

Integrating Transportation and Stormwater Infrastructure (TSI)

2D HEC-RAS Modeling for the Lake Worth Watershed

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1 Executive Summary

Task 3.1 (Project Area Hydrology and Hydraulics Assessment and Scenarios) of the 2021 TSI project agreement between the Texas Water Development Board (TWDB) and North Central Texas Council of Governments (NCTCOG) included a deliverable to “investigate and update Federal Emergency Management Agency (FEMA) generated Base Level Engineering (BLE) hydraulic models”. This report documents the modeling updates performed for the Lake Worth BLE hydraulic model using 2D HEC-RAS software. The Lake Worth BLE model was updated with flow output from the TSI enhanced West Fork Trinity River HEC-HMS model for existing 2020 conditions and future 2070 conditions. The peak flow rates from the West Fork HEC-HMS junctions were input as constant hydrographs into the 2D Lake Worth HEC-RAS model to produce quasi-steady state hydraulic results and inundation mapping. Significant bridge and culvert crossing structures were also added to the model according to the Texas Department of Transportation (TXDOT) as-built plan information. The modeling updates were performed in accordance with the TSI West HEC-RAS Model Development Standard Operating Procedure (SOP) document (February 2025). The model development and results for this analysis are documented in this report.

2 Data Sources

The following data was used in conjunction with the FEMA Lower West Fork Trinity River BLE modeling for Lake Worth. The data is sourced from the larger TSI West study area, the TSI HEC-HMS Model Development SOP and the TSI HEC-RAS Model Development SOP.

2.1 GIS Data

The GIS data in the following table was used to develop the enhanced 2D Lake Worth hydraulic modeling.

Table 2-1. GIS Data Sources

Data Type	Data Source	Description of the Data
Terrain	Terrain.lwft_mos_3ft.tif	DEM sourced from the Lower West Fork Trinity BLE model
Existing Dam Locations	Trinity_NID_2016	Dam locations from the National Inventory of Dams
Drainage Divides	TSI_Subbasins_2DBLE_LAWO.shp	West Fork TSI hydrology drainage divides for the Lake Worth area
Bridge Locations	TxDOT_Bridges_2DArea_LAWO.shp	TXDOT bridge locations point file clipped to the Lake Worth region
Stream Centerline	Trinity_HUC4_streams_clipped.shp	Trinity River HUC4 stream centerlines

2.2 HEC-HMS data

The TSI enhanced West Fork HEC-HMS model was used for the flow inputs for the Lake Worth HEC-RAS model. The peak discharges were extracted from the West Fork HEC-HMS model for the 2020 conditions and 2070 conditions with valley storage losses. The 2-, 10-, 50-, 100-, and 500-year storm events were modeled for 2020 and 2070 conditions. The model development procedure and details for the HEC-HMS model can be found in the TSI report titled “HEC-HMS Modeling for the West Fork of the Trinity River Area”.

3 HEC-RAS Model Development

The FEMA Lower West Fork Trinity River (LWFT) BLE modeling was used as a base for development of this HEC-RAS model. The BLE modeling for the LWFT area included separate 2D HEC-RAS models for the separate watersheds in the overall area. The Lake Worth area was one of the separate 2D HEC-RAS model areas under the folder name “LAWO”. This model was copied and edited to create the TSI enhanced model, but the BLE plans are saved in the HEC-RAS project file for comparison. This section details the specific updates made to the Lake Worth HEC-RAS model. HEC-RAS version 6.6. was used for this analysis.

3.1 Terrain and 2D Mesh

Although there is a TWDB seamless terrain file for use in the TSI project, the terrain in the BLE HEC-RAS model was not updated to the TWDB terrain. The terrain file that was included in the BLE modeling was used, since the break lines and 2D mesh features were developed based on the that terrain data. Also, using the original terrain data from the BLE model allows for better comparison with the BLE inundation results mapping. The terrain file from the BLE model was sourced from the 2019 USGS LiDAR for the Pecos and Dallas area.

The BLE 2D mesh boundary and cell spacing of 200x200-feet was not revised. Break lines were included in the BLE model along roads, berms, ridges, and other high ground that can impede flow as well as stream centerlines. The 2D mesh from the BLE model, with the break lines, was copied to create the geometry for the TSI enhanced mode. The break lines were only modified to add gaps in the break lines along roads at stream crossings where bridge structures were added to the model.

3.2 Boundary Conditions

The BLE model included two different flow input methods with corresponding plans, a precipitation plan with rain-on-grid across the entire 2D domain, and a plan with flow input hydrographs along the main stem of the West Fork Trinity River based on output from the Watershed Hydrology Assessment (WHA) Trinity River model. These BLE boundary conditions were not used in the TSI plans but rather flow inputs at the TSI hydrologic junctions were input as hydrograph boundary conditions from the TSI West Fork HEC-HMS model results.

Typically, flows are input into 2D HEC-RAS models by connecting the HEC-HMS results DSS file to hydrograph boundary condition inputs at each subbasin outlet within the 2D region. The flow attenuation through the reaches area accounted for in the 2D HEC-RAS model. However, the TSI West Fork HEC-HMS model already accounted for flow attenuation along reaches between junctions through the Modified Puls method, based on HEC-RAS storage-discharge outputs. Furthermore, the storage-discharge curves were reduced in the HEC-HMS model for the 2070 conditions to assume valley storage loss due to future floodplain encroachments. Since the flow attenuation along reaches was already accounted for in the HEC-HMS model, and also to model the effects of the valley storage loss in 2070 conditions, a different flow input methodology was used.

Rather than connecting the 2D HEC-RAS boundary conditions to the subbasin discharge results from the HEC-HMS DSS results file, constant hydrographs were developed for the peak discharge at each HEC-HMS junction. Since the flow in the 2D HEC-RAS model combines as the flood moves downstream through the model, the peak discharges of the upstream junctions were subtracted from the downstream junctions, and the difference was input into the boundary condition constant hydrograph. As a result, some of the constant hydrograph inputs are negative values. However, the simulation time was set to give to model sufficient time for the constant hydrographs to accumulate downstream and the resulting flow at the reference lines correspond to the peak HEC-HMS values at each corresponding junction (within 5%).

