Technical Assistance Project
Shunganunga Creek Watershed

City of Topeka

Kansas Department of Agriculture
Division of Water Resources

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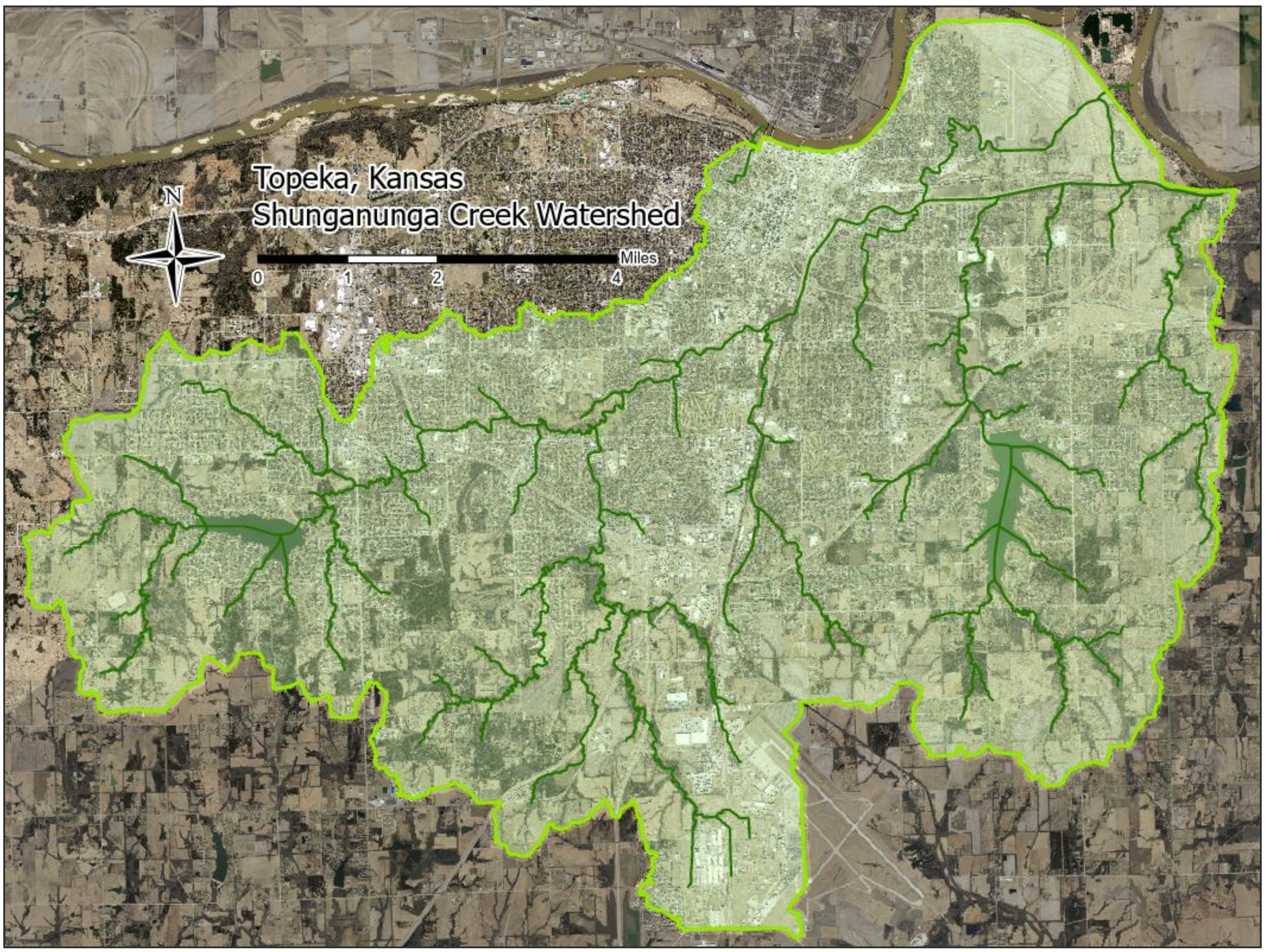
CONTENTS

1 BACKGROUND

The City of Topeka, Kansas has shown a strong desire to better understand flood risk in the community and to evaluate options for flood mitigation. As part of this initiative, the City has pursued stormwater master planning efforts, which include flood reduction measures along Shunganunga Creek. It is the desire of the City to evaluate potential alternatives on a model for Shunganunga Creek that accurately depicts the flood risk and that offers the ability to evaluate alternatives. With FEMA funding assistance provided by The Kansas Department of Agriculture (KDA), model enhancements were made to the two-dimensional HEC-RAS model previously developed for the Shunganunga Creek watershed, which was done as part of a prior Technical Assistance Project (TAP). This project will allow the City to focus their available funds on the evaluation of alternatives and master planning efforts rather than the modeling updates which are necessary to better align the existing 2D model with a USACE 1D study. An overview of the project area is shown in the following figure.

FIGURE 1-1 – OVERVIEW OF THE SHUNGANUNGA CREEK WATERSHED



Alfred Benesch & Company (Benesch) was contracted by Wood E&IS (Wood) to evaluate and update the modeling in the Shunganunga Creek watershed. Through discussion with the City of Topeka and Wood, Benesch completed a review of the available data for Shunganunga Creek. This included a feasibility study performed by the US Army Corps of Engineers (USACE), utilizing a 1-dimensional unsteady-flow HEC-RAS model. It also included the effective FEMA studies, as well as the 2D BLE floodplains created by Wood as part of the Topeka Technical Assistance project (TAP). After evaluation, relevant data was incorporated into an updated 2D HEC-RAS model. The updated model was then used as the base conditions for evaluating the impacts of potential alternatives across the watershed, done as part of the Topeka Stormwater Master Plan project.

2 MODEL EVALUATION

Previous studies of the Shunganunga Creek were evaluated. These are listed below, along with notes describing the big-picture description of the model. For more detailed discussion of each study, see the associated documentation, listed in the references section of this report.

