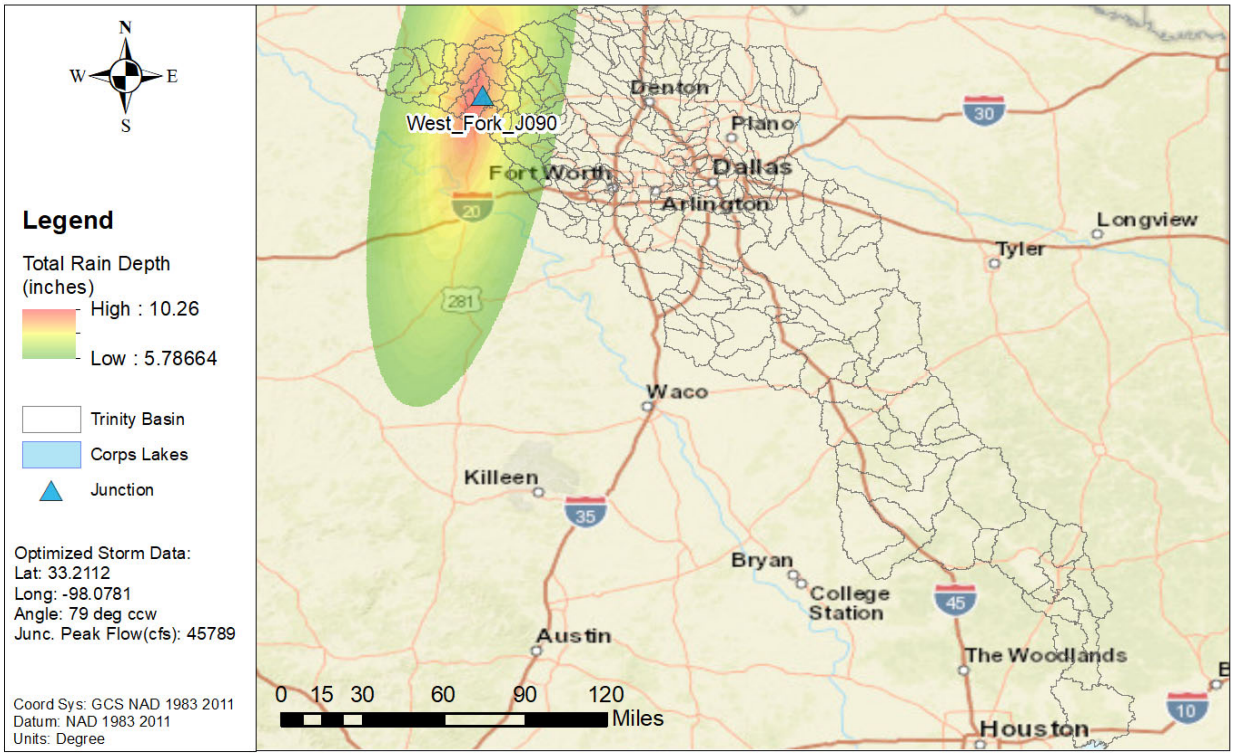


Figure 13b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below Carroll Creek

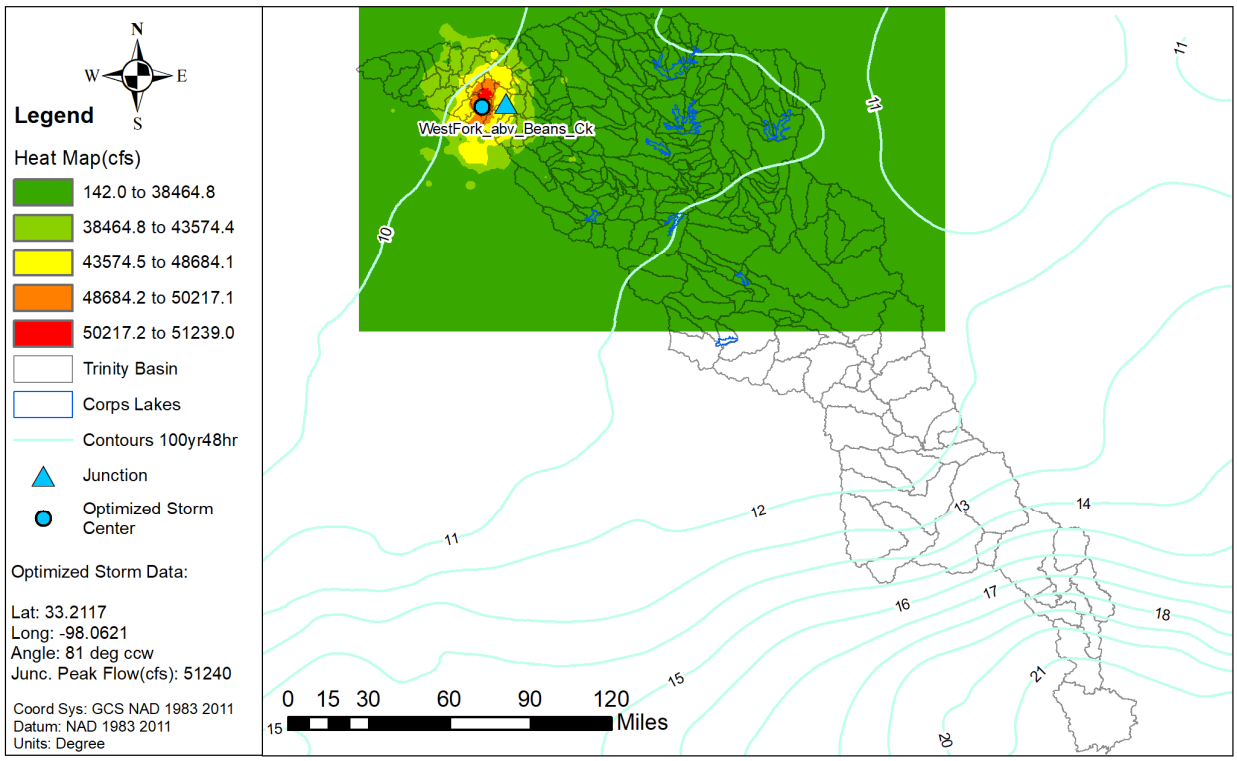


Figure 14a: Elliptical Storm Heat Map for the West Fork Trinity River above Beans Creek

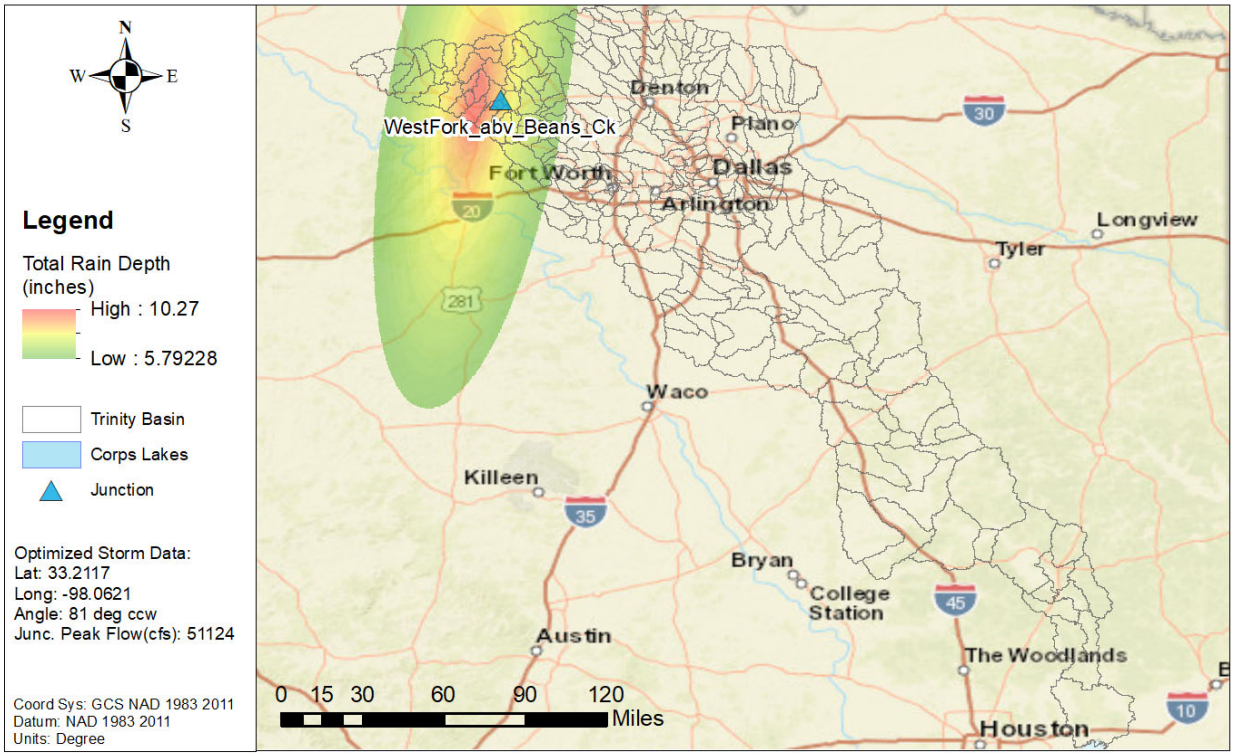


Figure 14b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River above Beans Creek

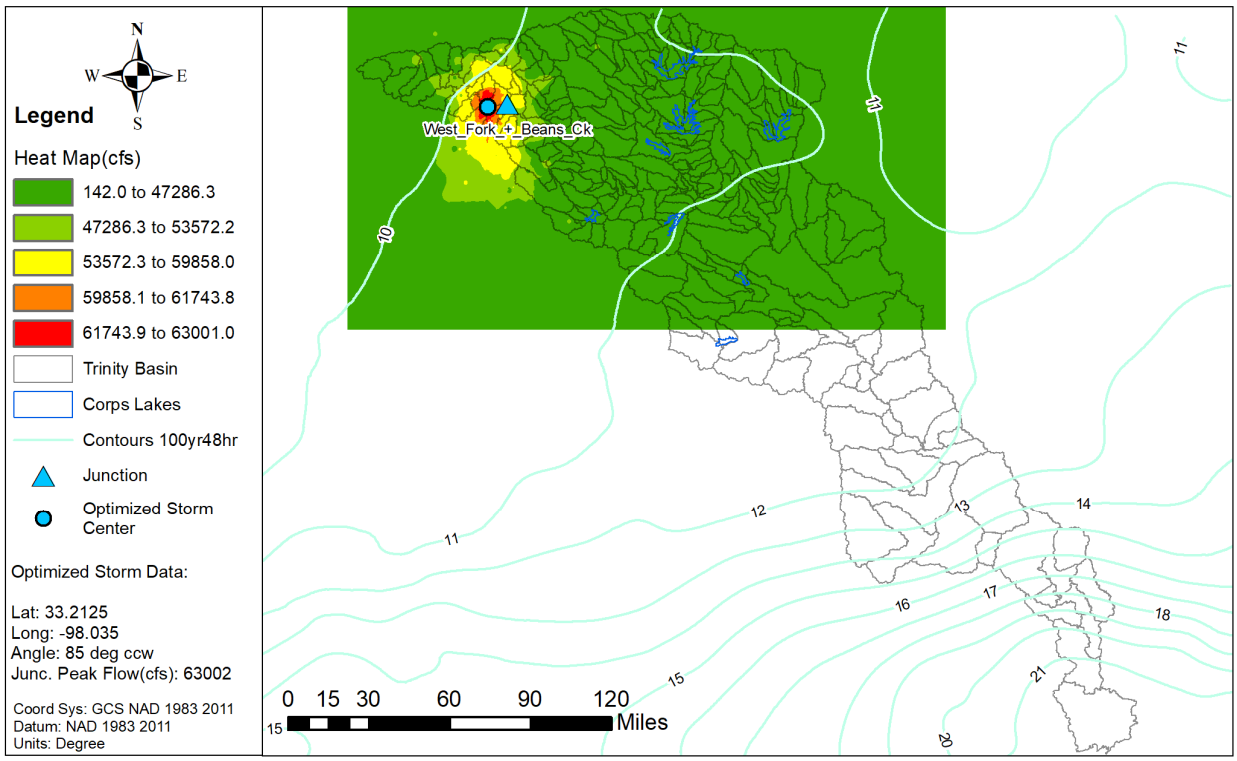


Figure 15a: Elliptical Storm Heat Map for the West Fork Trinity River below Beans Creek

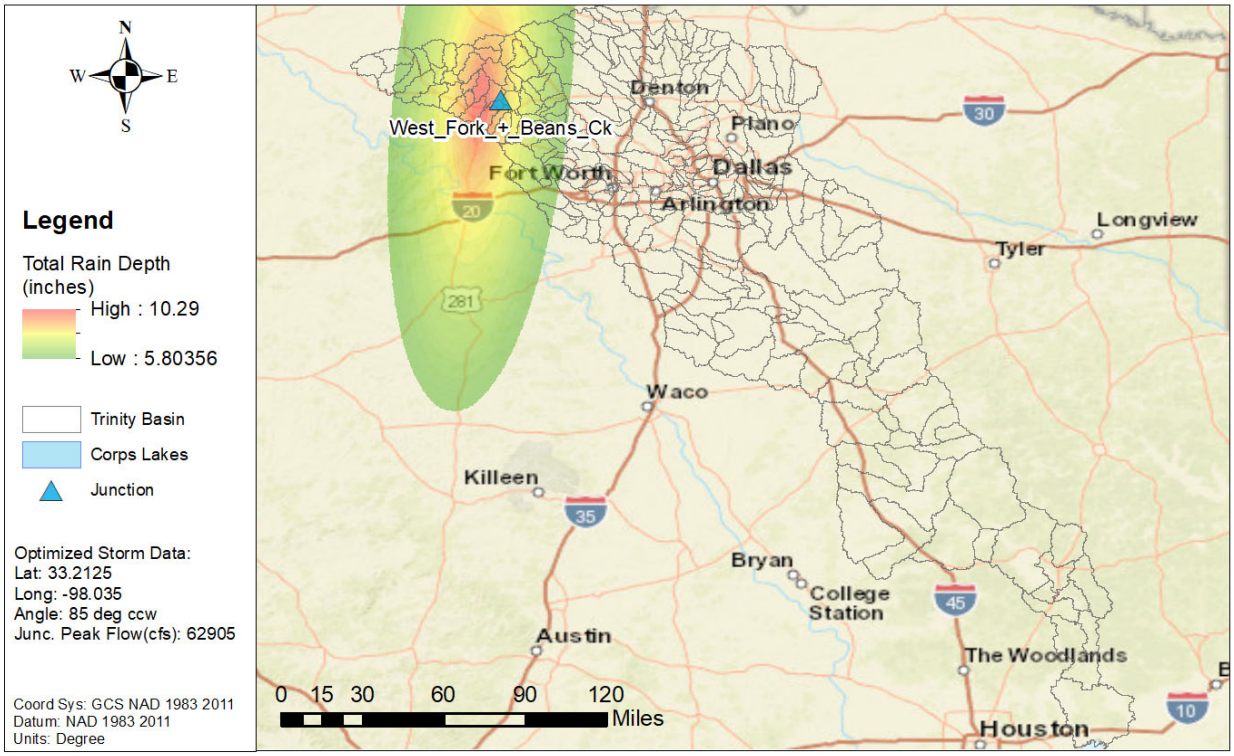


Figure 15b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below Beans Creek

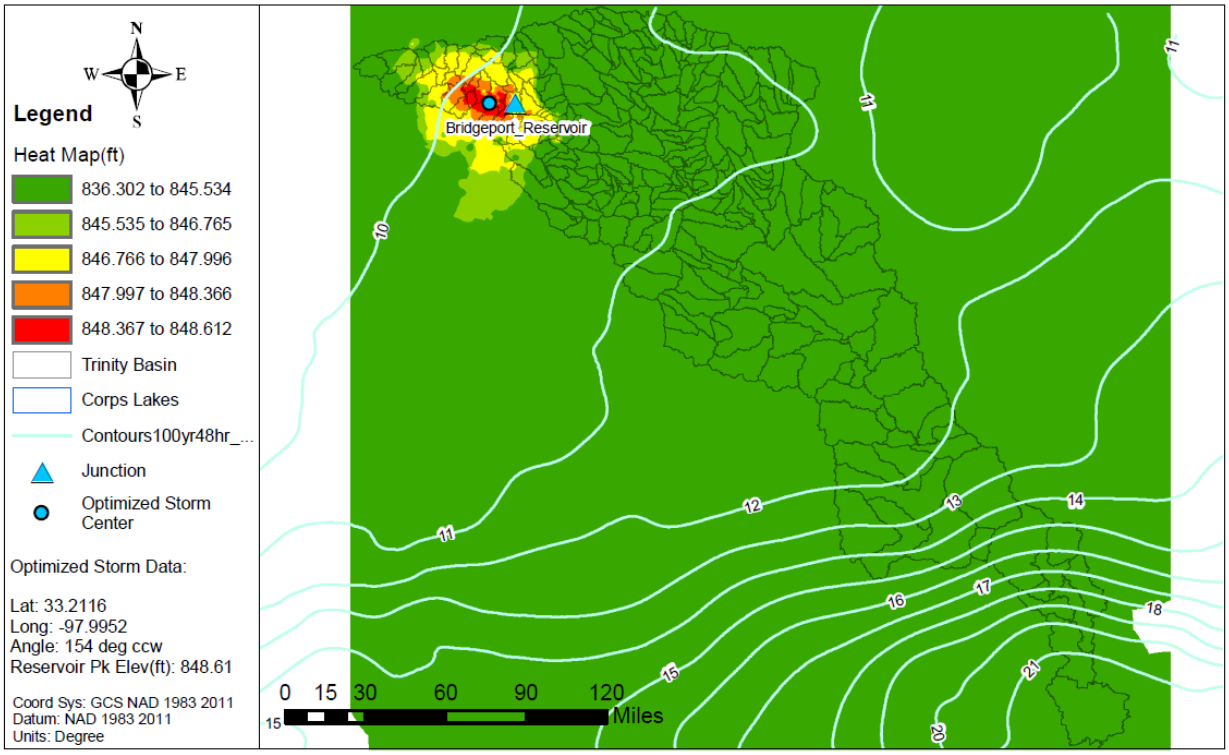


Figure 16a: Elliptical Storm Heat Map for the Bridgeport Reservoir

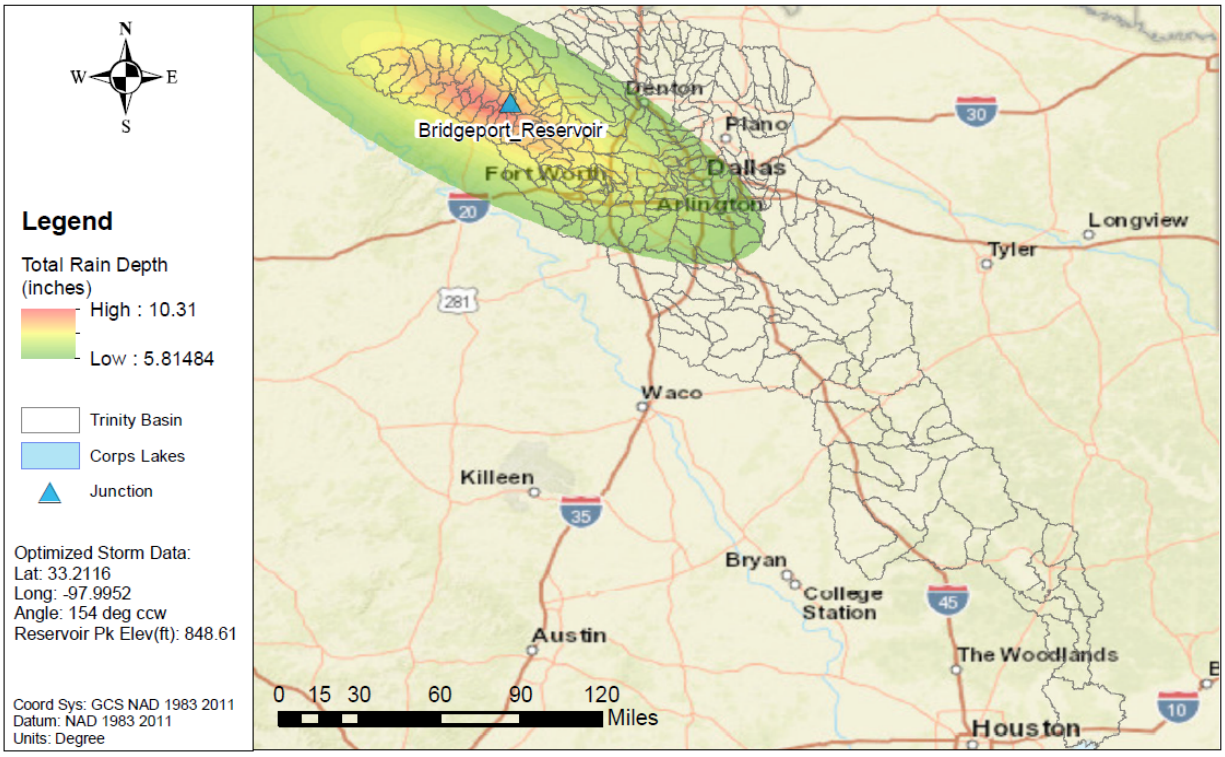


Figure 16b: NA14 1% AEP Elliptical Storm for the Bridgeport Reservoir

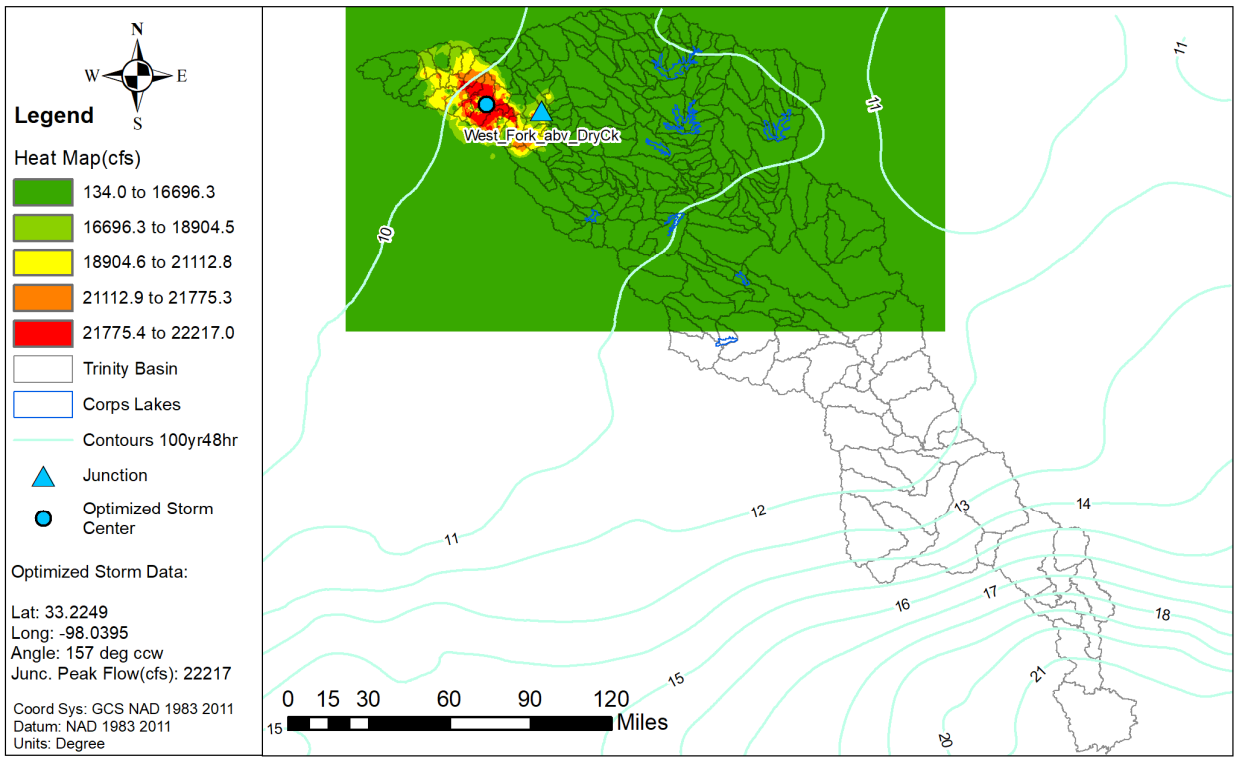


Figure 17a: Elliptical Storm Heat Map for the West Fork Trinity River above Dry Creek

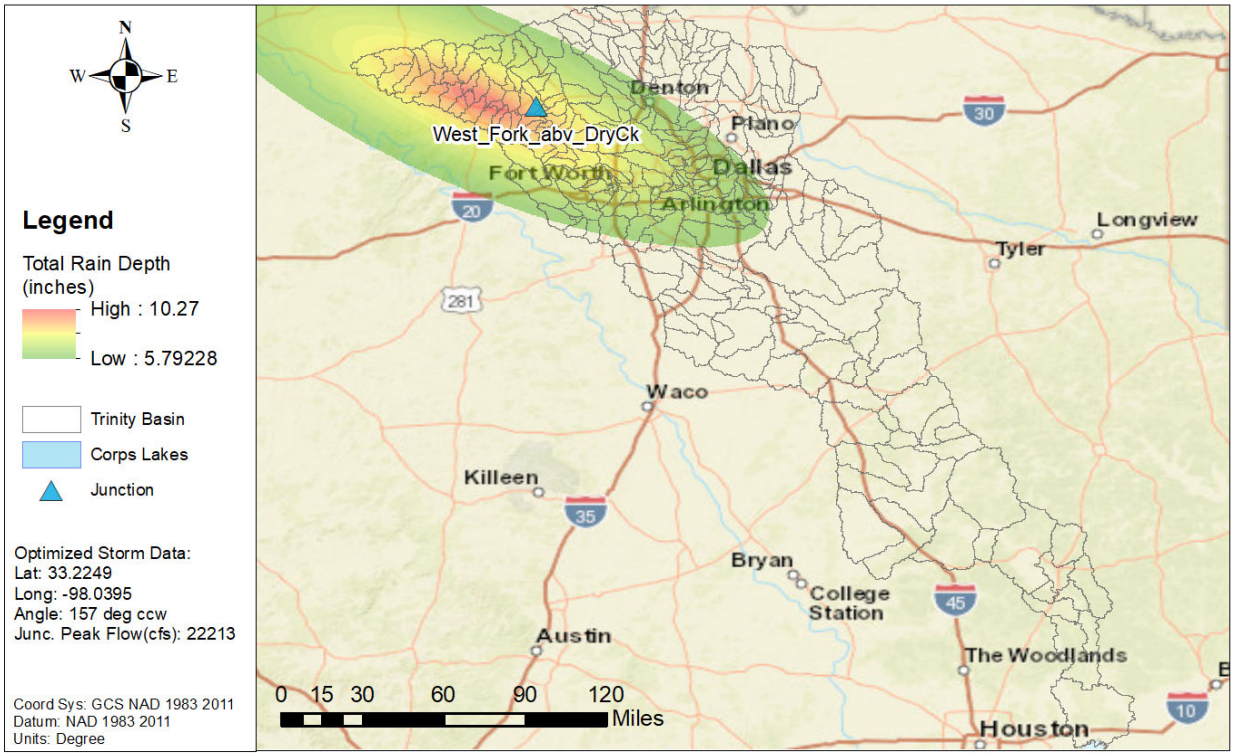


Figure 17b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River above Dry Creek

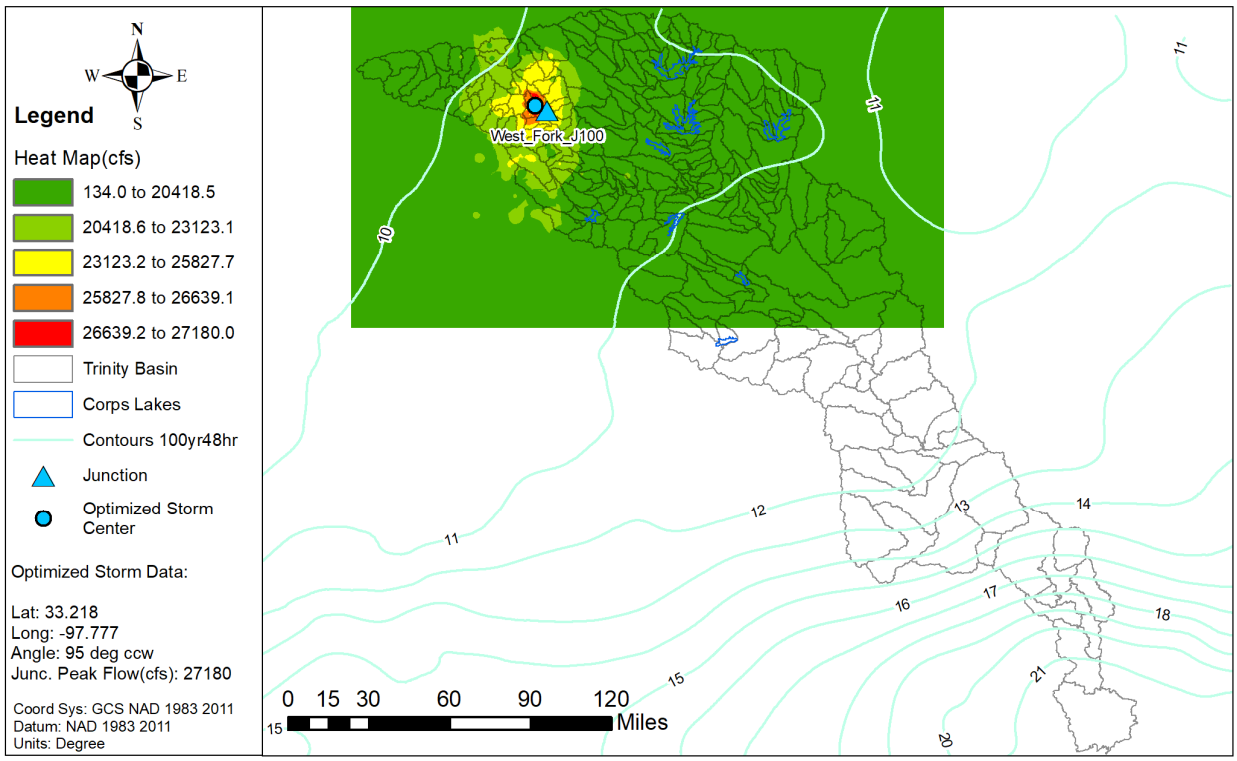


Figure 18a: Elliptical Storm Heat Map for the West Fork Trinity River below Dry Creek

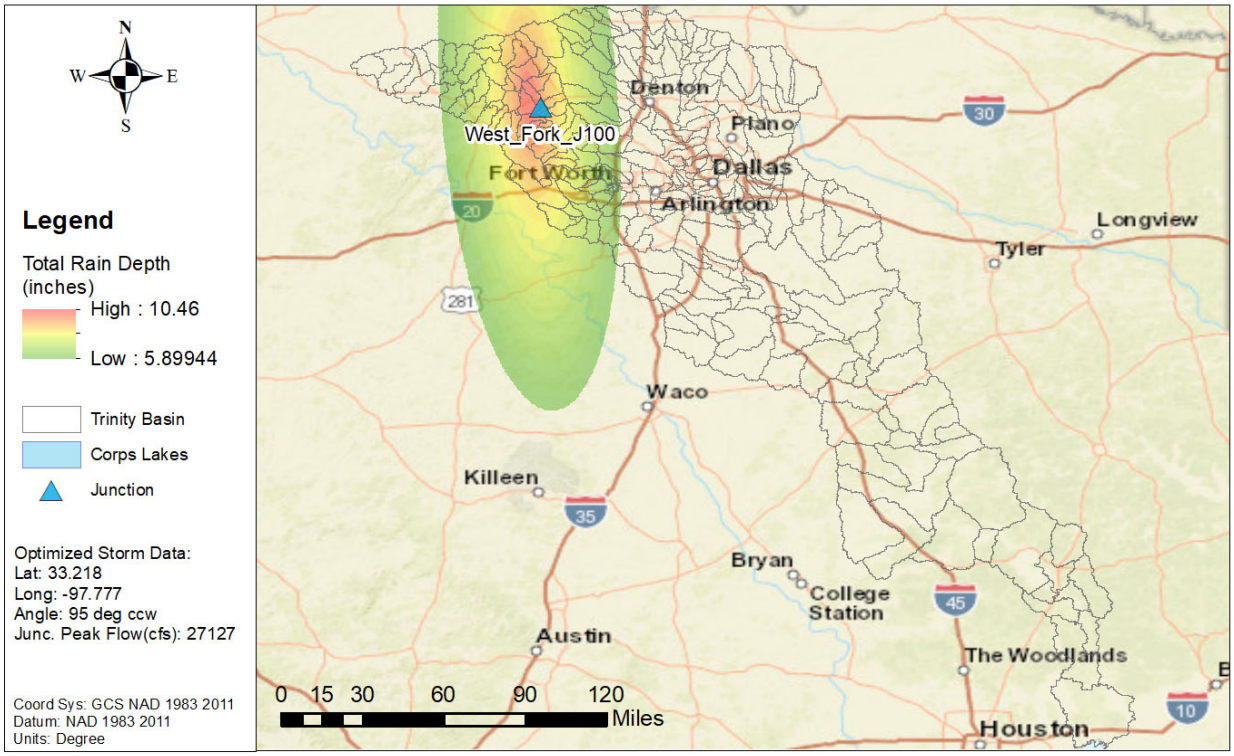


Figure 18b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below Dry Creek

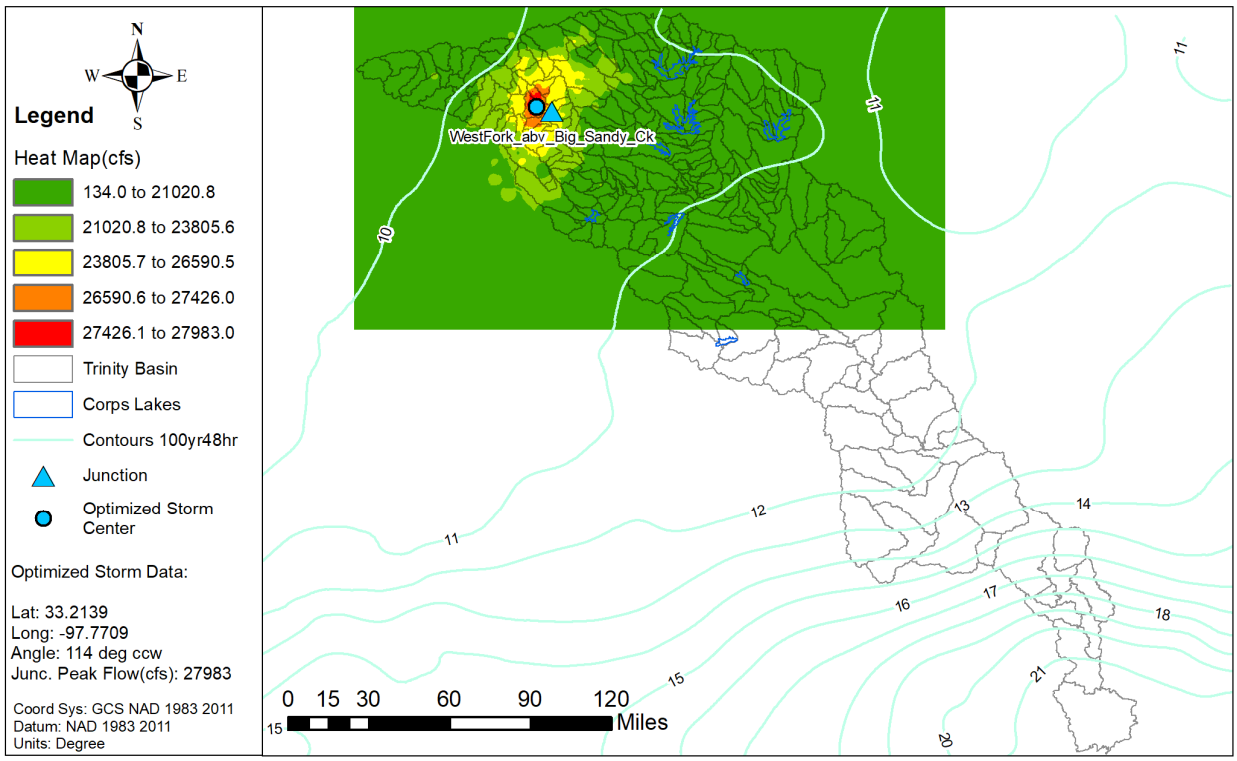


Figure 19a: Elliptical Storm Heat Map for the West Fork Trinity River above Big Sandy Creek

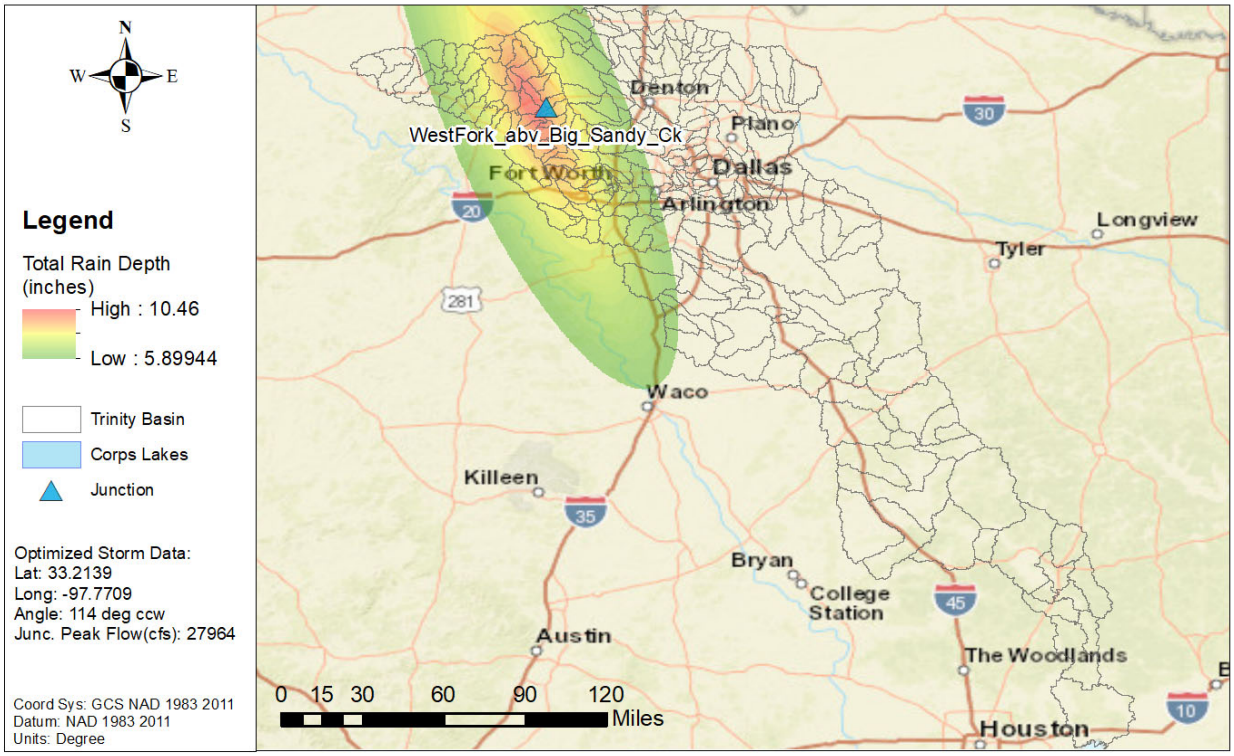


Figure 19b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River above Big Sandy Creek

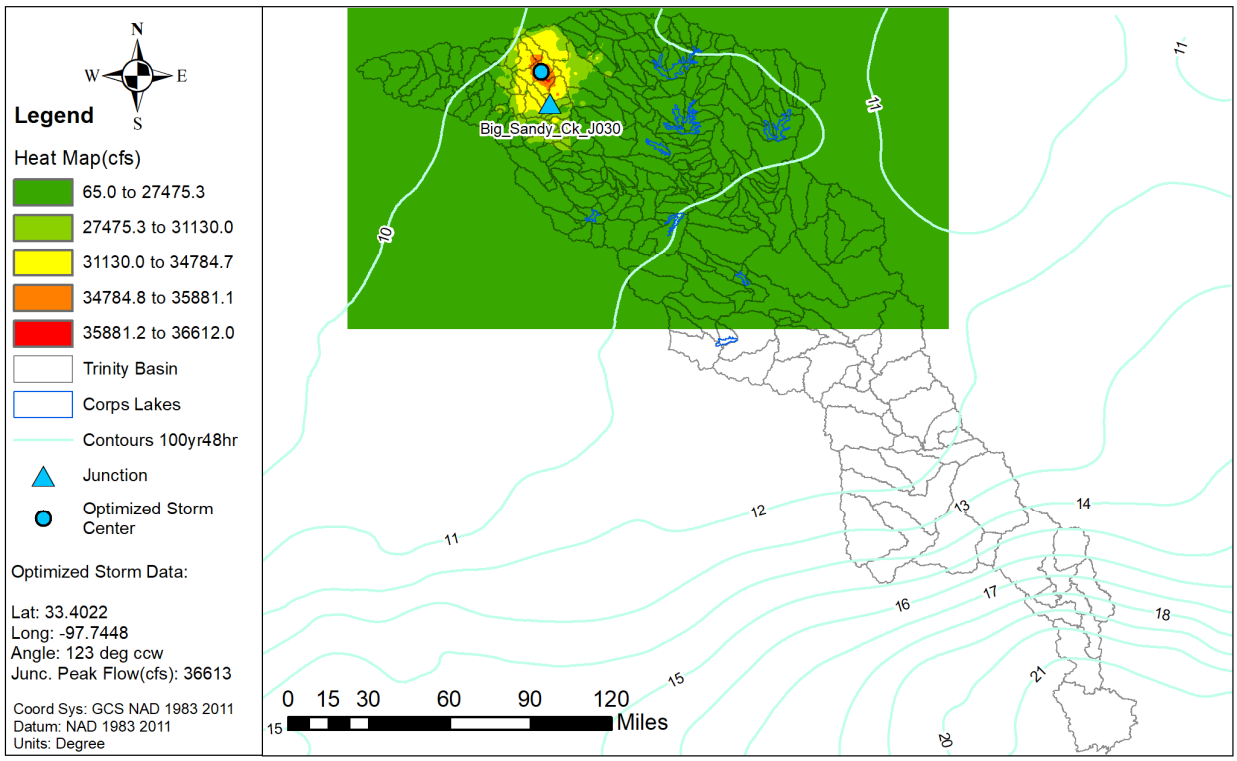


Figure 20a: Elliptical Storm Heat Map for Big Sandy Creek nr Bridgeport USGS Gage at Hwy 114 bridge

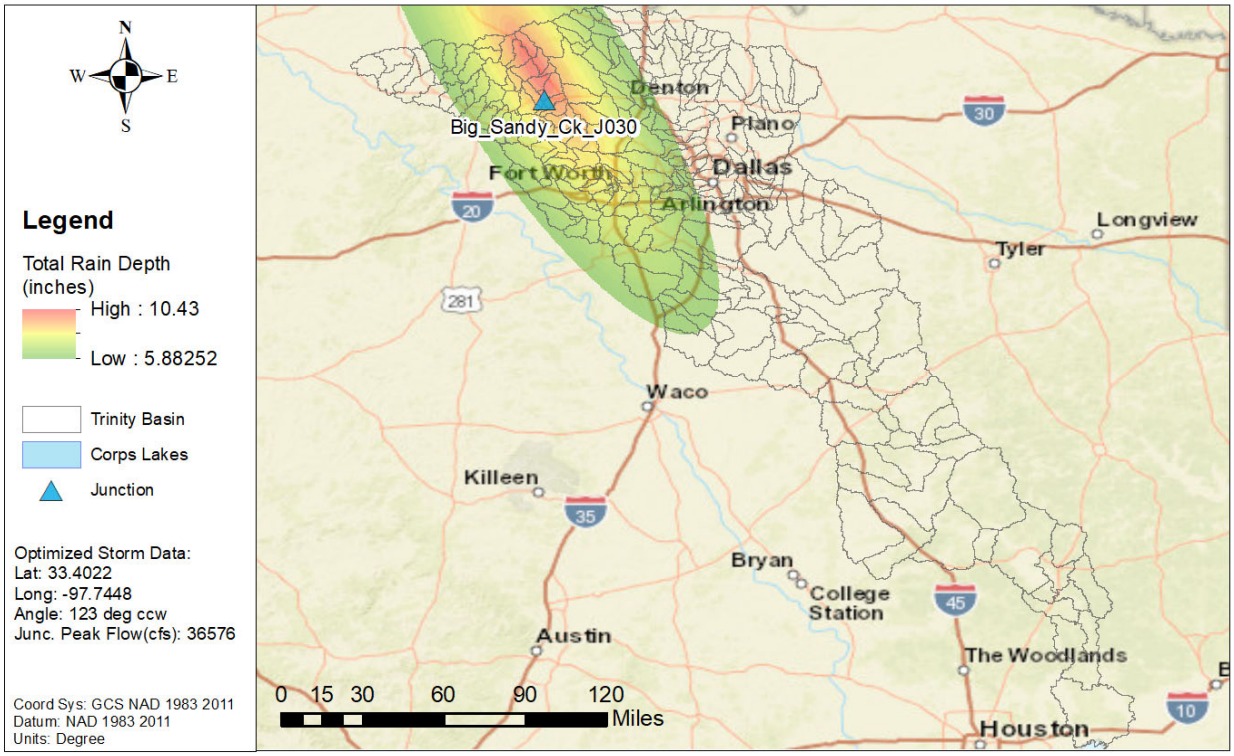


Figure 20b: NA14 1% AEP Elliptical Storm for Big Sandy Creek nr Bridgeport USGS Gage at Hwy 114

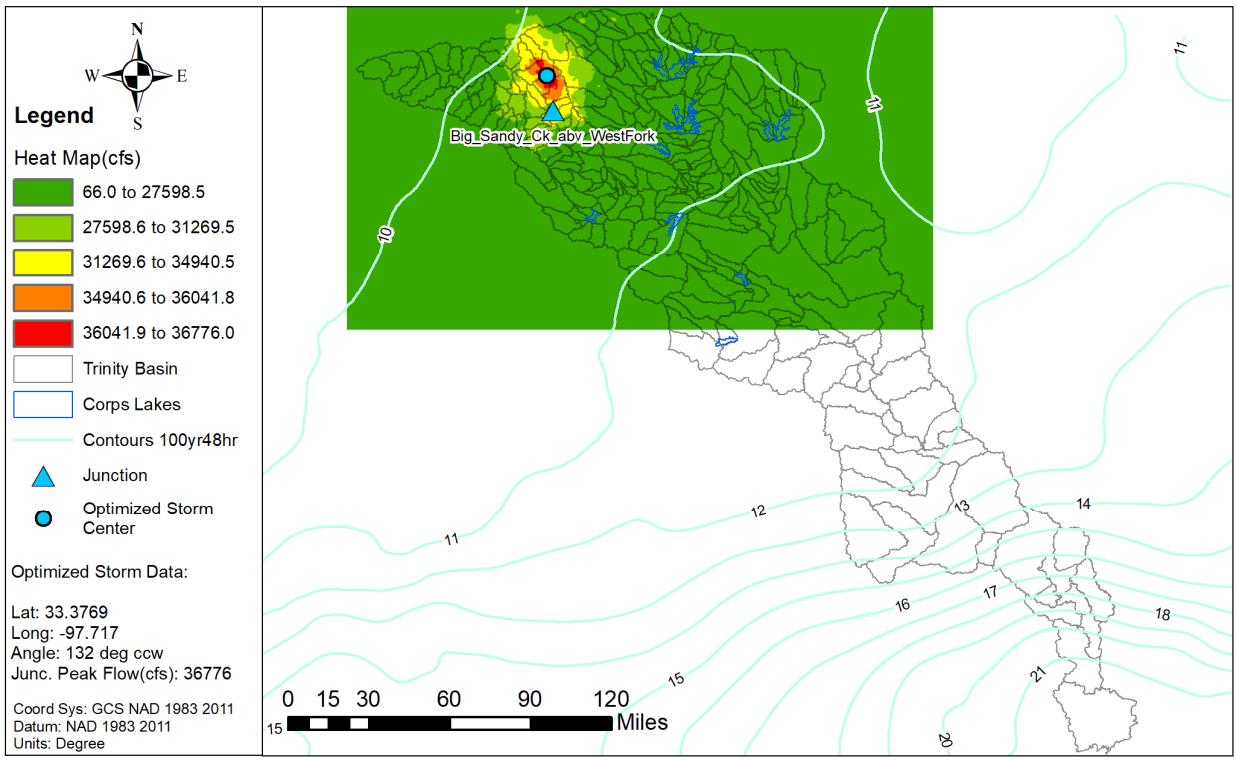


Figure 21a: Elliptical Storm Heat Map for the Big Sandy Creek above the West Fork Trinity River

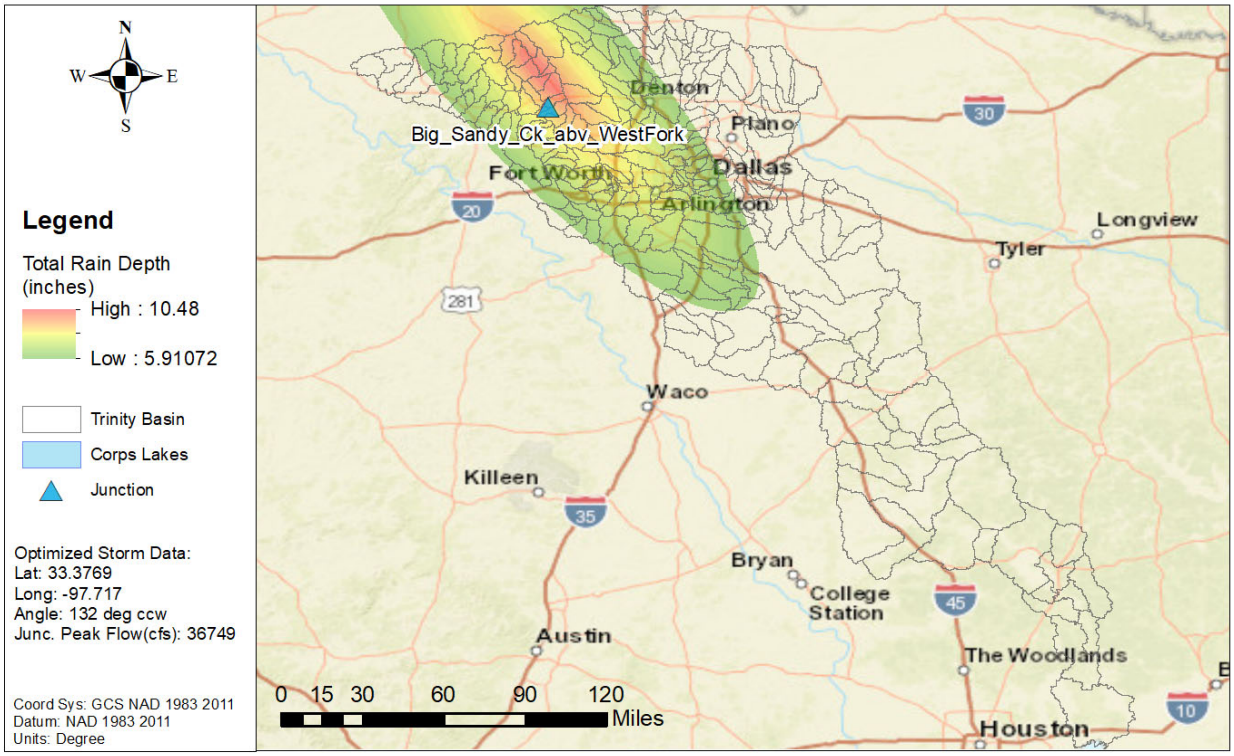


Figure 21b: NA14 1% AEP Elliptical Storm for the Big Sandy Creek above the West Fork Trinity River

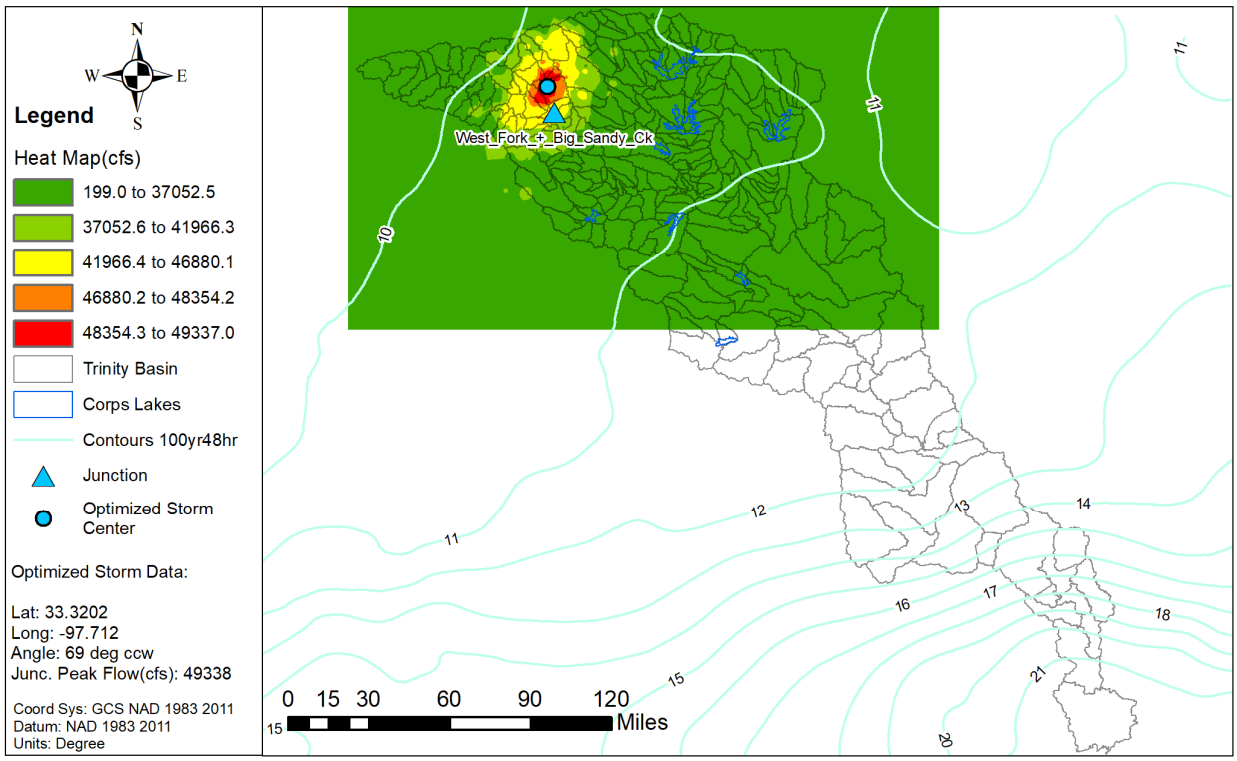


Figure 22a: Elliptical Storm Heat Map for the West Fork Trinity River below Big Sandy Creek

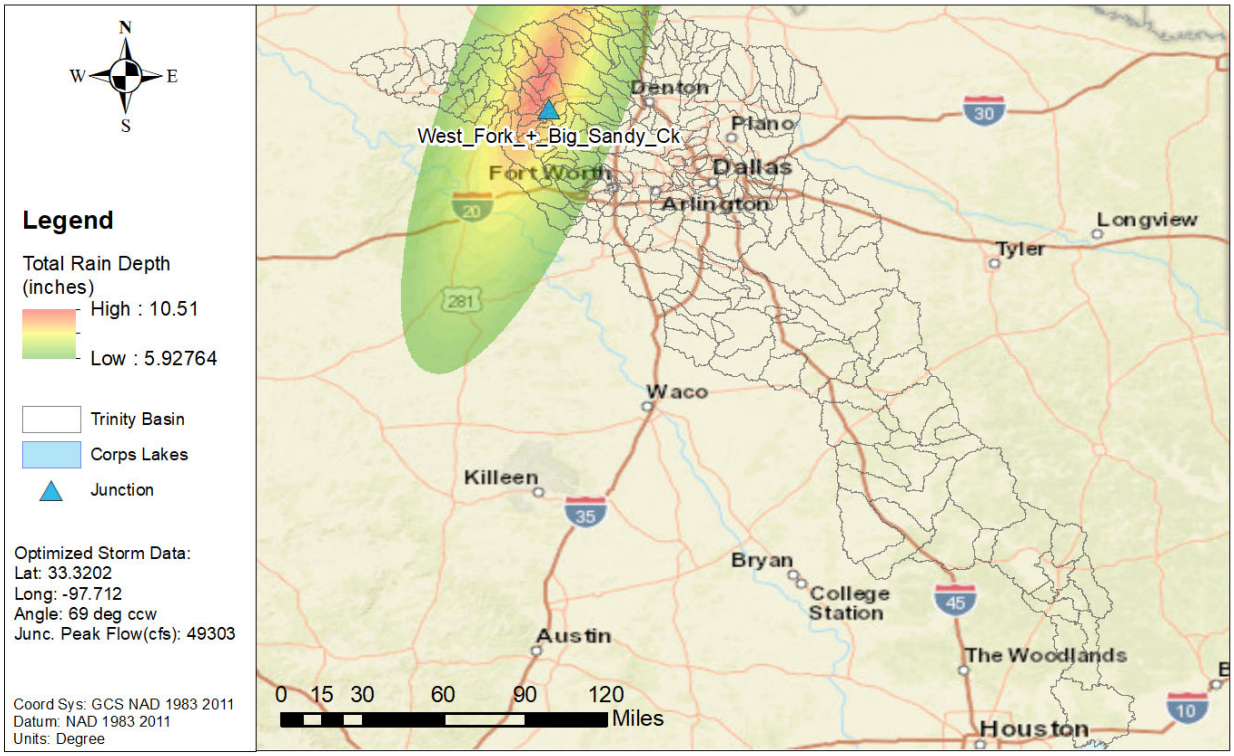


Figure 22b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below Big Sandy Creek

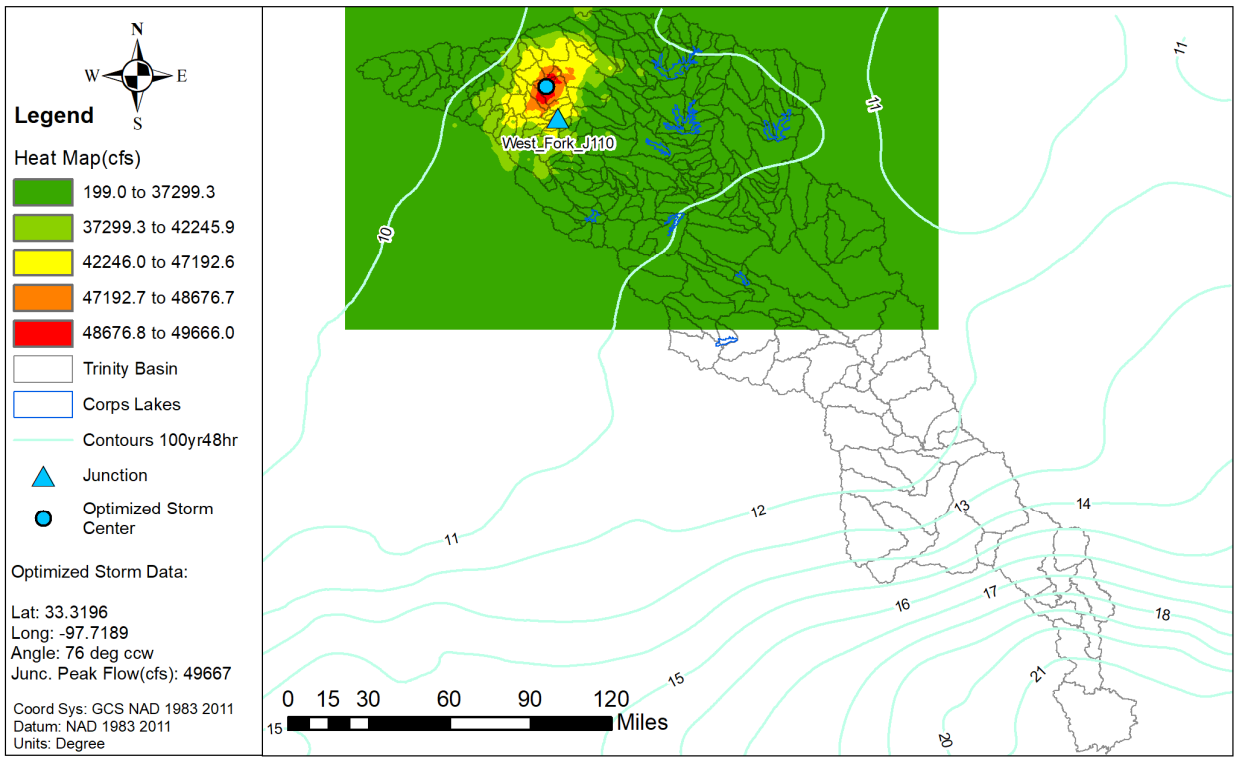


Figure 23a: Elliptical Storm Heat Map for the West Fork Trinity River at FM 3259 near Paradise, TX

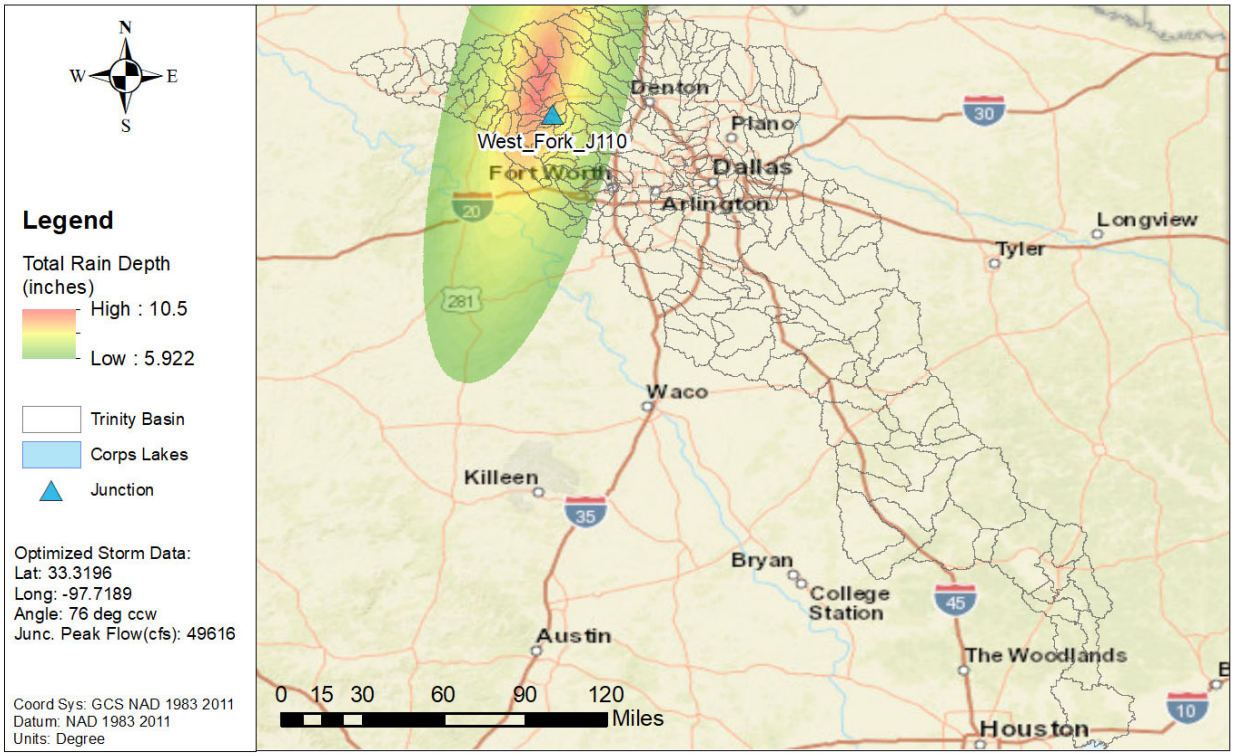


Figure 23b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River at FM 3259 near Paradise, TX

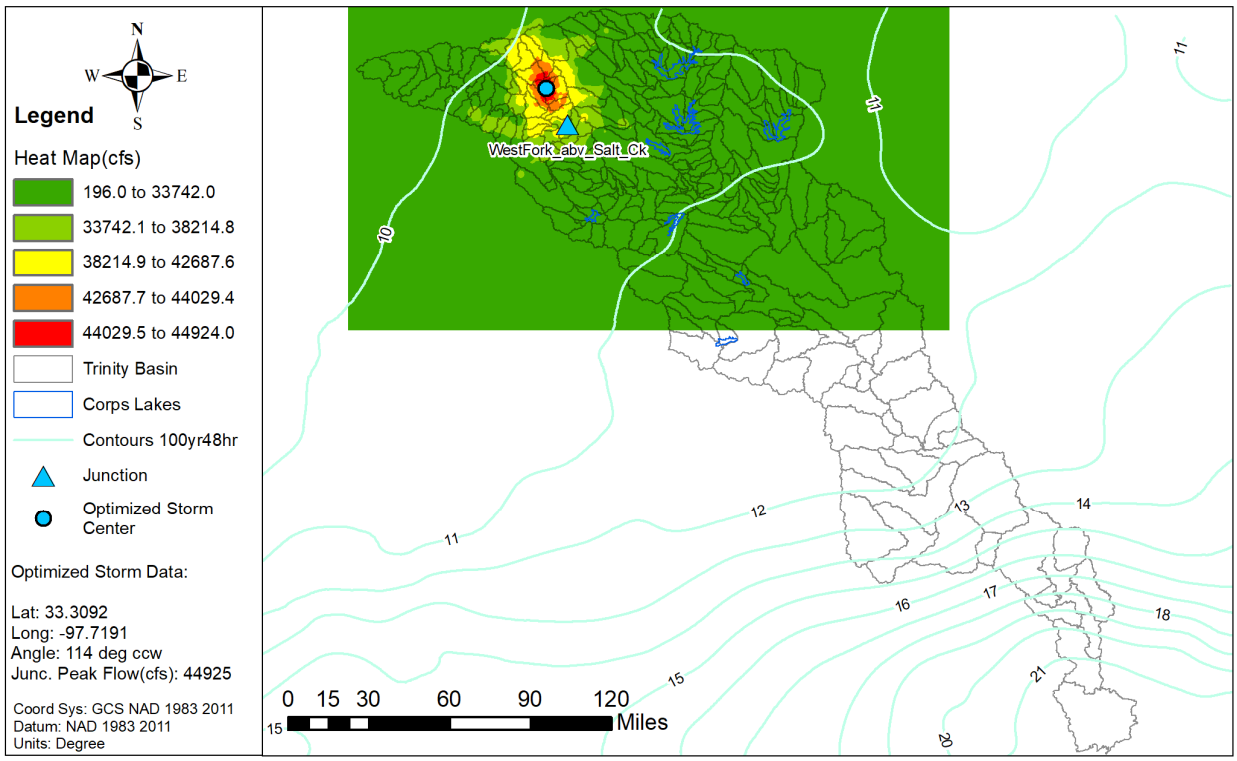


Figure 24a: Elliptical Storm Heat Map for the West Fork Trinity River above Salt Creek

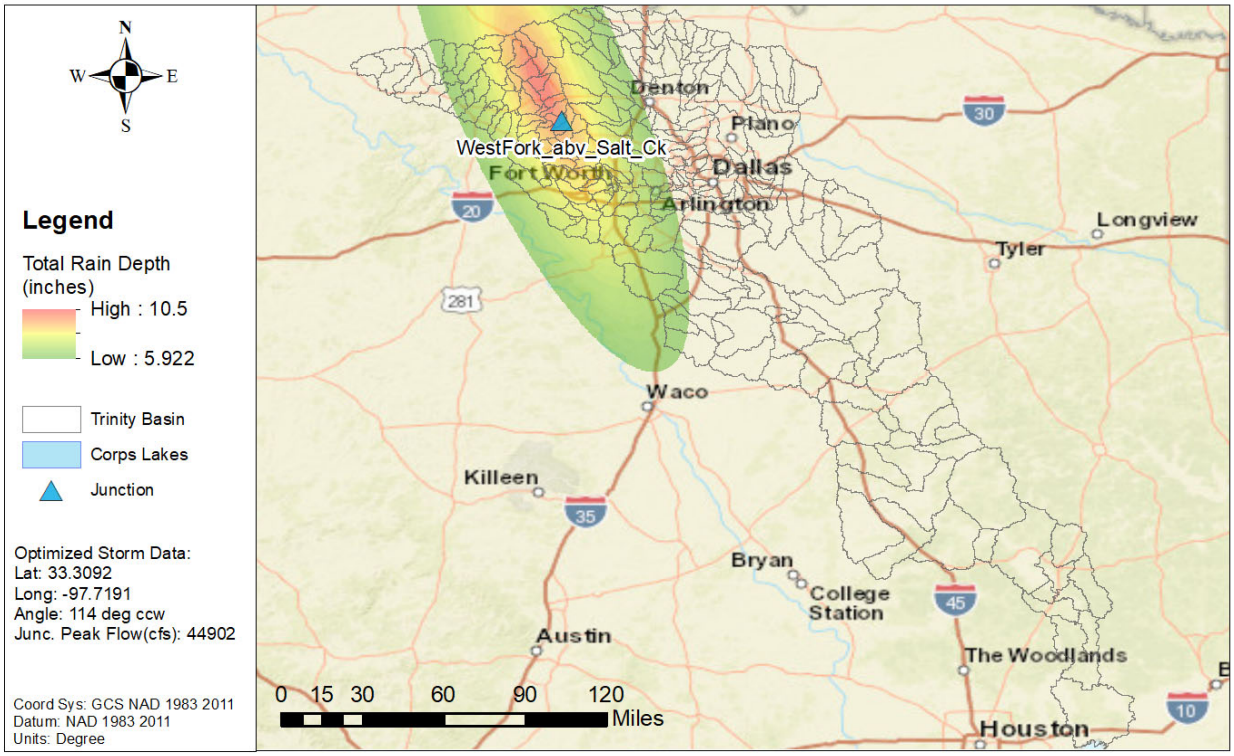


Figure 24b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River above Salt Creek

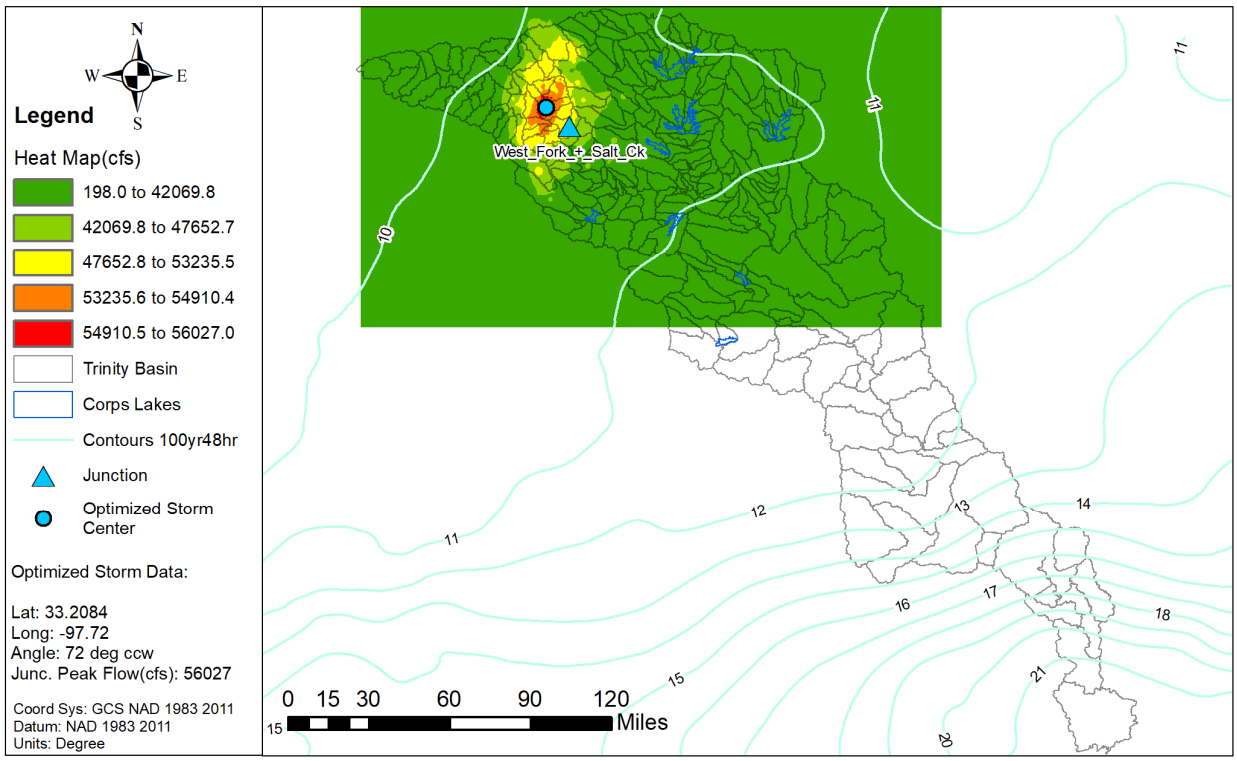


Figure 25a: Elliptical Storm Heat Map for the West Fork Trinity River below Salt Creek

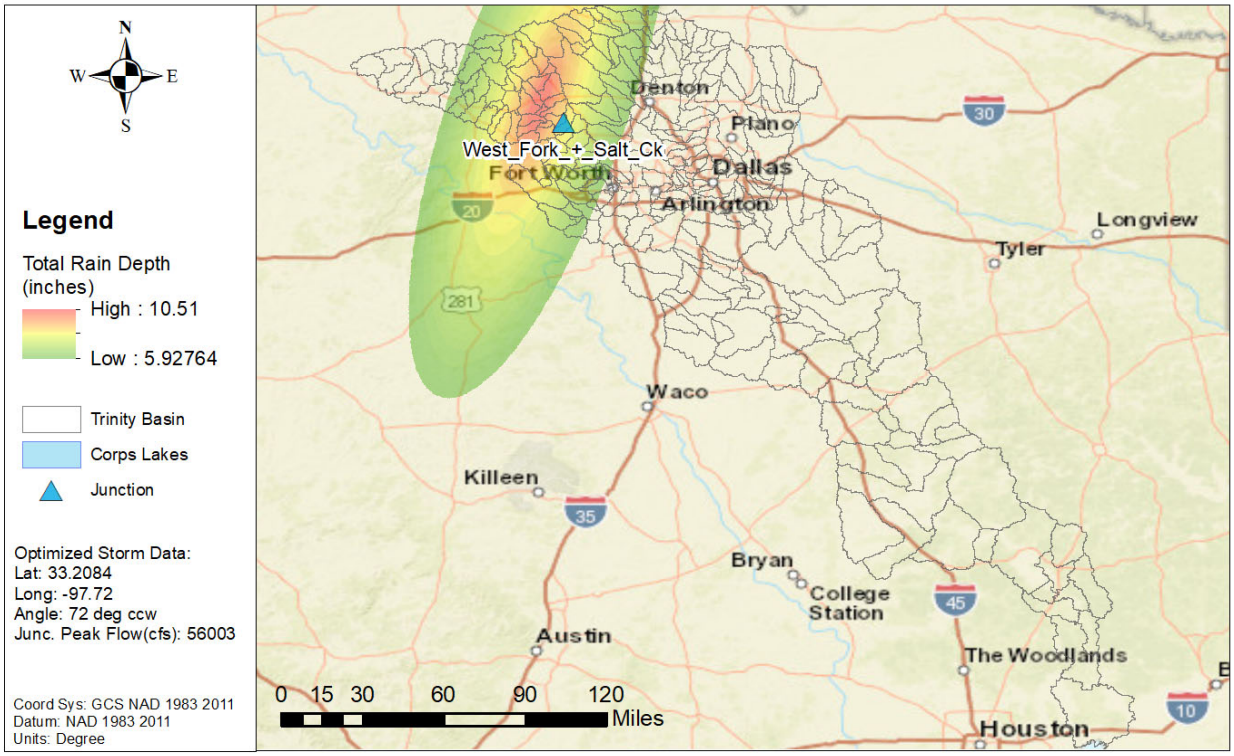


Figure 25b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below Salt Creek

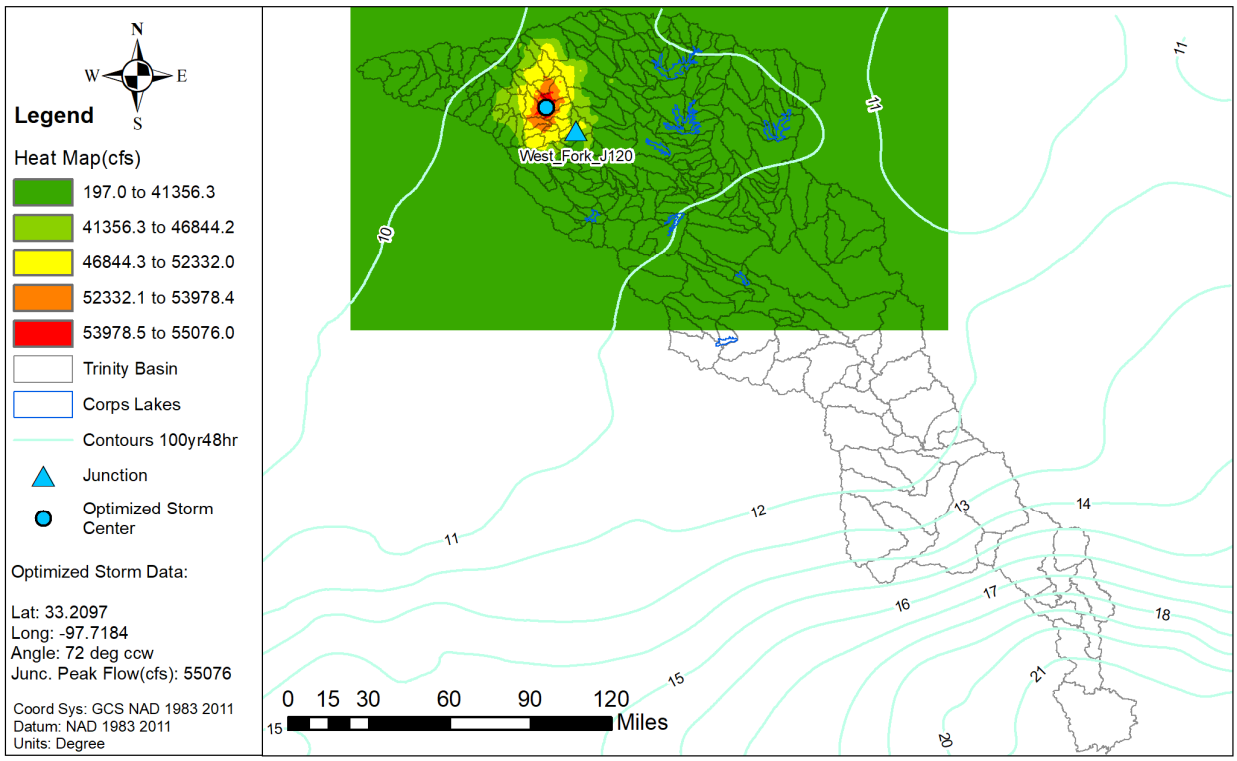


Figure 26a: Ellipt. Storm Heat Map for West Fork Trinity River nr Boyd, TX - USGS Gage at FM 730 bridge

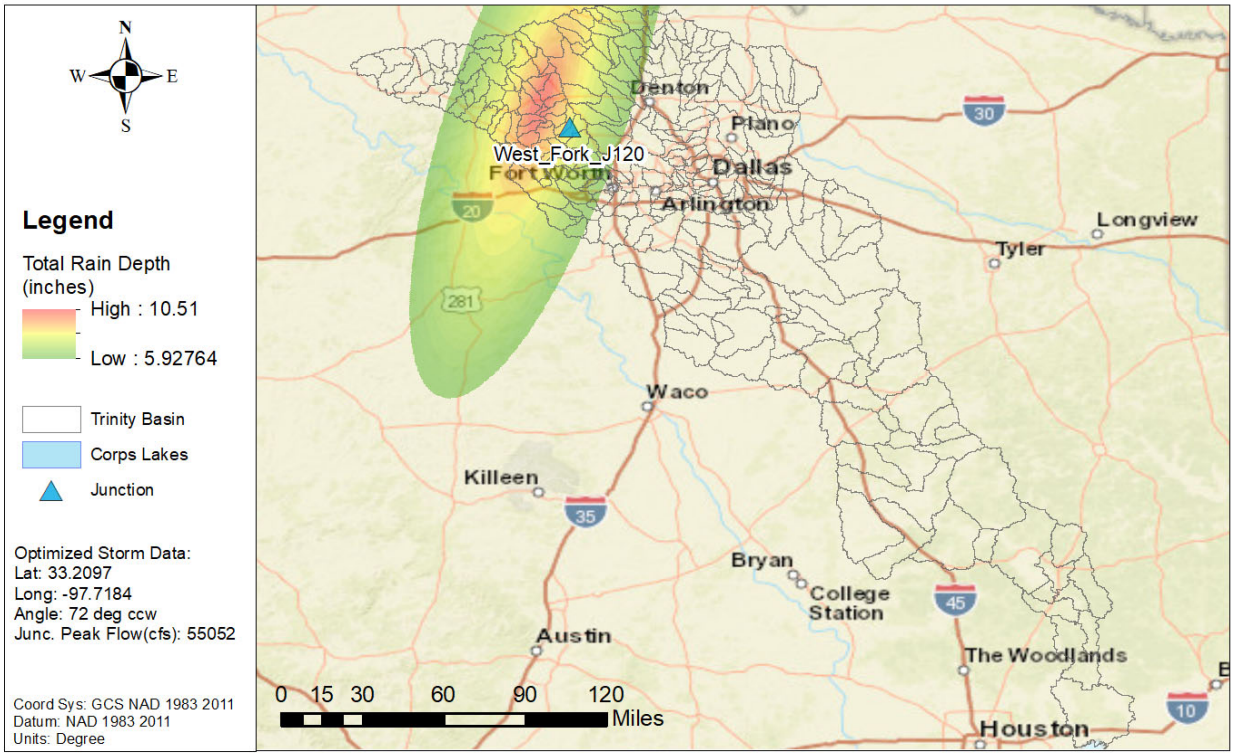


Figure 26b: NA14 1% AEP Ellip. Storm for West Fork Trinity River nr Boyd, TX - USGS Gage at FM 730

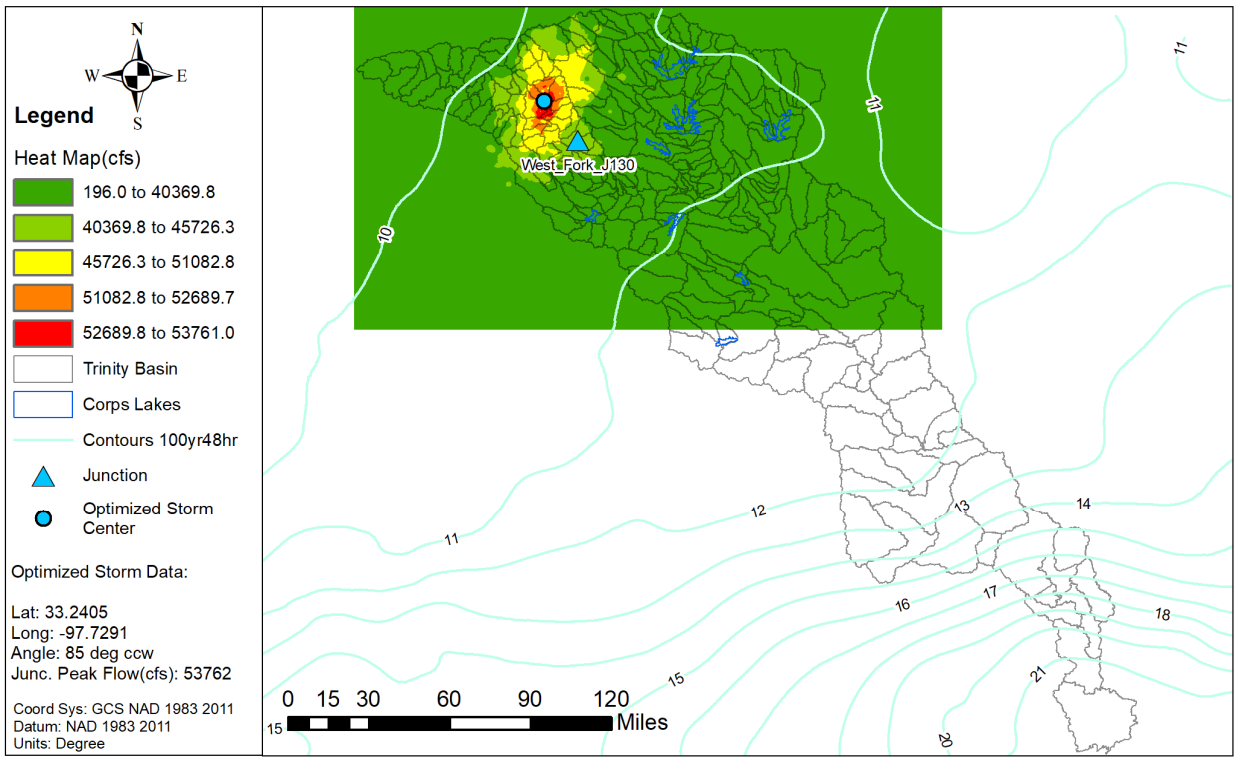


Figure 27a: Ellip. Storm Heat Map for West Fork Trinity River 0.8 miles upstream of FM 4757 in Wise Co.

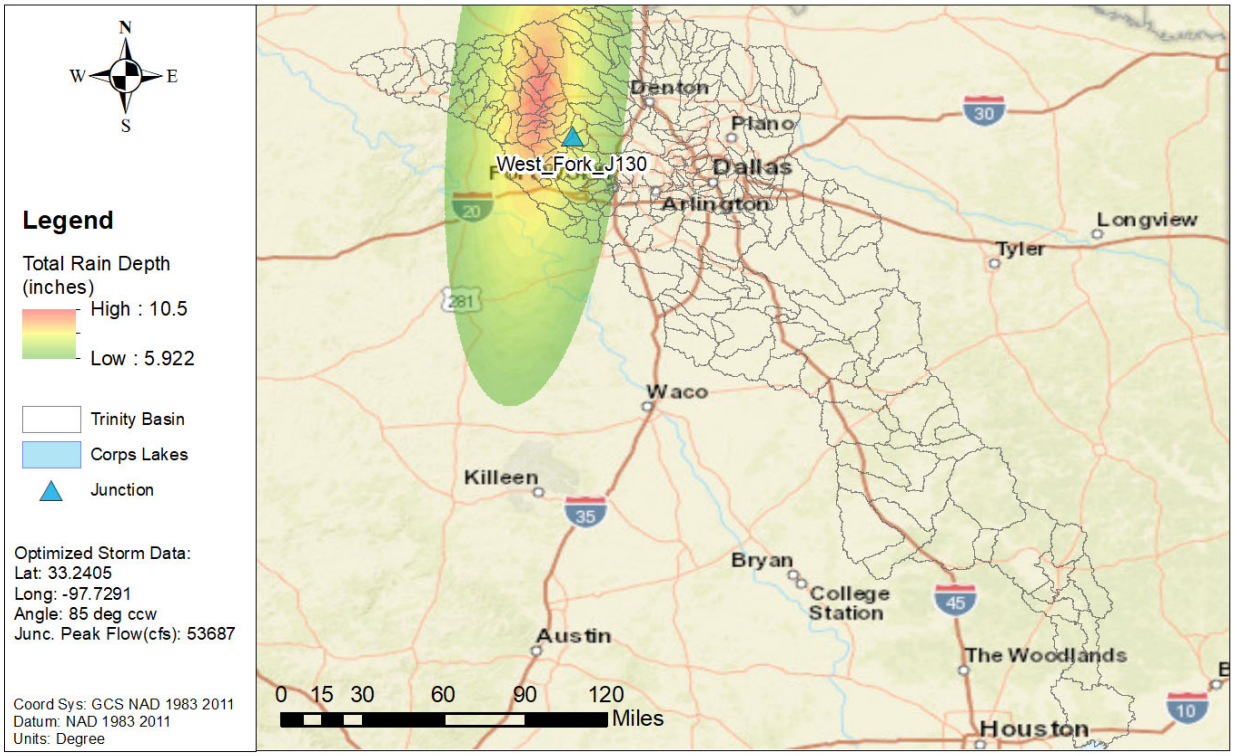


Figure 27b: NA14 1% AEP Ellip. Storm for W. Fork Trinity Riv. 0.8 miles upstream of FM 4757 in Wise Co.