For example, junction Silver_Ck_J010 has a peak 2020 2-year discharge of 28 CFS in the TSI West Fork HEC-HMS model. The next downstream junction Silver_Ck_J020_blw has a peak discharge of 74 CFS. Therefore, the 2D HEC-RAS boundary condition at Silver_Ck_J010 has a constant hydrograph input of 28 CFS and the boundary condition at Silver_Ck_J020_blw has a constant hydrograph input of 45 (74 minus 28) CFS. This process was continued downstream throughout the model. One additional calculation was made for junctions immediately downstream of a confluence with another tributary. The upstream junction peak discharge and the peak discharge of the connected tributary were subtracted from the peak discharge of the downstream junction to determine the constant hydrograph flow input downstream of tributary confluences.

Flow Hydrograph

2D: Lower Clear Fork BCLine: Silver_Ck_J020_blw

☐ Read from DSS before simulation Select DSS file and Path

File:

Path:

☒ Enter Table Data time interval: 1 Hour

Select/Enter the Data's Starting Time Reference

☒ Use Simulation Time: Date: 01Jan1900 Time: 00:00

☐ Fixed Start Time: Date: Time:

No. Ordinates Interpolate Missing Values Del Row Ins Row

Hydrograph Data			
	Date	Simulation Time (hours)	Flow (cfs)
1	31Dec1899 2400	0:00:00	45
2	01Jan1900 0100	1:00:00	45
3	01Jan1900 0200	2:00:00	45
4	01Jan1900 0300	3:00:00	45
5	01Jan1900 0400	4:00:00	45
6	01Jan1900 0500	5:00:00	45
7	01Jan1900 0600	6:00:00	45
8	01Jan1900 0700	7:00:00	45
9	01Jan1900 0800	8:00:00	45
10	01Jan1900 0900	9:00:00	45

Time Step Adjustment Options ("Critical" boundary conditions)

☐ Monitor this hydrograph for adjustments to computational time step

Max Change in Flow (without changing time step):

Min Flow: Multiplier: EG Slope for distributing flow along BC Line: 0.005 ☐ TW Check

Plot Data OK Cancel

Figure 3-1. Example Constant Hydrograph at Junction Silver_Ck_J020_blw

The model was run with a 72-hour simulation time to achieve a “steady” state of flow for inundation mapping. Reference lines were placed near the boundary condition flow input locations, which correspond to the HEC-HMS junction locations, and the sum of the flow in the HEC-RAS model at each reference line was compared to the HEC-HMS results at the junction to ensure proper flow input calculations. The results of the HEC-RAS model showed very close correlation to the peak discharges in HEC-HMS (within 5%), except for the 2020 2-year storm event along Silver Creek. There are two ponds within the terrain file along this creek that take a significant simulation time to fill up with the low 2-year discharge rates. Because of this, a much longer simulation time would be required for the 2-year to stabilize at the peak HEC-HMS flow rates. However, the junctions Silver_Ck_J100, J100_blw, J110_blw_Mill_Bk, and J_120 are within approximately 10% of the HEC-HMS peak flows for the 2020 2-year storm event. The simulation time was not increased, because all the higher storm events stabilized and were within 5% of the HEC-HMS discharges within a 72-hour simulation time.

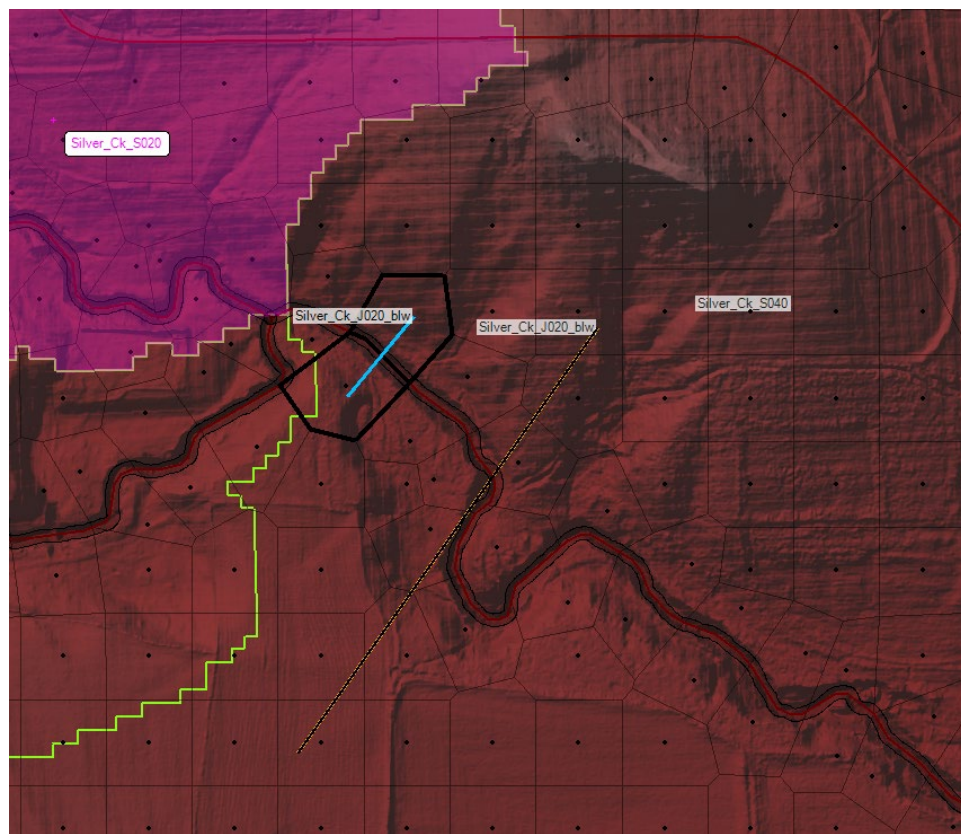


Figure 3-2. Example Boundary Condition with Reference Line for Junction Silver_Ck_J020_blw

3.3 Computation Parameters

The BLE model computation interval of 15 seconds was used in the TSI plans. The simulation time window of the model was revised to a 72-hour run time to give the model sufficient time to stabilize with the input peak hydrographs. The Diffusion Wave equation set was used in the BLE models and also the TSI plans. The simulation run time takes approximately 35-minutes with the Diffusion Wave equations and is stable.

3.4 Manning's n-values

The BLE base model developed Manning's n roughness values based on the National Land Cover Database (NLCD). The base land cover data from the BLE model was used in the TSI model. Calibration regions were created for the stream channel in the TSI model to manually revise the Manning's n value to 0.04 for the stream channels. The Trinity HUC4 stream centerlines ArcGIS lines were buffered by 15-feet on both sides to create the channel calibration regions. Table 3-1 provides a summary of the assigned base Manning's n values for each land cover category with the HEC User's Manual recommended guidelines for comparison.