1. Previous 2019 Technical Assistance Project performed by Wood
    - HEC-RAS version 5.0.7
    - Watershed-wide excess-rain-on-grid
    - Unsteady-state 2D modeling
2. Ongoing Feasibility Study performed by USACE
    - HEC-RAS version 5.0.3/5.0.7
    - Along Shunganunga Creek, calibrated to historical events
    - Unsteady-state 1D modeling
3. Previous 2011 watershed hydraulic study performed by USACE
    - HEC-RAS version 4.1
    - Along Shunganunga Creek and regulatory tributaries
    - Unsteady-state 1D networked modeling
4. 2011 Effective FEMA Study (H&H study performed by Amec, now Wood, in 2008)
    - HEC-RAS version 4.1
    - Along Shunganunga Creek and regulatory tributaries
    - Steady-state 1D modeling

3 MODEL ENHANCEMENTS

Relevant data from the multiple sources was incorporated into an updated 2D HEC-RAS model. The previous BLE model served as the base for these updates. The following sections highlight updates and enhancements performed on the base model. Additional information on the base model can be found in the documentation for the previous Technical Assistance Project performed by Wood.

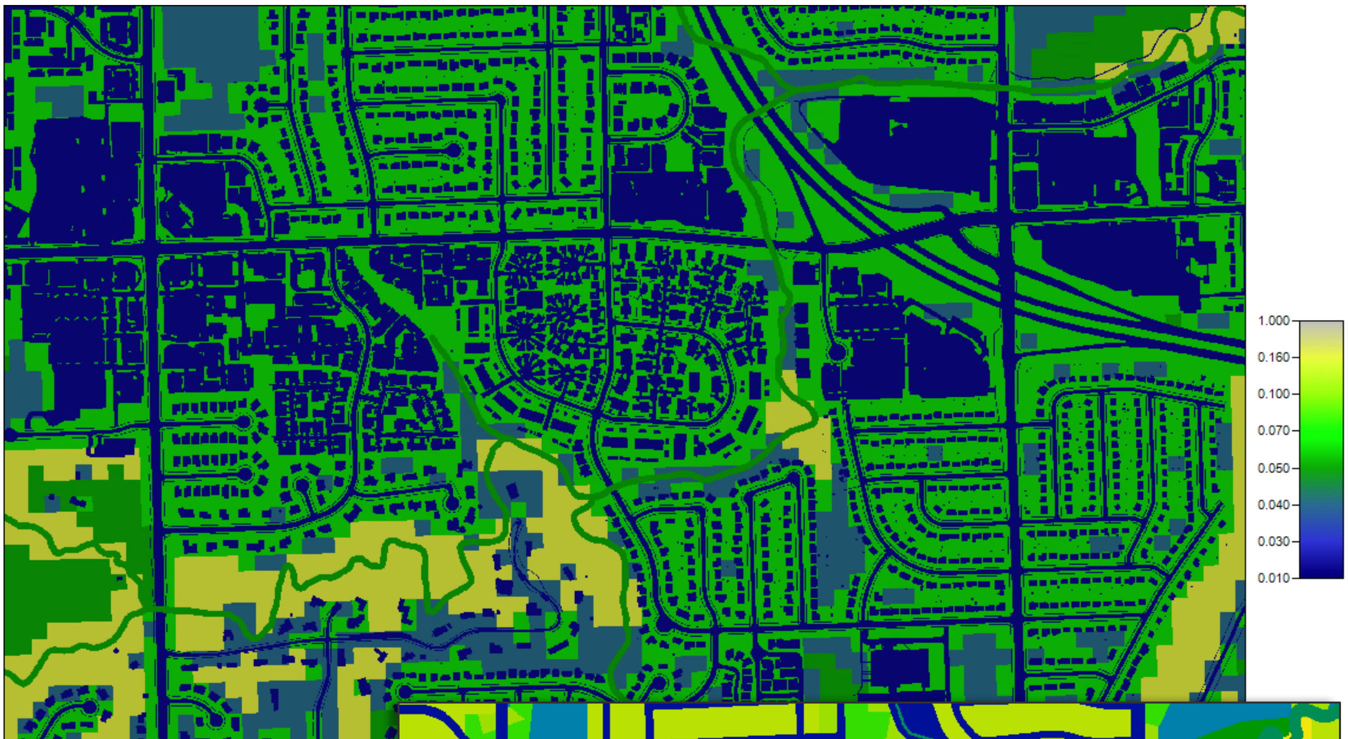
3.1 Modeling Software Version Update

As part of this update, the previous 2D modeling was updated from HEC-RAS version 5.0.7 to version 6.2. The newer version of the software provides the opportunity to incorporate bridge hydraulic routines, localized infiltration computations, and horizontally varying Manning's n values, which were unavailable in prior versions.

3.2 Landuse Refinement

The modeling software utilizes landuse data to apply spatially varying Manning's roughness values across the 2D study. The previous landuse layer utilized NLCD data supplemented with available parcel data from the City. As part of this update, the latest data from the National Land Cover Database (NLCD) 2019 products was obtained, and detailed data from the City was incorporated into the landuse layer, providing a level of detail beyond the previous parcel data. This included spatially accurate information representing building footprints, streets, and impervious areas. The following figures illustrate the modifications to the landuse layer.