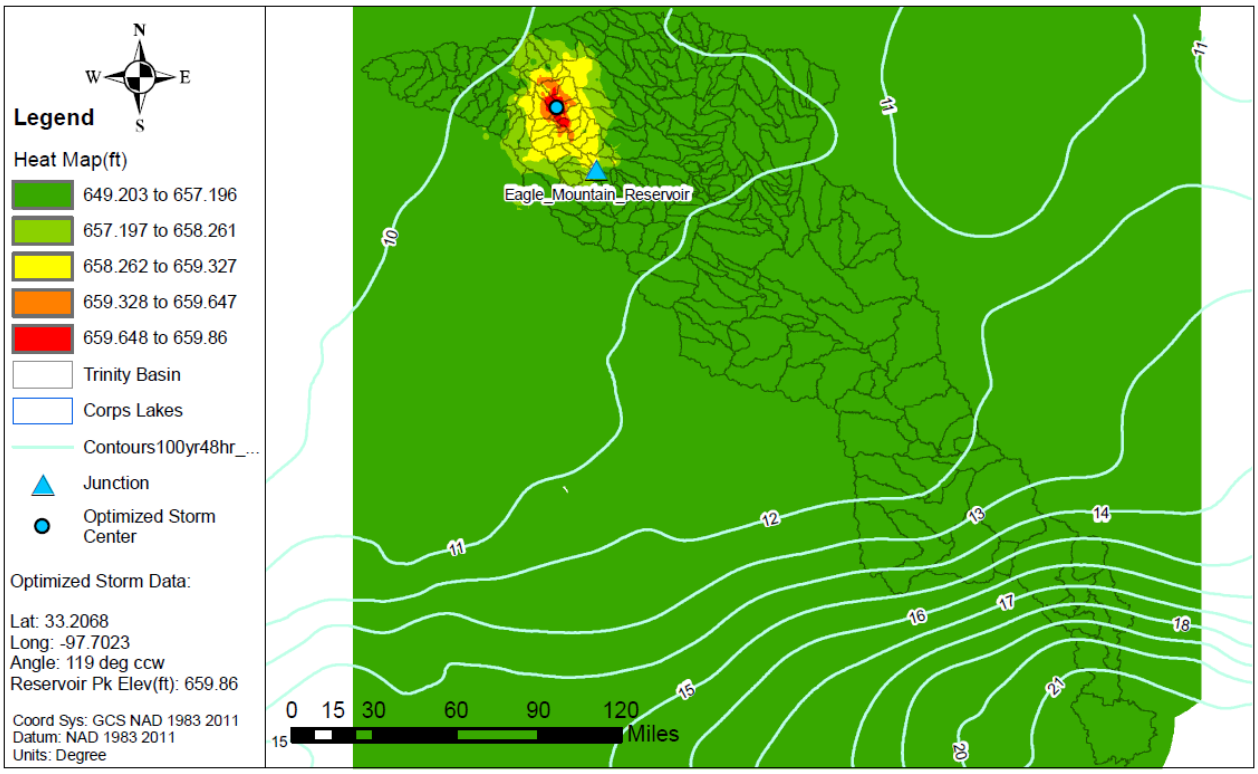


Figure 28a: Elliptical Storm Heat Map for the Eagle Mountain Reservoir

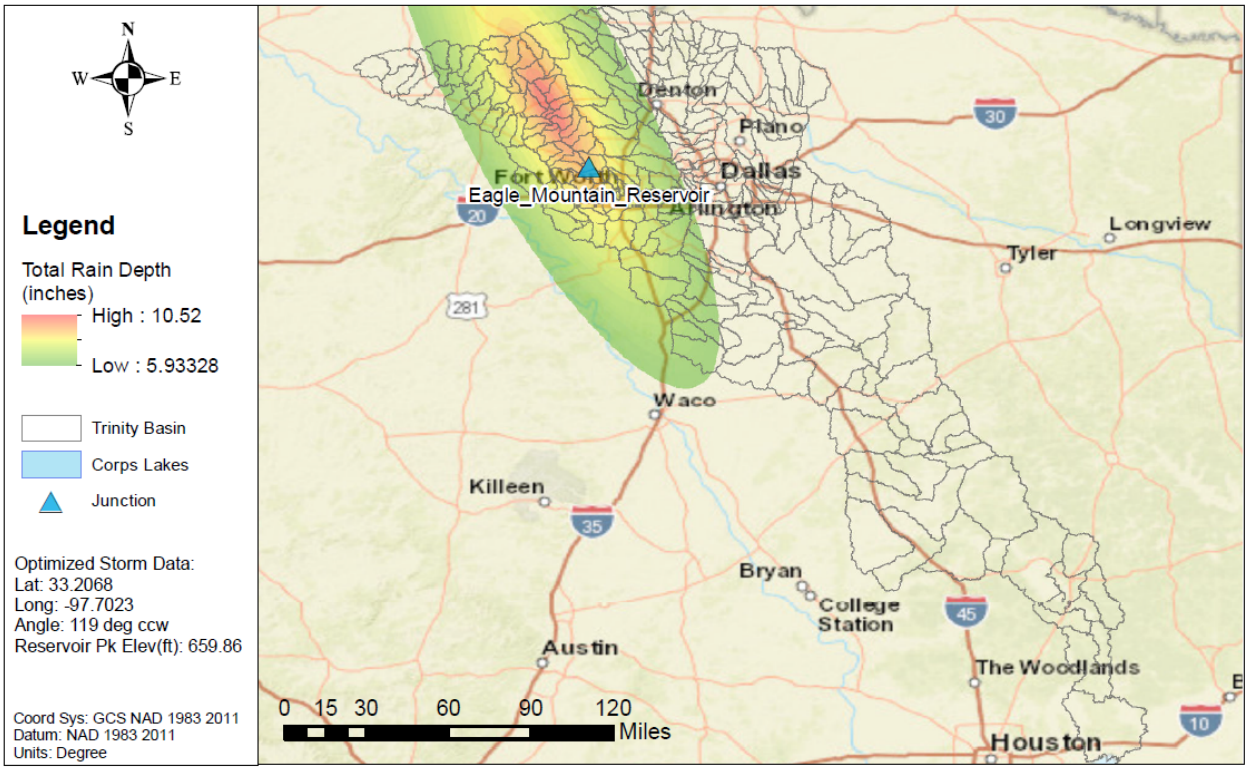


Figure 28b: NA14 1% AEP Elliptical Storm for the Eagle Mountain Reservoir

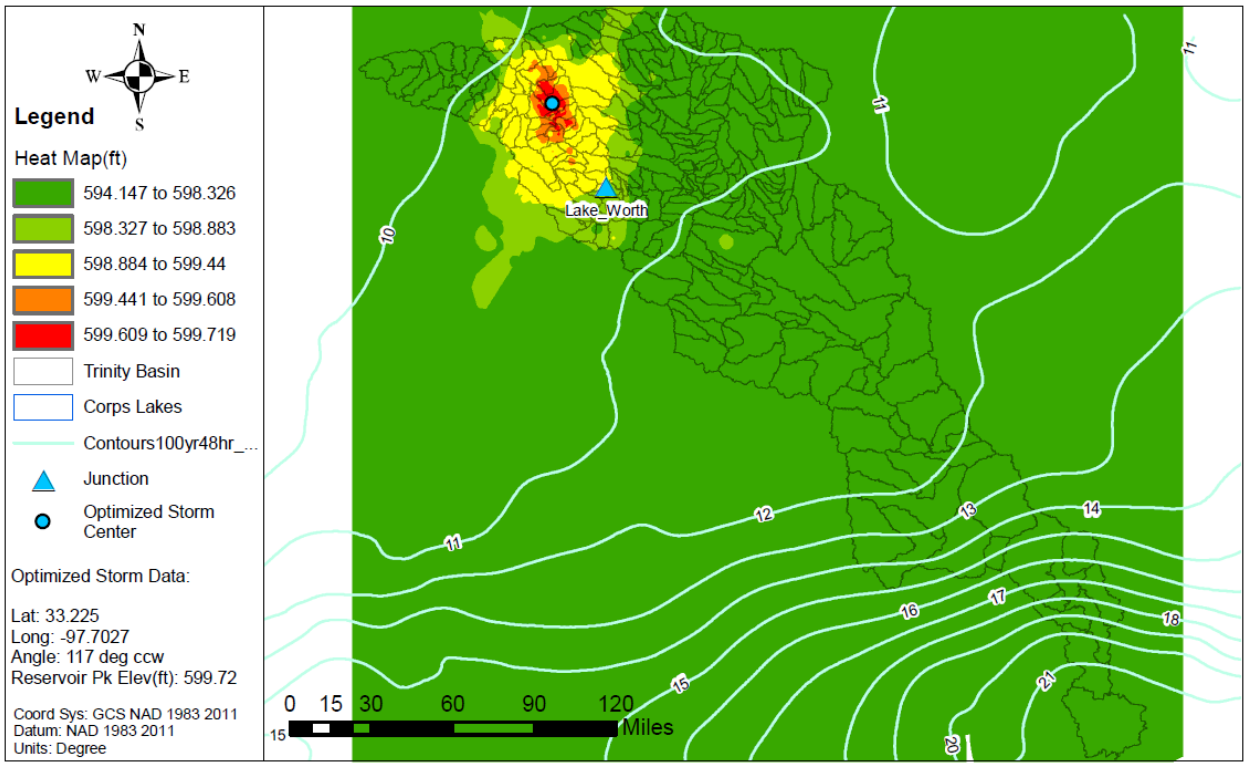


Figure 29a: Elliptical Storm Heat Map for the Lake Worth

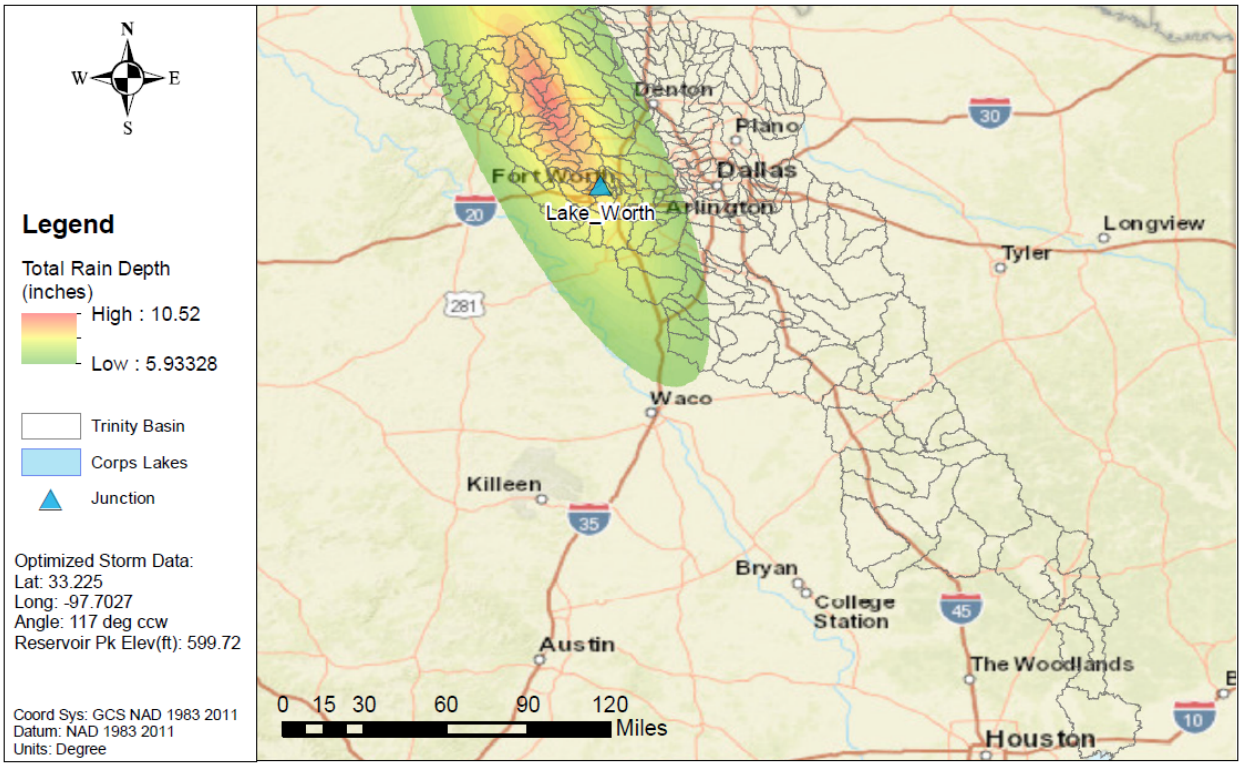


Figure 29b: NA14 1% AEP Elliptical Storm for the Lake Worth

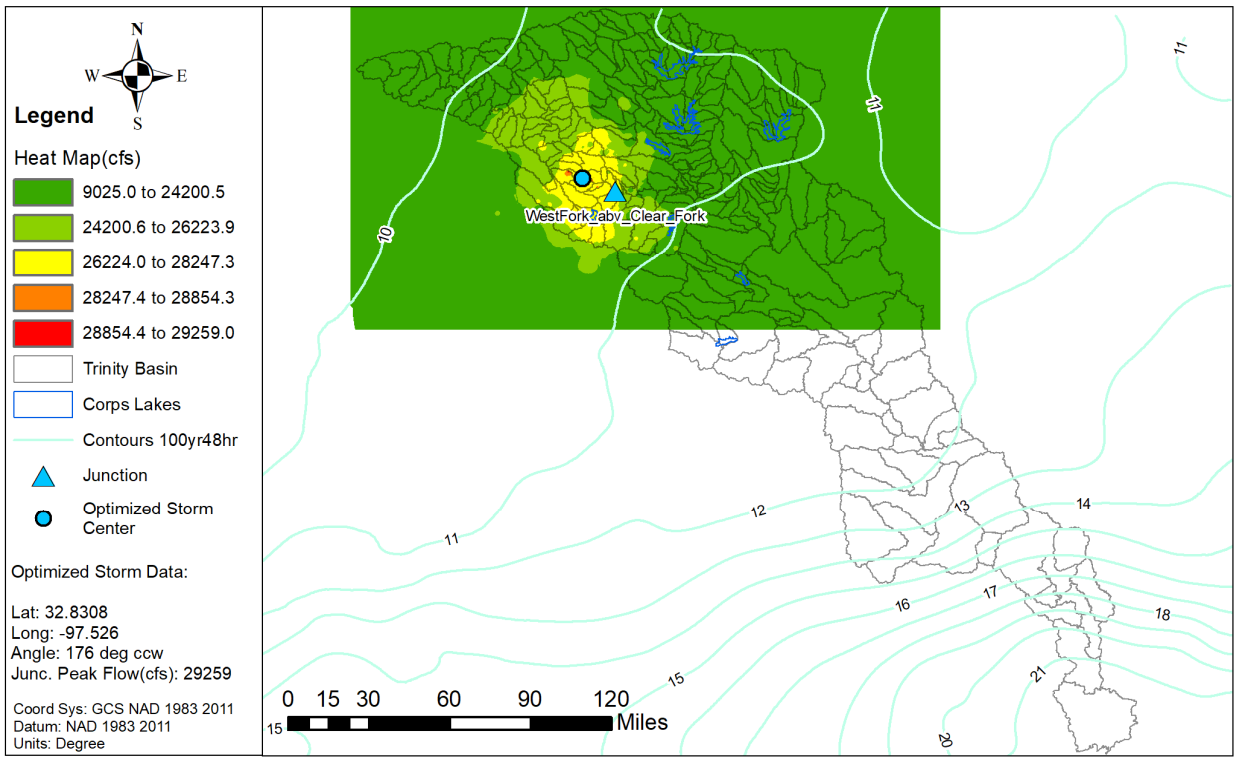


Figure 30a: Elliptical Storm Heat Map for the West Fork Trinity River above the Clear Fork

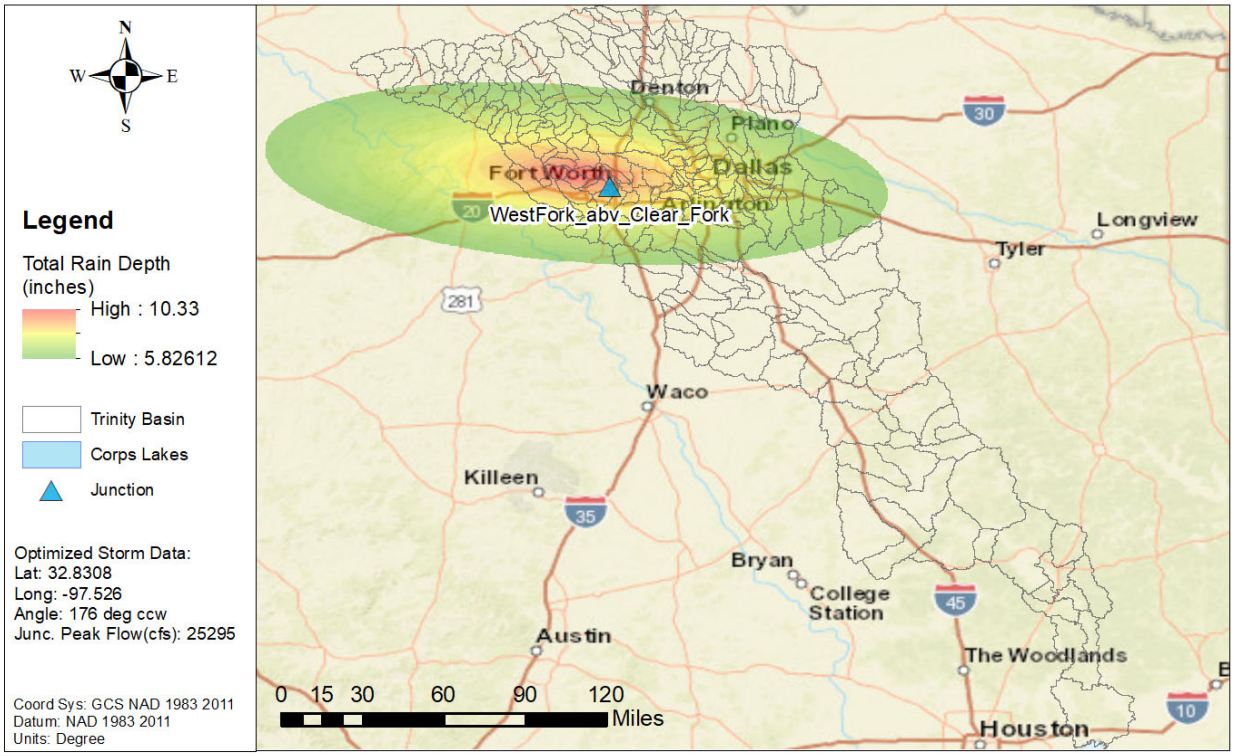


Figure 30b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River above the Clear Fork

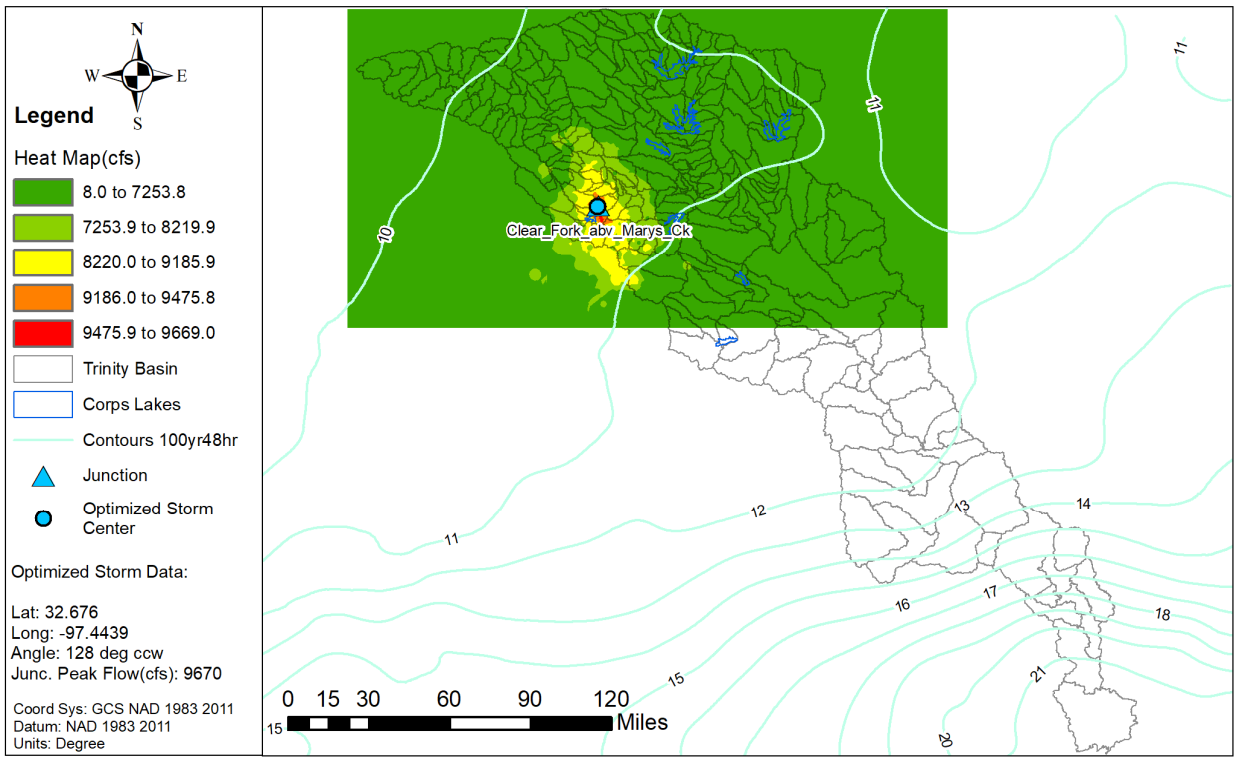


Figure 31a: Elliptical Storm Heat Map for the Clear Fork above Marys Creek

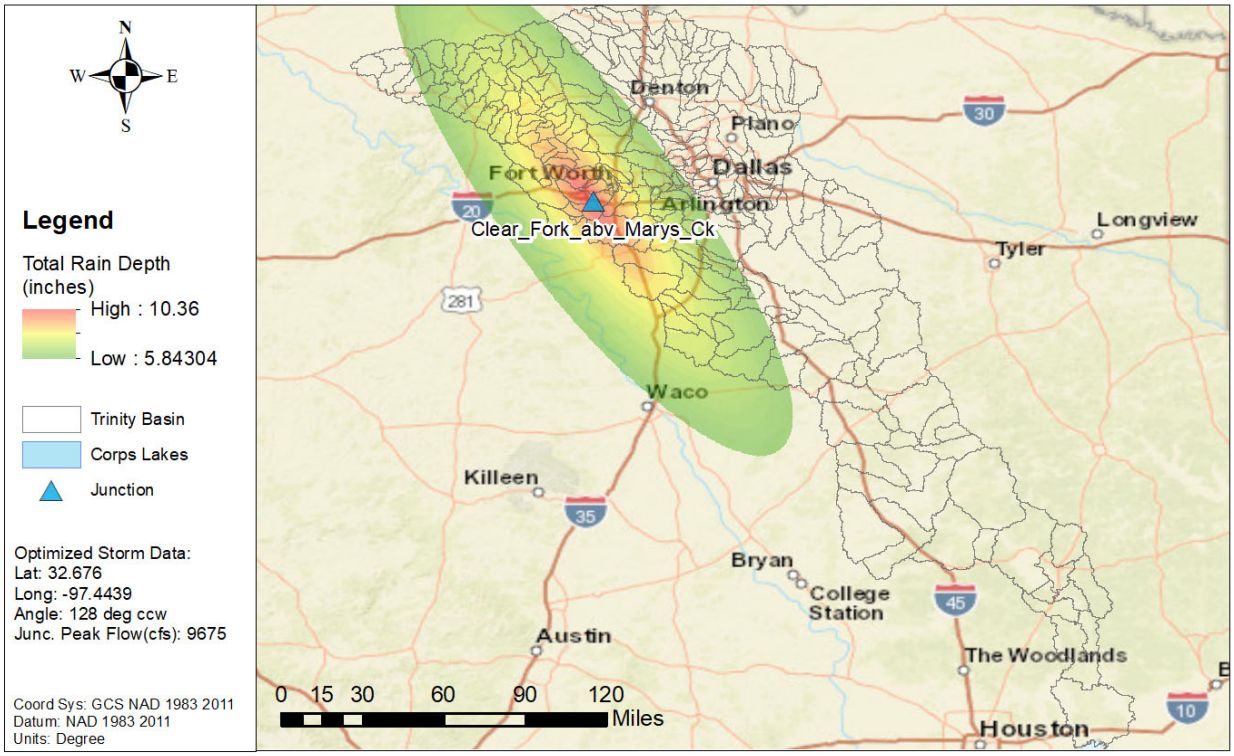


Figure 31b: NA14 1% AEP Elliptical Storm for the Clear Fork above Marys Creek

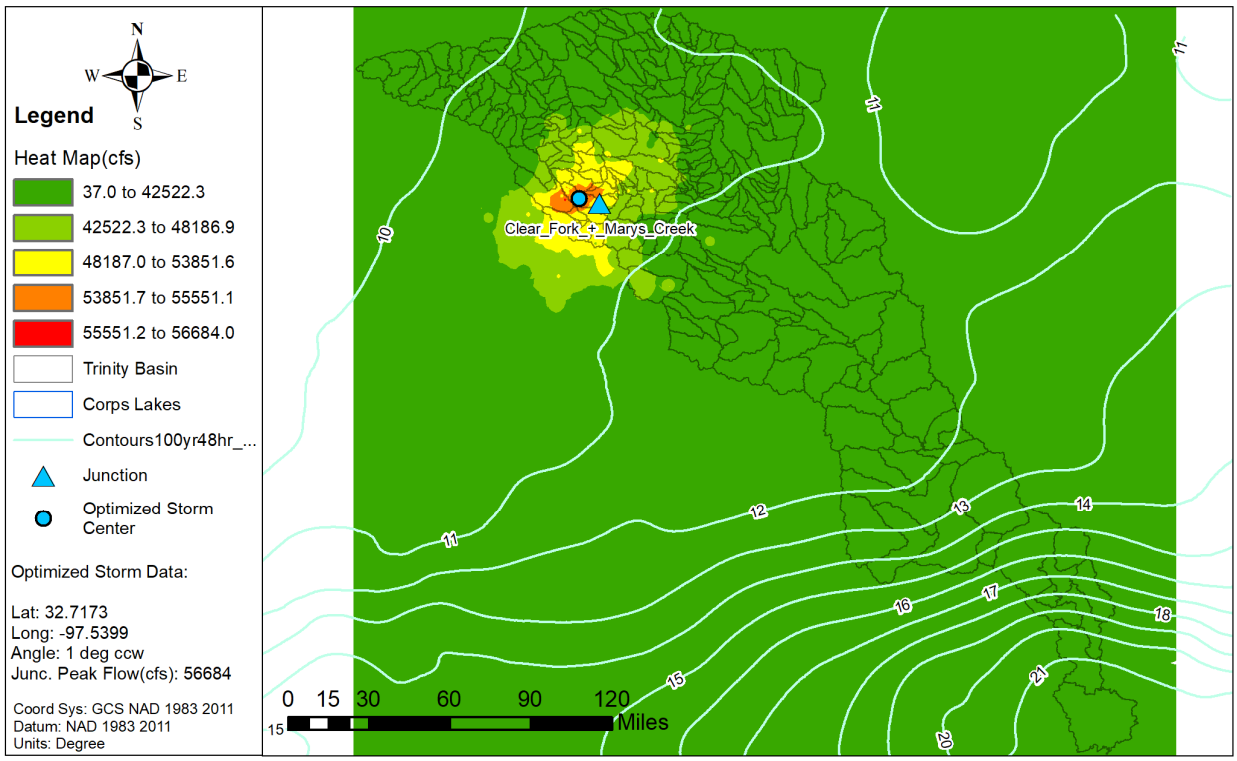


Figure 32a: Elliptical Storm Heat Map for the Clear Fork below Marys Creek

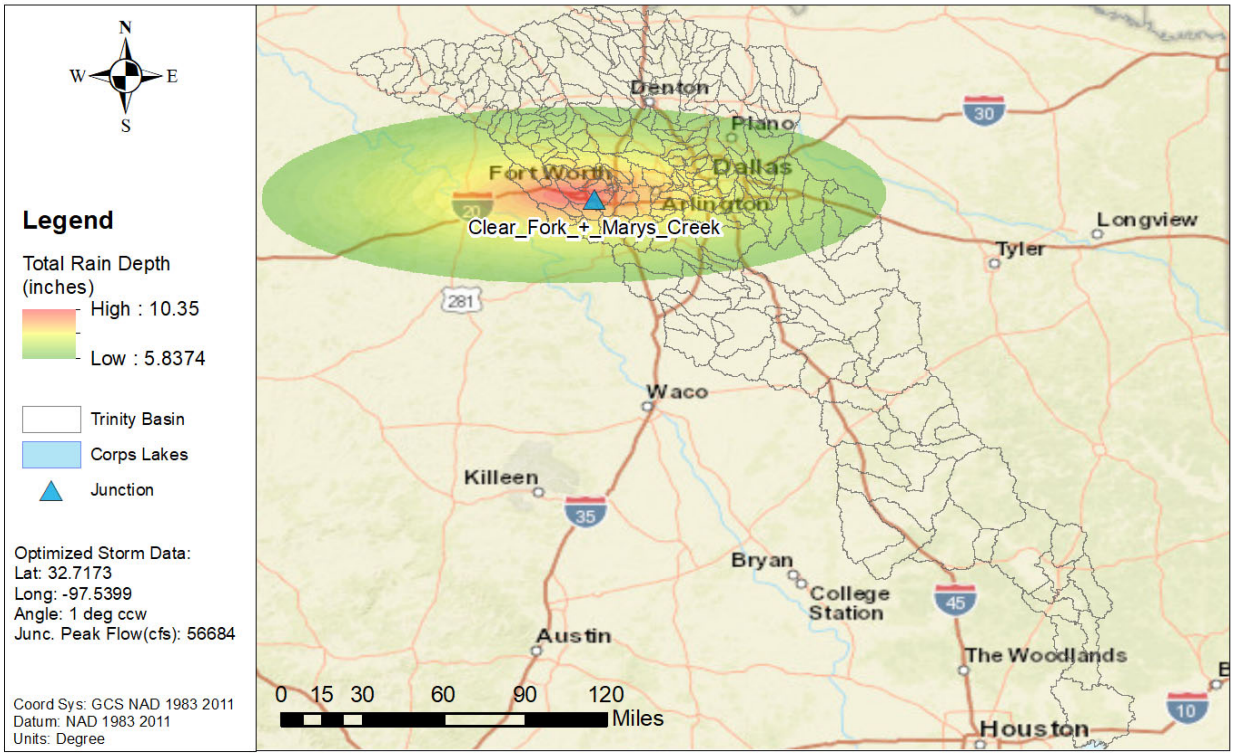


Figure 32b: NA14 1% AEP Elliptical Storm for the Clear Fork below Marys Creek

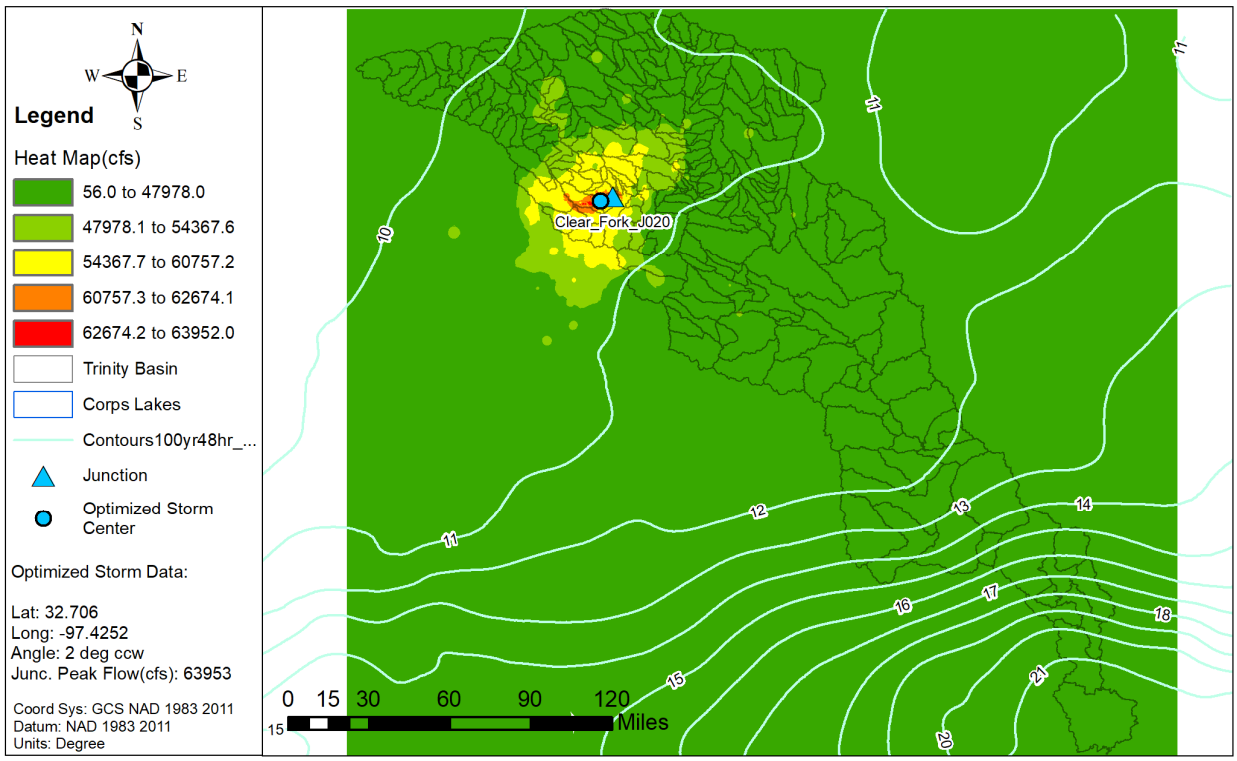


Figure 33a: Elliptical Storm Heat Map for the Clear Fork Trinity River at Fort Worth USGS gage

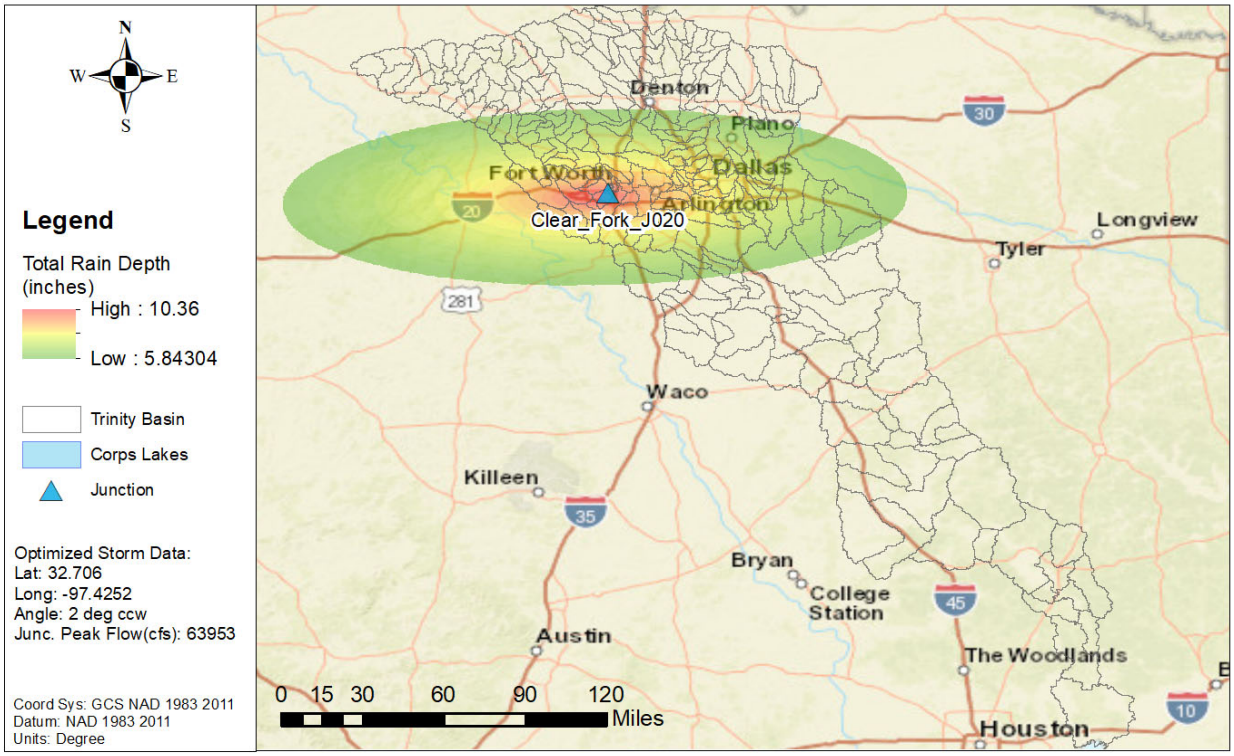


Figure 33b: NA14 1% AEP Elliptical Storm for the Clear Fork Trinity River at Fort Worth USGS gage

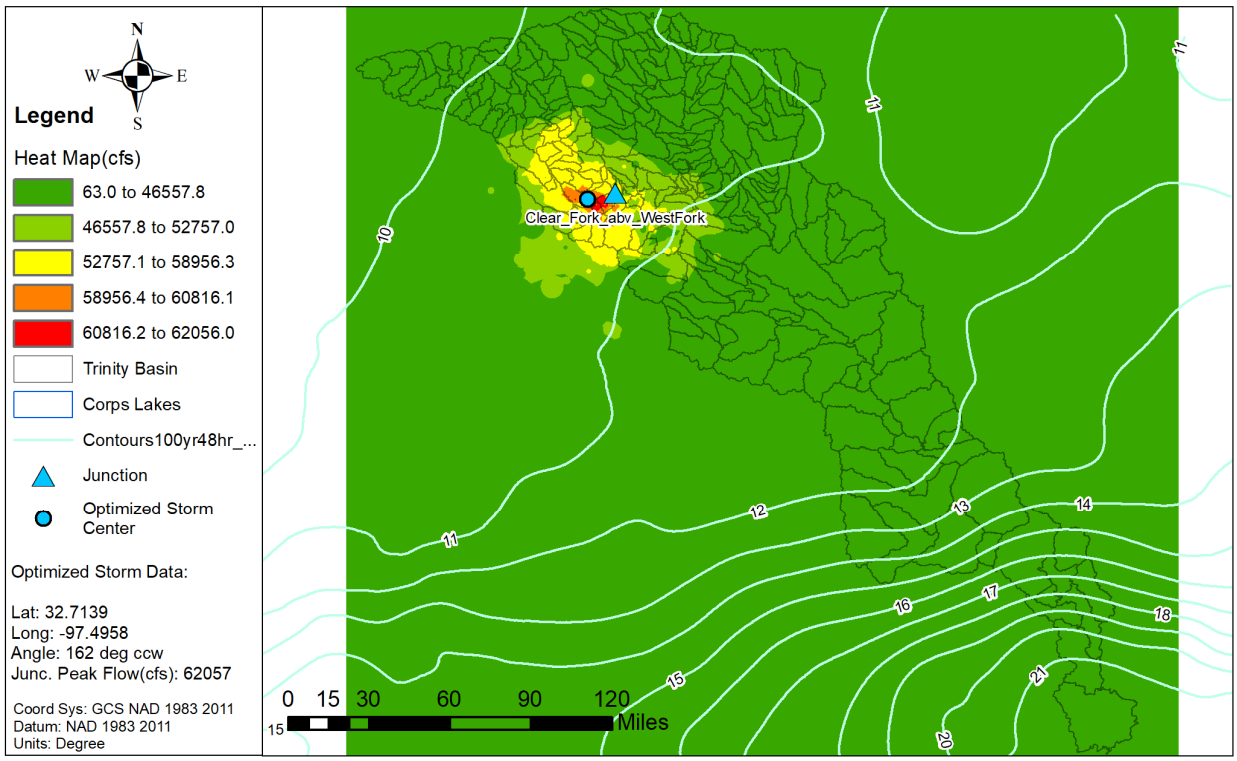


Figure 34a: Elliptical Storm Heat Map for the Clear Fork Trinity River above the West Fork

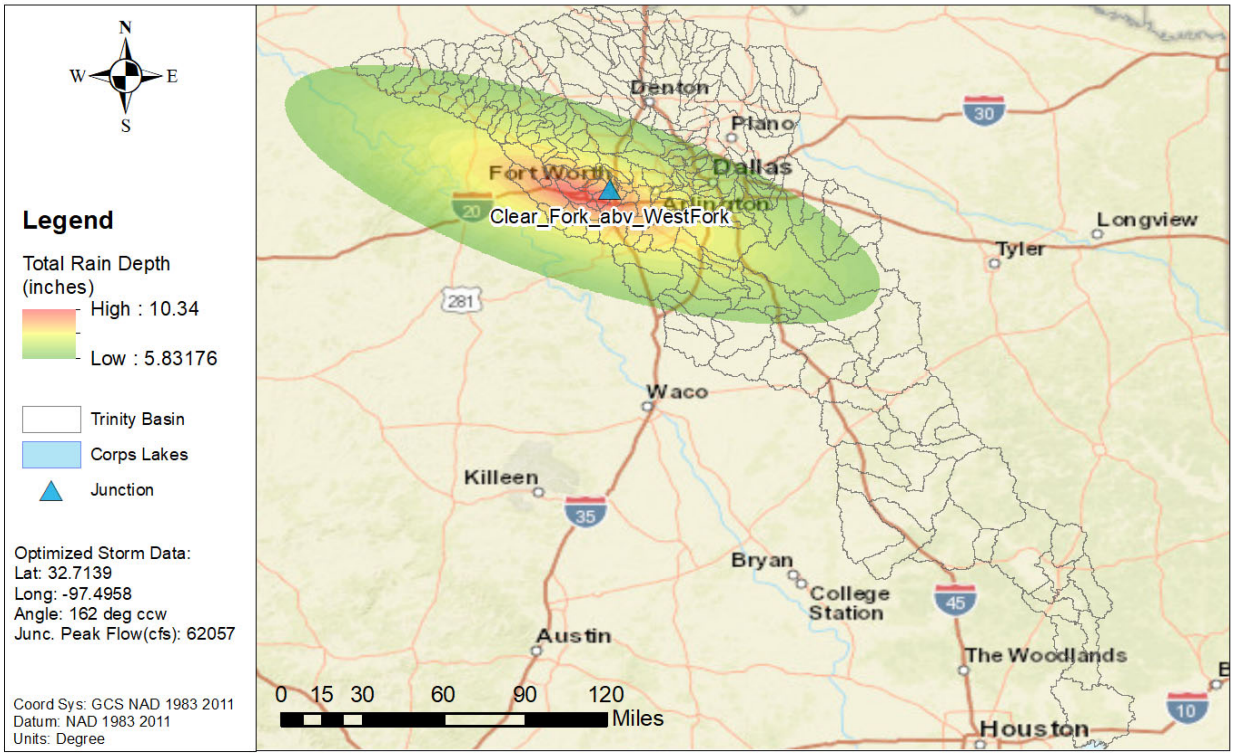


Figure 34b: NA14 1% AEP Elliptical Storm for the Clear Fork Trinity River above the West Fork

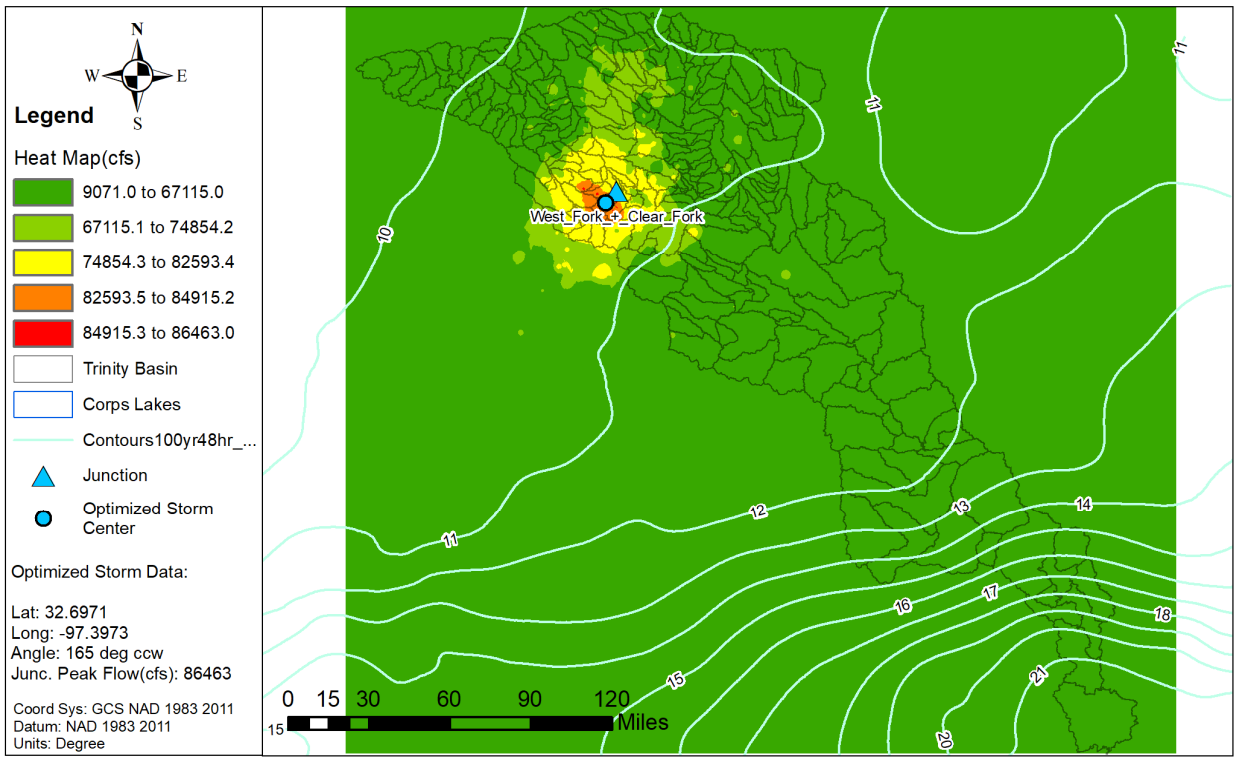


Figure 35a: Elliptical Storm Heat Map for the West Fork Trinity River below the Clear Fork

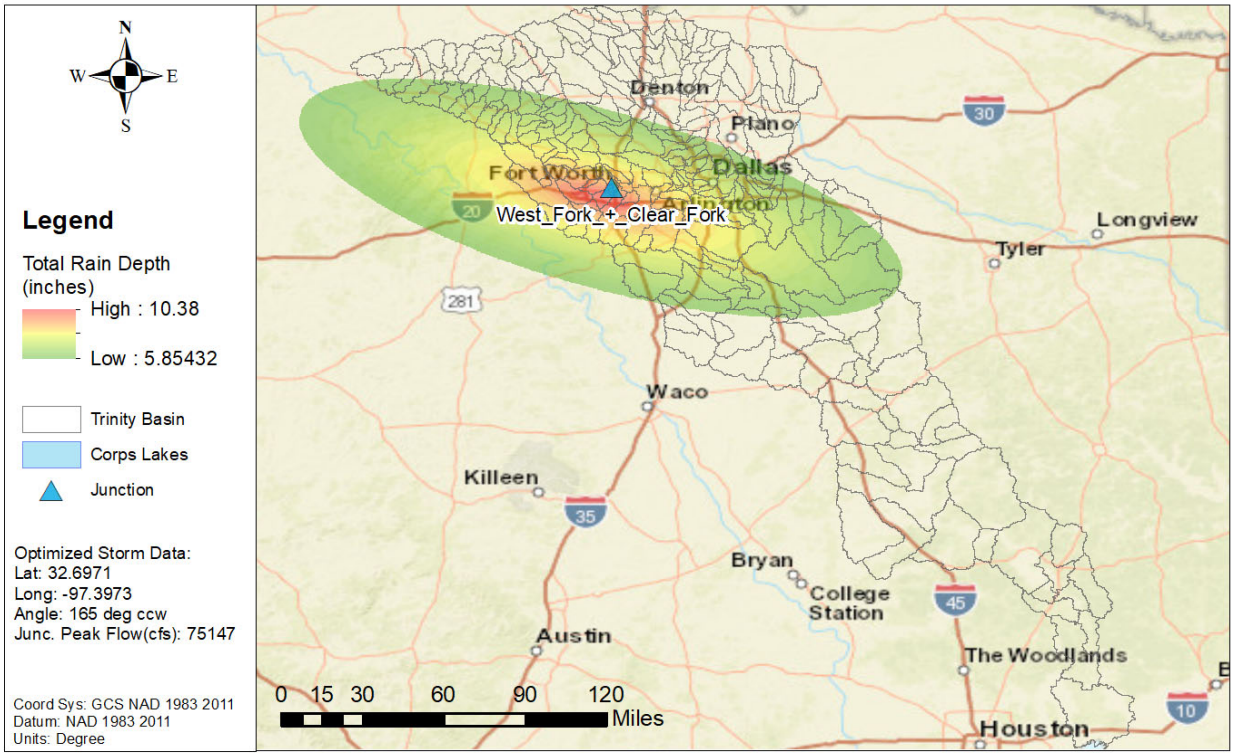


Figure 35b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below the Clear Fork

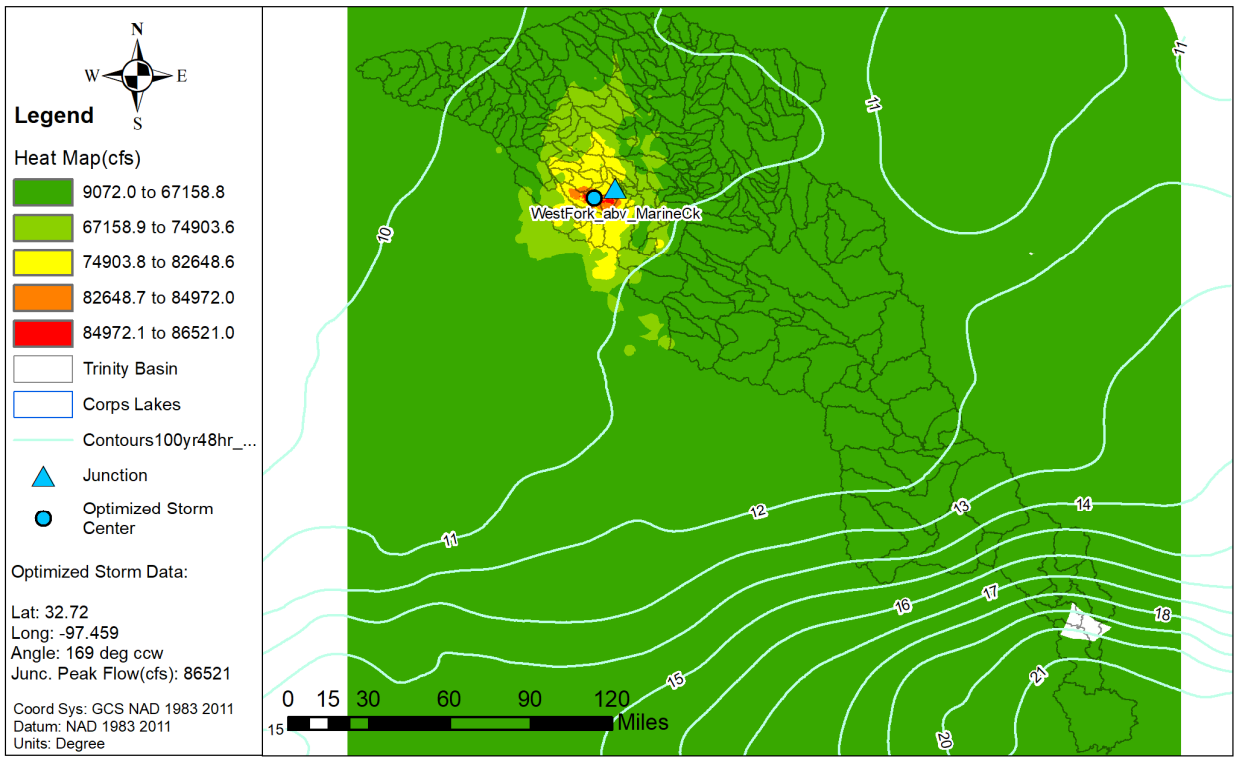


Figure 36a: Elliptical Storm Heat Map for the West Fork Trinity River above Marine Creek

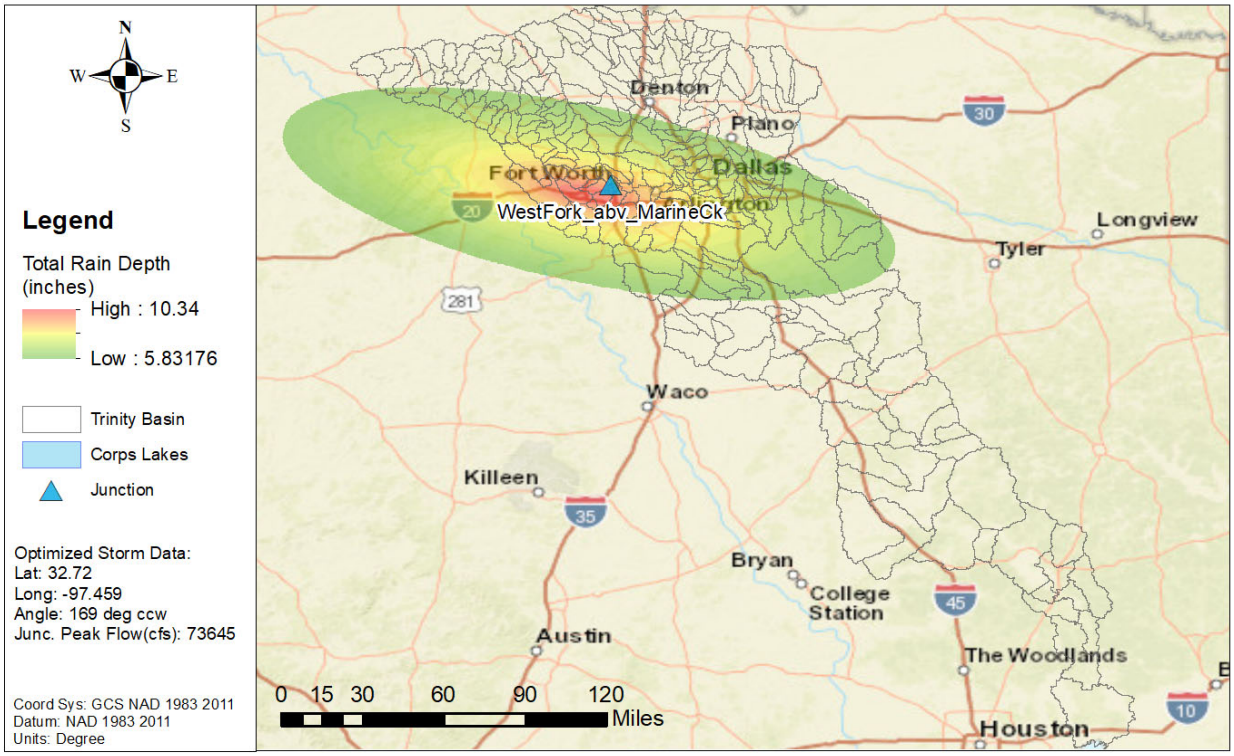


Figure 36b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River above Marine Creek

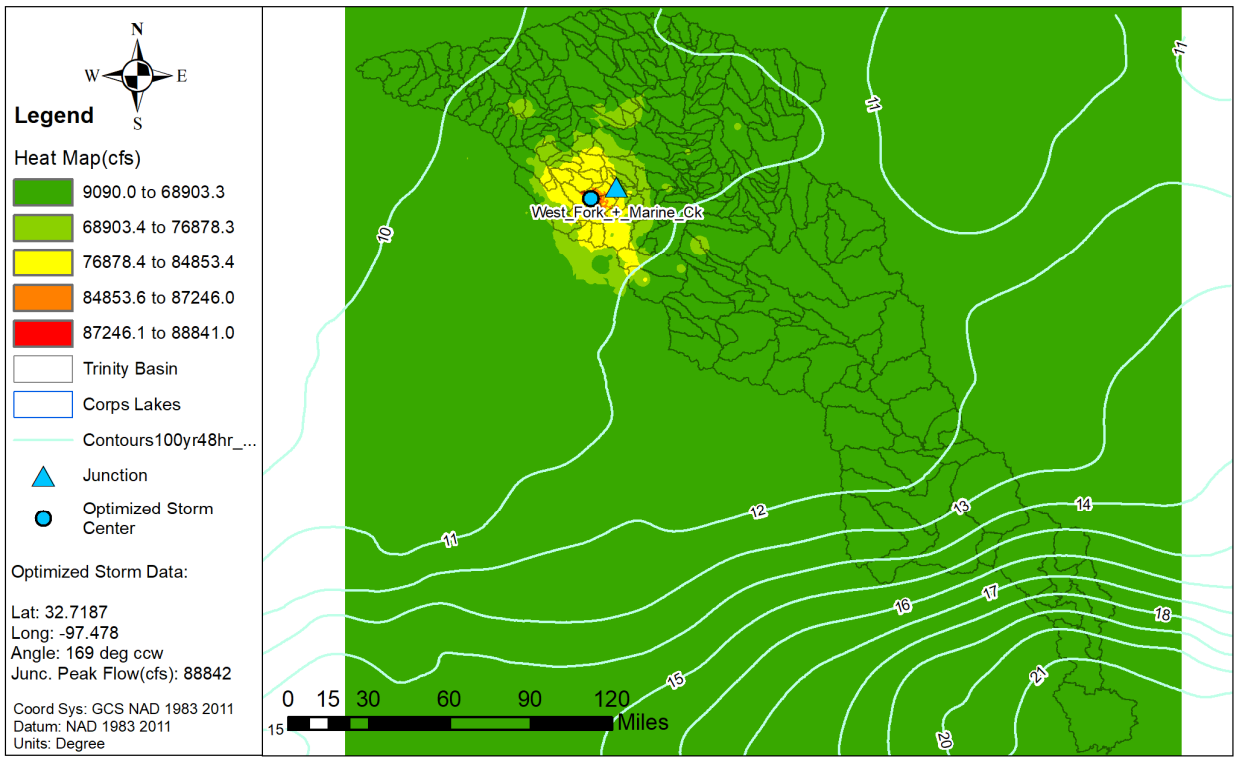


Figure 37a: Elliptical Storm Heat Map for the West Fork Trinity River below Marine Creek

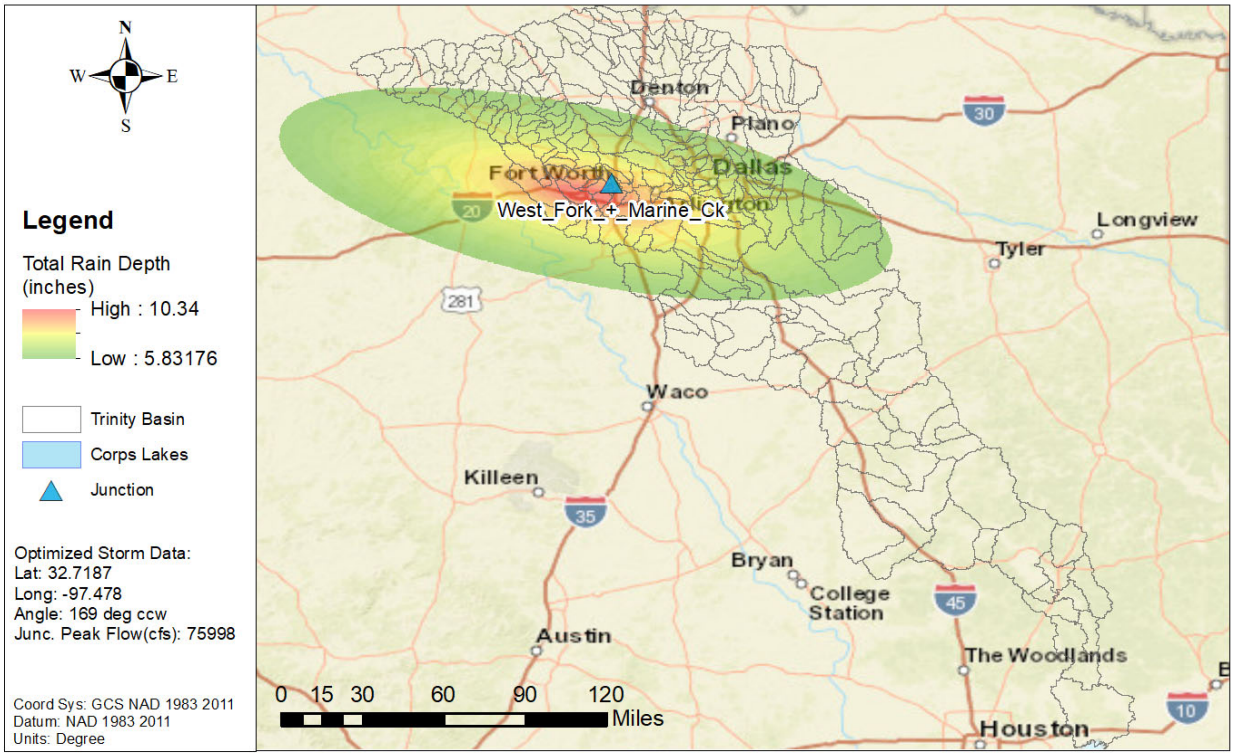


Figure 37b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below Marine Creek

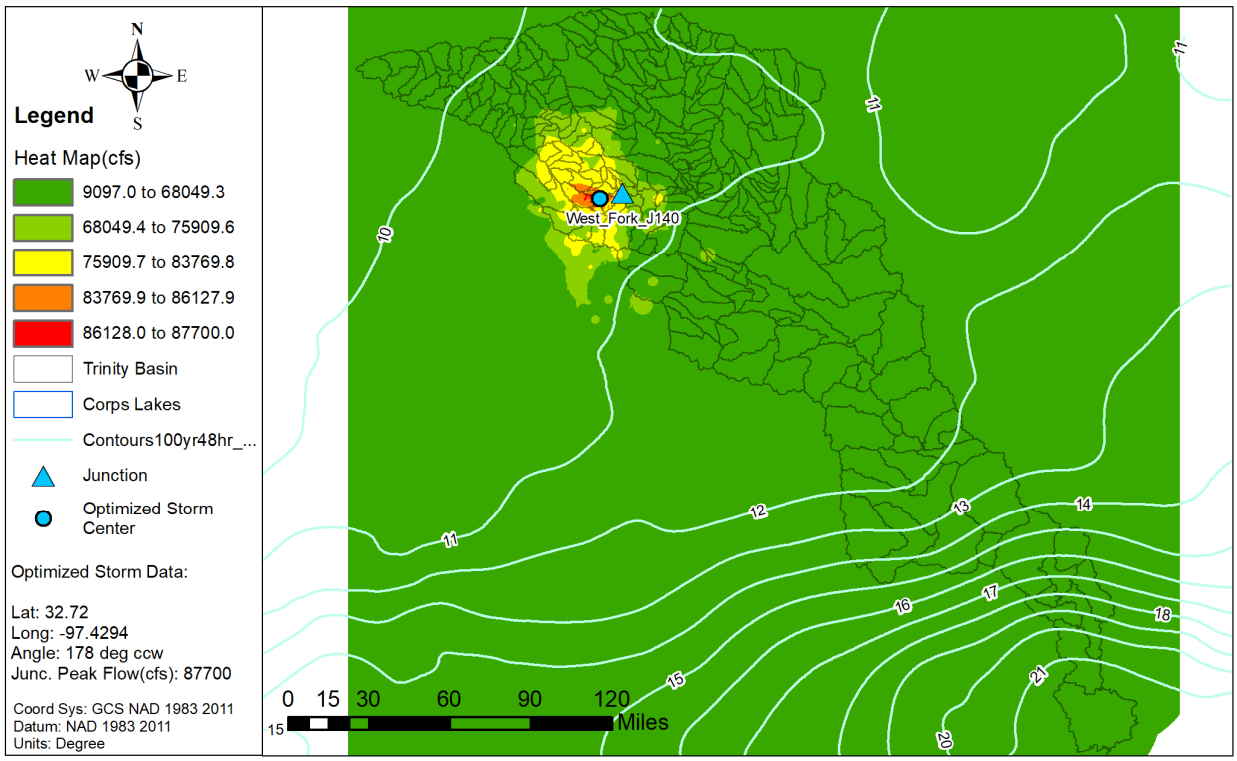


Figure 38a: Elliptical Storm Heat Map for the West Fork Trinity River above Sycamore Creek

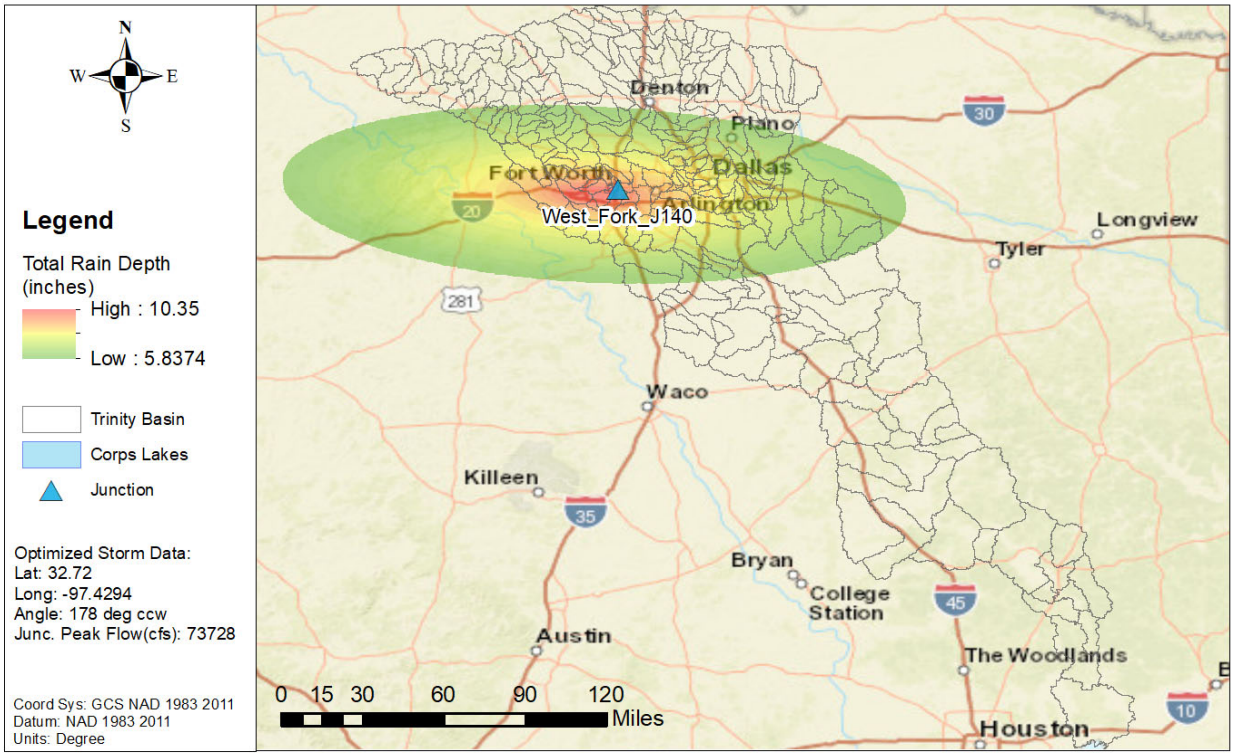


Figure 38b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River above Sycamore Creek

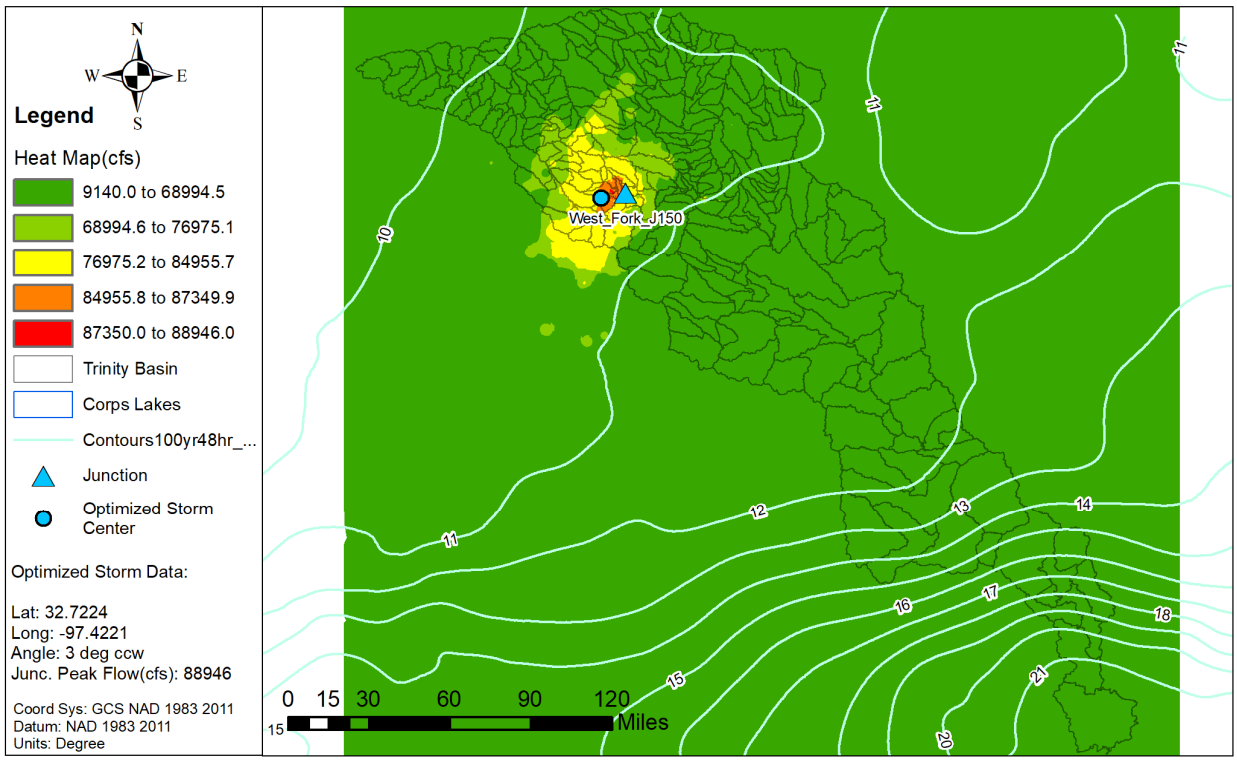


Figure 39a: Elliptical Storm Heat Map for the West Fork Trinity River below Sycamore Creek

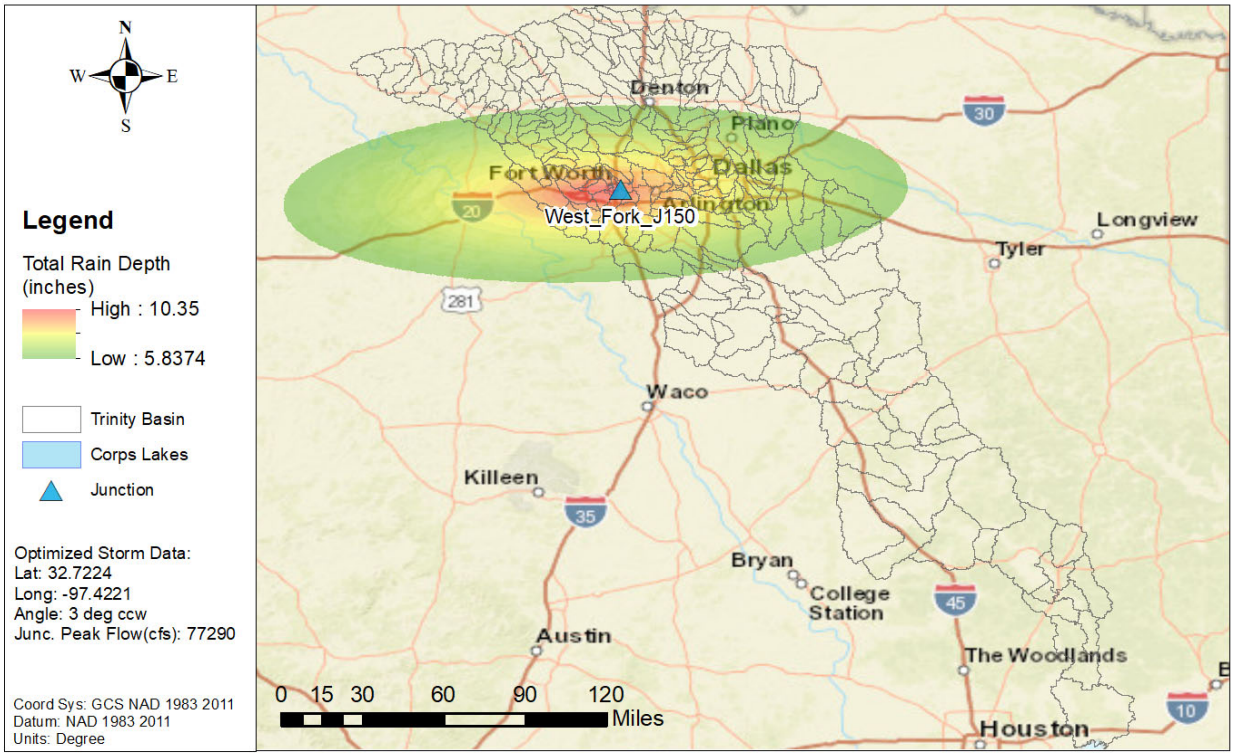


Figure 39b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below Sycamore Creek

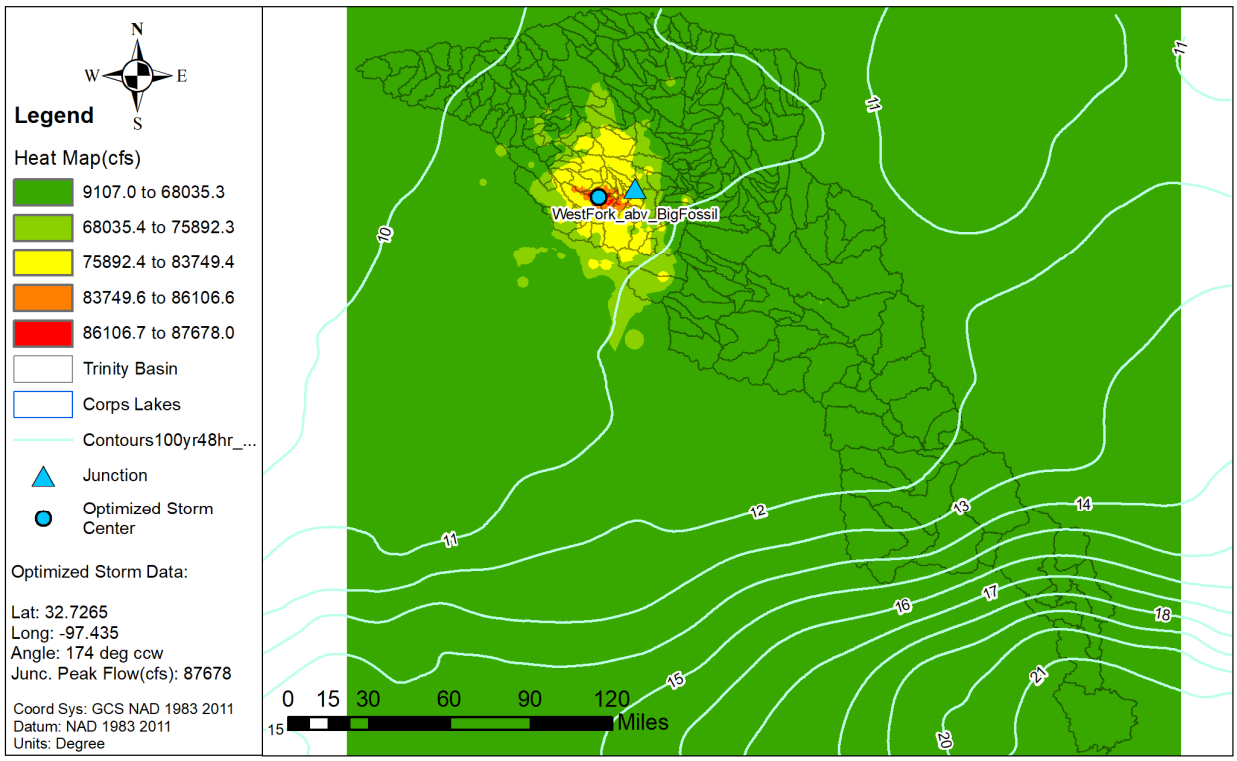


Figure 40a: Elliptical Storm Heat Map for the West Fork above Big Fossil

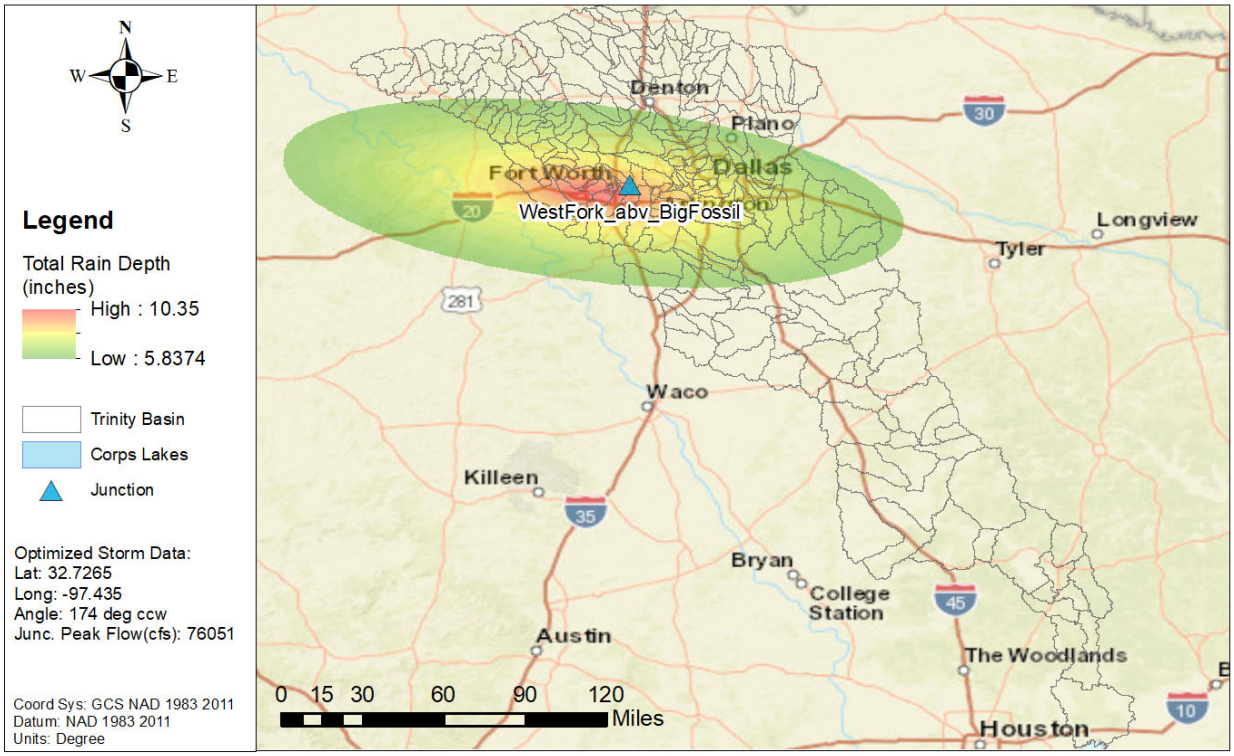


Figure 40b: NA14 1% AEP Elliptical Storm for the West Fork above Big Fossil

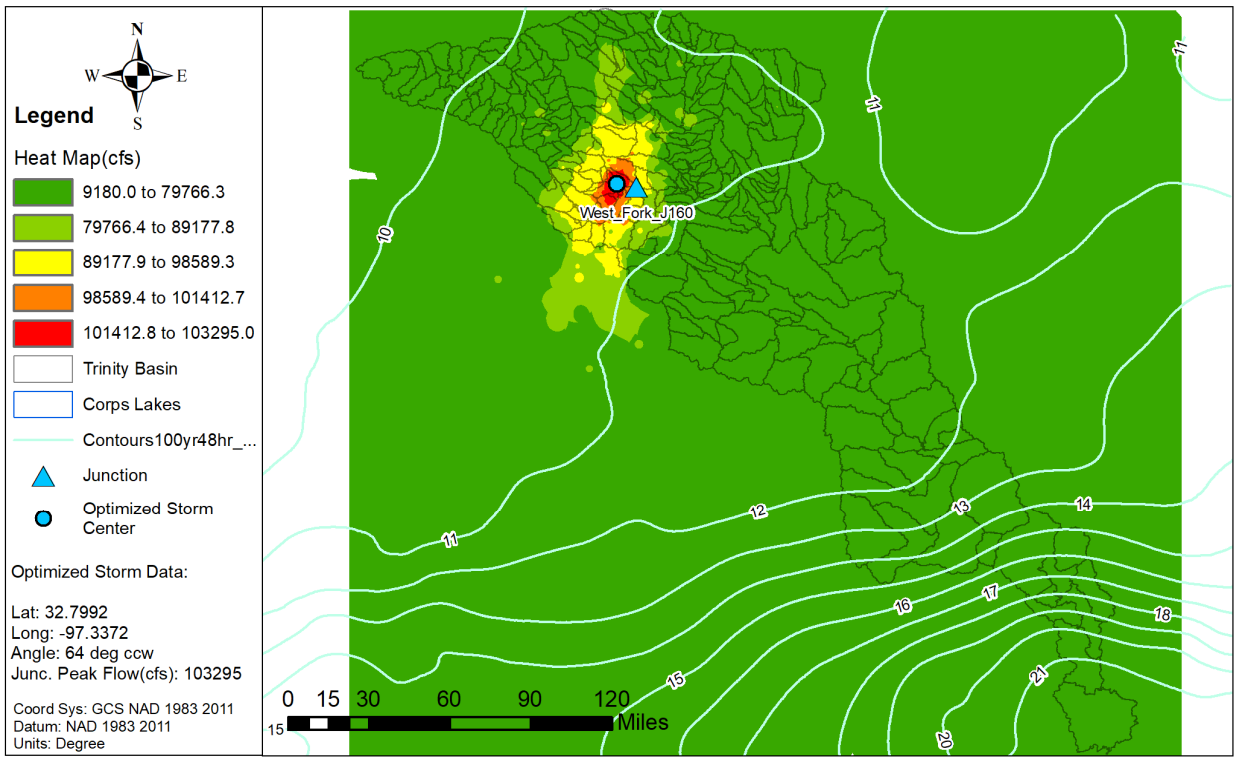


Figure 41a: Elliptical Storm Heat Map for the West Fork Trinity River and Big Fossil Creek Confluence

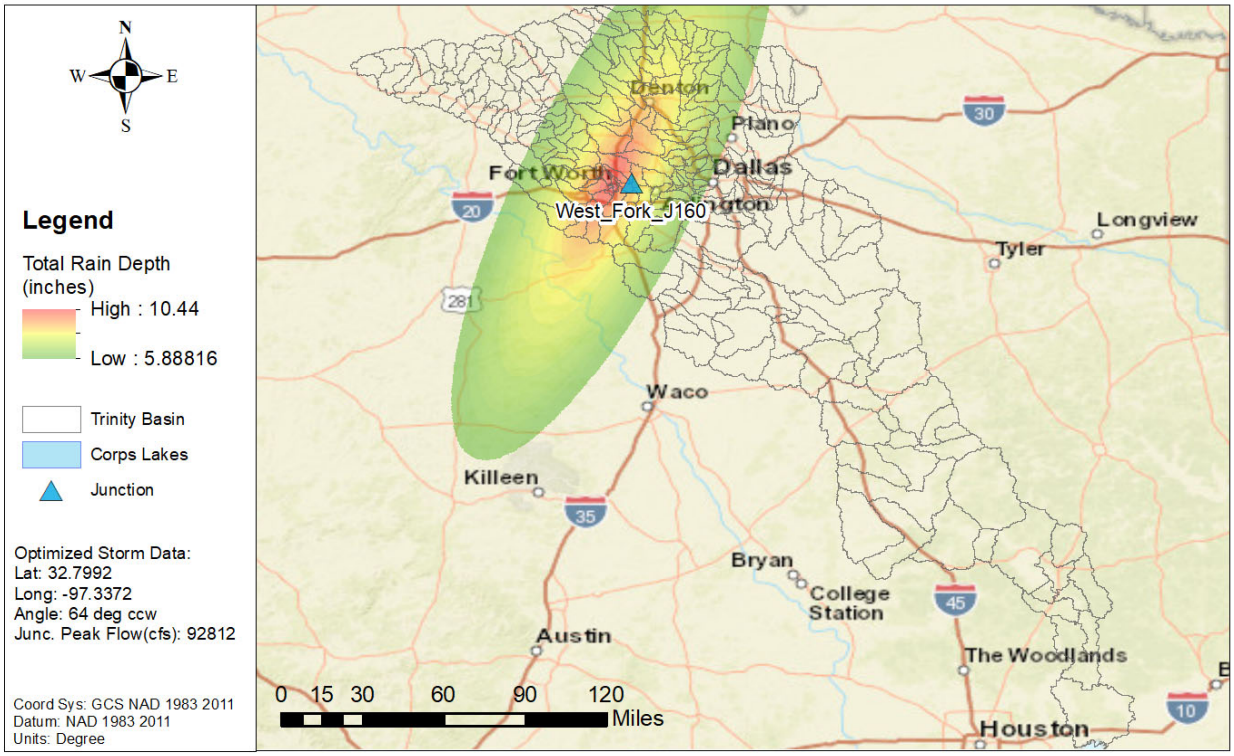


Figure 41b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River and Big Fossil Creek Confluence

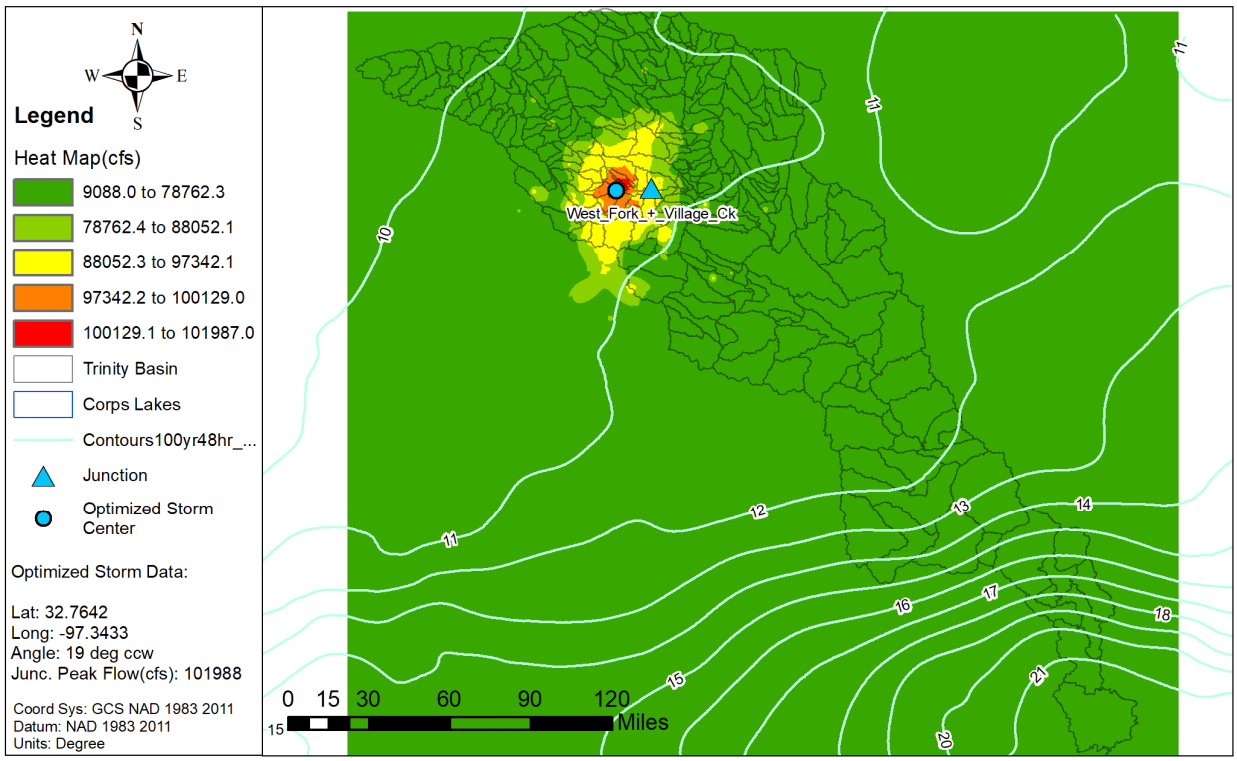


Figure 42a: Elliptical Storm Heat Map for the West Fork Trinity River below Village Creek

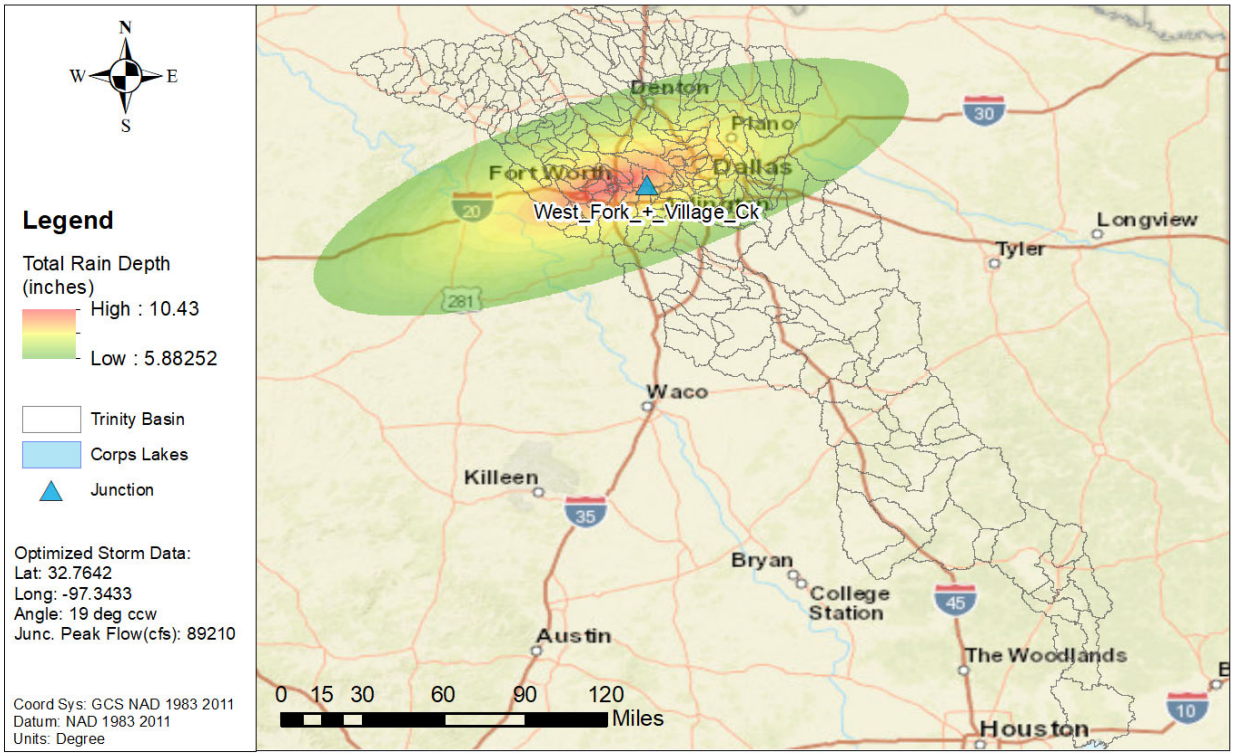


Figure 42b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below Village Creek

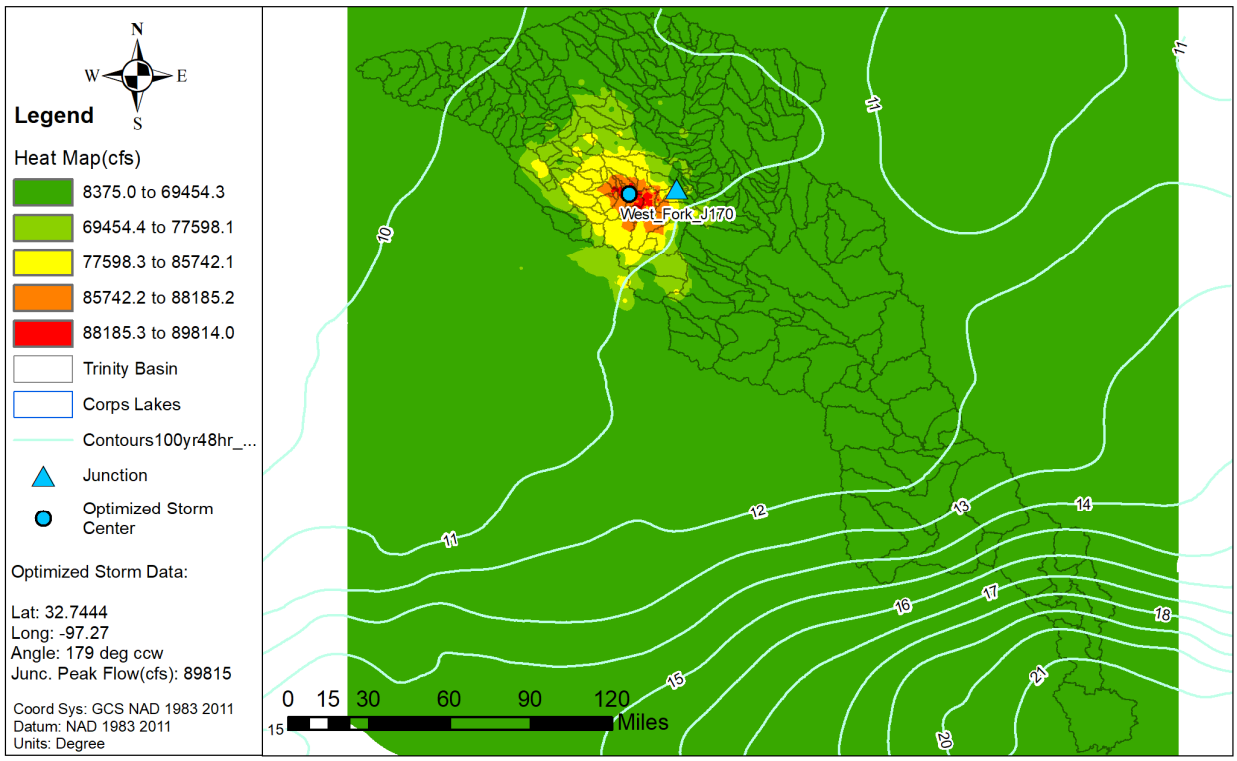


Figure 43a: Elliptical Storm Heat Map for the West Fork Trinity River below Johnson Creek