Table 3-1. Assigned Manning's n-values

NLCD Land Use Description	Assigned Manning's n-value	Minimum (2D User's Manual)	Maximum (2D User's Manual)
Developed, Open Space	0.04	0.03	0.05
Developed, Low Intensity	0.06	0.06	0.12
Developed, Medium Intensity	0.08	0.08	0.16
Developed, High Intensity	0.12	0.12	0.2
Cultivated Crops	0.04	0.02	0.05
Grassland-Herbaceous	0.03	0.025	0.05
Shrub-Scrub	0.06	0.07	0.16
Deciduous Forest	0.12	0.1	0.2
Evergreen Forest	0.12	0.08	0.16
Mixed Forest	0.12	0.08	0.20
Hay Pasture	0.04	0.025	0.05
Woody Wetlands	0.1	0.045	0.15
Emergent Herbaceous Wetland	0.08	0.05	0.085
Barren Land	0.03	0.23	0.03
Open Water	0.03	0.025	0.05

3.5 Structures

The BLE HEC-RAS geometry contained one existing structure for the Lake Worth dam weir and outlet rating curve. This existing structure was not modified in the TSI plans and was kept in the model. Additional structures were added for TXDOT and non-TXDOT roadway crossings following the procedures of the TSI Project West Study Region HEC-RAS Model Development SOP (February 2025) and the No As-built Process prepared by Freese and Nichols. The TXDOT structures were added based on TXDOT as-built plan information. No survey information was collected for this modeling effort.

3.5.1 SA/2D Connections

Roadway crossings were added to the TSI existing conditions geometry using SA/2D connections with either bridge deck/piers or culverts, based on TXDOT as-built information. As previously mentioned, the roadway break lines from the BLE model were modified to add a gap where the SA/2D connection was added. This was done so that an appropriate break line cell spacing could be set for the SA/2D connection that would appropriately model the roadway crossing with cell computation points placed along the bounding cross sections. The deck dimensions, guardrails, piers, and culverts were added based on TXDOT as-built information or assumptions were made if the as-builts were not available or unclear. The assumptions follow the No As-built Process document by FNI. Seventeen TXDOT crossings were added to the existing conditions geometry along with two non-TXDOT crossings. The non-TXDOT crossings did not have as-built information, so the structure parameters were estimated based on measurements from aerial imagery and Google Earth 3D views for culverts. Any further assumptions for the non-TXDOT structures were made following the No As-built Process document.

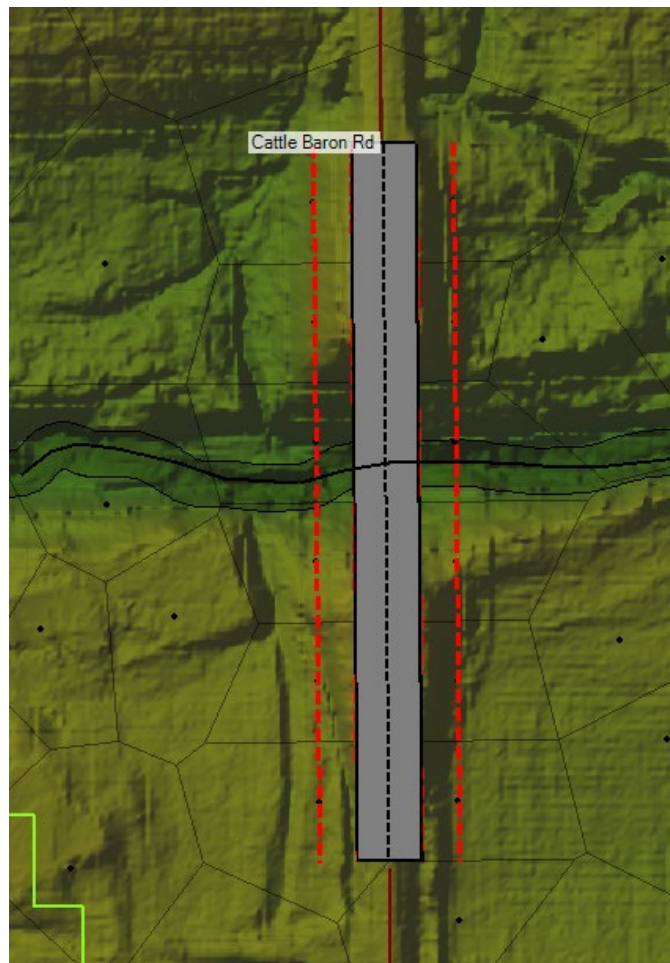


Figure 3-3. Example 2D/SA Connection Layout with Cell Spacing and Bounding Sections

The internal cross sections within the 2D/SA connection editions were updated to set bank stations and set the Manning's n roughness values. A Manning's n value of 0.04 was used for the channels in the cross sections, a value of 0.15 was used for heavily wooded overbanks, and a value of 0.1 was used for less dense and shorter vegetation overbanks. The contraction and expansion coefficients were set to 0.3 and 0.5 accordingly.

3.5.2 Terrain Modifications

The BLE terrain data contained breaks at stream crossing for roadways for most of the structures that were added to the TSI model as SA/2D connections. However, two roadway crossings required terrain modifications to “burn” the stream through the roadway, Silver Creek Azle Road and Tucker Drive. The channel bottom widths and side slopes for the terrain modifications were determined by comparing the adjacent stream terrain data.