FIGURE 3-1 – UPDATED LANDUSE INFORMATION SHOWING SPATIAL DETAIL AND RANGE OF MANNING'S VALUES



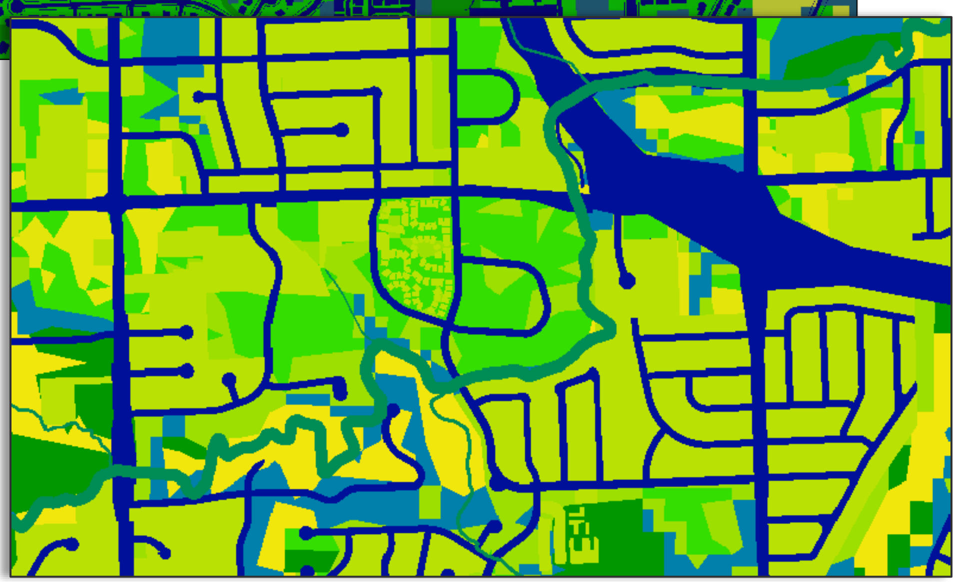


FIGURE 3-2 – PREVIOUS LANDUSE INFORMATION

The following table summarizes Manning's roughness values associated with each landuse type, and applied to the model. For buildings, the higher roughness value was used to represent buildings in the main floodplain where they obstruct flow, while the lower roughness value was used to represent runoff in the upper watershed and floodplain fringes. The cutoff buildings using the higher roughness value was determined by intersecting effective FEMA floodplains with initial modeling results of one foot of depth or more. Note that HEC-RAS version 6.2 has the ability to derive a composite roughness value from horizontally varying landuse across the cell faces, which has been utilized in the modeling. Note that this feature has been flagged as 'beta' in the software release notes, but an evaluation seems to confirm that this feature is functioning appropriately for this model.

TABLE 1 – MANNING'S VEGETATIVE ROUGHNESS FOR UPDATED LANDUSE

Landuse Description	Manning's Roughness
Barren Land / Bare Soil	0.03
Buildings	0.015 - 1
Channel	0.03 – 0.05
Cultivated Crops	0.05
Deciduous Forest	0.16
Developed, Low Intensity (excluding streets and buildings)	0.06
Developed, Medium Intensity (excluding streets and buildings)	0.06
Developed, High Intensity (excluding streets and buildings)	0.06
Developed, Open Space	0.04
Emergent Herbaceous Wetlands	0.07
Evergreen Forest	0.16
Grassland-Herbaceous	0.05
Impervious	0.015
Mixed Forest	0.16
Open Water	0.03
Pasture-Hay	0.05
Shrub-Scrub	0.1
Woody Wetlands	0.12

3.3 Spatially Varying Infiltration

As part of the previous 2D study, because the earlier version of HEC-RAS did not account for infiltration and evapotranspiration losses, these losses were computed independently, and the excess rainfall was applied to the model, utilizing a watershed-wide average curve number value.

As part of this study, the SCS Curve Number loss computations available in the newer software version were utilized. This allows for spatially varying infiltration losses to be computed across the 2D model area, providing finer detail that was previously lost to the basin-wide averaging.

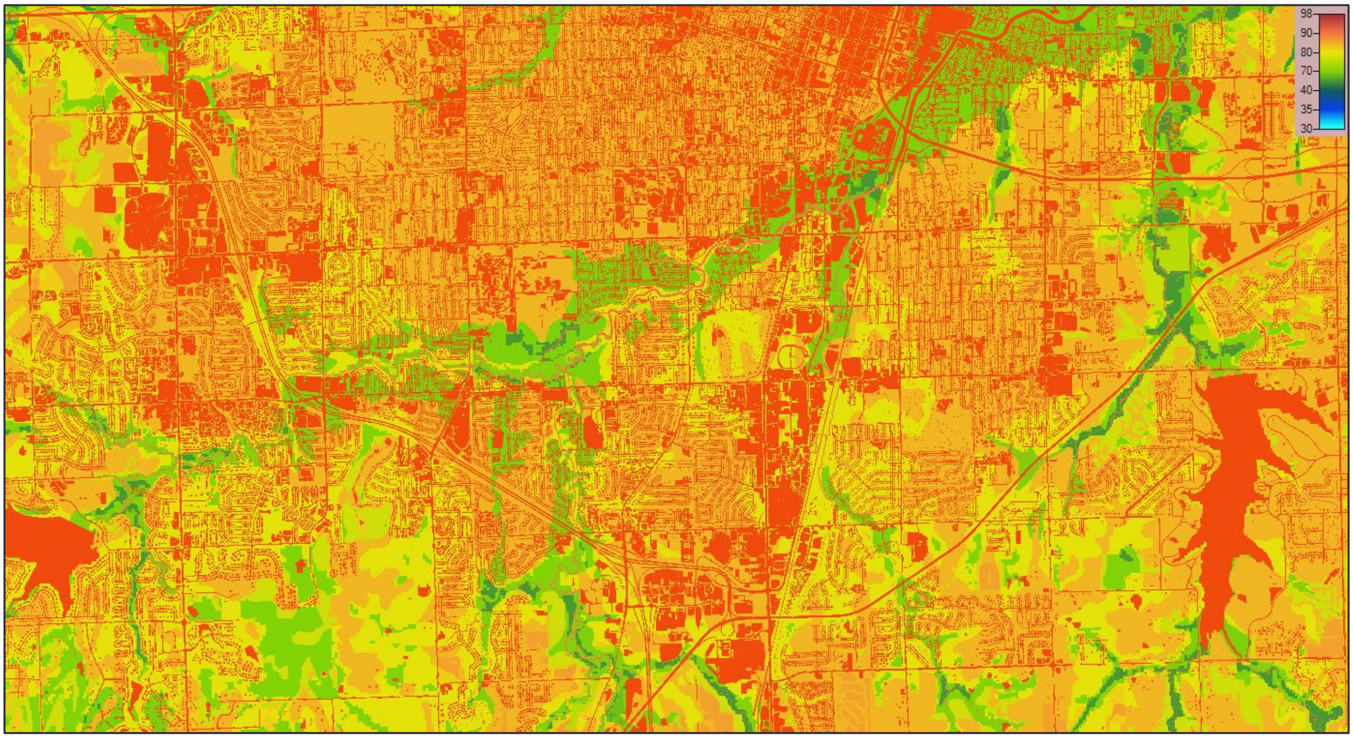
To determine the curve number values utilized by the model, refined landuse data described in the previous sections was utilized. Soils data was obtained the United Stated Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Web Soil Survey, which includes an aggregate hydrologic soil group for individual soil series. Assuming an antecedent runoff condition (ARC) of II, a curve number value was defined for each category of the landuse and soil layers. The following table summarizes these curve number values, which were applied to the model's infiltration layer.

TABLE 2 – CURVE NUMBER VALUES FOR SPATIALLY VARYING INFILTRATION

	Curve Number by Hydrologic Soil Group			
Landuse Description	**A**	**B**	**C**	**D**
Developed Open Space	49	69	79	84
Barren/Bare	77	86	91	94
Deciduous/Evergreen/Mixed Forest	30	55	70	77
Shrub/Scrub	43	65	76	82
Herbaceous	43	65	76	82
Hay/Pasture	49	69	79	84
Cultivated Crops	65	75	82	86
Woody Wetlands	36	60	73	79
Emergent Herbaceous Wetlands	36	60	73	79
Impervious Surfaces	98	98	98	98
Open Water	98	98	98	98

The following figure shows the spatially varying curve number values, utilized by the model to compute infiltration across the watershed on a cell-by-cell basis. The previous modeling utilized a curve number value of 83 across the entire watershed.