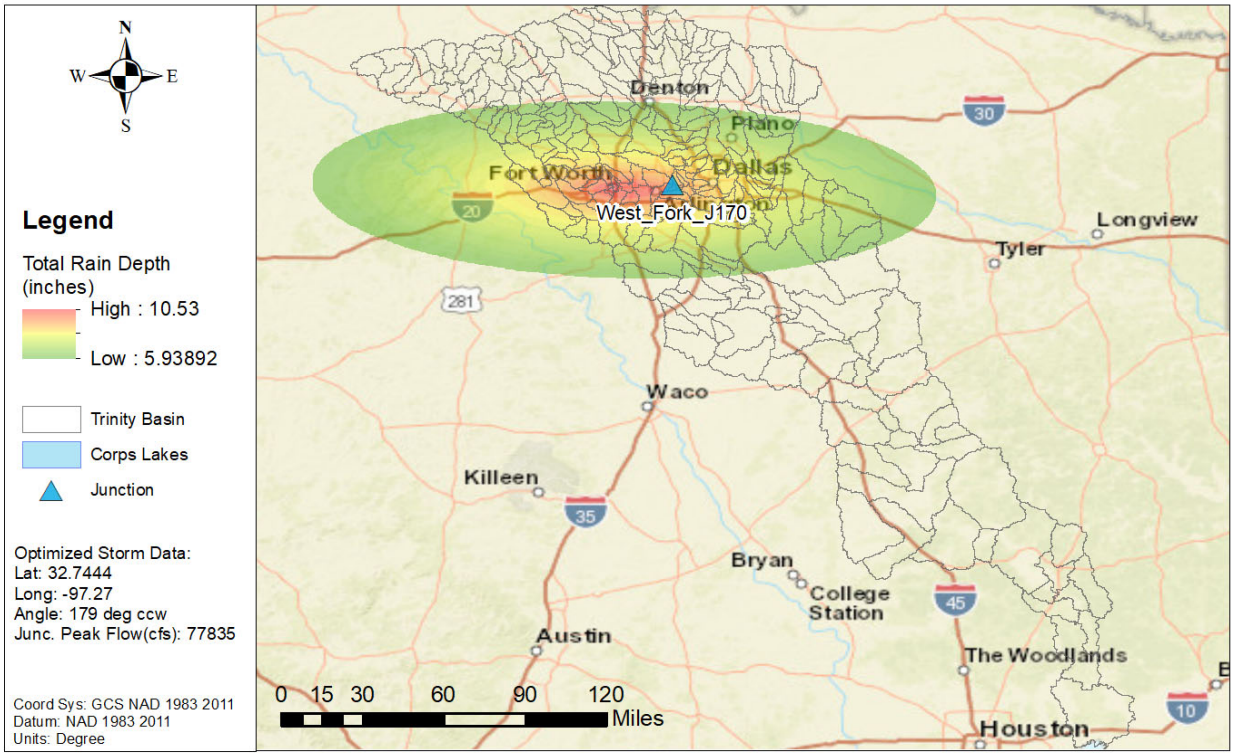


Figure 43b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below Johnson Creek

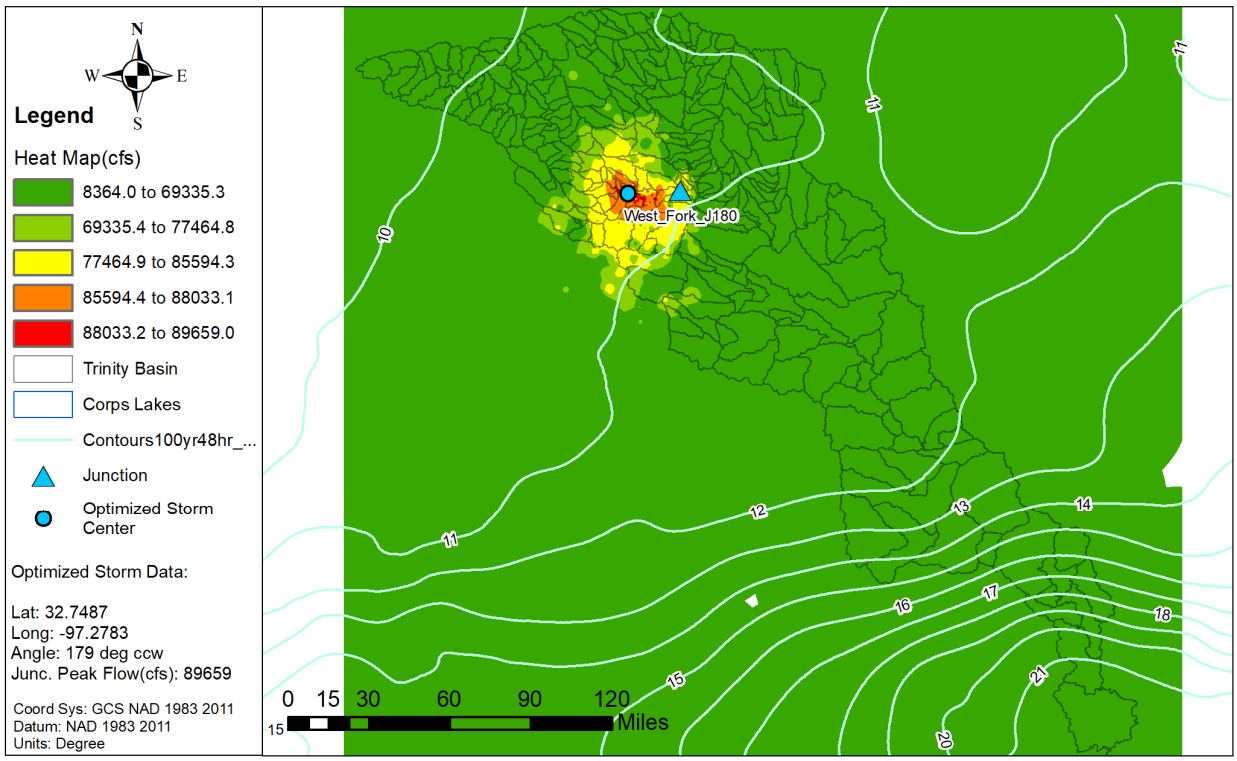


Figure 44a: Elliptical Storm Heat Map for the West Fork Trinity River at Grand Prairie USGS gage

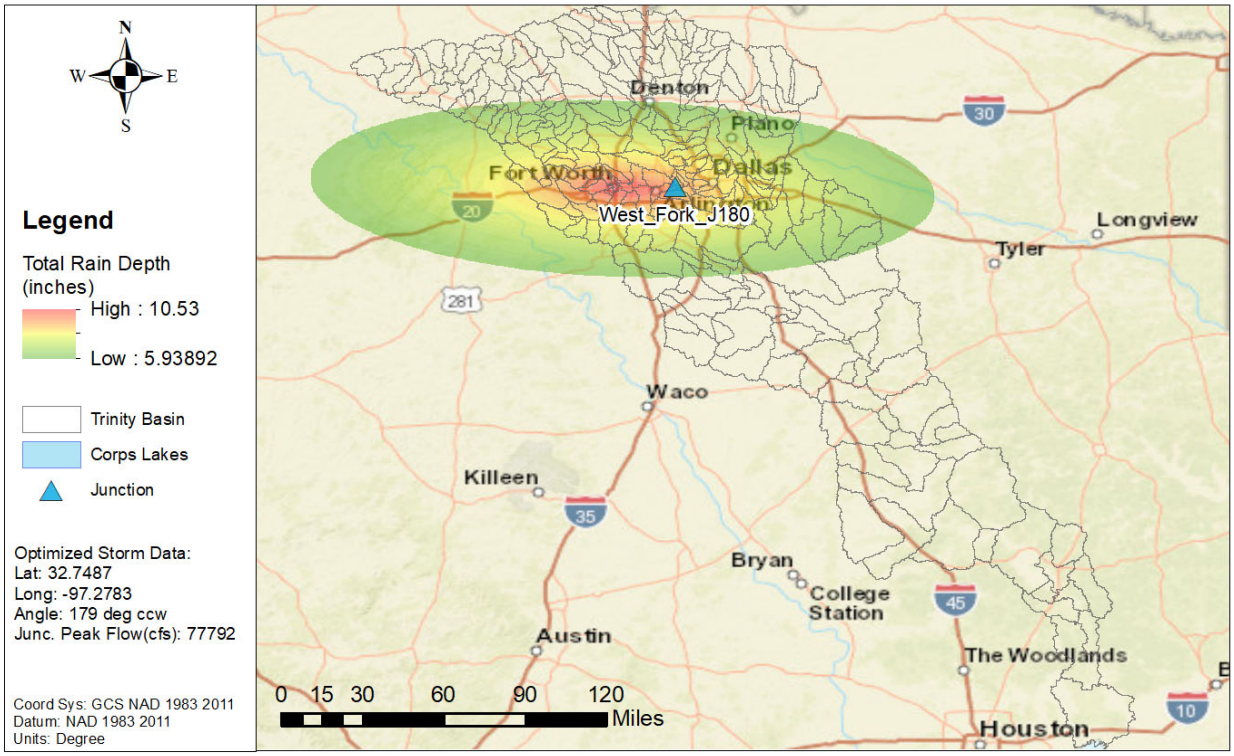


Figure 44b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River at Grand Prairie USGS gage

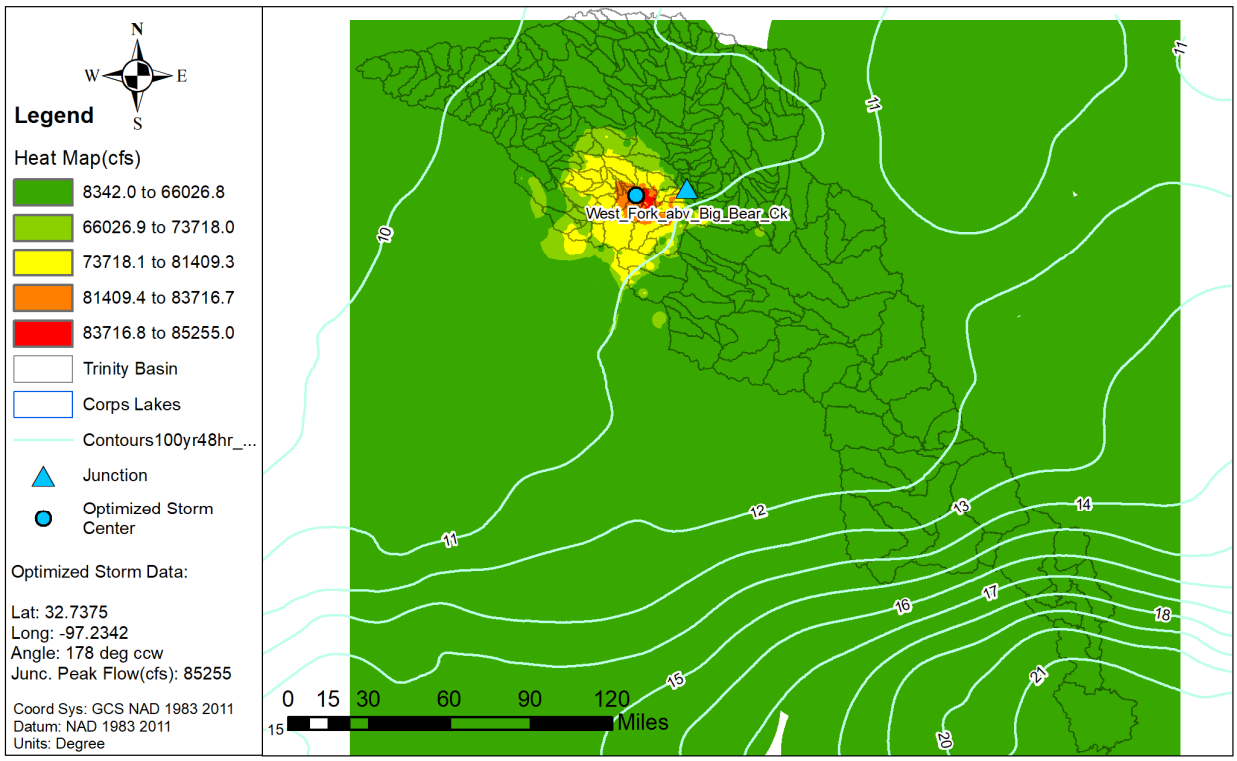


Figure 45a: Elliptical Storm Heat Map for the West Fork Trinity River above Big Bear Creek

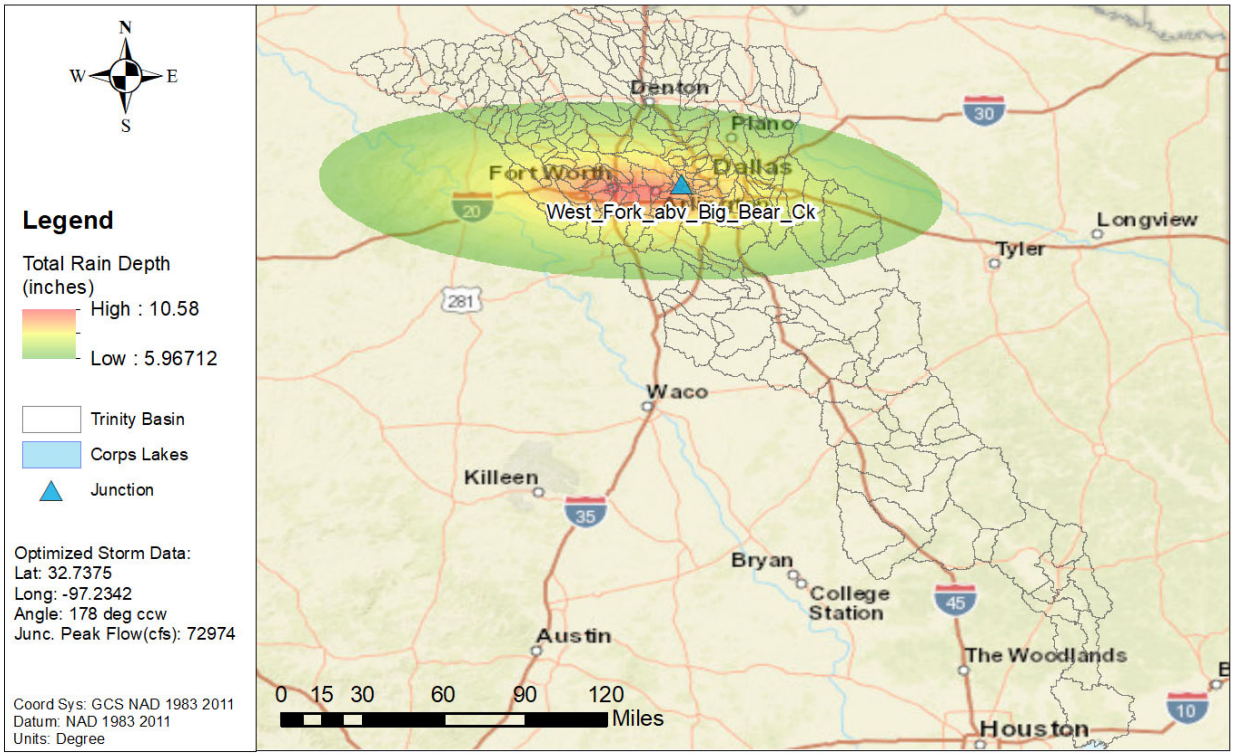


Figure 45b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River above Big Bear Creek

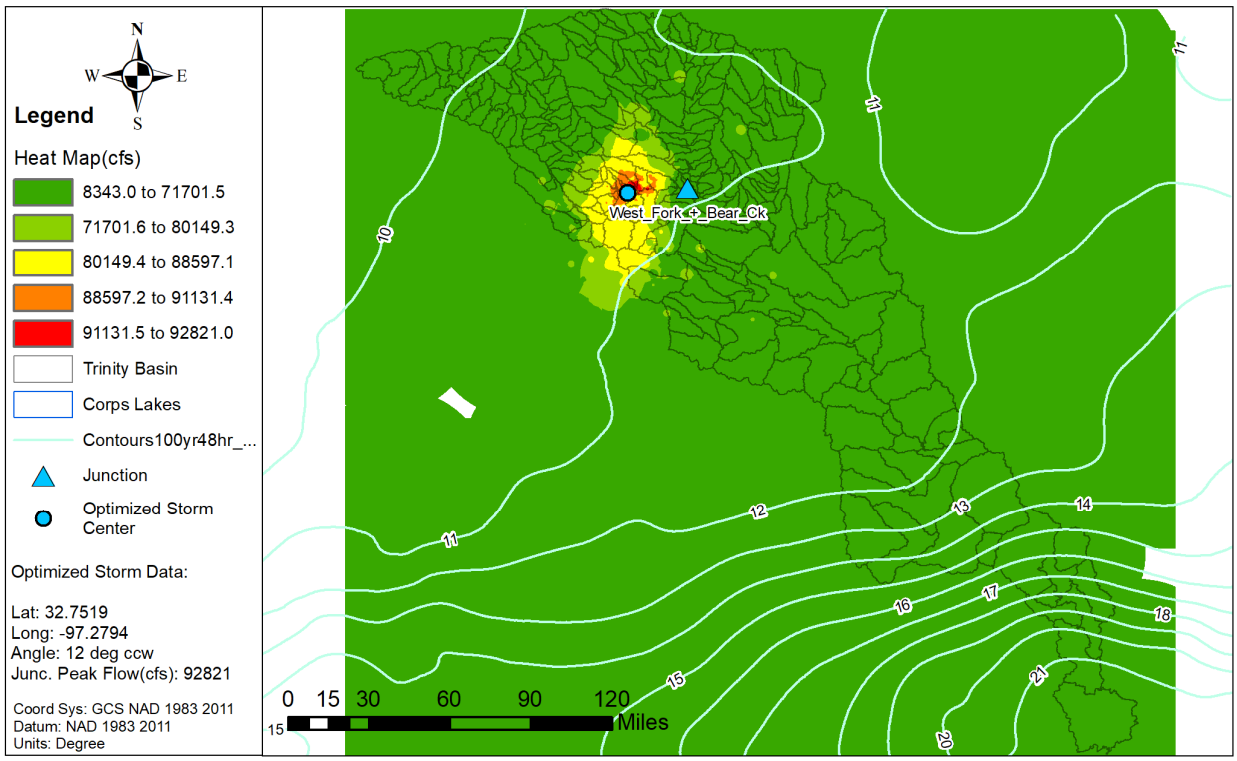


Figure 46a: Elliptical Storm Heat Map for the West Fork Trinity River below Big Bear Creek

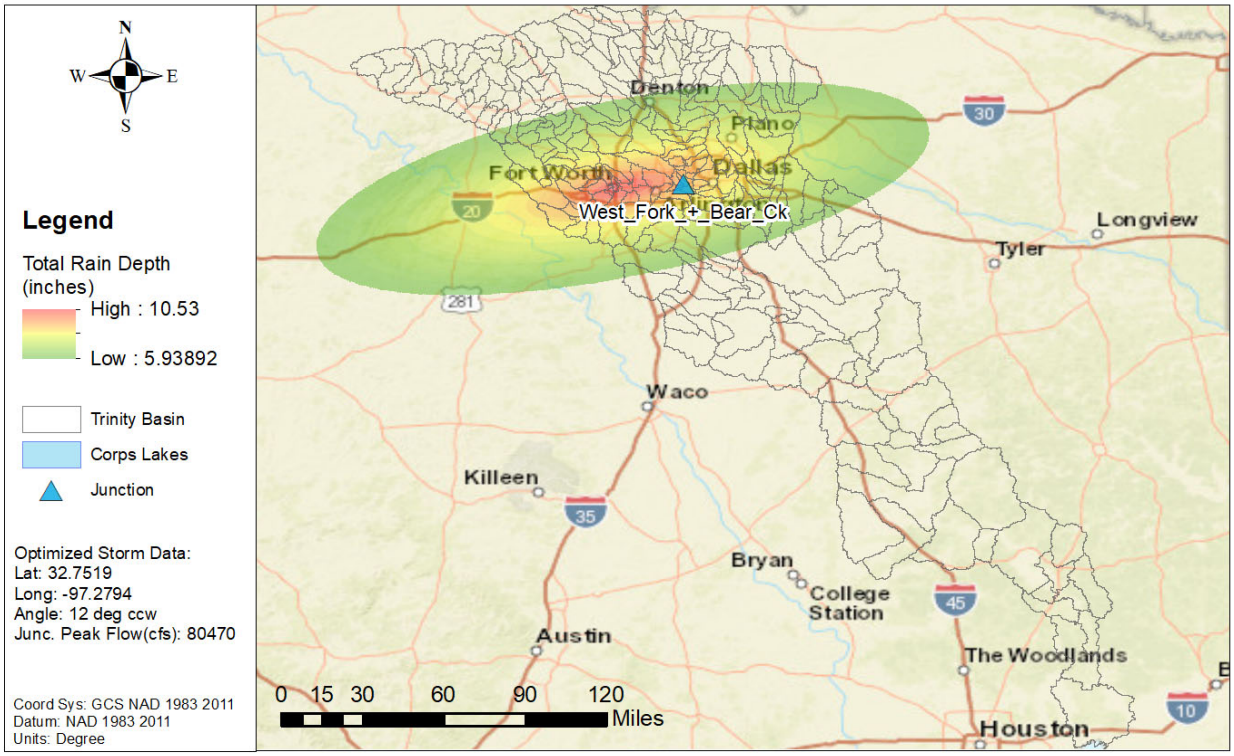


Figure 46b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below Big Bear Creek

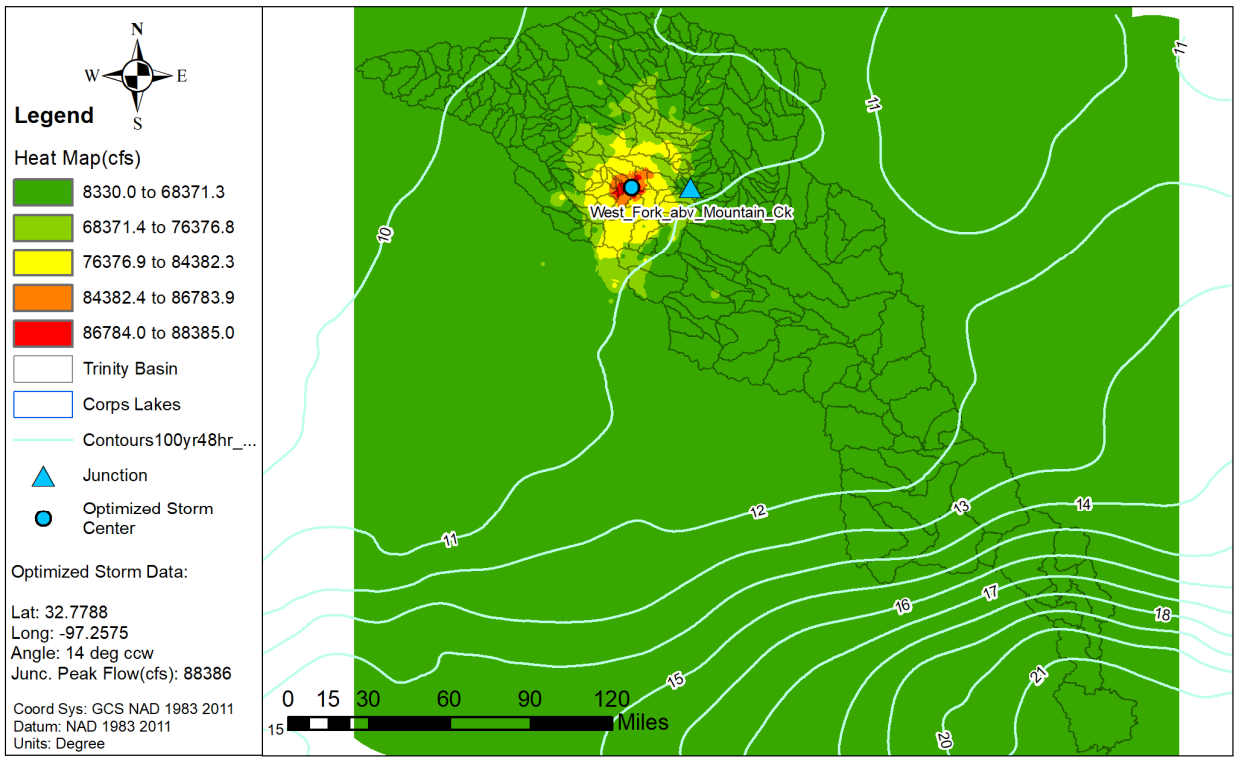


Figure 47a: Elliptical Storm Heat Map for the West Fork Trinity River above Mountain Creek

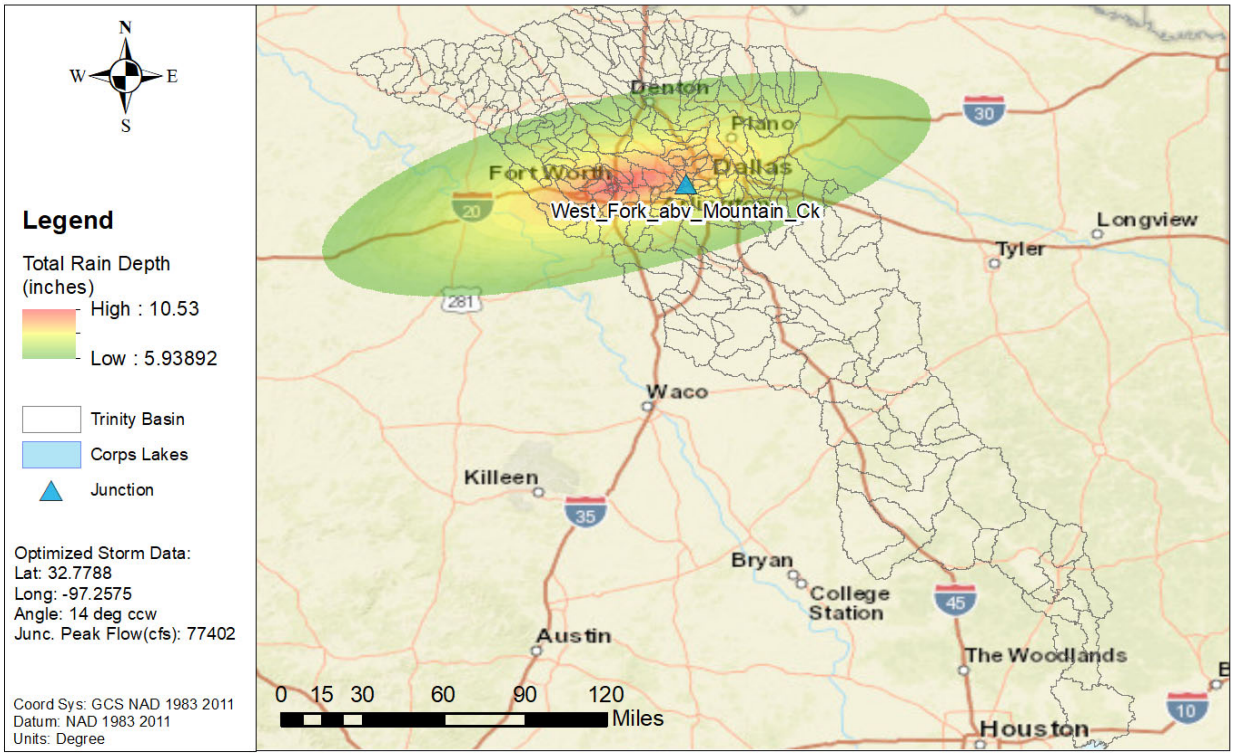


Figure 47b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River above Mountain Creek

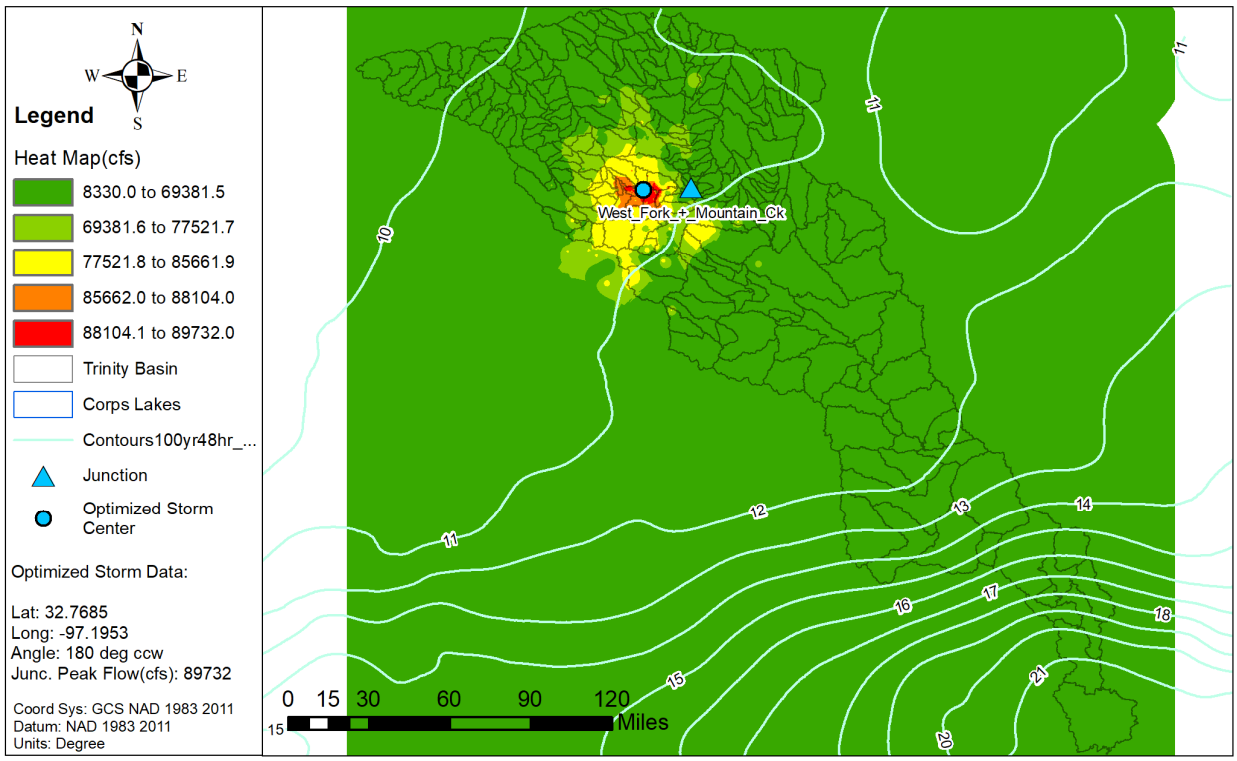


Figure 48a: Elliptical Storm Heat Map for the West Fork Trinity River below Mountain Creek

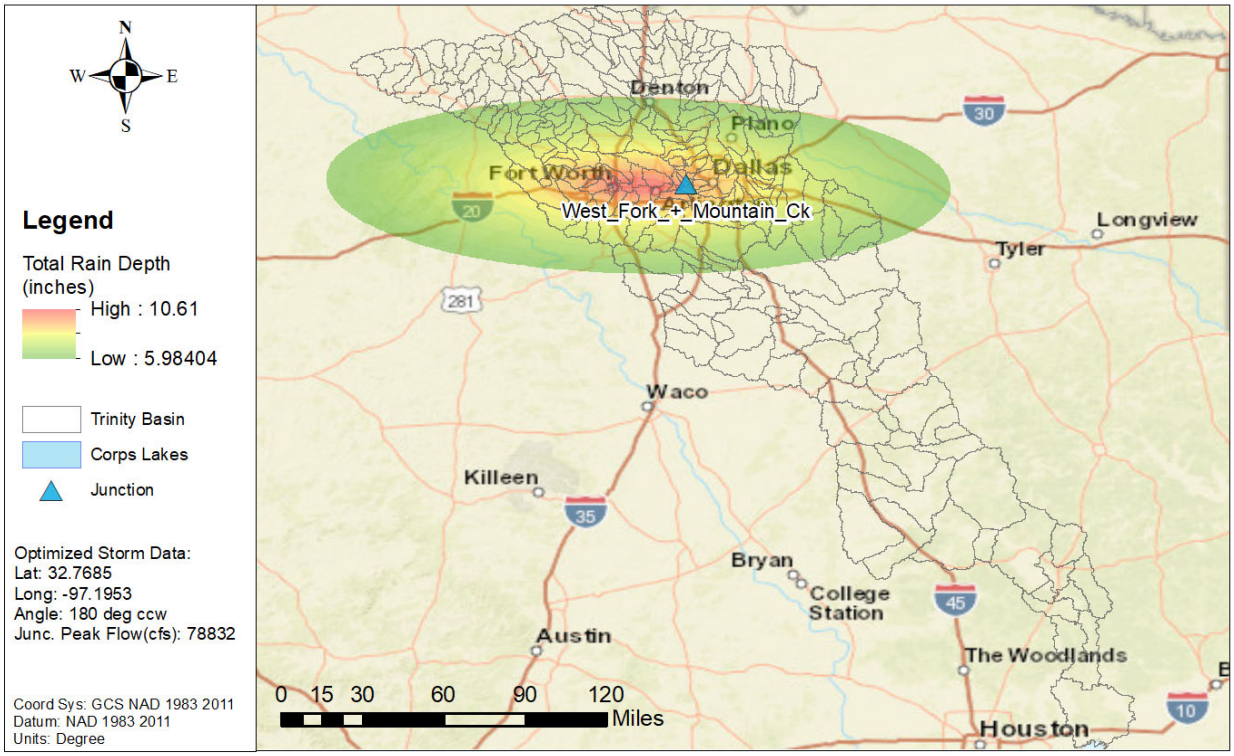


Figure 48b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below Mountain Creek

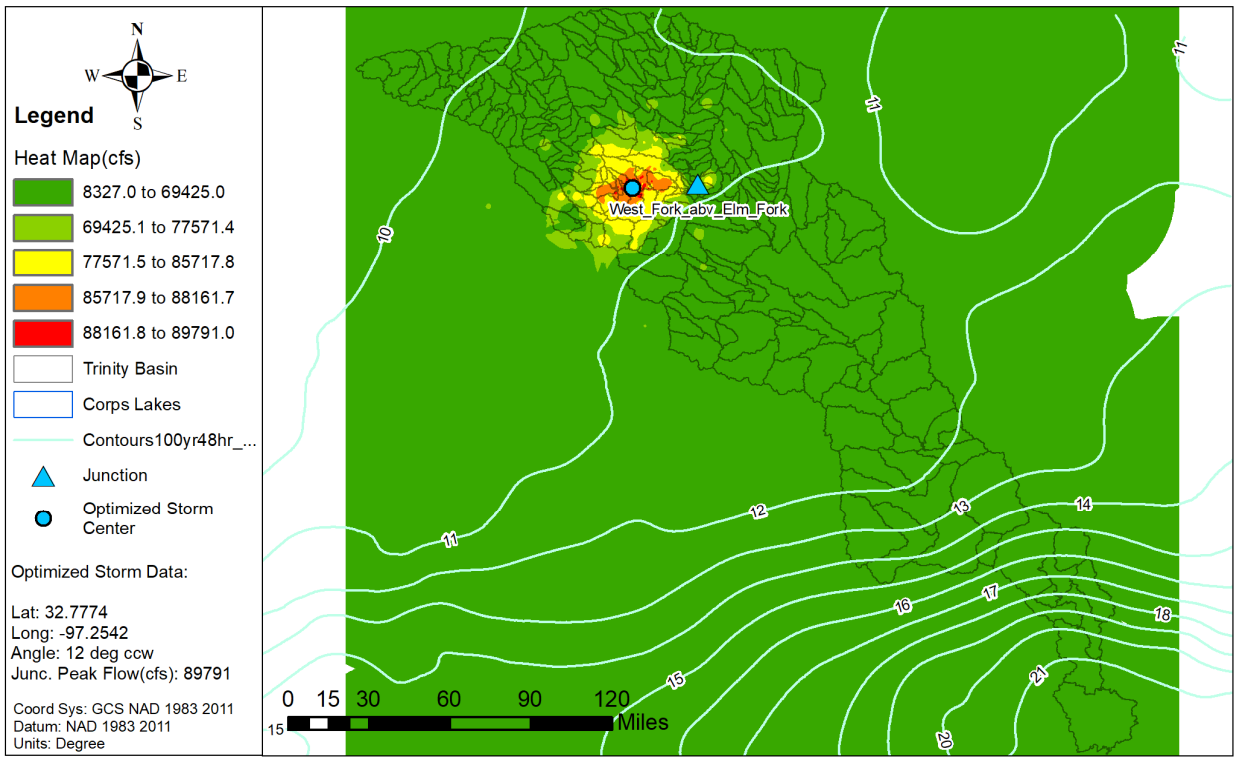


Figure 49a: Elliptical Storm Heat Map for the West Fork Trinity River above the Elm Fork Trinity River

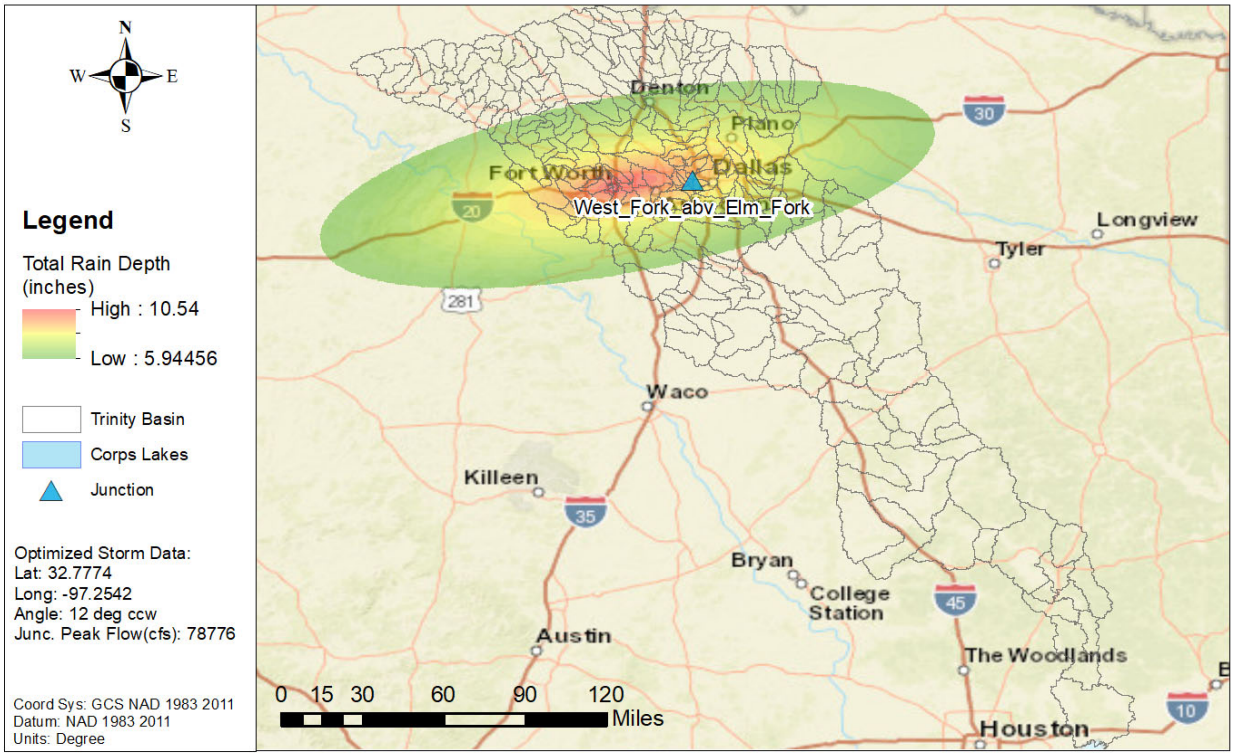


Figure 49b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River above the Elm Fork Trinity River

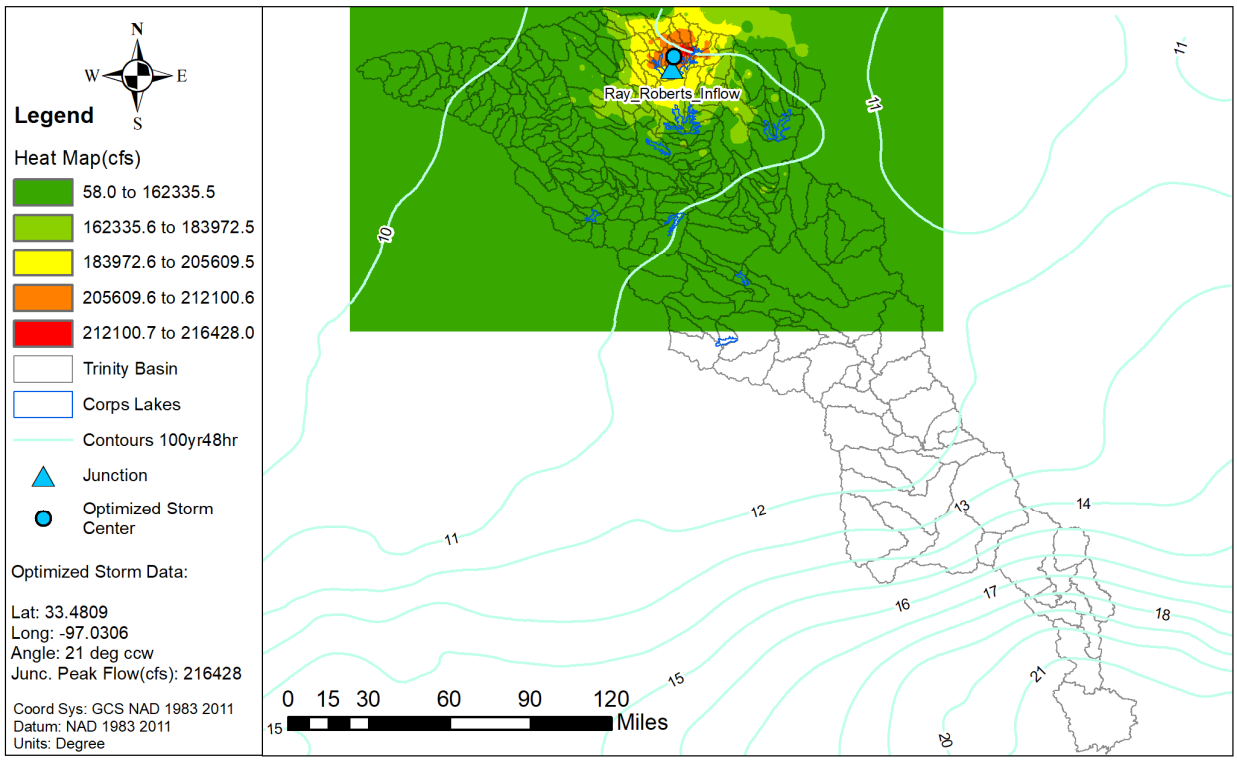


Figure 50a: Elliptical Storm Heat Map for the Ray Roberts Lake Inflow

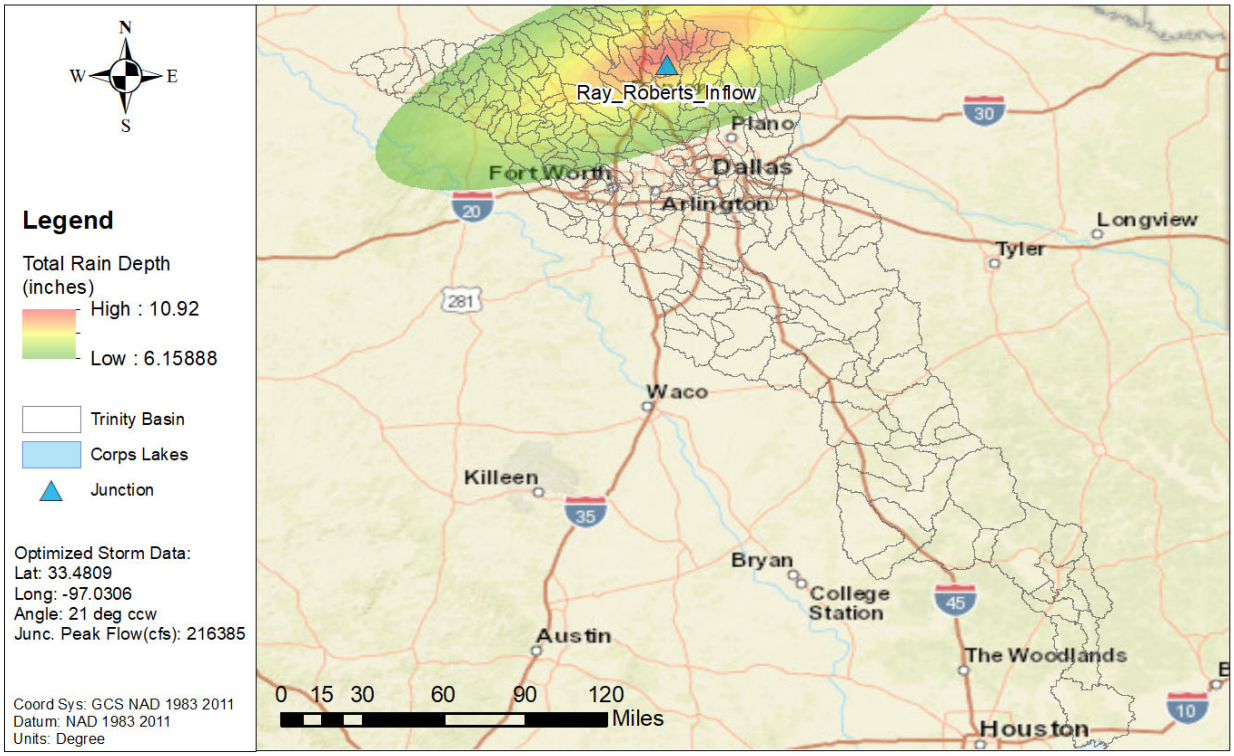


Figure 50b: NA14 1% AEP Elliptical Storm for the Ray Roberts Lake Inflow

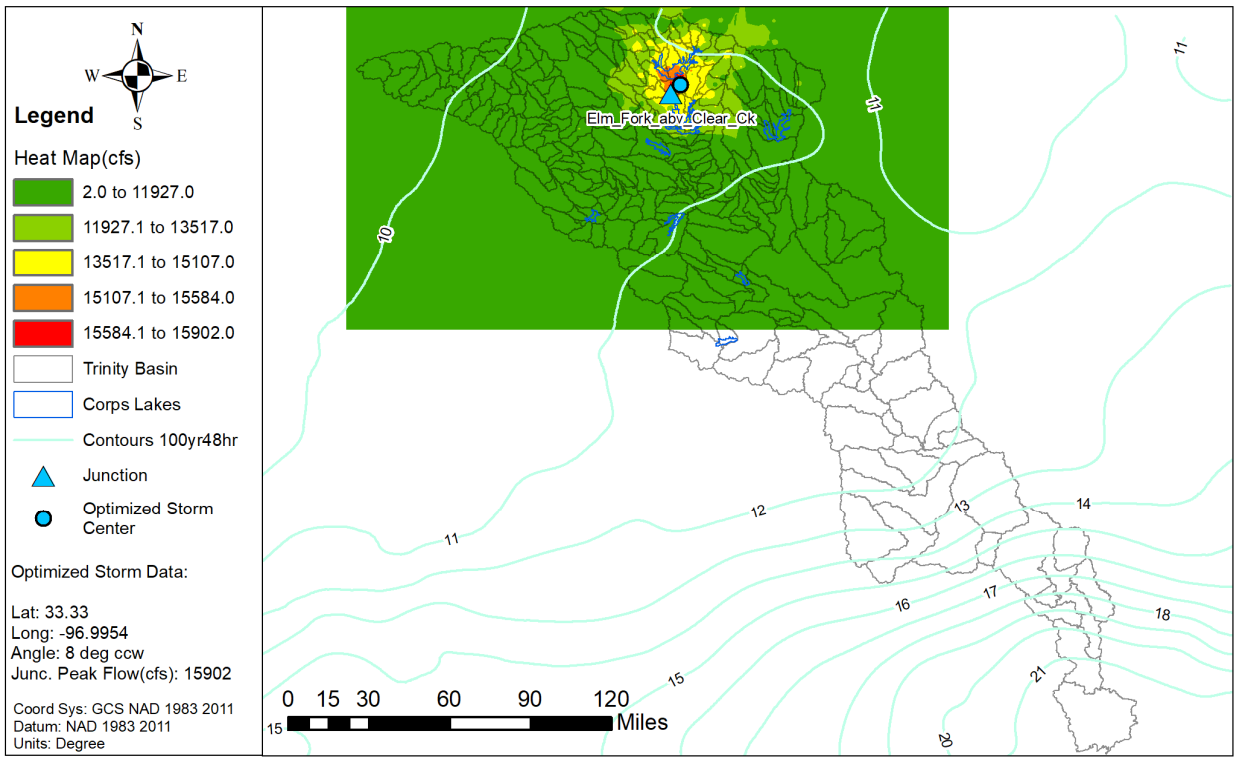


Figure 51a: Elliptical Storm Heat Map for the Elm Fork Trinity River above Clear Creek

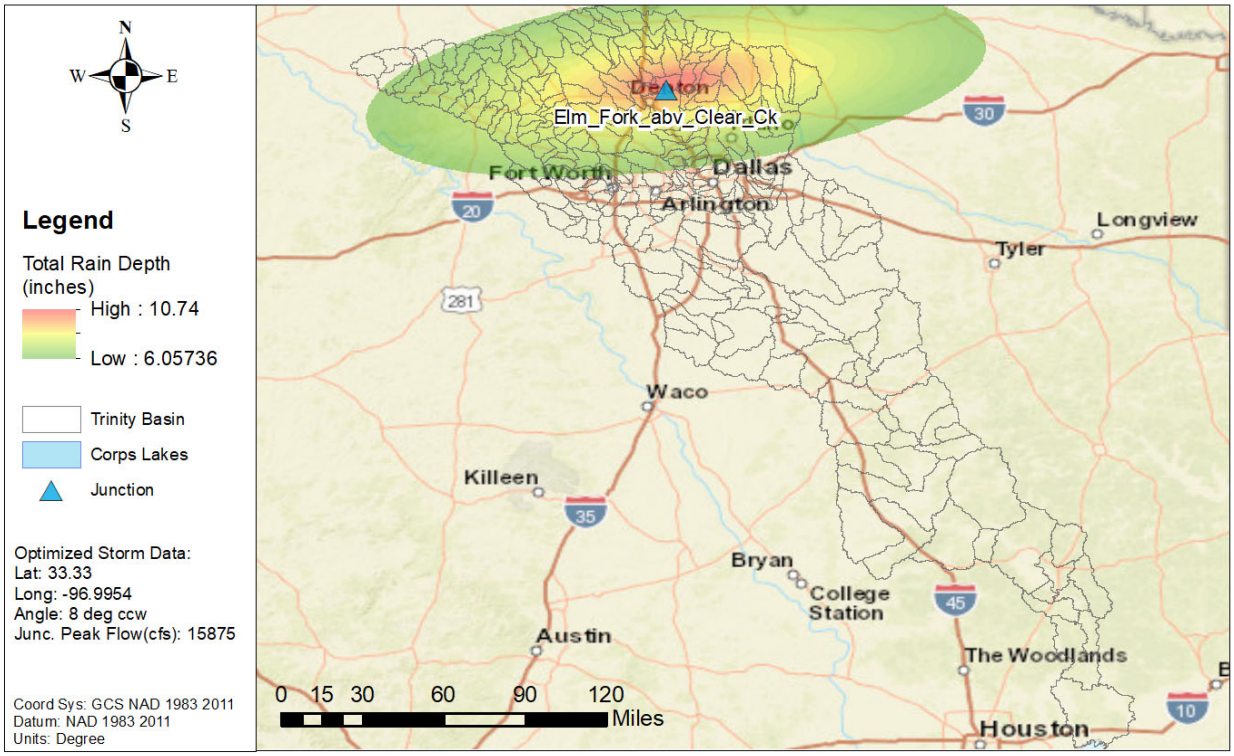


Figure 51b: NA14 1% AEP Elliptical Storm for the Elm Fork Trinity River above Clear Creek

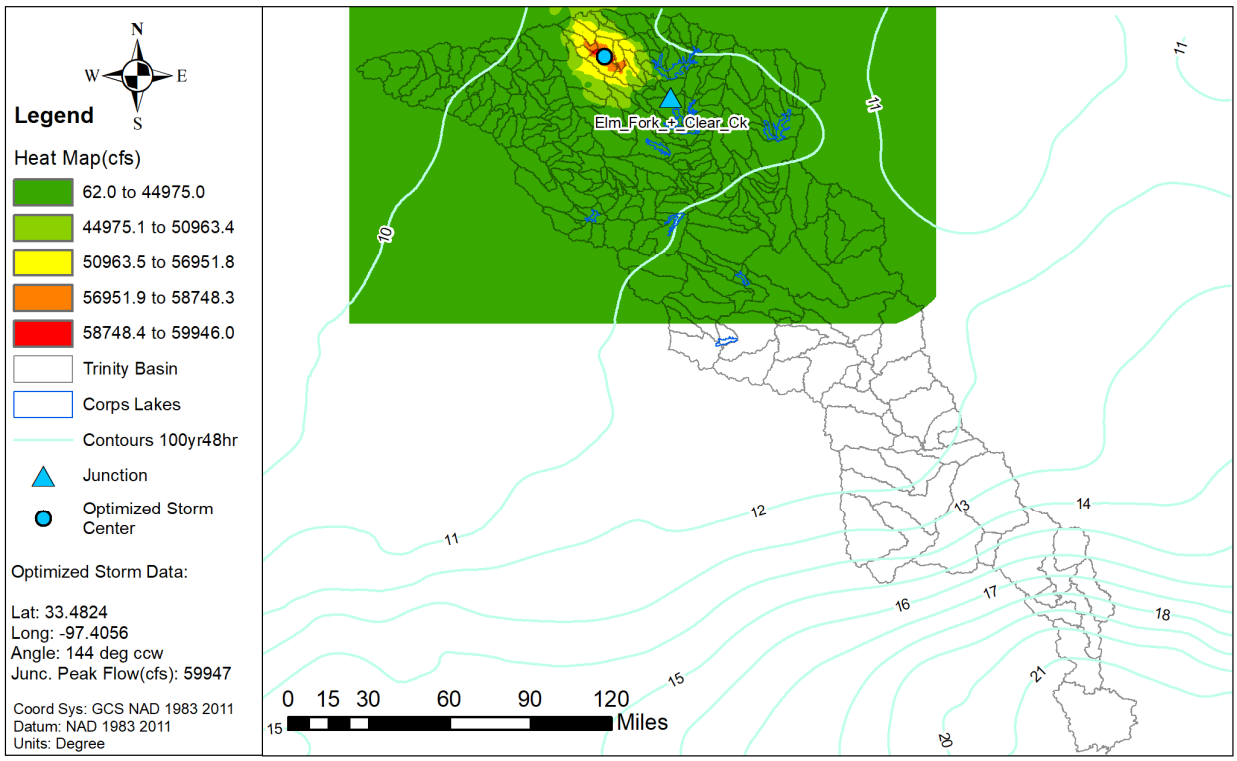


Figure 52a: Elliptical Storm Heat Map for the Elm Fork Trinity River below Clear Creek

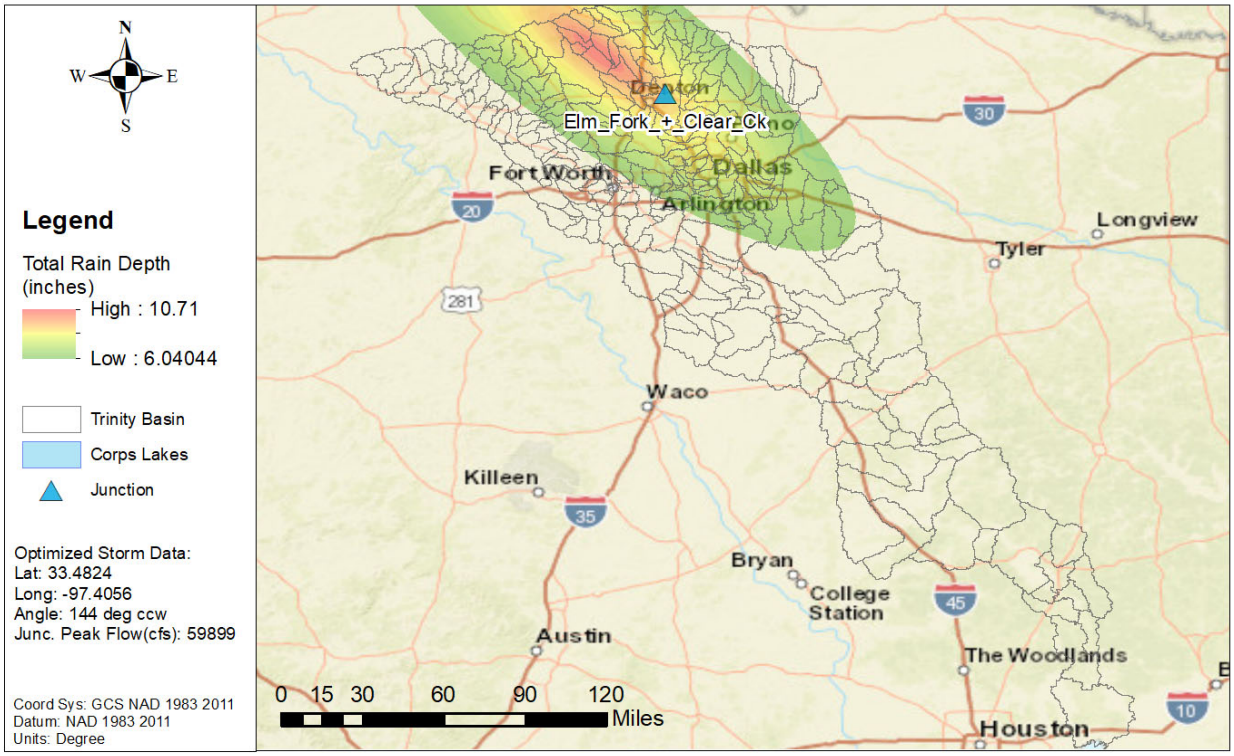


Figure 52b: NA14 1% AEP Elliptical Storm for the Elm Fork Trinity River below Clear Creek

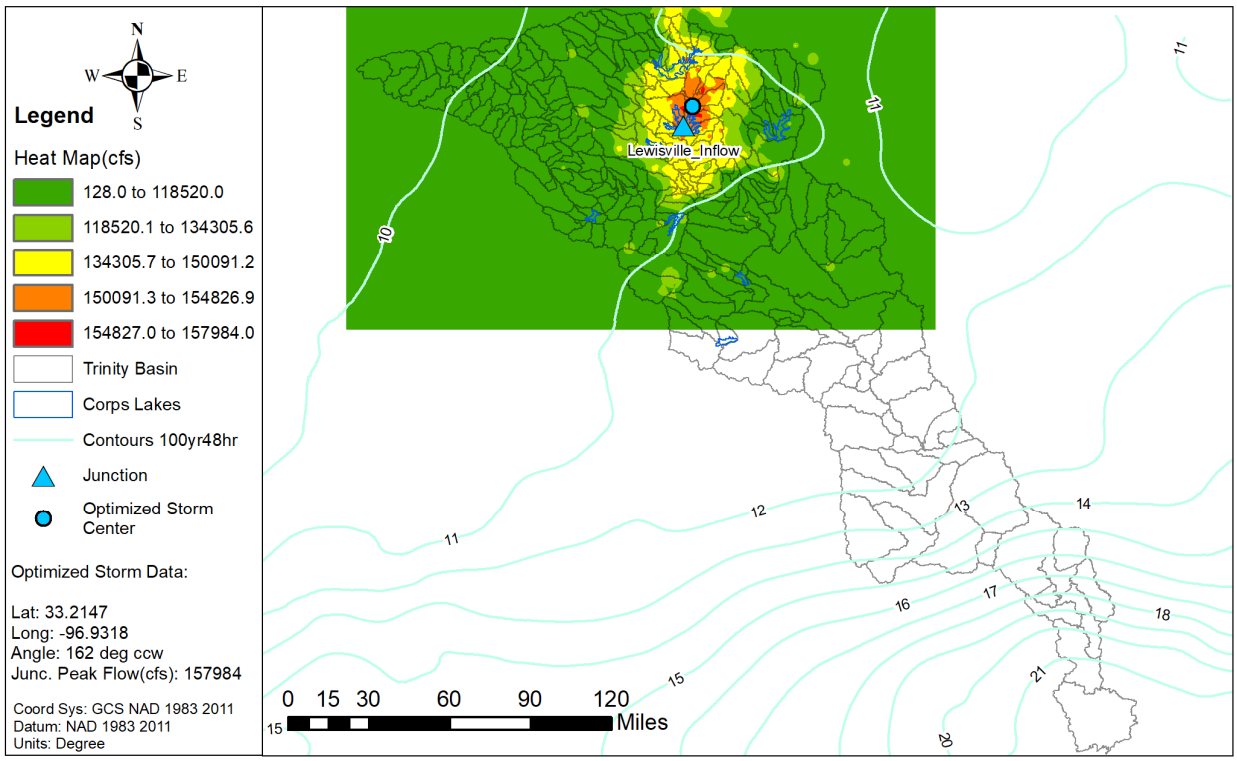


Figure 53a: Elliptical Storm Heat Map for the Lewisville Lake Inflow

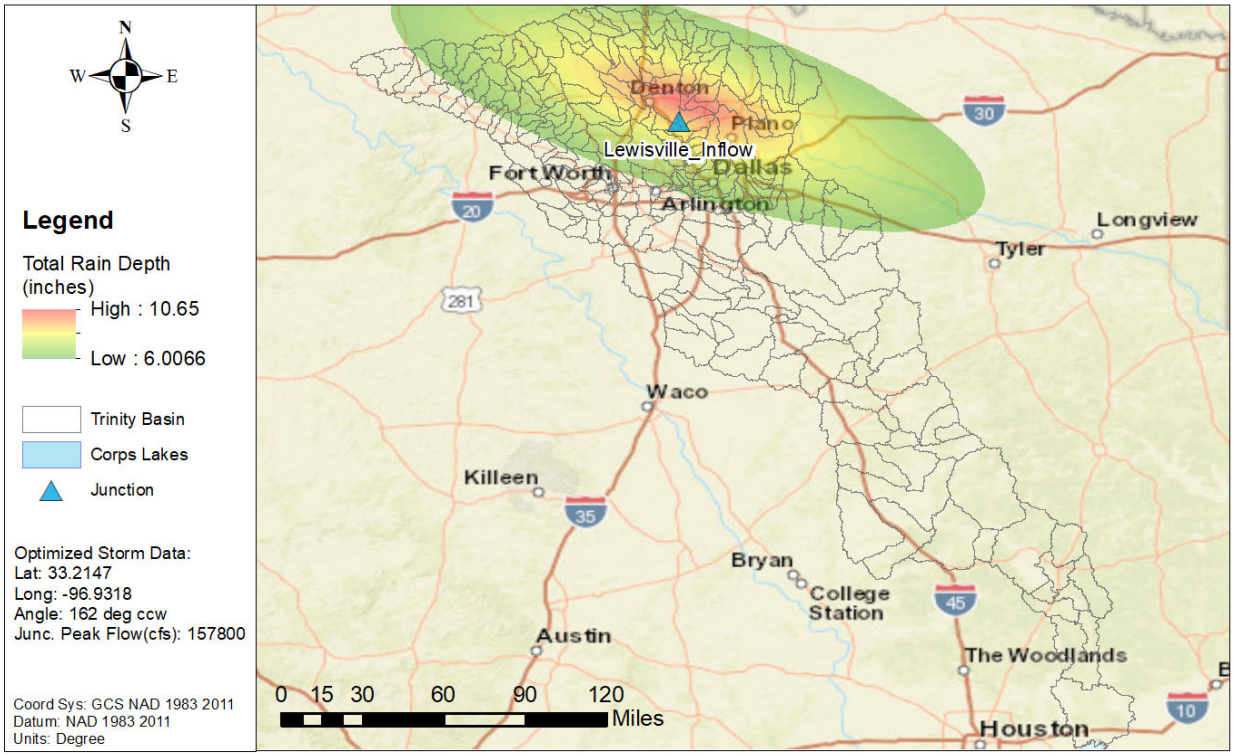


Figure 53b: NA14 1% AEP Elliptical Storm for the Lewisville Lake Inflow

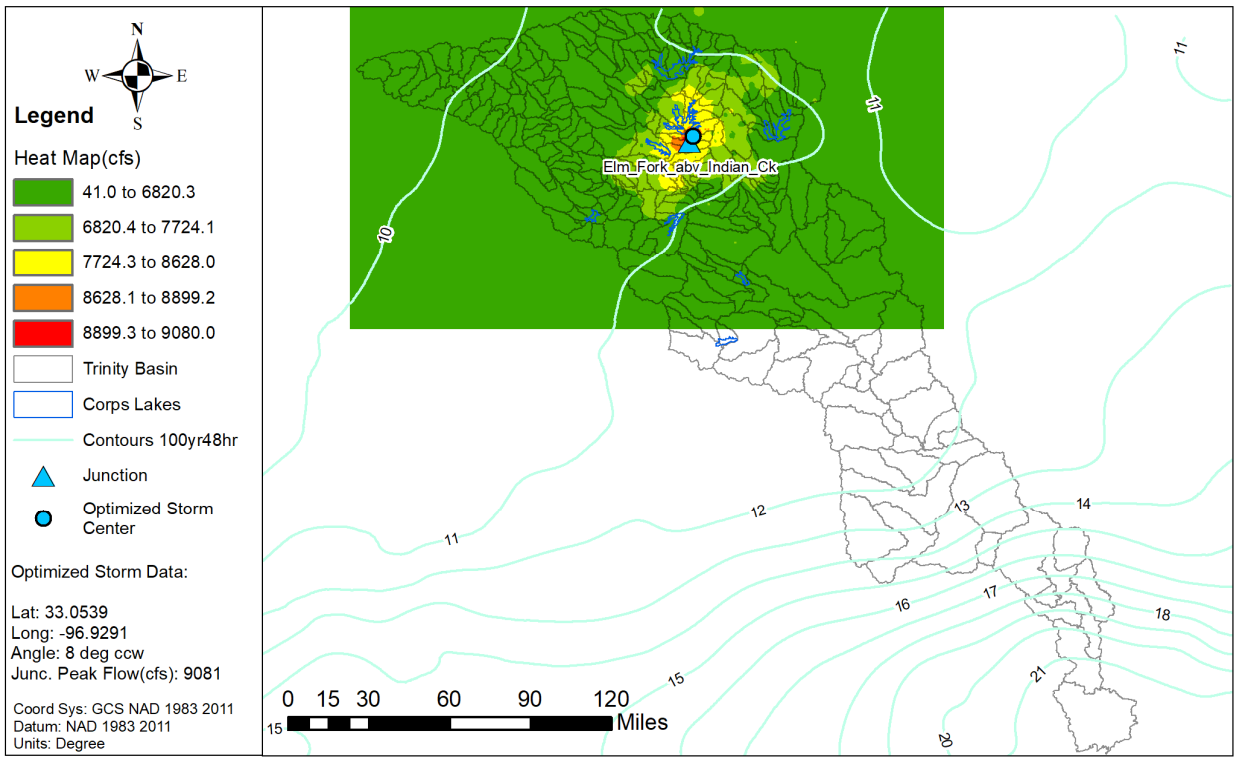


Figure 54a: Elliptical Storm Heat Map for the Elm Fork Trinity River above Indian Creek

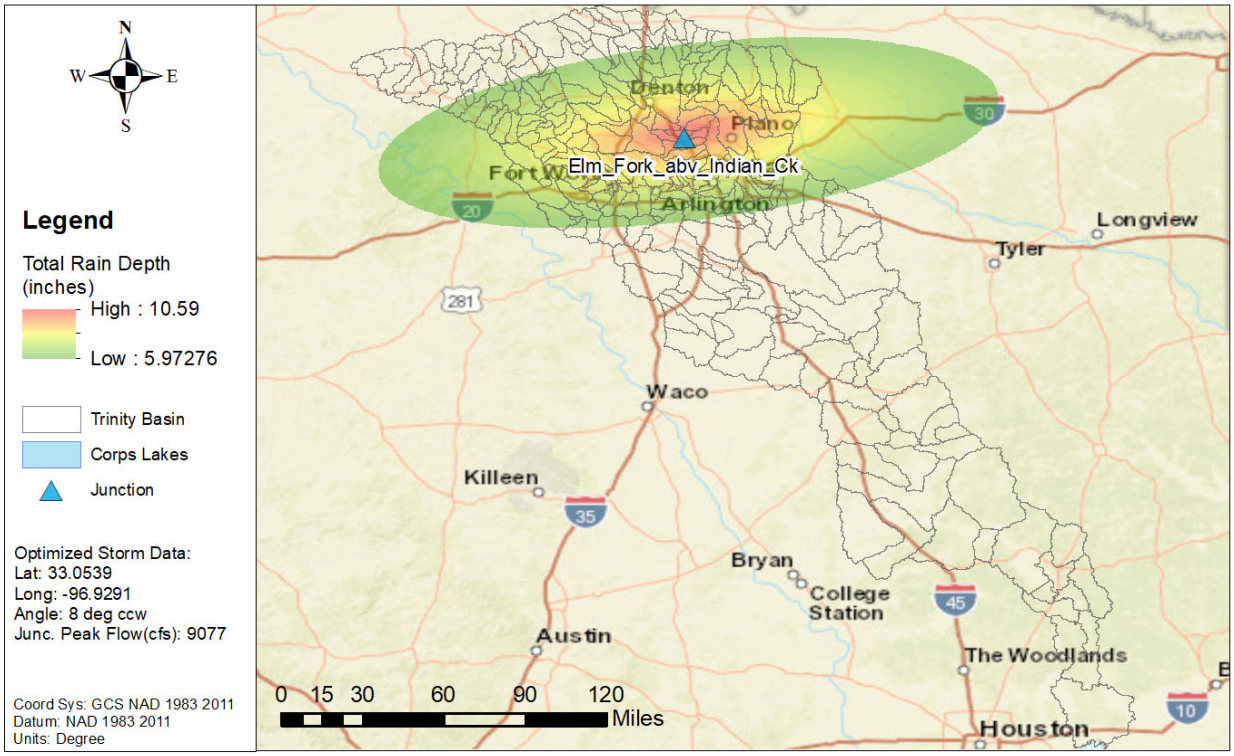


Figure 54b: NA14 1% AEP Elliptical Storm for the Elm Fork Trinity River above Indian Creek

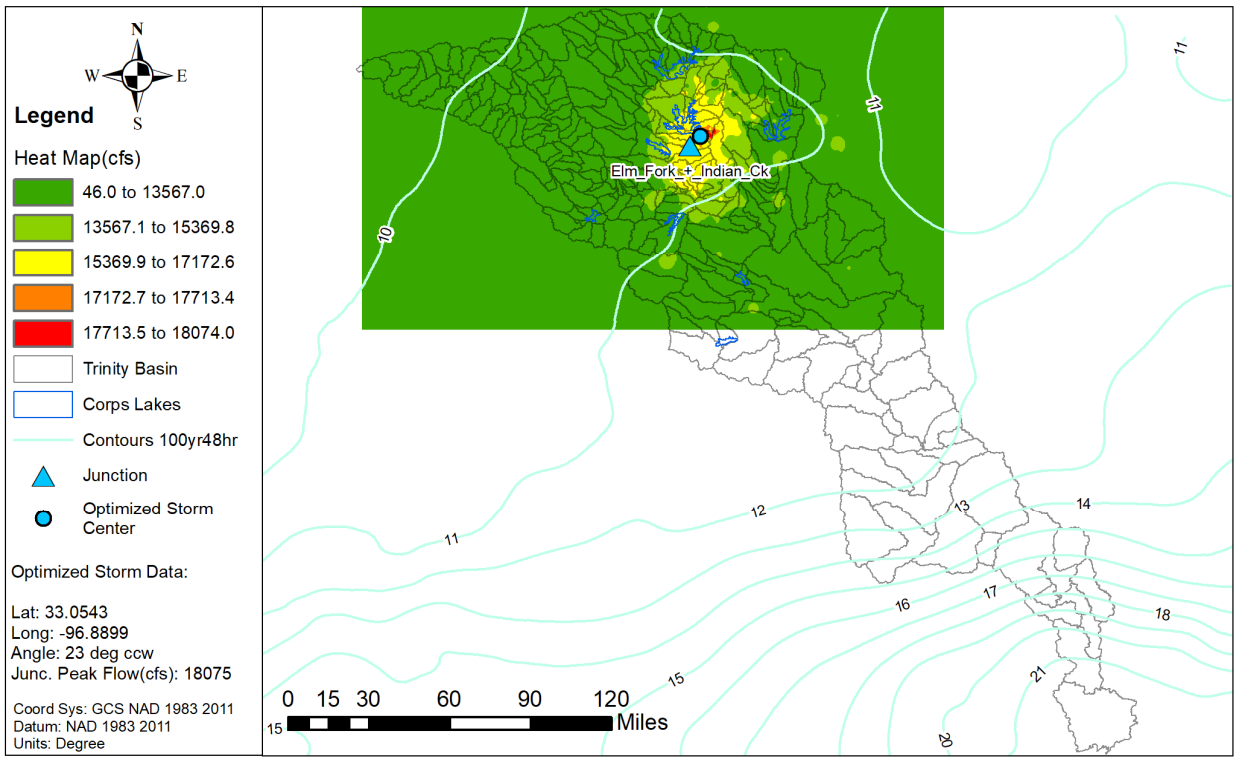


Figure 55a: Elliptical Storm Heat Map for the Elm Fort Trinity River below Indian Creek

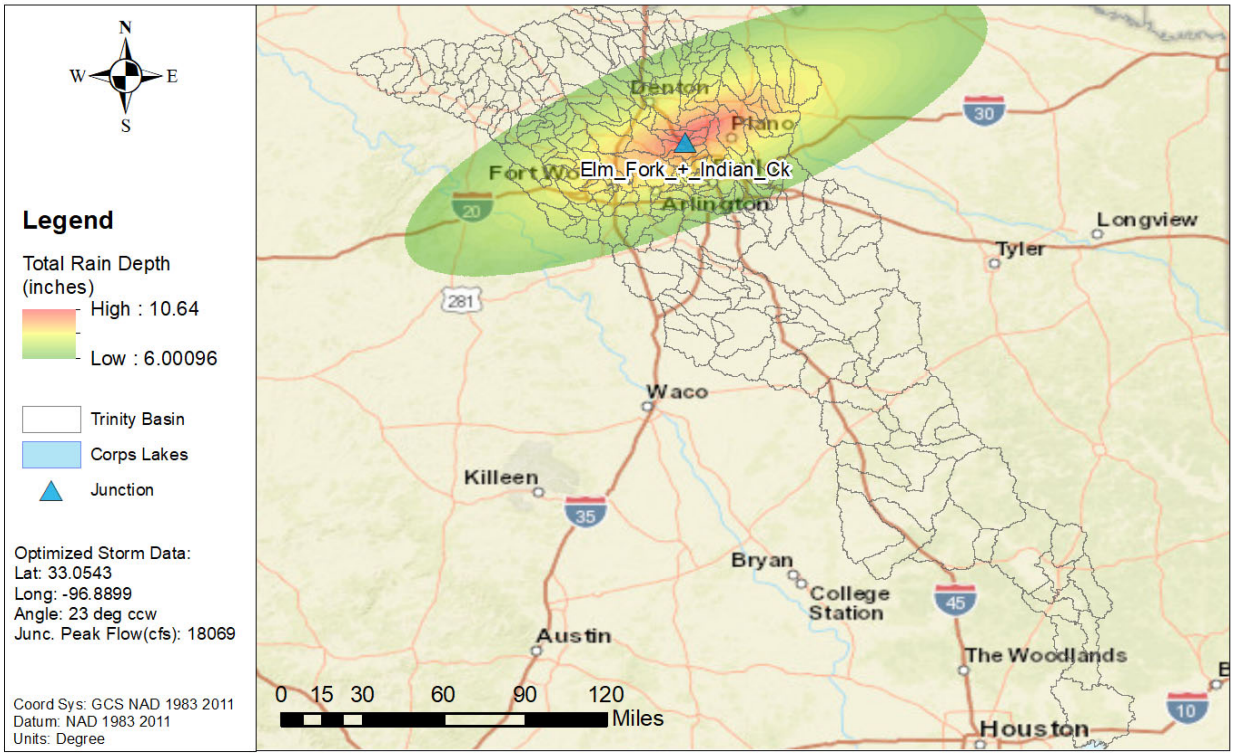


Figure 55b: NA14 1% AEP Elliptical Storm for the Elm Fort Trinity River below Indian Creek

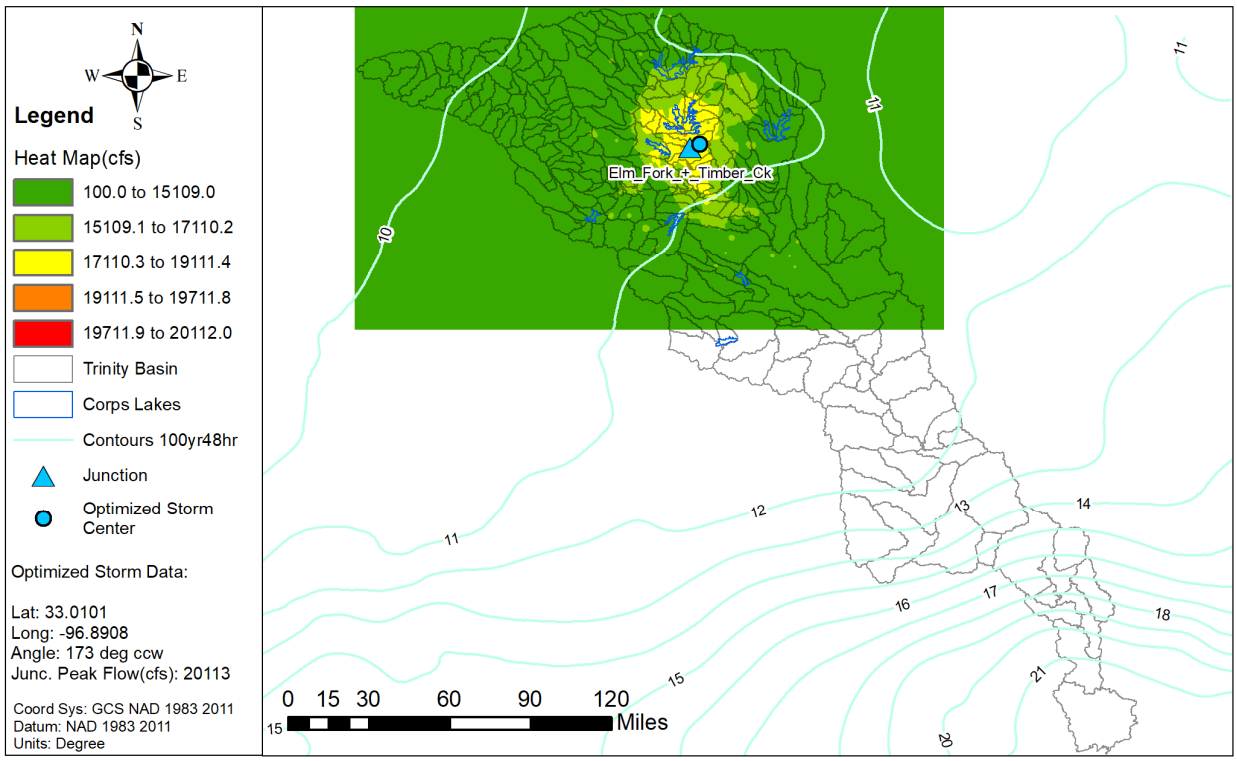


Figure 56a: Elliptical Storm Heat Map for the Elm Fork Trinity River below Timber Creek

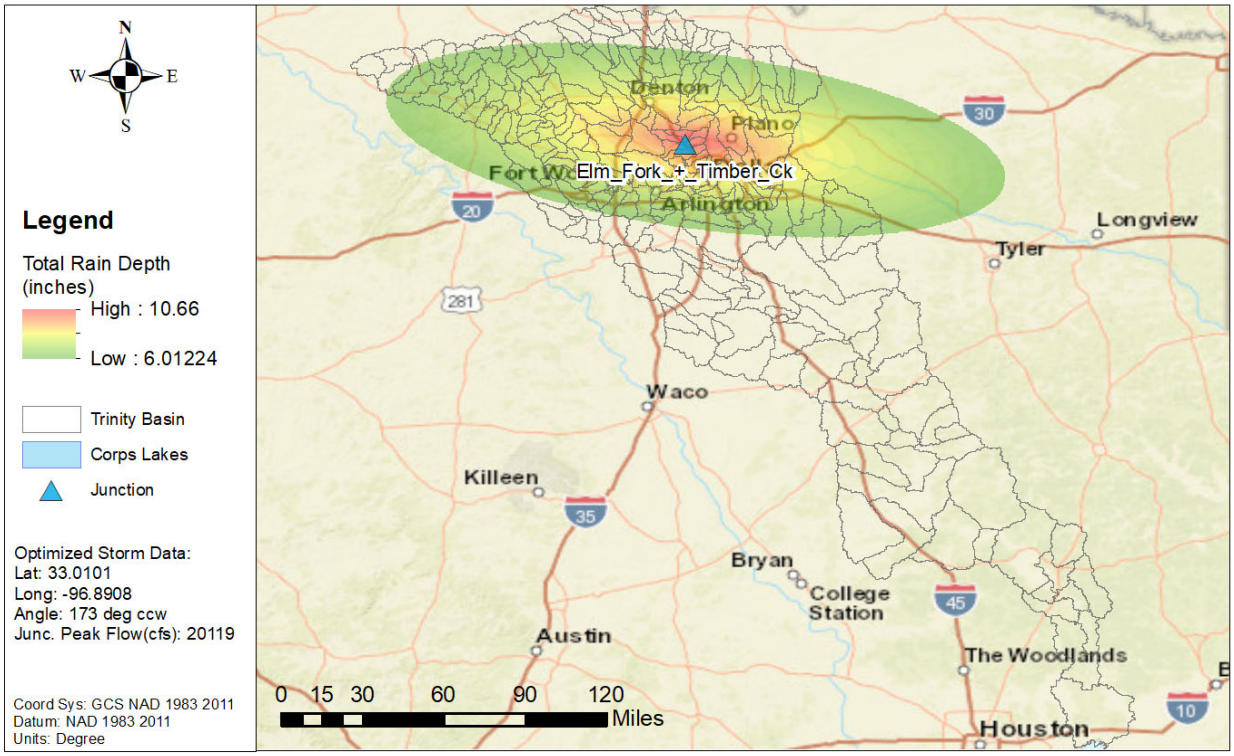


Figure 56b: NA14 1% AEP Elliptical Storm for the Elm Fork Trinity River below Timber Creek

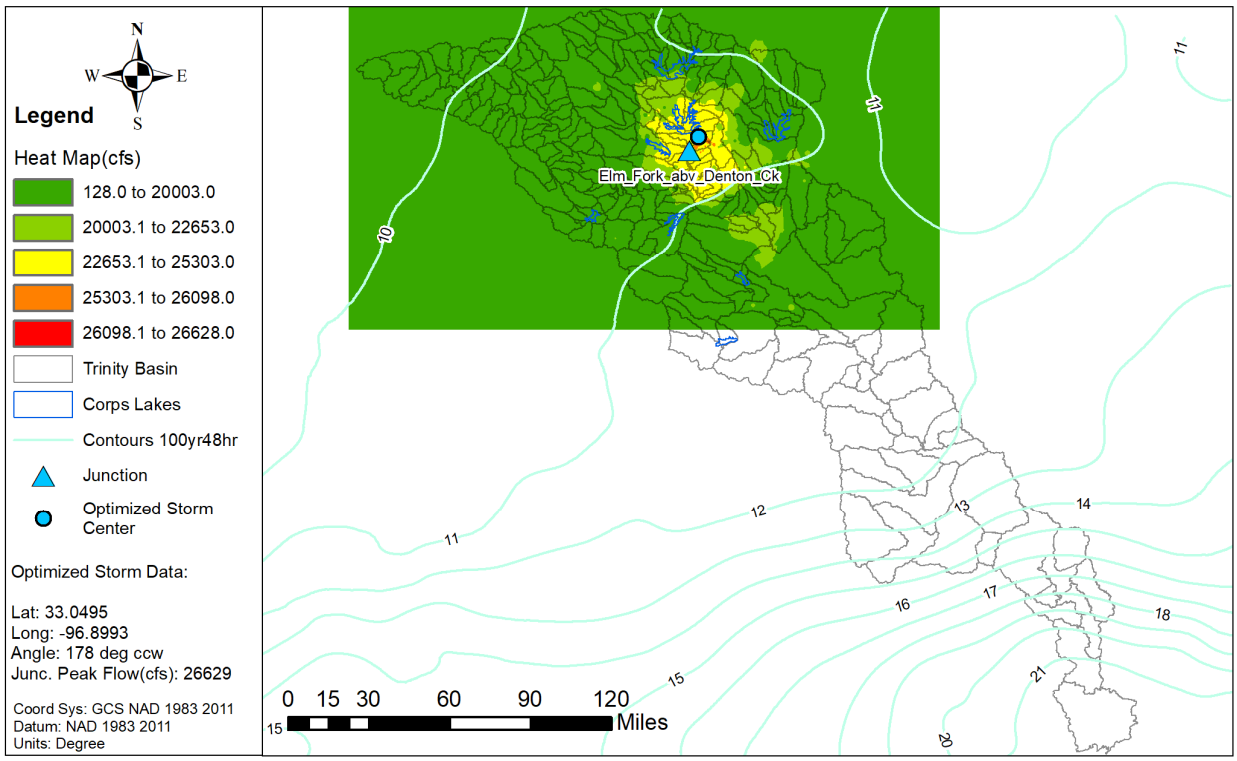


Figure 57a: Elliptical Storm Heat Map for the Elm Fork Trinity River above Denton Creek

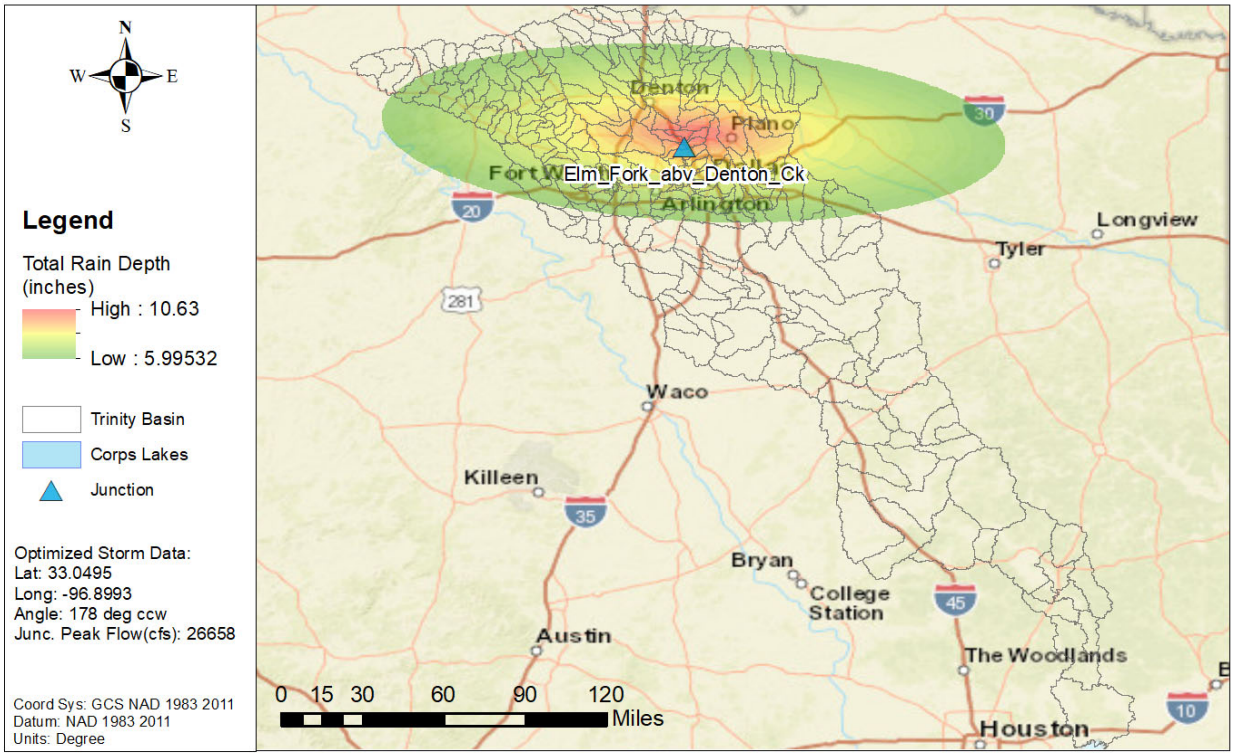


Figure 57b: NA14 1% AEP Elliptical Storm for the Elm Fork Trinity River above Denton Creek

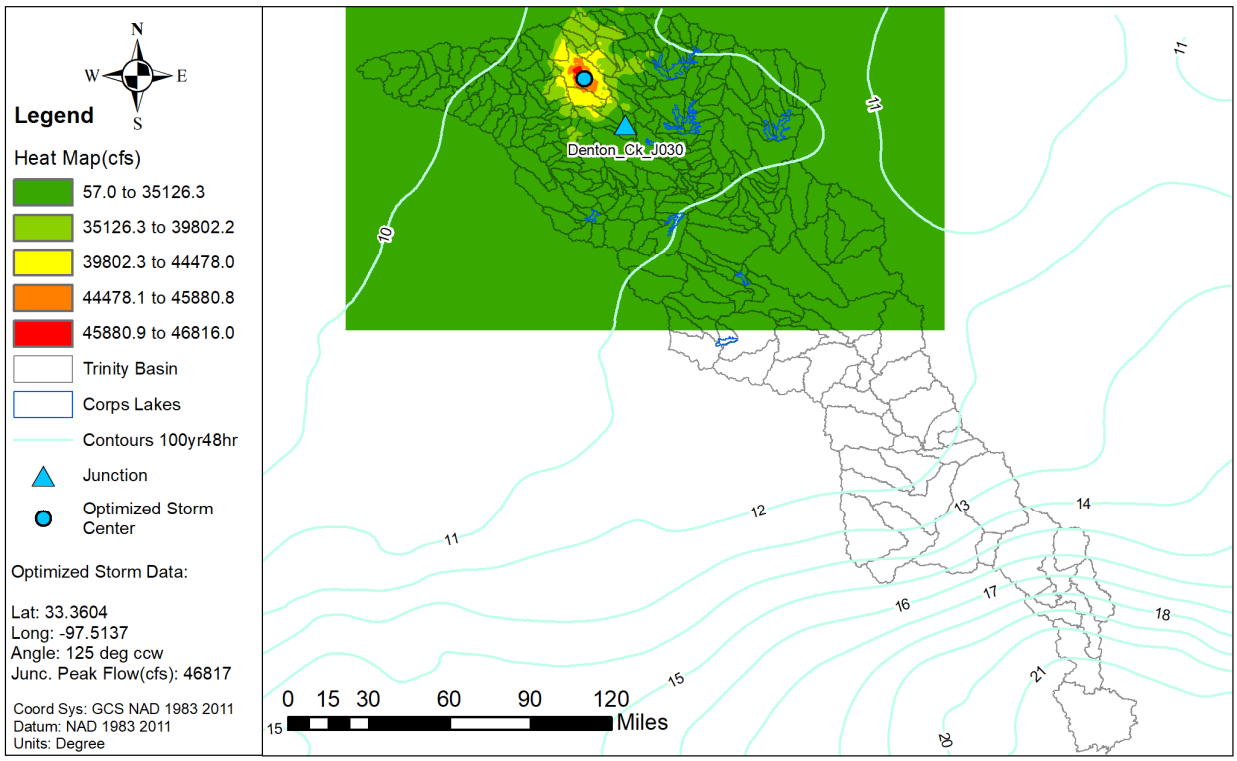


Figure 58a: Elliptical Storm Heat Map for the Denton Creek nr Justin, TX USGS gage