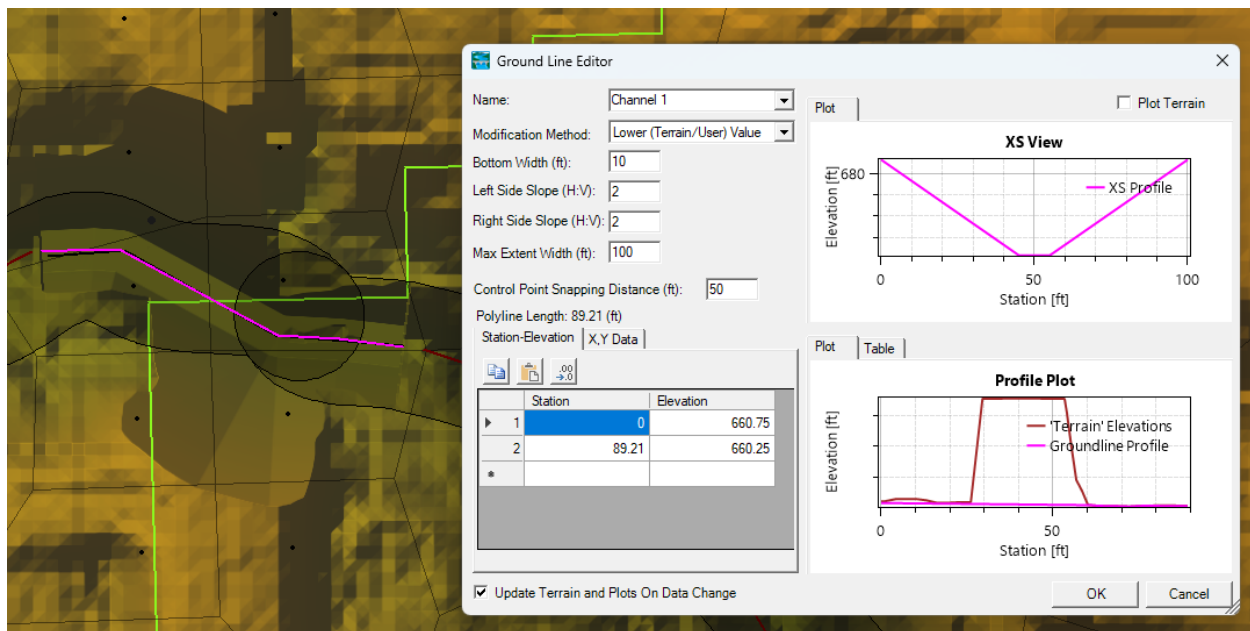


Figure 3-4. Example Terrain Modification at Siler Creek Azle Road

3.6 Flow Files

New flow files were created for the 2, 10, 50, 100, and 500-year storm events for the 2020 and 2070 conditions. Each flow file contains the corresponding storm event peak discharge constant hydrographs as described earlier in this report. Additionally, an initial condition elevation was set for each storm event flow file corresponding with the Lake Worth water surface elevations from the WHA model results for the 2020 conditions. For the 2070 conditions, the initial elevations for Lake Worth were sourced from a FEMA funded future conditions study of the Trinity River.

3.6.1 2020 Condition

The following table provides the HEC-HMS junction peak discharge results for the TWI West Fork model 2020 land use conditions.

Table 3-2. TSI West Fork HEC-HMS Results for 2020 (flow in CFS)

Junction	002yr	010yr	050yr	100yr	500yr
Little_Silver_Ck_J010	30	47	619	1018	1897
Little_Silver_Ck_J020_blw	70	1341	3257	4123	5984
Little_Silver_Ck_J030	71	1696	3965	4957	6703
Little_Silver_Ck_J040	78	1779	4357	5417	7374
Live_Oak_Ck_J010	183	1818	3615	4222	5608
Live_Oak_Ck_J020	217	2385	4982	5832	7785
Mill_Ck_J010	70	714	1385	1607	2119
Mill_Ck_J020	113	1196	2398	2795	3699
Mill_Ck_J030	137	838	3032	3909	5606
Mill_Ck_J040	113	1099	3754	4862	7203
Silver_Ck_J010	28	880	1799	2105	2757
Silver_Ck_J020_blw	74	2352	4949	5840	7696
Silver_Ck_J030	79	2704	5784	6911	9162
Silver_Ck_J040	41	801	1582	1839	2393
Silver_Ck_J050	79	1440	2752	3194	4240
Silver_Ck_J050_abv	55	2189	5718	7051	9601
Silver_Ck_J050_blw	121	2893	7800	9617	13056
Silver_Ck_J060_abv	115	2871	7872	9707	13233
Silver_Ck_J060_blw	192	4444	11963	14806	20409
Silver_Ck_J070	180	4651	12862	15947	21999
Silver_Ck_J080_blw	282	5215	15498	19340	26557
Silver_Ck_J090	33	52	585	918	1674
Silver_Ck_J100	36	58	915	1371	2511
Silver_Ck_J100_blw	294	5173	16293	20747	29377
Silver_Ck_J110_blw_Mill_Ck	369	5785	19376	24803	35260
Silver_Ck_J120	382	5640	17663	21664	33856
Eagle_Mountain_Reservoir	6801	15109	25892	32795	50232
West_Fork_J460	6801	15172	26020	32955	50451
Lake_Worth_Inflow	6801	19351	43383	52076	73377

As previously discussed, to determine the flow rates to input as constant hydrographs in HEC-RAS boundary conditions, the upstream HEC-HMS junction peaks were subtracted from the downstream and tributaries were also subtracted downstream of confluences. The resulting flow values used to create constant hydrographs at each junction are provided in the following table for 2020 land use conditions.

Table 3-3. HEC-RAS Flow Inputs for Constant Hydrographs for 2020 (flow in CFS)

Junction	002yr	010yr	050yr	100yr	500yr
Little_Silver_Ck_J010	30	47	619	1018	1897
Little_Silver_Ck_J020_blw	40	1295	2639	3105	4087
Little_Silver_Ck_J030	1	355	708	834	719
Little_Silver_Ck_J040	7	83	391	460	671
Live_Oak_Ck_J010	183	1818	3615	4222	5608
Live_Oak_Ck_J020	34	567	1368	1609	2177
Mill_Ck_J010	70	714	1385	1607	2119
Mill_Ck_J020	43	482	1013	1188	1581
Mill_Ck_J030	24	-358	633	1114	1907
Mill_Ck_J040	-24	261	723	953	1597
Silver_Ck_J010	28	880	1799	2105	2757
Silver_Ck_J020_blw	45	1471	3151	3735	4939
Silver_Ck_J030	6	352	834	1071	1466
Silver_Ck_J040	41	801	1582	1839	2393
Silver_Ck_J050	38	639	1170	1355	1846
Silver_Ck_J050_abv	-25	-515	-66	140	439
Silver_Ck_J050_blw	-13	-735	-670	-628	-785
Silver_Ck_J060_abv	-6	-22	73	90	177
Silver_Ck_J060_blw	-2	-206	-266	-318	-197
Silver_Ck_J070	-12	207	899	1141	1589
Silver_Ck_J080_blw	102	563	2637	3393	4558
Silver_Ck_J090	33	52	585	918	1674
Silver_Ck_J100	3	6	329	453	837
Silver_Ck_J100_blw	-24	-100	-120	36	309
Silver_Ck_J110_blw_Mill_Ck	-38	-487	-671	-806	-1320
Silver_Ck_J120	13	-145	-1714	-3139	-1405
Eagle_Mountain_Reservoir	6801	15109	25892	32795	50232
West_Fork_J460	0	63	129	160	219
Lake_Worth_Inflow	-598	-3784	-5153	-8215	-18496

3.6.2 2070 Condition

The following table provides the HEC-HMS junction peak discharge results for the TWI West Fork model 2070 land use conditions.