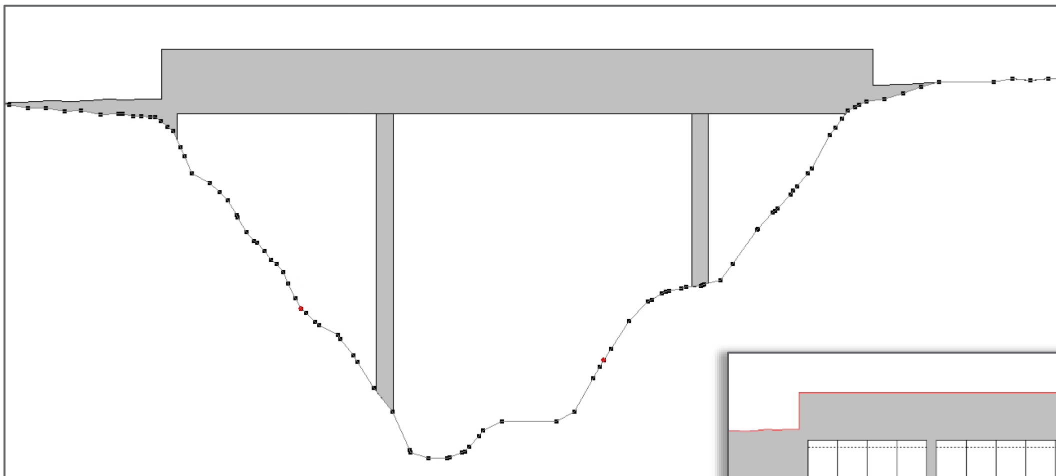
FIGURE 3-3 – ILLUSTRATION OF THE UPDATED CURVE NUMBER VALUES SHOWING SPATIAL VARIATION UTILIZED FOR COMPUTING INFILTRATION



3.4 Bridge Incorporation

As part of the previous 2D study, multiple structures were incorporated as culverts due to their hydraulic significance. Bridge structures were previously represented as culverts, due to the limitations of earlier versions of the HEC-RAS software. As part of this study, these structures were updated to utilize the bridge modeling capabilities that are available in the newer software version. The following figures illustrate the difference between the two representations, as viewed with the HEC-RAS interface.

FIGURE 3-4 – EXAMPLE OF UPDATED BRIDGE STRUCTURE WITHIN THE NEWER HEC-RAS SOFTWARE



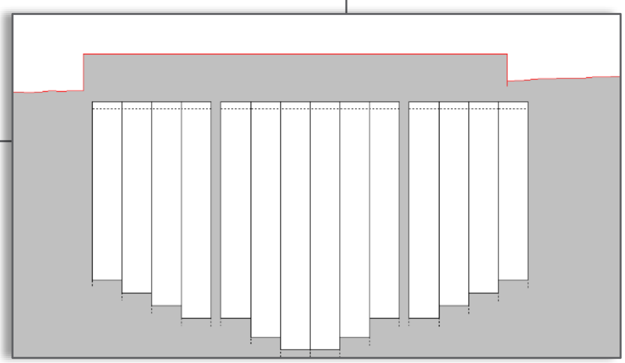


FIGURE 3-5 – EXAMPLE BRIDGE STRUCTURE PREVIOUSLY APPROXIMATED AS CULVERT

As part of this study, additional structures on Shunganunga Creek, taken from the USACE's feasibility study, were evaluated for hydraulic significance. Those causing a hydraulic drop of approximately one-quarter of a foot or more were incorporated into the updated modeling. This evaluation was based on the hydraulic results of the feasibility study's existing conditions 1%-annual-chance storm event. This scenario has water surface elevations generally lower than the effective FEMA study which resulted in varying levels of hydraulic significance for a given structure, relative to the two studies. The following hydraulic structures on the Shunganunga Creek were incorporated into the updated 2D model:

- Croco Road Bridge
- Utility Crossing Weir
- 6th Avenue Bridge
- Interstate 70 Bridge
- 15th Street Bridge
- BNSF Railroad Bridge
- Topeka Boulevard Bridge
- 21st Street Bridge
- Fillmore Street Bridge
- Buchanan Street Bridge
- Washburn Avenue Bridge
- Walking Trail Bridge
- Gage Boulevard Bridge
- Fairlawn Road Bridge
- 29th Street Bridge

These listed structures are in addition to those incorporated into the 2D model as part of the previous TAP and BLE projects, including multiple culverts across the watershed.

3.5 Levee Structure Incorporation

As part of this study, detail was added for the levee structures that outfall into Shunganunga Creek. The previous 2D modeling represented these structures as 'cuts' through the levee within the terrain data, which allowed flow to pass freely through the levee, restricted somewhat by the size of the cut. These structures were updated by entering the culvert data for the levee structures and representing the structures' flap gates within the modeling to prevent backflow into the interior side of the levee. For levee structures that outfall into the Kansas River, the previous modeling was maintained, utilizing stage hydrograph boundary conditions to mimic the Topeka levee certification study. The following figures show an example of the updated levee structures.