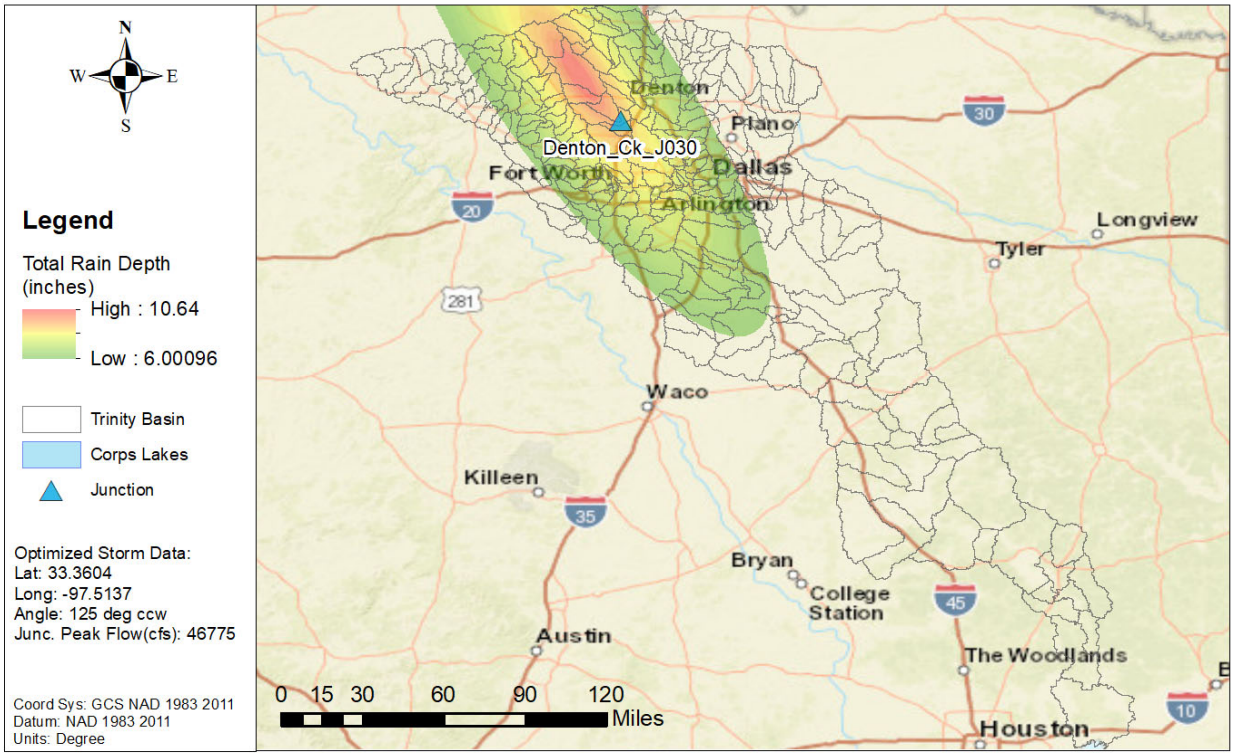


Figure 58b: NA14 1% AEP Elliptical Storm for the Denton Creek nr Justin, TX USGS gage

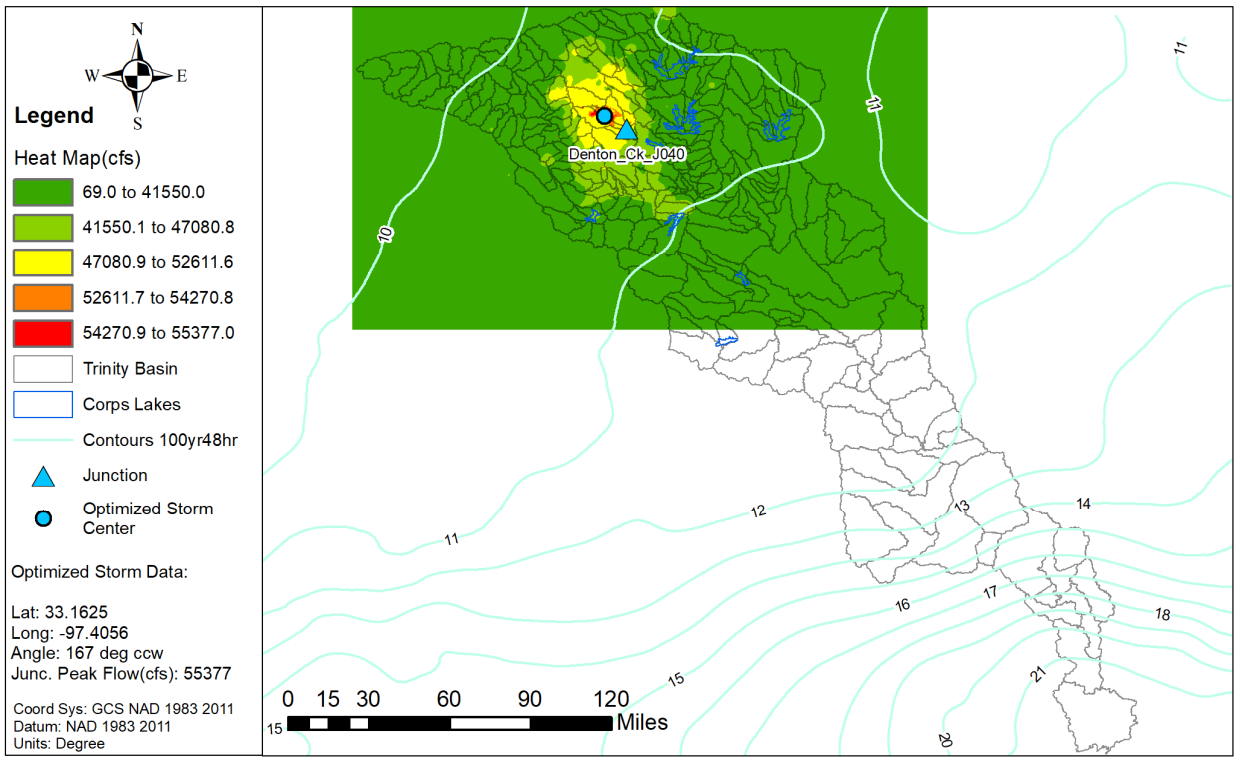


Figure 59a: Elliptical Storm Heat Map for the Denton Creek below Oliver Creek

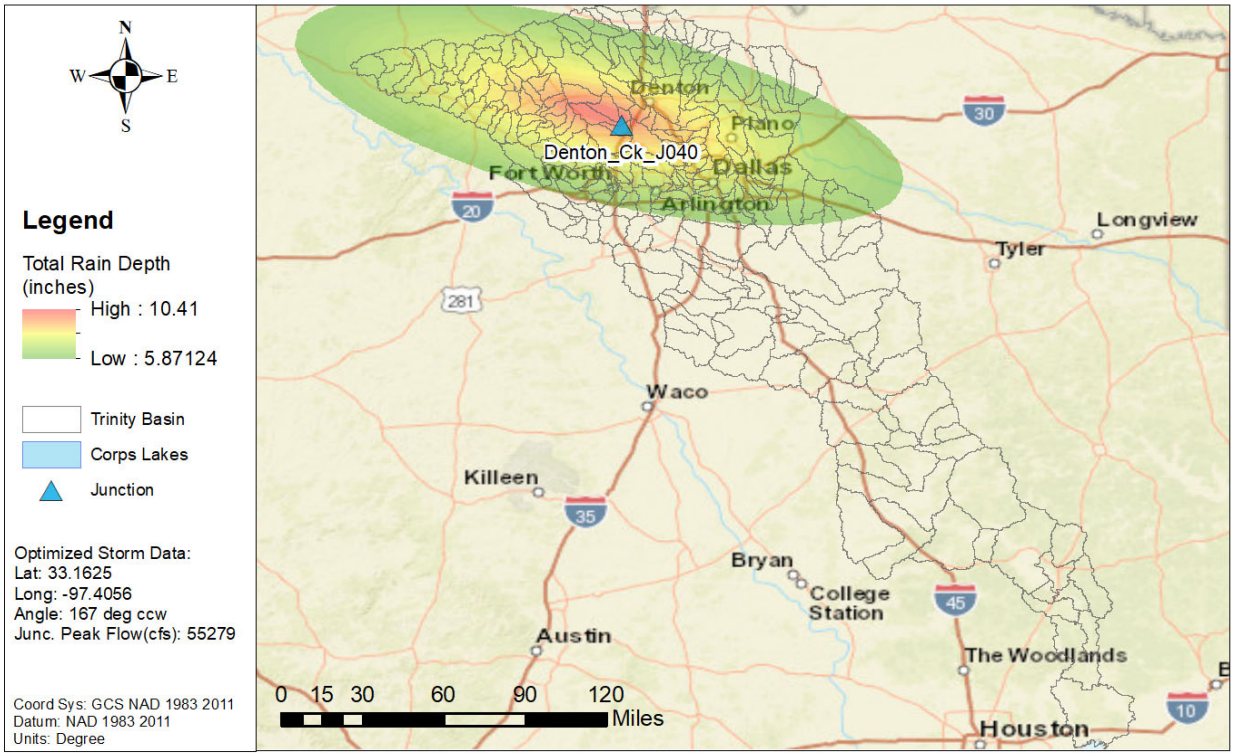


Figure 59b: NA14 1% AEP Elliptical Storm for the Denton Creek below Oliver Creek

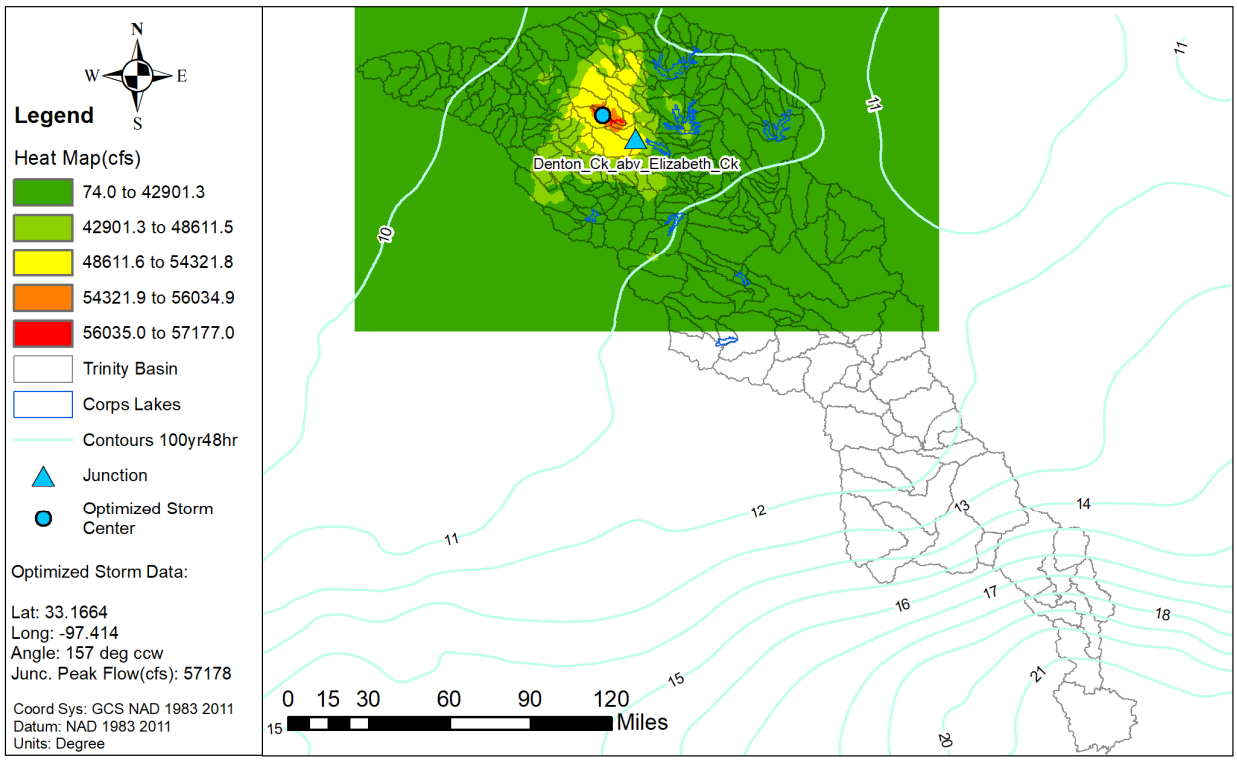


Figure 60a: Elliptical Storm Heat Map for the Denton Creek above Elizabeth Creek

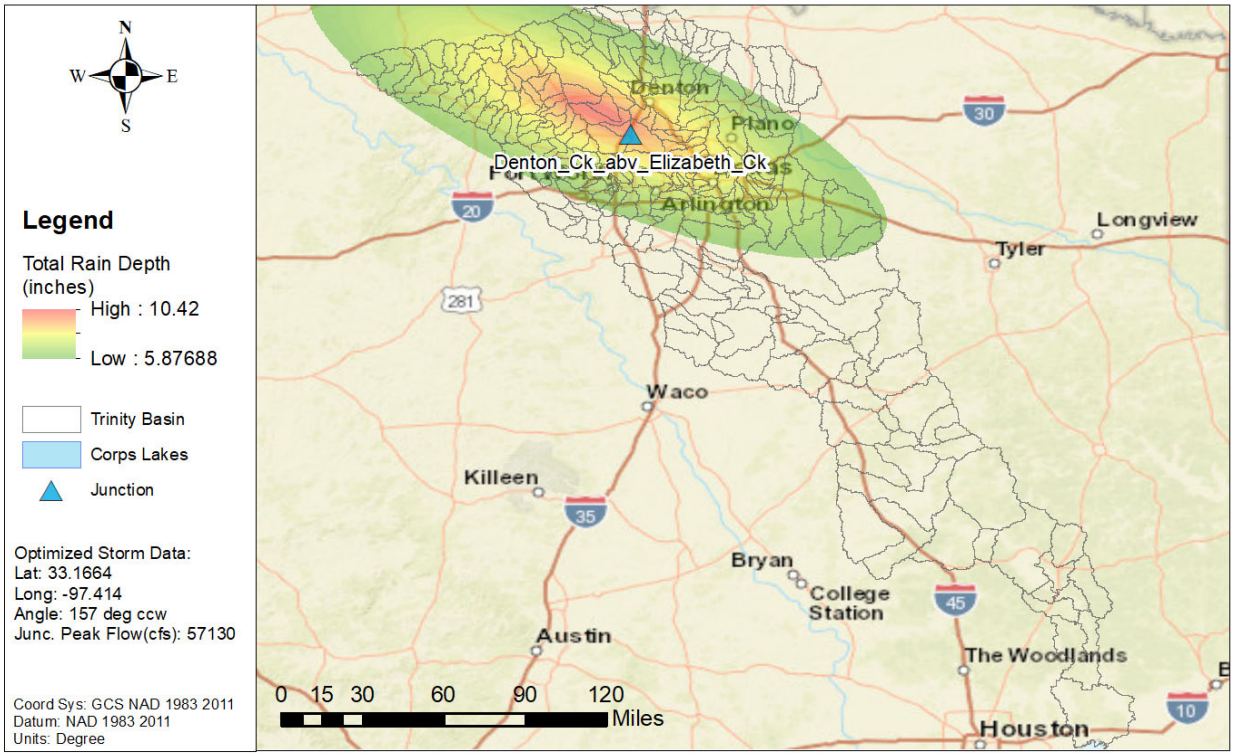


Figure 60b: NA14 1% AEP Elliptical Storm for the Denton Creek above Elizabeth Creek

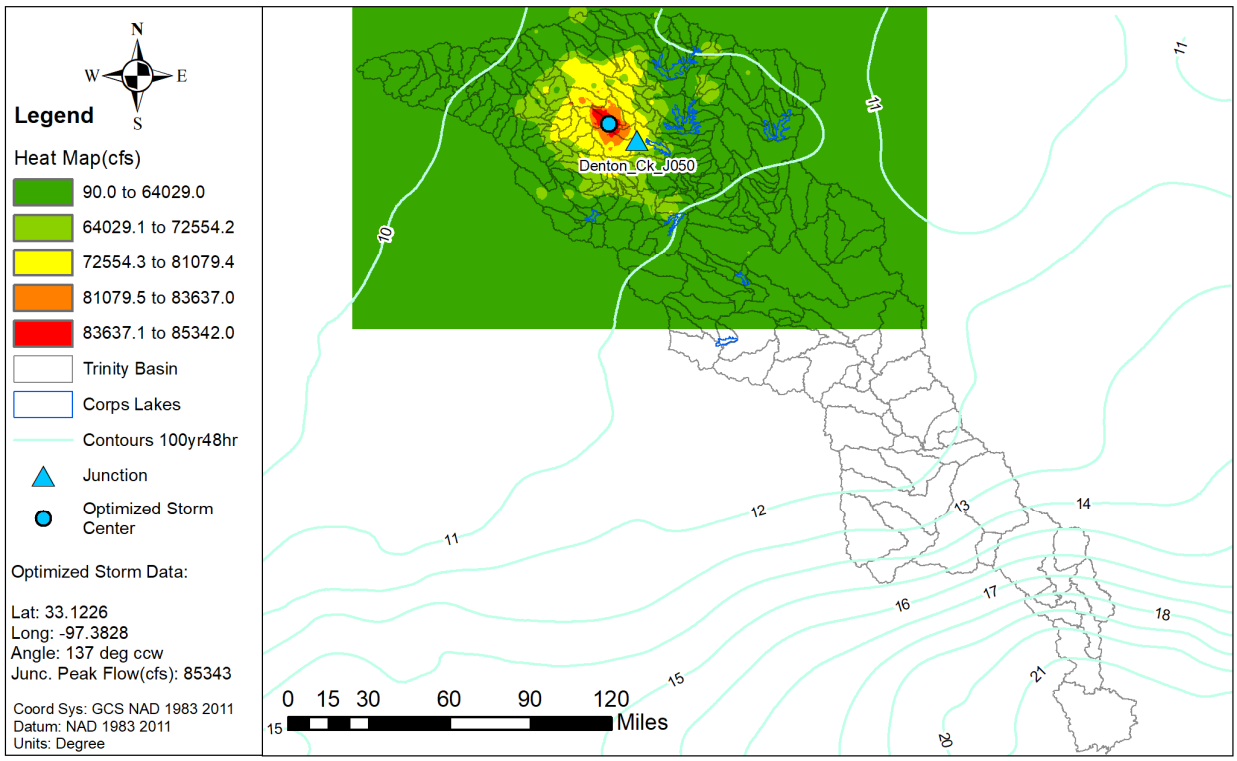


Figure 61a: Elliptical Storm Heat Map for the Denton Creek below Elizaveth Creek

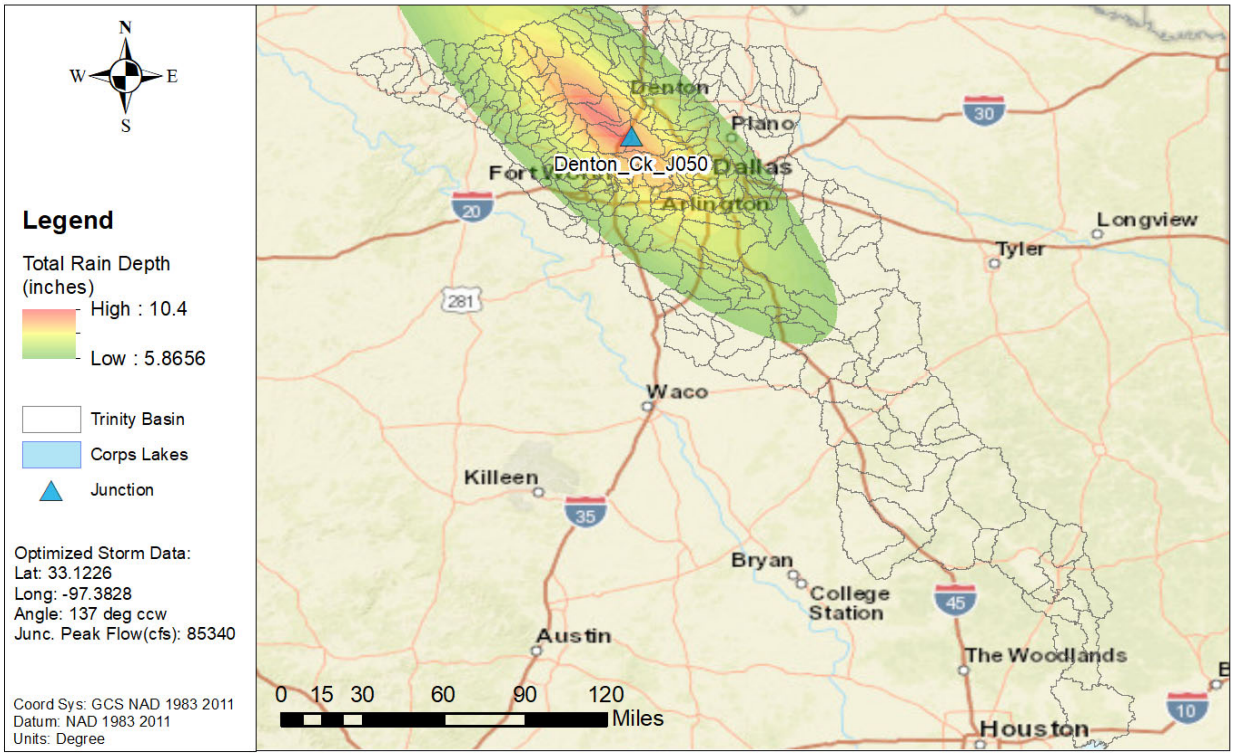


Figure 61b: NA14 1% AEP Elliptical Storm for the Denton Creek below Elizaveth Creek

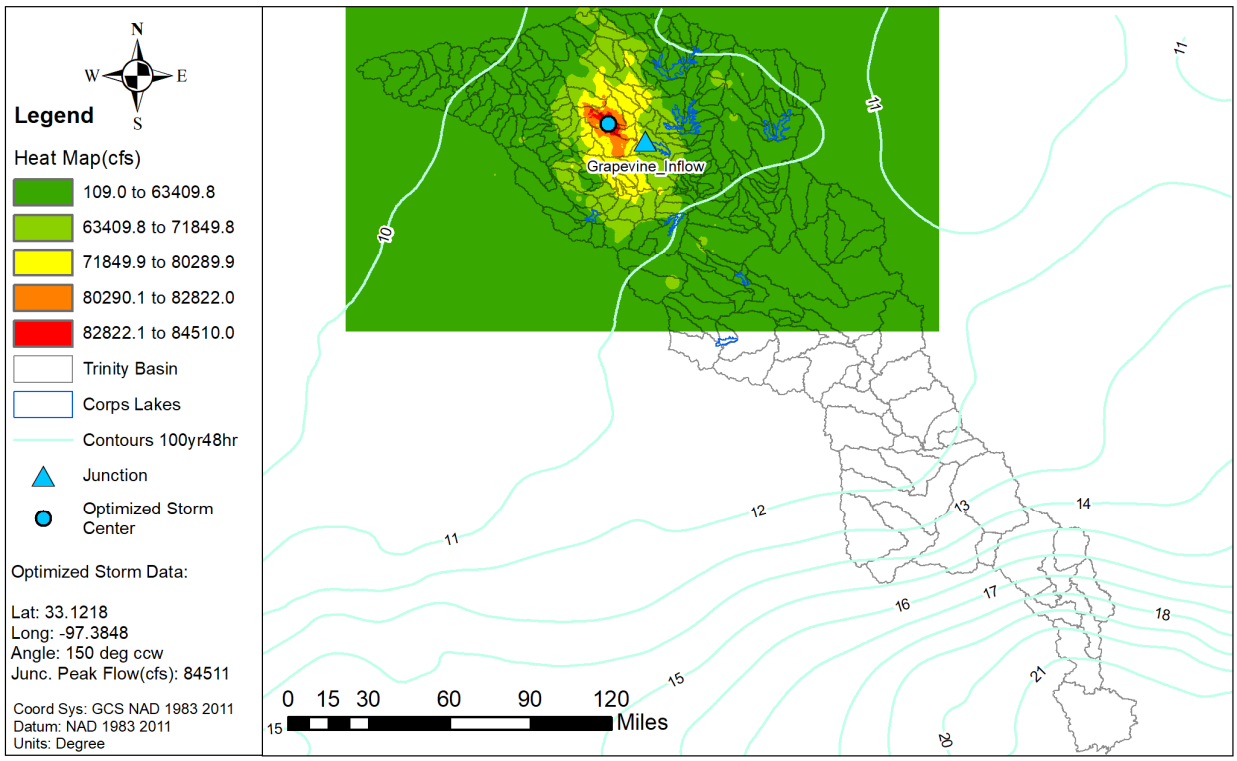


Figure 62a: Elliptical Storm Heat Map for the Grapevine Lake Inflow

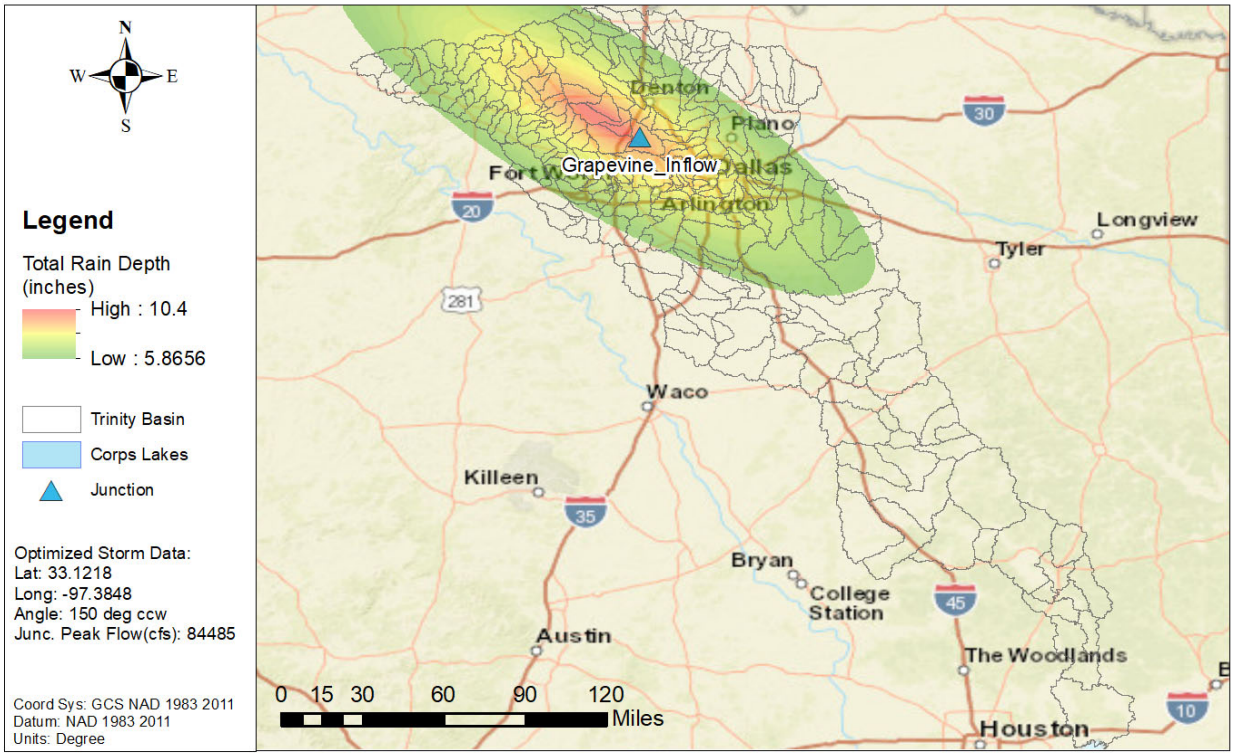


Figure 62b: NA14 1% AEP Elliptical Storm for the Grapevine Lake Inflow

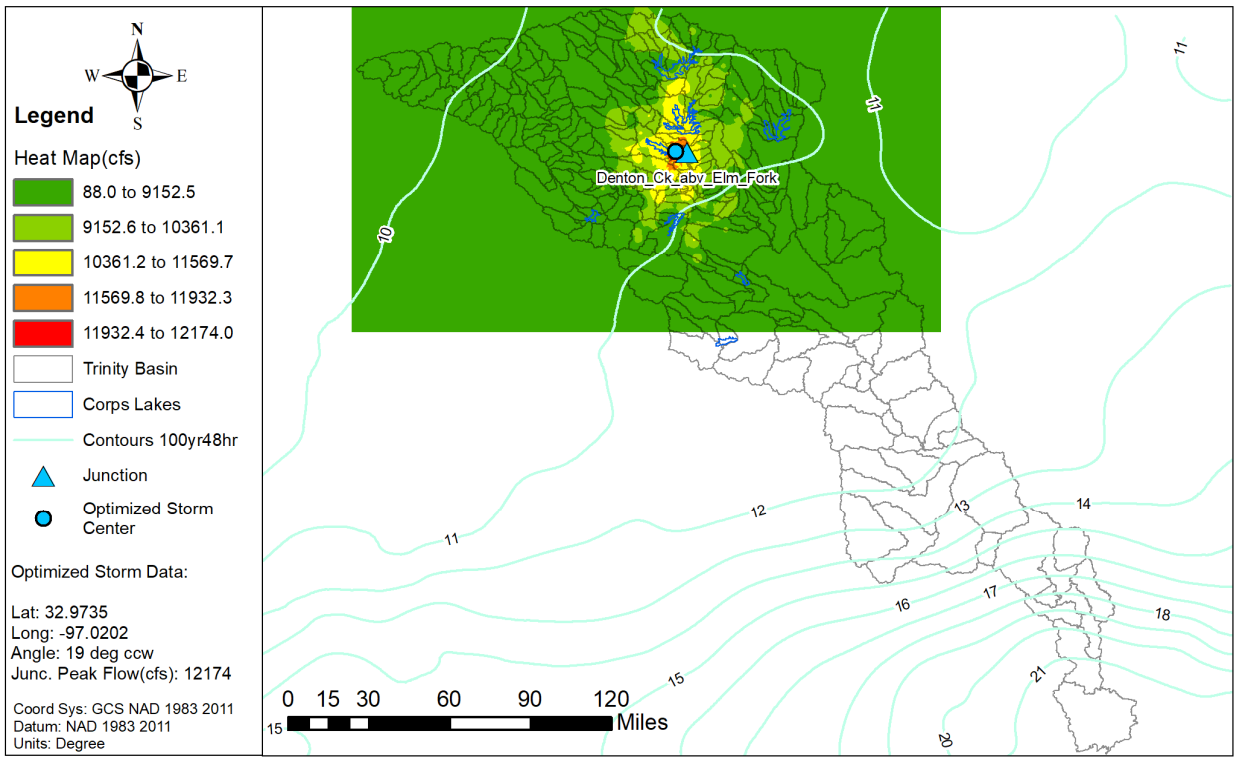


Figure 63a: Elliptical Storm Heat Map for the Denton Creek above the Elm Fork Trinity River

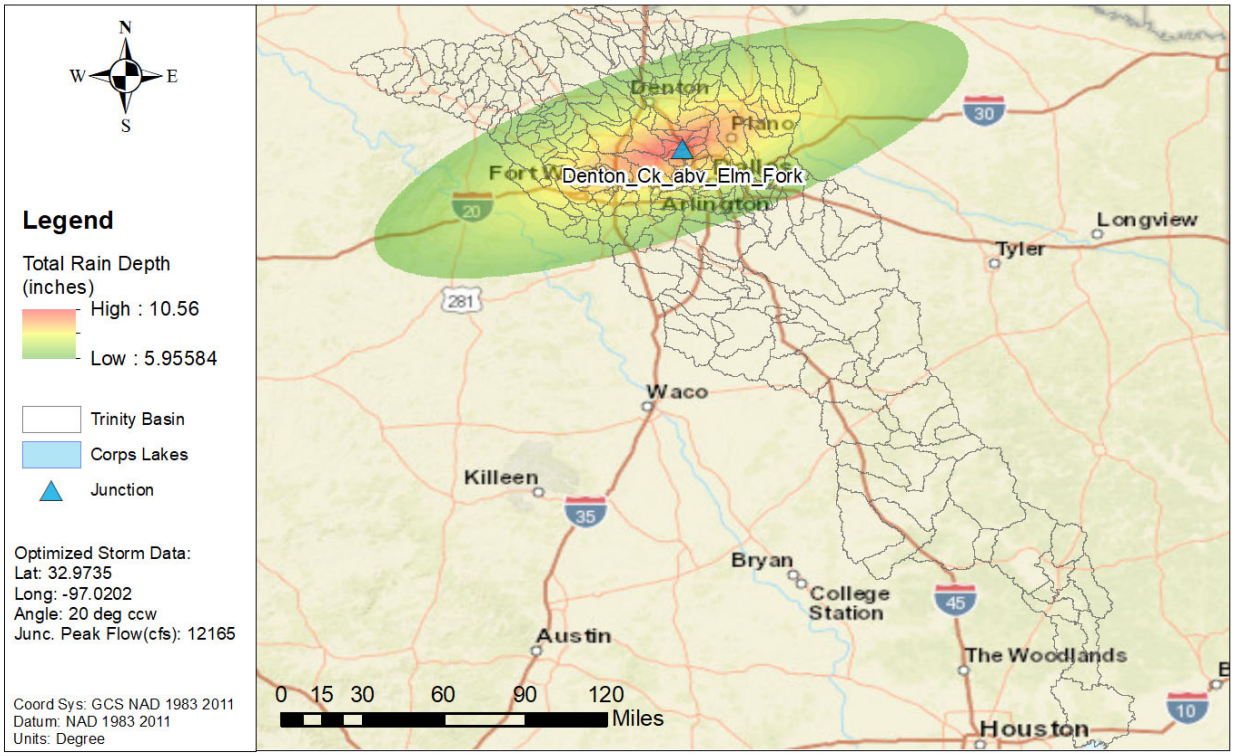


Figure 63b: NA14 1% AEP Elliptical Storm for the Denton Creek above the Elm Fork Trinity River

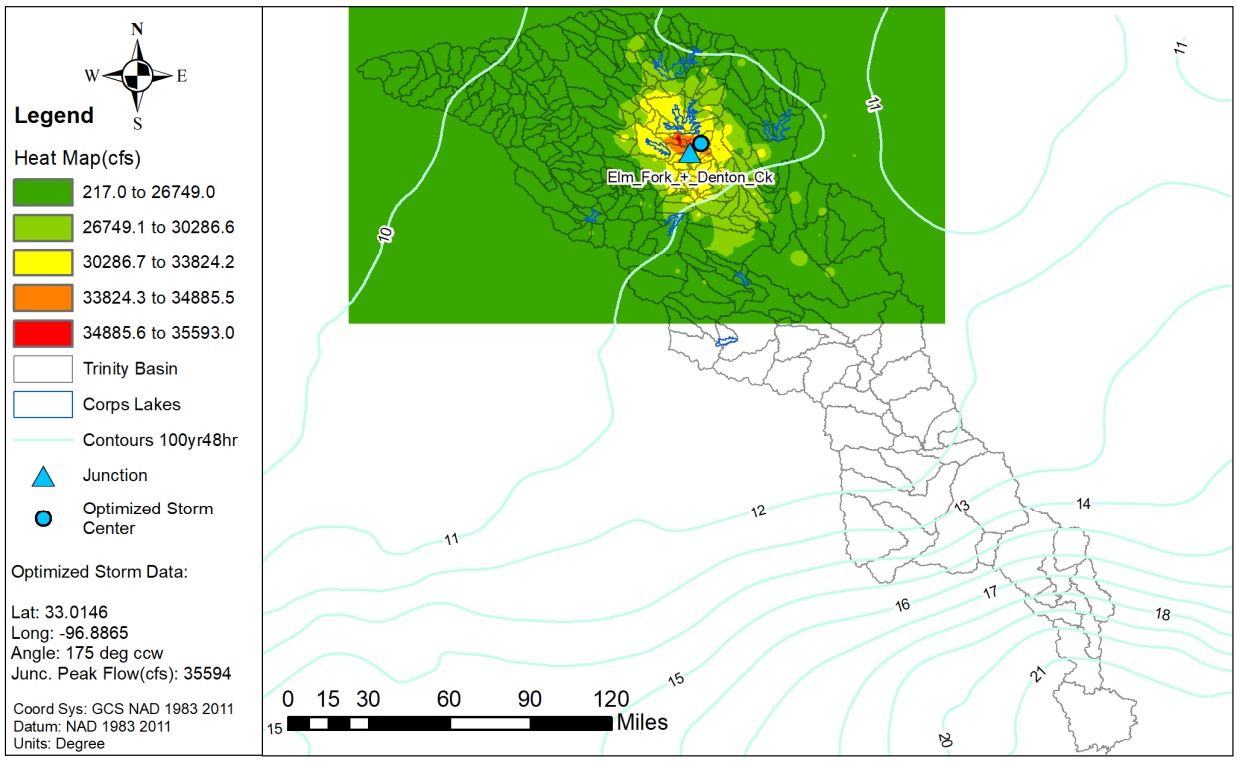


Figure 64a: Elliptical Storm Heat Map for the Elm Fork Trinity River near Carrollton USGS gage

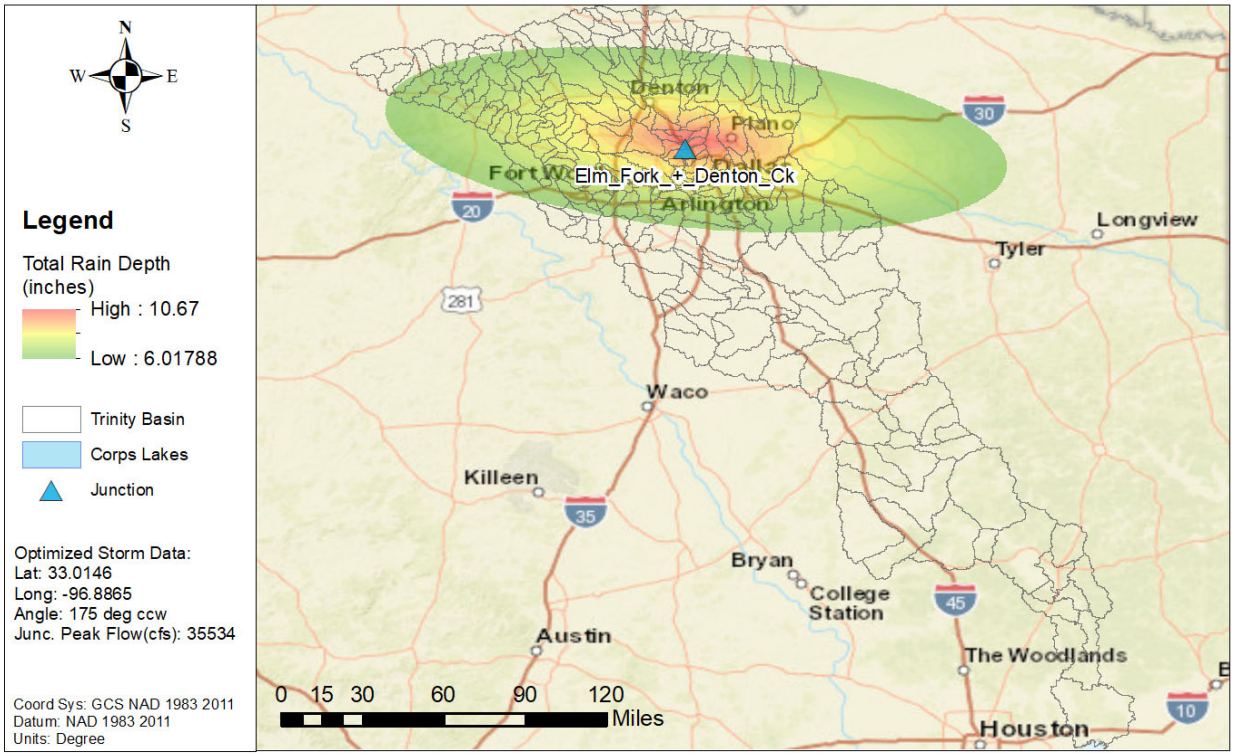


Figure 64b: NA14 1% AEP Elliptical Storm for the Elm Fork Trinity River near Carrollton USGS gage

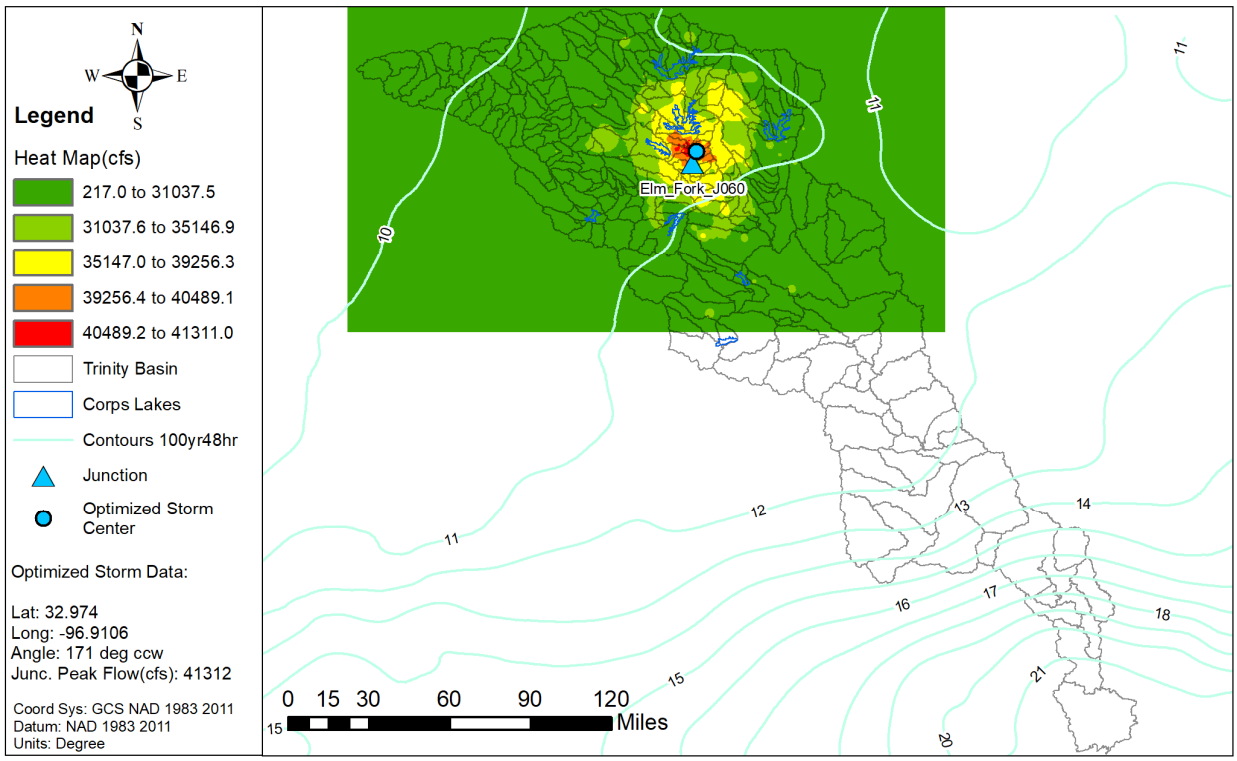


Figure 65a: Elliptical Storm Heat Map for the Elm Fork Trinity River at Interstate 635

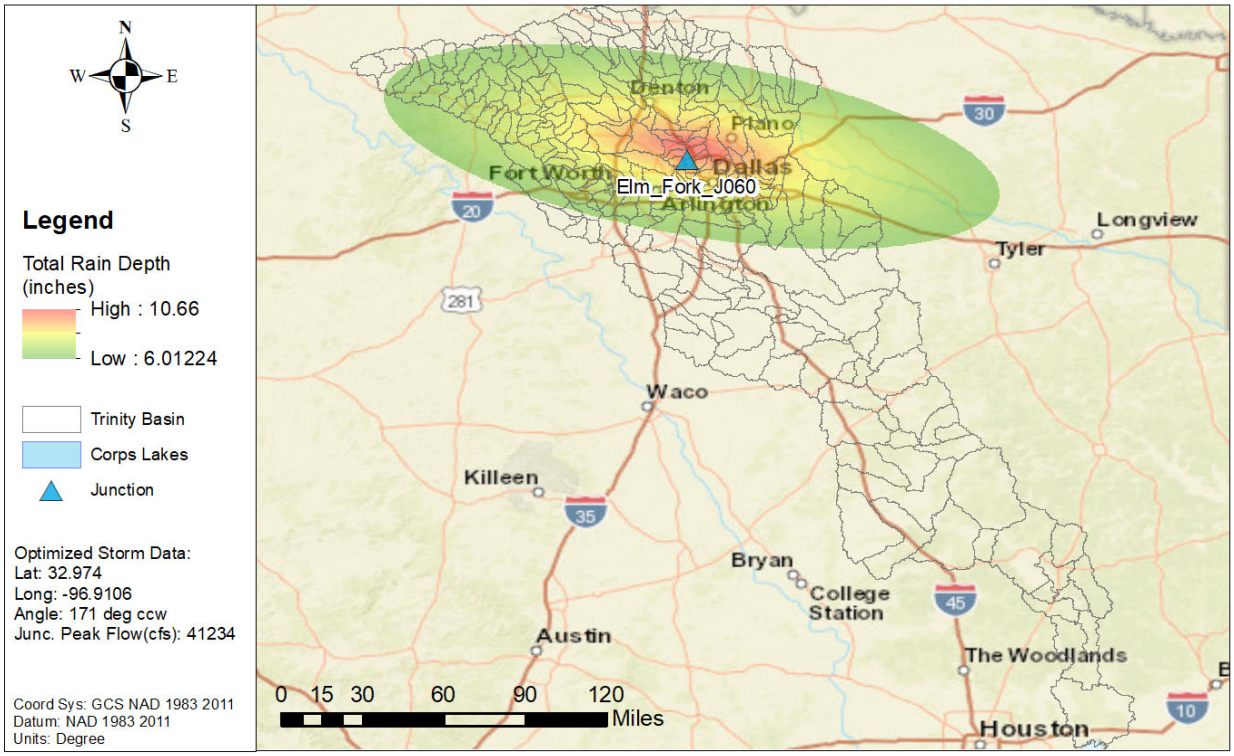


Figure 65b: NA14 1% AEP Elliptical Storm for the Elm Fork Trinity River at Interstate 635

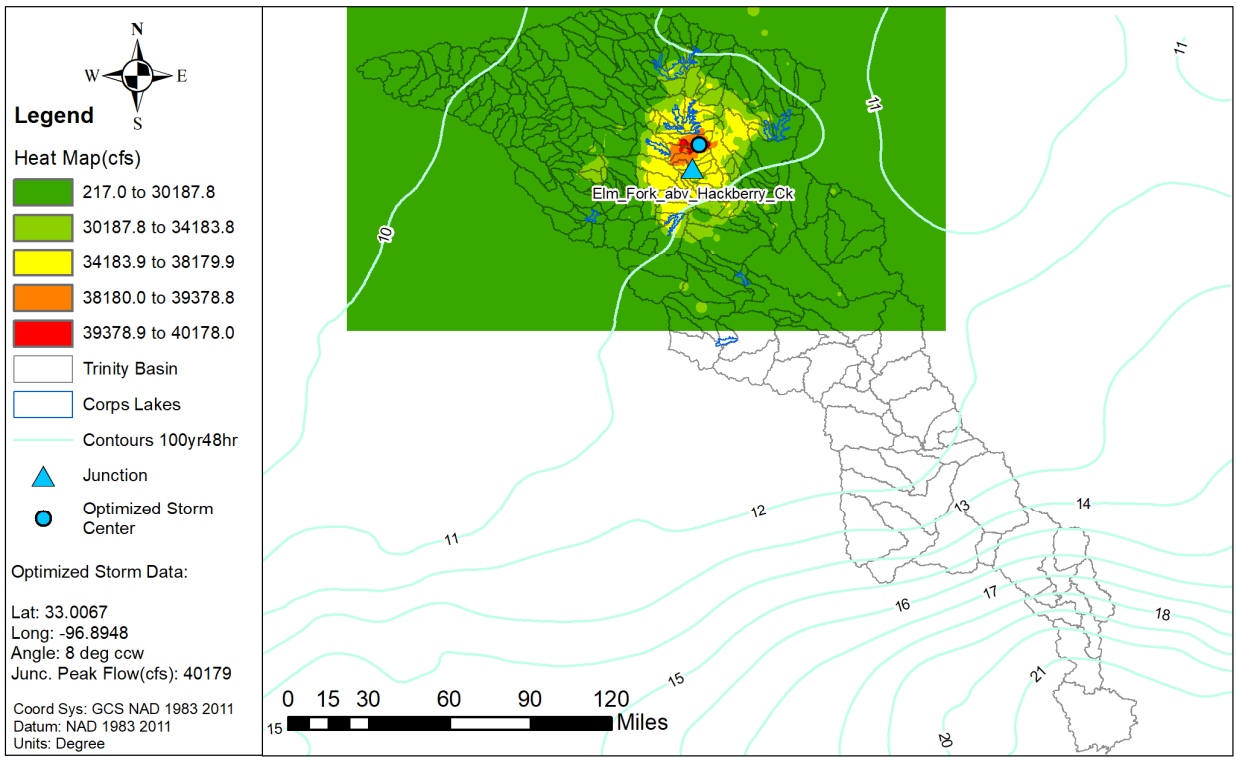


Figure 66a: Elliptical Storm Heat Map for the Elm Fork Trinity River above Hackleberry Creek

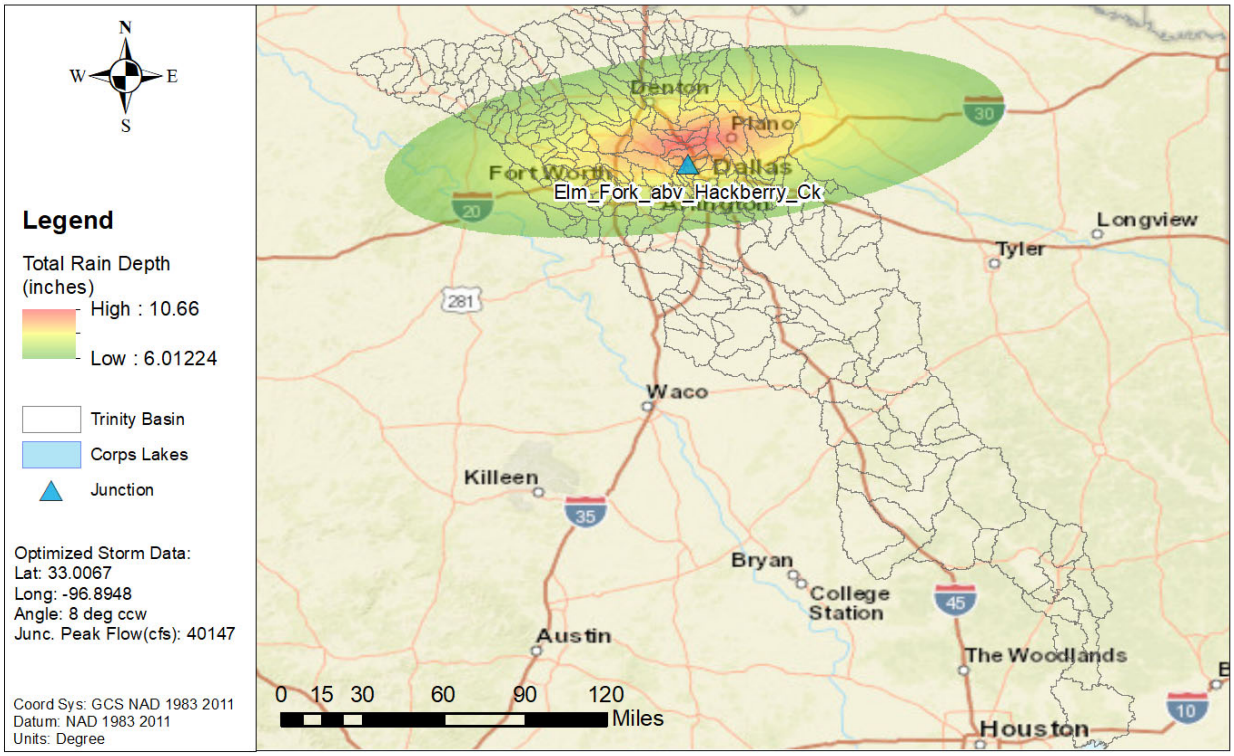


Figure 66b: NA14 1% AEP Elliptical Storm for the Elm Fork Trinity River above Hackleberry Creek

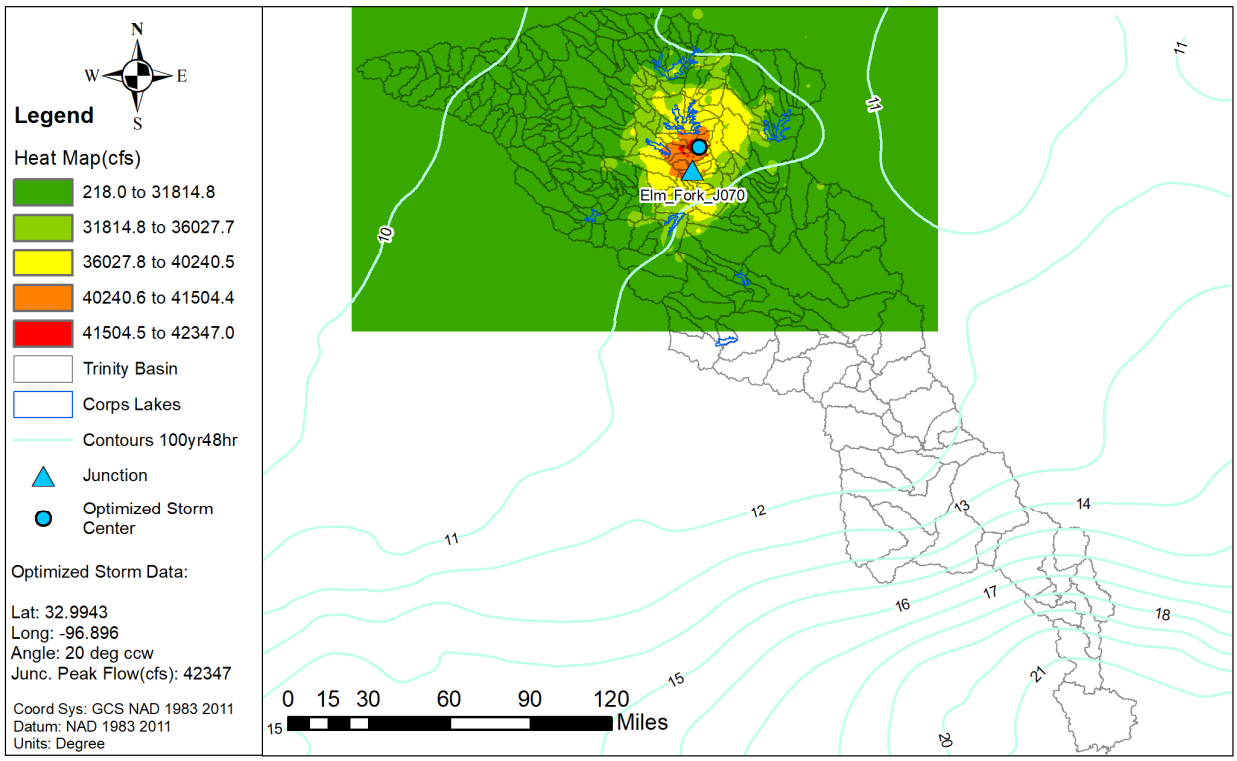


Figure 67a: Elliptical Storm Heat Map for the Elm Fk Trinity Rv at Spur 348 in Irving; TX USGS gage

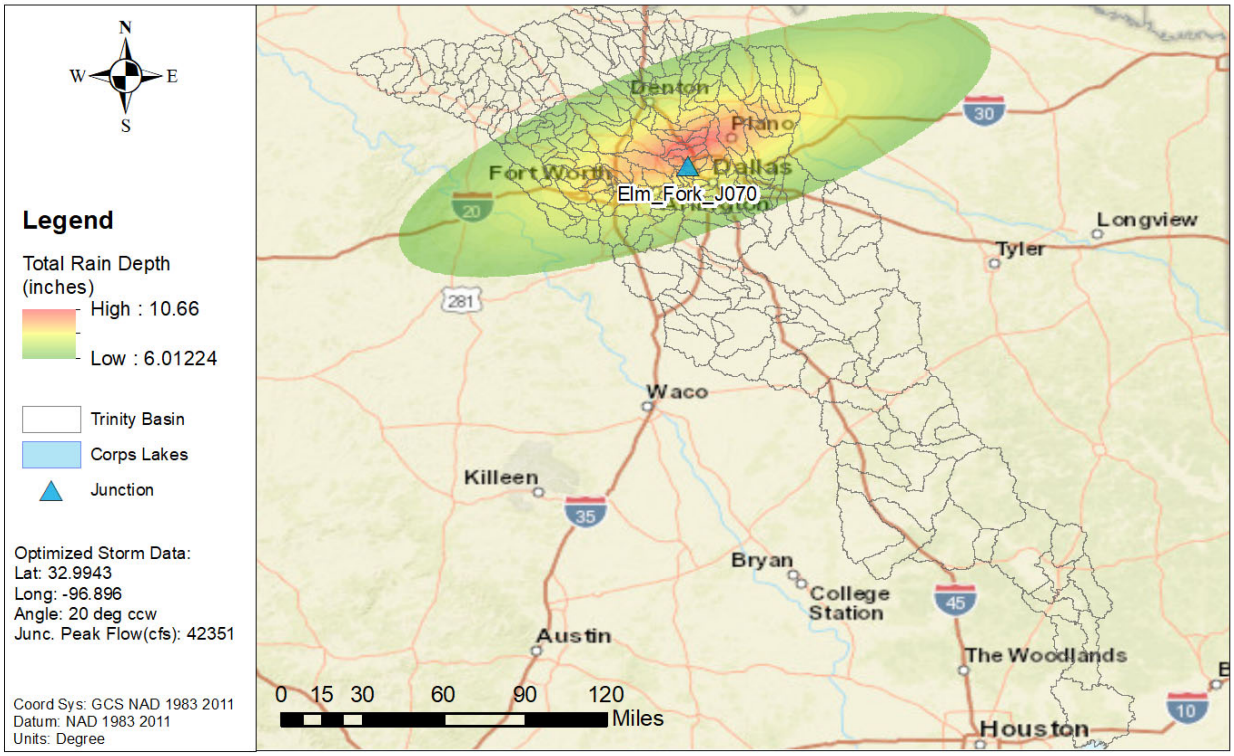


Figure 67b: NA14 1% AEP Elliptical Storm for the Elm Fk Trinity Rv at Spur 348 in Irving; TX USGS gage

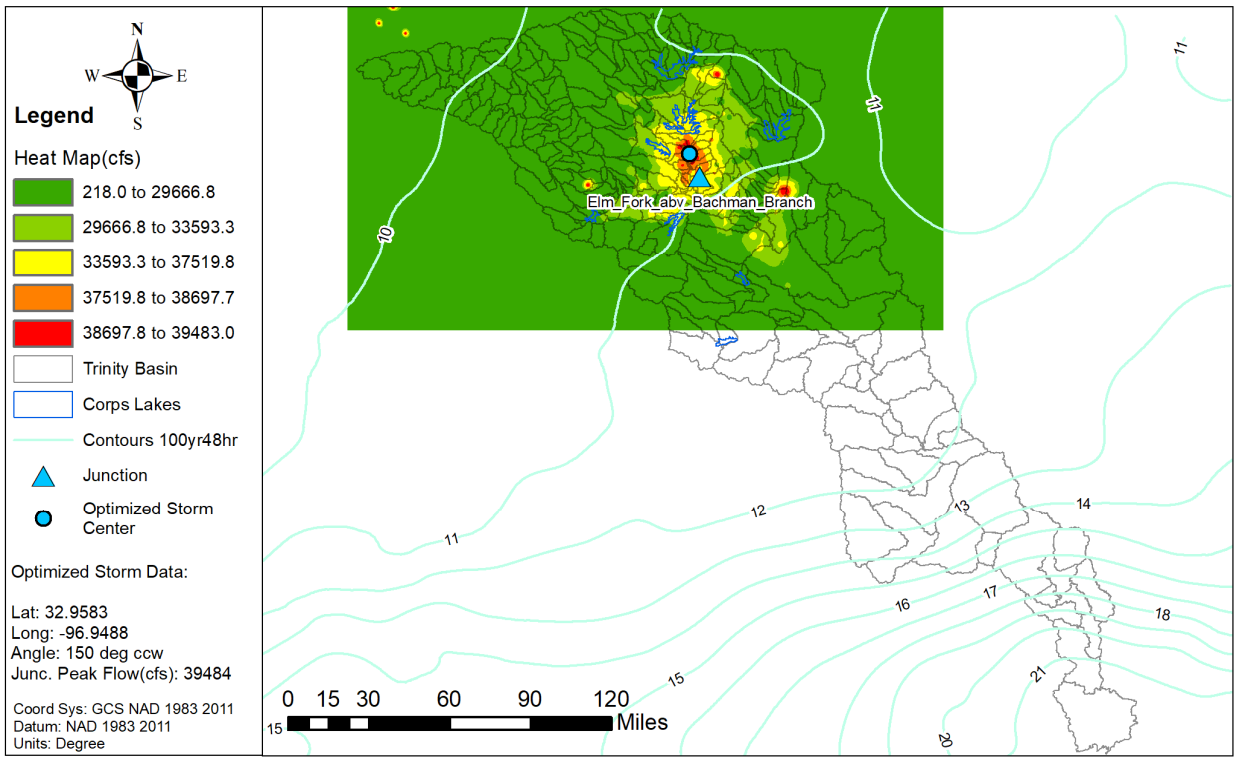


Figure 68a: Elliptical Storm Heat Map for the Elm Fork Trinity River above Bachman Branch

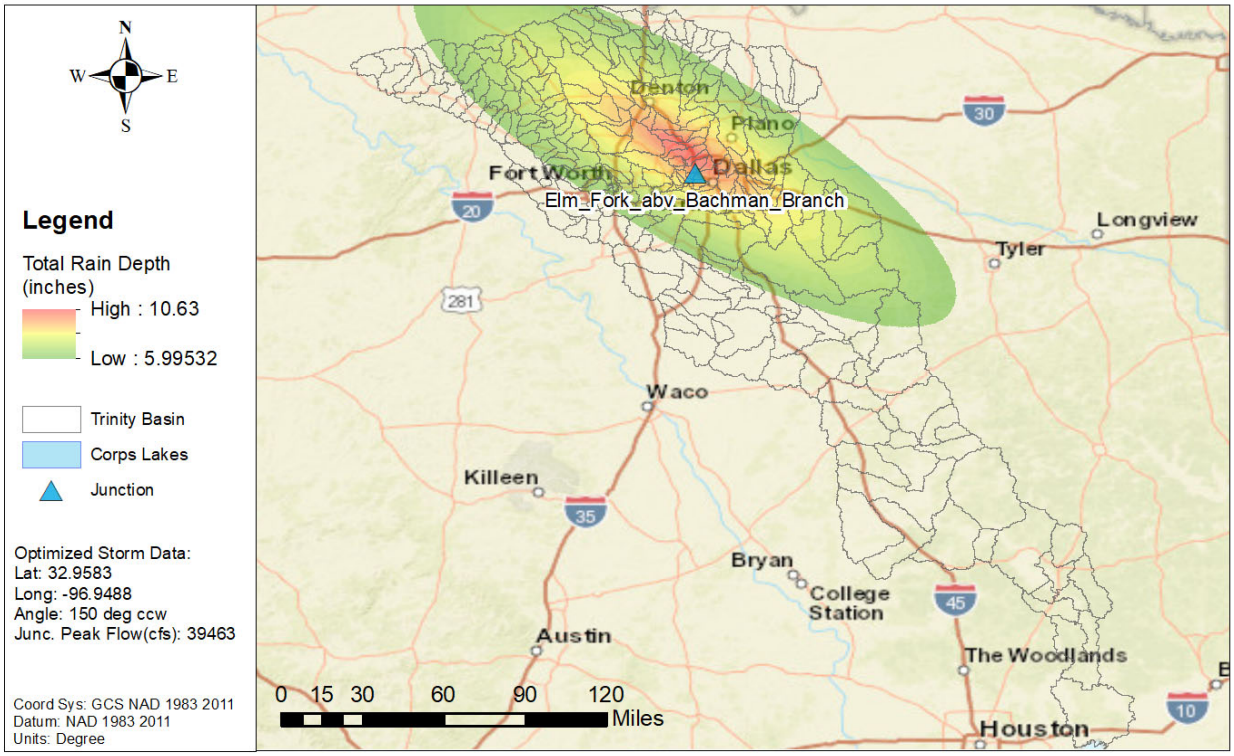


Figure 68b: NA14 1% AEP Elliptical Storm for the Elm Fork Trinity River above Bachman Branch

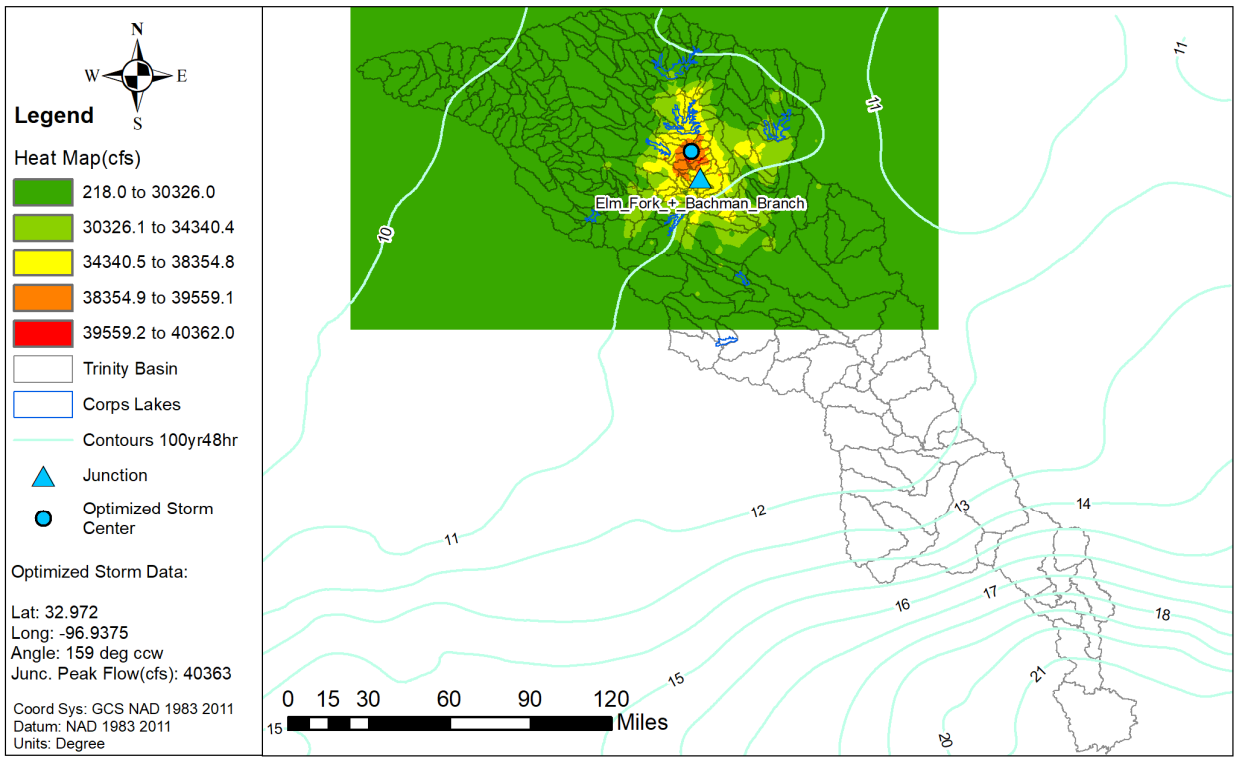


Figure 69a: Elliptical Storm Heat Map for the Elm Fork Trinity River below Bachman Branch

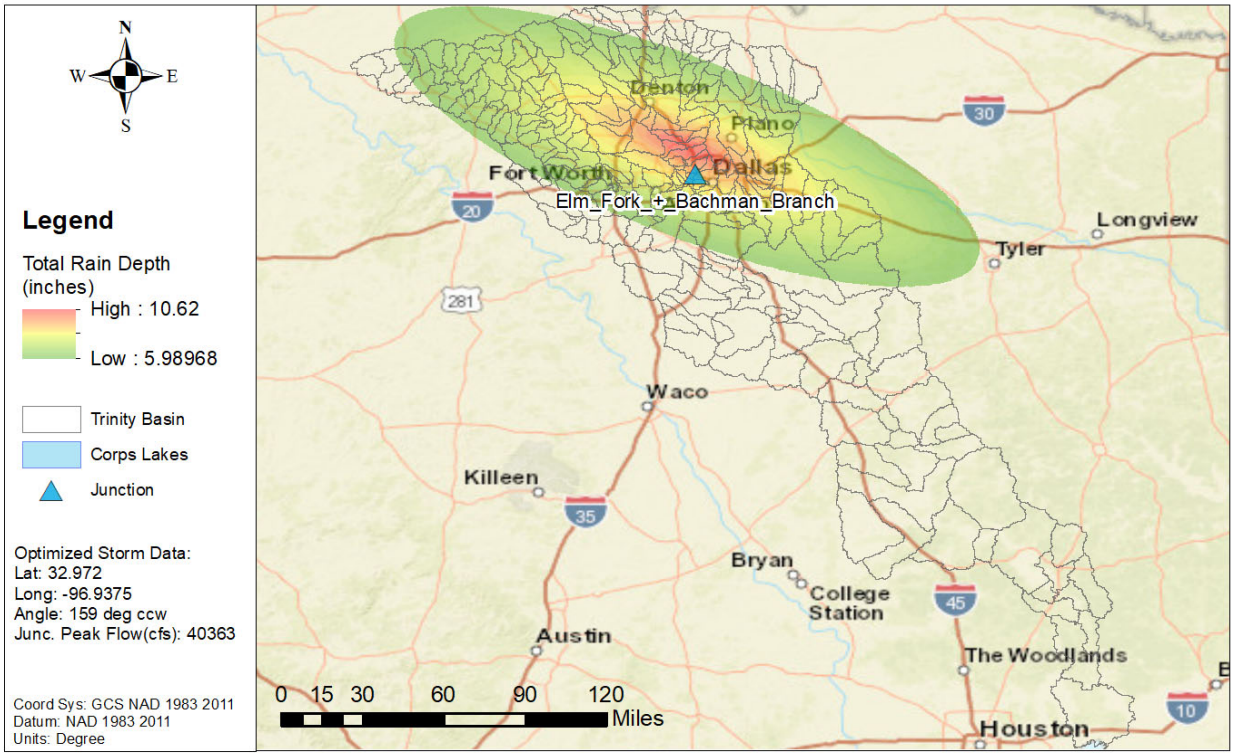


Figure 69b: NA14 1% AEP Elliptical Storm for the Elm Fork Trinity River below Bachman Branch

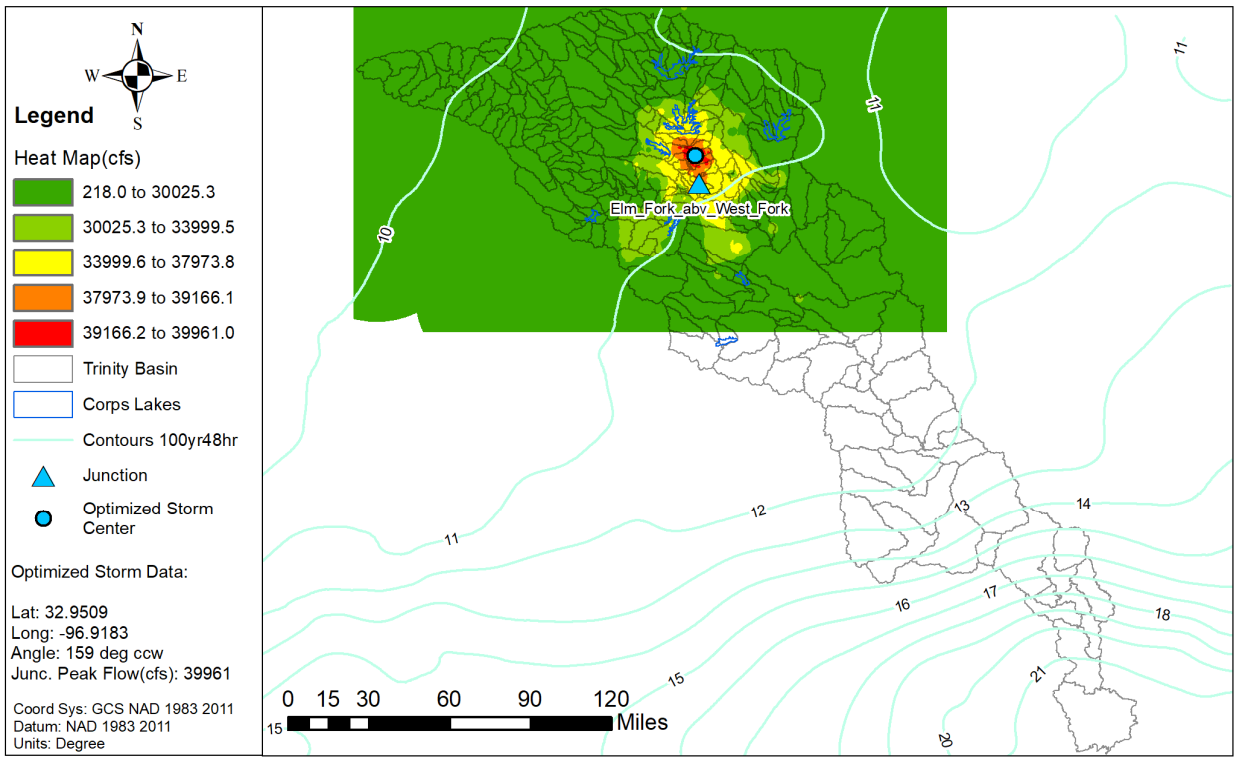


Figure 70a: Elliptical Storm Heat Map for the Elm Fork Trinity River above the West Fork Trinity River

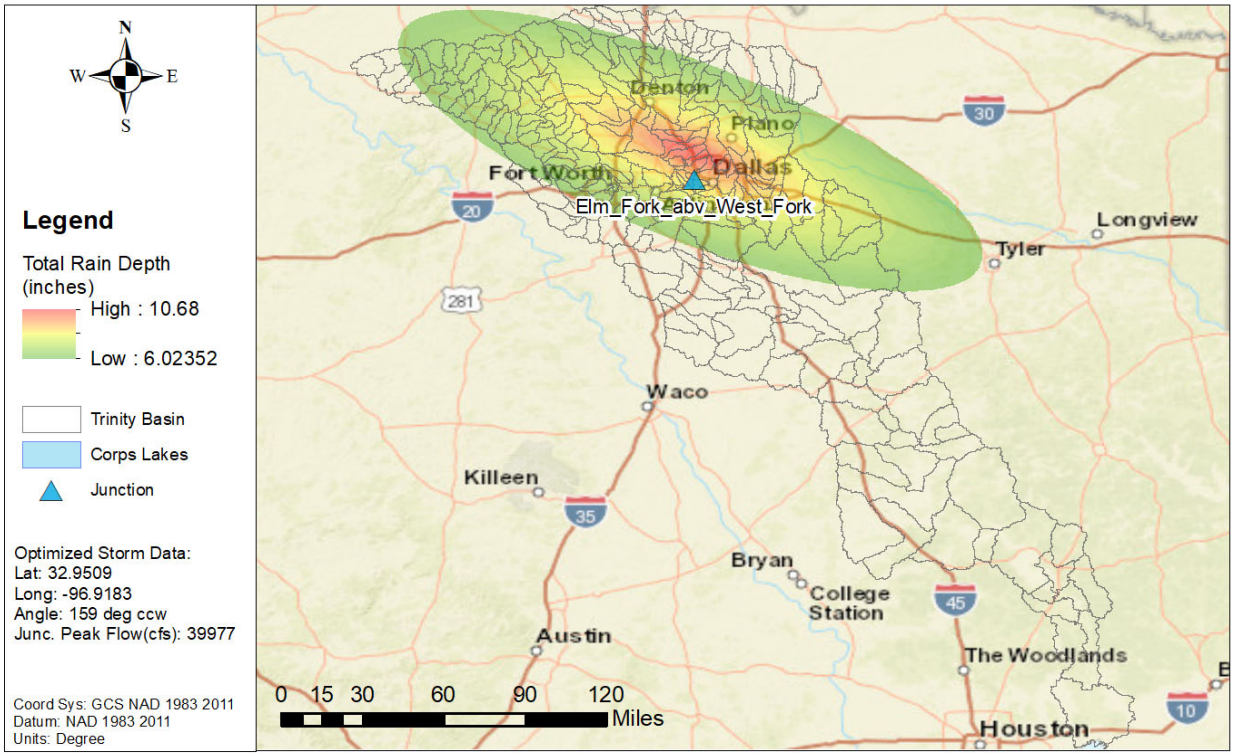


Figure 70b: NA14 1% AEP Elliptical Storm for the Elm Fork Trinity River above the West Fork Trinity River

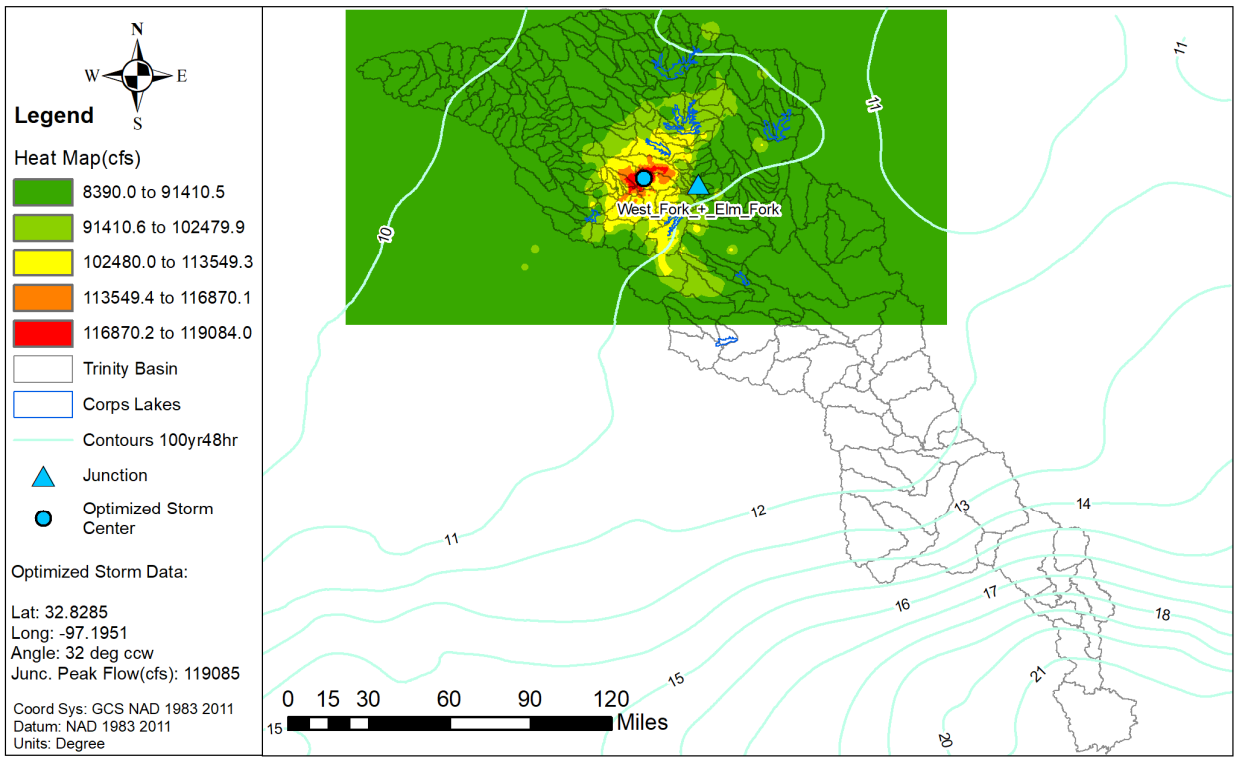


Figure 71a: Elliptical Storm Heat Map for the Trinity River below the West Fork and Elm Fork confluence

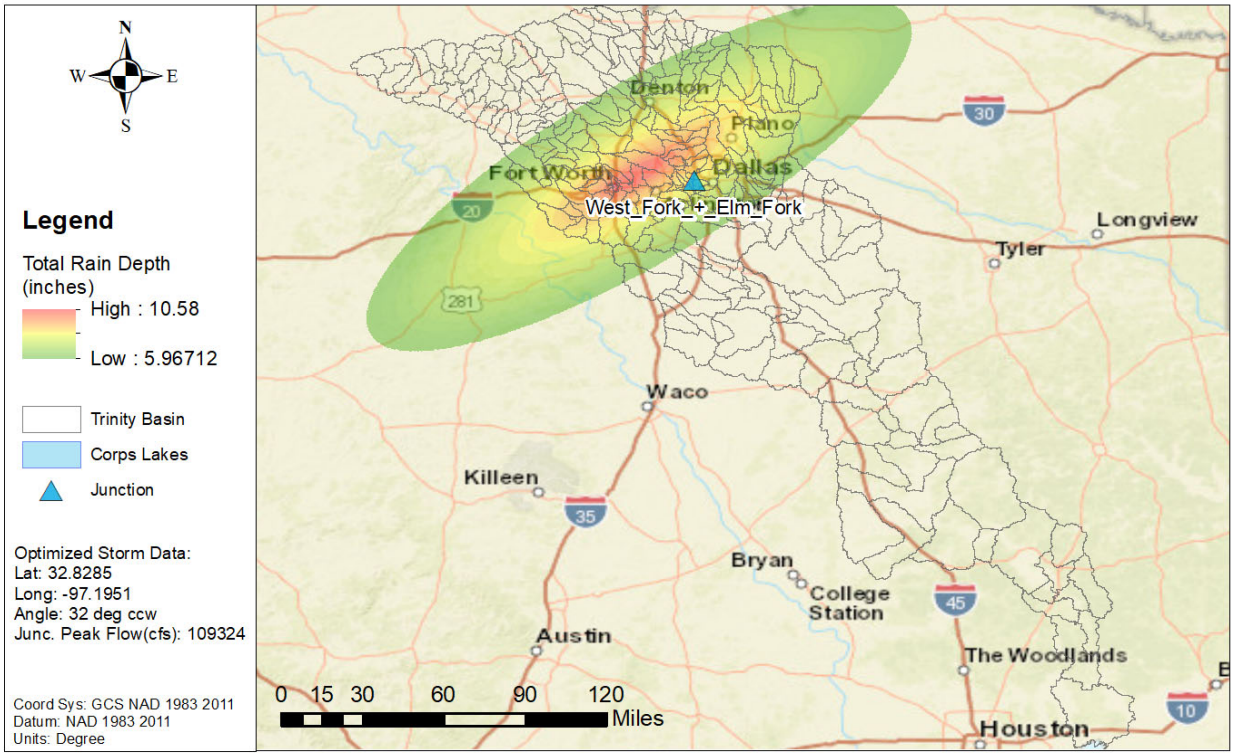


Figure 71b: NA14 1% AEP Elliptical Storm for the Trinity River below the West Fork & Elm Fork confluence

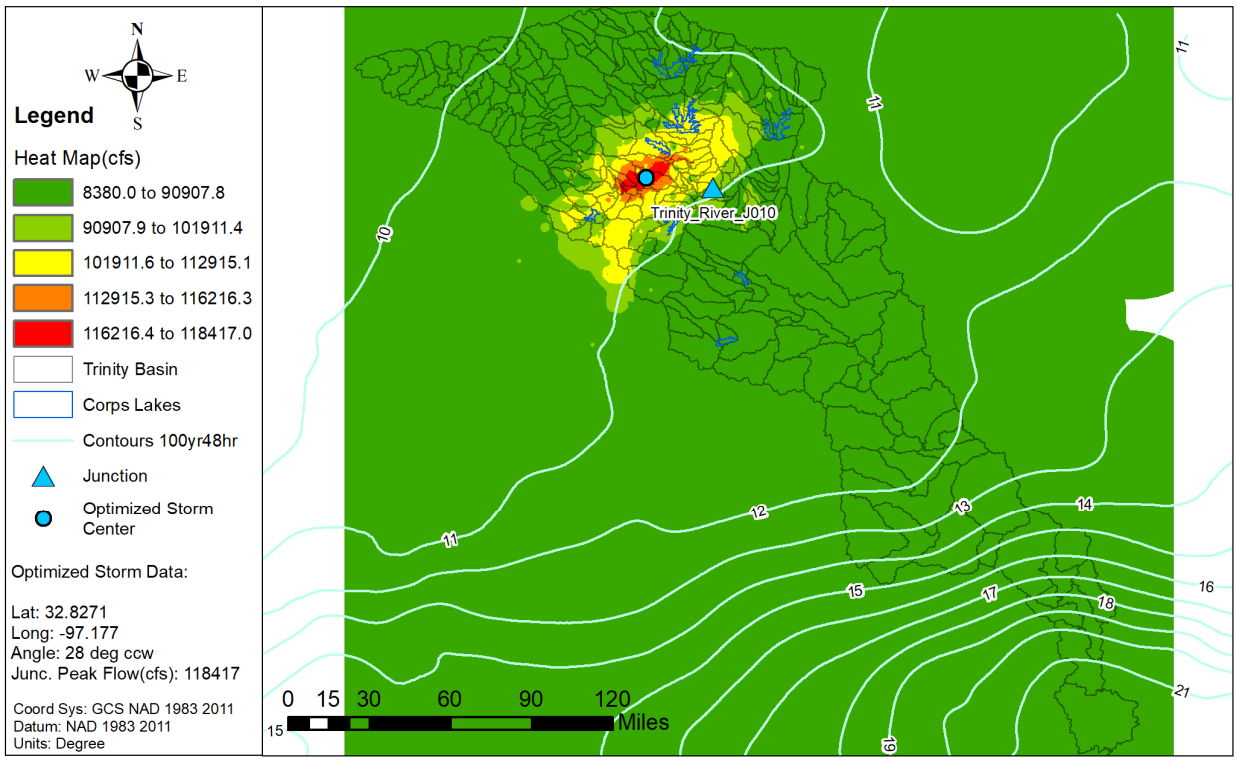


Figure 72a: Elliptical Storm Heat Map for the Trinity River at Dallas, TX USGS gage

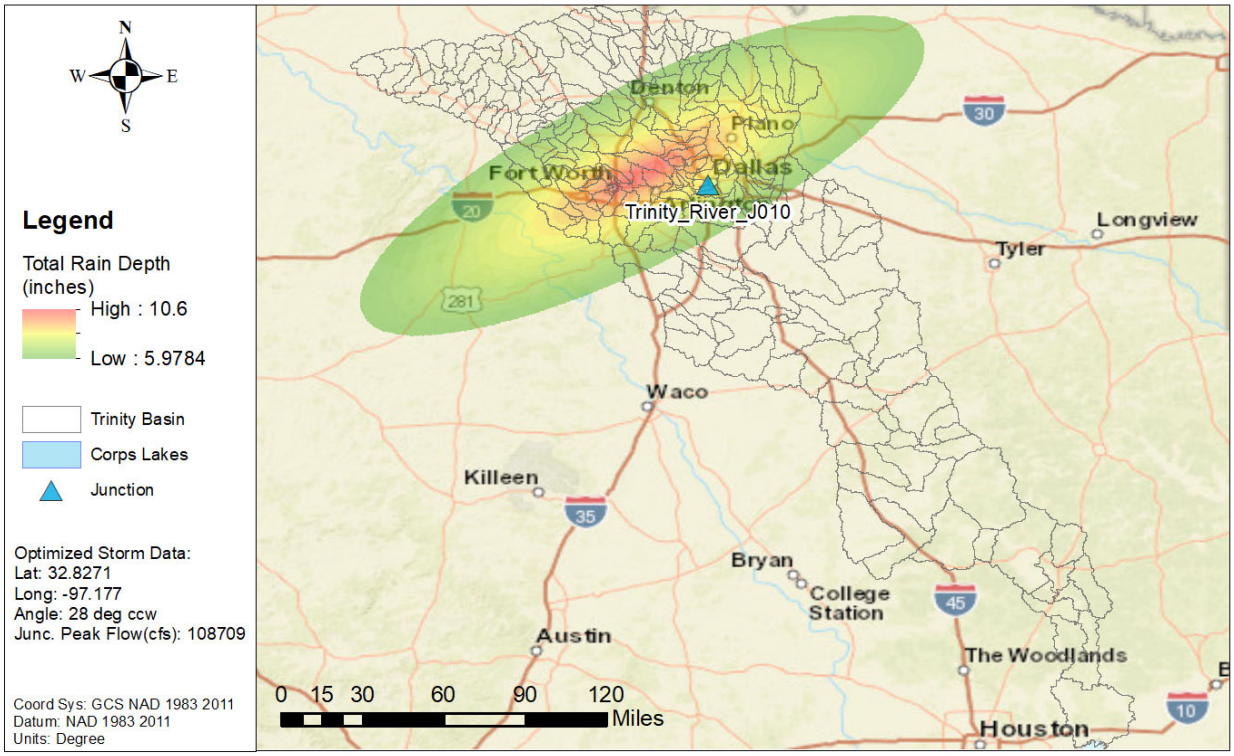


Figure 72b: NA14 1% AEP Elliptical Storm for the Trinity River at Dallas, TX USGS gage

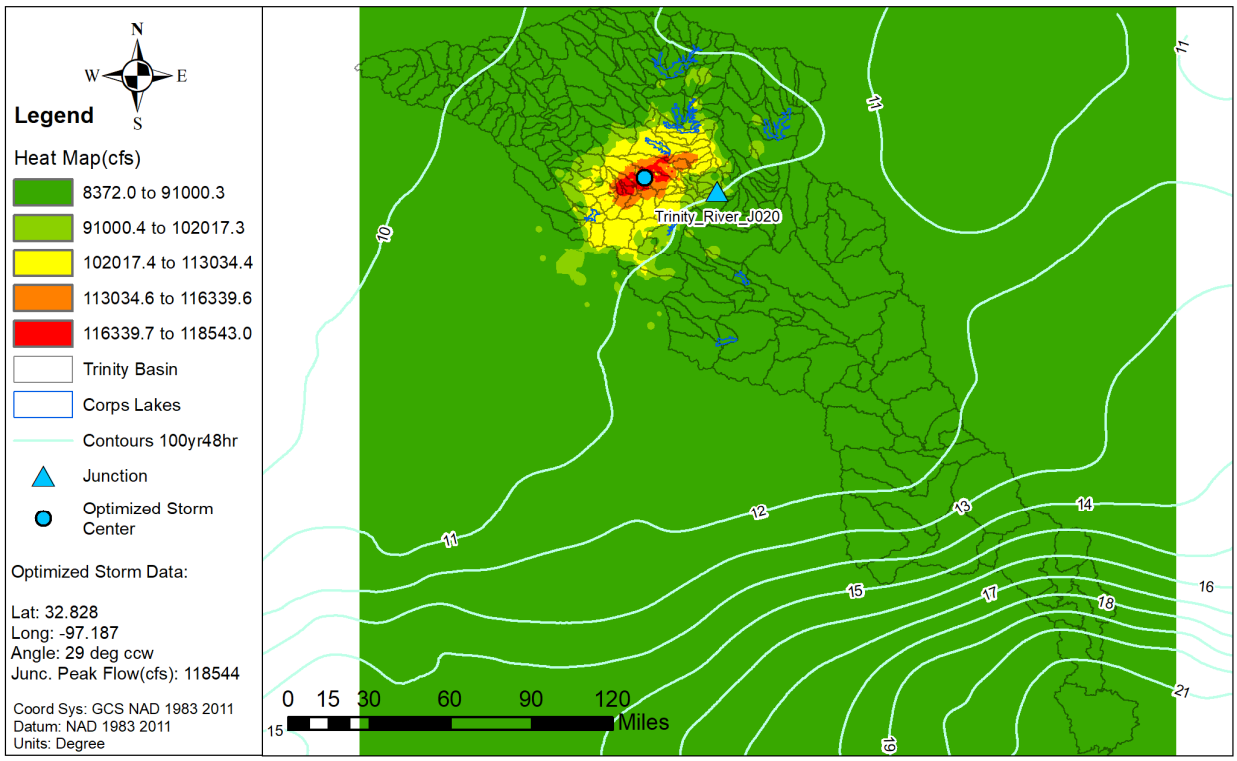


Figure 73a: Elliptical Storm Heat Map for the Trinity River at the Corinth Street bridge in Dallas, TX