Table 3-4. TSI West Fork HEC-HMS Results for 2070 (flow in CFS)

Junction	002yr	010yr	050yr	100yr	500yr
Little_Silver_Ck_J010	268	421	1047	1485	2444
Little_Silver_Ck_J020_blw	872	2376	4407	5351	7429
Little_Silver_Ck_J030	1016	2902	5307	6307	7808
Little_Silver_Ck_J040	577	3202	5783	6847	8515
Live_Oak_Ck_J010	966	2717	4537	5201	6793
Live_Oak_Ck_J020	1295	3606	6156	7083	9328
Mill_Ck_J010	277	992	1702	1948	2537
Mill_Ck_J020	518	1695	2959	3391	4443
Mill_Ck_J030	468	1646	4214	5053	6794
Mill_Ck_J040	571	2068	5294	6429	8927
Silver_Ck_J010	149	973	1857	2161	2819
Silver_Ck_J020_blw	628	2962	5549	6451	8416
Silver_Ck_J030	740	3448	6523	7604	9924
Silver_Ck_J040	260	1046	1833	2105	2712
Silver_Ck_J050	485	1914	3233	3713	4964
Silver_Ck_J050_abv	663	3267	6652	7831	10299
Silver_Ck_J050_blw	969	4344	9107	10713	13971
Silver_Ck_J060_abv	968	4318	9205	10853	14180
Silver_Ck_J060_blw	1480	6793	14587	17383	22577
Silver_Ck_J070	1550	7498	15740	18751	24477
Silver_Ck_J080_blw	2058	8943	19252	22975	29398
Silver_Ck_J090	350	550	1100	1440	2222
Silver_Ck_J100	426	669	1478	2108	3685
Silver_Ck_J100_blw	2280	9281	20905	25202	32933
Silver_Ck_J110_blw_Mill_Ck	2763	10903	25184	30338	39841
Silver_Ck_J120	2627	10603	21883	26396	39037
Eagle_Mountain_Reservoir	7296	18140	29712	36964	56077
West_Fork_J460	8013	18259	29918	37246	56402
Lake_Worth_Inflow	12552	30747	53661	62408	85443

The resulting flow values used to create constant hydrographs at each junction are provided in the following table for 2070 land use conditions.

Table 3-5. HEC-RAS Flow Inputs for Constant Hydrographs for 2070 (flow in CFS)

Junction	002yr	010yr	050yr	100yr	500yr
Little_Silver_Ck_J010	268	421	1047	1485	2444
Little_Silver_Ck_J020_blw	604	1955	3360	3866	4985
Little_Silver_Ck_J030	144	527	901	956	379
Little_Silver_Ck_J040	-439	300	475	540	707
Live_Oak_Ck_J010	966	2717	4537	5201	6793
Live_Oak_Ck_J020	330	889	1619	1882	2535
Mill_Ck_J010	277	992	1702	1948	2537
Mill_Ck_J020	242	703	1257	1443	1906
Mill_Ck_J030	-50	-49	1255	1662	2351
Mill_Ck_J040	103	421	1080	1376	2133
Silver_Ck_J010	149	973	1857	2161	2819
Silver_Ck_J020_blw	479	1989	3692	4290	5597
Silver_Ck_J030	112	486	975	1153	1508
Silver_Ck_J040	260	1046	1833	2105	2712
Silver_Ck_J050	225	868	1400	1608	2253
Silver_Ck_J050_abv	-76	-181	128	227	375
Silver_Ck_J050_blw	-179	-837	-778	-831	-1292
Silver_Ck_J060_abv	-1	-25	98	140	209
Silver_Ck_J060_blw	-66	-727	-401	-317	-118
Silver_Ck_J070	70	705	1152	1368	1899
Silver_Ck_J080_blw	508	1445	3512	4225	4922
Silver_Ck_J090	350	550	1100	1440	2222
Silver_Ck_J100	75	119	378	668	1463
Silver_Ck_J100_blw	-204	-331	175	118	-151
Silver_Ck_J110_blw_Mill_Ck	-88	-446	-1014	-1293	-2020
Silver_Ck_J120	-136	-300	-3301	-3941	-804
Eagle_Mountain_Reservoir	7296	18140	29712	36964	56077
West_Fork_J460	717	119	206	282	325
Lake_Worth_Inflow	1334	-1603	-4091	-8036	-18999

3.7 Description of Plans

The original BLE plans were left in the model for comparison with the TSI enhanced plans. There is a total of fourteen (14) BLE plans and ten (10) TSI plans. The follow table provides a description of the plans and the HEC-RAS plan file numbers for reference.

Table 3-6. HEC-RAS Plans

Plan Name	Description	Plan Files (.pXX)
LAWO_Precip	Original BLE plans with rain-on-mesh flow input with separate plans for the 10, 25, 50, 100, 500-year storm events and 100-year minus and 100-year-plus	05, 09, 10, 01, 06, 02, 13
LAWO_Combination	Original BLE plans with WHA hydrograph flow input along West Fork Trinity River with separate plans for the 10, 25, 50, 100, 500-year storm events and 100-year minus and 100-year-plus	07, 11, 12, 04, 08, 14, 15
TSI_2020	TSI enhanced plans for 2020 current conditions with separate plans for the 2, 10, 50, 100, and 500-year storm events	03, 16, 17, 18, 19
TSI_2070	TSI enhanced plans for 2070 future conditions with separate plans for the 2, 10, 50, 100, and 500-year storm events	20, 21, 22, 23, 24

4 HEC-RAS Model Results

The peak discharges for all storm events for the 2020 and 2070 conditions models were compared between the reference line outputs from HEC-RAS and the TSI West Fork HEC-HMS junction peaks. Additionally, the inundation for the 100-year storm events for the 2020 and 2070 conditions were exported and compared to the BLE inundation.

4.1 Comparison to HEC-HMS Discharges

The following tables provide the flows measured at the HEC-RAS reference lines and provides the difference with the HEC-HMS results at the corresponding junction.