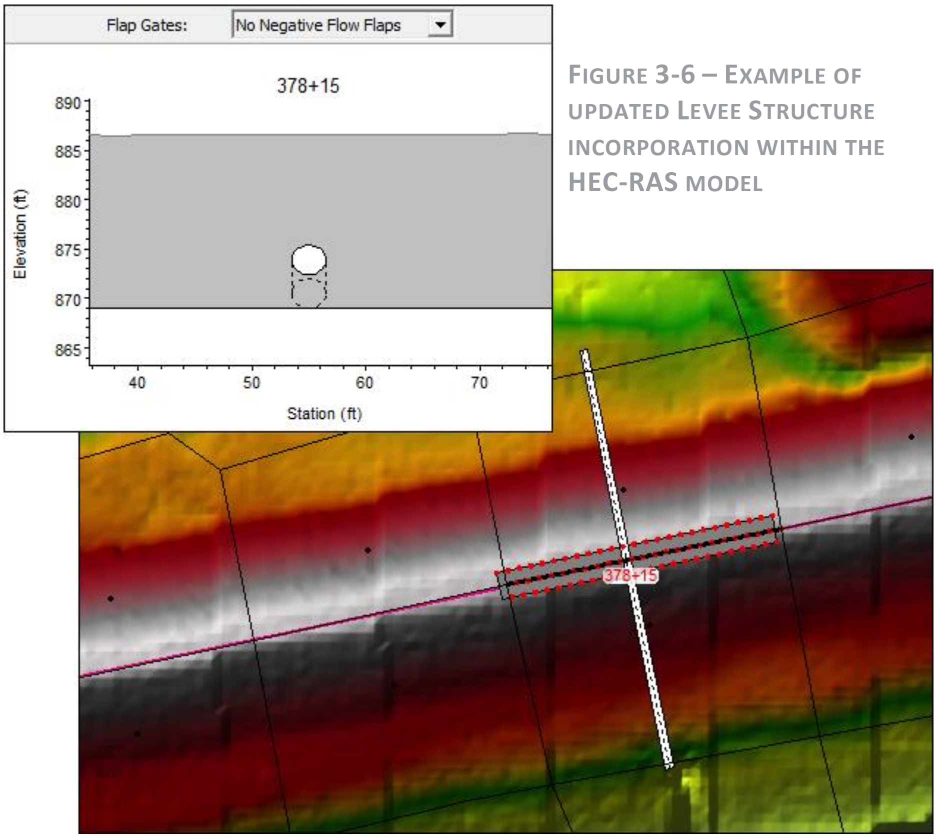


FIGURE 3-6 – EXAMPLE OF UPDATED LEVEE STRUCTURE INCORPORATION WITHIN THE HEC-RAS MODEL

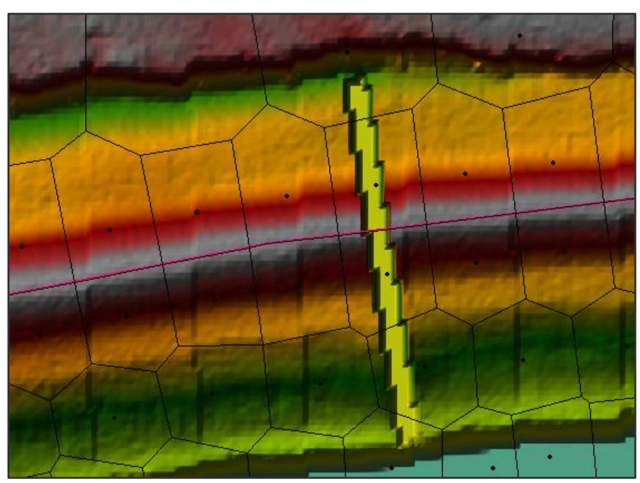
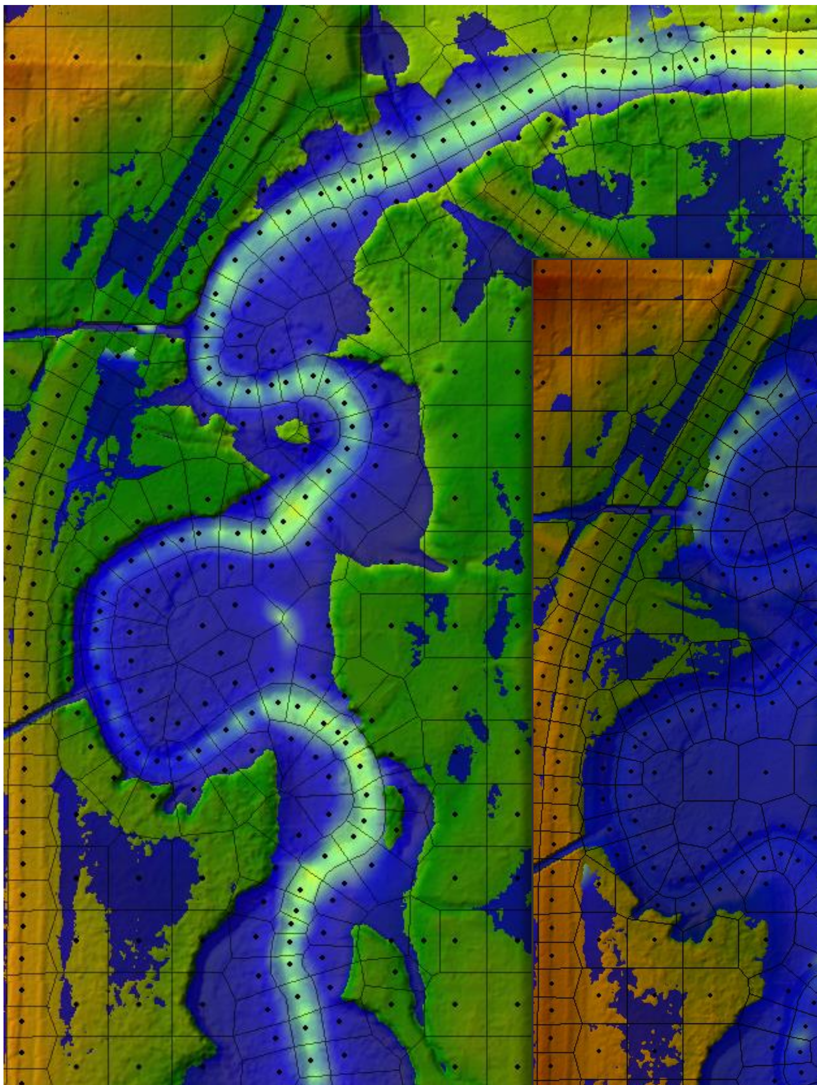


FIGURE 3-7 – REPRESENTATION OF LEVEE STRUCTURE IN PREVIOUS MODELING USING TERRAIN ENFORCEMENT

3.6 Mesh Refinement

While the previous 2D model mesh was generally in good shape, several modifications were made to refine the mesh. Streamlines were previously enforced as breaklines using the stream centerlines, up to one-quarter of a square mile drainage areas. To better represent the channel and channel velocities, these breaklines were converted to refinement regions to center cell faces along the channel. The mesh was also modified along the bridges and culverts to ensure these structures were properly modeled, and to ensure the model computation remained stable. The following figures illustrate enhancements made to the model mesh.