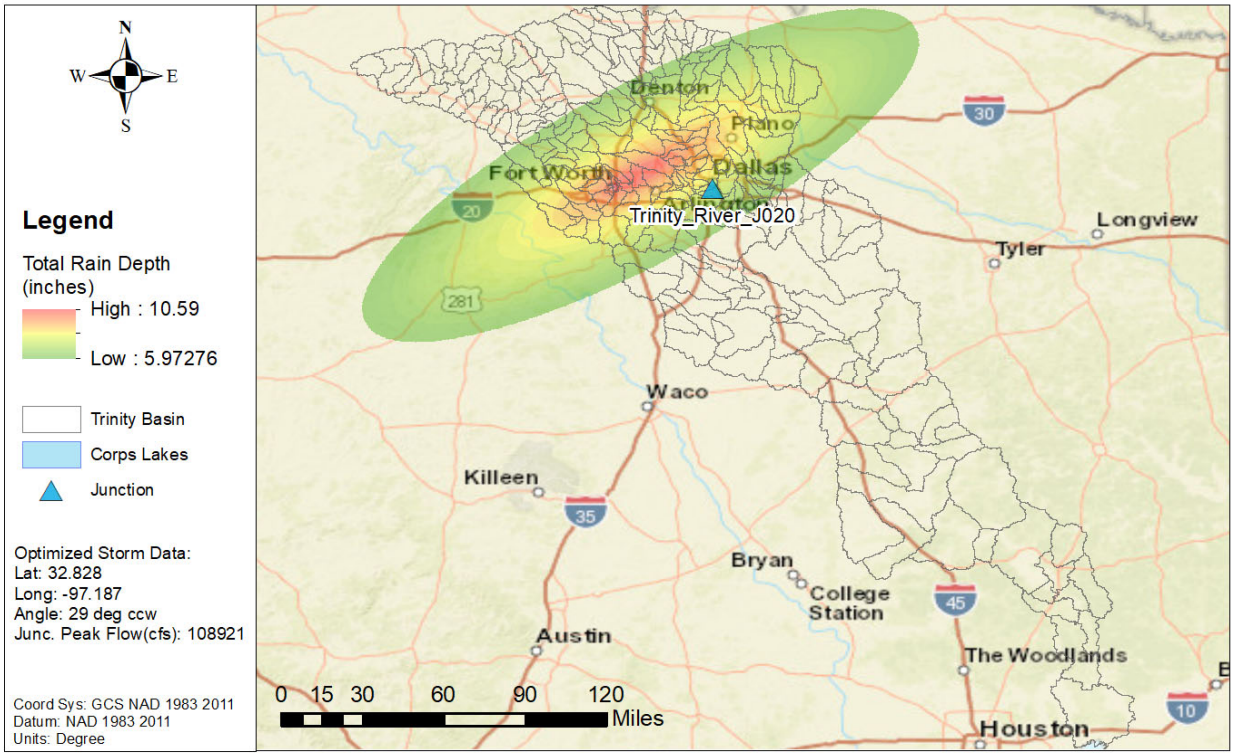


Figure 73b: NA14 1% AEP Elliptical Storm for the Trinity River at the Corinth Street bridge in Dallas, TX

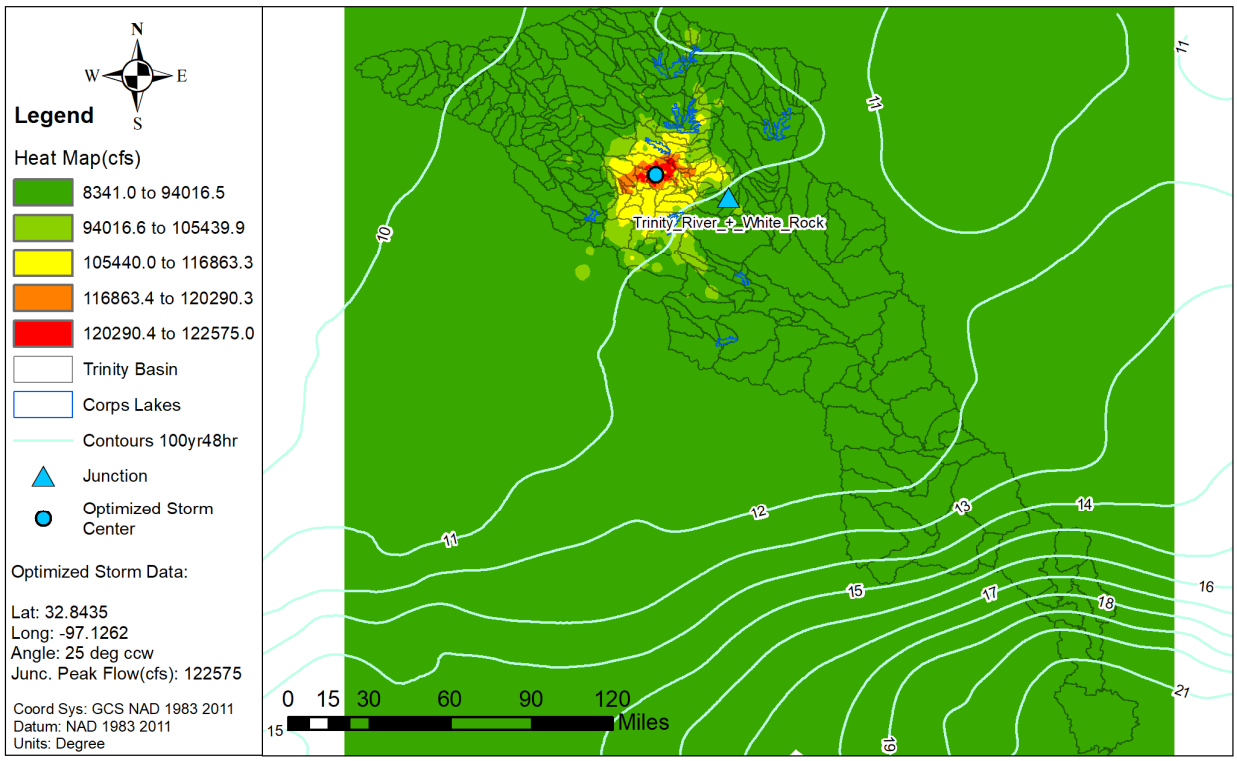


Figure 74a: Elliptical Storm Heat Map for the Trinity River below White Rock Creek

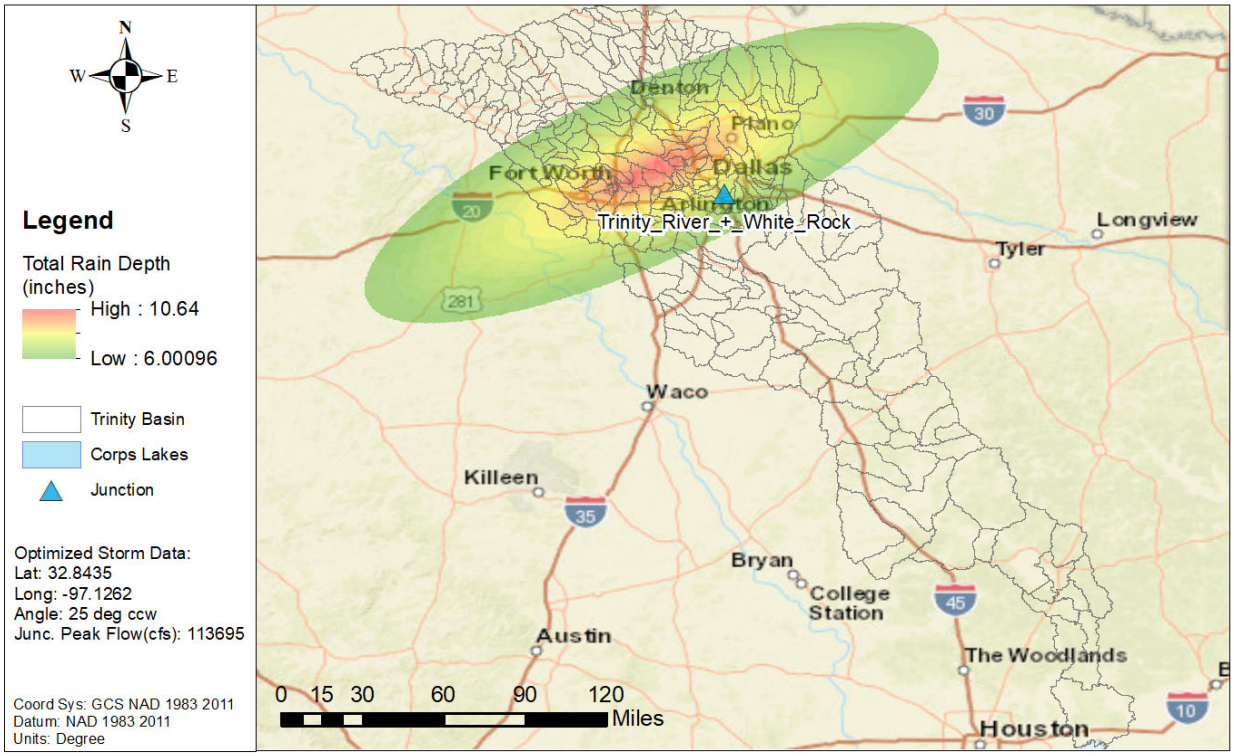


Figure 74b: NA14 1% AEP Elliptical Storm for the Trinity River below White Rock Creek

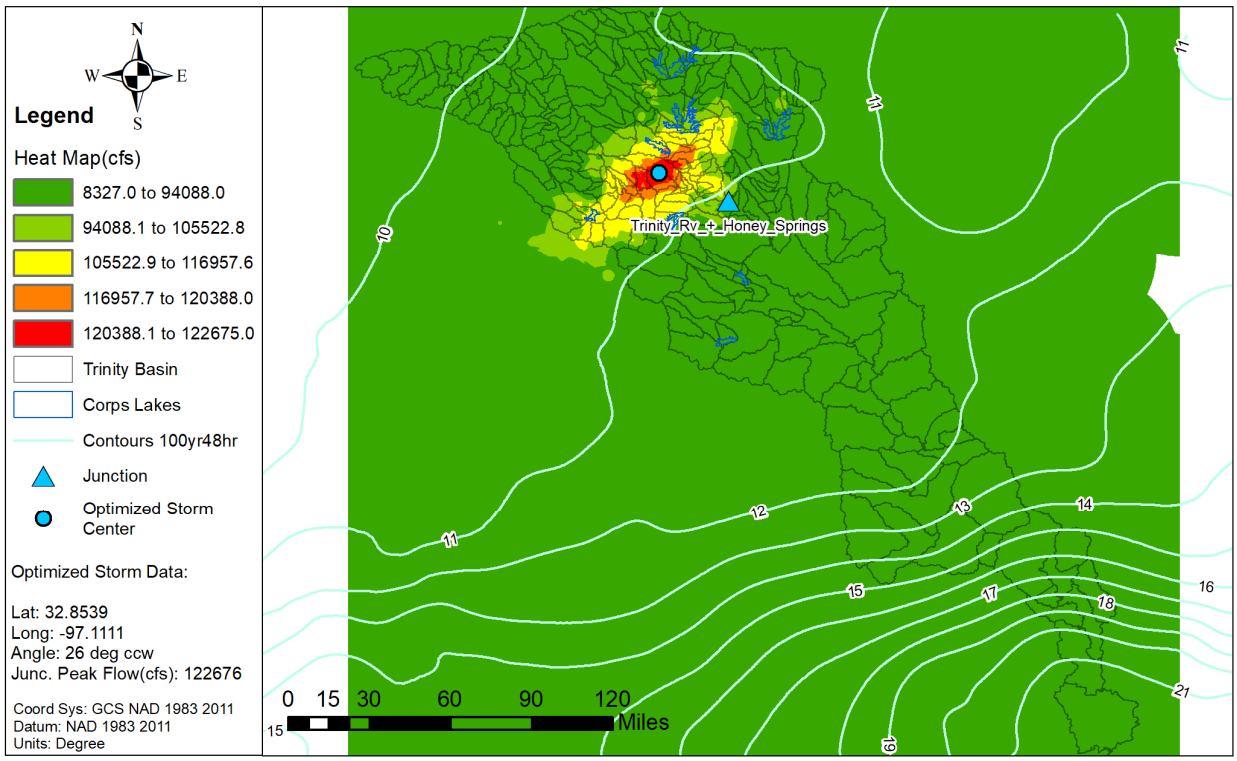


Figure 75a: Elliptical Storm Heat Map for the Trinity River below Honey Springs Branch

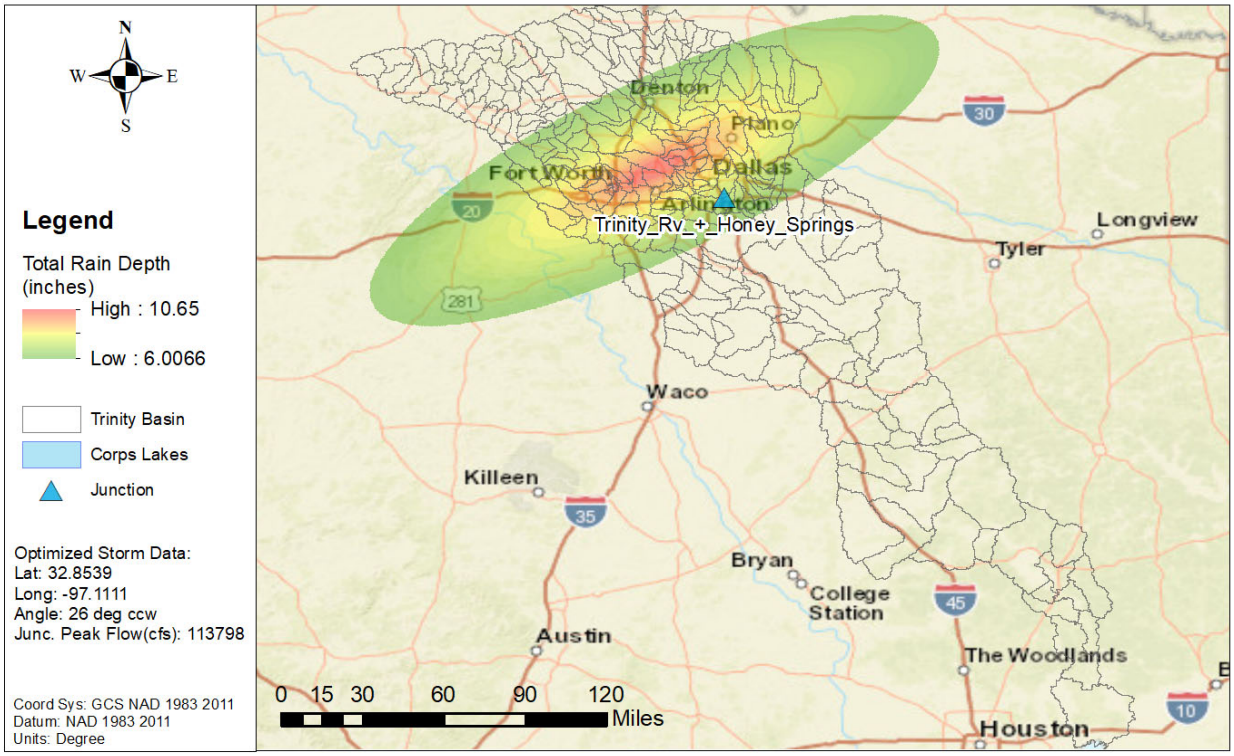


Figure 75b: NA14 1% AEP Elliptical Storm for the Trinity River below Honey Springs Branch

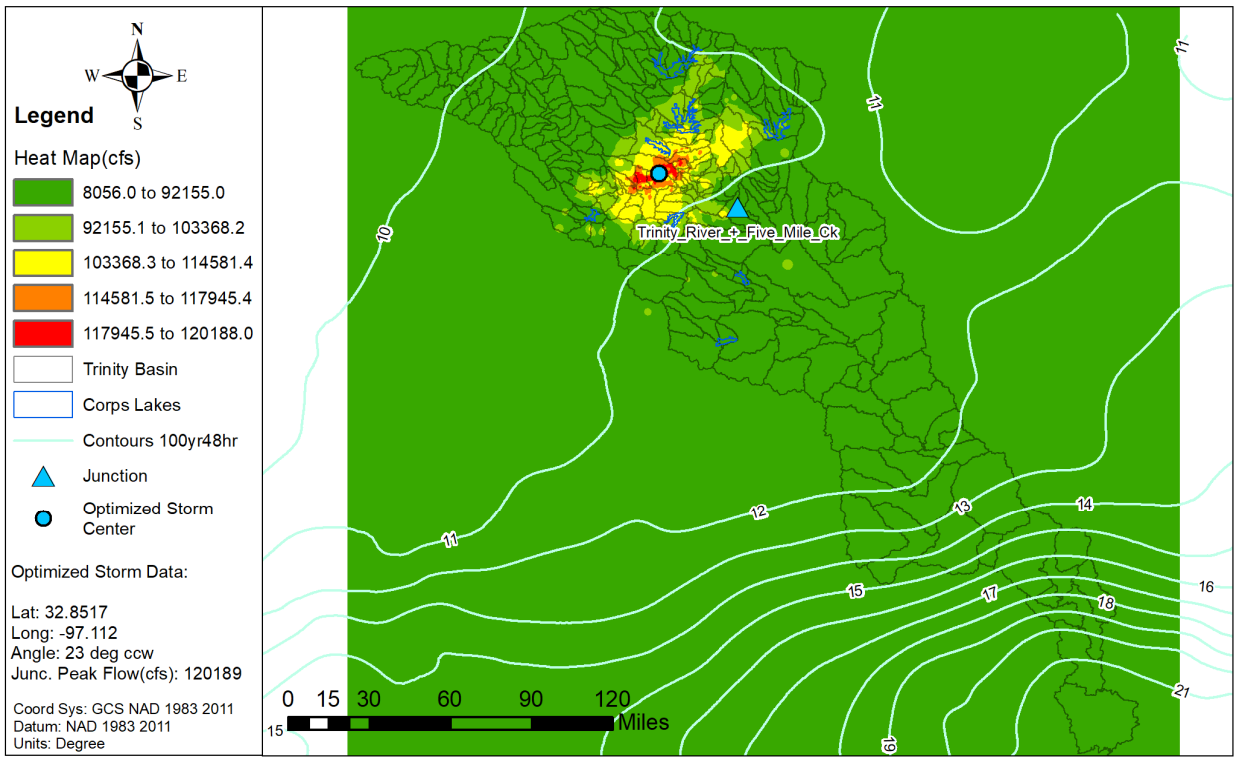


Figure 76a: Elliptical Storm Heat Map for the Trinity River below Five Mile Ceek

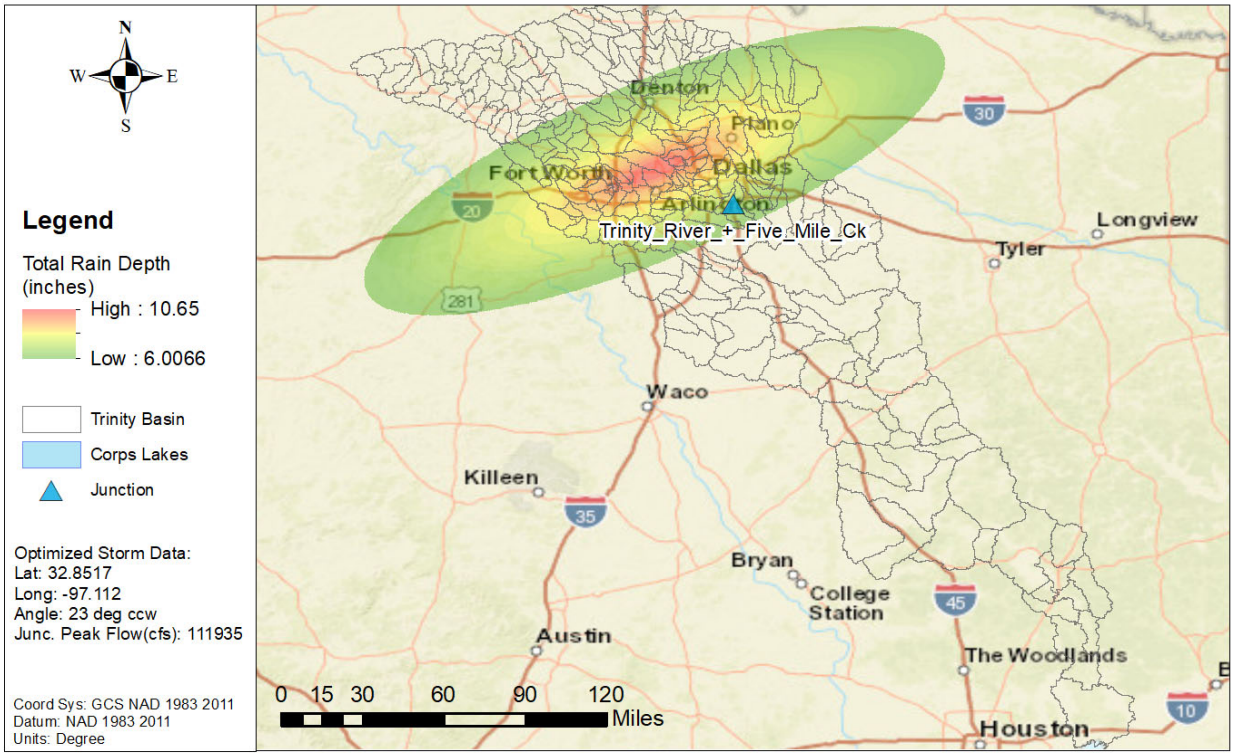


Figure 76b: NA14 1% AEP Elliptical Storm for the Trinity River below Five Mile Ceek

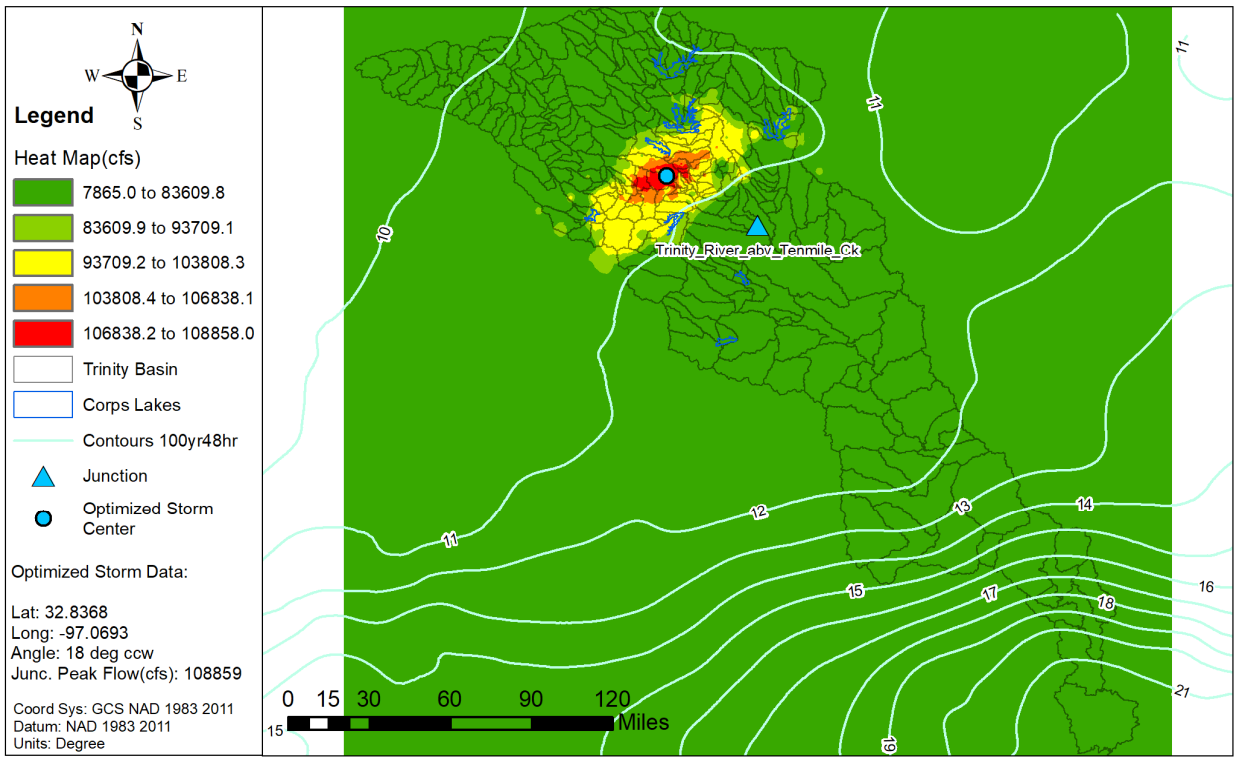


Figure 77a: Elliptical Storm Heat Map for the Trinity River above Ten Mile Creek

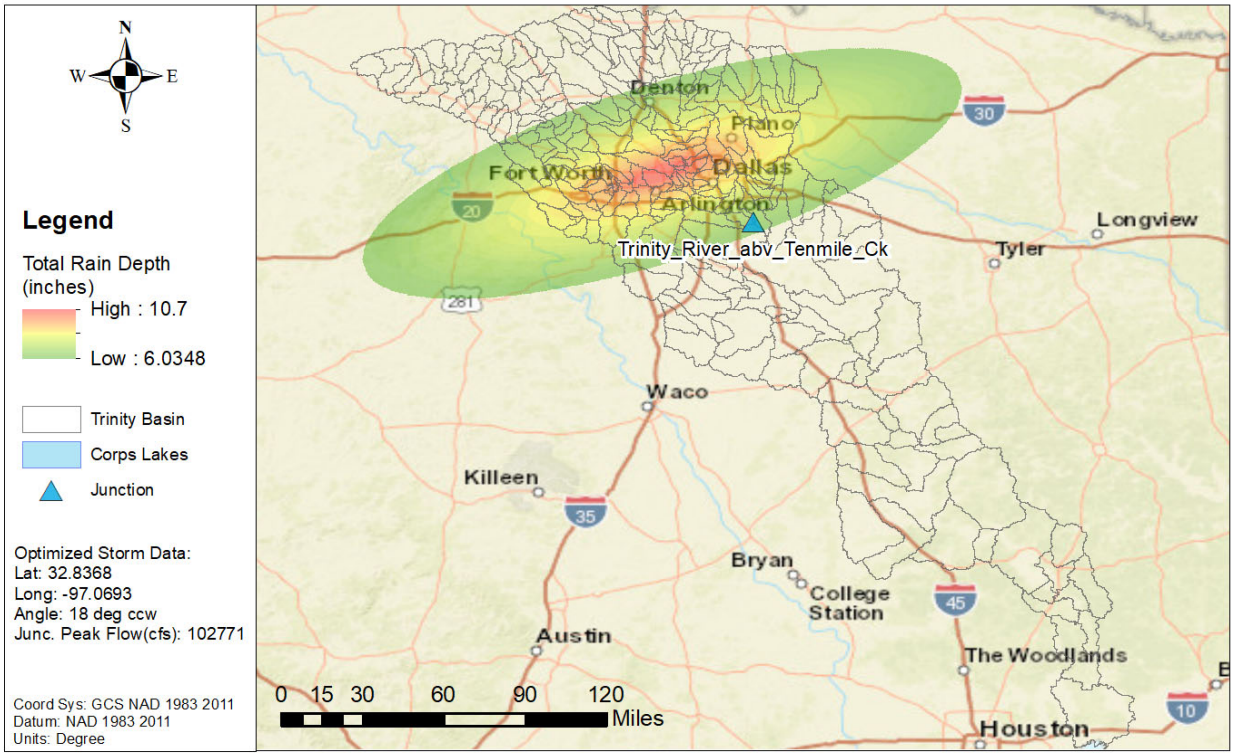


Figure 77b: NA14 1% AEP Elliptical Storm for the Trinity River above Ten Mile Creek

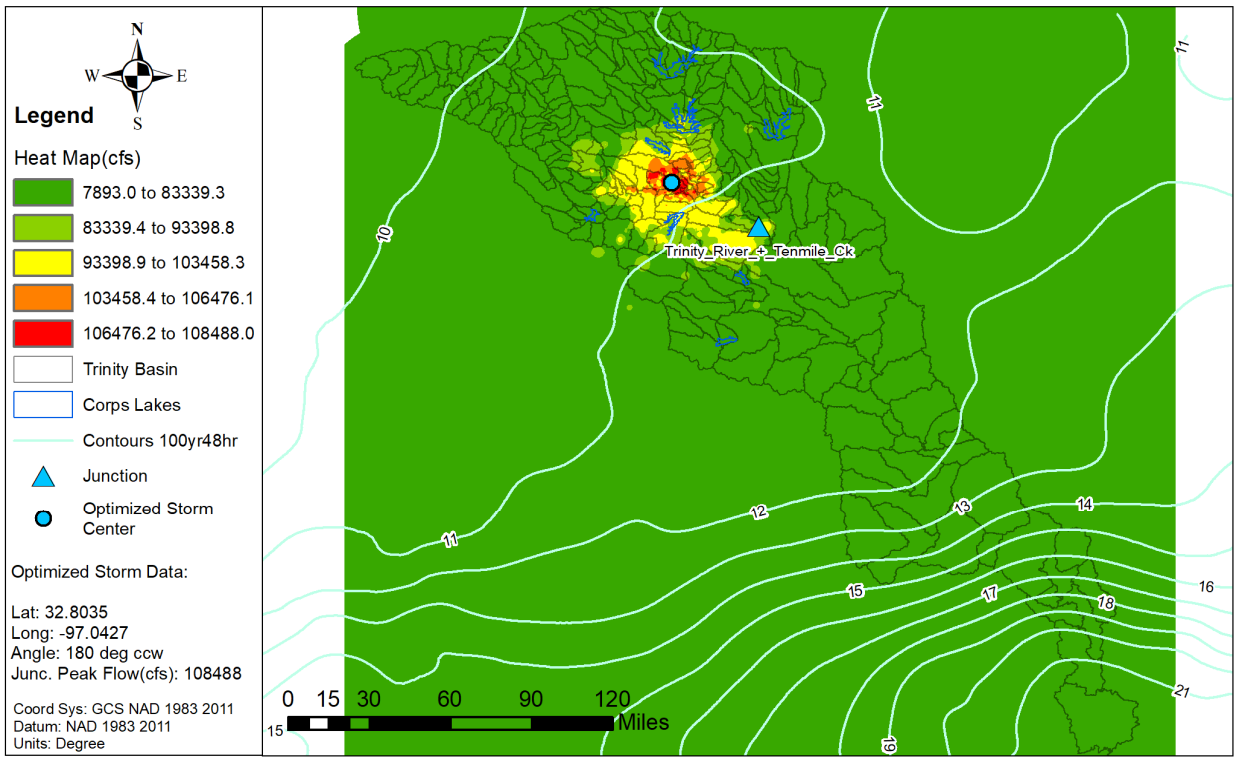


Figure 78a: Elliptical Storm Heat Map for the Trinity River below Ten Mile Creek

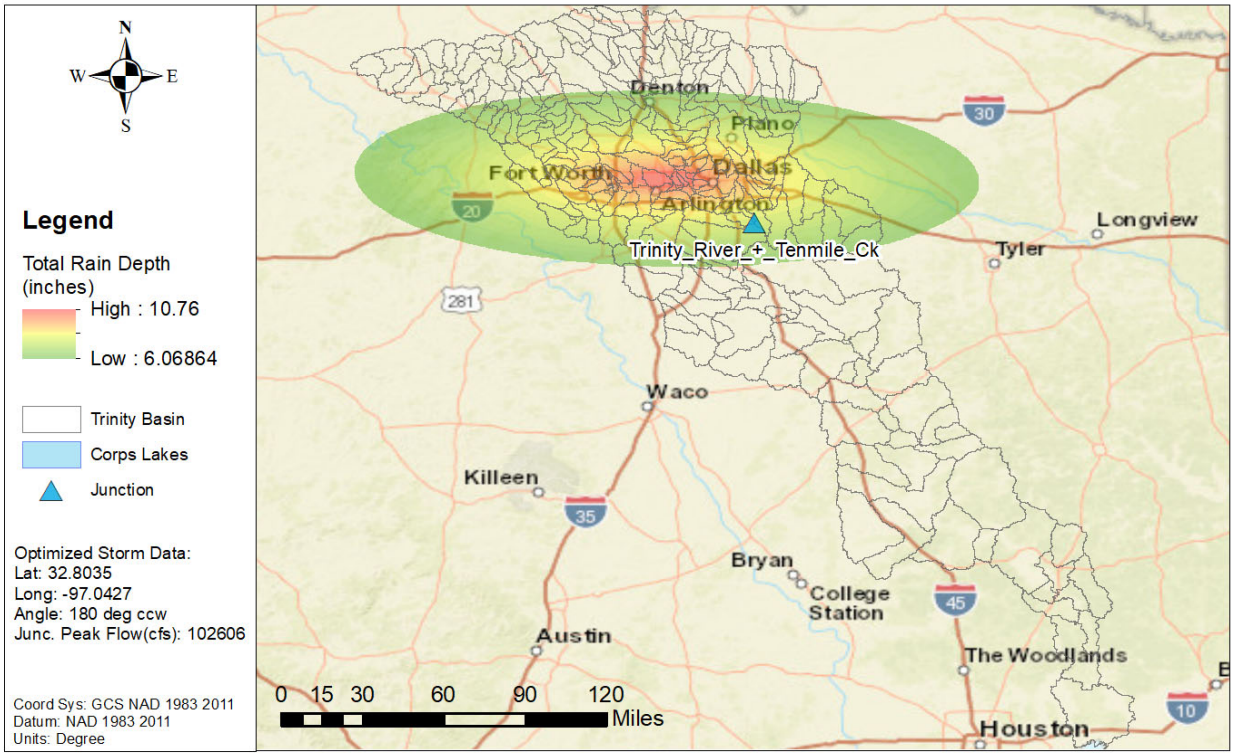


Figure 78b: NA14 1% AEP Elliptical Storm for the Trinity River below Ten Mile Creek

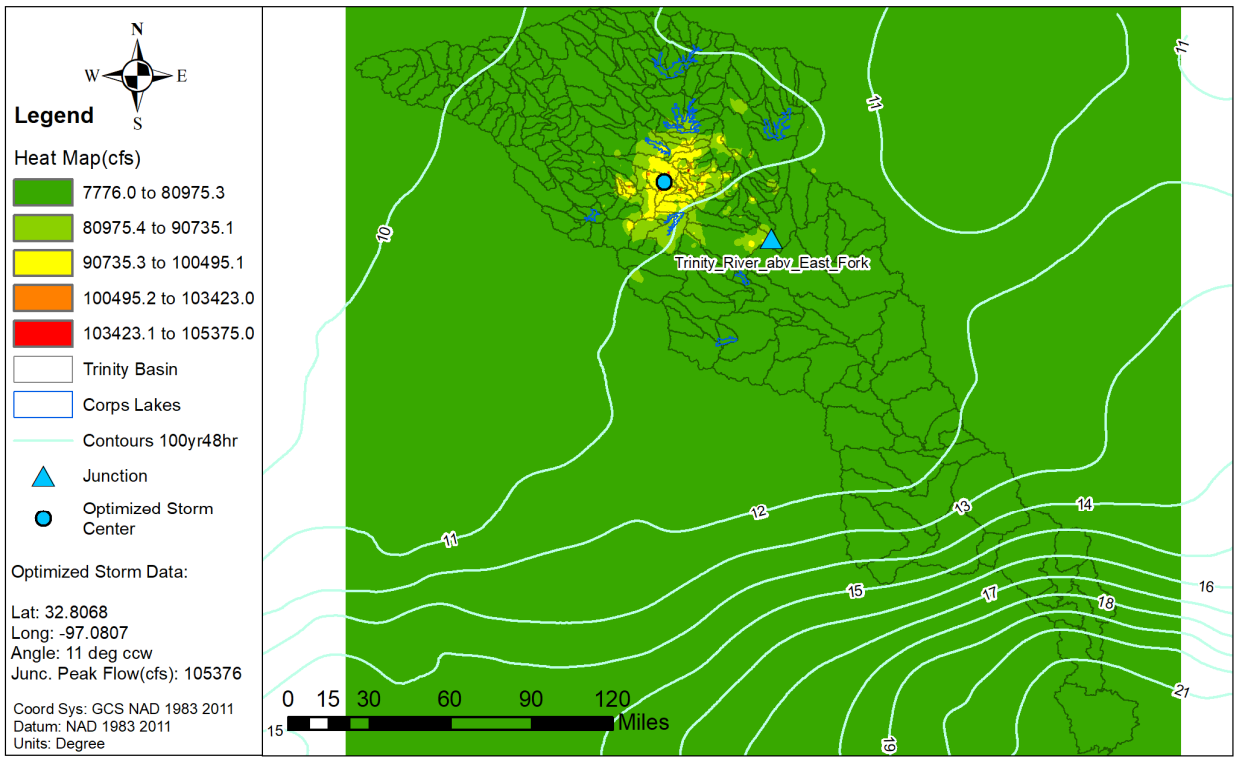


Figure 79a: Elliptical Storm Heat Map for the Trinity River above the East Fork Trinity River

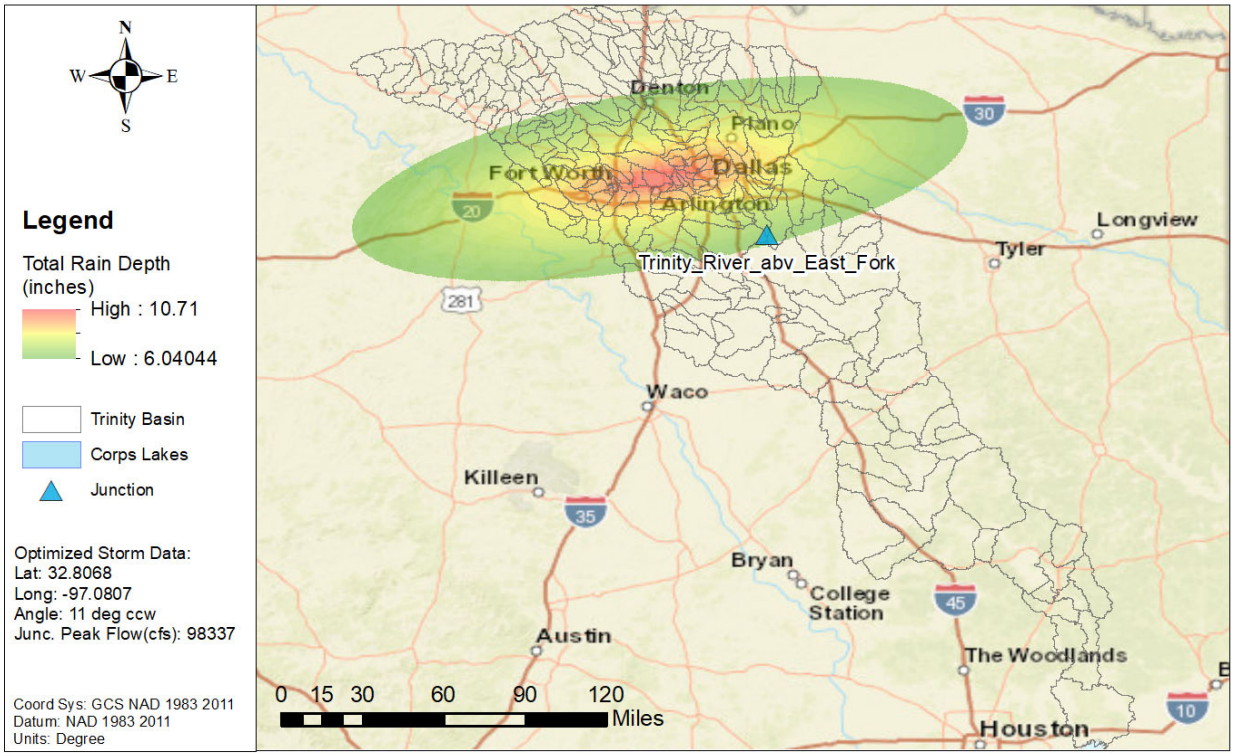


Figure 79b: NA14 1% AEP Elliptical Storm for the Trinity River above the East Fork Trinity River

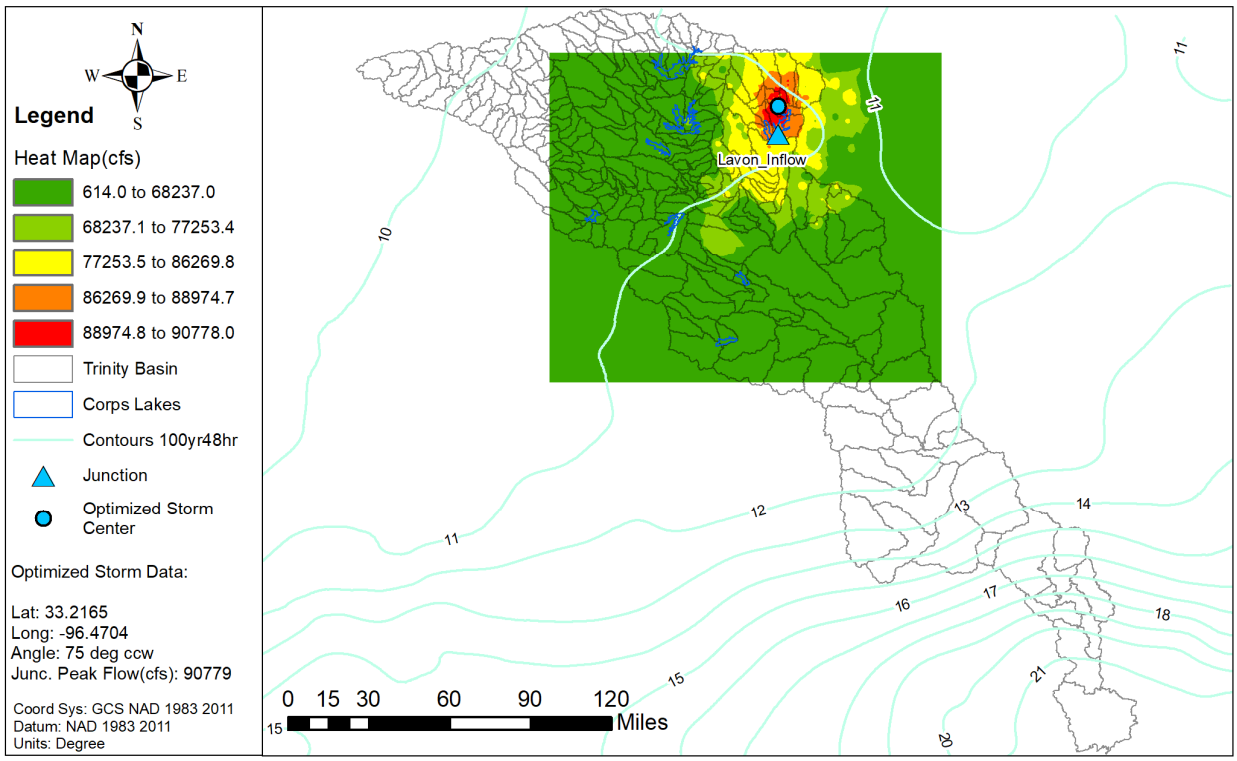


Figure 80a: Elliptical Storm Heat Map for the Lavon Lake Inflow

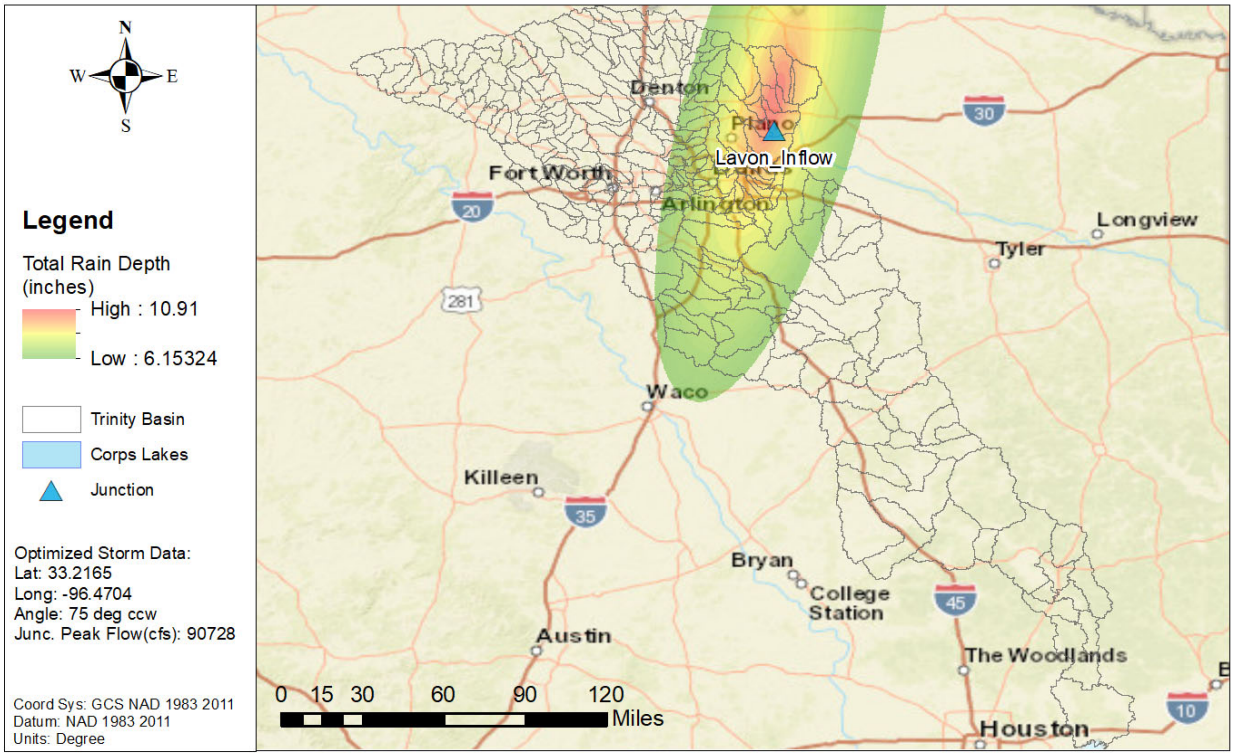


Figure 80b: NA14 1% AEP Elliptical Storm for the Lavon Lake Inflow

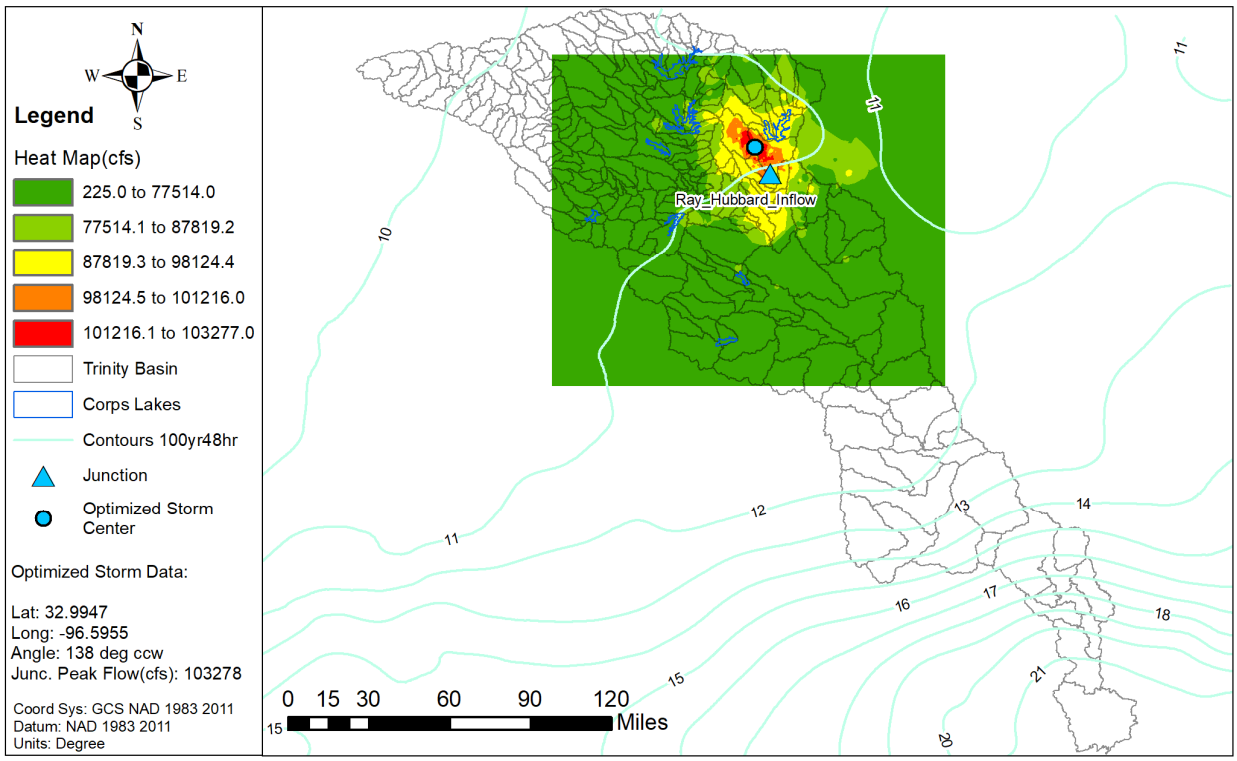


Figure 81a: Elliptical Storm Heat Map for the Ray Hubbard Lake Inflow

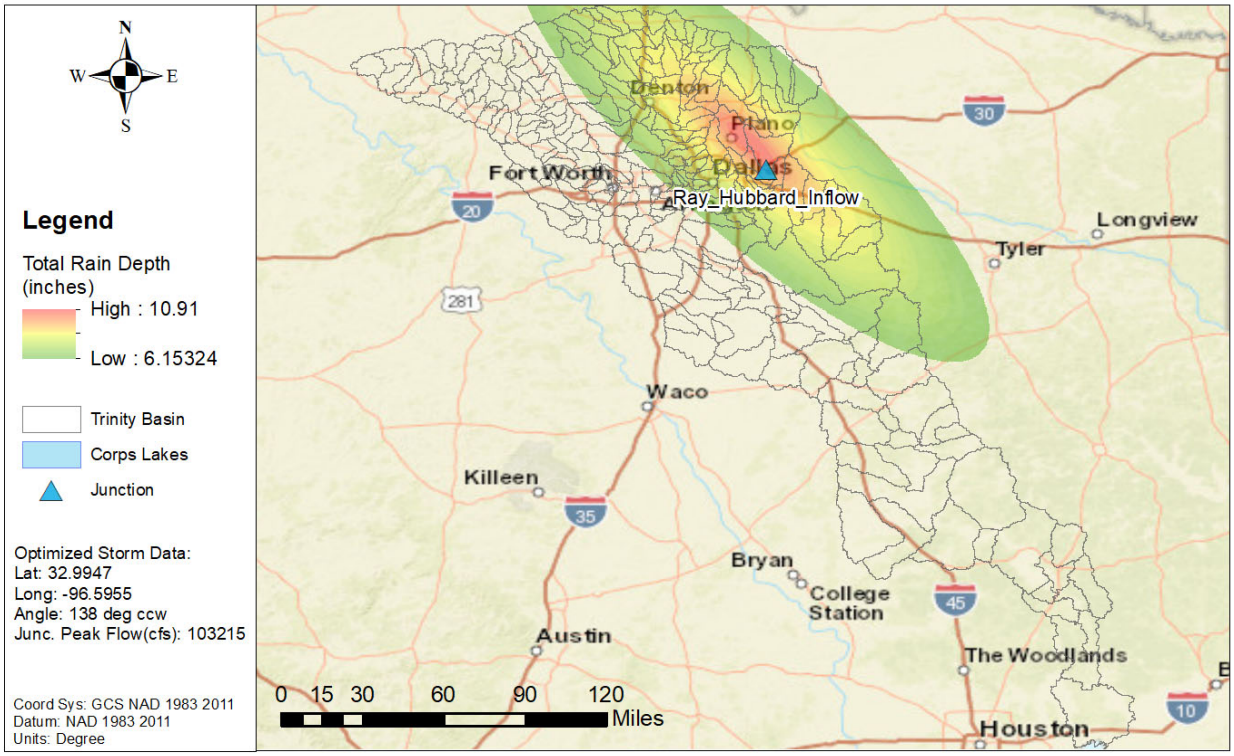


Figure 81b: NA14 1% AEP Elliptical Storm for the Ray Hubbard Lake Inflow

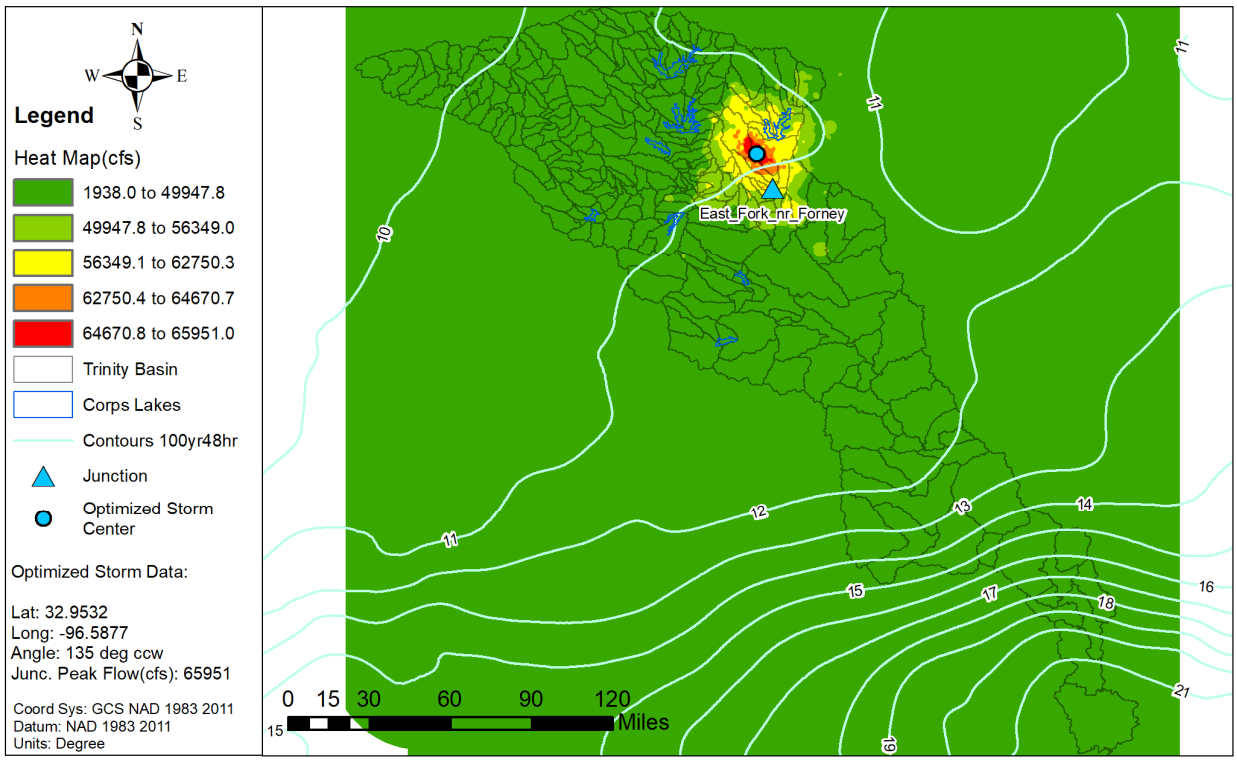


Figure 82a: Elliptical Storm Heat Map for the East Fork Trinity River near Forney USGS gage

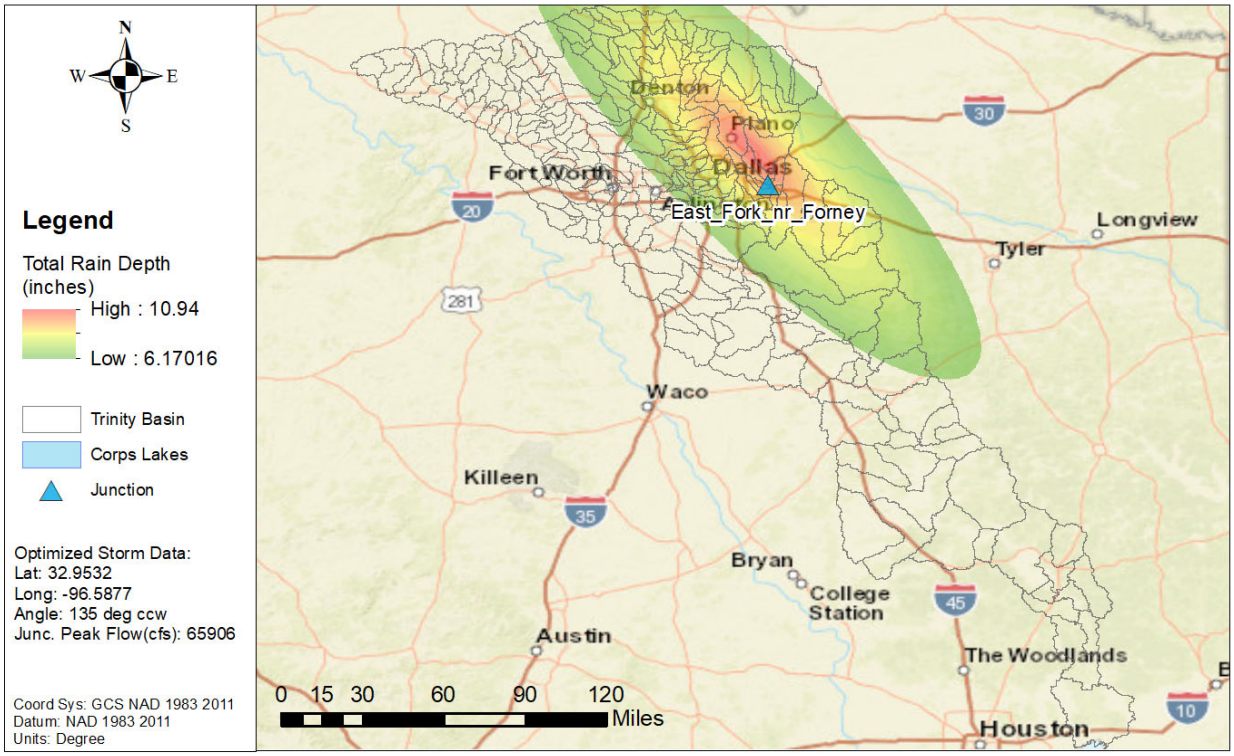


Figure 82b: NA14 1% AEP Elliptical Storm for the East Fork Trinity River near Forney USGS gage

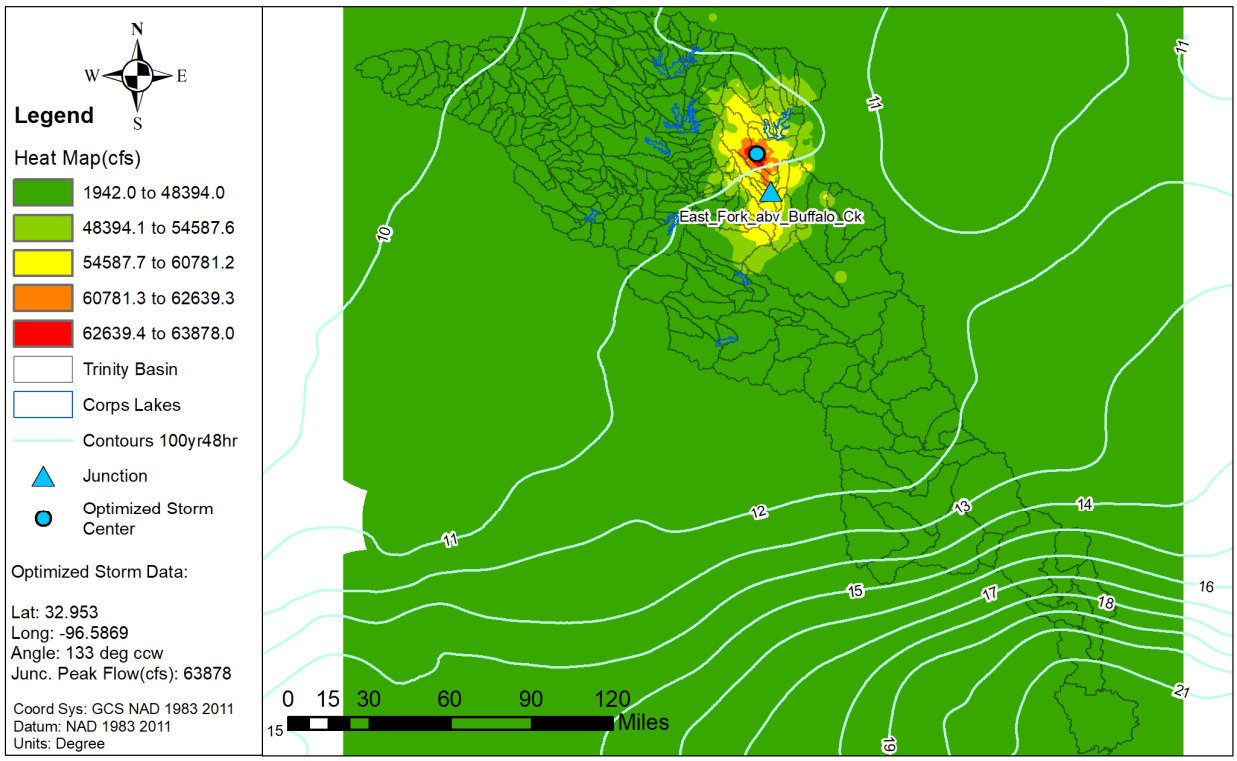


Figure 83a: Elliptical Storm Heat Map for the East Fork Trinity River above Buffalo Creek

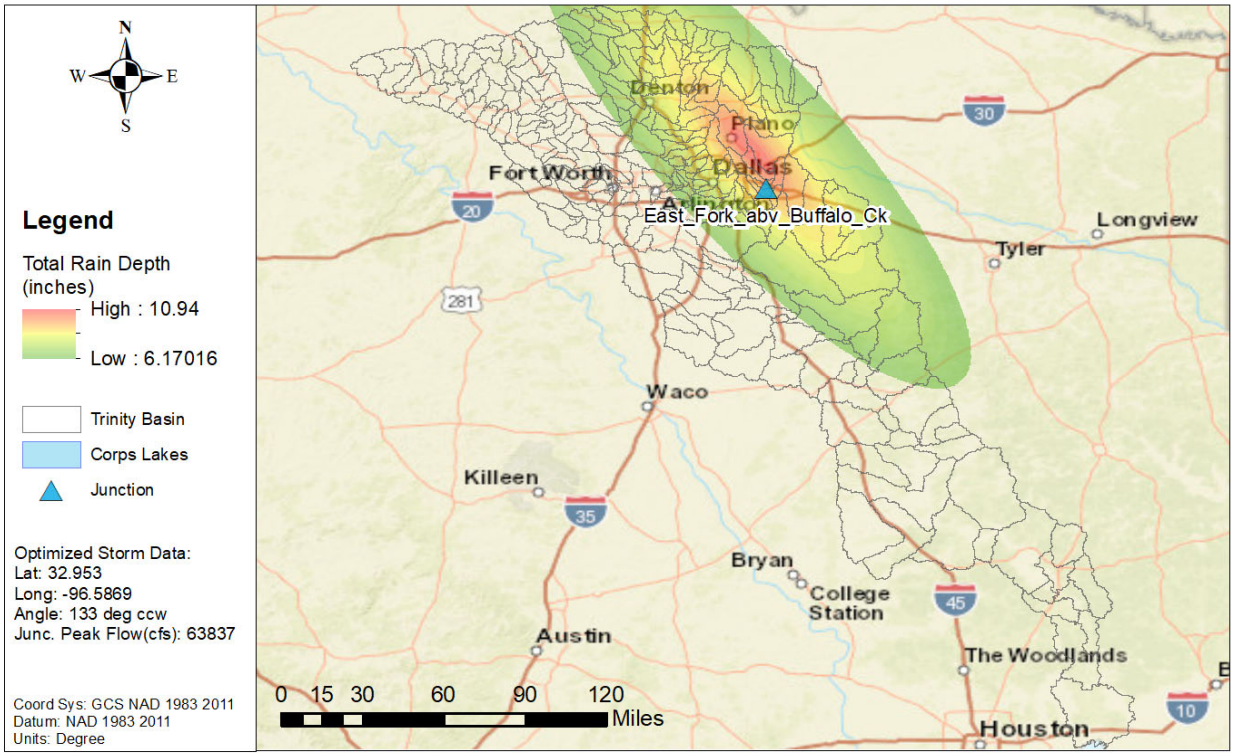


Figure 83b: NA14 1% AEP Elliptical Storm for the East Fork Trinity River above Buffalo Creek

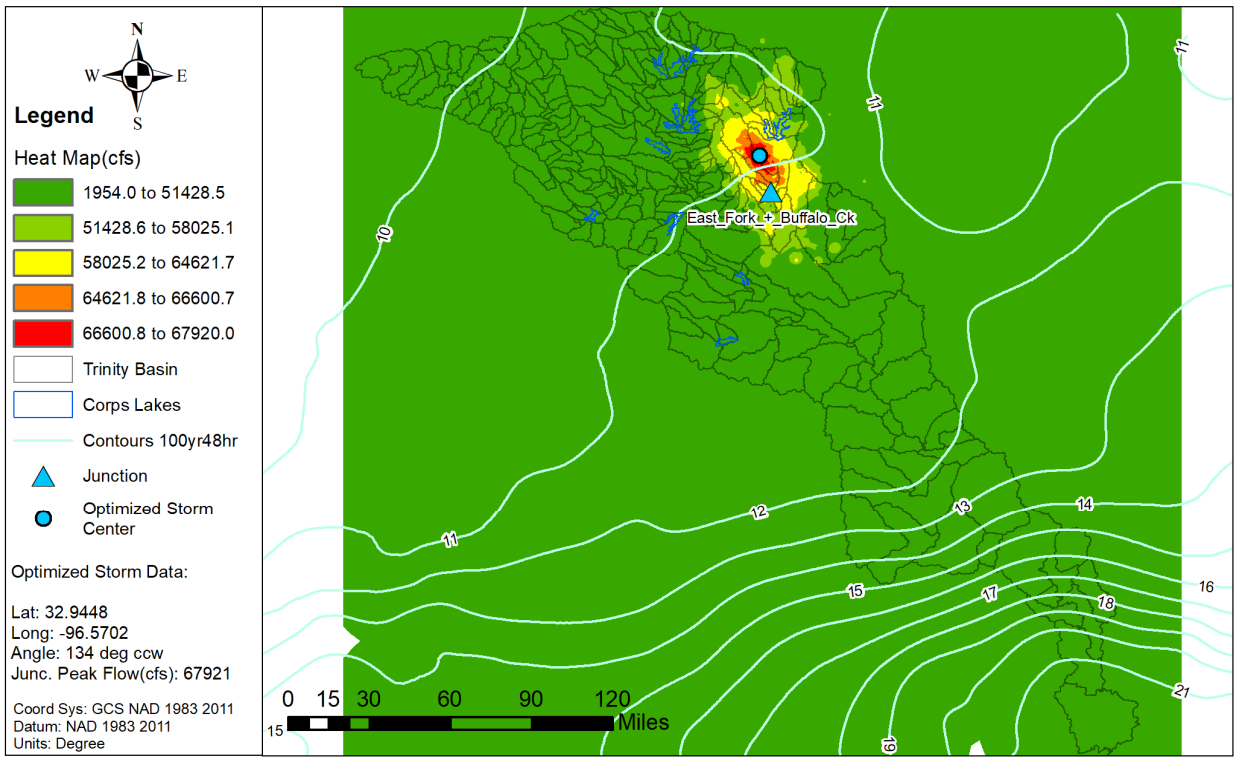


Figure 84a: Elliptical Storm Heat Map for the East Fork Trinity River below Buffalo Creek

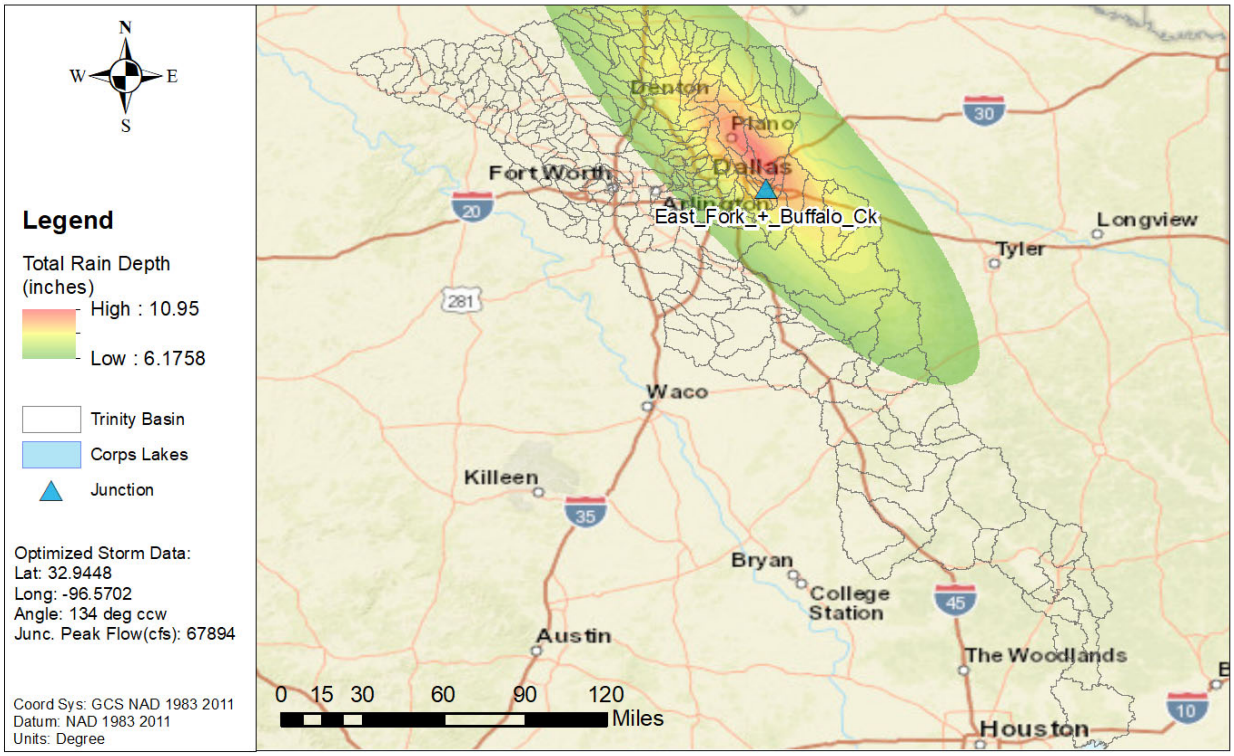


Figure 84b: NA14 1% AEP Elliptical Storm for the East Fork Trinity River below Buffalo Creek

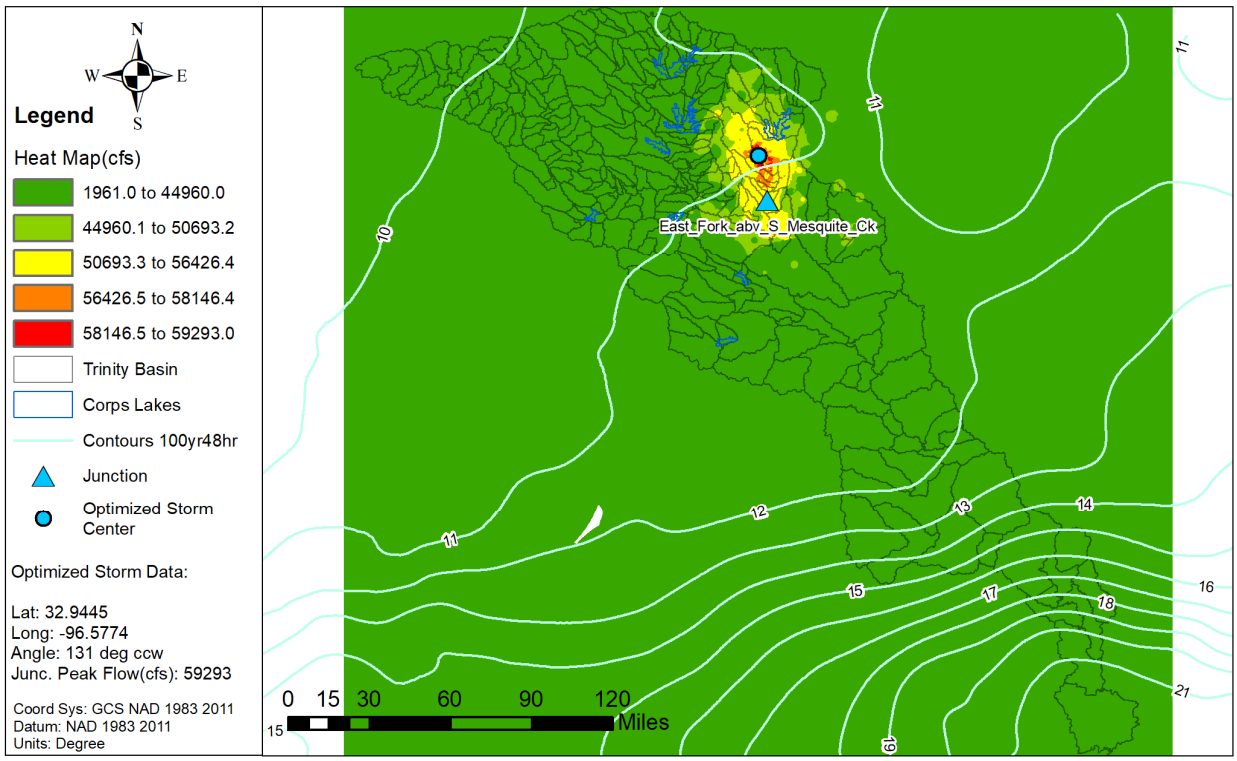


Figure 85a: Elliptical Storm Heat Map for the East Fork Trinity River above South Mesquite Creek

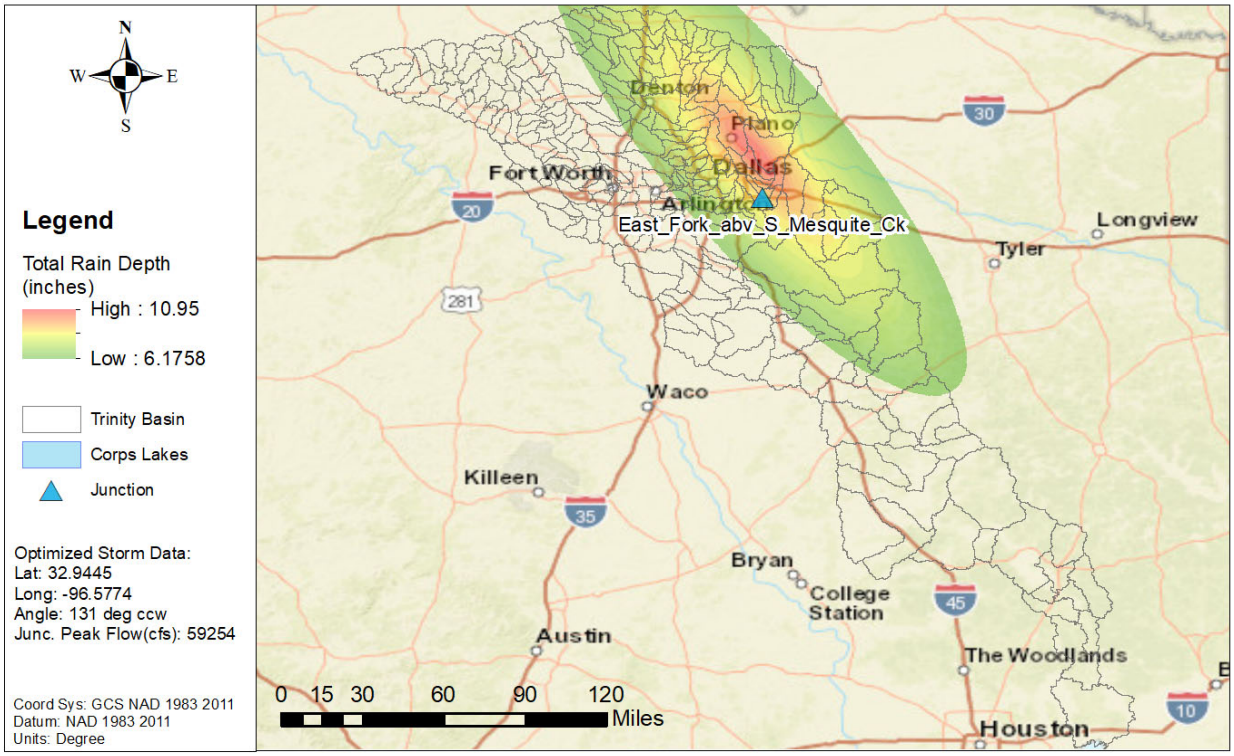


Figure 85b: NA14 1% AEP Elliptical Storm for the East Fork Trinity River above South Mesquite Creek

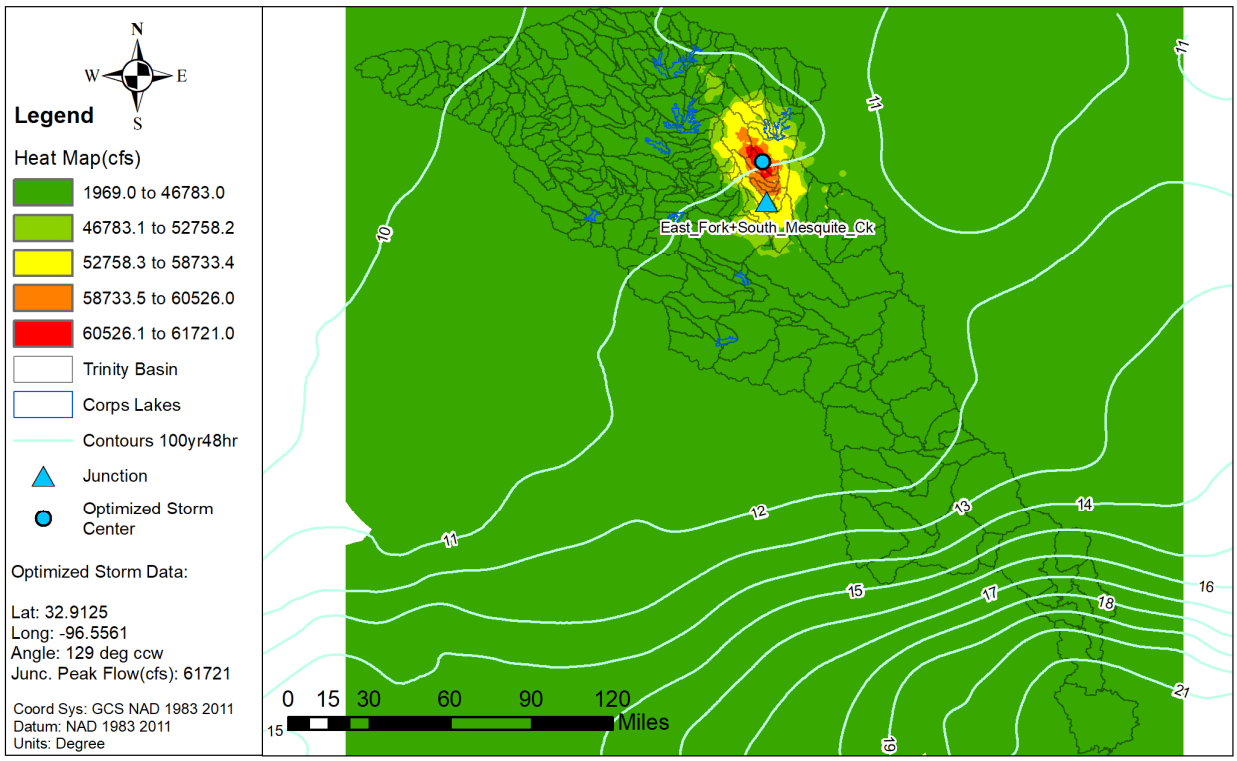


Figure 86a: Elliptical Storm Heat Map for the East Fork Trinity River below South Mesquite Creek

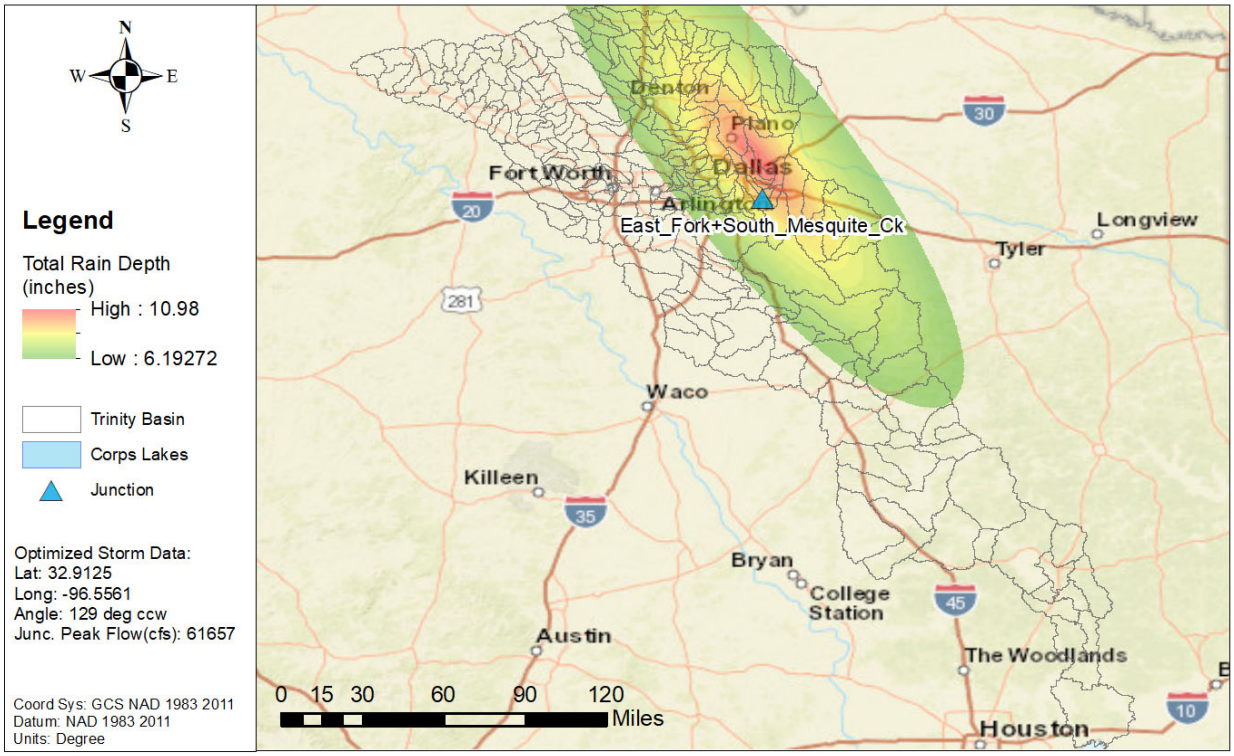


Figure 86b: NA14 1% AEP Elliptical Storm for the East Fork Trinity River below South Mesquite Creek

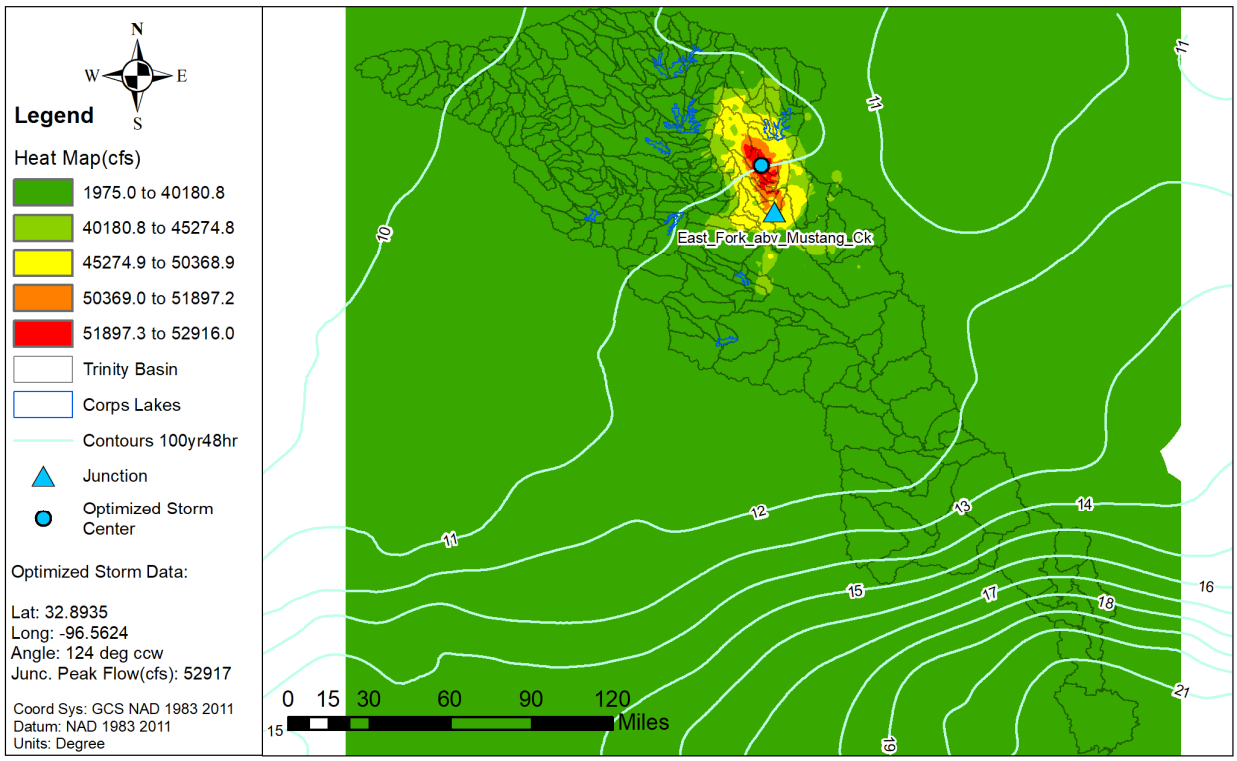


Figure 87a: Elliptical Storm Heat Map for the East Fork Trinity River above Mustang Creek

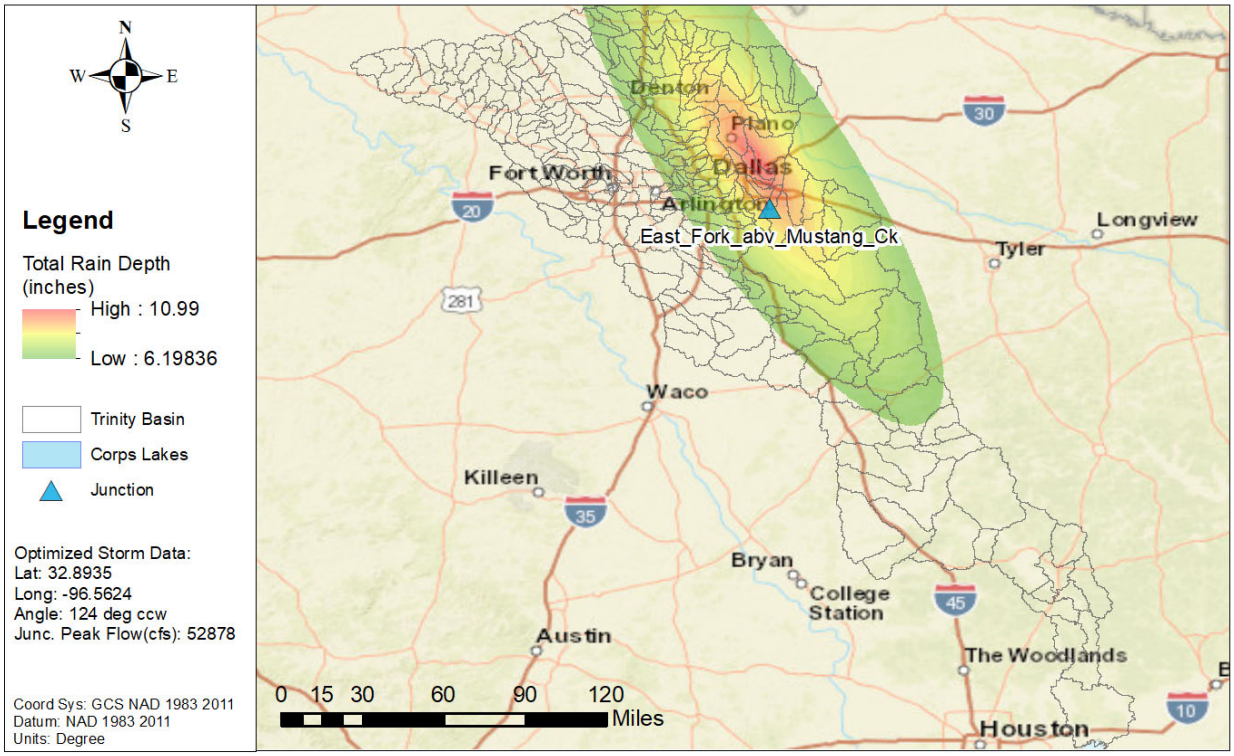


Figure 87b: NA14 1% AEP Elliptical Storm for the East Fork Trinity River above Mustang Creek

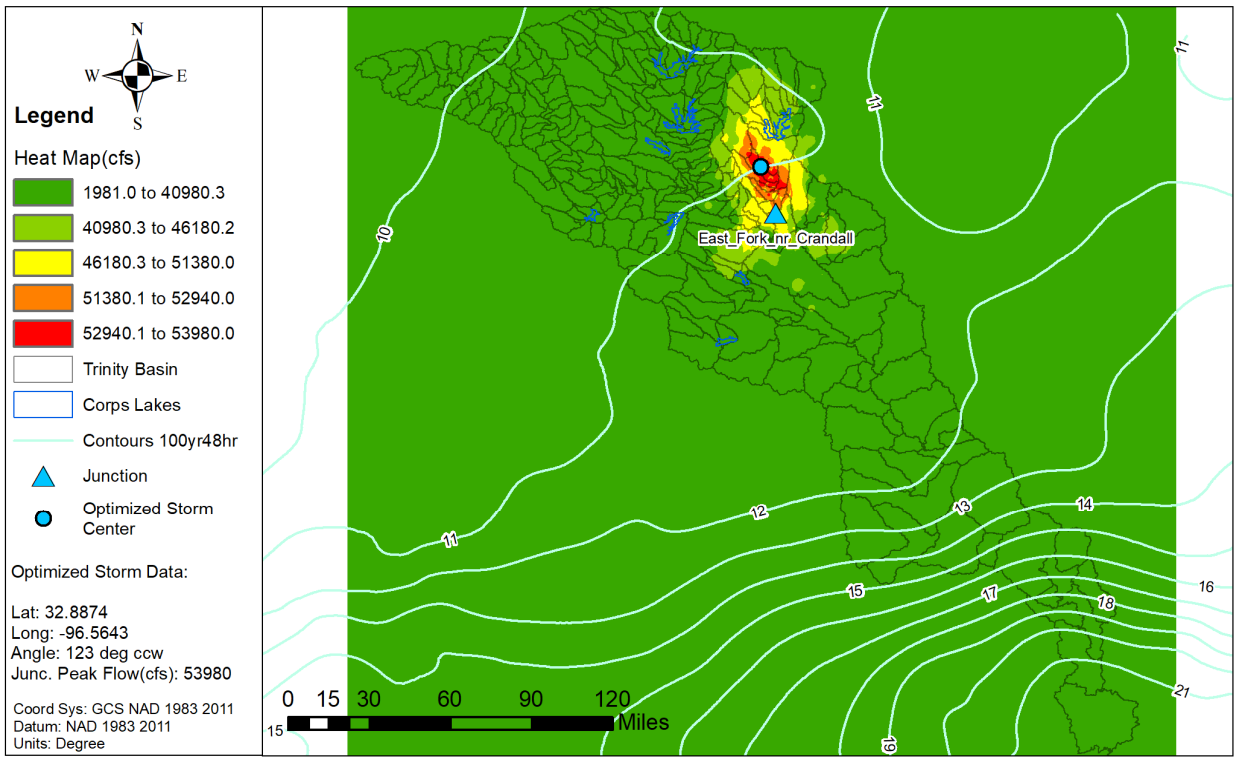


Figure 88a: Elliptical Storm Heat Map for the East Fork Trinity River near Crandall, TX USGS gage