Table 4-1. Lake Worth Reference Line Flows Compared to HEC-HMS Results for 2020 Conditions

Junction	002yr	Diff. (%)	010yr	Diff. (%)	050yr	Diff. (%)	100yr	Diff. (%)	500yr	Diff. (%)
Little_Silver_Ck_J010	30	1%	47	0%	619	0%	1018	0%	1897	0%
Little_Silver_Ck_J020_blw	70	1%	1342	0%	3258	0%	4123	0%	5984	0%
Little_Silver_Ck_J030	71	0%	1697	0%	3966	0%	4957	0%	6700	0%
Little_Silver_Ck_J040	78	0%	1780	0%	4357	0%	5417	0%	7374	0%
Live_Oak_Ck_J010	183	0%	1818	0%	3615	0%	4222	0%	5608	0%
Live_Oak_Ck_J020	217	0%	2385	0%	4983	0%	5831	0%	7785	0%
Mill_Ck_J010	70	1%	714	0%	1385	0%	1607	0%	2119	0%
Mill_Ck_J020	113	0%	1196	0%	2398	0%	2795	0%	3700	0%
Mill_Ck_J030	137	0%	839	0%	3028	0%	3910	0%	5607	0%
Mill_Ck_J040	121	6%	1120	2%	3754	0%	4862	0%	7204	0%
Silver_Ck_J010	28	-2%	880	0%	1800	0%	2108	0%	2756	0%
Silver_Ck_J020_blw	73	-1%	2351	0%	4950	0%	5840	0%	7696	0%
Silver_Ck_J030	79	0%	2703	0%	5784	0%	6924	0%	9195	0%
Silver_Ck_J040	41	1%	801	0%	1582	0%	1839	0%	2393	0%
Silver_Ck_J050	79	0%	1440	0%	2764	0%	3213	1%	4210	-1%
Silver_Ck_J050_abv	54	-1%	2188	0%	5718	0%	7051	0%	9602	0%
Silver_Ck_J050_blw	120	-1%	2893	0%	7800	0%	9618	0%	13054	0%
Silver_Ck_J060_blw	190	-1%	4445	0%	11964	0%	14806	0%	20409	0%
Silver_Ck_J070	178	-1%	4666	0%	12912	0%	15974	0%	22081	0%
Silver_Ck_J080_blw	280	-1%	5212	0%	15521	0%	19355	0%	26543	0%
Silver_Ck_J090	32	-2%	52	0%	586	0%	918	0%	1674	0%
Silver_Ck_J100	7	-81%	55	-5%	914	0%	1371	0%	2511	0%
Silver_Ck_J100_blw	263	-11%	5170	0%	16295	0%	20744	0%	29321	0%
Silver_Ck_J110_blw_Mill_Ck	336	-9%	5785	0%	19379	0%	24803	0%	35262	0%
Silver_Ck_J120	350	-8%	5636	0%	17664	0%	21664	0%	33846	0%
Eagle_Mountain_Reservoir	6801	0%	15109	0%	25892	0%	32795	0%	50232	0%
Lake_Worth_Inflow	6727	-1%	19448	0%	43546	0%	52336	0%	73947	1%

Table 4-2. Lake Worth Reference Line Flows Compared to HEC-HMS Results for 2070 Conditions

Junction	002yr	Diff. (%)	010yr	Diff. (%)	050yr	Diff. (%)	100yr	Diff. (%)	500yr	Diff. (%)
Little_Silver_Ck_J010	268	0%	421	0%	1047	0%	1485	0%	2444	0%
Little_Silver_Ck_J020_blw	872	0%	2376	0%	4407	0%	5351	0%	7429	0%
Little_Silver_Ck_J030	1016	0%	2903	0%	5308	0%	6307	0%	7774	0%
Little_Silver_Ck_J040	577	0%	3203	0%	5783	0%	6847	0%	8515	0%
Live_Oak_Ck_J010	966	0%	2717	0%	4537	0%	5201	0%	6793	0%
Live_Oak_Ck_J020	1296	0%	3606	0%	6145	0%	7083	0%	9344	0%
Mill_Ck_J010	277	0%	992	0%	1702	0%	1948	0%	2537	0%
Mill_Ck_J020	519	0%	1695	0%	2959	0%	3391	0%	4443	0%
Mill_Ck_J030	467	0%	1648	0%	4214	0%	5070	0%	6794	0%
Mill_Ck_J040	566	-1%	2067	0%	5294	0%	6429	0%	8925	0%
Silver_Ck_J010	149	0%	973	0%	1857	0%	2161	0%	2811	0%
Silver_Ck_J020_blw	628	0%	2962	0%	5549	0%	6451	0%	8416	0%
Silver_Ck_J030	740	0%	3448	0%	6524	0%	7596	0%	9969	0%
Silver_Ck_J040	260	0%	1046	0%	1833	0%	2105	0%	2712	0%
Silver_Ck_J050	485	0%	1908	0%	3261	1%	3685	-1%	5000	1%
Silver_Ck_J050_abv	664	0%	3267	0%	6652	0%	7832	0%	10300	0%
Silver_Ck_J050_blw	970	0%	4344	0%	9109	0%	10714	0%	13973	0%
Silver_Ck_J060_blw	1480	0%	6795	0%	14587	0%	17383	0%	22577	0%
Silver_Ck_J070	1550	0%	7505	0%	15766	0%	18753	0%	26253	7%
Silver_Ck_J080_blw	2058	0%	8937	0%	19266	0%	22970	0%	31791	8%
Silver_Ck_J090	350	0%	549	0%	1109	1%	1432	-1%	2226	0%
Silver_Ck_J100	425	0%	669	0%	1478	0%	2115	0%	3683	0%
Silver_Ck_J100_blw	2279	0%	9284	0%	20900	0%	25181	0%	35133	7%
Silver_Ck_J110_blw_Mill_Ck	2764	0%	10906	0%	25185	0%	30335	0%	40411	1%
Silver_Ck_J120	2628	0%	10607	0%	21883	0%	26394	0%	35524	-9%
Eagle_Mountain_Reservoir	7296	0%	18140	0%	29712	0%	36964	0%	56076	0%
Lake_Worth_Inflow	12513	0%	30779	0%	53790	0%	62663	0%	85886	1%

As shown in the tables, the flow input method of constant hydrographs based on peak discharges at junctions, with subtracted upstream junctions, produced results consistent with the peak discharges in the HEC-HMS model. As mentioned previously, the HEC-RAS results for the very low flows for the 2020 2-year storm event and the reach with multiple ponds along the reach, did not align with the HEC-HMS peaks and the HEC-RAS model simulation time would need to be longer. Additionally, there was some instability in the 2070 500-year HEC-RAS results that caused oscillations in the HEC-RAS hydrographs, leading to peak discharges not matching the HEC-HMS results as closely at junctions along Silver Creek. However, these results demonstrate that the flow input methodology is viable so long as sufficient simulation time is provided and stability issues are resolved.