Figure 3-8 – Example of Updated cell refinement and resulting channel velocities



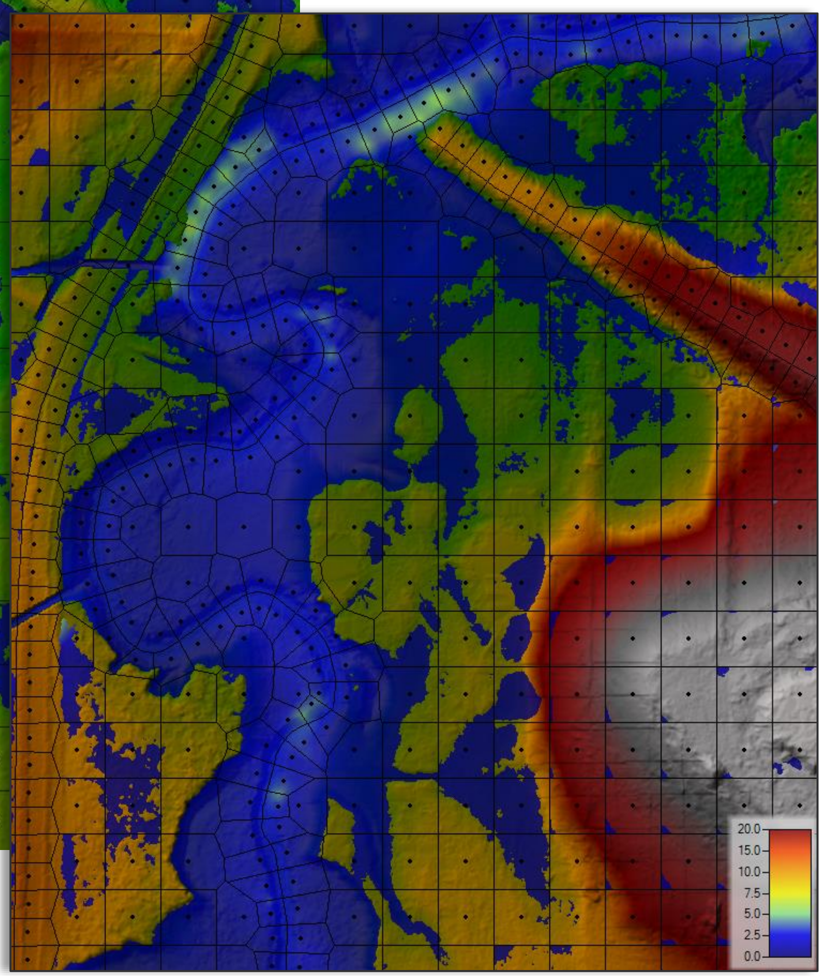


Figure 3-9 – previous cell alignment and channel velocities

3.7 Channel Terrain Refinement

In addition to refinement of the mesh cells and Manning's vegetative roughness along the channel, modifications were made to the terrain data along Shunganunga Creek, where water in the stream results in 'noise' in the lidar-derived elevation data. To resolve this, channel inverts were taken from the USACE's 1D modeling and enforced into the terrain using Ras Mapper's terrain modification capabilities. The following figure illustrates the modifications made to the channel terrain