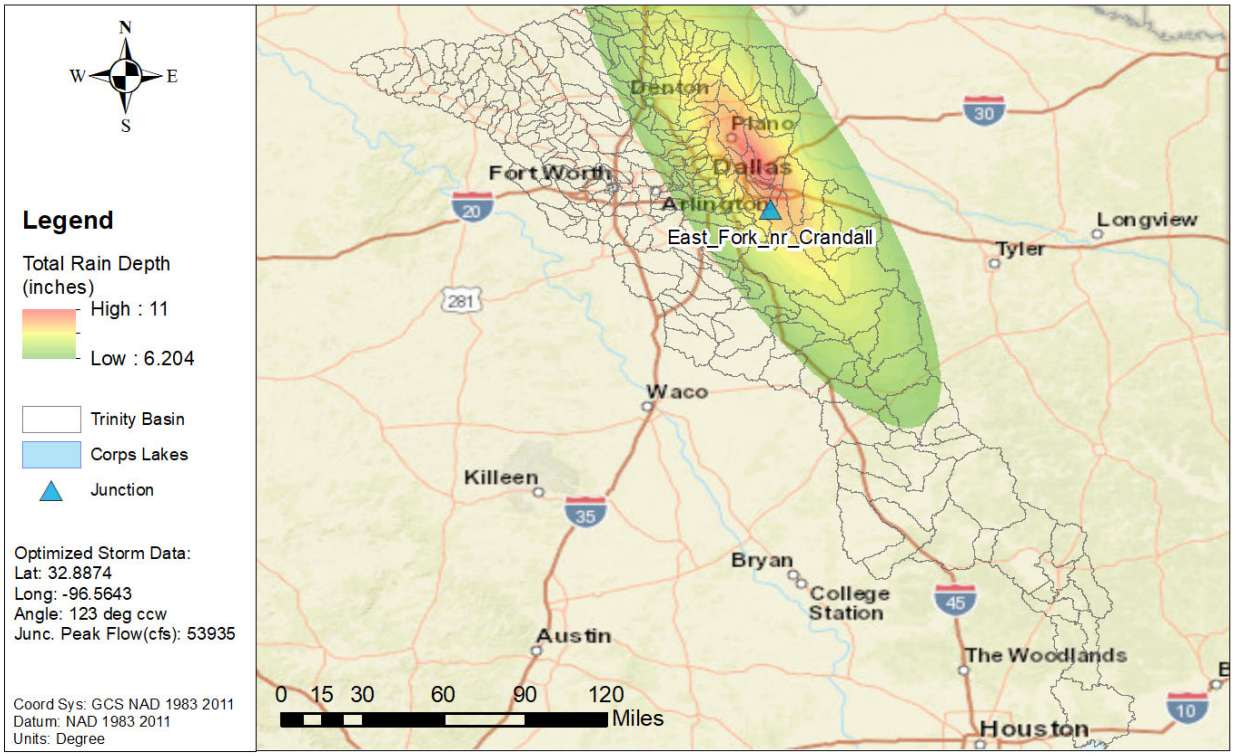


Figure 88b: NA14 1% AEP Elliptical Storm for the East Fork Trinity River near Crandall, TX USGS gage

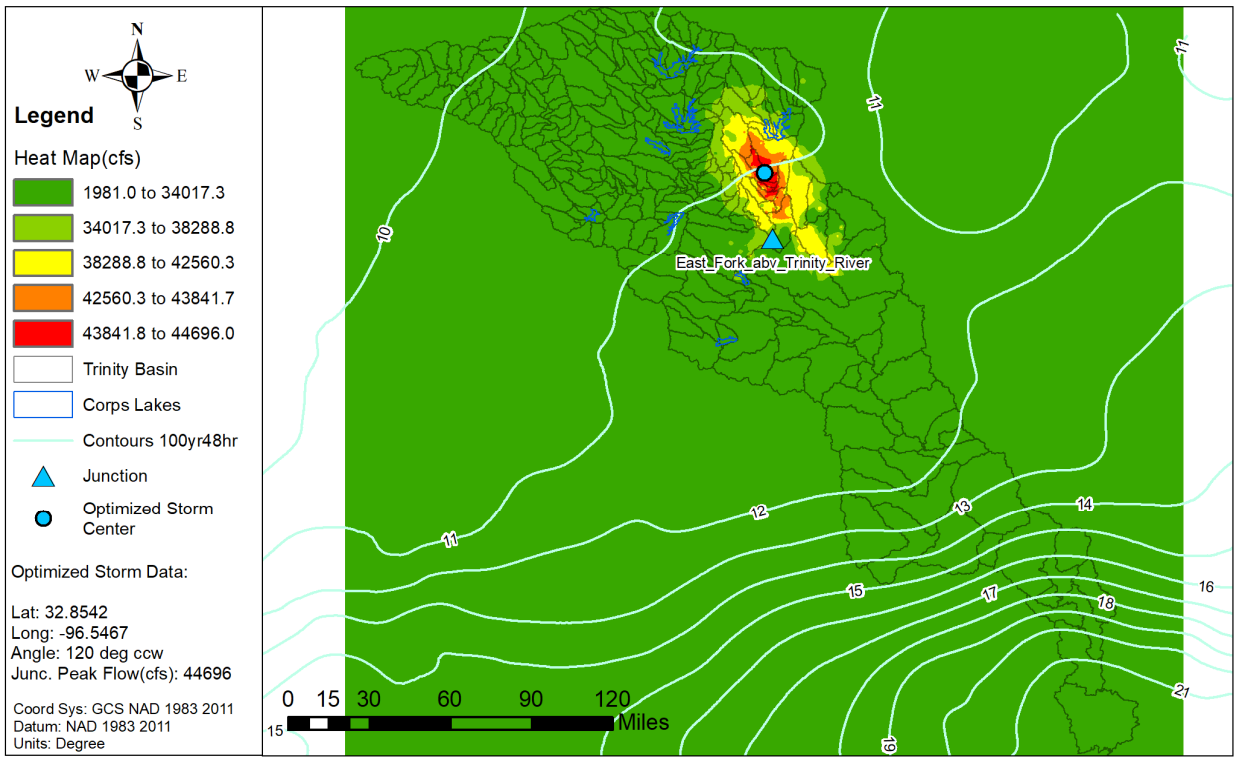


Figure 89a: Elliptical Storm Heat Map for the East Fork Trinity River above the Trinity River

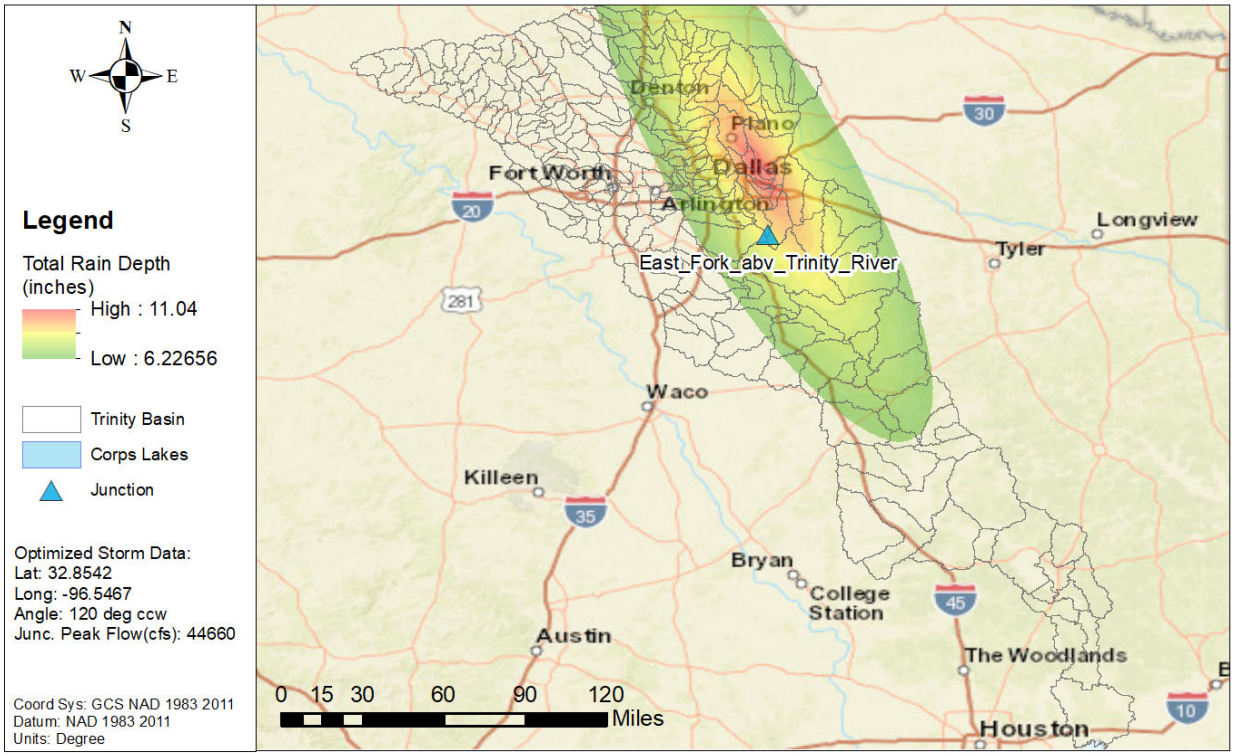


Figure 89b: NA14 1% AEP Elliptical Storm for the East Fork Trinity River above the Trinity River

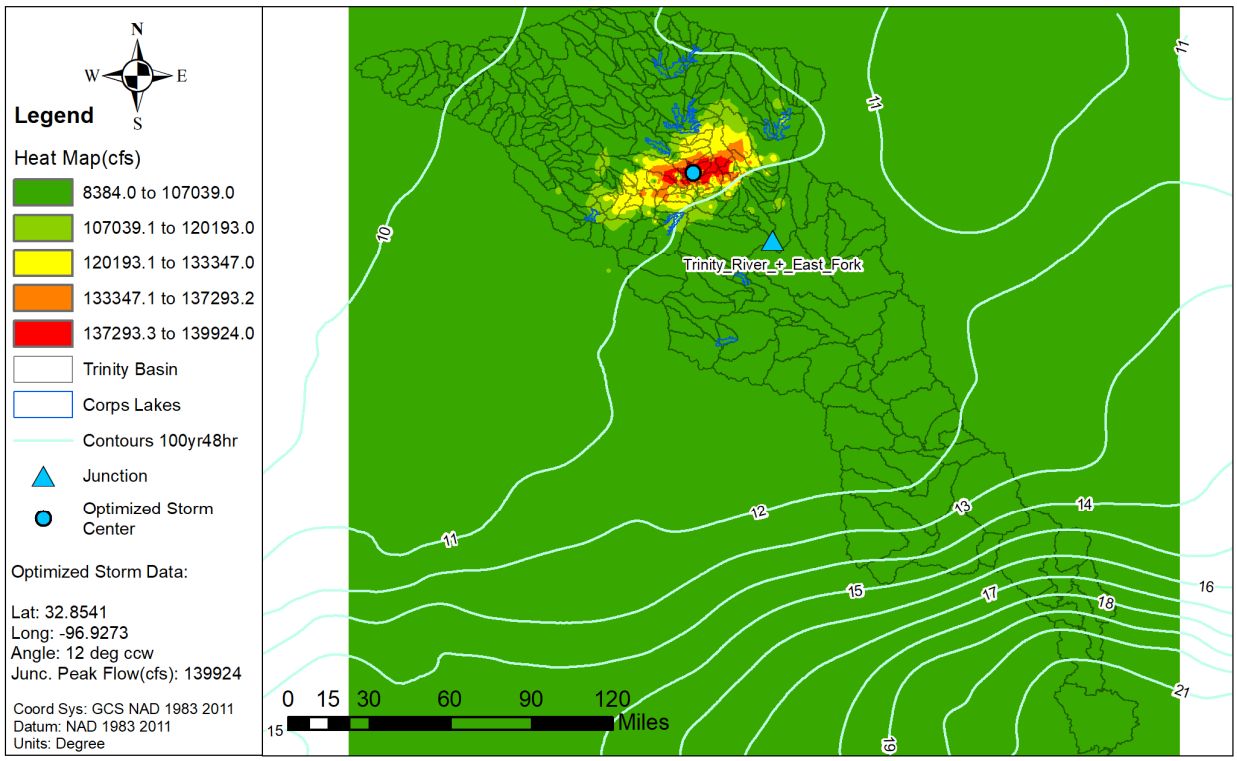


Figure 90a: Elliptical Storm Heat Map for the Trinity River below the East Fork Trinity River

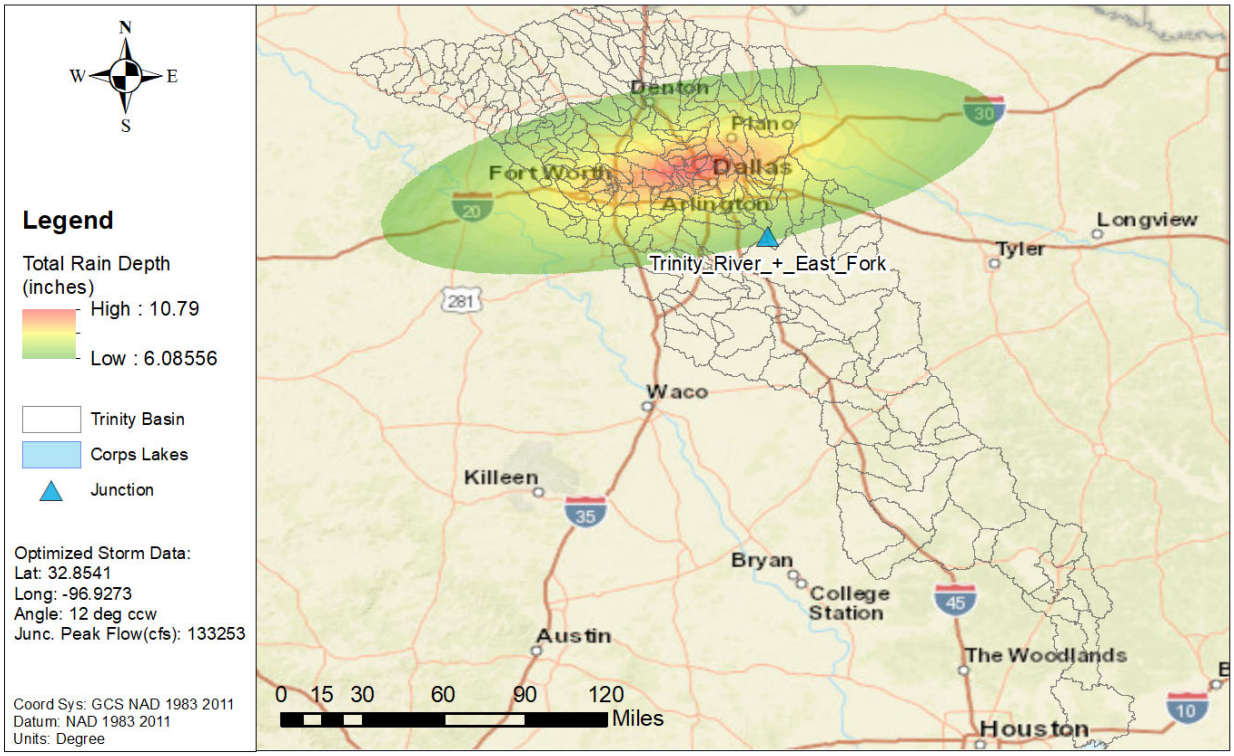


Figure 90b: NA14 1% AEP Elliptical Storm for the Trinity River below the East Fork Trinity River

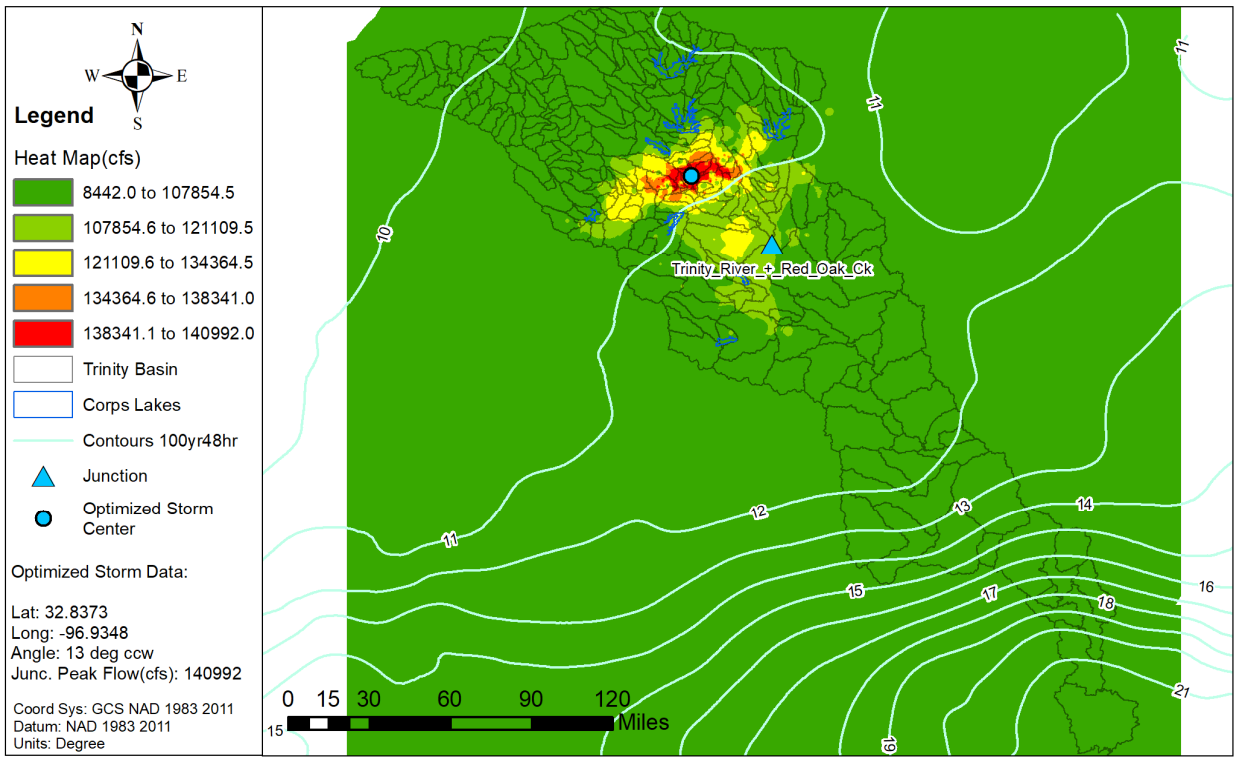


Figure 91a: Elliptical Storm Heat Map for the Trinity River below Red Oak Creek

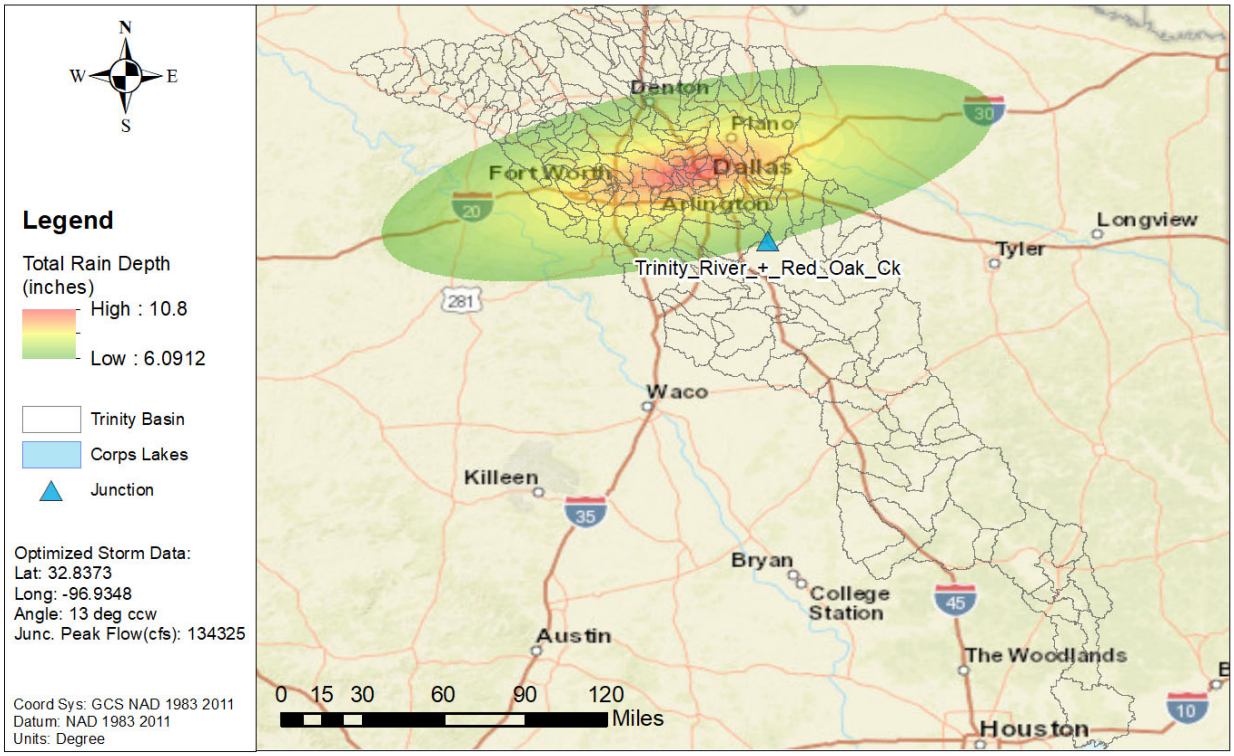


Figure 91b: NA14 1% AEP Elliptical Storm for the Trinity River below Red Oak Creek

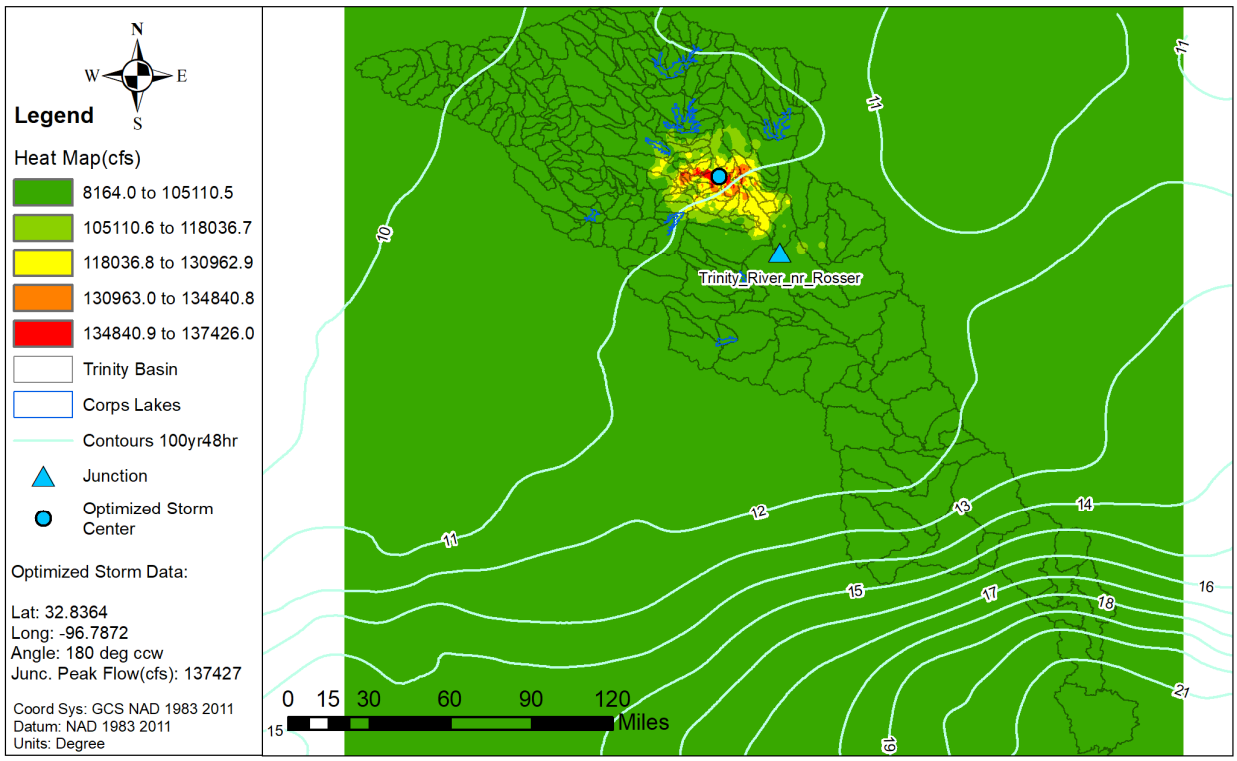


Figure 92a: Elliptical Storm Heat Map for the Trinity River near Rosser, TX USGS gage

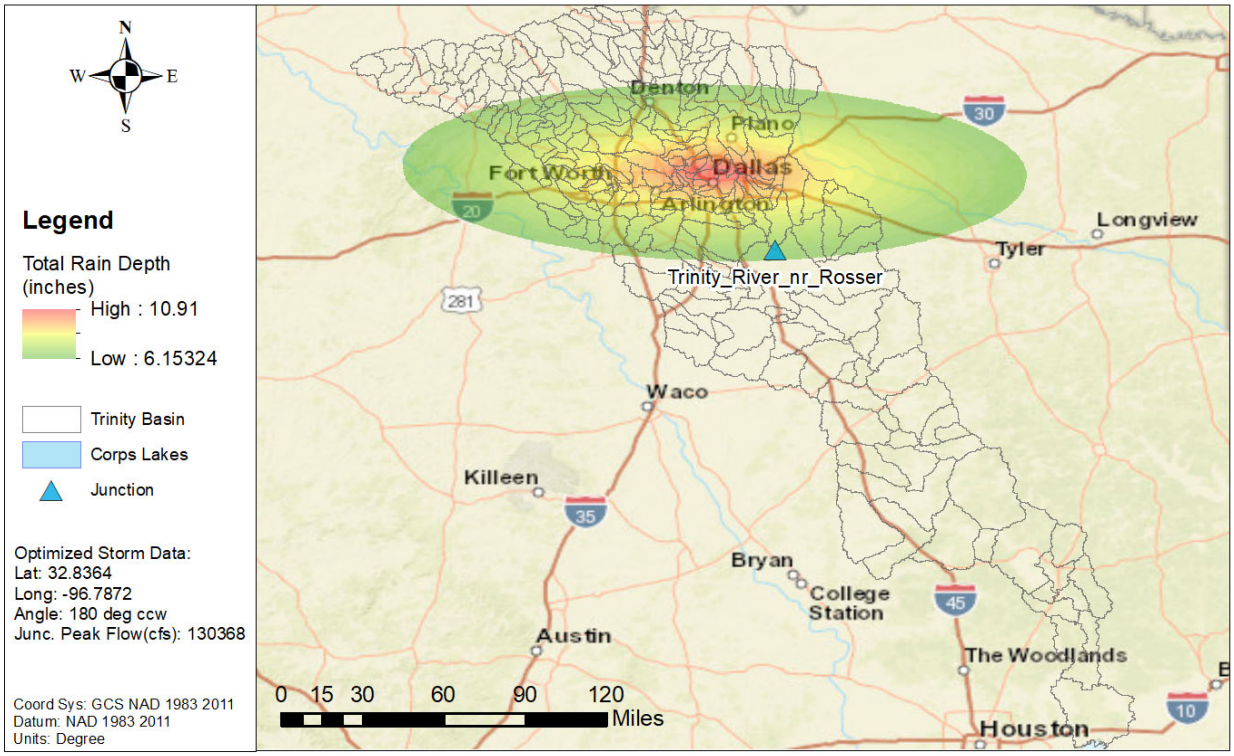


Figure 92b: NA14 1% AEP Elliptical Storm for the Trinity River near Rosser, TX USGS gage

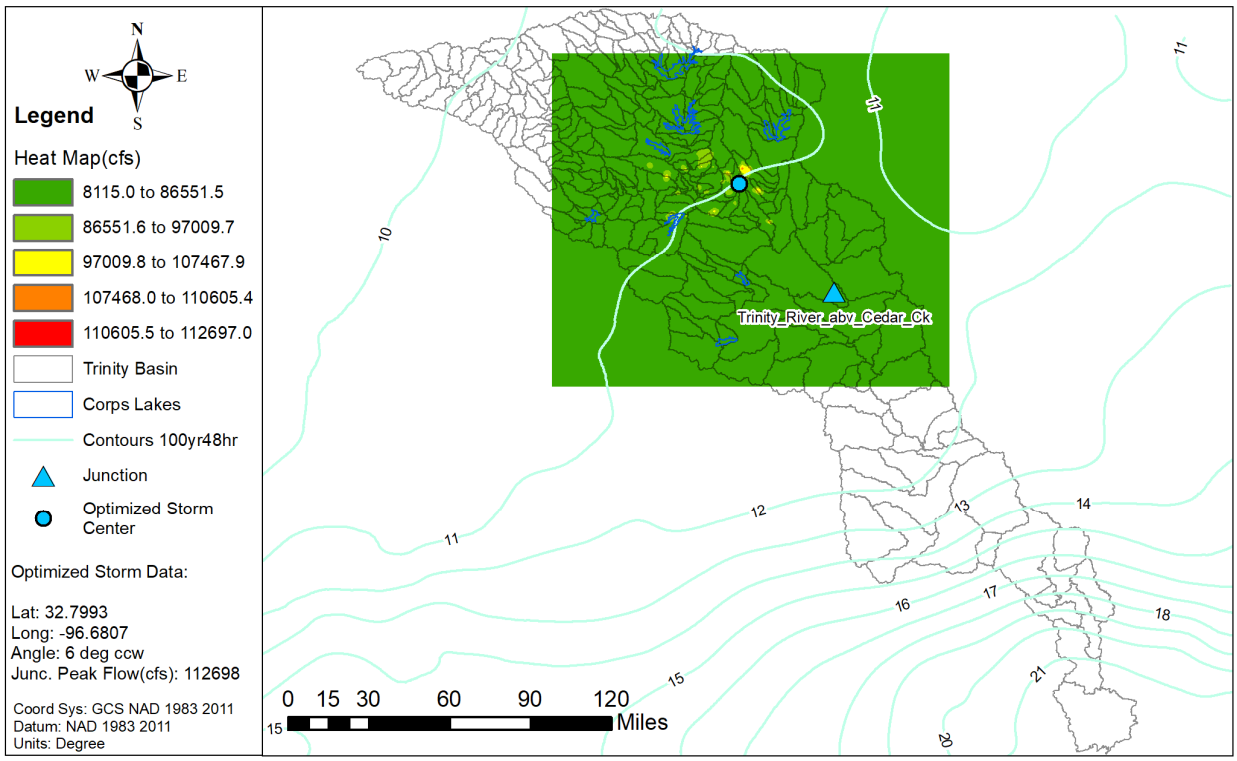


Figure 93a: Elliptical Storm Heat Map for the Trinity River above Cedar Creek

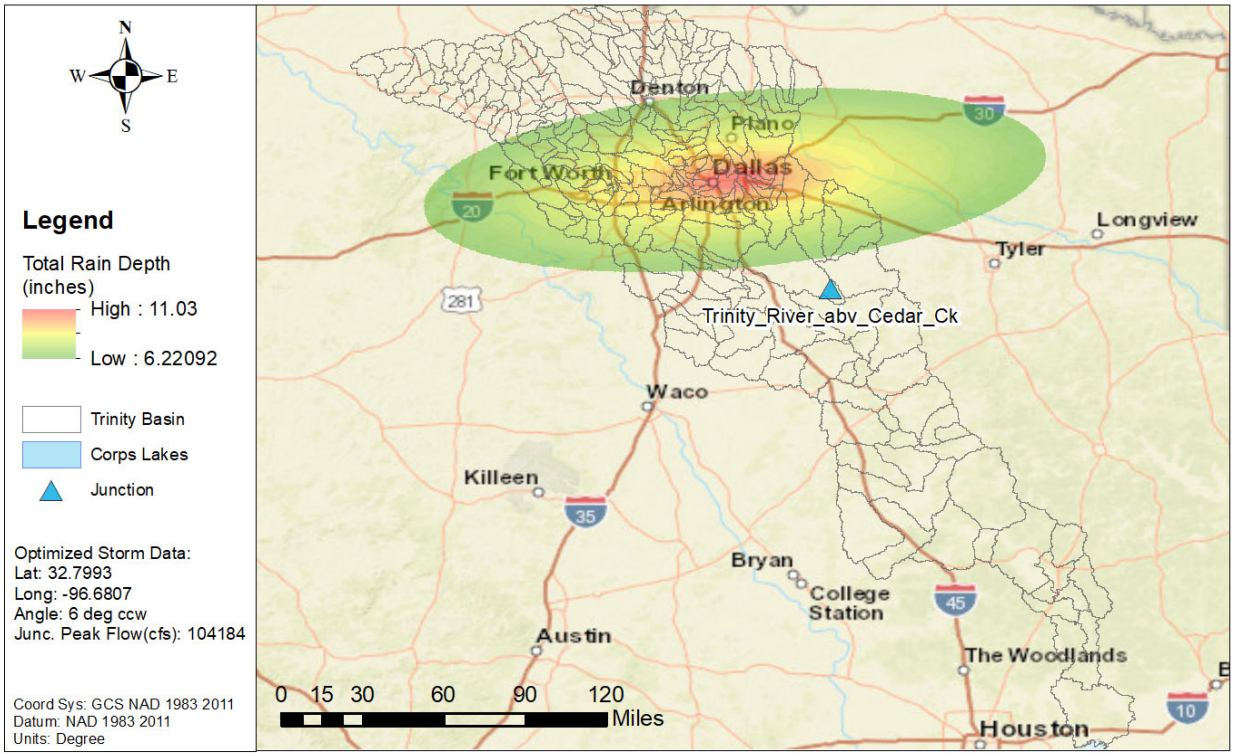


Figure 93b: NA14 1% AEP Elliptical Storm for the Trinity River above Cedar Creek

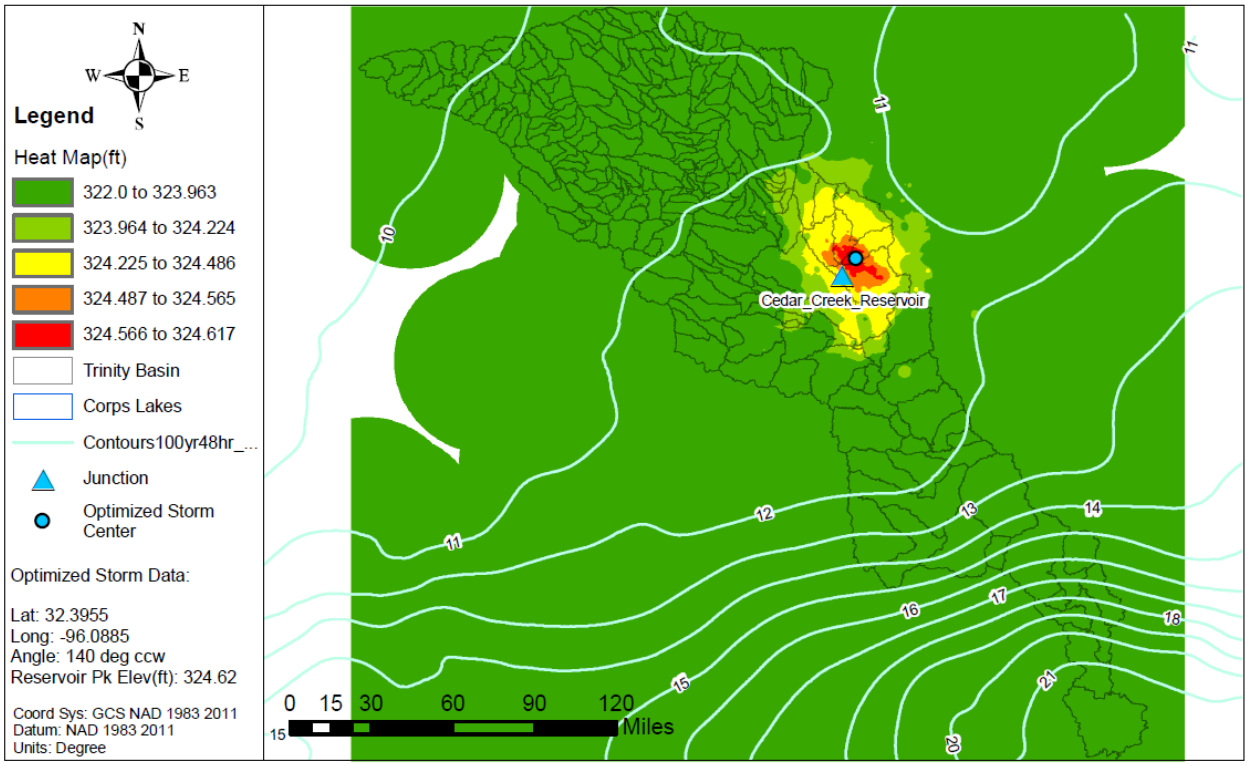


Figure 94a: Elliptical Storm Heat Map for the Cedar Creek Reservoir

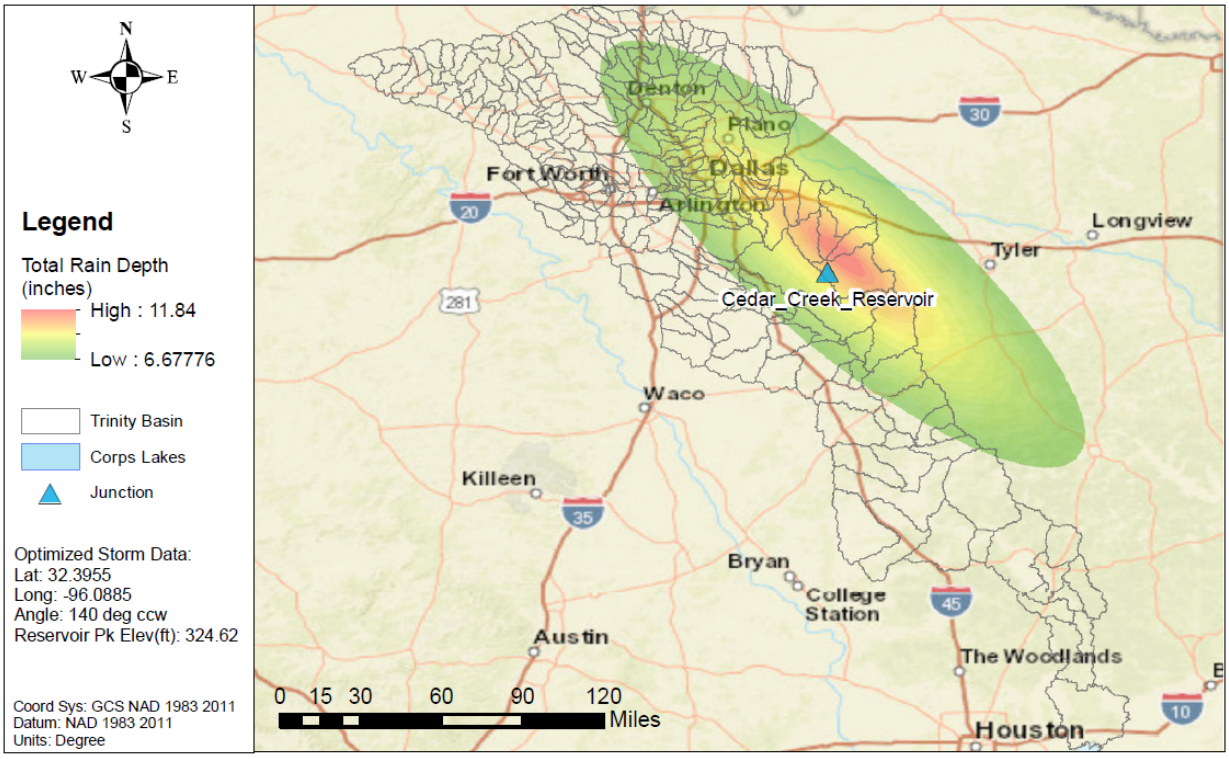


Figure 94b: NA14 1% AEP Elliptical Storm for the Cedar Creek Reservoir

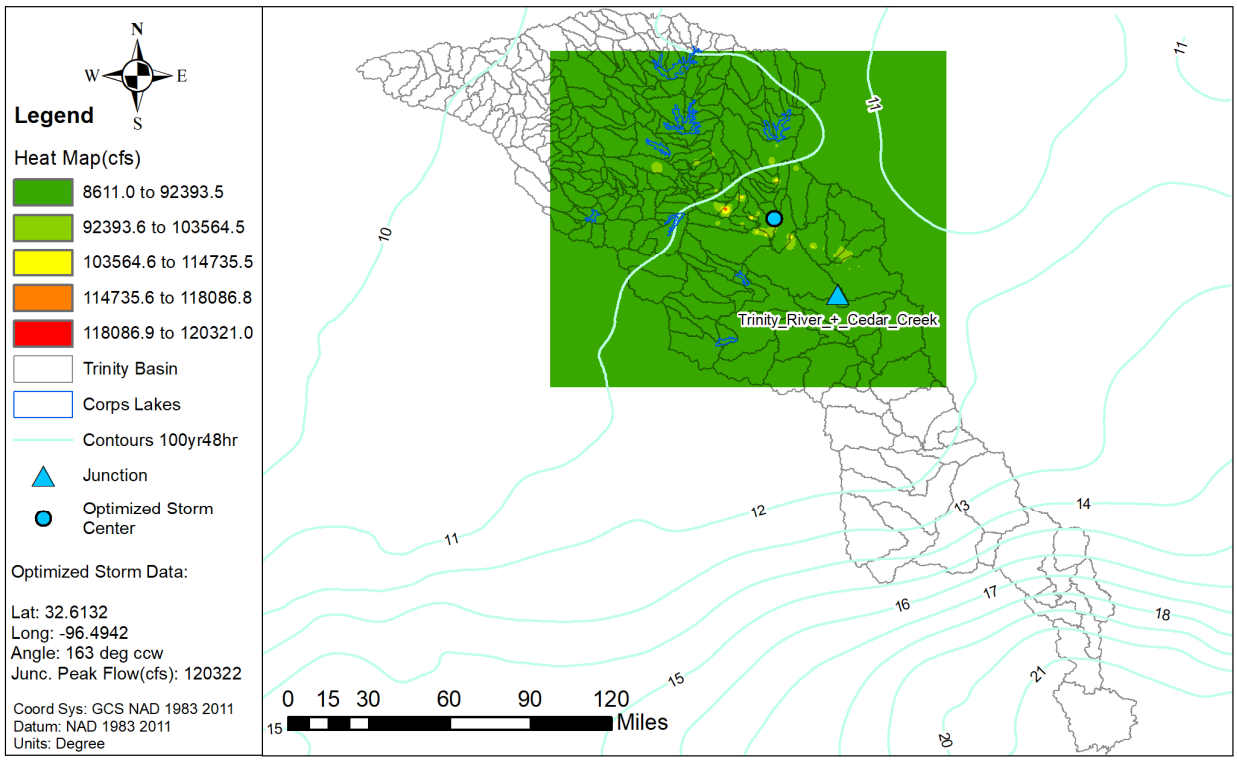


Figure 95a: Elliptical Storm Heat Map for the Trinity River below Cedar Creek

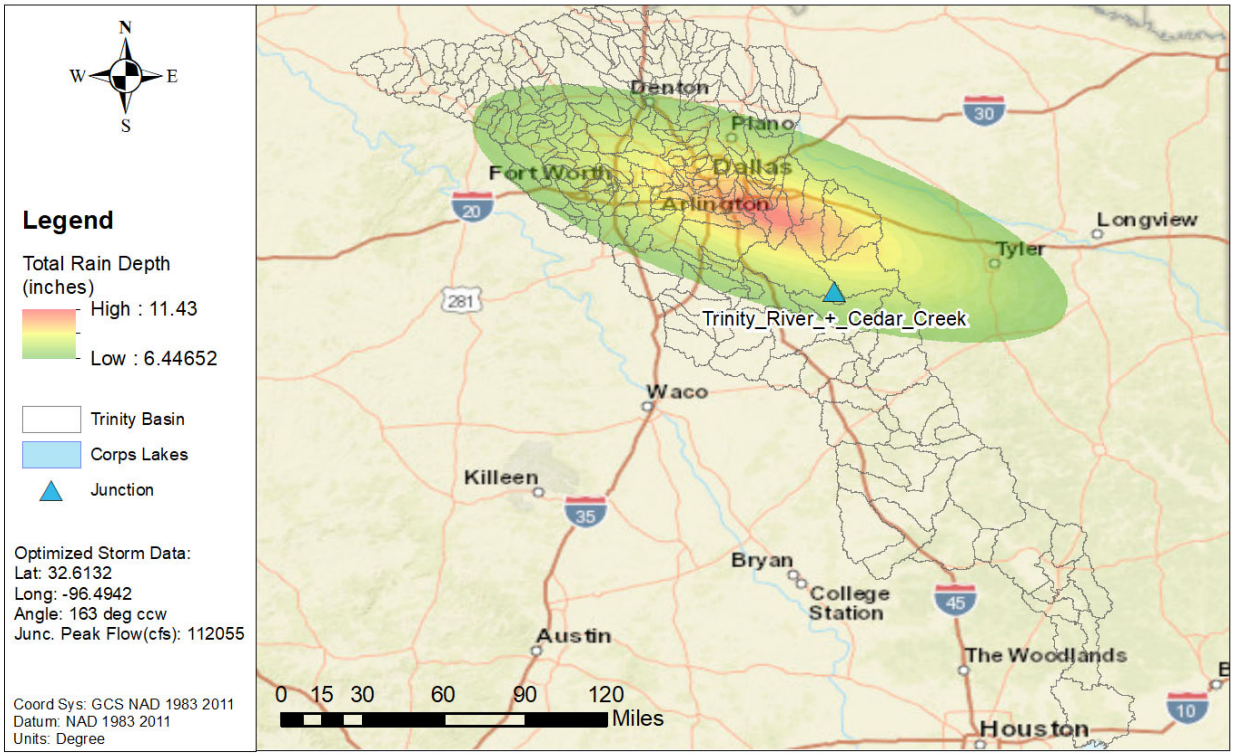


Figure 95b: NA14 1% AEP Elliptical Storm for the Trinity River below Cedar Creek

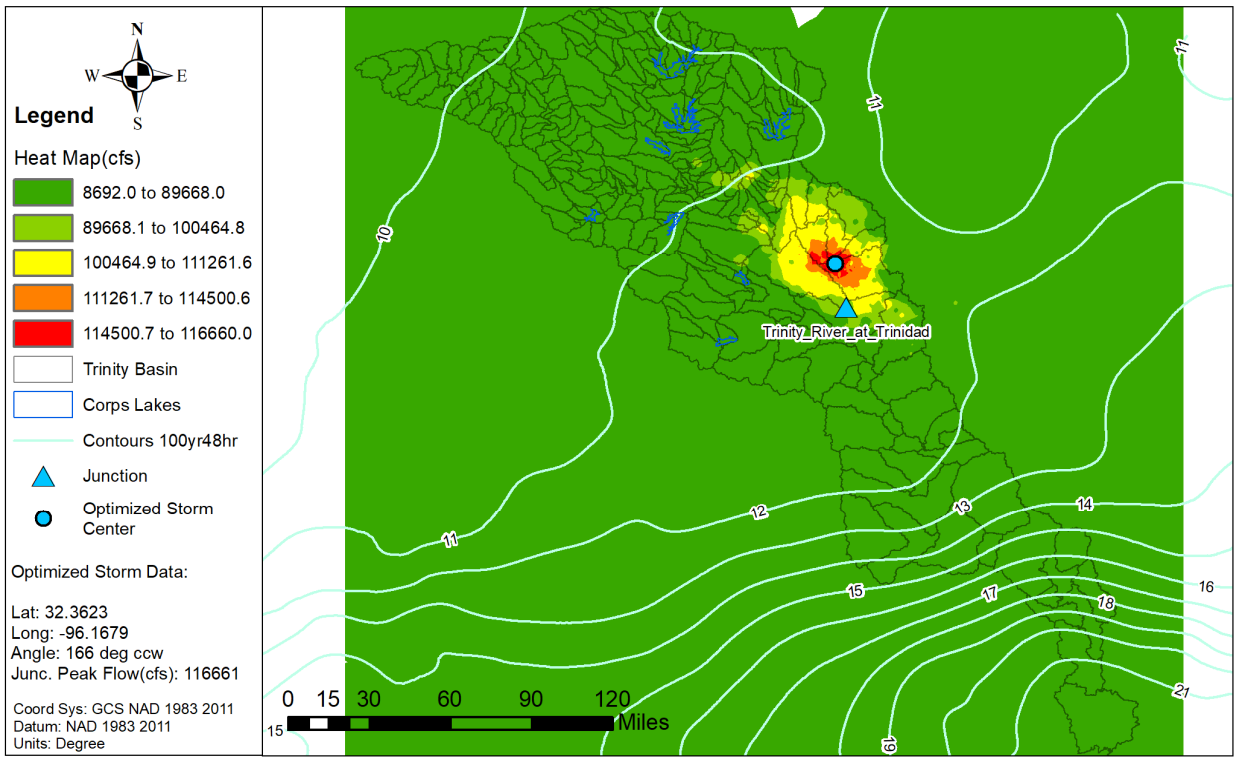


Figure 96a: Elliptical Storm Heat Map for the Trinity River at Trinidad, TX USGS gage

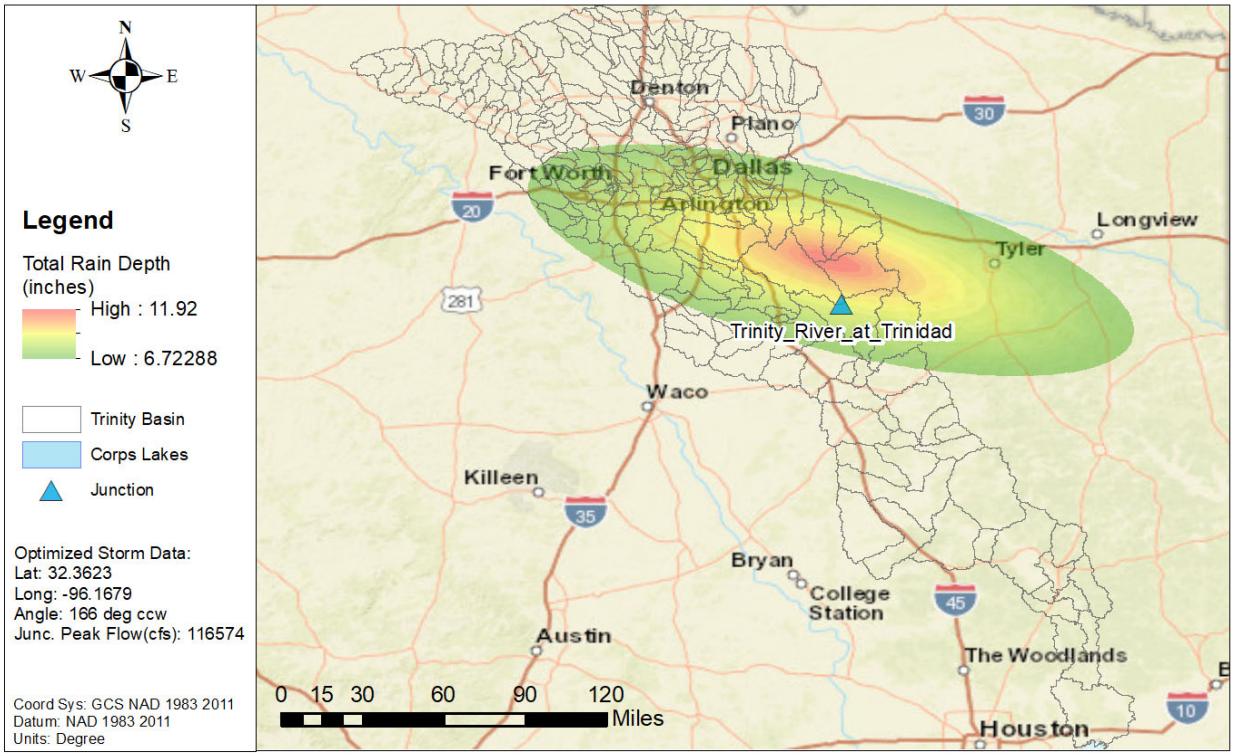


Figure 96b: NA14 1% AEP Elliptical Storm for the Trinity River at Trinidad, TX USGS gage

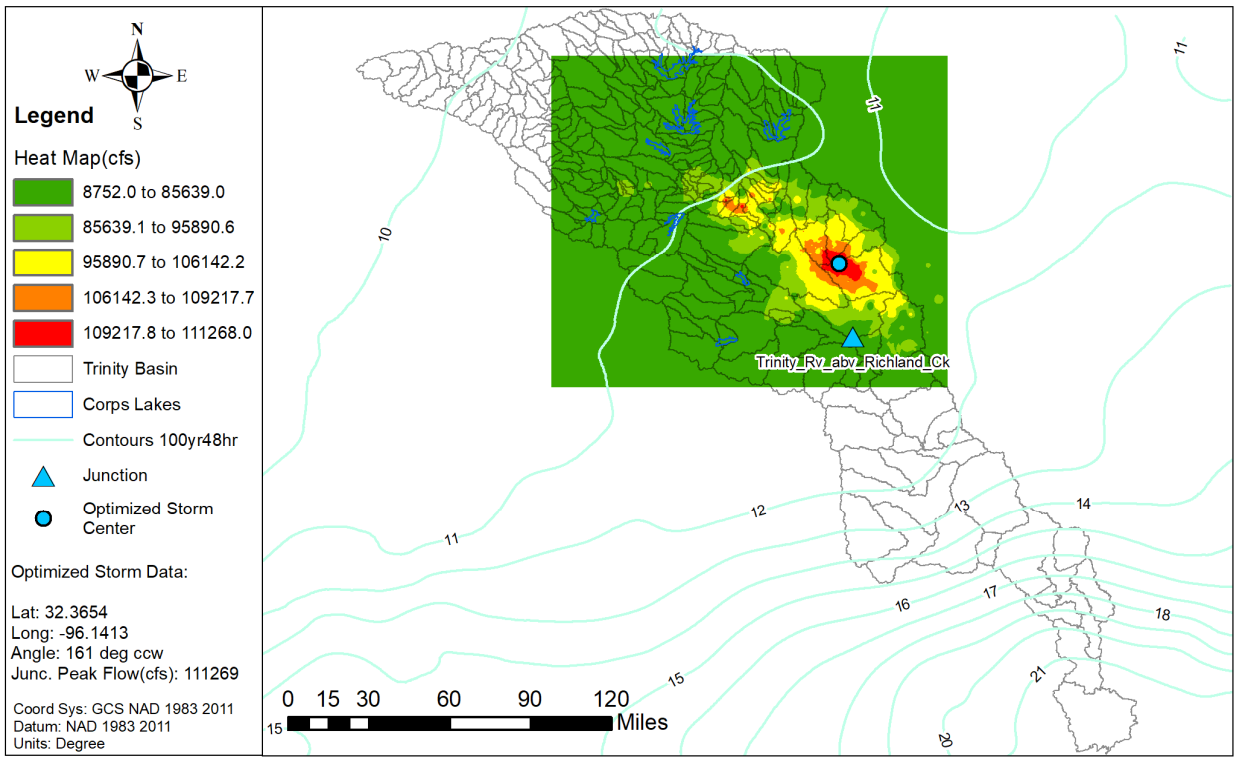


Figure 97a: Elliptical Storm Heat Map for the Trinity River above Richland Creek

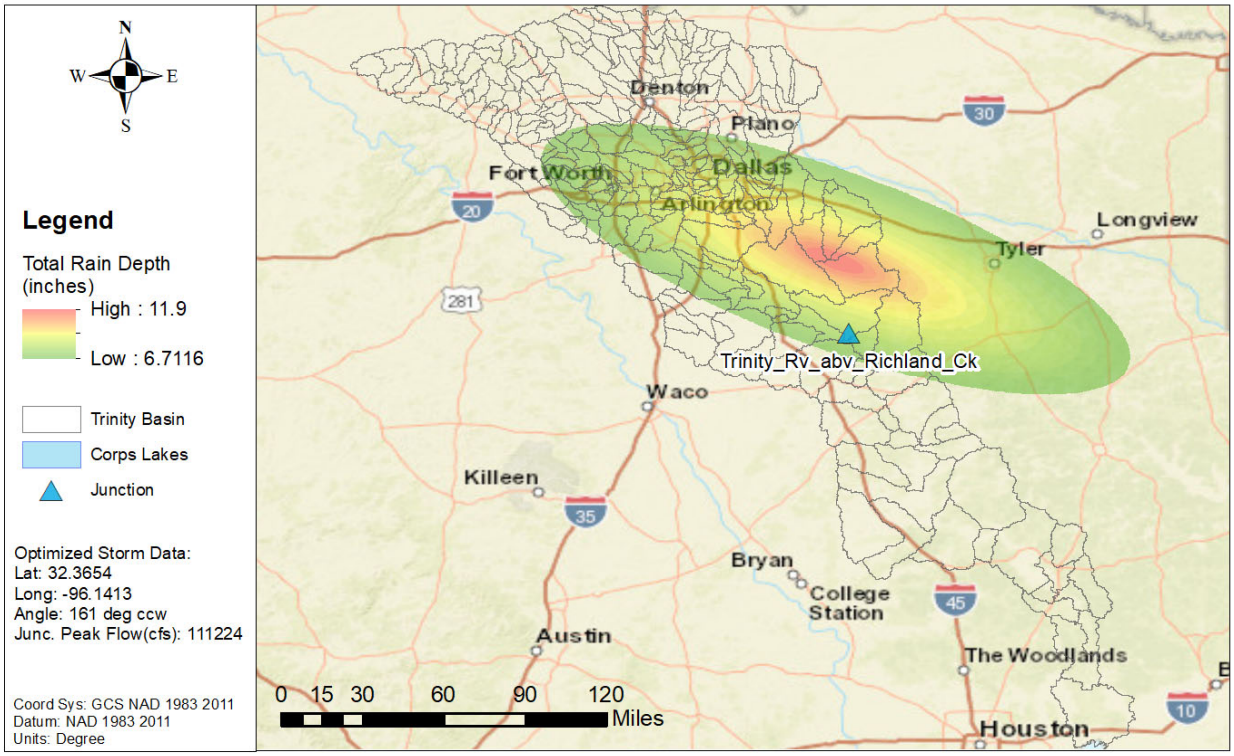


Figure 97b: NA14 1% AEP Elliptical Storm for the Trinity River above Richland Creek

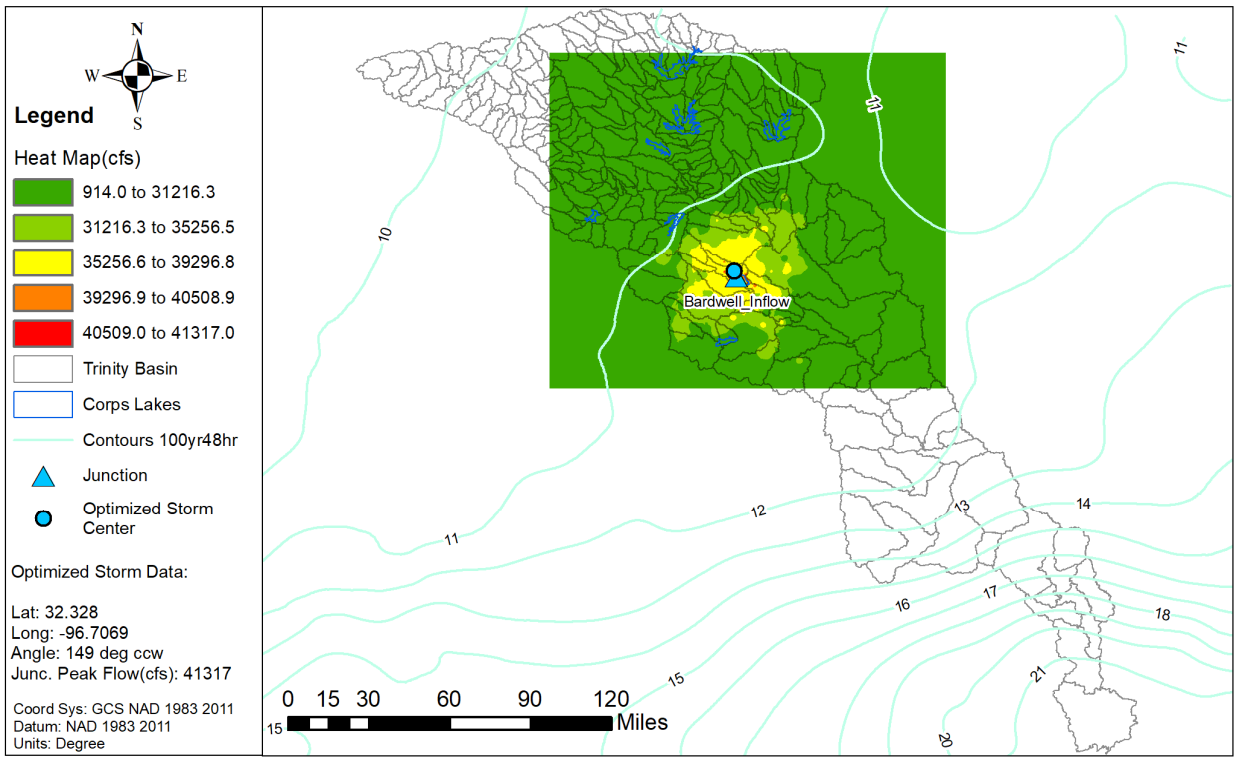


Figure 98a: Elliptical Storm Heat Map for the Bardwell Lake Inflow

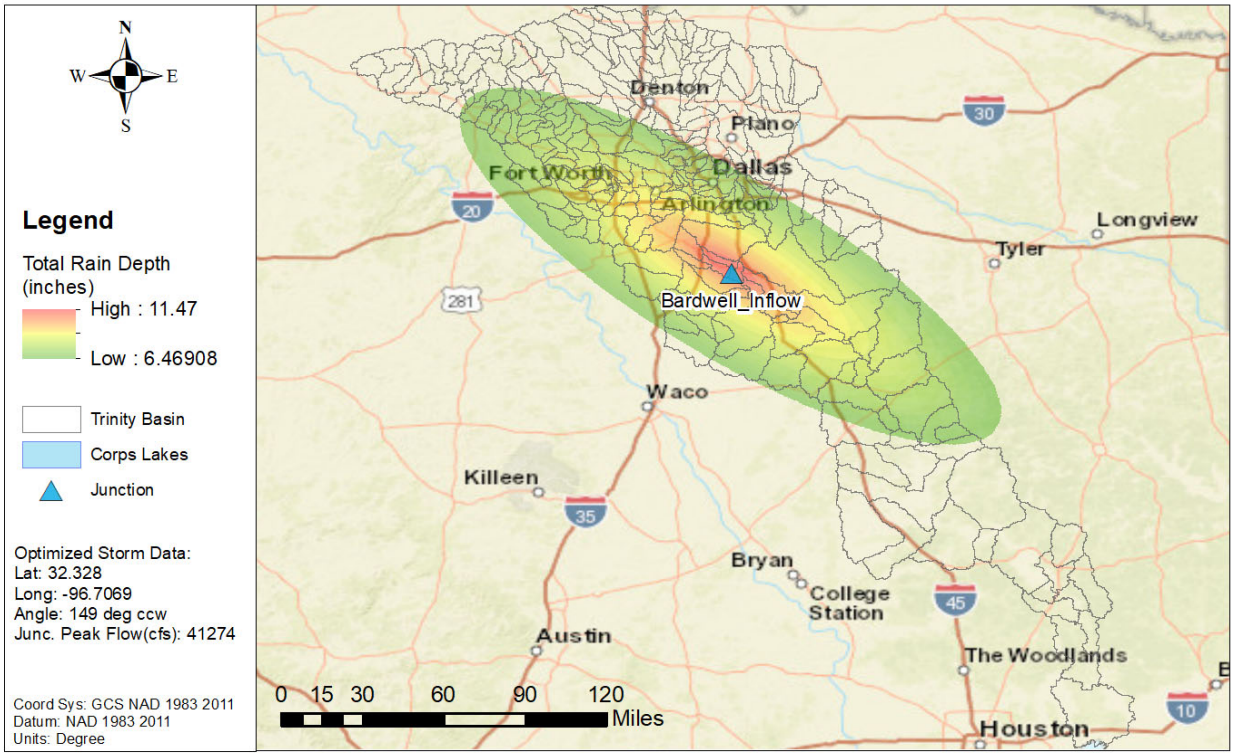


Figure 98b: NA14 1% AEP Elliptical Storm for the Bardwell Lake Inflow

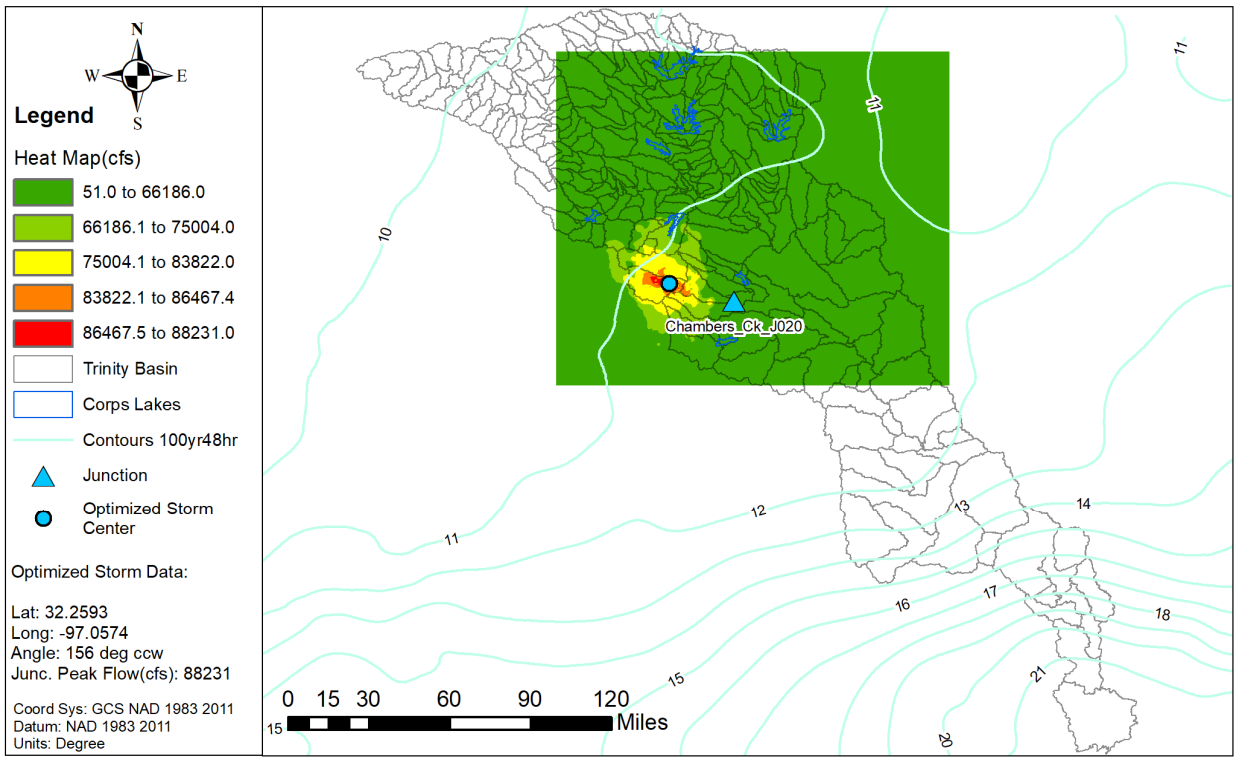


Figure 99a: Elliptical Storm Heat Map for the Chambers Creek below Mill Creek

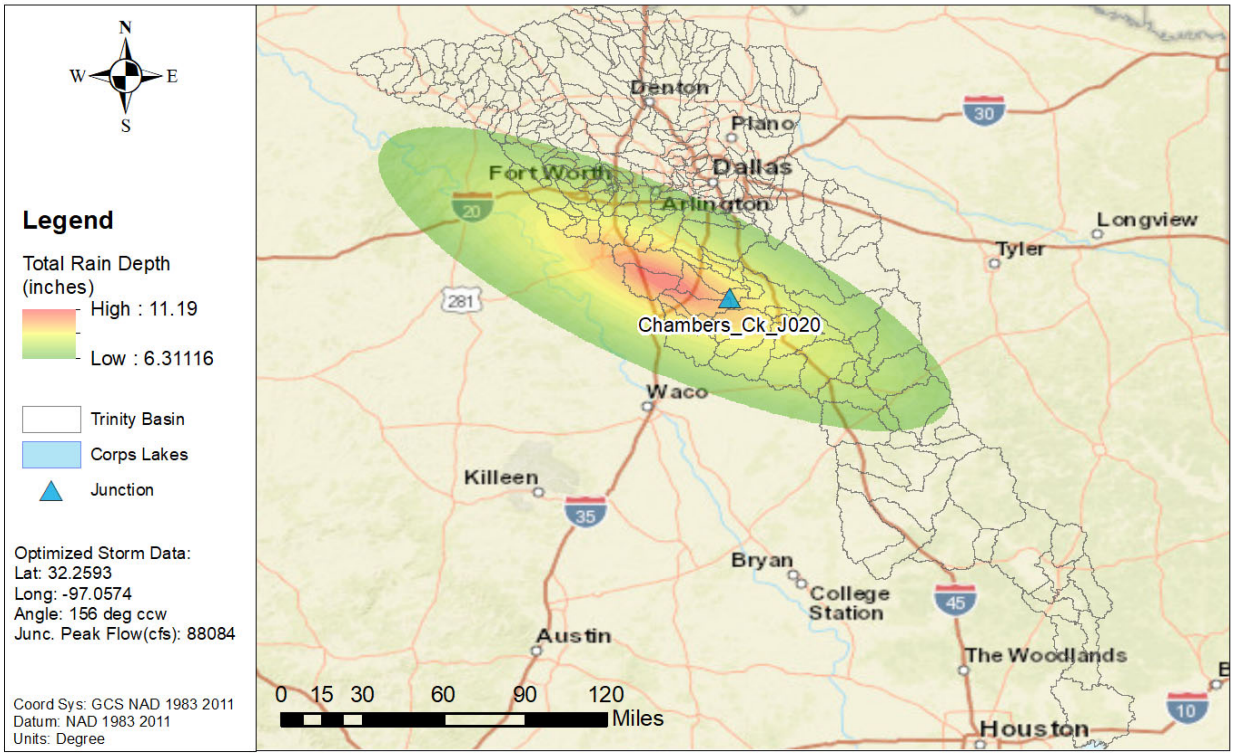


Figure 99b: NA14 1% AEP Elliptical Storm for the Chambers Creek below Mill Creek

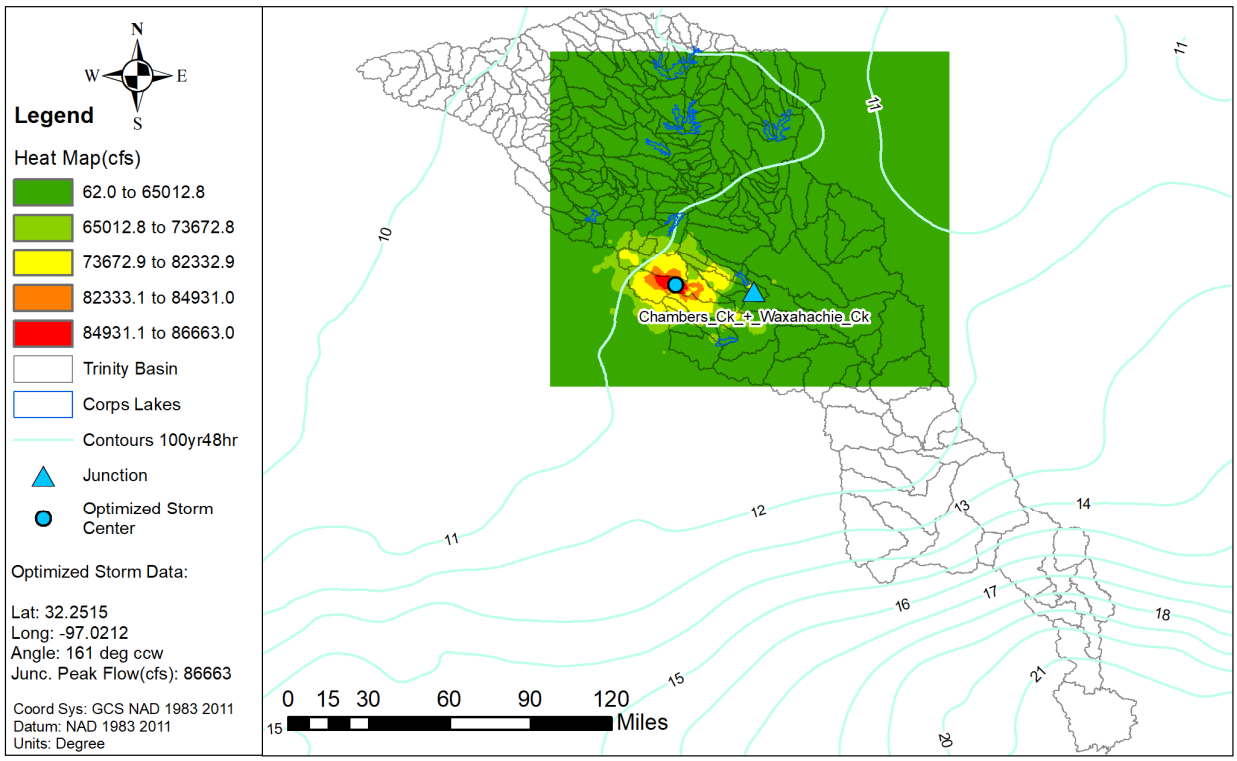


Figure 100a: Elliptical Storm Heat Map for the Chambers Creek below Waxahachie Creek

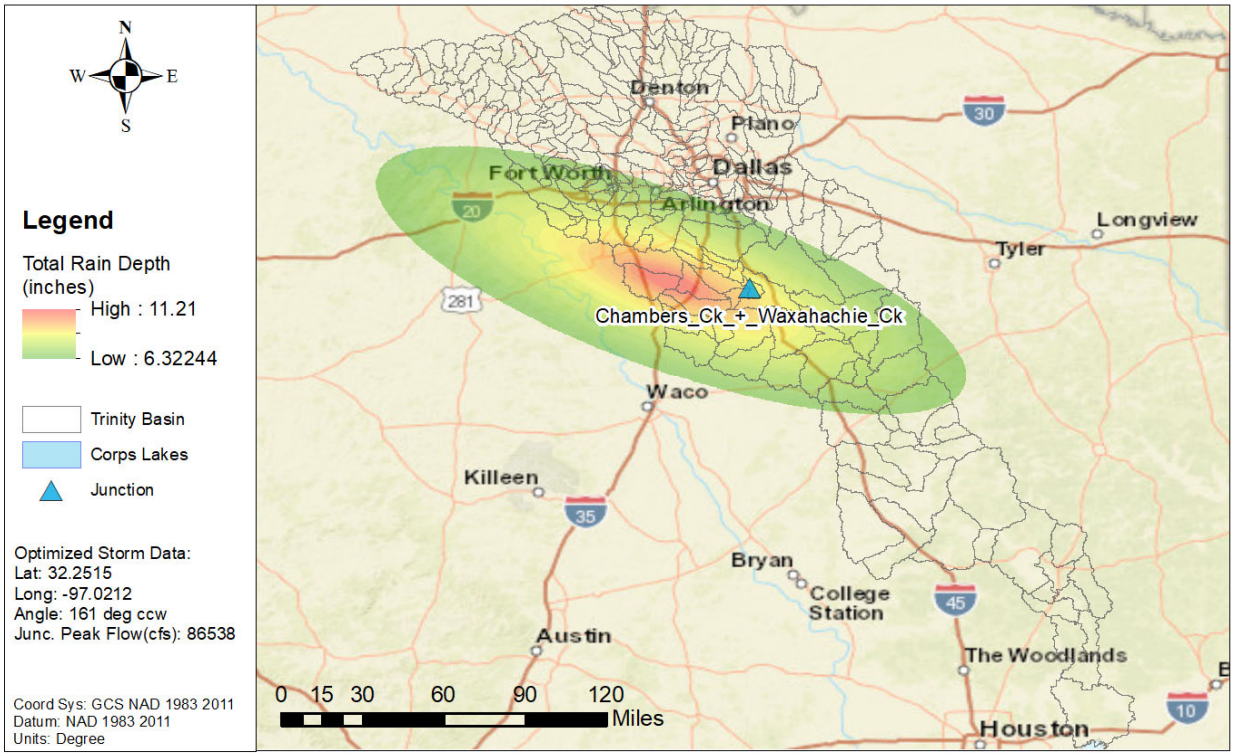


Figure 100b: NA14 1% AEP Elliptical Storm for the Chambers Creek below Waxahachie Creek

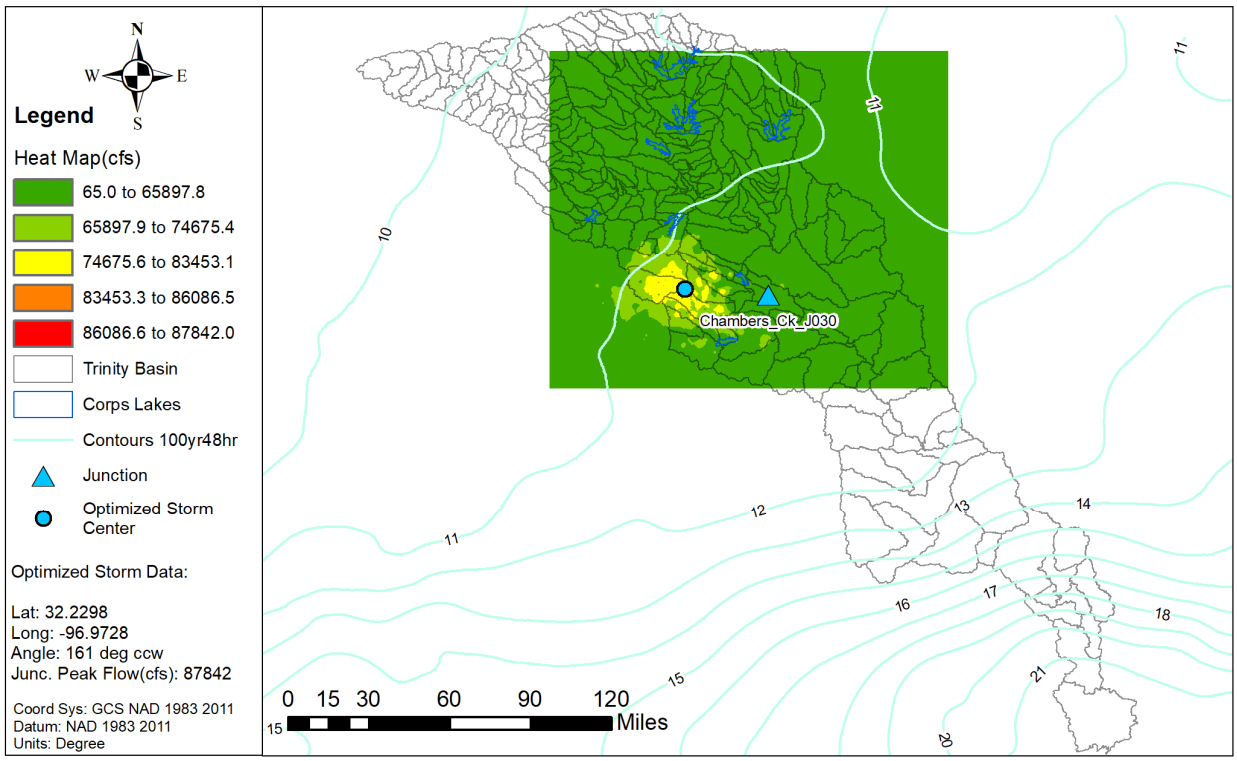


Figure 101a: Elliptical Storm Heat Map for the Chambers Creek near Rice, TX USGS gage

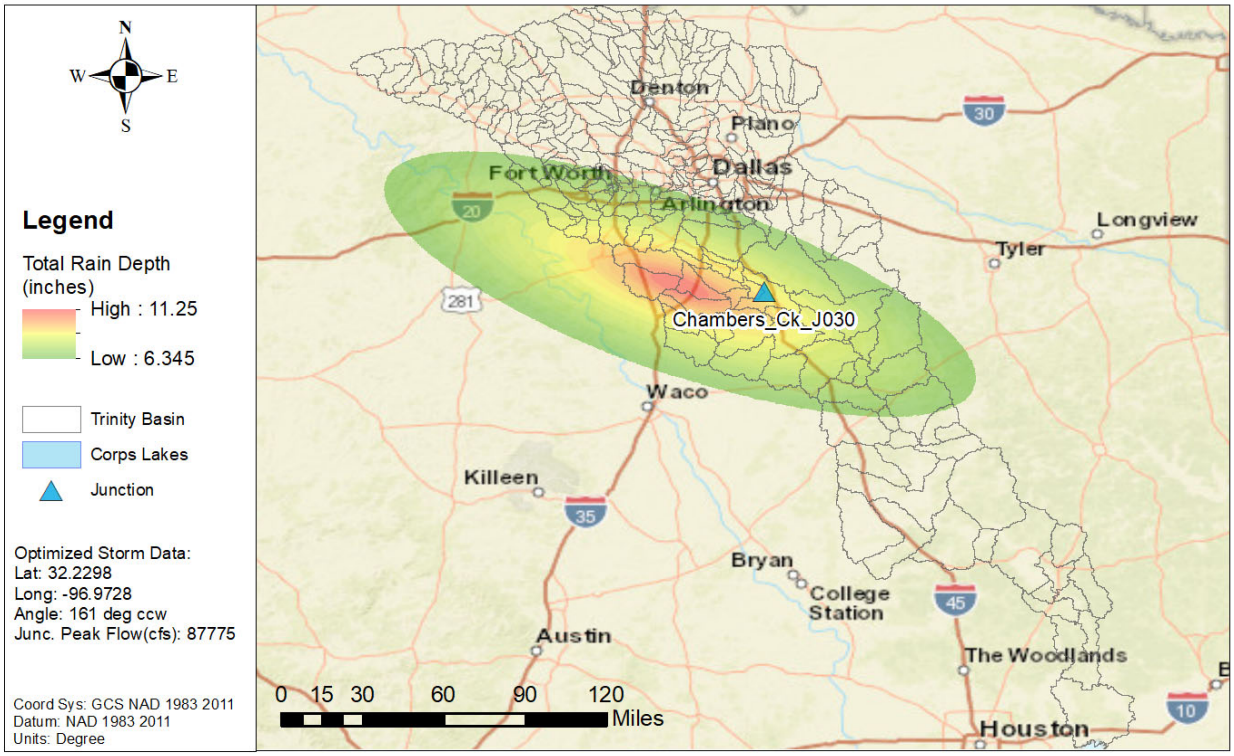


Figure 101b: NA14 1% AEP Elliptical Storm for the Chambers Creek near Rice, TX USGS gage

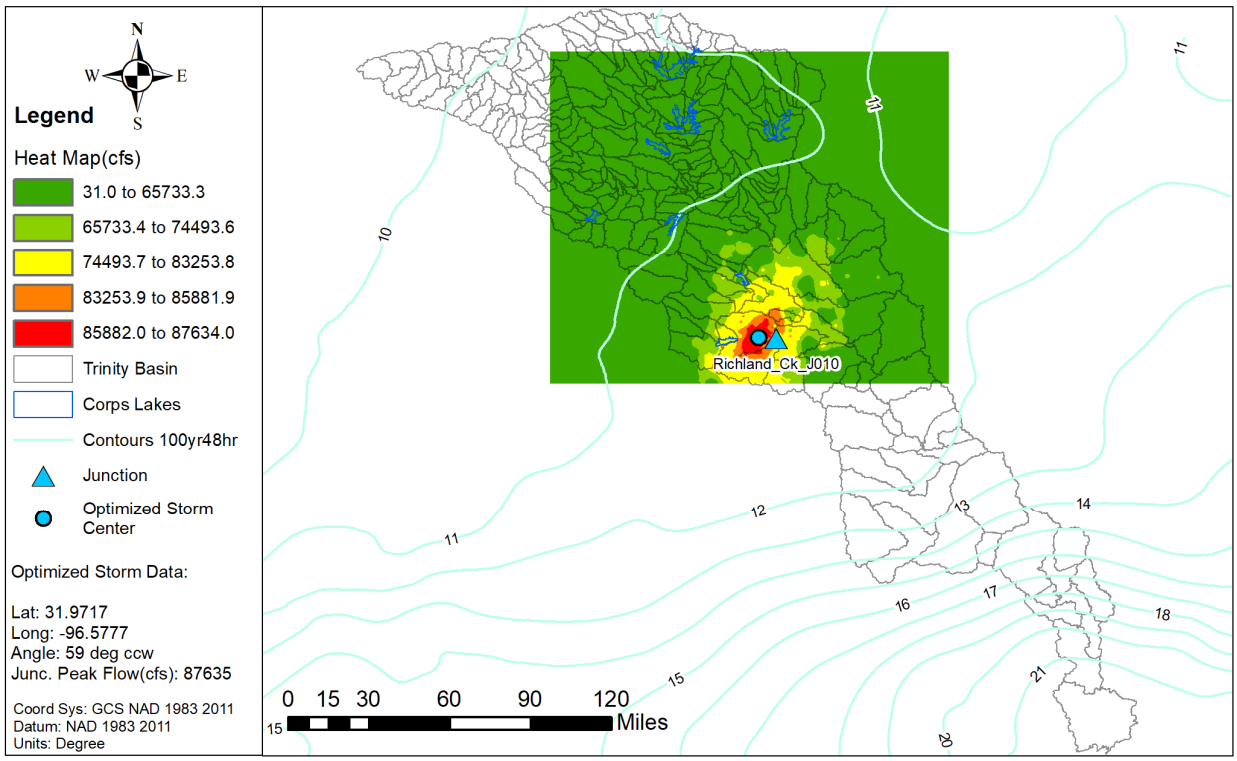


Figure 102a: Elliptical Storm Heat Map for the Richland Creek below Pin Oak Creek

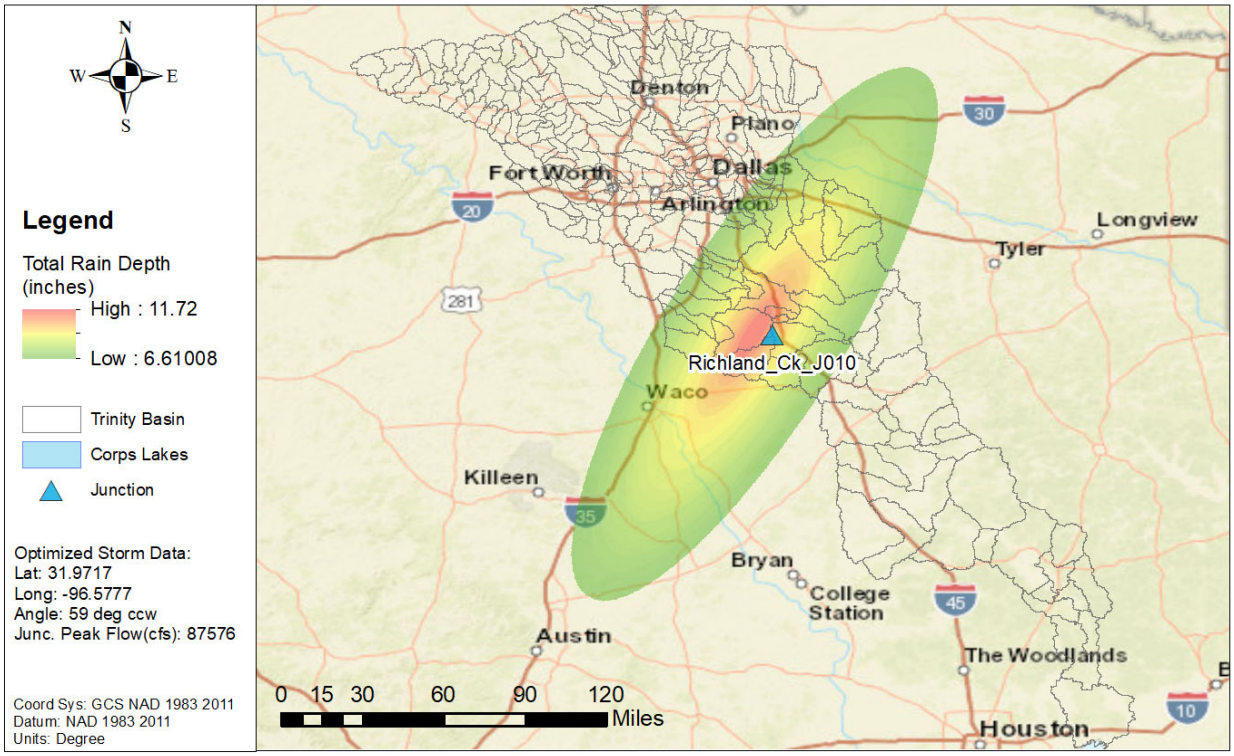


Figure 102b: NA14 1% AEP Elliptical Storm for the Richland Creek below Pin Oak Creek