4.2 2020 Conditions

The inundation shapefiles for the 100-year and 500-year storm events for the 2020 condition were exported and compared to the BLE results. The inundation layers were edited in RAS mapper to remove dry areas within the inundation area and remove wet areas outside of the inundation area that were not connected to the stream inundation. Since the BLE inundation was developed based on rain-on-grid flow inputs, there is inundation throughout the 2D domain. The TSI flow input method only input flows along the major tributaries centerlines where there were junctions in the TSI West Fork HEC-HMS model. Therefore, the inundation of the BLE models have a greater coverage than the TSI results for all storm events. The figure below compares the BLE precipitation-based inundation to the TSI 2020 inundation for the 100-year storm event.



Figure 4-1. Comparison of BLE Inundation (blue) to TSI 2020 Inundation (red) for 100-year Storm

The comparison shows the BLE inundation covering a greater extent beyond the major tributaries, but it also shows a wider width along the major streams. This could be due to the different flow input methodology.

Although the BLE inundation is greater than the TSI inundation along the major tributaries, the TSI inundation was greater than the BLE inundation along the West Fork Trinity River. The BLE inundation along the West Fork Trinity River was provided in the plans based on flow input hydrographs from the WHA model results. The figure below compares the BLE hydrograph-based inundation to the TSI 2020 inundation for the 100-year storm event.



Figure 4-2. Comparison of BLE Inundation (blue) to TSI 2020 Inundation (red) for 100-year Storm

Although the BLE 100-year inundation area was generally wider than the TSI 2020 inundation along the tributaries, the TSI 2020 inundation was wider than the BLE 100-year inundation along Silver Creek between FM 1886 and Covered Bridge Drive. Adding Covered Bridge Drive to the hydraulic model as a structure increased the 100-year inundation upstream. Figure 4-3 below

shows a comparison of the BLE and TSI 100-year inundation. It appears based on Google aerial imagery that two or three residential structures may be located within the 100-year inundation area based on TSI modeling, which were not included in the BLE 100-year inundation area.



Figure 4-3. Comparison of BLE Inundation (blue) to TSI 2020 Inundation (red) for 100-year Storm Upstream of Covered Bridge Dr

4.3 2070 Conditions

The results for the 2070 conditions were similar to the 2020 conditions when compared to the BLE inundations. The BLE precipitation-based inundation had a greater extent of inundation and wider inundation along the major tributaries compared to the TSI 2070 inundation, but the TSI 2070 inundation along the West Fork Trinity River was wider than the BLE hydrograph-based inundation.



Figure 4-4. Comparison of BLE Inundation (blue) to TSI 2070 Inundation (magenta) for 100-year Storm

When comparing the TSI 2020 inundation to the TSI 2070 inundation, there was not a significant increase in the inundation. The figure below shows a comparison of the TSI 2020 inundation to the 2070 inundation for the 100-year storm event.

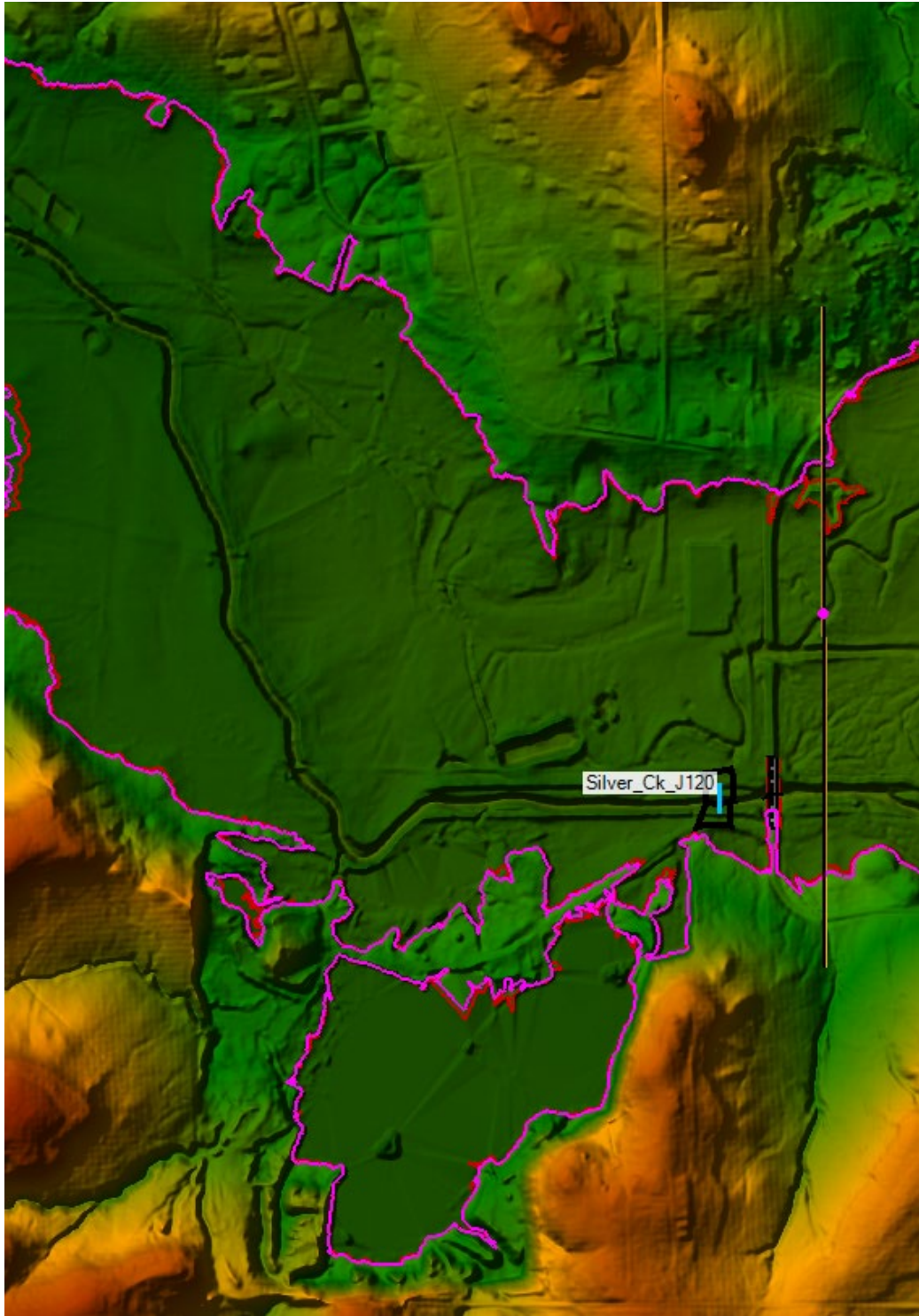


Figure 4-5. Comparison of 2020 TSI (red) to 2070 TSI (magenta) Inundation for 100-year Storm

The increase in inundation for the 2070 conditions 100-year was a result in increased water surface elevations up to approximately 0.8-feet along Silver Creek, for example. The figure

below shows the comparison of the 2020 and 2070 100-year water surface area along the Silver_Ck_J120 reference line.

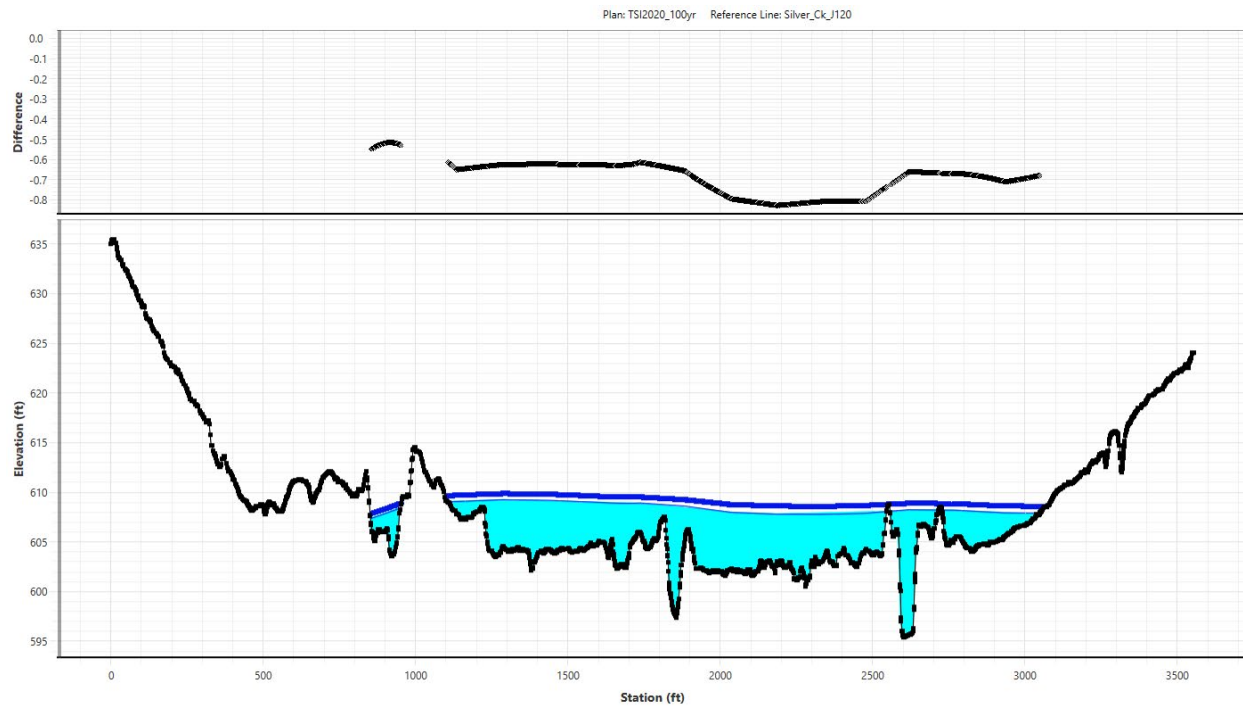


Figure 4-6. Comparison of 2070 TSI to 2020 TSI 100-year Water Surface at Silver_Ck_J120

5 Conclusions

The FEMA Base Level Engineering (BLE) 2D HEC-RAS model for the West Fork Trinity River in the Lake Worth area was enhanced for the TSI project to provide more accurate hydraulic modeling, including roadway structures and updated TSI hydrologic flow results. Roadway structures were added based on TXDOT as-built information and the TSI hydrologic flow results were input into the model to determine the 2020 and 2070 flood inundation for the 2-, 10-, 50-, 100-, and 500-year storm events. The flows were not input into the 2D HEC-RAS model using standard hydrograph connections to the HEC-HMS hydrologic results, but rather the peak flows at junctions were added as constant hydrographs to produce quasi-steady state hydraulic results and inundation mapping. This flow input methodology also shows the impact on flows and inundation based on valley storage loss in the floodplain, as modeled in HEC-HMS.

In general, the TSI 2020 and 2070 100-year flood inundation areas compared well to the existing BLE inundation areas. However, the BLE inundation areas were based on a different “rain-on-grid” modeling method and showed greater inundation on the tributaries as compared to the TSI model results. The TSI 2020 and 2070 100-year flood inundation was greater than the BLE inundation along West Fork Trinity River, between Eagle Mountain Lake and Lake Worth. Additionally, increased inundation in the TSI model was observed along Silver Creek upstream Covered Bridge Drive. This increased inundation shows two to three residential structures in the 100-year flood inundation based on TSI modeling, which were not in the BLE 100-year flood inundation. This increased inundation is likely because the BLE model did not include roadway structures, so this enhancement to the TSI model provides a more accurate estimation of inundation upstream of the roadways. These enhanced TSI 2D HEC-RAS models can be used as improved base level data when developing future flood studies and analysis in the TSI region. Furthermore, these models include a 2020 existing condition model and a 2070 future condition result to identify areas of increased inundation based on projected 2070 increases in flows.

Future increases to impervious cover and loss of valley storage resulting from development are expected to increase flood risk throughout the watershed unless new mitigation measures are implemented. The 100-yr floodplain inundation area increased 3% from 8,188 acres to 8,430 acres from 2020 to 2070 conditions. The number of National Structure Inventory (NSI) structures located within the 100-yr inundation area increased 14% from 558 to 637.

6 References

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