FIGURE 3-10 – EXAMPLE LOCATION SHOWING TERRAIN ADJUSTMENTS WITHIN THE CHANNEL

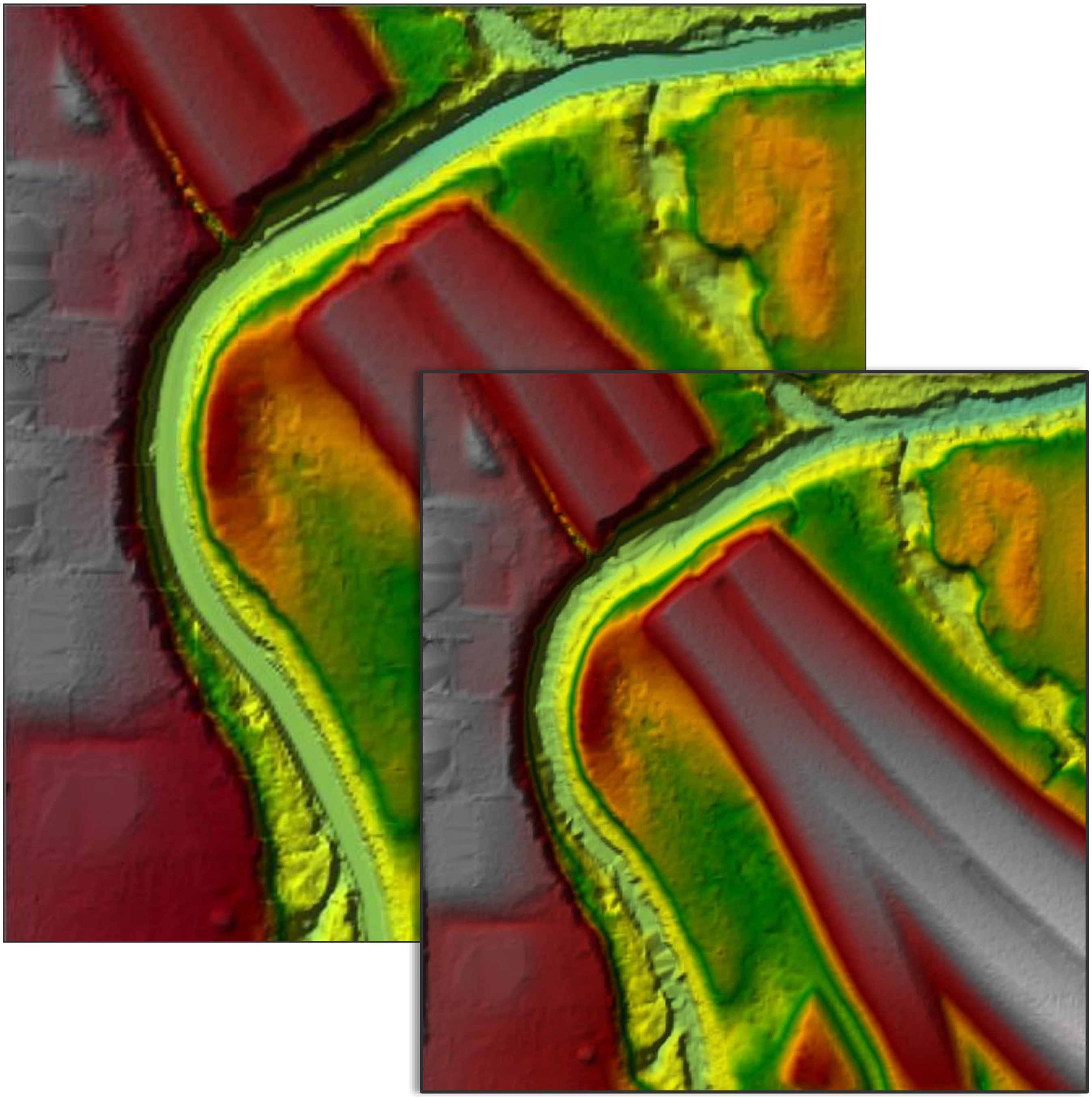


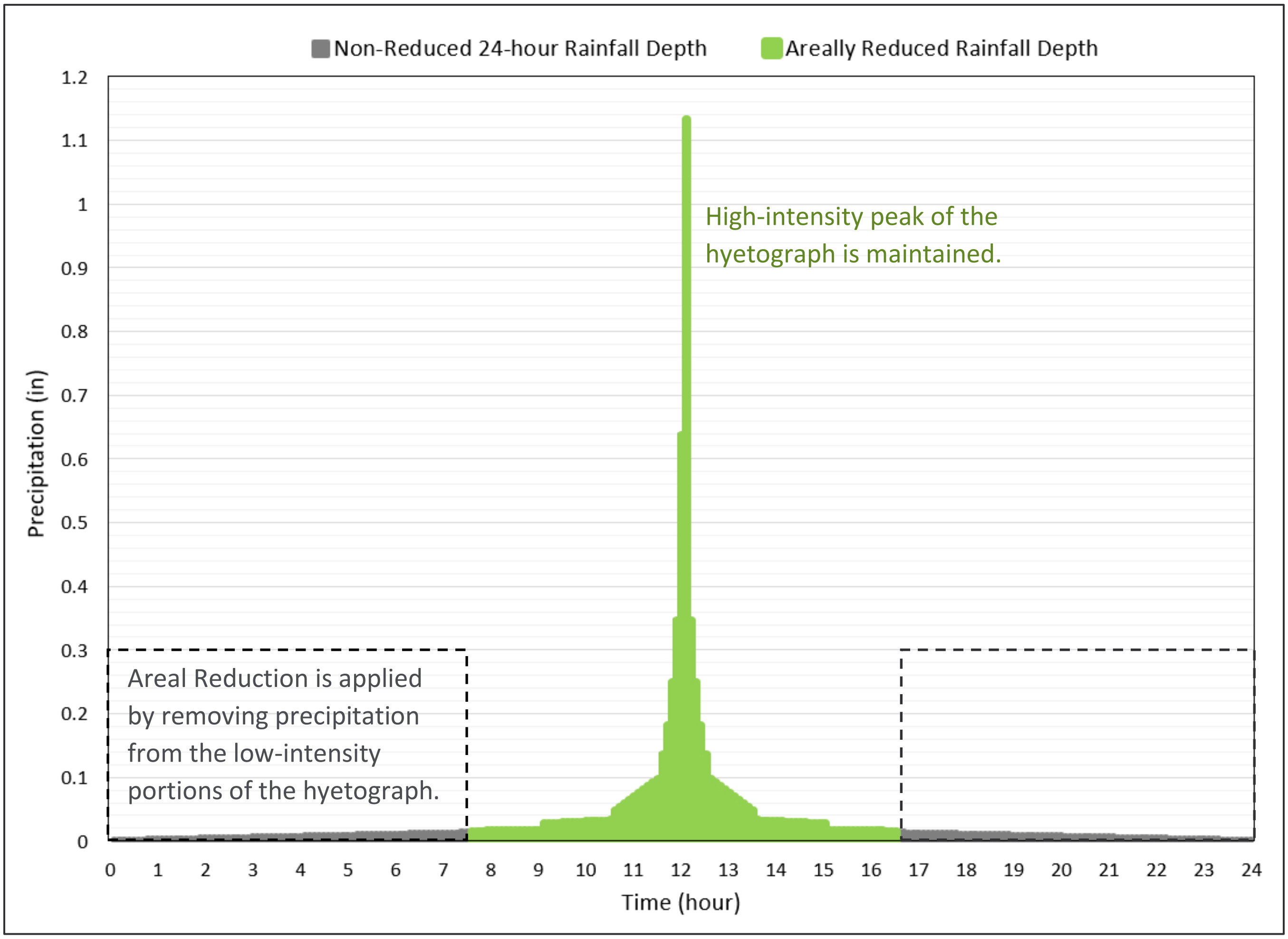
FIGURE 3-11 – EXAMPLE OF RAW LIDAR WITHOUT CHANNEL ADJUSTMENTS

3.8 Rainfall Areal Reduction

Initial model results were evaluated and compared to available data for this watershed, including comparisons to the USACE feasibility study, USGS gage measurements, and neighboring watershed studies. Based on this evaluation, it was determined that rainfall areal reduction was warranted in the Shunganunga Creek watershed.

Areal reduction is often utilized for larger watersheds. For the Shunganunga Creek Watershed, the most appropriate areal reduction ratio was determined to be 82% based on the watershed size. This percentage was applied as a ratio of the total rainfall depth utilizing a modified excess rainfall hyetograph, as shown in the following figure.

FIGURE 3-12 – RAINFALL HYETOGRAPH AND APPLICATION OF AREAL REDUCTION



By removing the leading and trailing ends of the hyetograph, the overall runoff volume contributing to larger drainage areas, which are typically volume-sensitive, is reduced without decreasing the peak intensity for streams with smaller drainage areas, which are typically peak-sensitive. Due to the nature of the nested rainfall distribution that is utilized for the design storm events, the modified hyetograph is essentially a representation of an event with a duration shorter than the initial 24-hour design storm, while still representing the same frequency event (e.g. 100-year storm event). The following table compares flows along Shunganunga Creek and shows the impacts of the areal reduction, resulting in flows that more generally align with the previous study.

The one exception would be downstream of Deer Creek, where the impact of Lake Shawnee on hydrograph timing somewhat amplifies the reduction.

TABLE 3 – COMPARISON OF PEAK 1%-ANNUAL-CHANCE FLOWS*

Location	USACE Feasibility Study	2D Modeling without Rainfall Areal Reduction	2D Modeling 0.82 Areal Reduction Ratio
Upstream of Butcher Creek	9,000	10,600	9,100
Downstream of Butcher Creek	11,400	15,300	13,100
DS of I-70	11,500	16,100	12,700
Upstream of 6th	12,100	15,900	13,000
Golden Ave (Upstream of Deer Ck)	12,500	16,300	13,400
Upstream of Rice Rd (Downstream of Deer Ck)	20,900	20,900	17,800

*in cubic feet per second (cfs), rounded to nearest 100cfs

4 RESULTS COMPARISONS

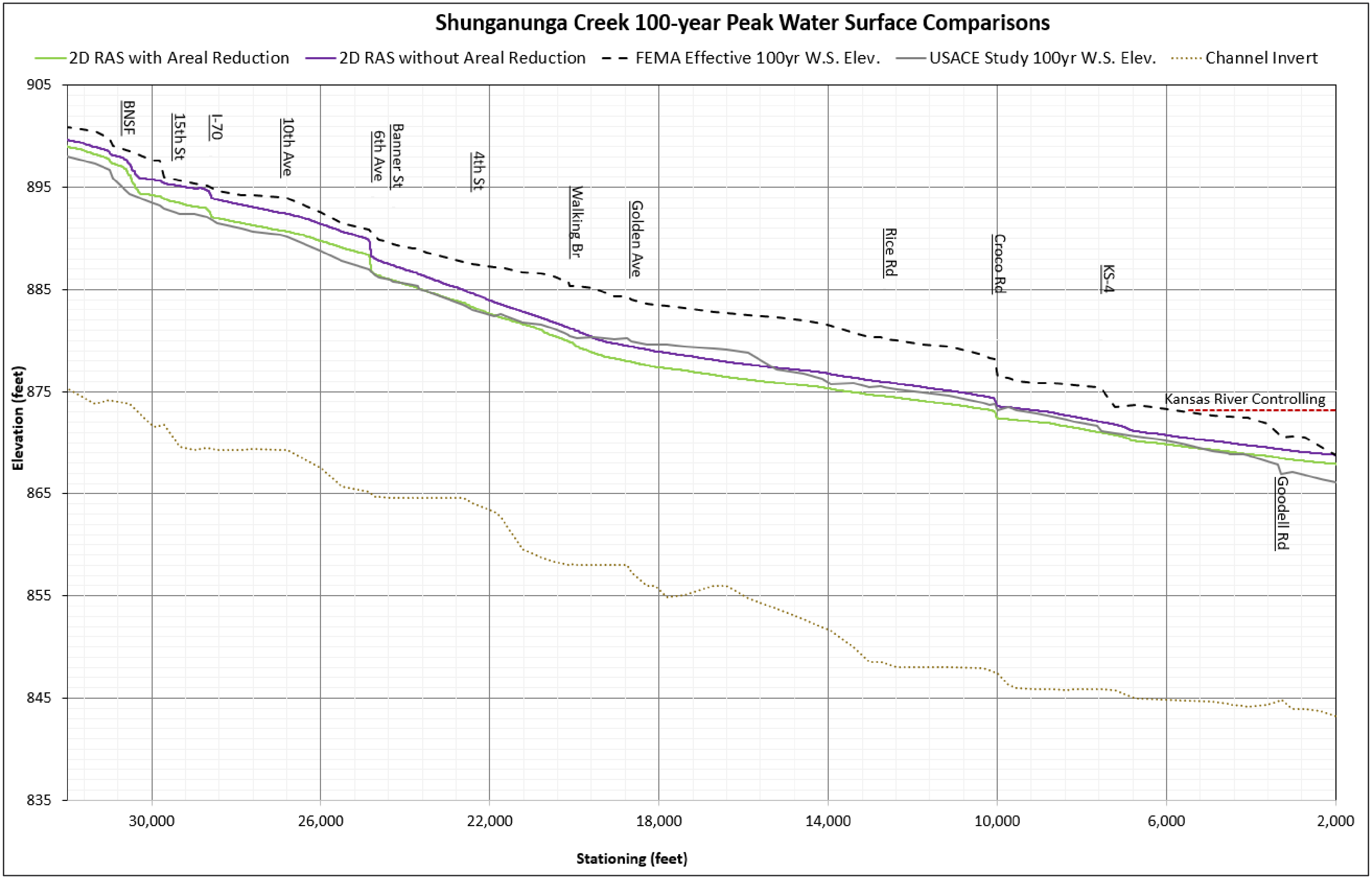
Results of the updated model were evaluated against previous studies, based on the 1%-annual-chance storm event. In general, the updated 2D model resulted in peak water surface elevations that are generally slightly lower than the previous 2D modeling, with some localized variation, due to the modeling updates and the areal reduction of rainfall.

TABLE 4 – COMPARISON OF PEAK 1%-ANNUAL-CHANCE WATER SURFACE ELEVATIONS

Location	Effective 2008 1D Study (NAVD88)	USACE 2011 / 2022 1D Study (NAVD88)	Previous 2019 2D Study (NAVD88)	Updated 2D Study without Rainfall Areal Reduction (NAVD88)	Updated 2D Study with Rainfall Areal Reduction (NAVD88)
Butcher Creek Just DS of SE 37th St	951.8	949.2	952.2	951.3	951.1
Colly Creek Just US of SW 45th St	962.5	962.4	962.2	961.8	961.6
Deer Creek Approximately 1,725 ft US of SE 6th Avenue	889.6	887.3	890.8	887.9	887.2
Indian Hills Tributary Just DS of SW Arvonia Place	967.3	964.5	967.3	967.3	966.9
SW Branch Elevation Creek Approx. 2,025 ft US of SW 41st St	1027.5	1026.8	1027.6	1028.3	1027.9
Shunganunga Creek Just US of SW Arrowhead Road	950.1	948.0 / 950.3	950.2	949.6	949.1

Based on more recent studies, it was expected that the updated modeling would result in peak water surface elevations somewhat lower than the effective FEMA study along Shunganunga Creek. In this area, results of the updated study align more appropriately with USACE's feasibility study, which was calibrated to historical flood events. To better align with the calibrated model, adjustments to channel manning's along the creek were made. The following graph shows a profile view along Shunganunga Creek for comparison.

FIGURE 4-1 – PROFILE VIEW COMPARING PEAK WATER SURFACE ELEVATIONS ALONG SHUNGANUNGA CREEK



5 CONCLUSION

The updated 2D model includes enhancements that improve the overall detail and accuracy of the model for predicting flood conditions. This in-turn will allow the City to more accurately evaluate impacts of potential alternatives throughout the watershed, as part of master planning efforts, since the enhanced model will be used as the base conditions for evaluating further mitigation opportunities. More specifically, the Master Plan will include Capital Improvement Plan projects focused on flood reduction measures across the watershed, which will be evaluated in part using this model.

6 REFERENCES

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