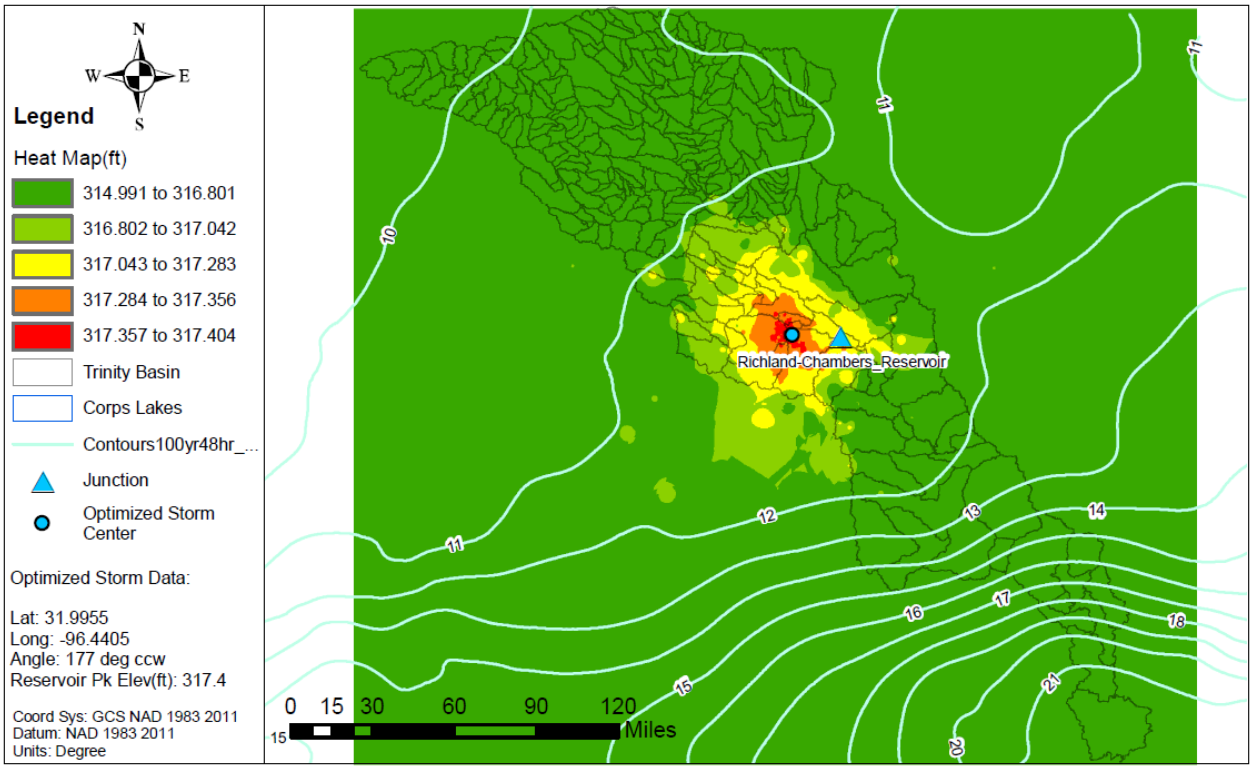


Figure 103a: Elliptical Storm Heat Map for the Richland Chambers Reservoir

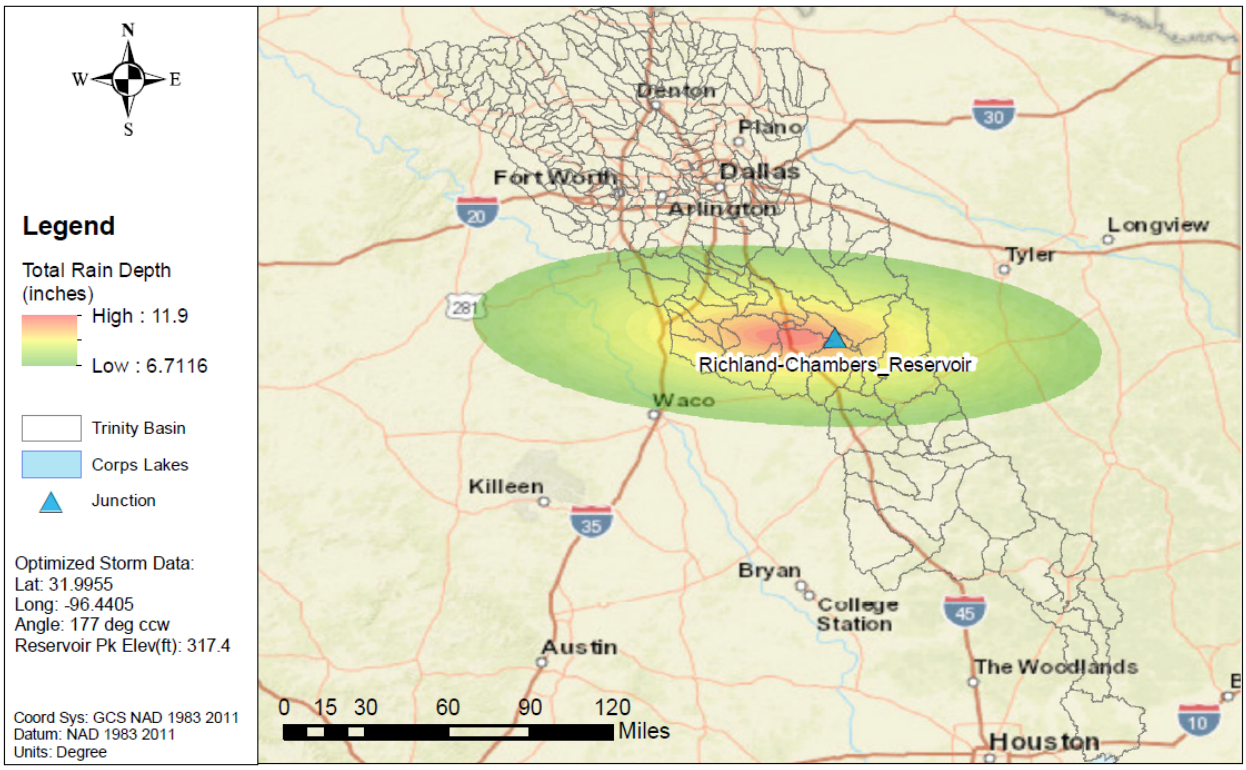


Figure 103b: NA14 1% AEP Elliptical Storm for the Richland Chambers Reservoir

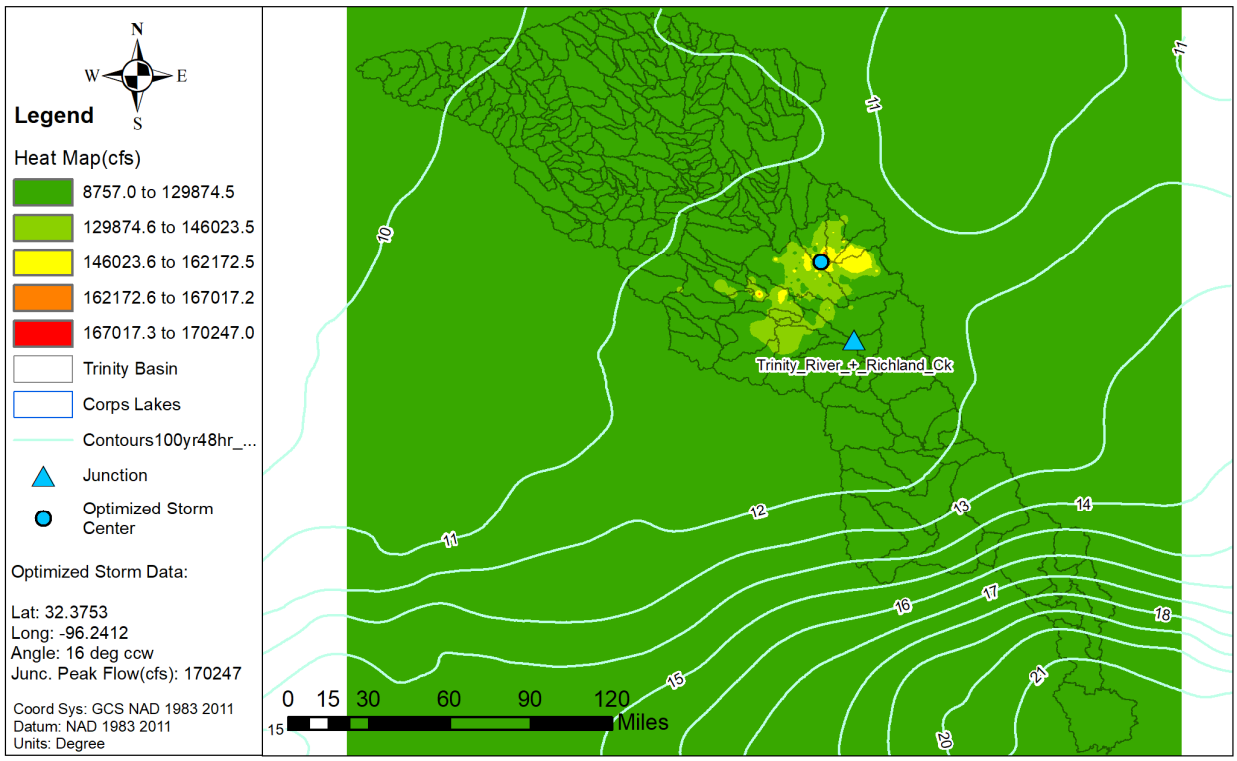


Figure 104a: Elliptical Storm Heat Map for the Trinity River below Richland Creek

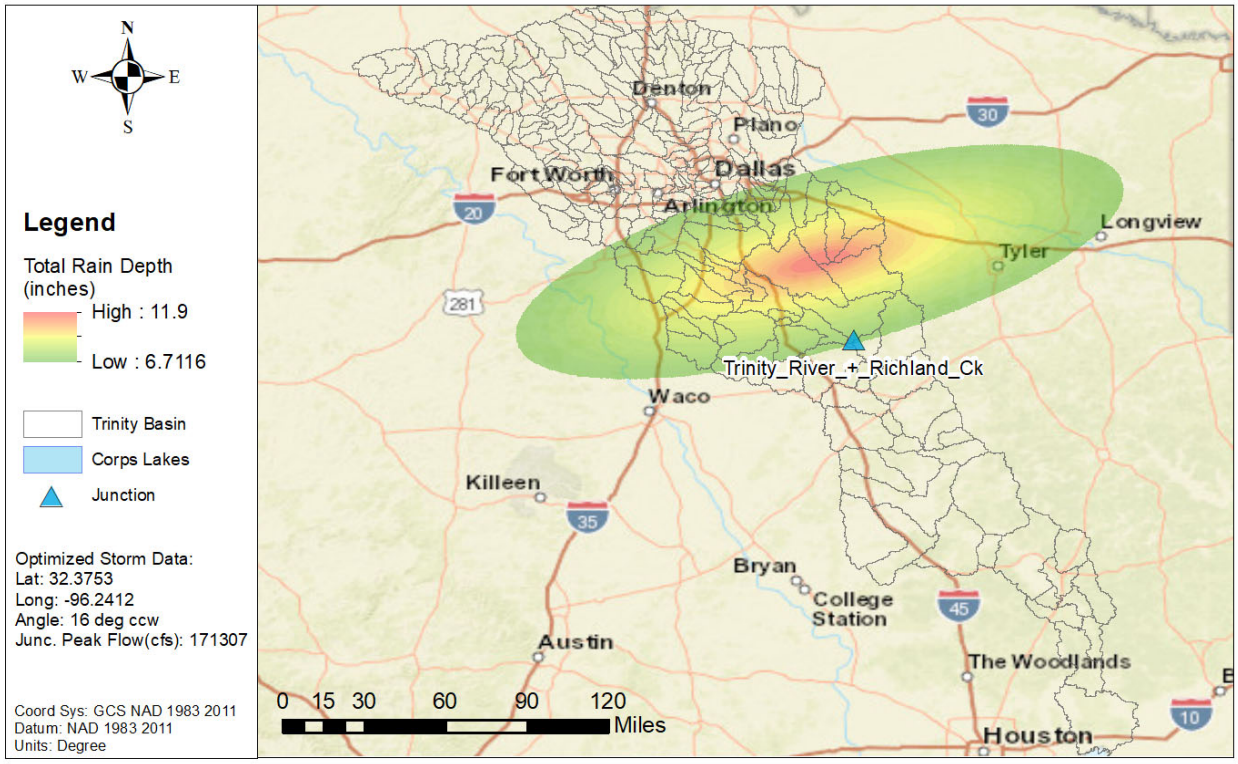


Figure 104b: NA14 1% AEP Elliptical Storm for the Trinity River below Richland Creek

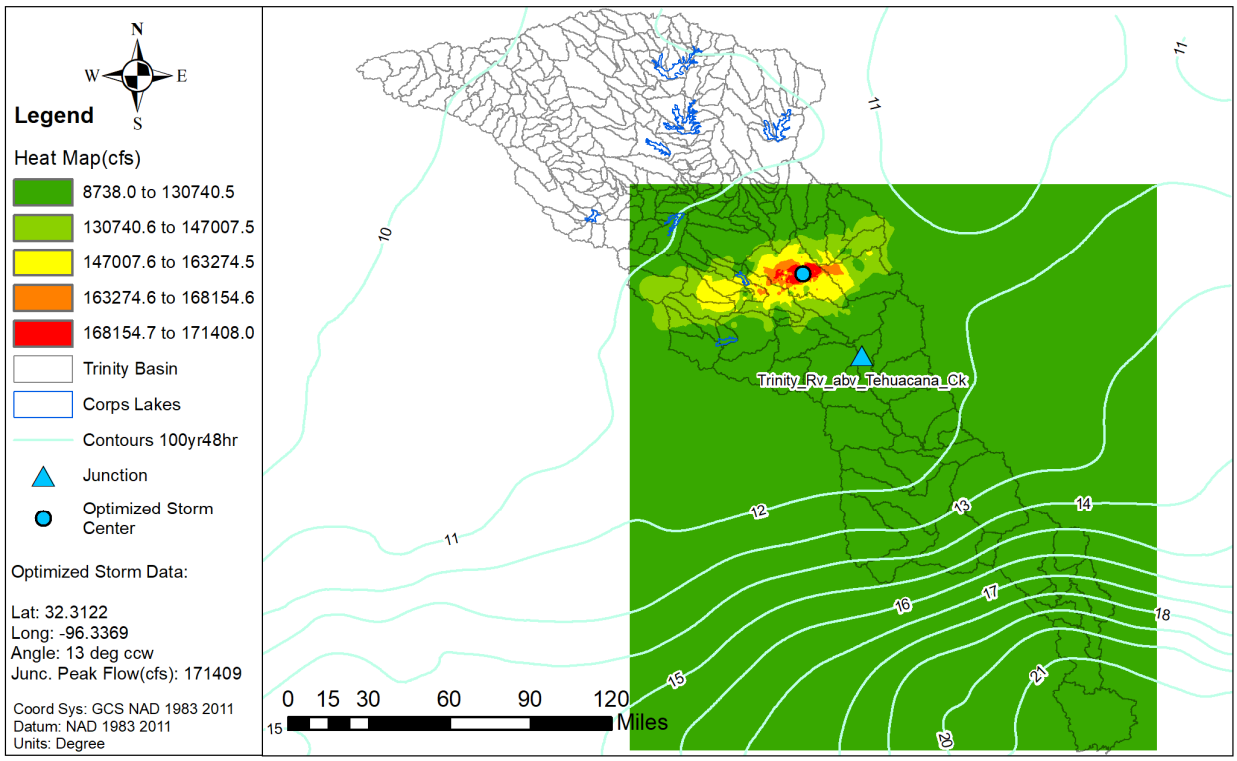


Figure 105a: Elliptical Storm Heat Map for the Trinity River above Tehuacana Creek

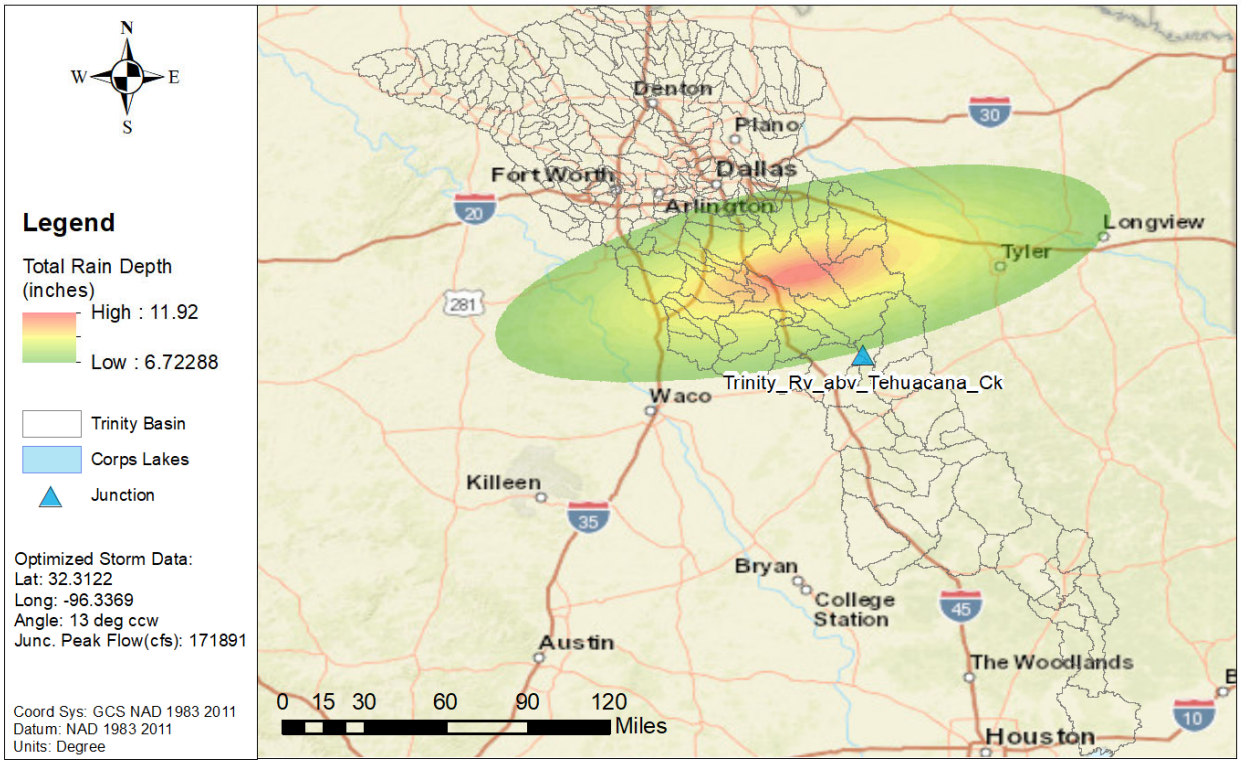


Figure 105b: NA14 1% AEP Elliptical Storm for the Trinity River above Tehuacana Creek

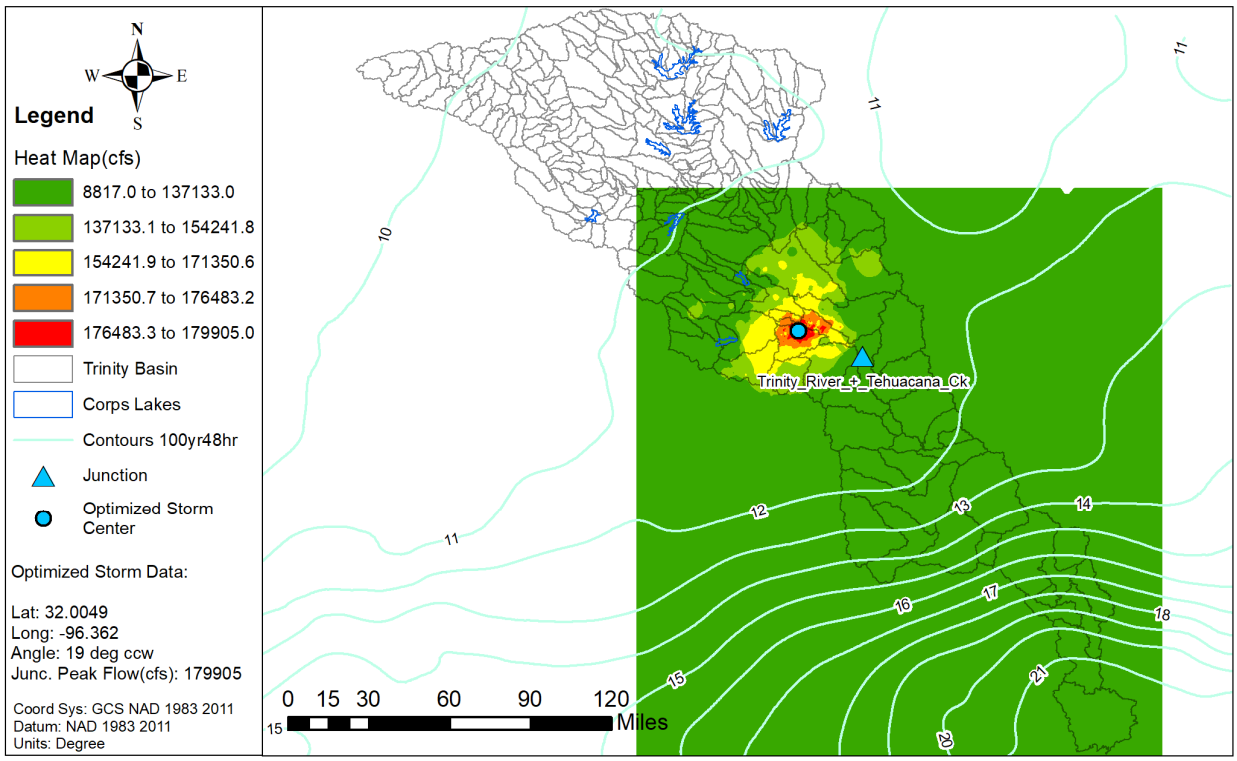


Figure 106a: Elliptical Storm Heat Map for the Trinity River below Tehuacana Creek

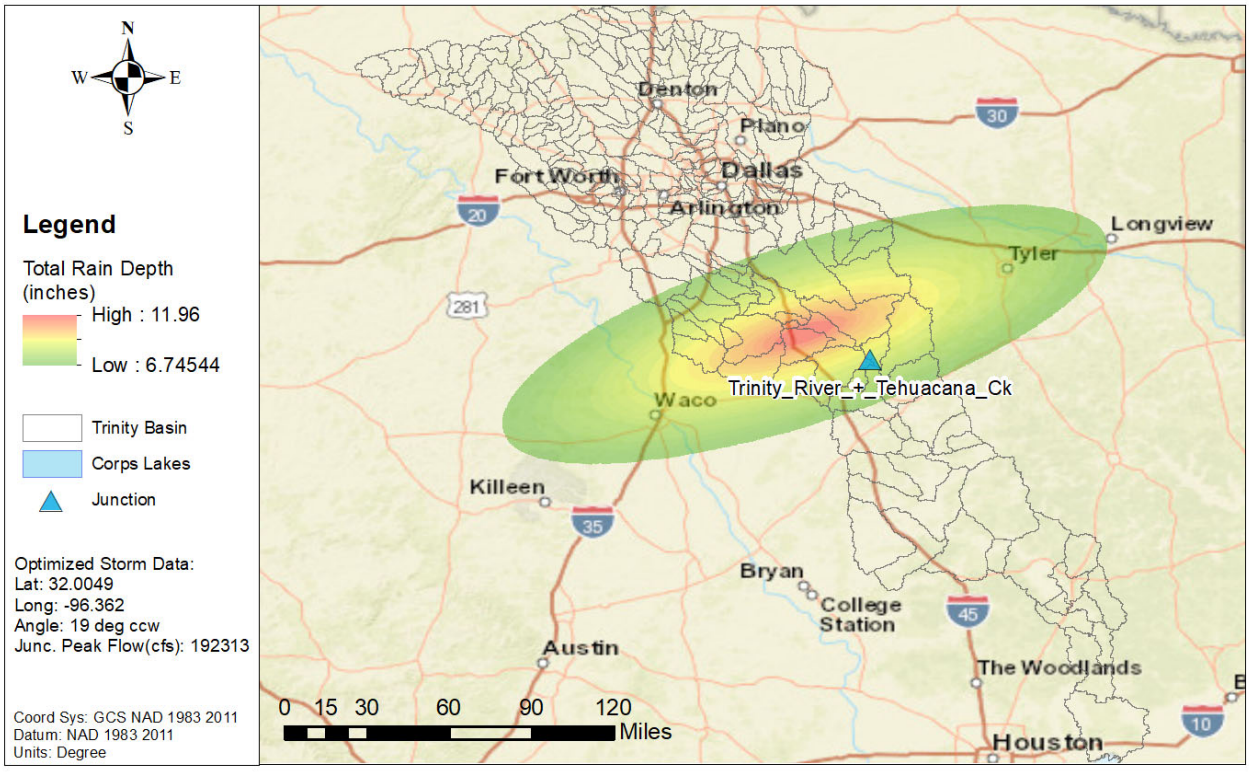


Figure 106b: NA14 1% AEP Elliptical Storm for the Trinity River below Tehuacana Creek

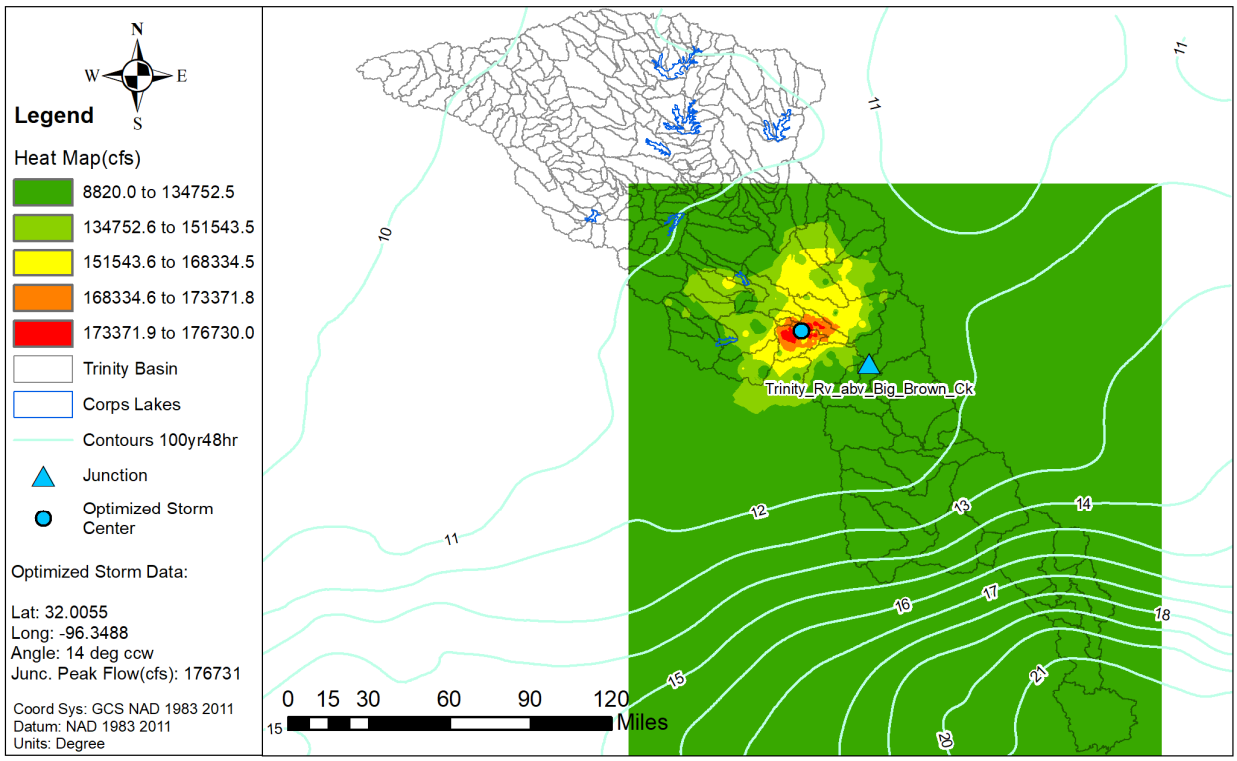


Figure 107a: Elliptical Storm Heat Map for the Trinity River above Big Brown Creek

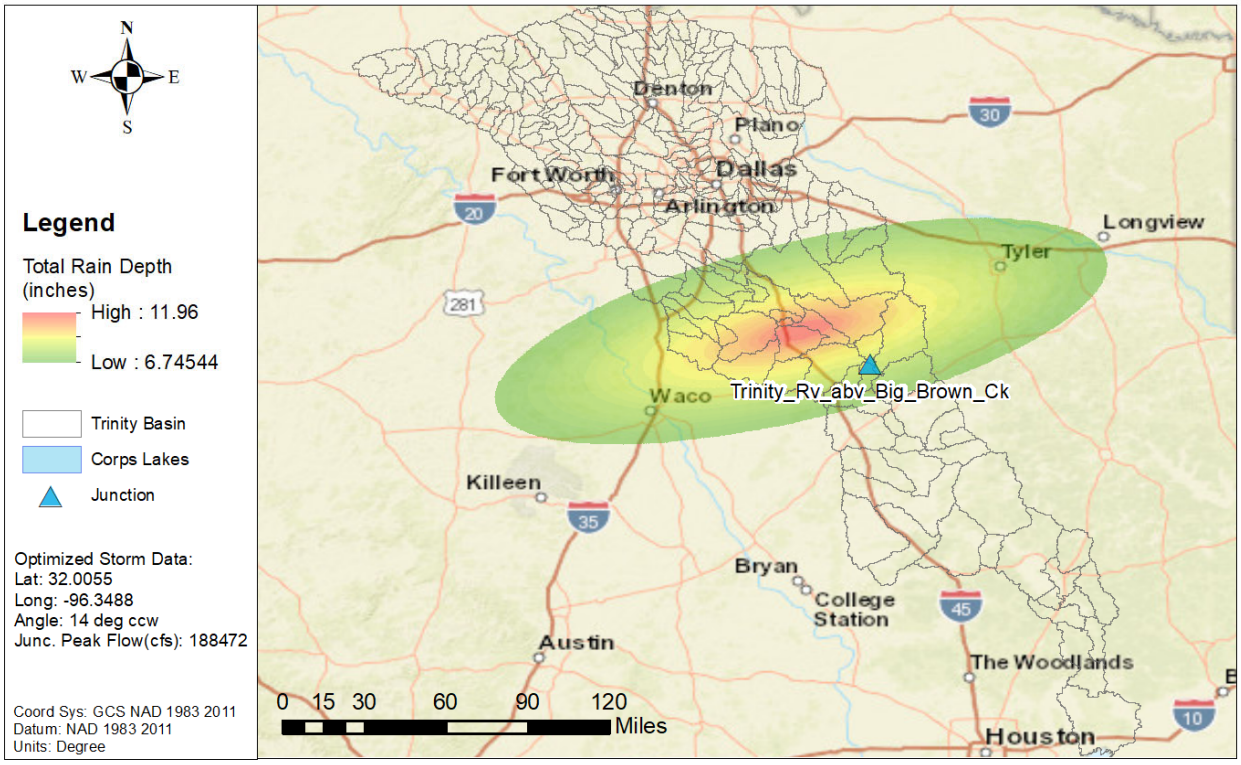


Figure 107b: NA14 1% AEP Elliptical Storm for the Trinity River above Big Brown Creek

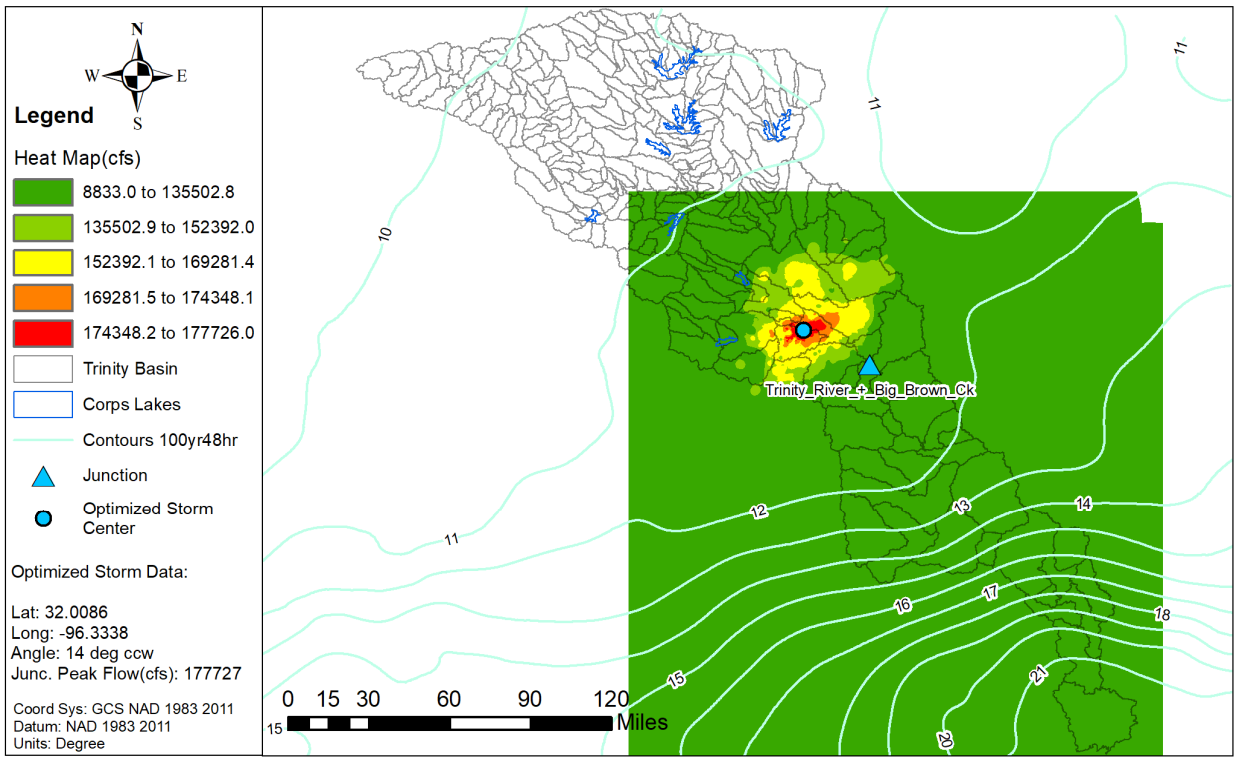


Figure 108a: Elliptical Storm Heat Map for the Trinity River below Big Brown Creek

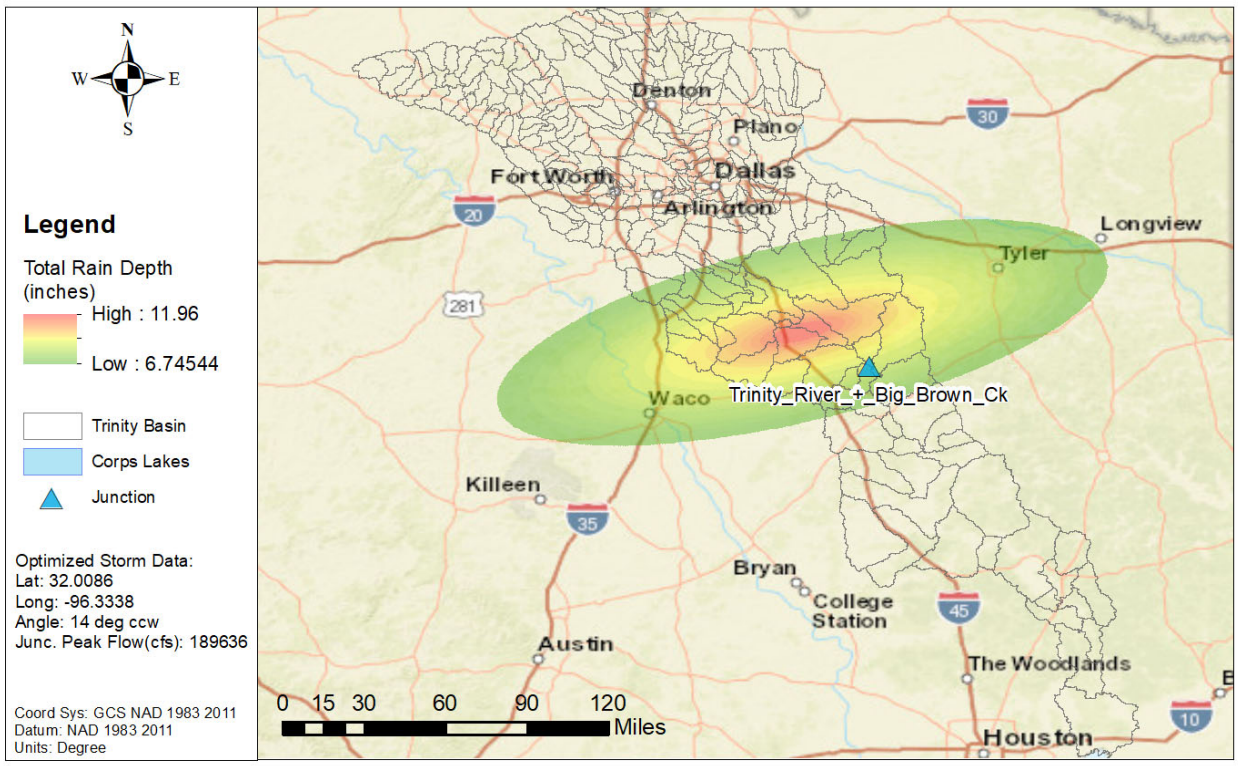


Figure 108b: NA14 1% AEP Elliptical Storm for the Trinity River below Big Brown Creek

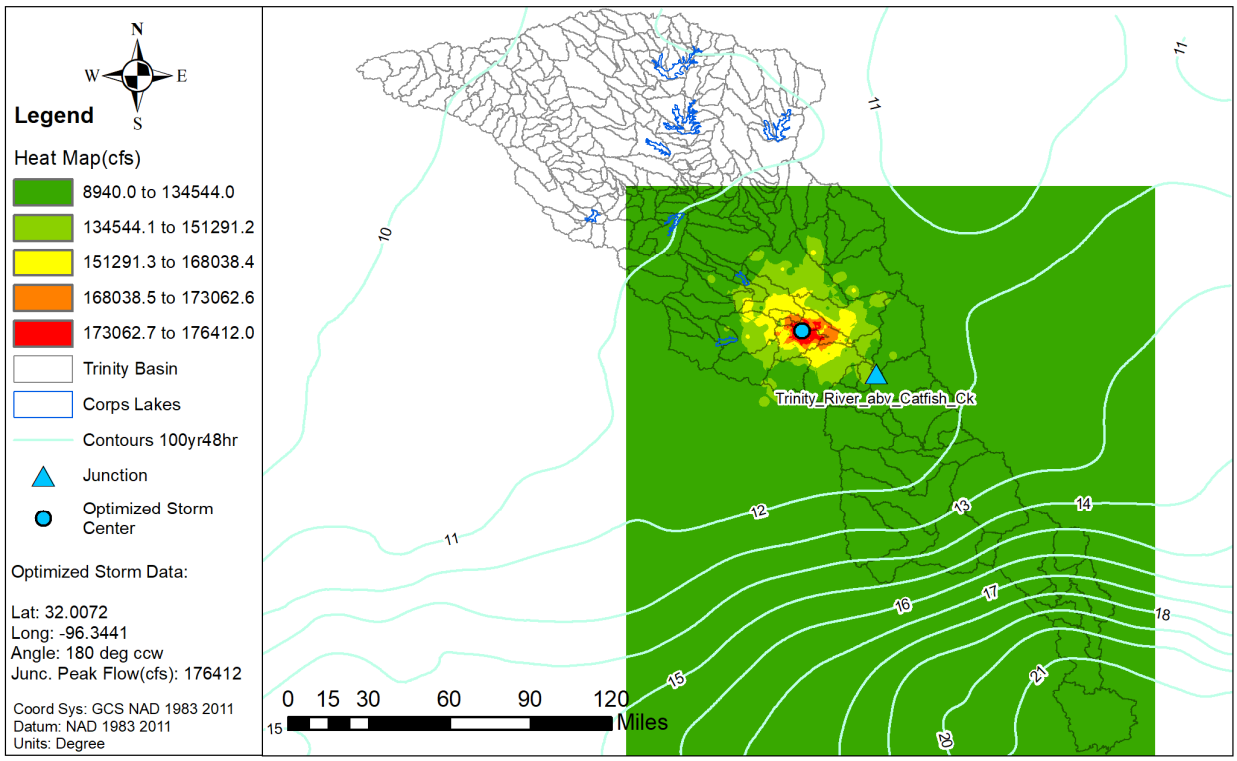


Figure 109a: Elliptical Storm Heat Map for the Trinity River above Catfish Creek

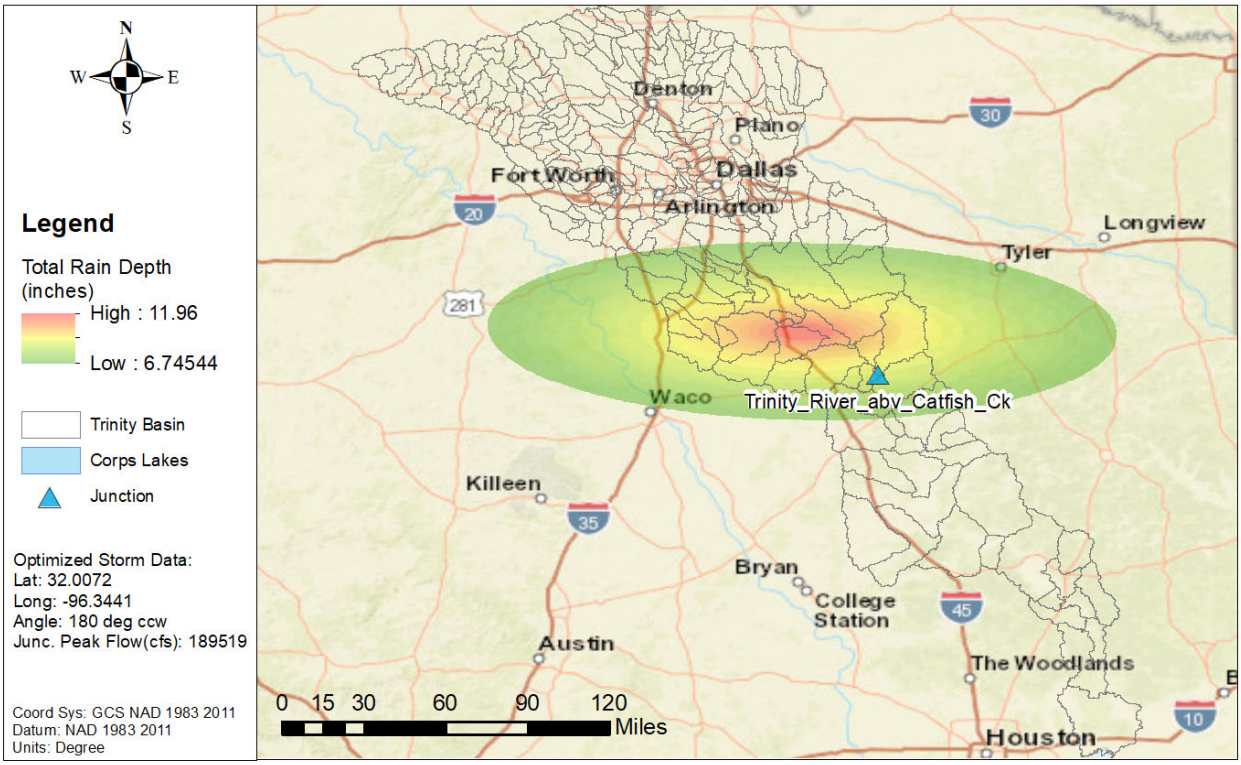


Figure 109b: NA14 1% AEP Elliptical Storm for the Trinity River above Catfish Creek

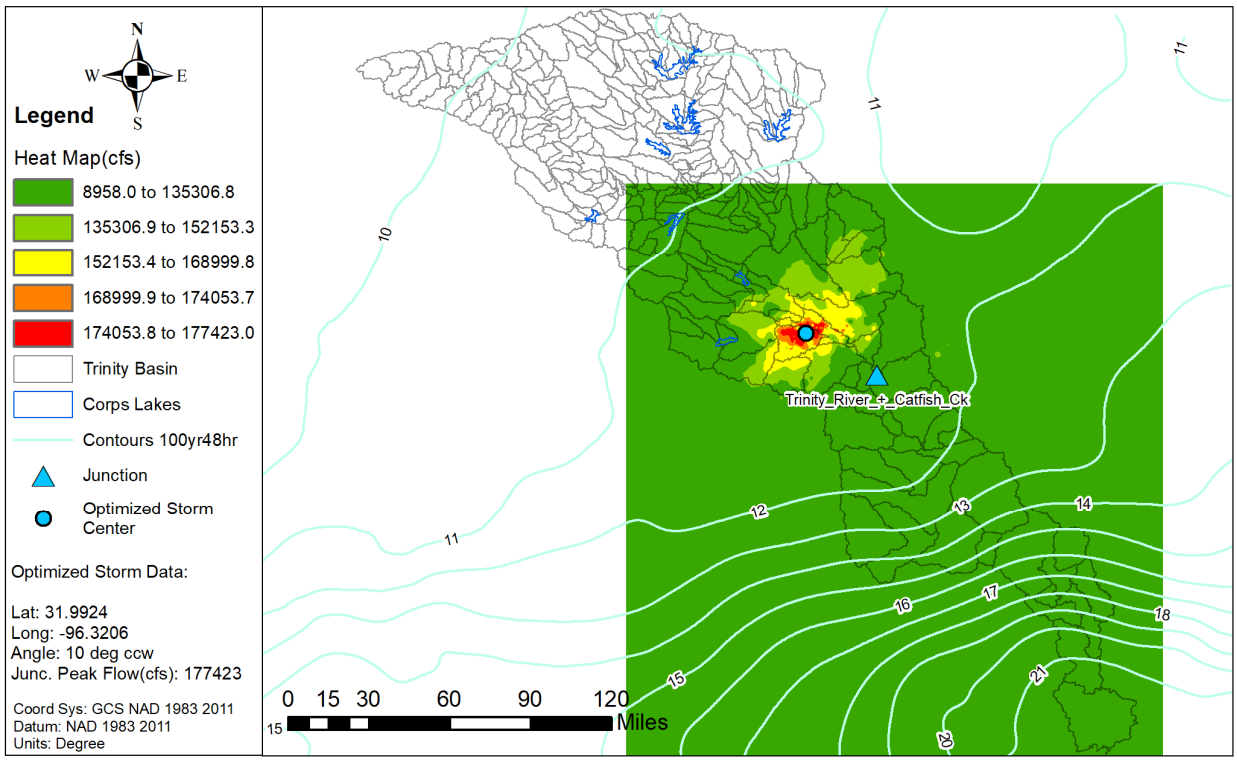


Figure 110a: Elliptical Storm Heat Map for the Trinity River below Catfish Creek

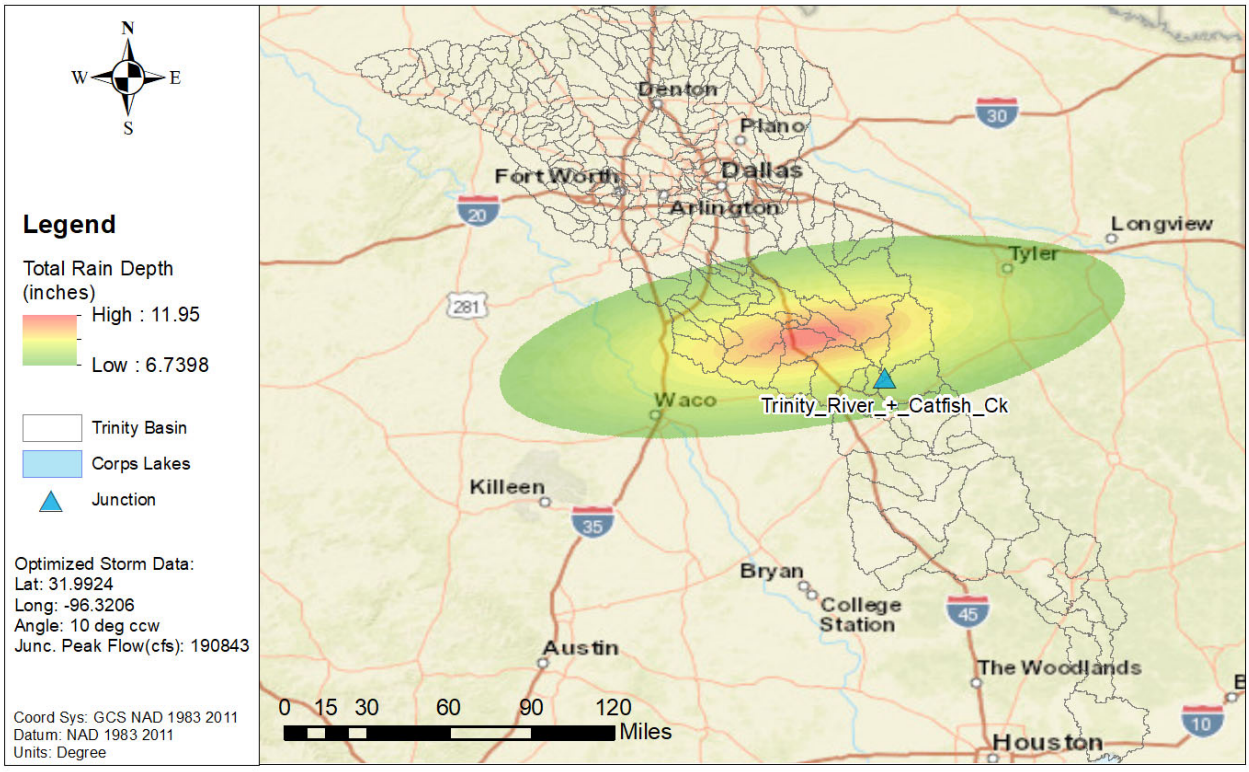


Figure 110b: NA14 1% AEP Elliptical Storm for the Trinity River below Catfish Creek

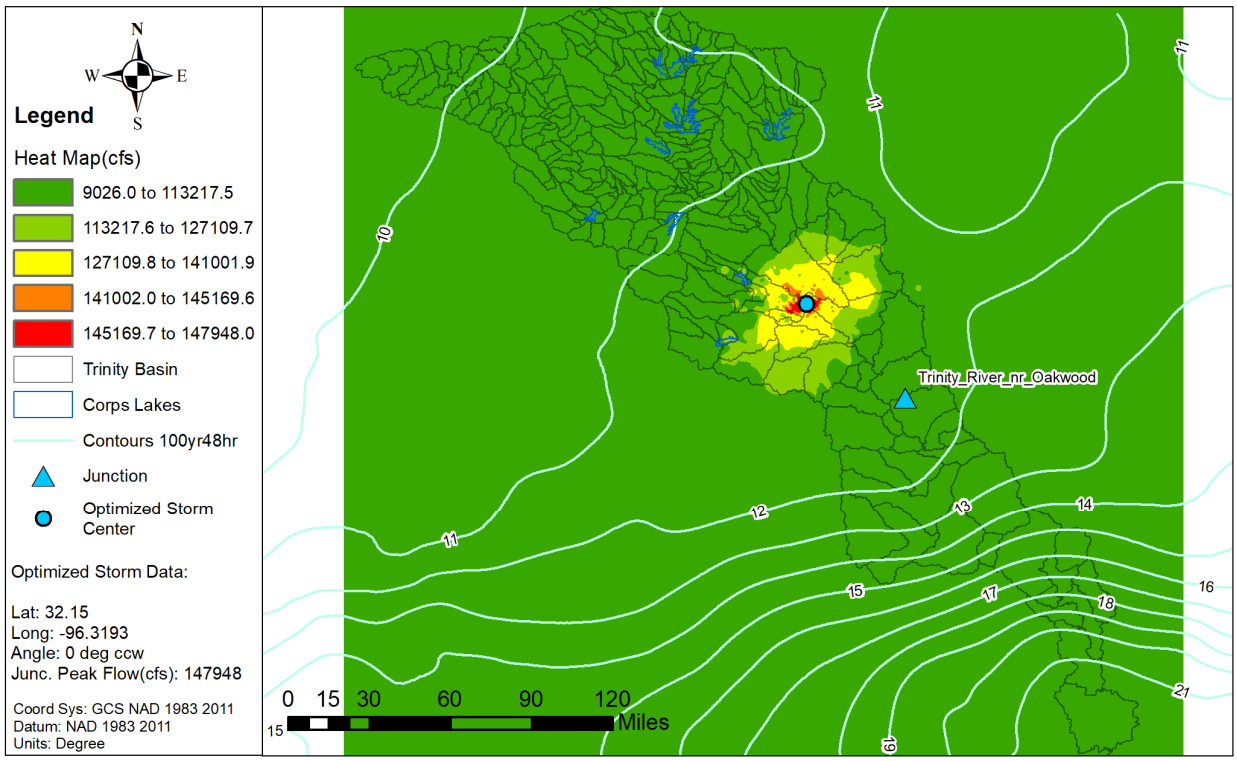


Figure 111a: Elliptical Storm Heat Map for the Trinity River near Oakwood, TX USGS gage

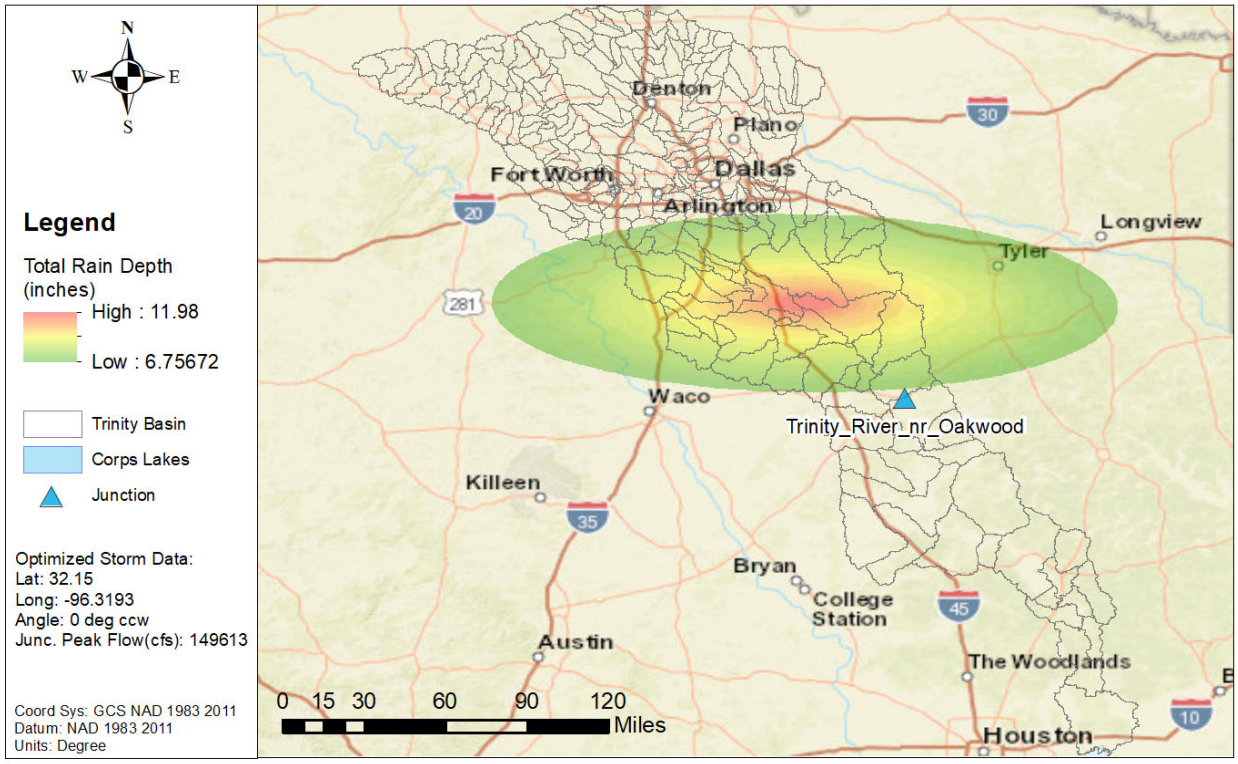


Figure 111b: NA14 1% AEP Elliptical Storm for the Trinity River near Oakwood, TX USGS gage

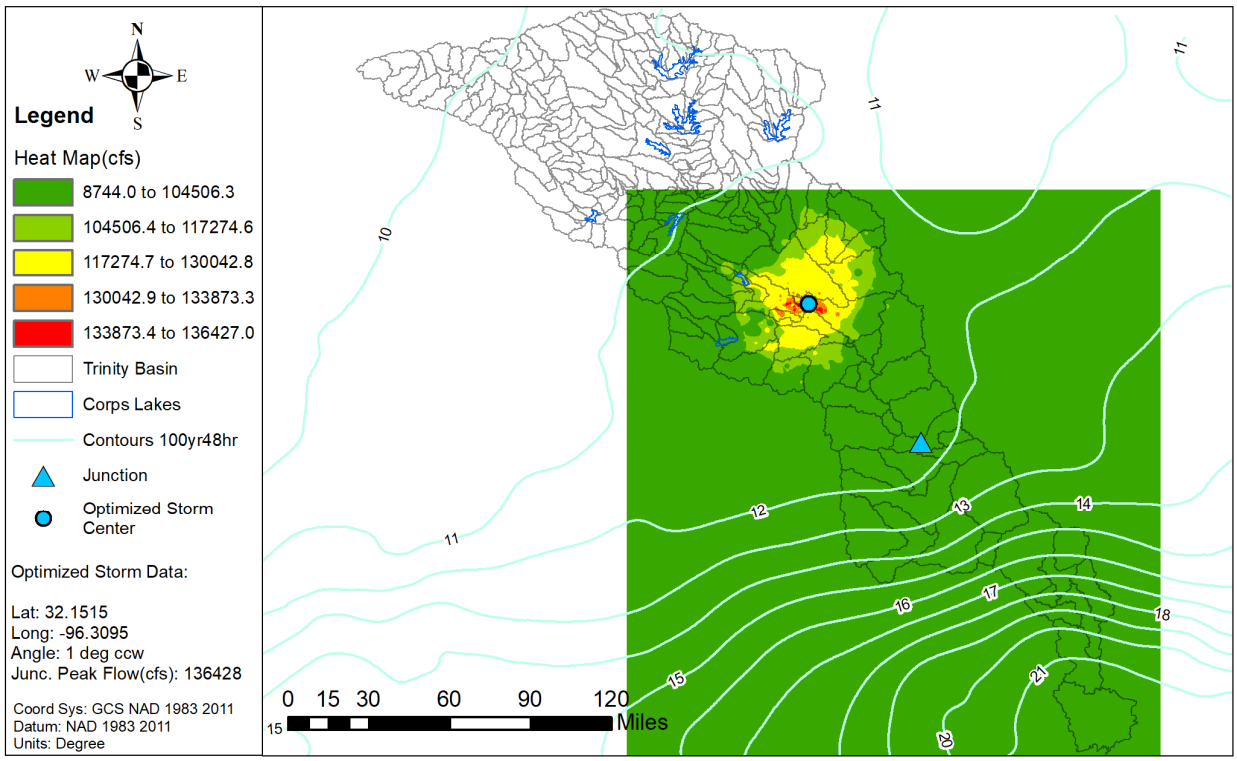


Figure 112a: Elliptical Storm Heat Map for the Trinity River above Upper Keechi Creek

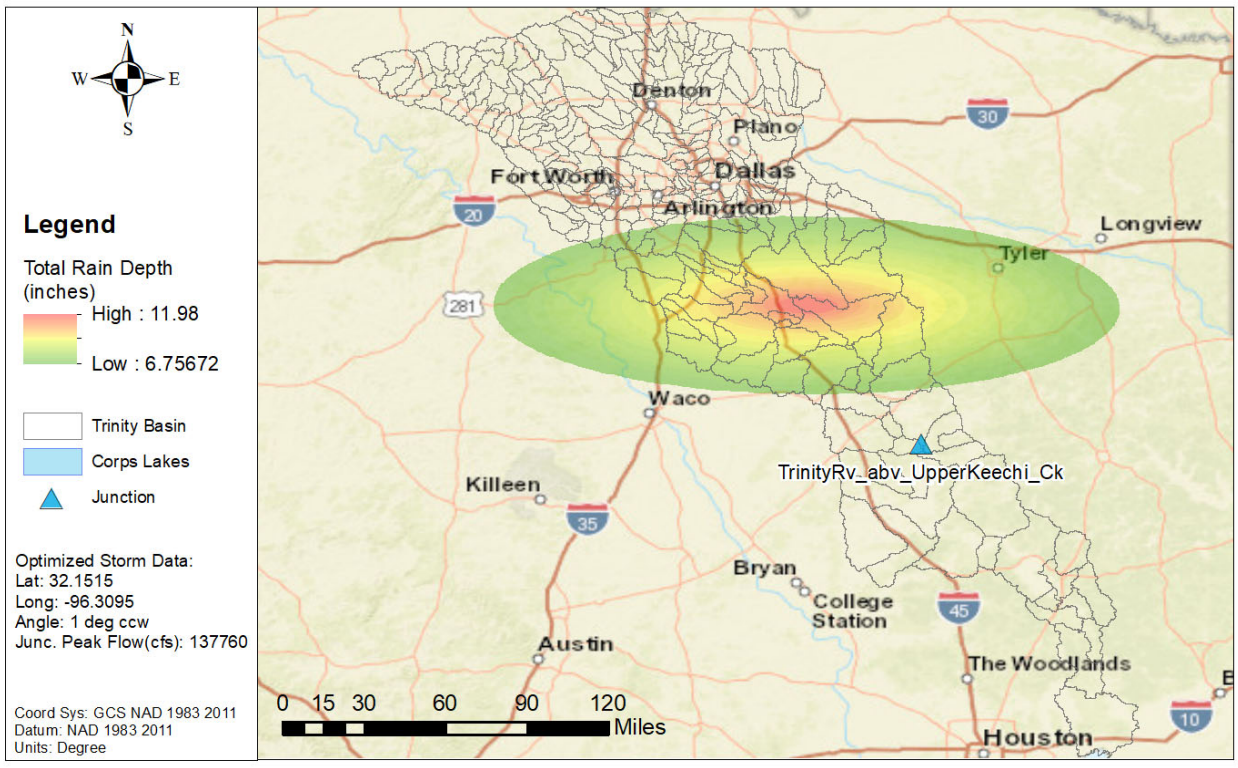


Figure 112b: NA14 1% AEP Elliptical Storm for the Trinity River above Upper Keechi Creek

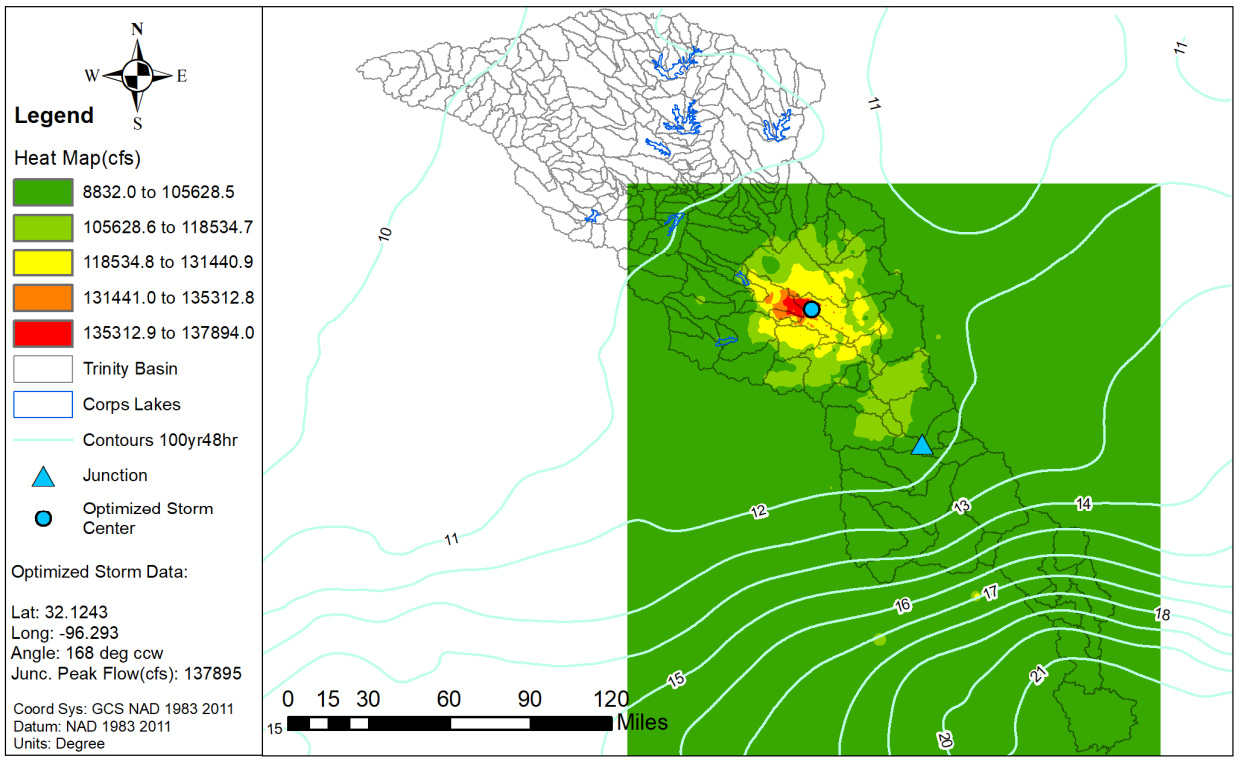


Figure 113a: Elliptical Storm Heat Map for the Trinity River below Upper Keechi Creek

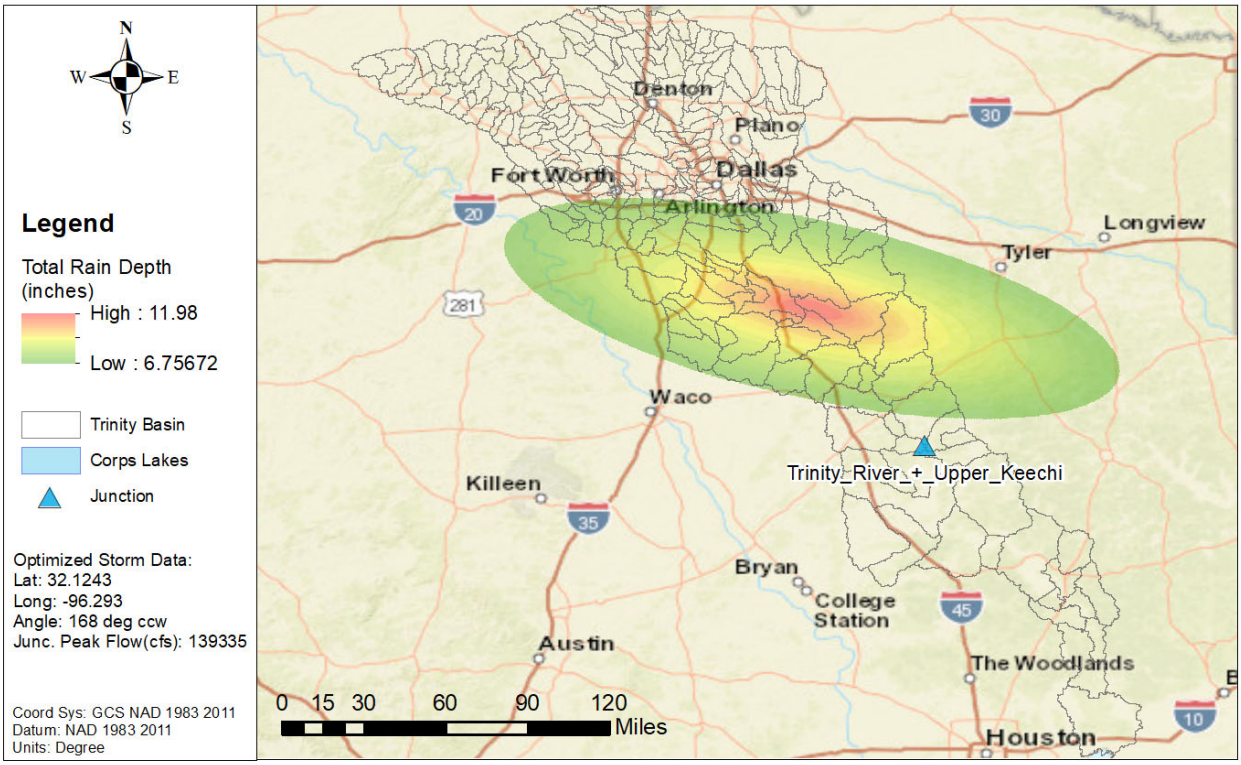


Figure 113b: NA14 1% AEP Elliptical Storm for the Trinity River below Upper Keechi Creek

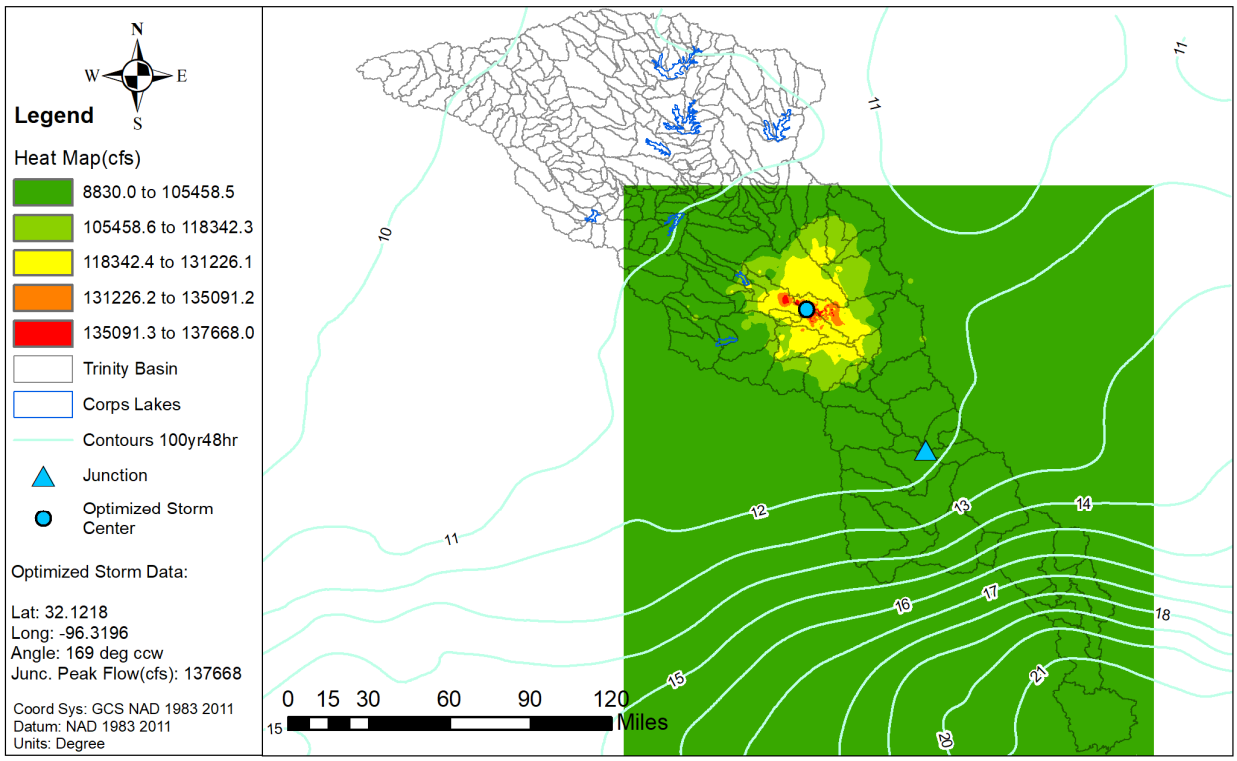


Figure 114a: Elliptical Storm Heat Map for the Trinity River above Big Elkhart Creek

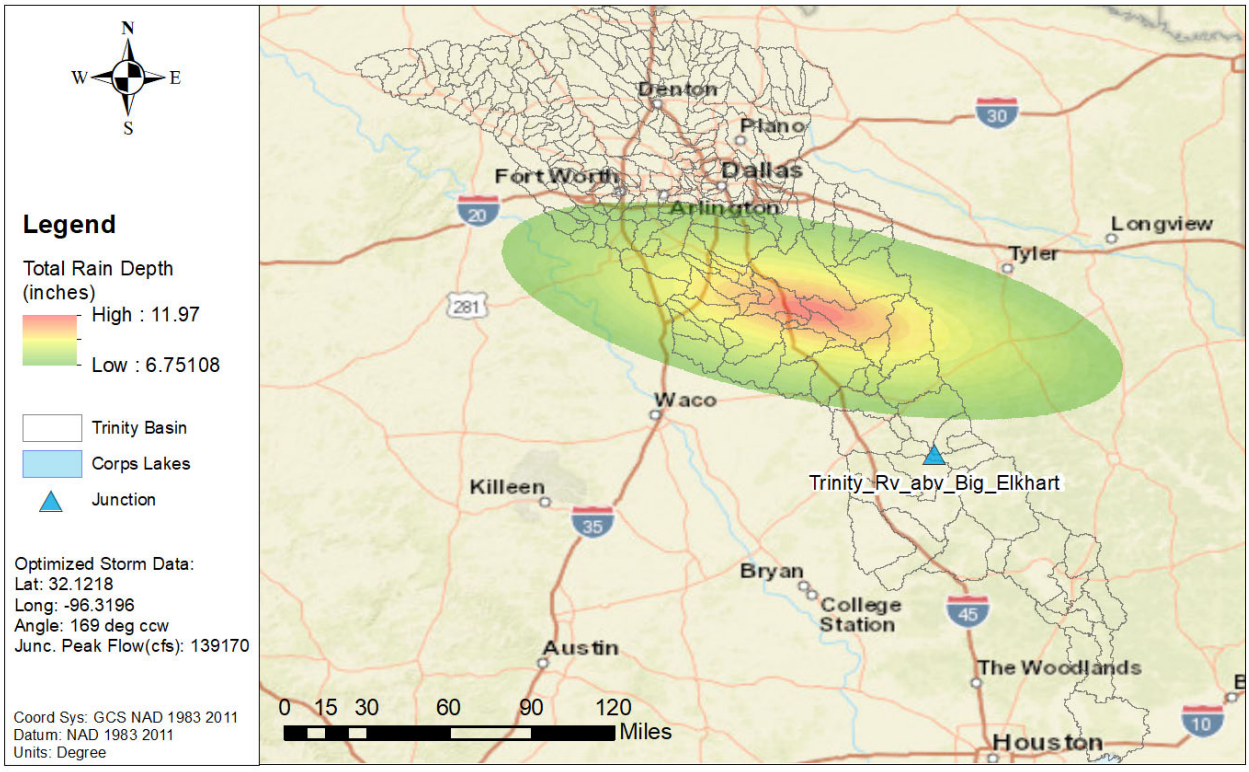


Figure 114b: NA14 1% AEP Elliptical Storm for the Trinity River above Big Elkhart Creek

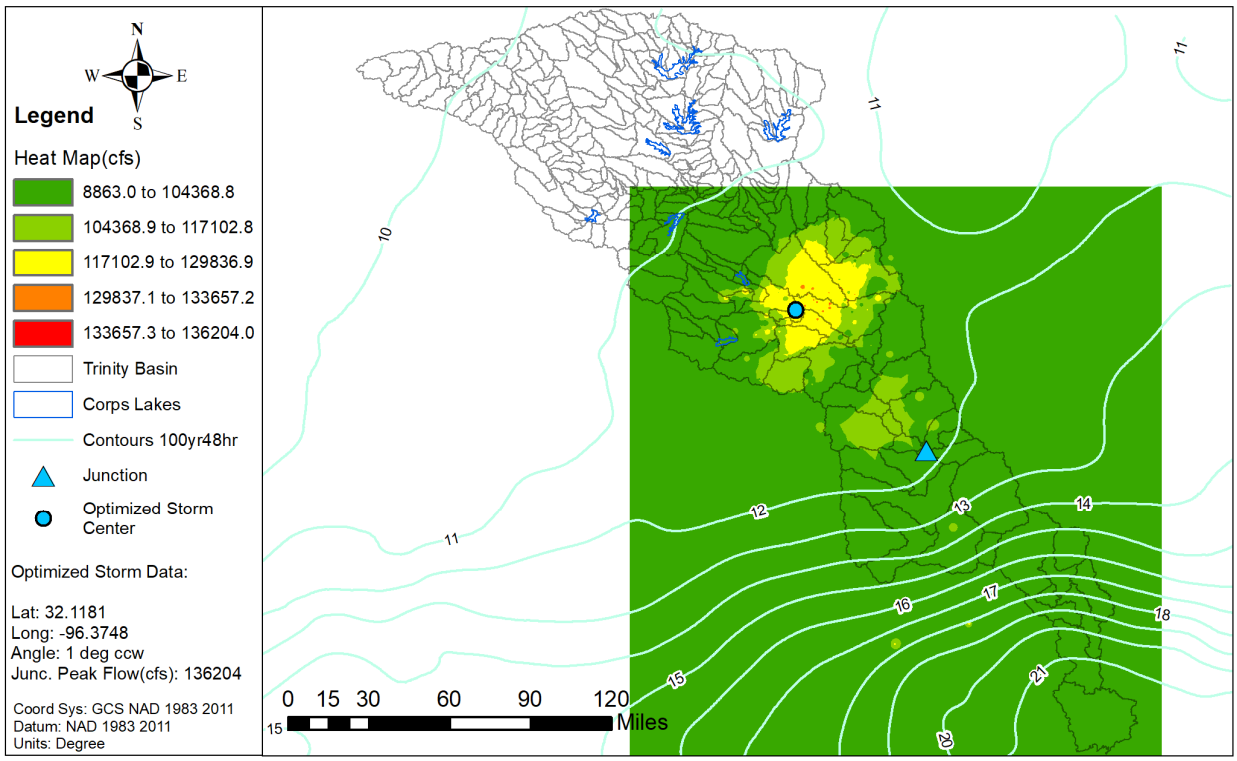


Figure 115a: Elliptical Storm Heat Map for the Trinity River below Big Elkhart Creek

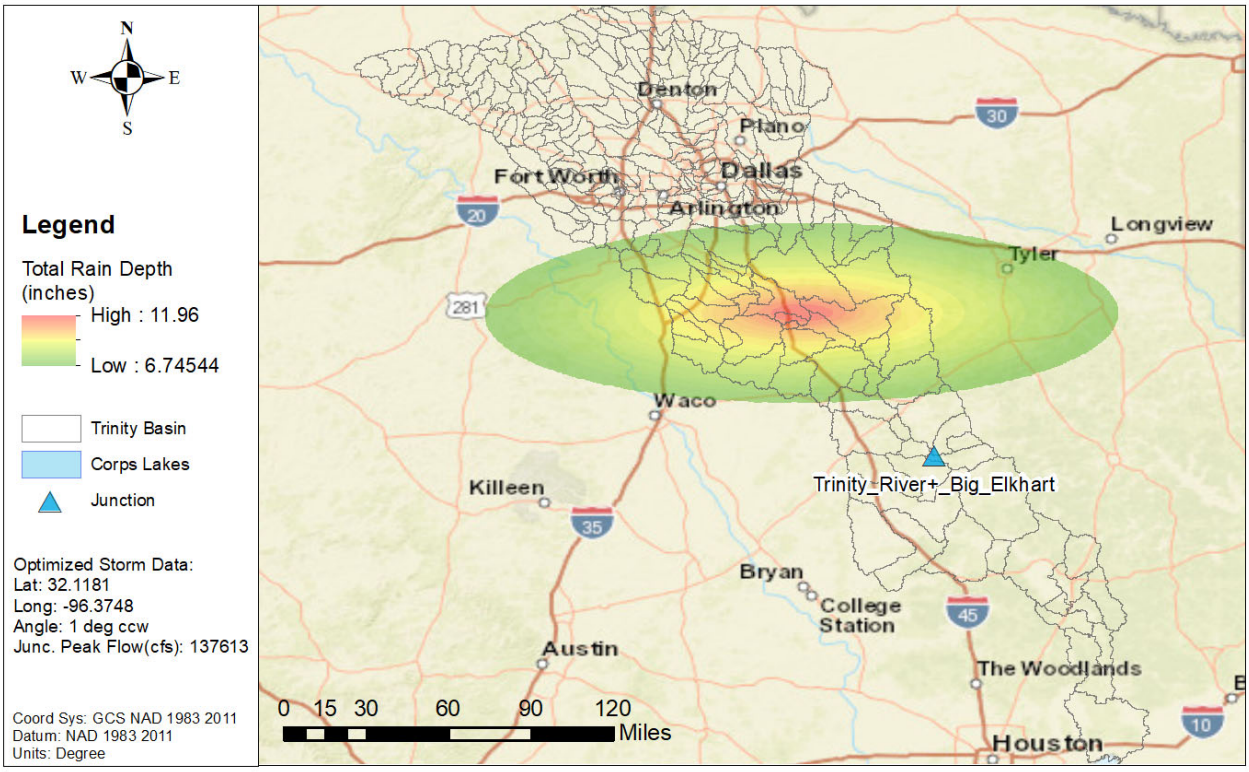


Figure 115b: NA14 1% AEP Elliptical Storm for the Trinity River below Big Elkhart Creek

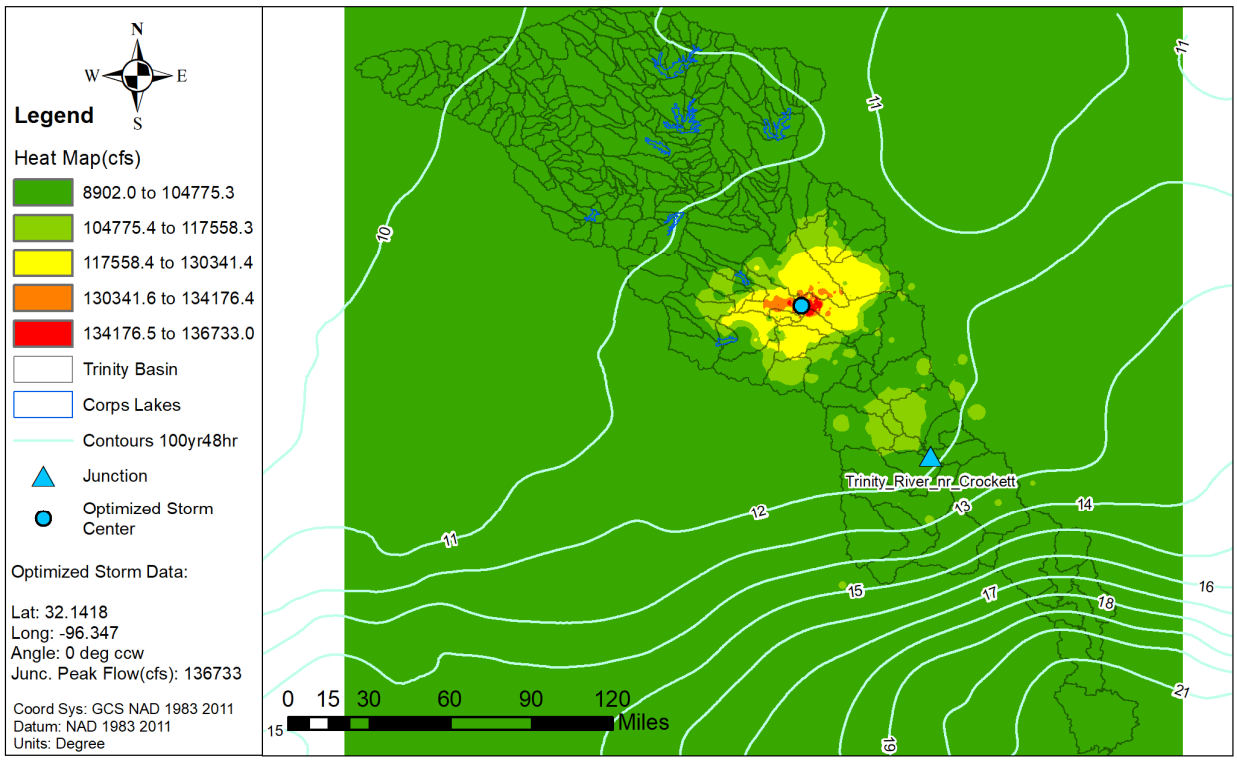


Figure 116a: Elliptical Storm Heat Map for the Trinity River near Crockett, TX USGS gage

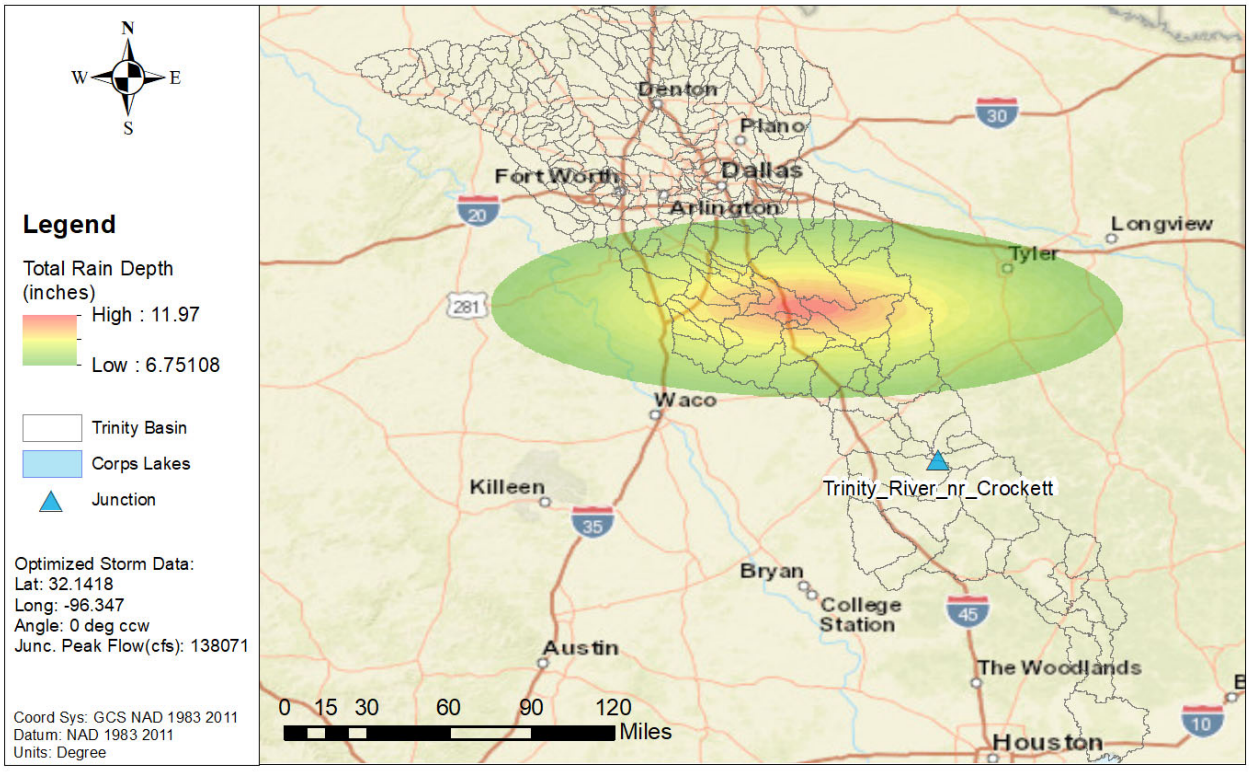


Figure 116b: NA14 1% AEP Elliptical Storm for the Trinity River near Crockett, TX USGS gage

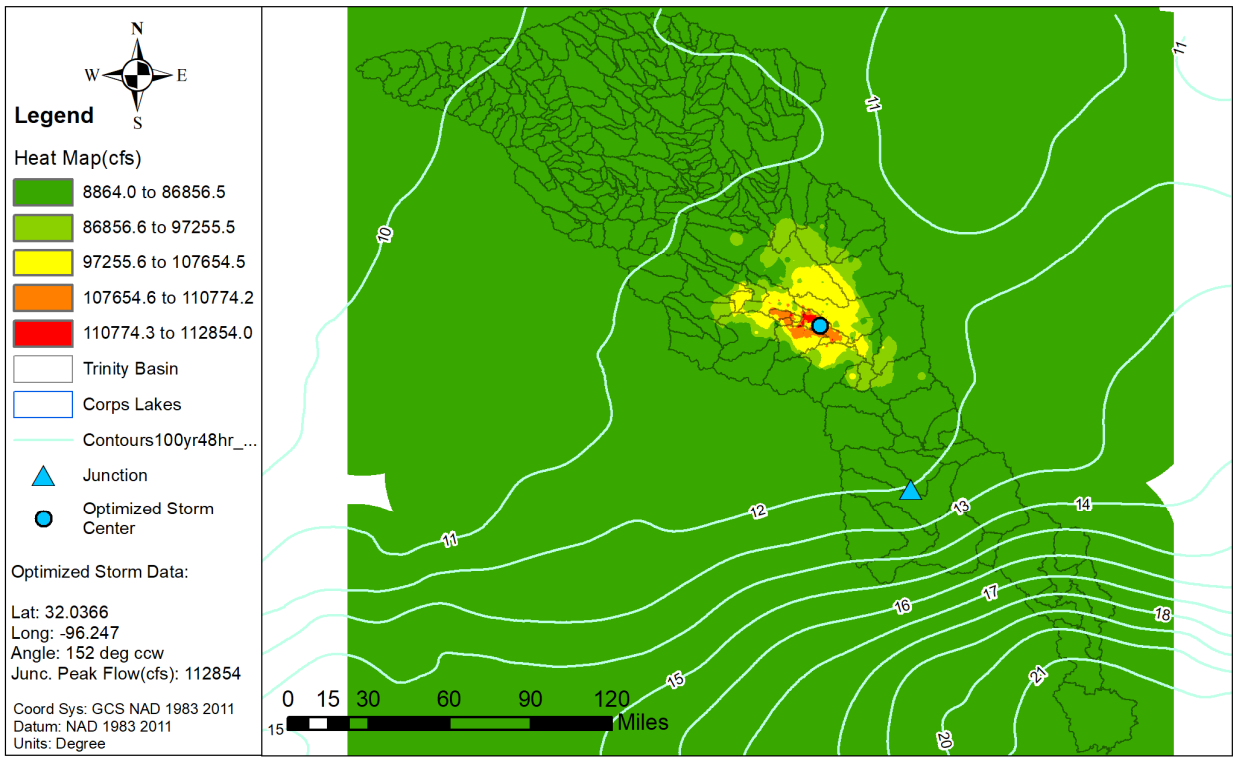


Figure 117a: Elliptical Storm Heat Map for the Trinity River above Lower Keechi Creek

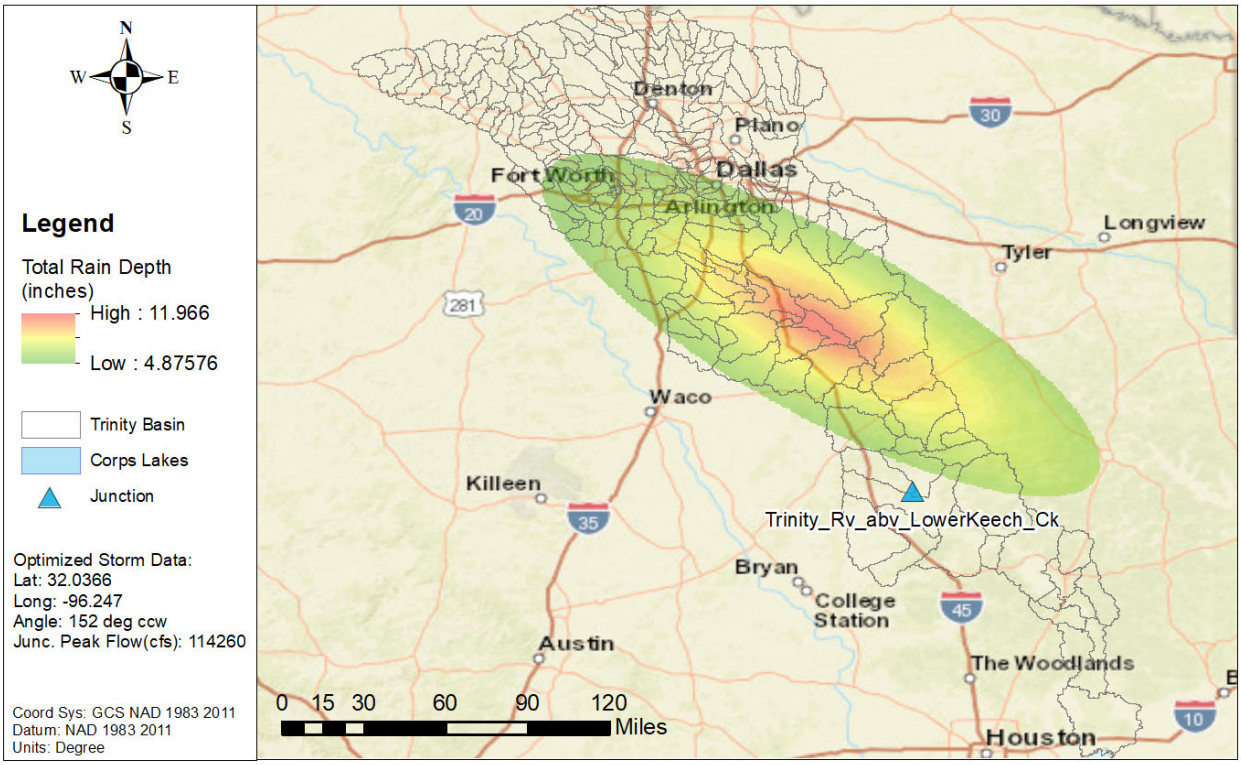


Figure 117b: NA14 1% AEP Elliptical Storm for the Trinity River above Lower Keechi Creek

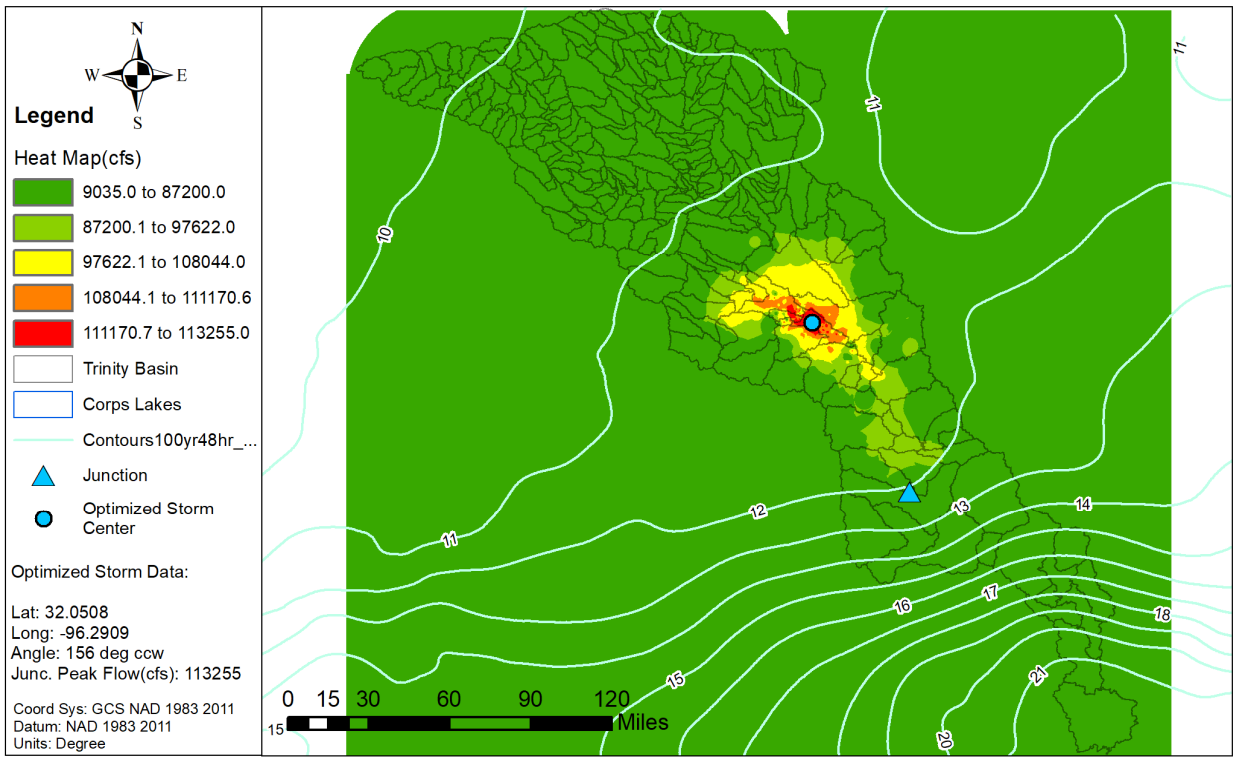


Figure 118a: Elliptical Storm Heat Map for the Trinity River below Lower Keechi Creek

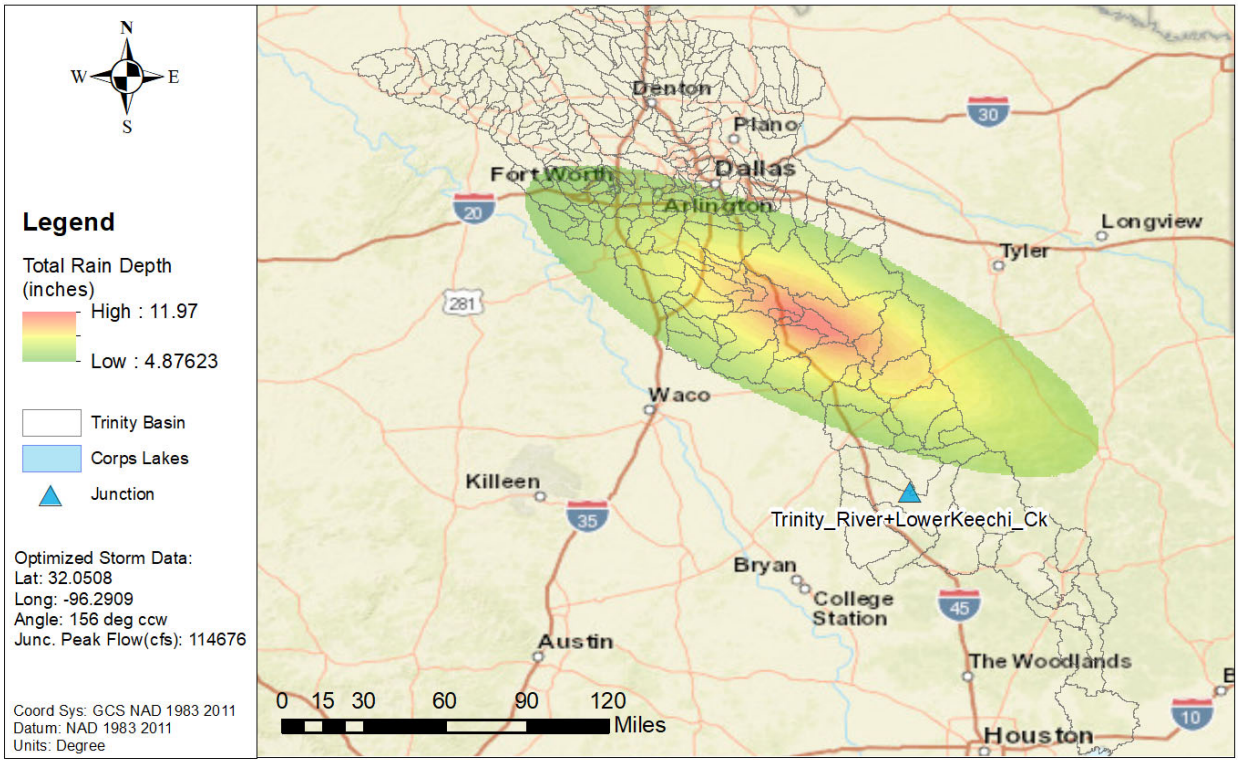


Figure 118b: NA14 1% AEP Elliptical Storm for the Trinity River below Lower Keechi Creek

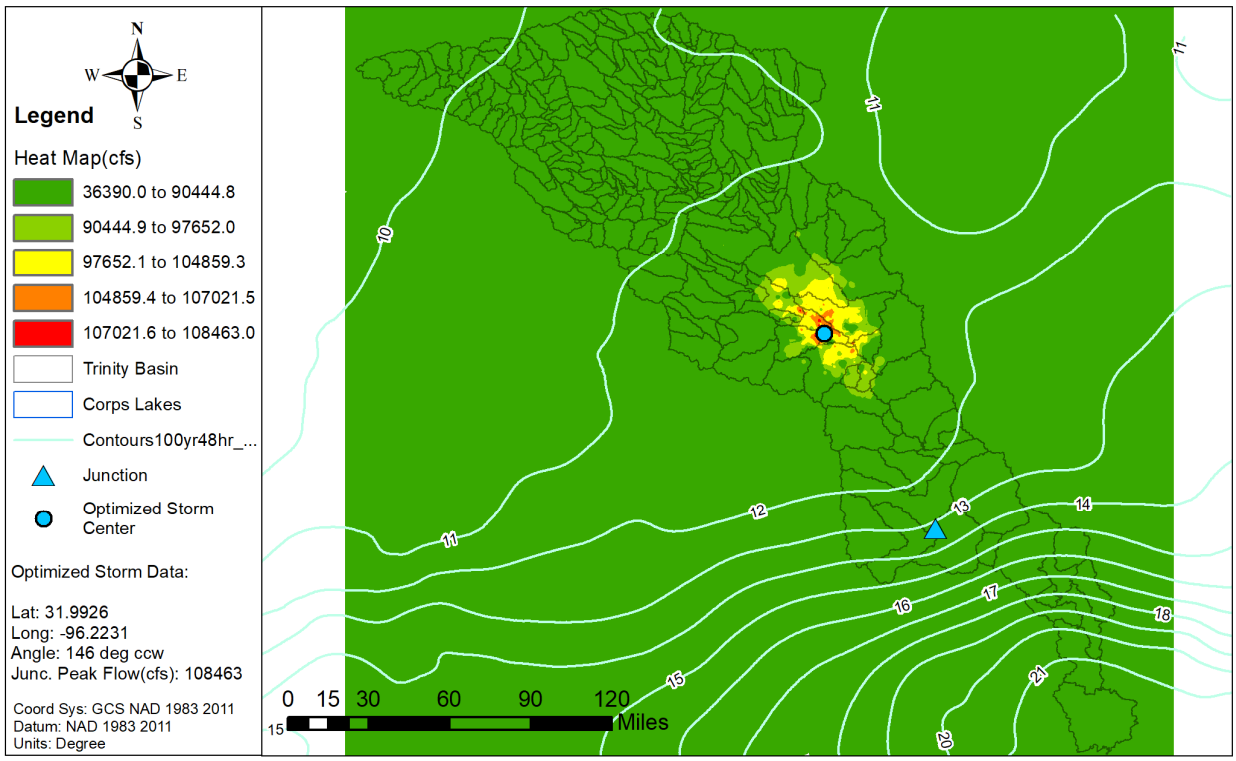


Figure 119a: Elliptical Storm Heat Map for the Trinity River above Bedias Creek

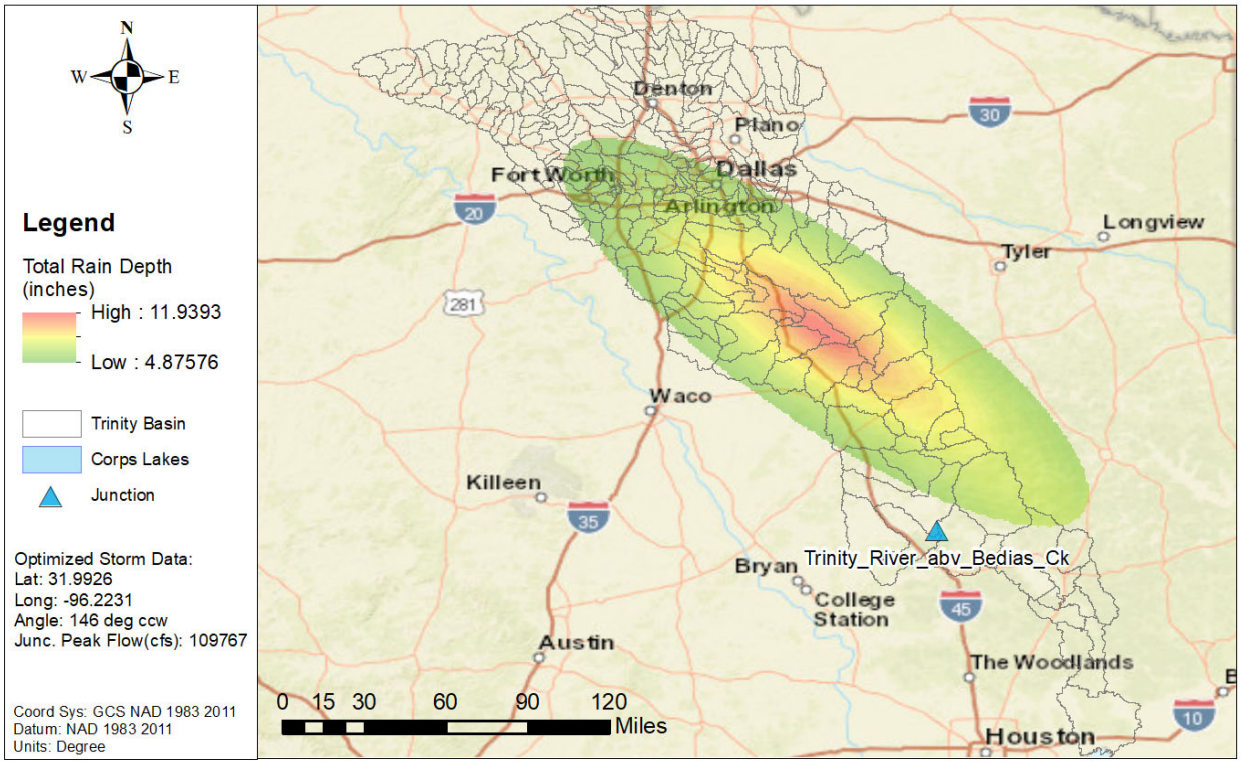


Figure 119b: NA14 1% AEP Elliptical Storm for the Trinity River above Bedias Creek

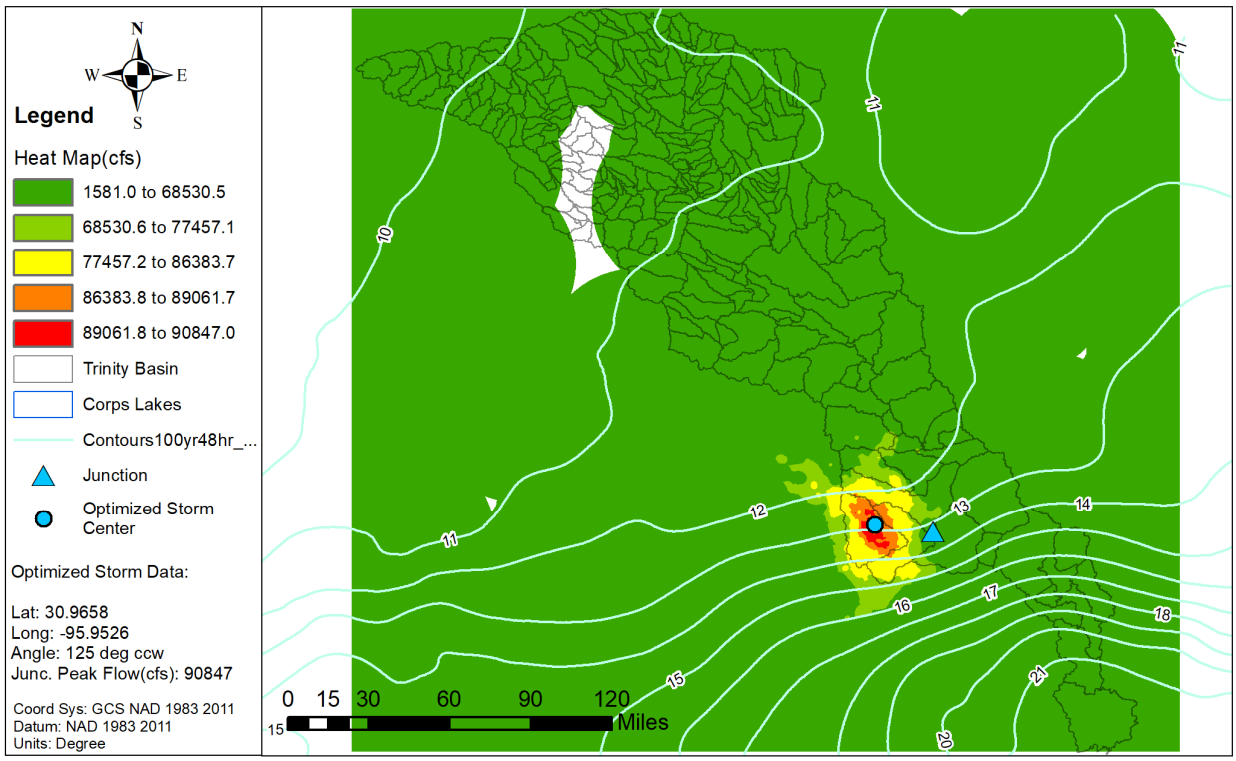


Figure 120a: Elliptical Storm Heat Map for the Bedias Creek above the Trinity River

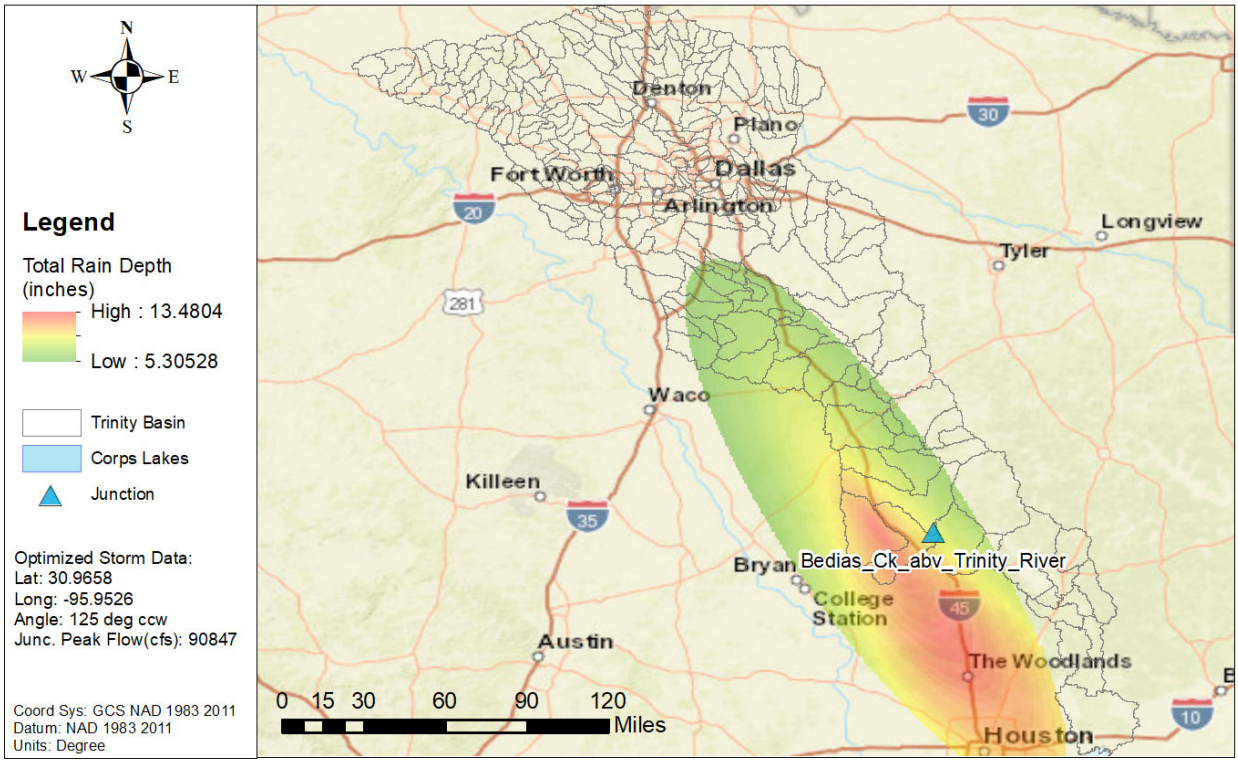


Figure 120b: NA14 1% AEP Elliptical Storm for the Bedias Creek above the Trinity River

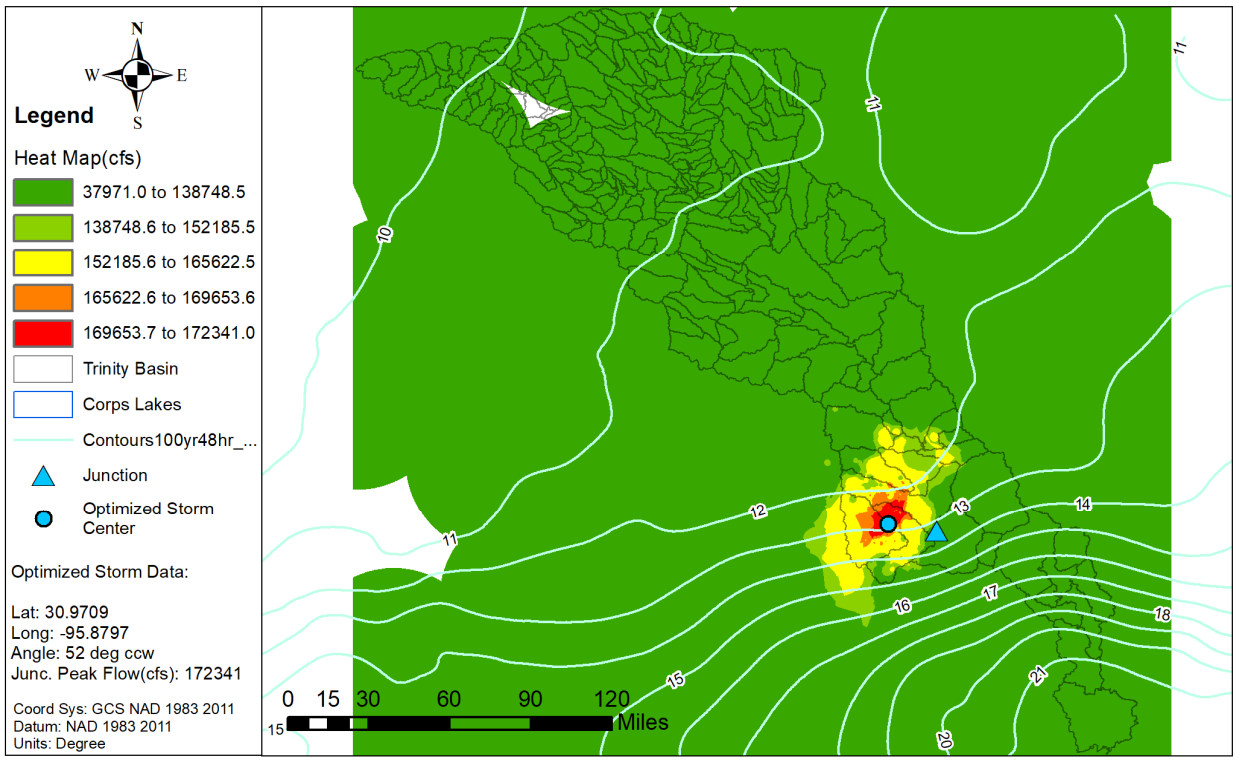


Figure 121a: Elliptical Storm Heat Map for the Trinity River below Bedias Creek

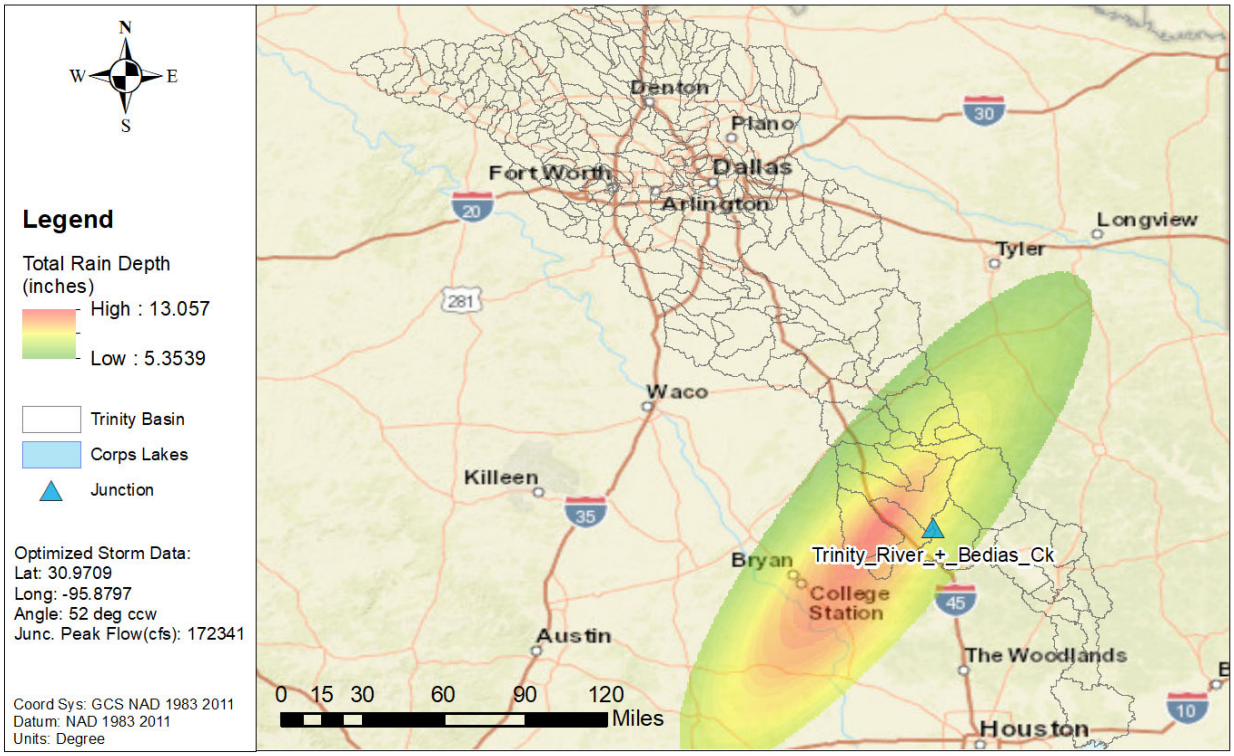


Figure 121b: NA14 1% AEP Elliptical Storm for the Trinity River below Bedias Creek

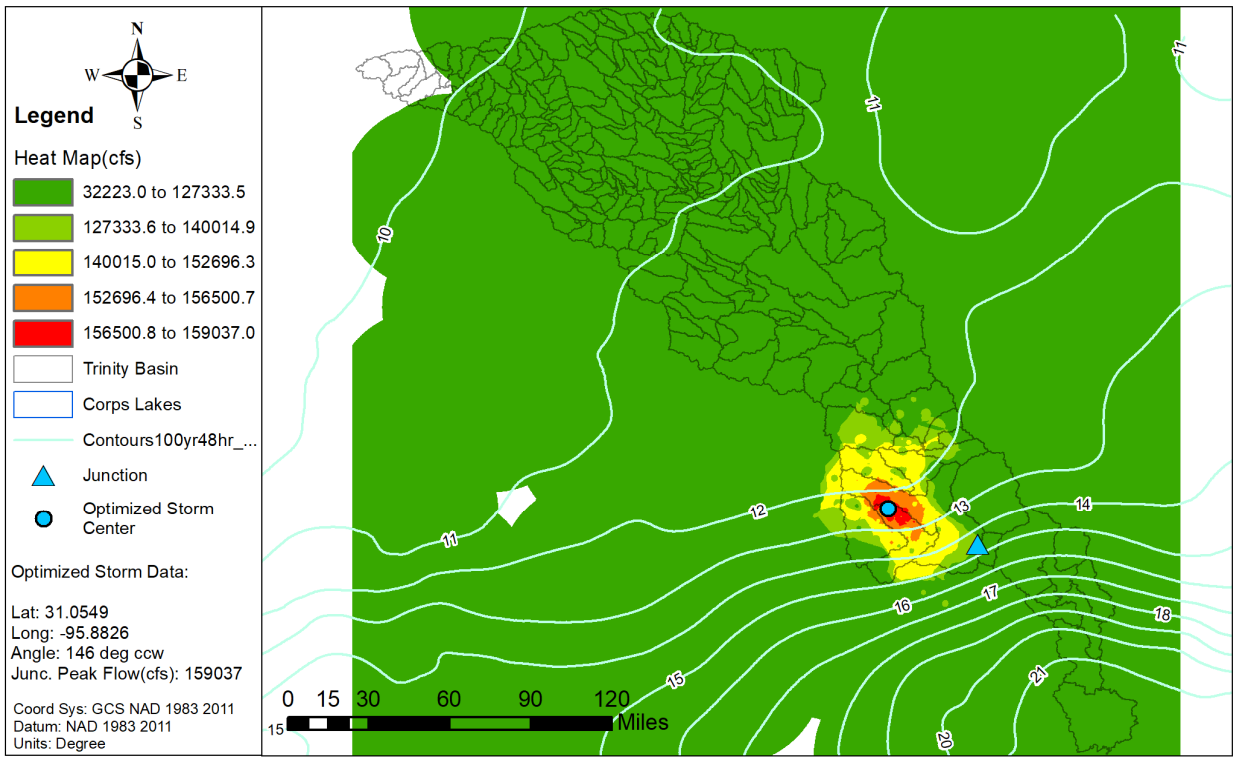


Figure 122a: Elliptical Storm Heat Map for the Trinity River at Riverside, TX USGS gage

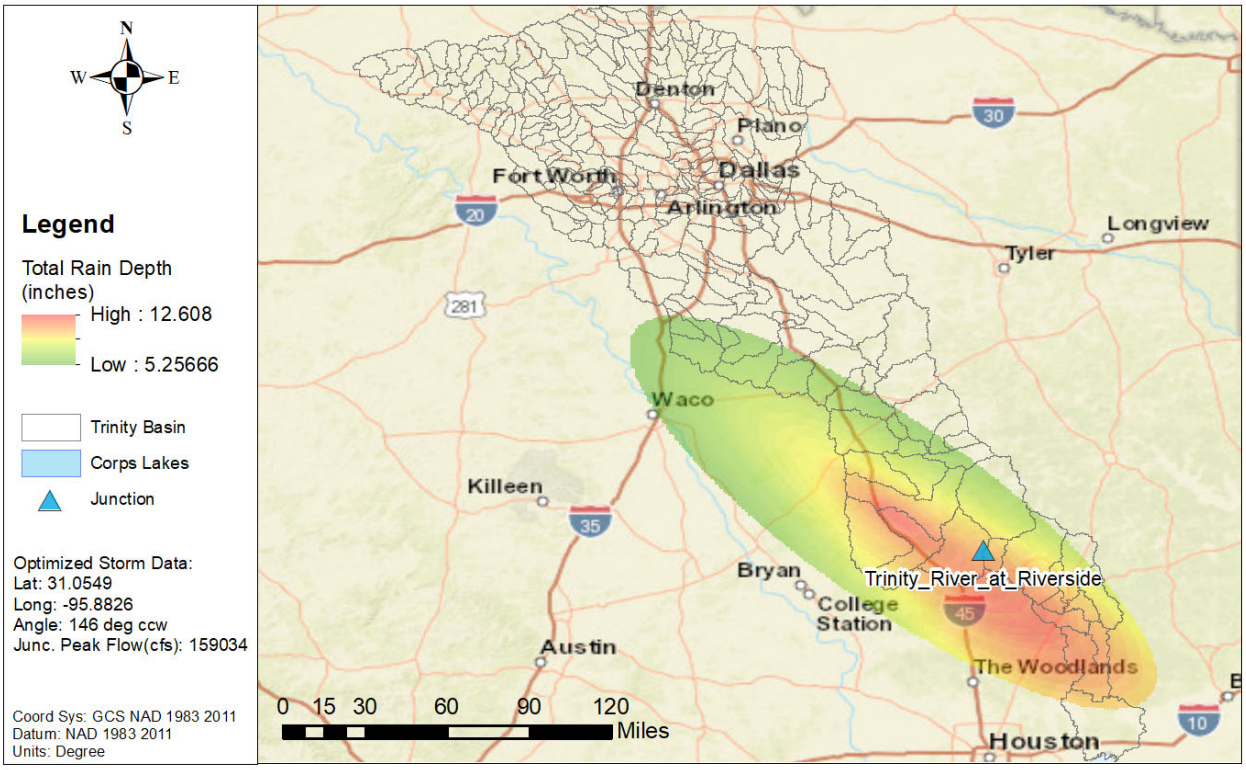


Figure 122b: NA14 1% AEP Elliptical Storm for the Trinity River at Riverside, TX USGS gage

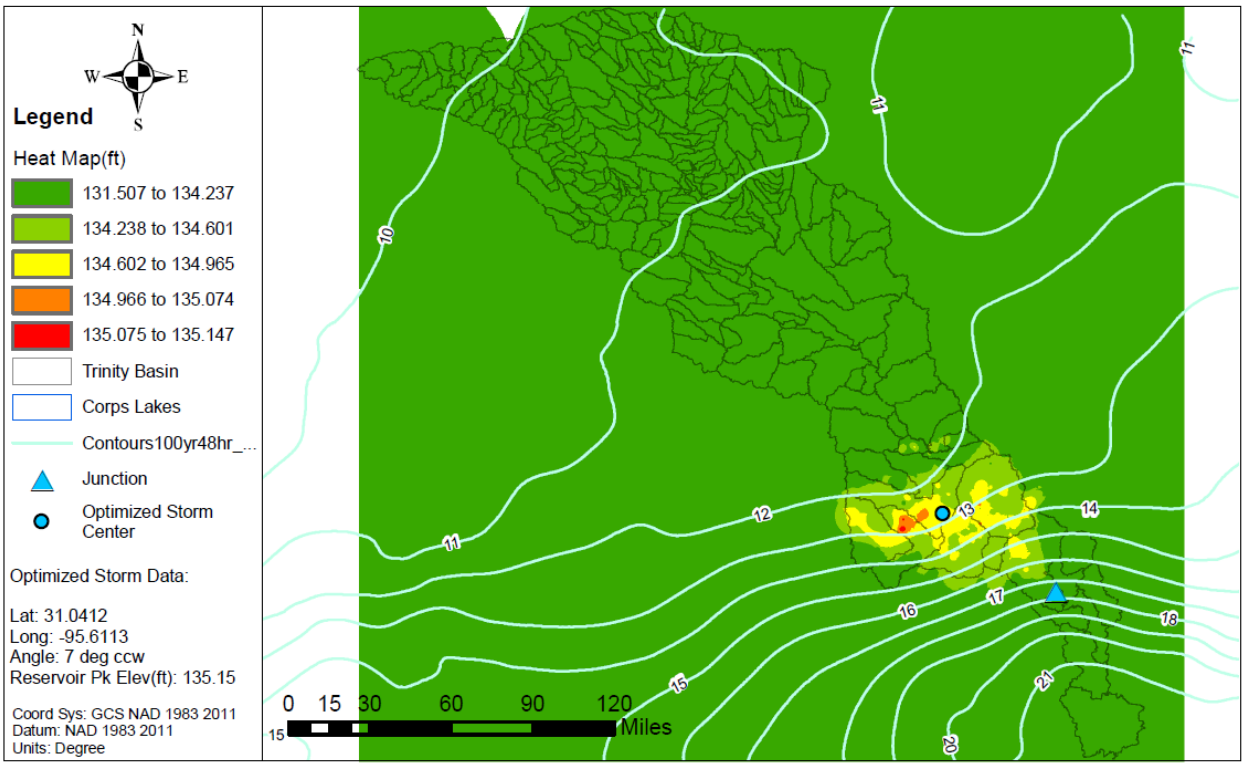


Figure 123a: Elliptical Storm Heat Map for the Lake Livingston

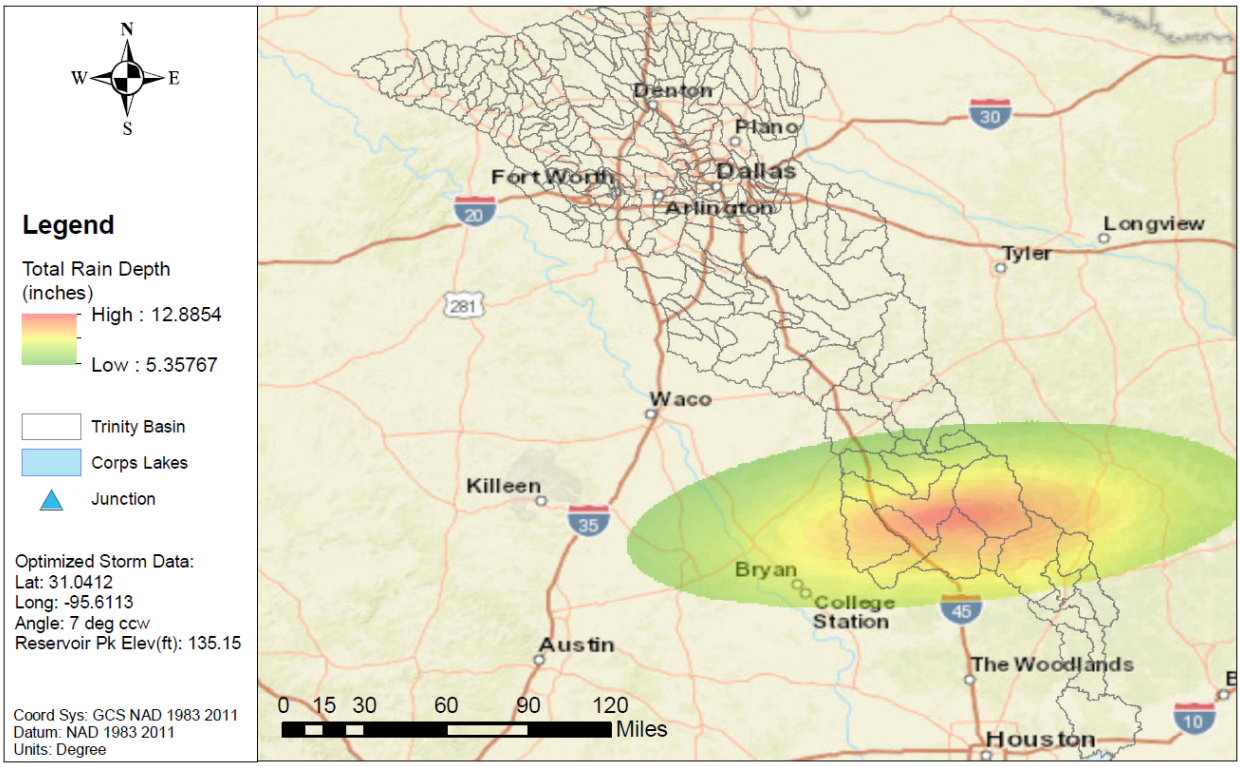


Figure 123b: NA14 1% AEP Elliptical Storm for the Lake Livingston

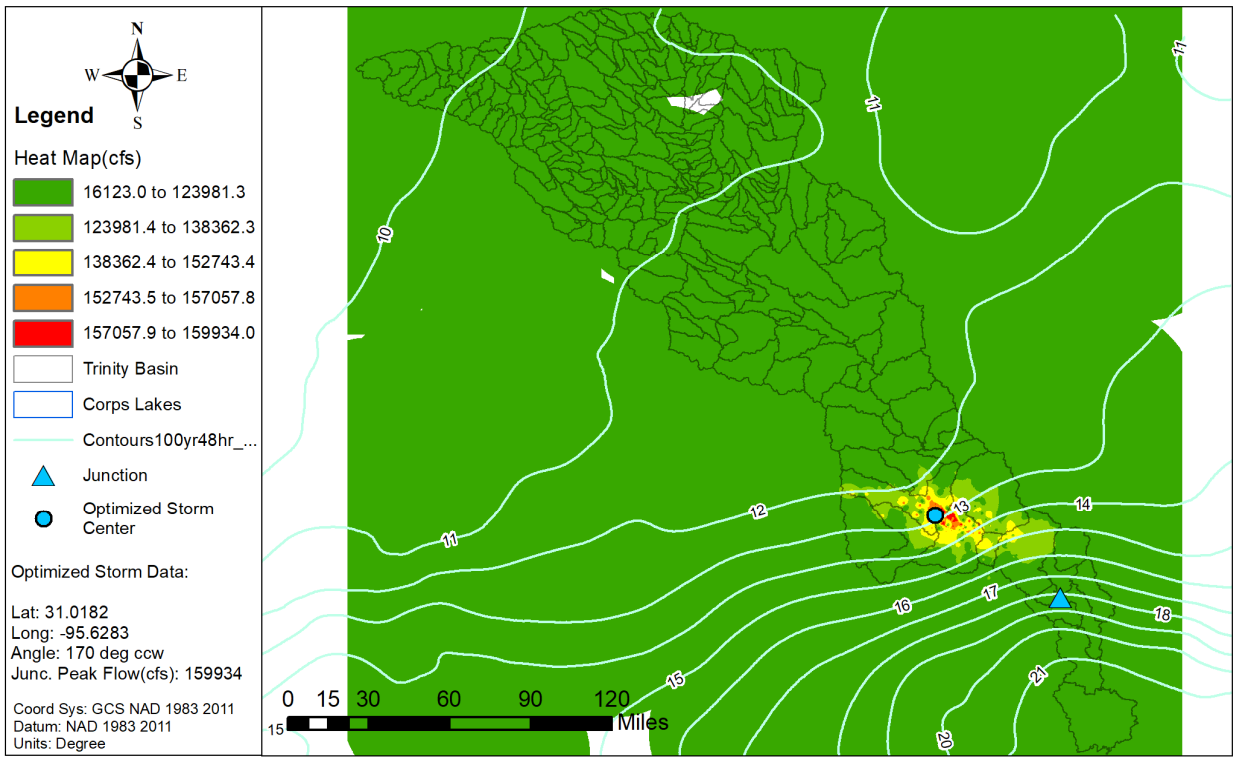


Figure 124a: Elliptical Storm Heat Map for the Trinity River above Long King Creek

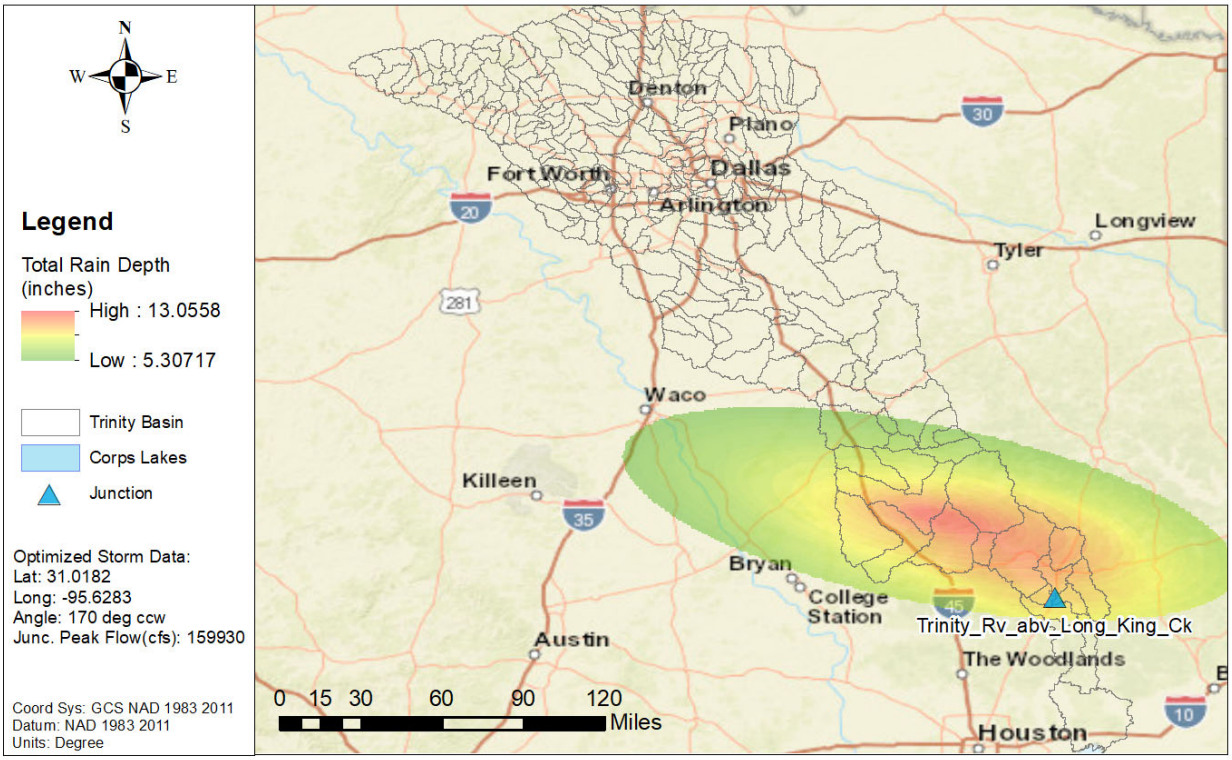


Figure 124b: NA14 1% AEP Elliptical Storm for the Trinity River above Long King Creek

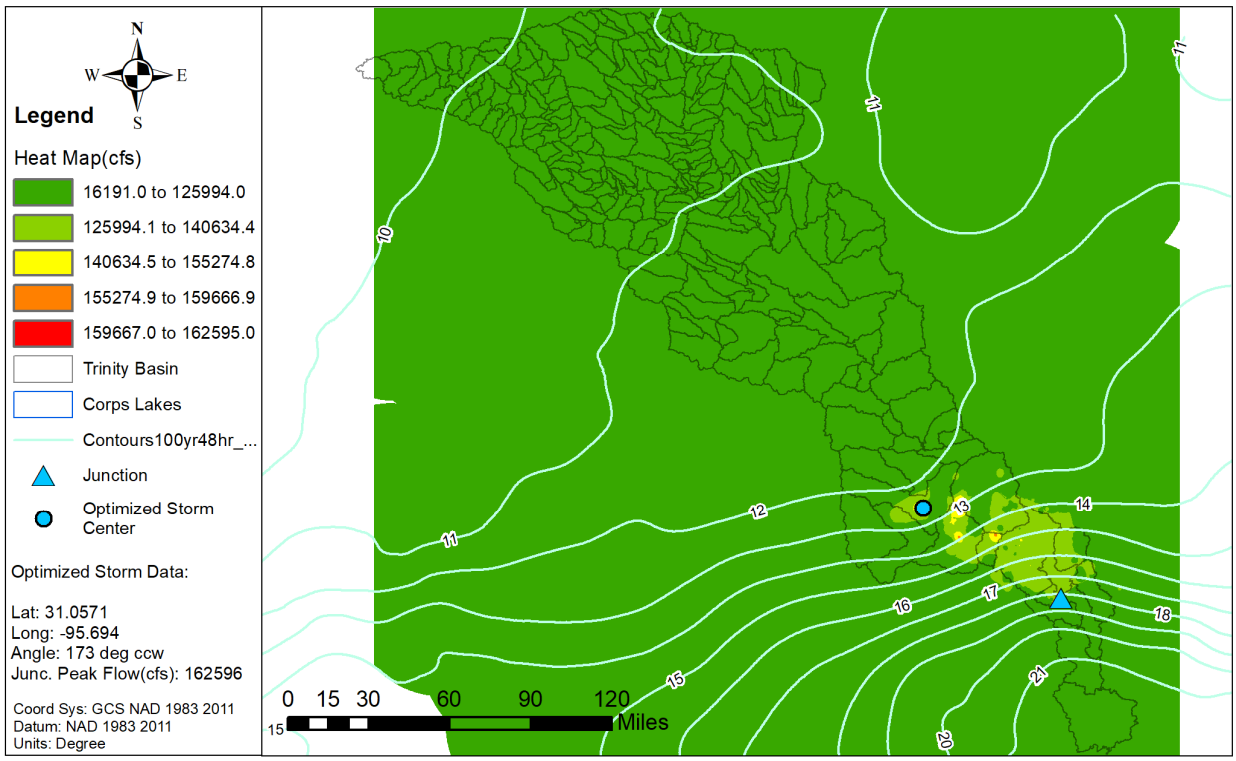


Figure 125a: Elliptical Storm Heat Map for the Trinity River at Goodrich, TX USGS gage

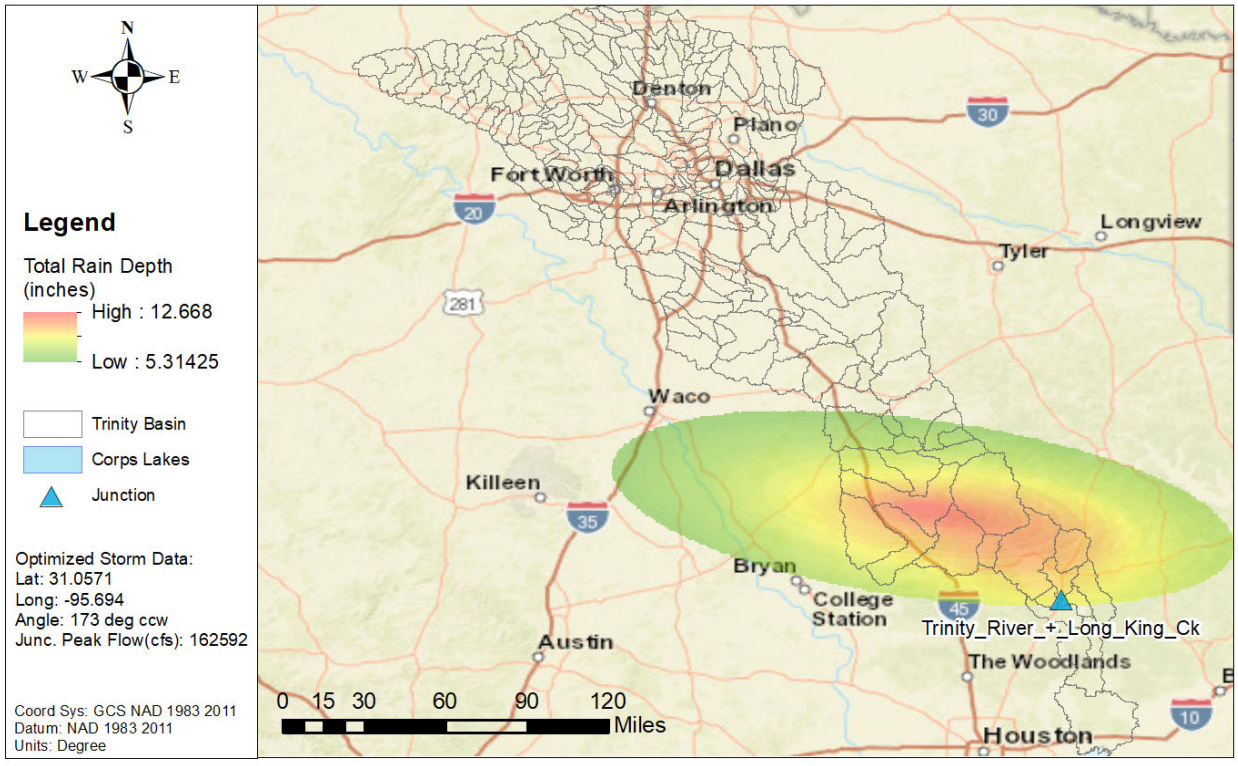


Figure 125b: NA14 1% AEP Elliptical Storm for the Trinity River at Goodrich, TX USGS gage

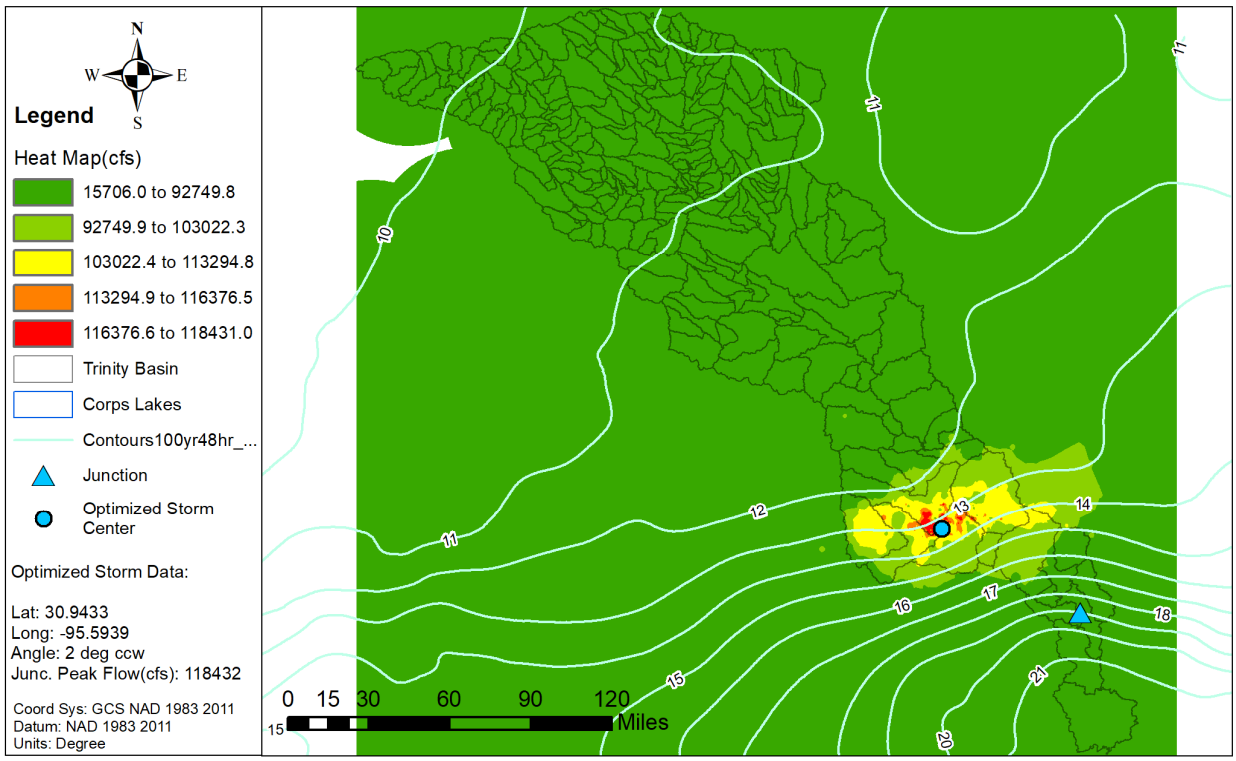


Figure 126a: Elliptical Storm Heat Map for the Trinity River above Menard Creek

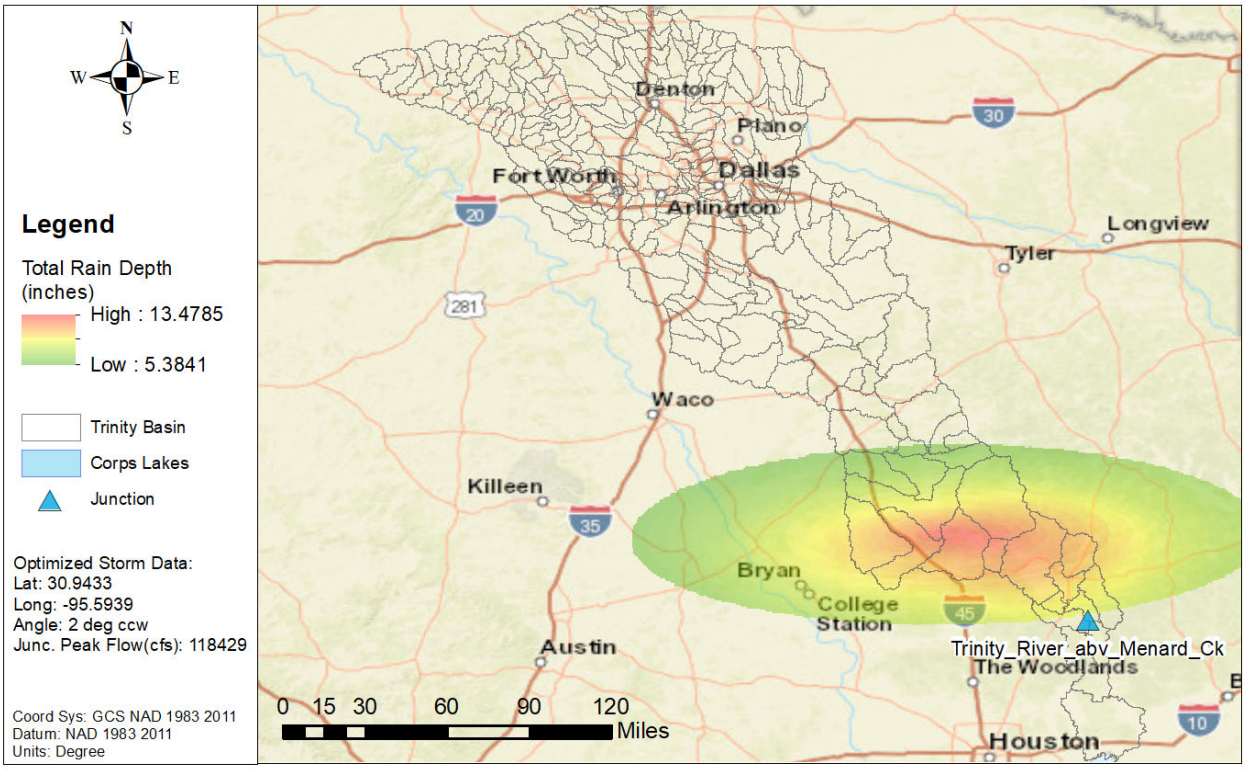


Figure 126b: NA14 1% AEP Elliptical Storm for the Trinity River above Menard Creek

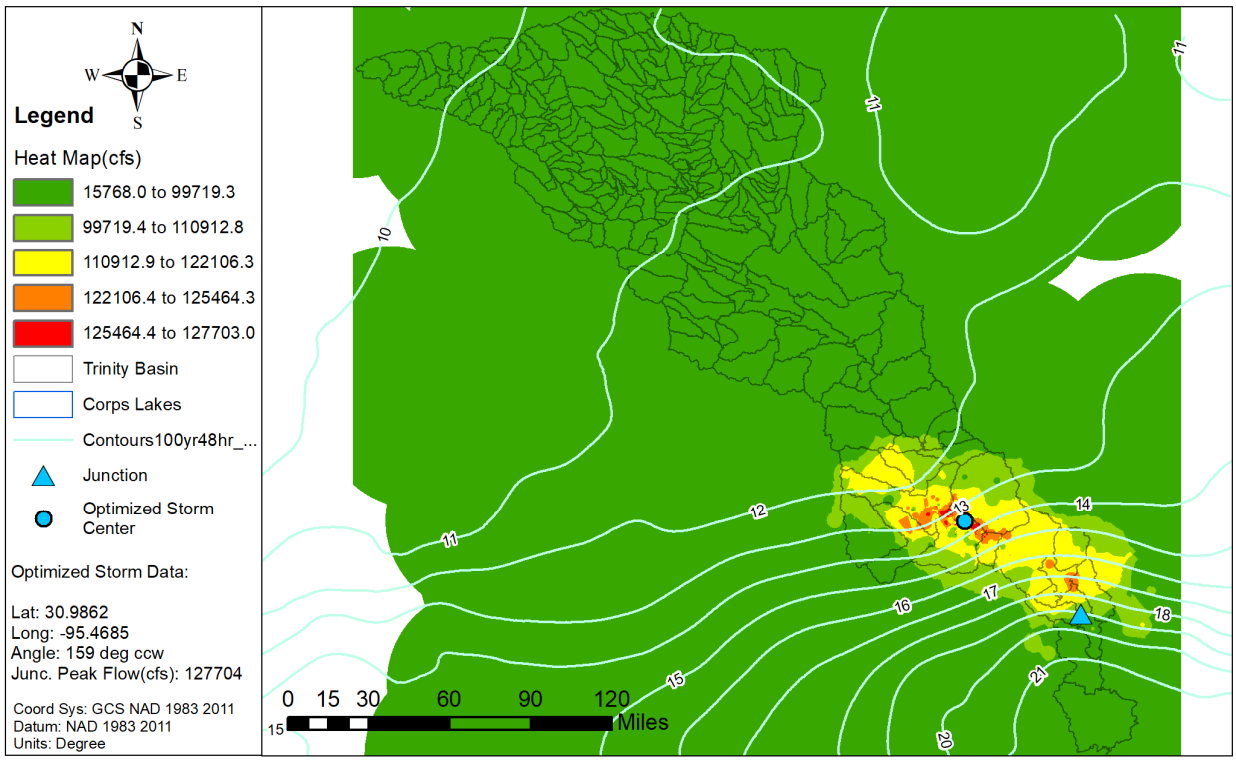


Figure 127a: Elliptical Storm Heat Map for the Trinity River below Menard Creek

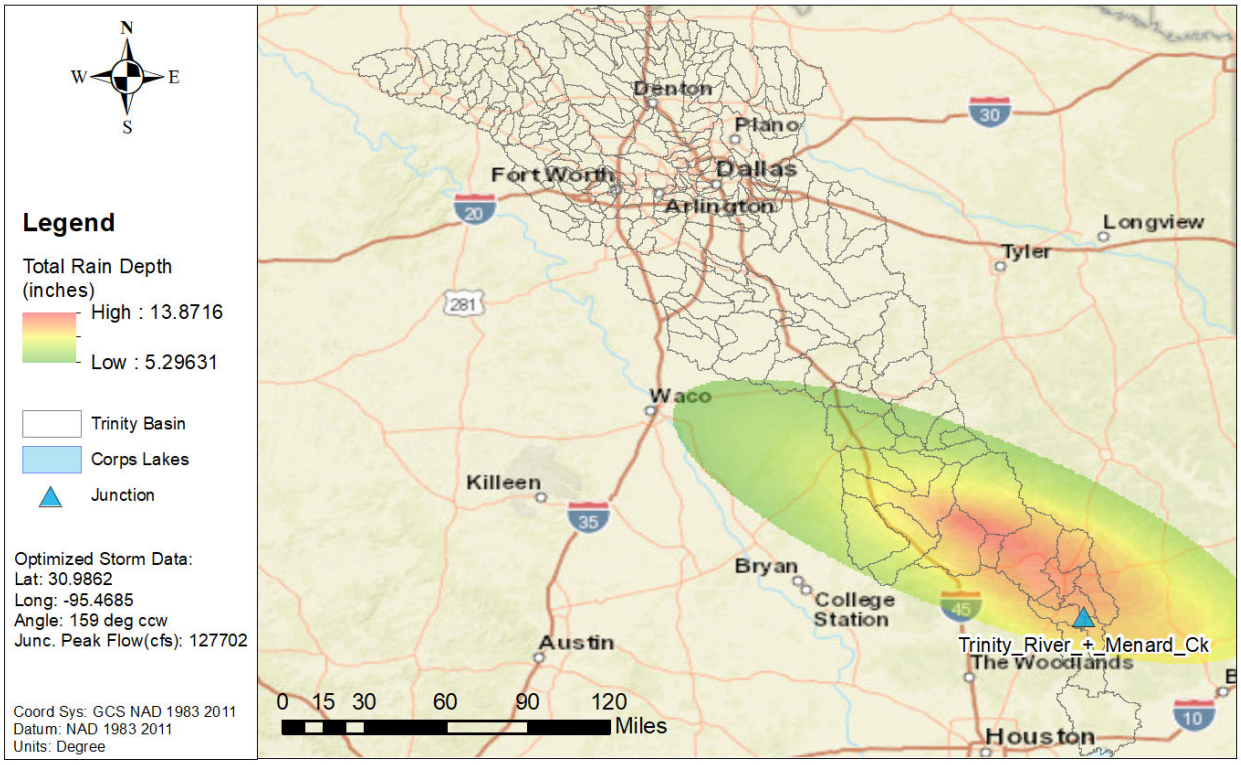


Figure 127b: NA14 1% AEP Elliptical Storm for the Trinity River below Menard Creek

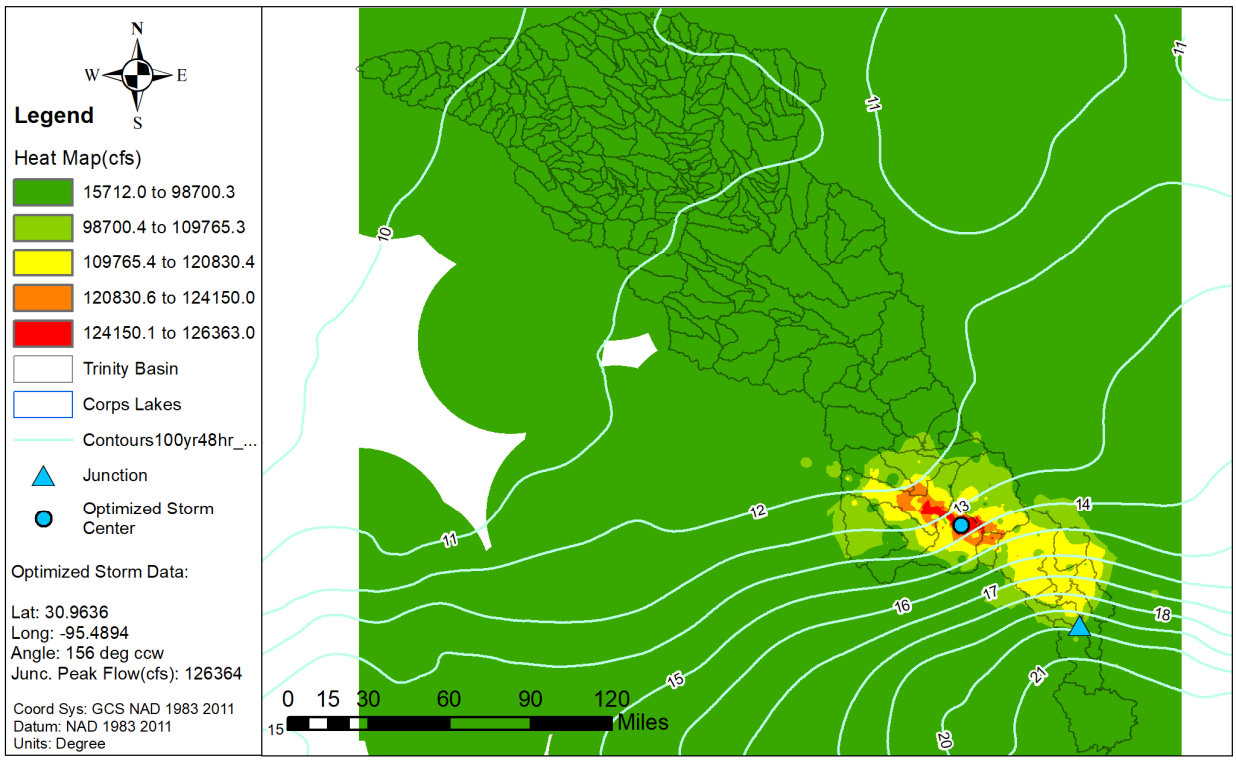


Figure 128a: Elliptical Storm Heat Map for the Trinity River at Romayor, TX USGS gage

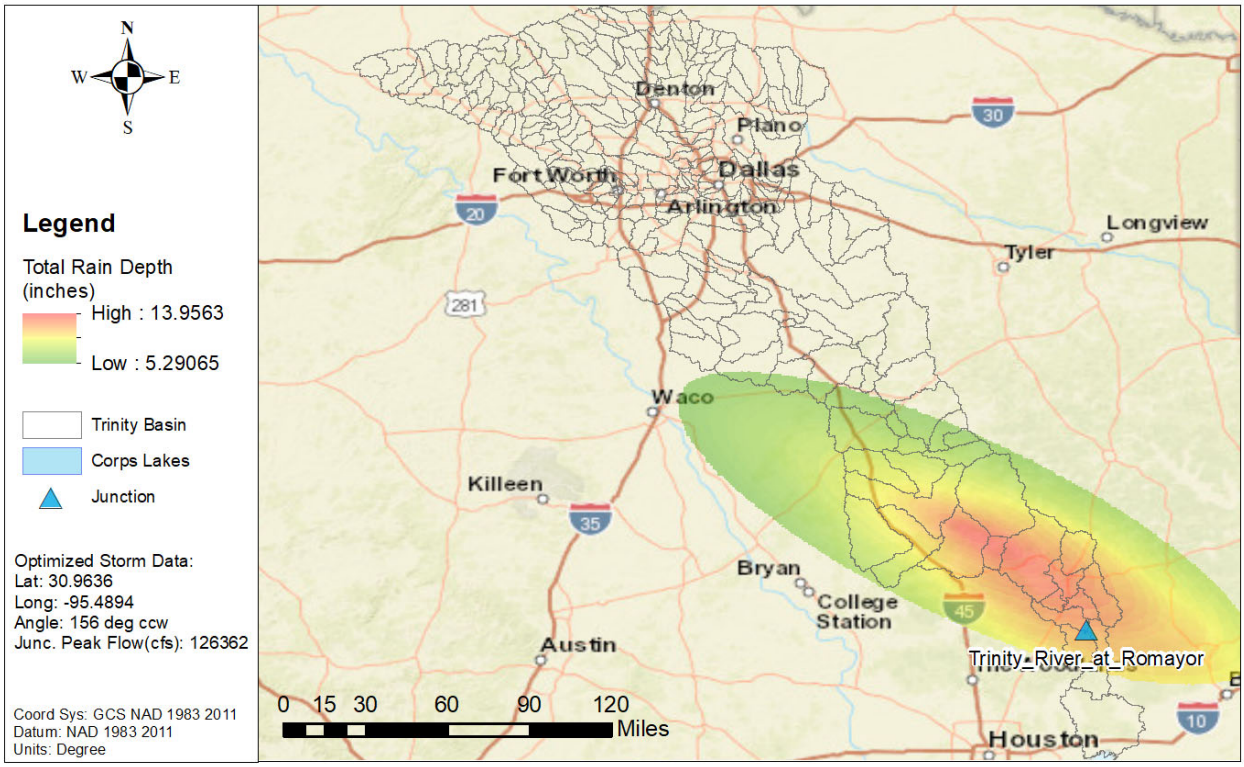


Figure 128b: NA14 1% AEP Elliptical Storm for the Trinity River at Romayor, TX USGS gage

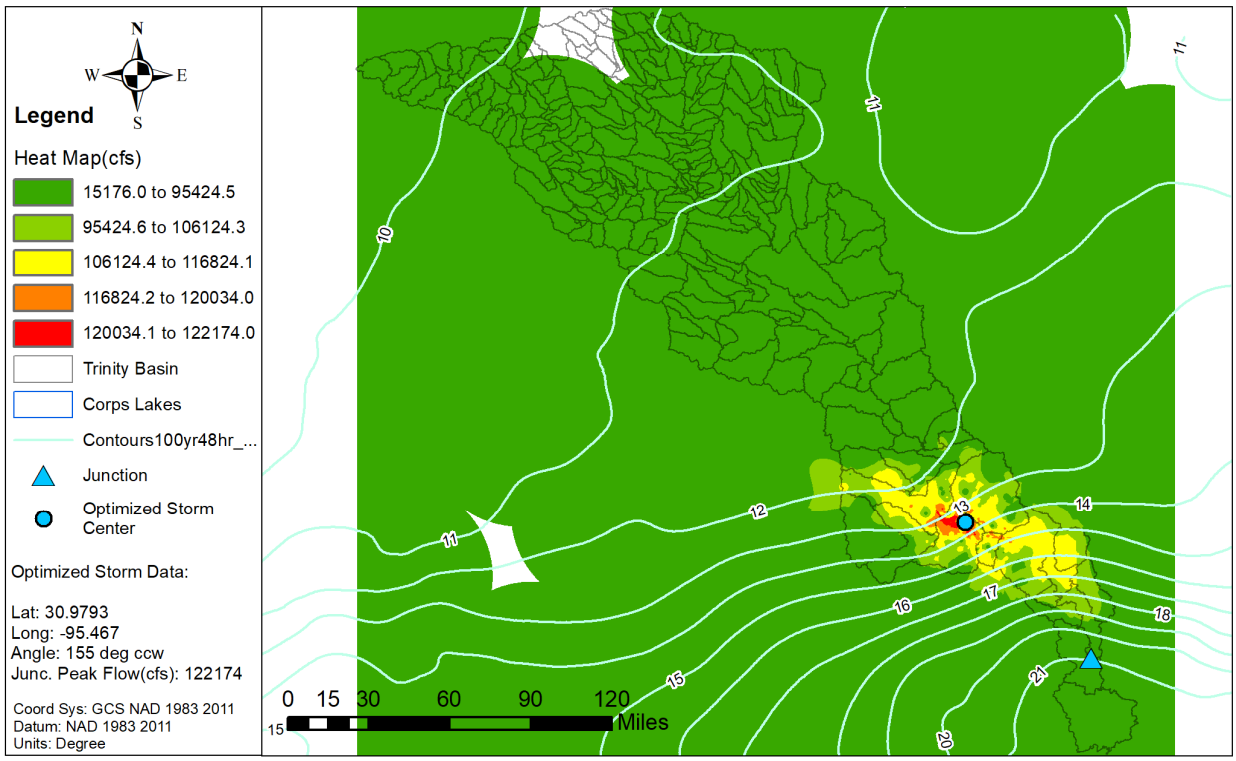


Figure 129a: Elliptical Storm Heat Map for the Trinity River near Moss Hill, TX

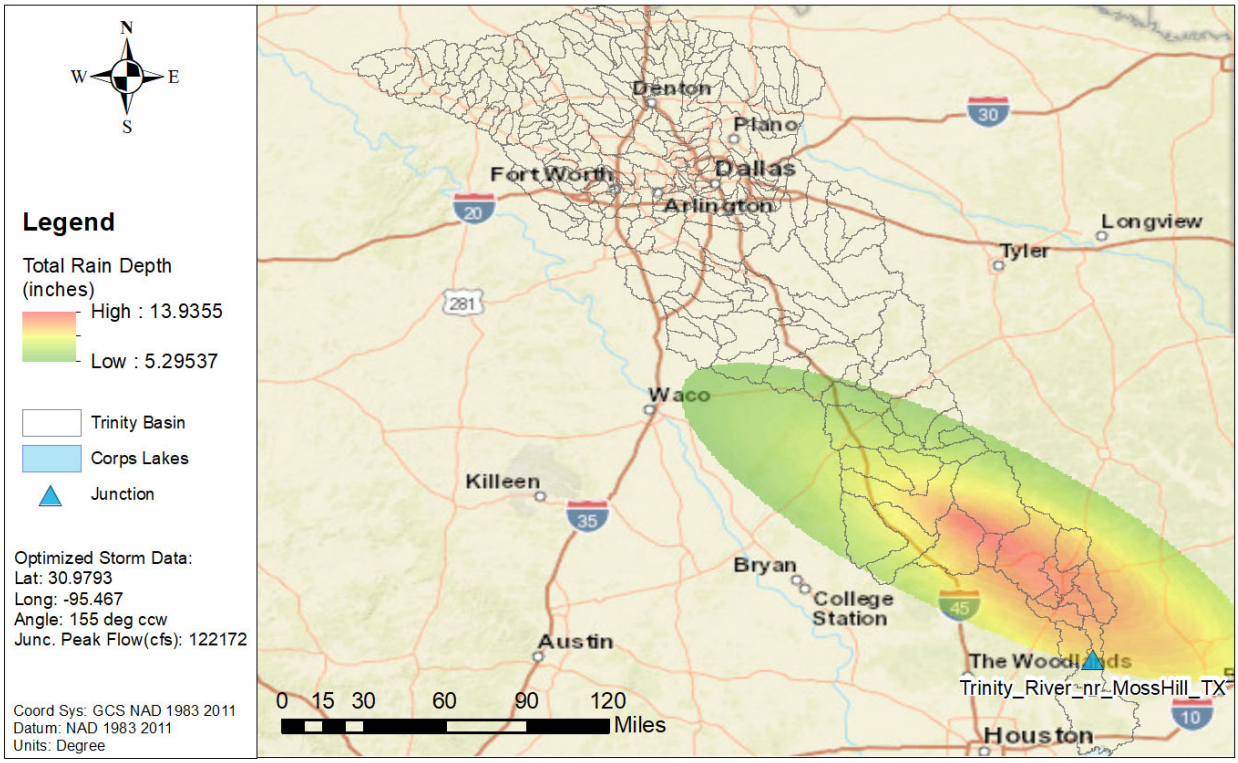


Figure 129b: NA14 1% AEP Elliptical Storm for the Trinity River near Moss Hill, TX

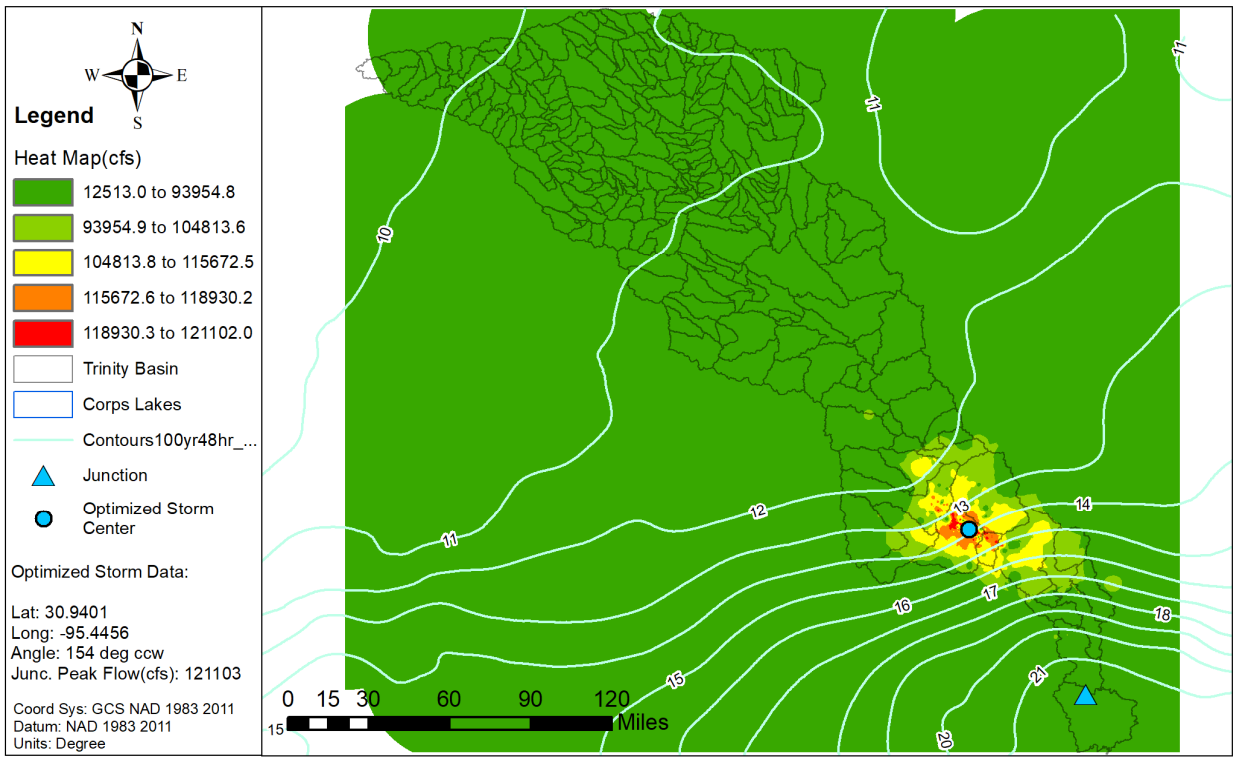


Figure 130a: Elliptical Storm Heat Map for the Trinity River at Liberty, TX USGS gage

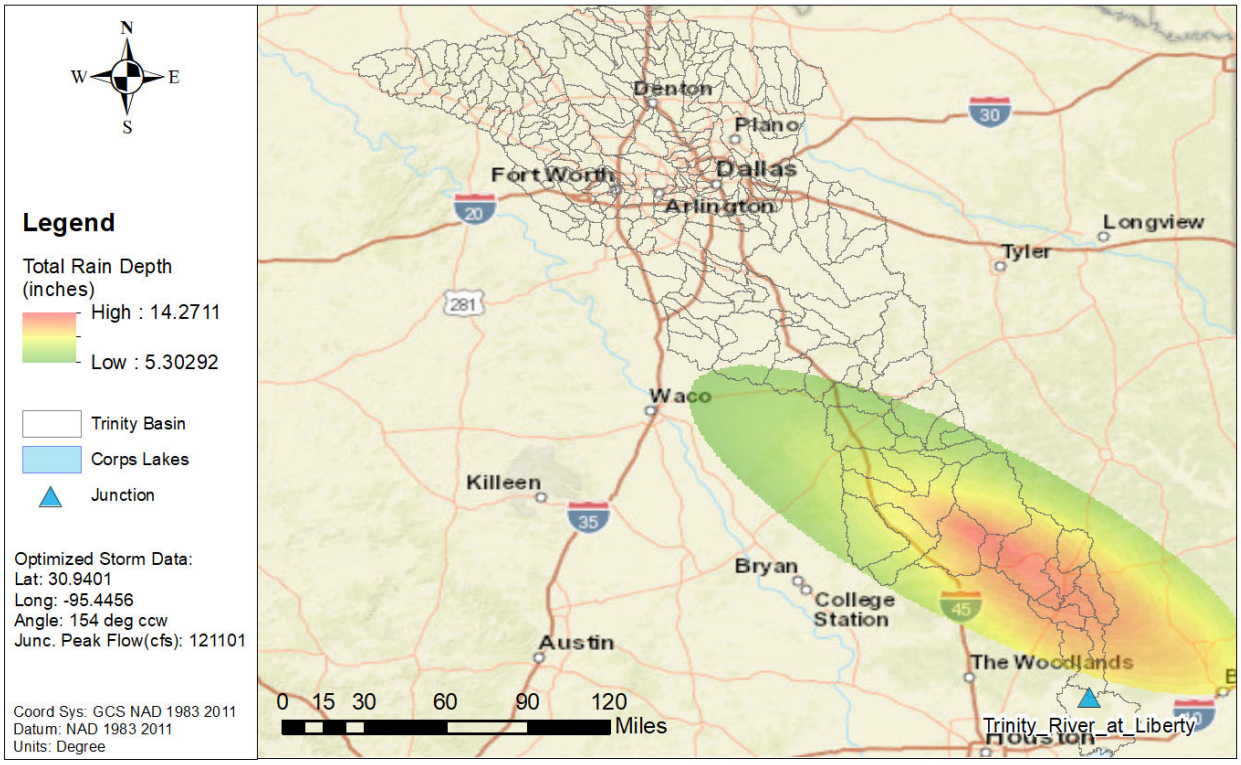


Figure 130b: NA14 1% AEP Elliptical Storm for the Trinity River at Liberty, TX USGS gage

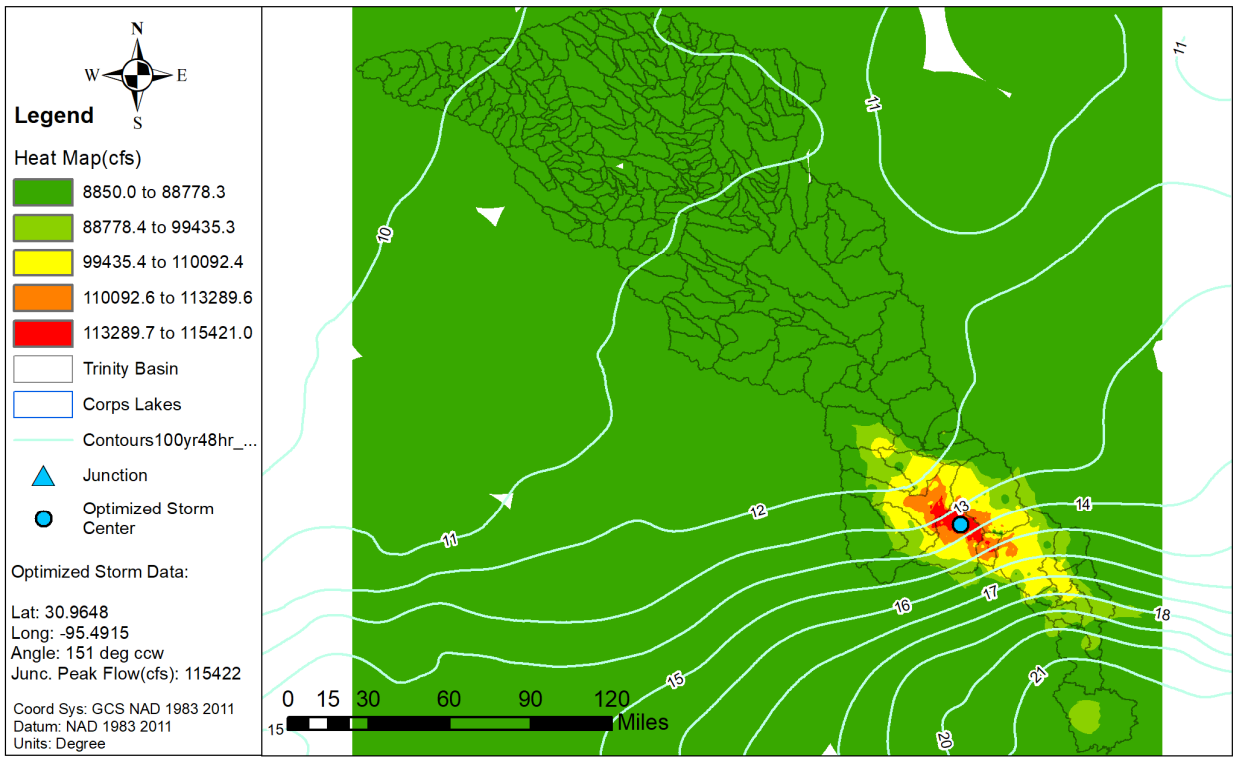


Figure 131a: Elliptical Storm Heat Map for the Trinity River at Wallisville, TX USGS gage

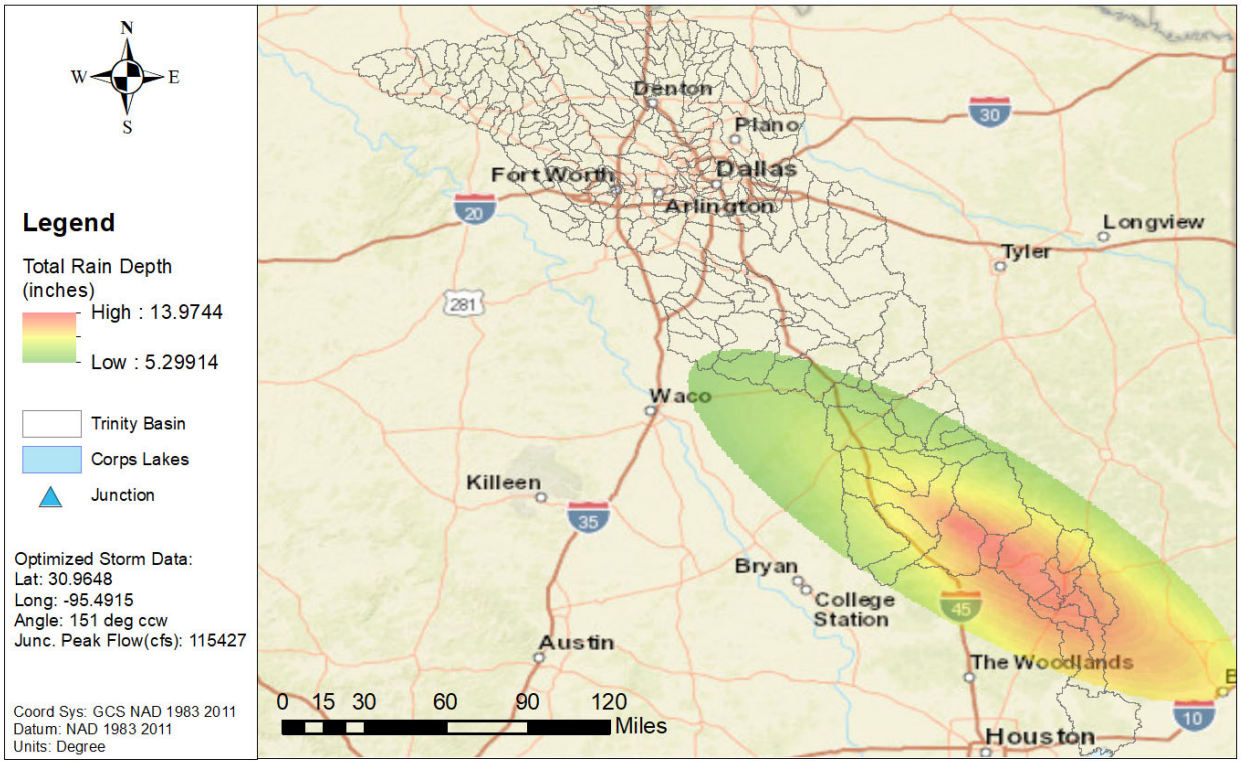


Figure 131b: NA14 1% AEP Elliptical Storm for the Trinity River at Wallisville, TX USGS gage

2 References and Resources

2.1 REFERENCES

Duan, Q. Y., Gupta, V. K., & Sorooshian, S. (1993). Shuffled complex evolution approach for effective and efficient global minimization. *Journal of optimization theory and applications*, 76(3), 501-521.

Hansen, E.M., Schreiner, L.C. & Miller, J.F. (1982). Application of Probable Maximum Precipitation Estimates – United States East of the 105th Meridian. *Hydrometeorlogical Report No. 52*. National Weather Service, Washington D.C.

Hershfield, D.M. (1961). Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years. *Technical Paper (TP) 40*. National Weather Service.

NOAA. Hydrometeorlogical Design Studies Center. Precipitation Frequency Data Server (PFDS). https://hdsc.nws.noaa.gov/hdsc/pfds/ Accessed Oct 2018.

NOAA. (2018). *NOAA Atlas 14 Precipitation Frequency Atlas of the United States: Volume 11 Version 2.0: Texas*.

U.S. Army Corps of Engineers. (1945). Storm rainfall in the United States, depth, area, duration data. Revised to January 2, 1962.

2.2 SOFTWARE

Environmental Systems Research Institute, Inc., ArcGIS 10.5. (2016). Retrieved from http://www.esri.com/.

U.S. Army Corps of Engineers, Corps Water Management System, CWMS 2.1. (2012). Retrieved from http://www.hec.usace.army.mil.

U.S. Army Corps of Engineers, Hydrologic Engineering Center Data Storage System Visual Utility Engine, HEC-DSSVue 2.0.1. (2009). Retrieved from http://www.hec.usace.army.mil.

U.S. Army Corps of Engineers, Hydrologic Engineering Center Geospatial Hydrologic Modeling Extension, HEC-GeoHMS 10.2. (2014). Retrieved from http://www.hec.usace.army.mil.

U.S. Army Corps of Engineers, Hydrologic Engineering Center Hydrologic Modeling System, HEC-HMS 4.2.1. (2017). Retrieved from http://www.hec.usace.army.mil.

Python Software Foundation. Python Language Reference, version 2.7. Retrieved from http://www.python.org.

2.3 DATA SOURCES, GUIDANCE, AND PROCEDURES

Environmental Systems Research Institute, Inc. (ESRI). United States National Boundary, County Boundaries, Street Centerlines.
Available from: http://www.esri.com/software/arcgis/arcgisonline/services/map-services

Environmental Systems Research Institute, Inc. (ESRI),
http://www.esri.com/software/arcgis/arcgisonline/map_services.html
ESRI Streetmap2D Image Service - ESRI basemap data, DeLorme basemap layers, Automotive Navigation Data (AND) road data, U.S. Geological Survey (USGS) elevation data, UNEP-WCMC parks and protected areas for the world, Tele Atlas Dynamap® and Multinet® street data for North America and Europe and First American (CoreLogic) parcel data for the United States.
ESRI World Imagery Service - Imagery from NASA, icubed, U.S. Geological Survey (USGS), U.S. Department of Agriculture Farm Services Agency (USDA FSA), GeoEye, and Aerials Express.
ESRI. ArcGIS software. Application reference available from: http://www.esri.com/

USACE, HEC. “HEC-HMS Hydrologic Modeling System User’s Manual,” USACE, Davis, CA, November 2006.

U.S. Geological Survey (USGS). National Elevation Dataset. Available from: http://ned.usgs.gov/

U.S. Geological Survey (USGS). National Hydrography Dataset. Available from: http://nhd.usgs.gov/data.html

3 Terms of Reference

AEP	Annual Exceedance Probability
ARF	Areal Reduction Factor
cfs	cubic feet per second
CWMS	Corps Water Management System
DAR	Depth Area Reduction
EM	Engineering Manual
EMA	expected moment algorithm
ERDC	Engineering Research & Development Center of USACE
FEMA	Federal Emergency Management Agency
FIS	flood insurance study
GeoHMS	Geospatial Hydrologic Model System extension
GIS	Geographic Information Systems
GO	Global Optimization
HEC	Hydrologic Engineering Center
HMR	Hydrometeorological Report
HMS	Hydrologic Modeling System
InFRM	Interagency Flood Risk Management
MAP	Mean Areal Precipitation
NA14	NOAA Atlas 14
NMSM	Nelder and Mead Simplex Method
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
PFDS	Precipitation Frequency Data Server
PMP	Probable Maximum Precipitation
SCE	Shuffled Complex Evolution
sq mi	square miles
TP40	Technical Paper 40
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey