# Healthy Soils Initiative

## Technical Assistance Project

June 2023

WSP USA Environment & Infrastructure INC.
100 SE 9th Street
Suite 400
Topeka, KS 66612

# Table of Contents

# Introduction

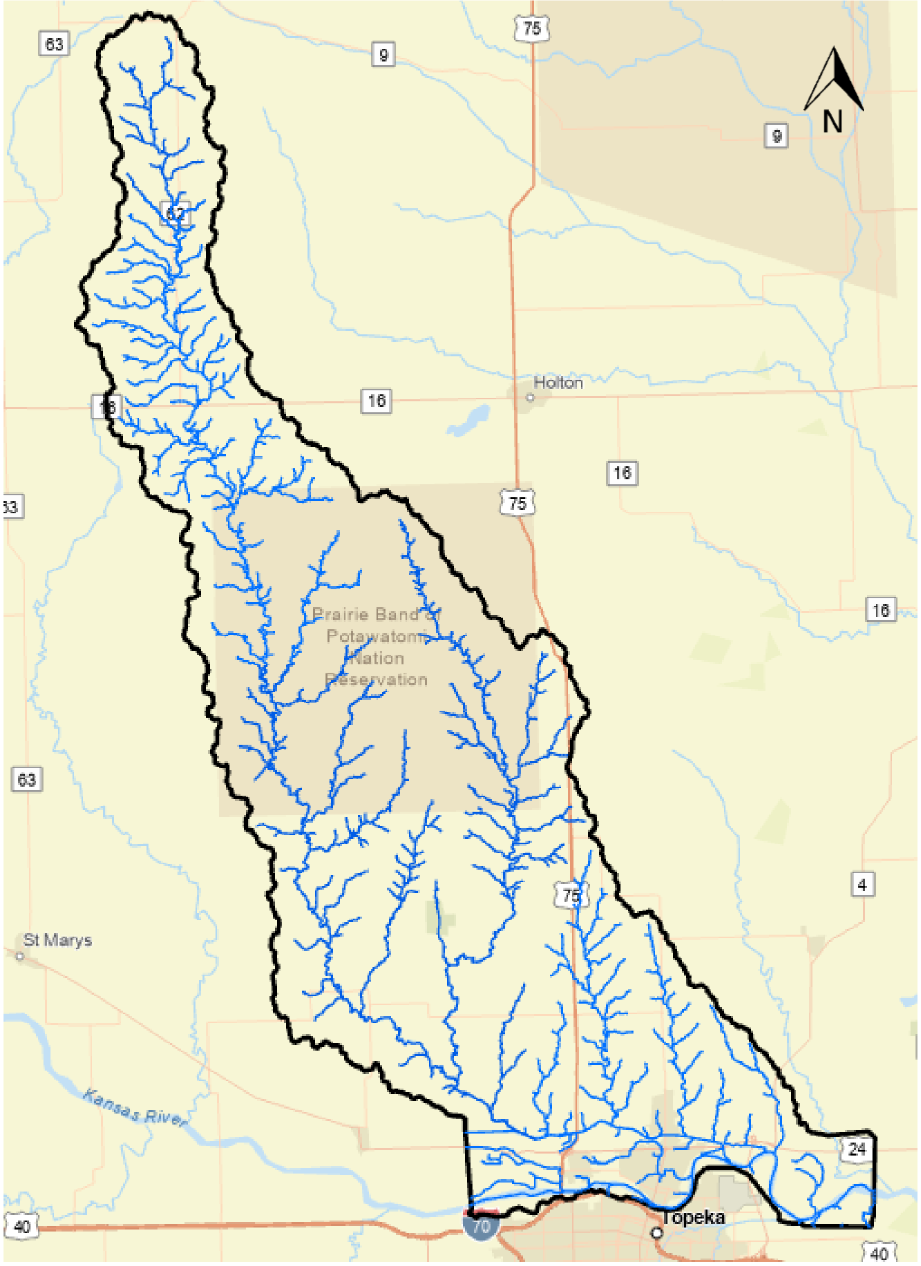
The Kansas Department of Agriculture (KDA) is working to assist the U.S. Army Corps of Engineers (USACE) Silver Jackets Program Kansas Hazard Mitigation Team in evaluating the benefits that soil heath and conservation practices provide to the flood risk at a watershed scale. The Soldier Creek watershed, shown in Figure 1, was chosen for analysis.

The USACE Kansas City District completed a study evaluating the effects of increased rainfall infiltration on Hydrology in the Soldier Creek Watershed. Hydrological Engineering Center's Hydrologic Modeling System (HEC-HMS) was used to determine theoretical flow reductions based on differing infiltration parameters. WSP USA Environment & Infrastructure Inc. was retained by KDA to evaluate the effects these differing infiltration parameters have on water surface elevations using two-dimensional (2D) Hydrological Engineering Center's River Analysis System (HEC-RAS) rain-on-mesh (ROM) modeling previously developed for floodplain mapping projects.

This report presents the results of five scenarios analyzed across the watershed. Each of these scenarios was evaluated using the 50%, 10%, 4%, 2%, and 1% annual chance storm frequencies with both 24-hour and 3-hour storm durations. The five scenarios are:

1. Existing Conditions Infiltration Rates with NOAA Atlas 14 Rainfall Depths
2. 50% Adoption Rate of Healthy Soils Practices Infiltration Rates with NOAA Atlas 14 Rainfall Depths
3. 100% Adoption Rate of Healthy Soils Practices Infiltration Rates with NOAA Atlas 14 Rainfall Depths
4. Existing Conditions Infiltration Rates with RCP4.5 2055 Rainfall Depths
5. 50% Adoption Rate of Healthy Soils Practices Infiltration Rates with RCP4.5 2055 Rainfall Depths

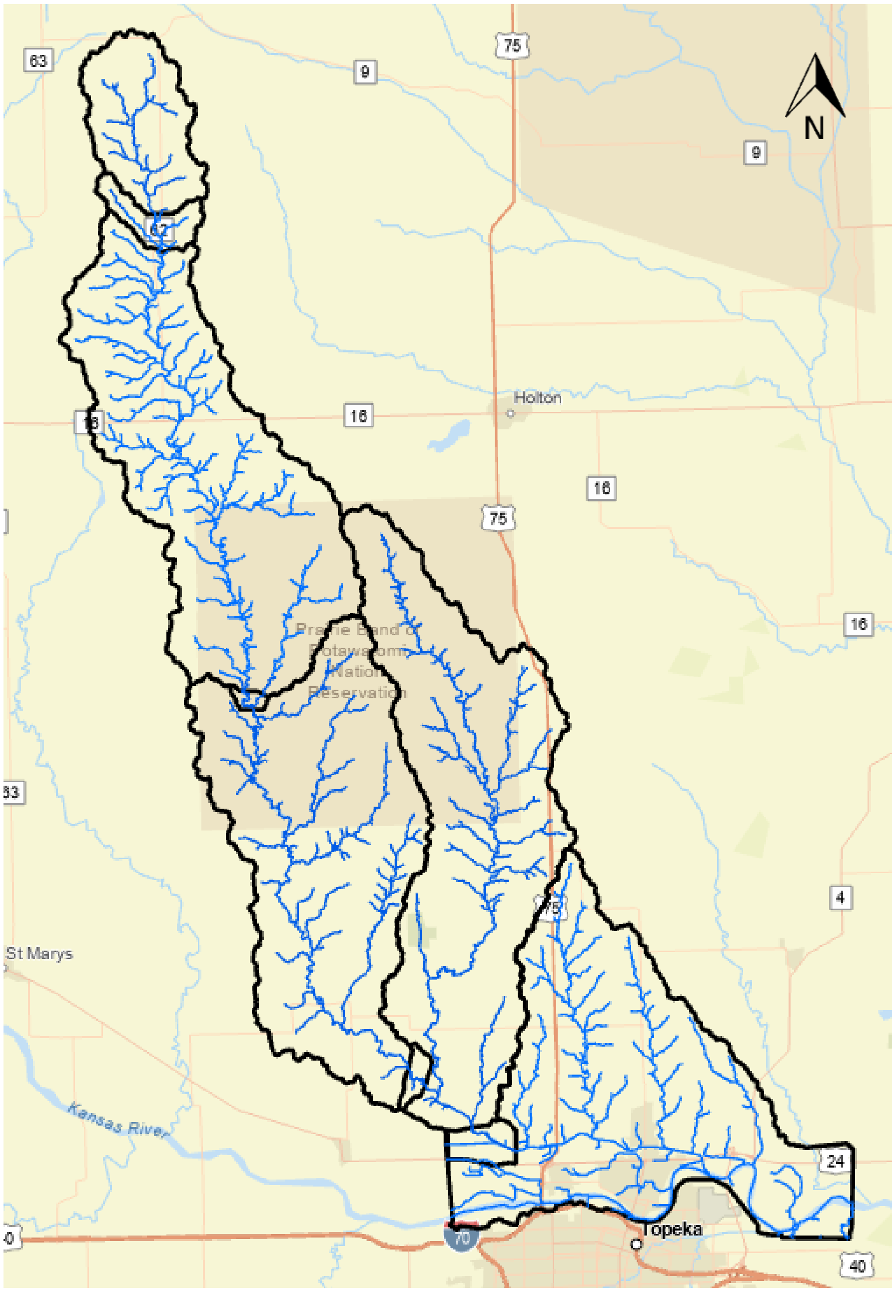
**Figure 1. Soldier Creek watershed boundary**



## Model Development

A total of five unsteady state 2D HEC-RAS version 6.3.1 ROM models were used to analyze the Soldier Creek watershed. These models were adapted from the Upper Kansas Custom Watershed Base-Level Engineering (BLE) and Jackson County Custom Watershed - Enhanced Detailed Study Projects contracted by KDA. The model boundaries are shown in Figure 2.

**Figure 2. Soldier Creek watershed broken up into the 5 modeled basins**



## Rainfall and Hyetographs

Current conditions rainfall depths for the two durations of the different annual chance storm events were taken from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 site. The depths were then converted into hyetographs using a percent total duration-depth curve based on regional observations of storm tendencies.

While the current conditions scenarios were created using measured data, the future conditions rainfall depth values were estimated via Representative Concentration Pathway (RCP) 4.5 2055. RCP 4.5 is an intermediate prediction of greenhouse gas concentrations and resulting climate change effects. This scenario has emissions peaking in 2040 and then declining, but global temperatures will likely rise by 2-3°C by 2100. When developed, each RCP scenario was analyzed for three time periods. The 2055 time period, which covers years 2045-2069, was used for the purposes of this study. Once calculated, the estimated 2055 rainfall depths were then converted into hyetographs using the same percent total duration-depth curve as the current conditions rainfall depths. The average rainfall depths for all annual chance storm events, conditions and durations are included in Table 1.

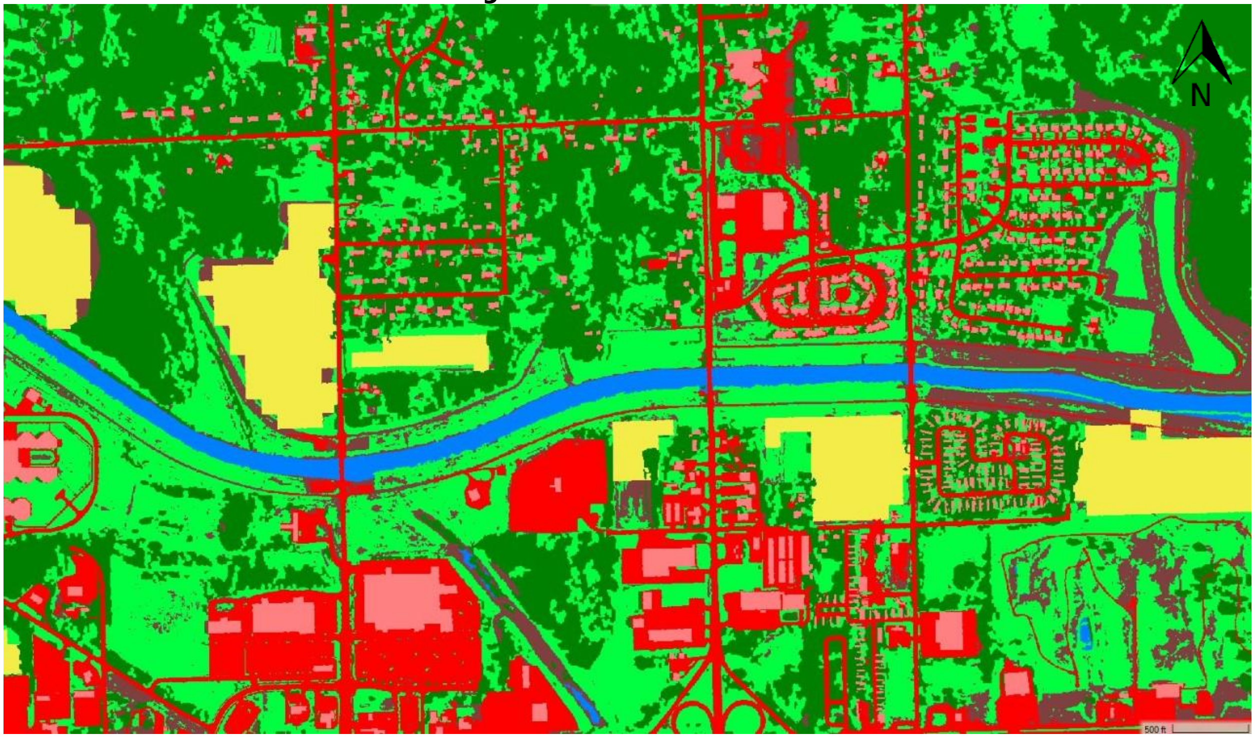
**Table 1. Soldier Creek watershed average rainfall depths**

| Rainfall Depths | 24-hour Current Conditions Rainfall Depth (in) | 24-hour Future Conditions Rainfall Depth (in) | 3-hour Current Conditions Rainfall Depth (in) | 3-hour Future Conditions Rainfall Depth (in) |
|---|---|---|---|---|
| **50%** | 3.16 | 3.40 | 2.05 | 2.20 |
| **10%** | 4.62 | 5.01 | 3.08 | 3.34 |
| **4%** | 5.59 | 6.10 | 3.72 | 4.06 |
| **2%** | 6.36 | 7.01 | 4.21 | 4.64 |
| **1%** | 7.16 | 7.96 | 4.69 | 5.22 |

## Detailed Land Use

Detailed land use was developed by classifying land cover information using 1-meter National Agriculture Imagery Program (NAIP) imagery with machine learning to rapidly identify different land cover types. Training samples were collected directly from the imagery and used to statistically derive land cover from each pixel within the imagery's 5 target classes: Trees, Herbaceous Areas (Grasses/Low Level Vegetation), Impervious Surfaces, Water, and Bare Ground. Once the imagery was classified post processing was performed to clean the results by running majority filters to aggregate clumps of similar pixels and remove pixilated "noise" effects in the raw data. Existing features, such as building footprints from lidar and agriculture lands from the USDA, were then incorporated to produce additional classes for more detailed land use.

**Figure 3. Detailed land use**



## Green and Ampt Infiltration

Soils data was acquired from the Gridded Soil Survey Geographic (gSSURGO) Database to determine the soil textures across the watershed. Green and Ampt infiltration uses the soil texture to determine parameters such as porosity, saturated hydraulic conductivity, wetting front suction, etc. Green and Ampt infiltration values for the models were chosen from the values and ranges originally developed by Rawls et al. in 1982. Table 2 lists all the parameters and values needed for model inputs. A field for bedrock, impervious, and open water values was added to account for the areas that experience no infiltration.

**Table 2. Green and Ampt infiltration values**

| Soil Texture | Wetting Front Suction (in) | Saturated Hydraulic Conductivity (in/hr) | Initial Soil Water Content | Saturated Soil Water Content | Residual Soil Water Content | Pore Size Distribution Index |
|---|---|---|---|---|---|---|
| **Sand** | 1.95 | 4.64 | 0.1311 | 0.437 | 0.02 | 0.694 |
| **Loamy Sand** | 2.41 | 1.18 | 0.1311 | 0.437 | 0.035 | 0.553 |
| **Sandy Loam** | 4.33 | 0.43 | 0.1359 | 0.453 | 0.041 | 0.378 |
| **Loam** | 3.5 | 0.13 | 0.1389 | 0.463 | 0.027 | 0.252 |
| **Silt Loam** | 6.57 | 0.26 | 0.1503 | 0.501 | 0.015 | 0.234 |
| **Sandy Clay Loam** | 8.6 | 0.06 | 0.1194 | 0.398 | 0.068 | 0.319 |
| **Clay Loam** | 8.22 | 0.04 | 0.1392 | 0.464 | 0.075 | 0.242 |
| **Silty Clay Loam** | 10.75 | 0.04 | 0.1413 | 0.471 | 0.04 | 0.177 |
| **Sandy Clay** | 9.41 | 0.02 | 0.129 | 0.43 | 0.109 | 0.223 |
| **Silty Clay** | 11.5 | 0.02 | 0.1437 | 0.479 | 0.056 | 0.15 |
| **Clay** | 12.45 | 0.01 | 0.1425 | 0.475 | 0.09 | 0.165 |
| **Bedrock/ Impervious/ Open Water** | 0 | 0 | 0 | 0 | 0 | 0 |

In addition to the watershed-wide baseline infiltration grid, two additional infiltration grids were created. One for the 50% adoption of agricultural practices that improve soil hydraulic conductivity and one for 100% adoption of these agricultural practices. Anywhere in which the agricultural practices were theoretically implemented resulted in a 50% increase of the saturated hydraulic conductivity values as shown in Table 3.

**Table 3. Green and Ampt infiltration values with increased Saturated Hydraulic Conductivity**

| Soil Texture | Wetting Front Suction (in) | Saturated Hydraulic Conductivity (in/hr) | Initial Soil Water Content | Saturated Soil Water Content | Residual Soil Water Content | Pore Size Distribution Index |
|---|---|---|---|---|---|---|
| **Sand** | 1.95 | 6.96 | 0.1311 | 0.437 | 0.02 | 0.694 |
| **Loamy Sand** | 2.41 | 1.77 | 0.1311 | 0.437 | 0.035 | 0.553 |
| **Sandy Loam** | 4.33 | 0.64 | 0.1359 | 0.453 | 0.041 | 0.378 |
| **Loam** | 3.5 | 0.2 | 0.1389 | 0.463 | 0.027 | 0.252 |
| **Silt Loam** | 6.57 | 0.38 | 0.1503 | 0.501 | 0.015 | 0.234 |
| **Sandy Clay Loam** | 8.6 | 0.09 | 0.1194 | 0.398 | 0.068 | 0.319 |
| **Clay Loam** | 8.22 | 0.06 | 0.1392 | 0.464 | 0.075 | 0.242 |
| **Silty Clay Loam** | 10.75 | 0.06 | 0.1413 | 0.471 | 0.04 | 0.177 |
| **Sandy Clay** | 9.41 | 0.03 | 0.129 | 0.43 | 0.109 | 0.223 |
| **Silty Clay** | 11.5 | 0.03 | 0.1437 | 0.479 | 0.056 | 0.15 |
| **Clay** | 12.45 | 0.02 | 0.1425 | 0.475 | 0.09 | 0.165 |
| **Bedrock/ Impervious / Open Water** | 0 | 0 | 0 | 0 | 0 | 0 |

Unlike the HEC-HMS model where infiltration is applied as an average value for each subbasin, HEC-RAS 2D ROM models apply infiltration at each mesh cell. Because of this, the agricultural land use had to be isolated to apply healthy soils infiltration parameters. For the 50% adoption scenario, half of the land was randomly selected to apply healthy soils infiltration parameters.

To isolate the agricultural areas, the crops and vegetation classes were isolated from the detailed land use layer and the Grassland/Herbaceous, Pasture/Hay, and Cultivated Crops classes were isolated from the NLCD landcover raster. These two isolated rasters were then intersected to eliminate any non-agricultural vegetation. The resulting raster was then converted to a polygon and GIS processes were used to smooth the edges and eliminate any areas smaller than roughly a half of an acre. Once the agricultural polygons were cleaned up, a field was added to the attribute table and python code was used to randomly assign the polygons a value of 0 or 1. The agricultural polygons that received a value of 1 were then used to create the 50% adoption infiltration layer, while all the agricultural polygons were used to create the 100% adoption infiltration layer.

All three infiltration layers were imported into the models. Since only one infiltration layer can be associated with a HEC-RAS geometry, two copies of the geometry were created with the different infiltration layers applied.

### Manning’s Roughness Coefficients

All models utilize the detailed land use to create Manning’s ‘n’ layers. Additional detail was added to the land use to represent channel Manning’s ‘n’ values for streams that do not show water in the NAIP imagery. Channel Manning’s ‘n’ values were applied to these areas ranging from 0.030 to 0.045 depending on stream size. The streamlines were buffered by a distance that was based on the drainage area for each stream segment, and this buffered area was enforced into the detailed land use. To account for the higher roughness in shallow flow areas, increased Manning’s ‘n’ values were applied to areas in the model that do not exceed 0.5 feet of depth during the 1% annual storm event.

These layers were imported into the models and had Manning’s ‘n’ values applied as shown in Table 1. Areas with depths greater than 0.5 feet in the 1% annual chance storm event had values in the Manning’s ‘n’ column applied. Areas with depths less than 0.5 feet in the 1% annual chance storm event had values in the Overland Manning’s ‘n’ column applied. The Manning’s grids had values that ranged from 0.015 to 1. The Manning’s values and their associated landcover types are shown in Table 4.

**Table 4. Overland Manning's Landcover types and values**

| Land Use Designation | Manning's 'n' | Overland Manning's 'n' |
|---|---|---|
| **Open Water** | 0.030 | 0.030 |
| **Perennial Ice/Snow** | 0.030 | 0.030 |
| **Developed, Open Space** | 0.040 | 0.240 |
| **Developed, Low Intensity** | 0.080 | 0.100 |
| **Developed, Medium Intensity** | 0.070 | 0.080 |
| **Developed, High Intensity** | 0.050 | 0.150 |
| **Barren Land (Rock/Sand/Clay)** | 0.030 | 0.030 |
| **Deciduous Forest** | 0.160 | 0.800 |
| **Evergreen Forest** | 0.160 | 0.800 |
| **Mixed Forest** | 0.160 | 0.800 |
| **Shrub/Scrub** | 0.100 | 0.800 |
| **Grassland/Herbaceous** | 0.070 | 0.240 |
| **Pasture/Hay** | 0.060 | 0.150 |
| **Cultivated Crops** | 0.060 | 0.170 |
| **Woody Wetlands** | 0.120 | 0.800 |
| **Emergent Herbaceous Wetlands** | 0.070 | 0.400 |
| **Small Channel** | 0.050 | 0.050 |
| **Medium Channel** | 0.045 | 0.045 |
| **Large Channel** | 0.040 | 0.040 |
| **X-Large Channel** | 0.035 | 0.035 |
| **XX-Large Channel** | 0.030 | 0.030 |
| **Building Footprints Without Raised Terrain** | 1.000 | 1.000 |
| **Roads/Impervious** | 0.015 | 0.015 |
| **Grass Lawn** | 0.040 | 0.240 |
| **Grass Prairie** | 0.060 | 0.150 |
| **Ground** | 0.030 | 0.030 |
| **Tree** | 0.160 | 0.800 |
| **Crops** | 0.060 | 0.170 |

### Model Scenarios

The project scope covered 5 different modeling scenarios, each ran with the 50%, 10%, 4%, 2%, and 1% annual chance storm frequencies with both 24-hour and 3-hour storm durations. This resulted in 50 model simulations.

## Results

There are four USGS gages located throughout the watershed, the locations of which can be found in Figure 4. Three of the four gages had sufficient data to perform a gage analysis on for calibration purposes. This is included in Table 5 along with the 1% baseline model flows at the same locations. Model data was collected at the four gages to compare the difference that an increase in saturated hydraulic conductivity can cause. Summary tables and figures of data can be found at each of the gage locations in the following sections.

**Figure 4. Locations of the USGS gages throughout the watershed.**

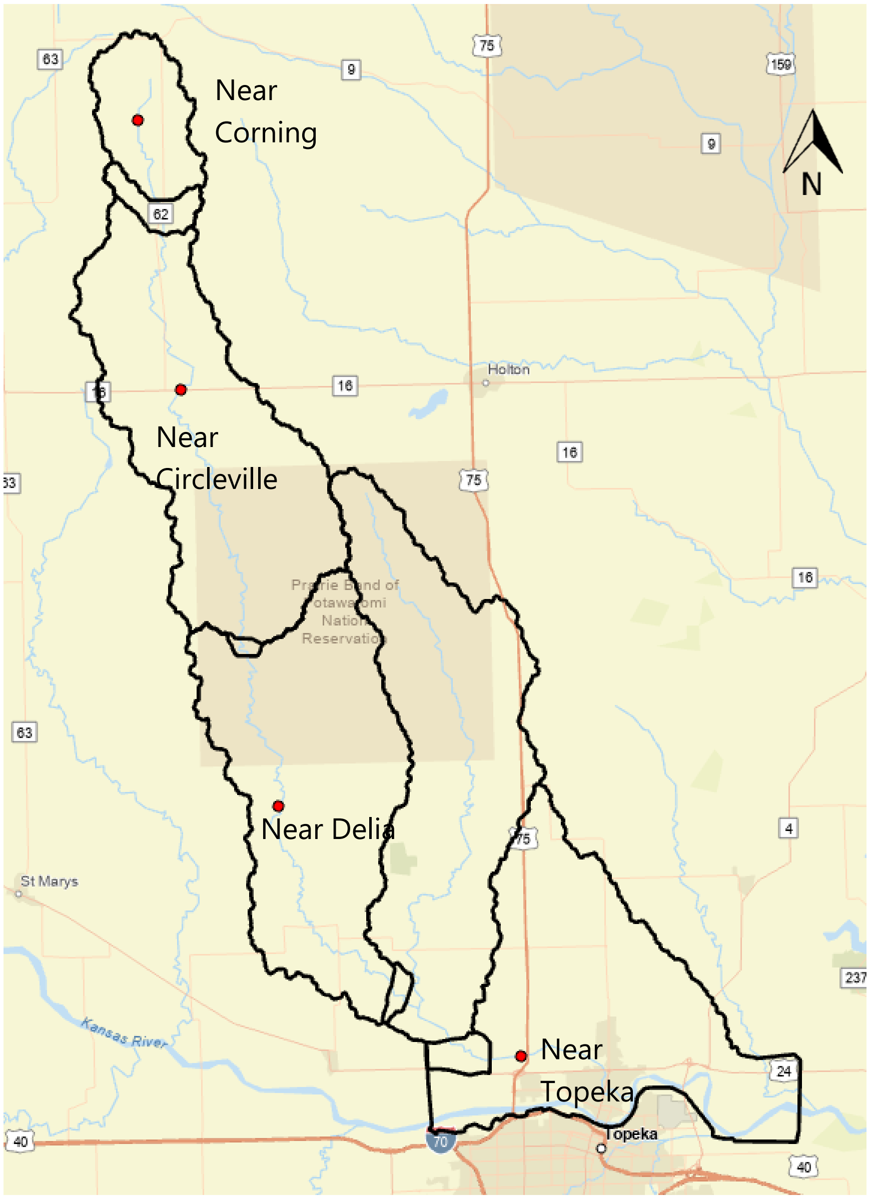


**Table 5. USGS gage information and 1% annual chance storm frequency flows**

| Location | USGS Gage Number | Drainage Area (sqmi) | 1% Calculated Gage Flow (cfs) | 1% Model Flow (cfs) |
|---|---|---|---|---|
| **Near Corning** | 06889110 | 9.27 | Insufficient Data | 5,240 |
| **Near Circleville** | 06889160 | 49.3 | 17,340 | 16,500 |
| **Near Delia** | 06889200 | 149 | 31,620 | 30,910 |
| **Near Topeka** | 06889500 | 290 | 38,420 | 34,260 |

## Data Results Near Corning- Gage 06889110

As can be seen in Table _, the increased saturated hydraulic conductivity does result in a decrease in flows across storm events. Table 7 shows the percent of peak flow reduction for each storm event to better illustrate the resulting changes. This also shows how the positive effects of the infiltration decrease as the storm events get larger and more infrequent.

**Table 6. Flow values (cfs) at gage 06889110 near Corning, KS**

| Near Corning- Gage 06889110 | Storm Event | Baseline | 50% Adoption | 100% Adoption | Baseline Future Conditions | 50% Adoption Future Conditions |
|---|---|---|---|---|---|---|
| **24 Hour Duration** | 50% | 1,330 | 1,190 | 1,020 | 1,550 | 1,400 |
| | 10% | 2,690 | 2,530 | 2,330 | 3,070 | 2,910 |
| | 4% | 3,630 | 3,460 | 3,280 | 4,140 | 3,980 |
| | 2% | 4,400 | 4,230 | 4,040 | 5,070 | 4,910 |
| | 1% | 5,240 | 5,070 | 4,870 | 6,070 | 5,900 |
| **3 Hour Duration** | 50% | 2,190 | 2,070 | 1,900 | 2,500 | 2,370 |
| | 10% | 4,890 | 4,680 | 4,460 | 5,700 | 5,480 |
| | 4% | 6,920 | 6,700 | 6,460 | 8,020 | 7,810 |
| | 2% | 8,510 | 8,300 | 8,060 | 9,940 | 9,730 |
| | 1% | 10,110 | 9,900 | 9,650 | 11,940 | 11,730 |

**Table 7. Percent of peak flow reduction at gage 06889110 near Corning, KS**

| Near Corning- Gage 06889110 | Storm Event | Baseline vs. 50% Adoption | Baseline vs. 100% Adoption | Baseline Future Conditions vs. 50% Adoption Future Conditions |
|---|---|---|---|---|
| **24 Hour Duration** | 50% | 10.53% | 23.31% | 9.68% |
| | 10% | 5.95% | 13.38% | 5.21% |
| | 4% | 4.68% | 9.64% | 3.86% |
| | 2% | 3.86% | 8.18% | 3.16% |
| | 1% | 3.24% | 7.06% | 2.80% |
| **3 Hour Duration** | 50% | 5.48% | 13.24% | 5.20% |
| | 10% | 4.29% | 8.79% | 3.86% |
| | 4% | 3.18% | 6.65% | 2.62% |
| | 2% | 2.47% | 5.29% | 2.11% |
| | 1% | 2.08% | 4.55% | 1.76% |

An increase in saturated hydraulic conductivity also results in a decrease in water surface elevation as seen in Table 8. Figure 5 shows how the amount of flow and height of the water surface change throughout the storm event for the 100-year 24-hour current conditions scenarios. Lastly, Figure 6 shows the slight differences of the floodplain plots from each of the same scenarios.

**Table 8. Water surface elevation values at gage 06889110 near Corning, KS**

| Near Corning- Gage 06889110 | Storm Event | Baseline | 50% Adoption | 100% Adoption | Baseline Future Conditions | 50% Adoption Future Conditions |
|---|---|---|---|---|---|---|
| 24 Hour Duration | 50% | 1263.3 | 1262.8 | 1262.2 | 1264.0 | 1263.5 |
| | 10% | 1266.2 | 1266.0 | 1265.7 | 1266.6 | 1266.5 |
| | 4% | 1267.3 | 1267.1 | 1266.9 | 1267.7 | 1267.6 |
| | 2% | 1268.0 | 1267.8 | 1267.7 | 1268.6 | 1268.4 |
| | 1% | 1268.7 | 1268.6 | 1268.4 | 1269.3 | 1269.2 |
| 3 Hour Duration | 50% | 1265.4 | 1265.2 | 1264.8 | 1265.9 | 1265.7 |
| | 10% | 1268.3 | 1268.2 | 1268.0 | 1269.0 | 1268.8 |
| | 4% | 1269.8 | 1269.7 | 1269.5 | 1270.5 | 1270.4 |
| | 2% | 1270.8 | 1270.7 | 1270.5 | 1271.5 | 1271.4 |
| | 1% | 1271.6 | 1271.5 | 1271.4 | 1272.5 | 1272.4 |

**Figure 5. Flow and WSEL hydrographs for the 100-year 24-hour current condition scenarios**

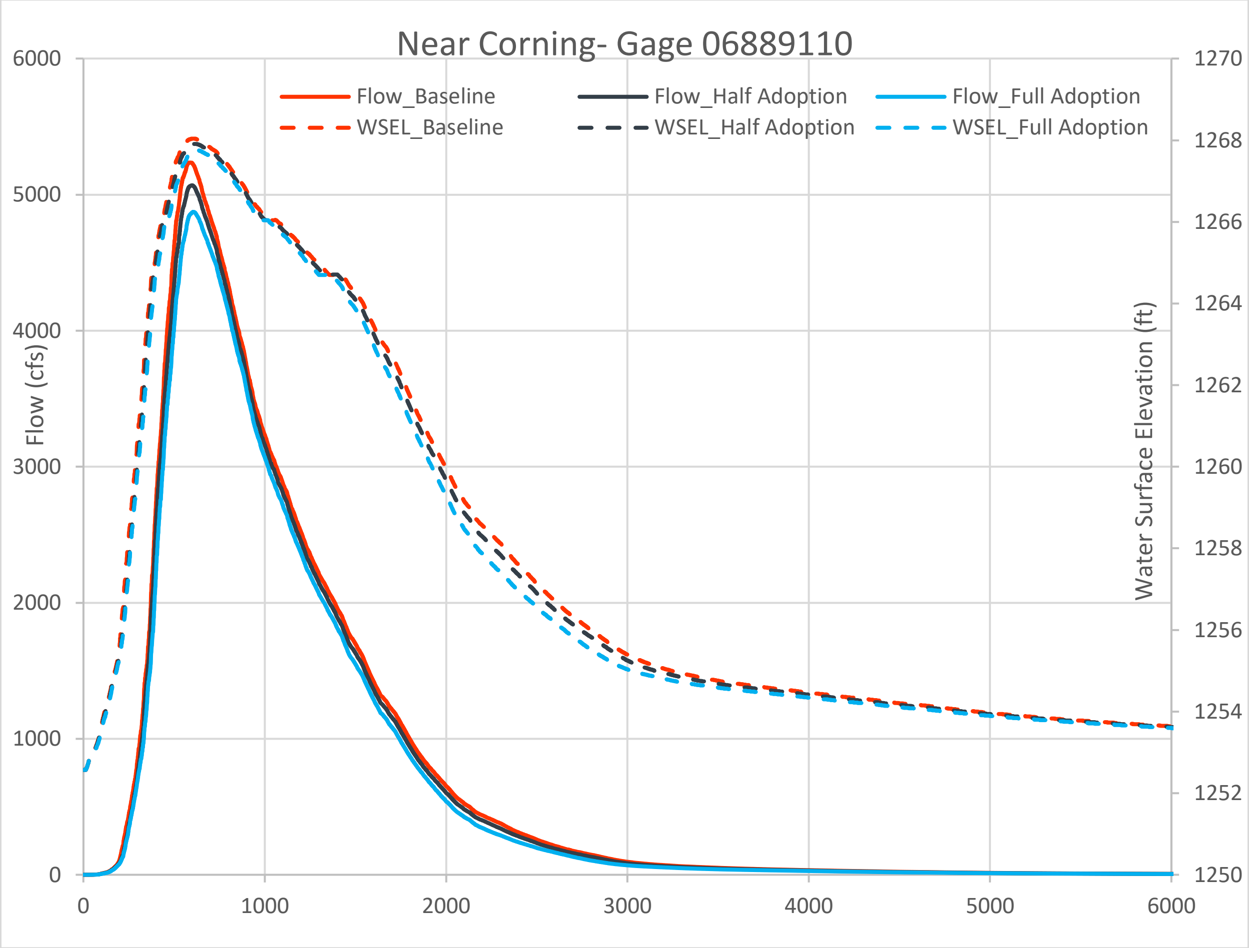


**Figure 6. 100-year 24-hour current conditions floodplain plots at gage 06889110 near Corning, KS**

## Data Results Near Circleville- Gage 06889160

As can be seen in Table 9, the increased saturated hydraulic conductivity does result in a decrease in flows across storm events. Table 10 shows the percent of peak flow reduction for each storm event to better illustrate the resulting changes. This also shows how the positive effects of the infiltration decrease as the storm events get larger and more infrequent.

**Table 9. Flow values (cfs) at gage 06889160 near Circleville, KS**

| Near Circleville-Gage 06889160 | Storm Event | Baseline | 50% Adoption | 100% Adoption | Baseline Future Conditions | 50% Adoption Future Conditions |
|---|---|---|---|---|---|---|
| 24 Hour Duration | 50% | 4,500 | 3,840 | 3,650 | 5,140 | 4,500 |
| | 10% | 8,620 | 7,890 | 7,700 | 9,750 | 9,030 |
| | 4% | 11,450 | 10,700 | 10,510 | 13,090 | 12,270 |
| | 2% | 13,900 | 13,100 | 12,900 | 15,990 | 15,150 |
| | 1% | 16,500 | 15,660 | 15,460 | 19,170 | 18,310 |
| 3 Hour Duration | 50% | 5,670 | 5,240 | 5,210 | 6,270 | 5,850 |
| | 10% | 10,140 | 9,620 | 9,600 | 11,380 | 10,820 |
| | 4% | 13,320 | 12,710 | 12,680 | 15,190 | 14,530 |
| | 2% | 16,050 | 15,390 | 15,360 | 18,600 | 17,890 |
| | 1% | 18,910 | 18,200 | 18,170 | 22,210 | 21,470 |

**Table 10. Percent of peak flow reduction at gage 06889160 near Circleville, KS**

| Near Circleville-Gage 06889160 | Storm Event | Baseline vs. 50% Adoption | Baseline vs. 100% Adoption | Baseline Future Conditions vs. 50% Adoption Future Conditions |
|---|---|---|---|---|
| 24 Hour Duration | 50% | 14.67% | 18.89% | 12.45% |
| | 10% | 8.47% | 10.67% | 7.38% |
| | 4% | 6.55% | 8.21% | 6.26% |
| | 2% | 5.76% | 7.19% | 5.25% |
| | 1% | 5.09% | 6.30% | 4.49% |
| 3 Hour Duration | 50% | 7.58% | 8.11% | 6.70% |
| | 10% | 5.13% | 5.33% | 4.92% |
| | 4% | 4.58% | 4.80% | 4.34% |
| | 2% | 4.11% | 4.30% | 3.82% |
| | 1% | 3.75% | 3.91% | 3.33% |

An increase in saturated hydraulic conductivity also results in a decrease in water surface elevation as seen in Table 11. Figure 7 shows how the amount of flow and height of the water surface change throughout the storm event for the 100-year 24-hour current conditions scenarios. Lastly, Figure 8 shows the slight differences of the floodplain plots from each of the same scenarios.

**Table 11. Water surface elevation values at gage 06889160 near Circleville, KS**

| Near Circleville-Gage 06889160 | Storm Event | Baseline | 50% Adoption | 100% Adoption | Baseline Future Conditions | 50% Adoption Future Conditions |
|---|---|---|---|---|---|---|
| 24 Hour Duration | 50% | 1111.0 | 1110.2 | 1109.9 | 1111.7 | 1111.0 |
| | 10% | 1113.6 | 1113.3 | 1113.2 | 1113.9 | 1113.7 |
| | 4% | 1114.5 | 1114.2 | 1114.2 | 1114.9 | 1114.7 |
| | 2% | 1115.1 | 1114.9 | 1114.8 | 1115.6 | 1115.4 |
| | 1% | 1115.7 | 1115.5 | 1115.5 | 1116.3 | 1116.1 |
| 3 Hour Duration | 50% | 1112.1 | 1111.8 | 1111.7 | 1112.5 | 1112.2 |
| | 10% | 1114.1 | 1113.9 | 1113.9 | 1114.4 | 1114.3 |
| | 4% | 1114.9 | 1114.8 | 1114.8 | 1115.4 | 1115.2 |
| | 2% | 1115.6 | 1115.4 | 1115.4 | 1116.1 | 1116.0 |
| | 1% | 1116.2 | 1116.1 | 1116.0 | 1116.8 | 1116.7 |

Figure 7. Flow and WSEL hydrographs for the 100-year 24-hour current condition scenarios

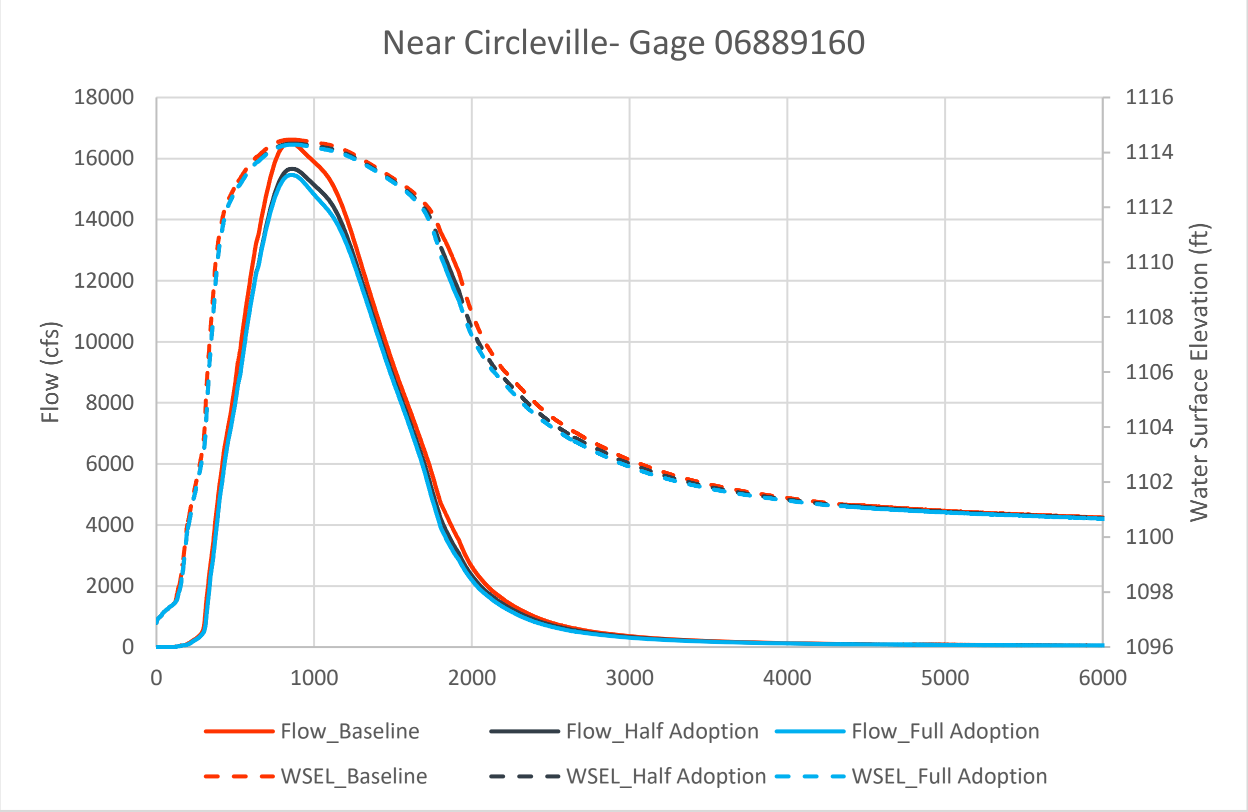
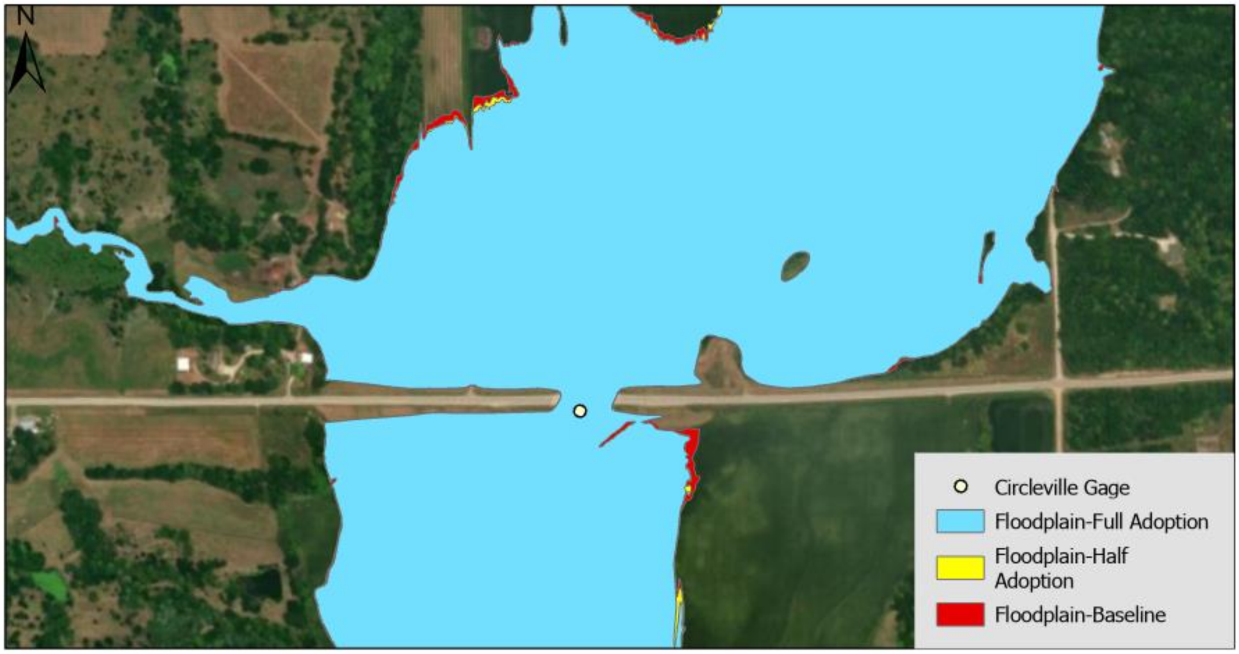


Figure 8. 100-year 24-hour current conditions floodplain plots at gage 06889160 near Circleville, KS



## Data Results Near Delia- Gage 06889200

As can be seen in Table 12, the increased saturated hydraulic conductivity does result in a decrease in flows across storm events. Table 13 shows the percent of peak flow reduction for each storm event to better illustrate the resulting changes. This also shows how the positive effects of the infiltration decrease as the storm events get larger and more infrequent.

**Table 12. Flow values (cfs) at gage 06889200 near Delia, KS**

| Near Delia- Gage 06889200 | Storm Event | Baseline | 50% Adoption | 100% Adoption | Baseline Future Conditions | 50% Adoption Future Conditions |
|---|---|---|---|---|---|---|
| 24 Hour Duration | 50% | 7,580 | 6,660 | 6,510 | 8,460 | 7,570 |
| | 10% | 14,010 | 12,560 | 12,390 | 16,220 | 14,610 |
| | 4% | 19,790 | 17,970 | 17,730 | 23,290 | 21,280 |
| | 2% | 25,080 | 23,020 | 22,720 | 29,790 | 27,630 |
| | 1% | 30,910 | 28,750 | 28,400 | 36,750 | 34,570 |
| 3 Hour Duration | 50% | 7,460 | 7,090 | 7,060 | 8,040 | 7,680 |
| | 10% | 12,530 | 11,960 | 11,860 | 14,280 | 13,610 |
| | 4% | 16,990 | 16,290 | 16,110 | 19,510 | 18,790 |
| | 2% | 20,660 | 19,910 | 19,730 | 24,020 | 23,230 |
| | 1% | 24,420 | 23,630 | 23,450 | 28,760 | 27,860 |

**Table 13. Percent of peak flow reduction at gage 06889200 near Delia, KS**

| Near Delia- Gage 06889200 | Storm Event | Baseline vs. 50% Adoption | Baseline vs. 100% Adoption | Baseline Future Conditions vs. 50% Adoption Future Conditions |
|---|---|---|---|---|
| 24 Hour Duration | 50% | 12.14% | 14.12% | 10.52% |
| | 10% | 10.35% | 11.56% | 9.93% |
| | 4% | 9.20% | 10.41% | 8.63% |
| | 2% | 8.21% | 9.41% | 7.25% |
| | 1% | 6.99% | 8.12% | 5.93% |
| 3 Hour Duration | 50% | 4.96% | 5.36% | 4.48% |
| | 10% | 4.55% | 5.35% | 4.69% |
| | 4% | 4.12% | 5.18% | 3.69% |
| | 2% | 3.63% | 4.50% | 3.29% |
| | 1% | 3.24% | 3.97% | 3.13% |

An increase in saturated hydraulic conductivity also results in a decrease in water surface elevation as seen in Table 14. Figure 9 shows how the amount of flow and height of the water surface change throughout the storm event for the 100-year 24-hour current conditions scenarios. Lastly, Figure 10 shows the slight differences of the floodplain plots from each of the same scenarios.

**Table 14. Water surface elevation values at gage 06889200 near Delia, KS**

| Near Delia-Gage 06889200 | Storm Event | Baseline | 50% Adoption | 100% Adoption | Baseline Future Conditions | 50% Adoption Future Conditions |
|---|---|---|---|---|---|---|
| **24 Hour Duration** | 50% | 966.9 | 965.8 | 965.6 | 967.8 | 966.9 |
| | 10% | 970.2 | 970.0 | 970.0 | 970.5 | 970.3 |
| | 4% | 970.8 | 970.7 | 970.6 | 971.2 | 971.0 |
| | 2% | 971.3 | 971.1 | 971.1 | 971.7 | 971.5 |
| | 1% | 971.8 | 971.6 | 971.6 | 972.2 | 972.1 |
| **3 Hour Duration** | 50% | 966.8 | 966.3 | 966.3 | 967.4 | 967.0 |
| | 10% | 970.0 | 969.9 | 969.8 | 970.2 | 970.2 |
| | 4% | 970.5 | 970.5 | 970.4 | 970.8 | 970.7 |
| | 2% | 970.9 | 970.8 | 970.8 | 971.2 | 971.2 |
| | 1% | 971.3 | 971.2 | 971.2 | 971.6 | 971.5 |

**Figure 9. Flow and WSEL hydrographs for the 100-year 24-hour current condition scenarios**

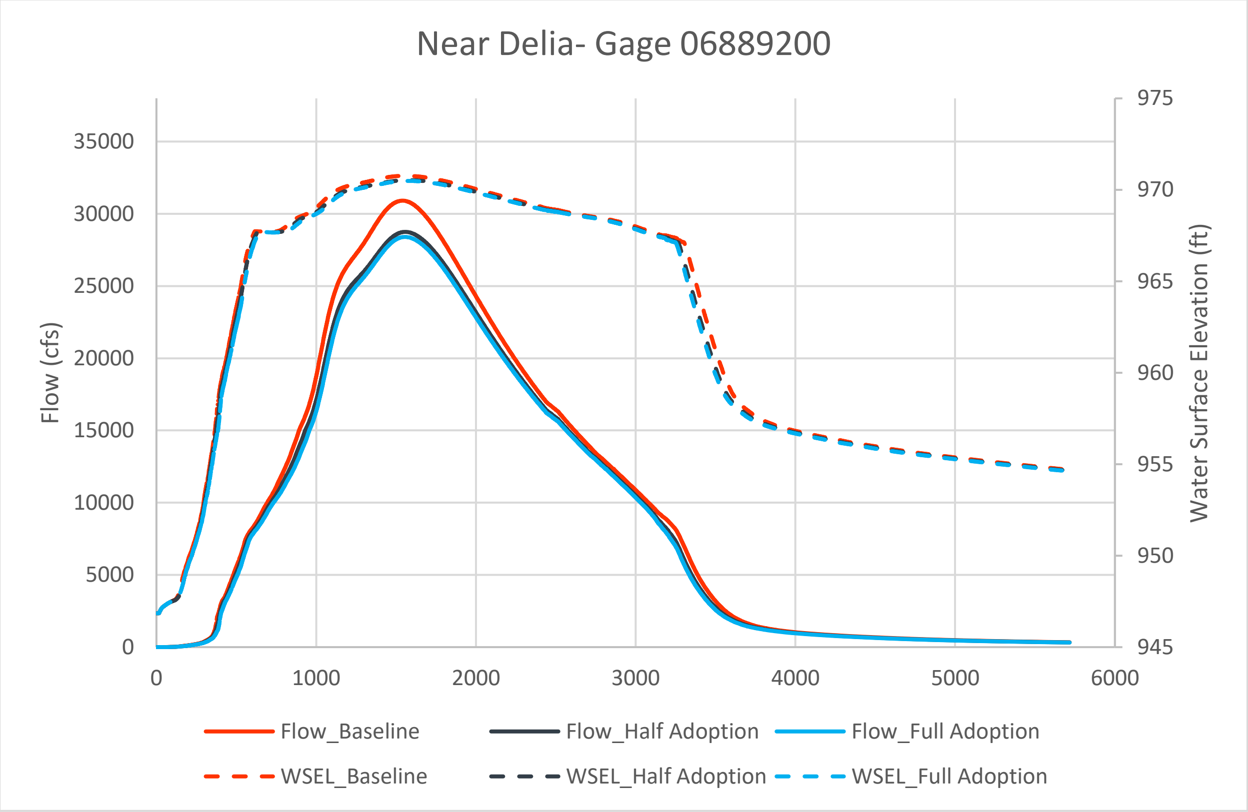
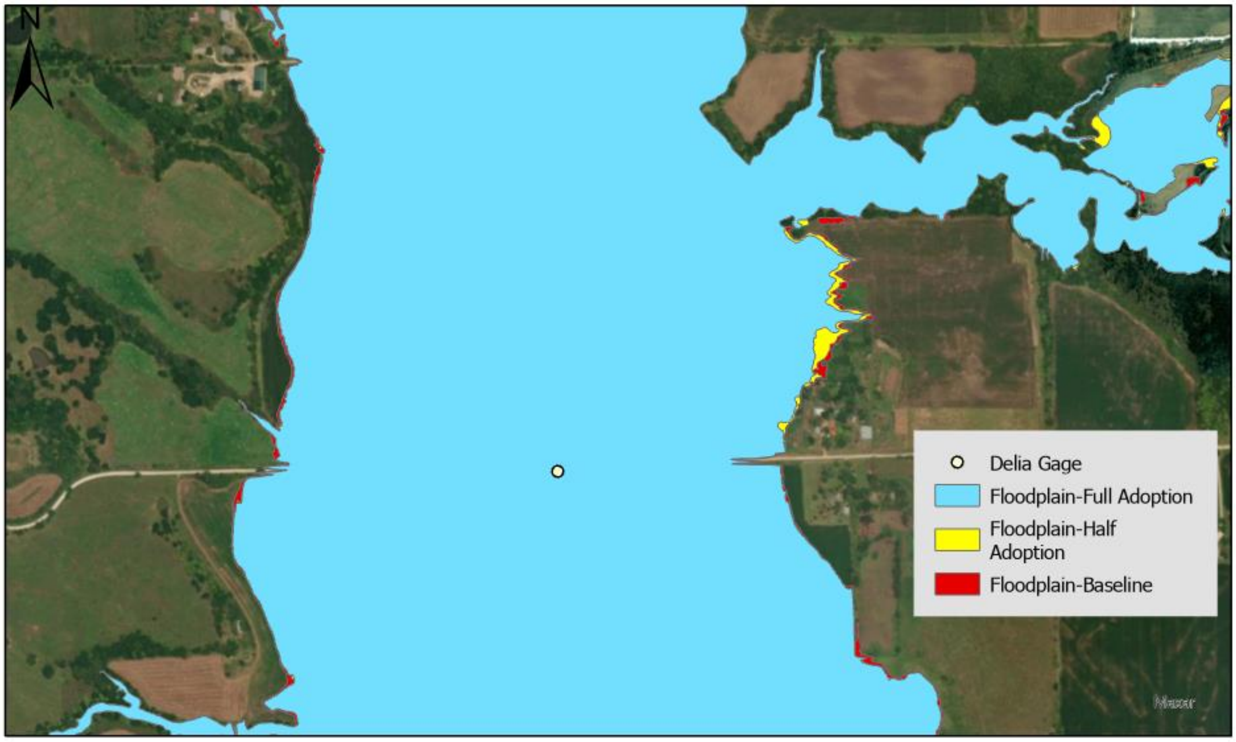


Figure 10.100-year 24-hour current conditions floodplain plots at gage 06889200 near Delia, KS



## Data Results Near Topeka- Gage 06889500

As can be seen in Table 15, the increased saturated hydraulic conductivity does result in a decrease in flows across storm events. Table 16 shows the percent of peak flow reduction for each storm event to better illustrate the resulting changes. This also shows how the positive effects of the infiltration decrease as the storm events get larger and more infrequent.

Table 15. Flow values (cfs) at gage 06889500 near Topeka, KS

| Near Topeka-Gage 06889500 | Storm Event | Baseline | 50% Adoption | 100% Adoption | Baseline Future Conditions | 50% Adoption Future Conditions |
|---|---|---|---|---|---|---|
| 24 Hour Duration | 50% | 11,670 | 10,310 | 9,340 | 13,510 | 12,150 |
| | 10% | 21,350 | 20,320 | 19,500 | 23,310 | 22,350 |
| | 4% | 25,890 | 25,040 | 24,370 | 28,770 | 27,560 |
| | 2% | 30,230 | 28,950 | 28,950 | 33,640 | 32,560 |
| | 1% | 34,260 | 33,250 | 32,670 | 37,320 | 36,340 |
| 3 Hour Duration | 50% | 12,530 | 11,880 | 11,370 | 13,950 | 13,340 |
| | 10% | 20,700 | 20,220 | 19,860 | 22,320 | 21,880 |
| | 4% | 24,500 | 24,100 | 23,790 | 26,360 | 25,940 |
| | 2% | 27,480 | 26,790 | 26,480 | 30,150 | 29,750 |
| | 1% | 30,440 | 30,010 | 29,730 | 33,660 | 33,270 |

**Table 16. Percent of peak flow reduction at gage 06889500 near Topeka, KS**

| Near Topeka-Gage 06889500 | Storm Event | Baseline vs. 50% Adoption | Baseline vs. 100% Adoption | Baseline Future Conditions vs. 50% Adoption Future Conditions |
|---|---|---|---|---|
| 24 Hour Duration | 50% | 11.65% | 19.97% | 10.07% |
| | 10% | 4.82% | 8.67% | 4.12% |
| | 4% | 3.28% | 5.87% | 4.21% |
| | 2% | 4.23% | 4.23% | 3.21% |
| | 1% | 2.95% | 4.64% | 2.63% |
| 3 Hour Duration | 50% | 5.19% | 9.26% | 4.37% |
| | 10% | 2.32% | 4.06% | 1.97% |
| | 4% | 1.63% | 2.90% | 1.59% |
| | 2% | 2.51% | 3.64% | 1.33% |
| | 1% | 1.41% | 2.33% | 1.16% |

An increase in saturated hydraulic conductivity also results in a decrease in water surface elevation as seen in Table 17. Figure 11 shows how the amount of flow and height of the water surface change throughout the storm event for the 100-year 24-hour current conditions scenarios. Lastly, Figure 12 shows the slight differences of the floodplain plots from each of the same scenarios.

**Table 17. Water surface elevation values at gage 06889500 near Topeka, KS**

| Near Topeka-Gage 06889500 | Storm Event | Baseline | 50% Adoption | 100% Adoption | Baseline Future Conditions | 50% Adoption Future Conditions |
|---|---|---|---|---|---|---|
| 24 Hour Duration | 50% | 883.7 | 882.6 | 881.8 | 885.2 | 884.1 |
| | 10% | 890.1 | 889.6 | 889.1 | 891.0 | 890.6 |
| | 4% | 892.1 | 891.8 | 891.6 | 892.9 | 892.6 |
| | 2% | 893.4 | 893.0 | 893.0 | 894.6 | 894.2 |
| | 1% | 894.8 | 894.5 | 894.2 | 895.8 | 895.5 |
| 3 Hour Duration | 50% | 884.2 | 883.7 | 883.3 | 885.3 | 884.8 |
| | 10% | 889.6 | 889.4 | 889.2 | 890.5 | 890.3 |
| | 4% | 891.5 | 891.4 | 891.3 | 892.3 | 892.1 |
| | 2% | 892.5 | 892.4 | 892.3 | 893.3 | 893.2 |
| | 1% | 893.4 | 893.2 | 893.2 | 894.5 | 894.4 |

**Figure 11. Flow and WSEL hydrographs for the 100-year 24-hour current condition scenarios**

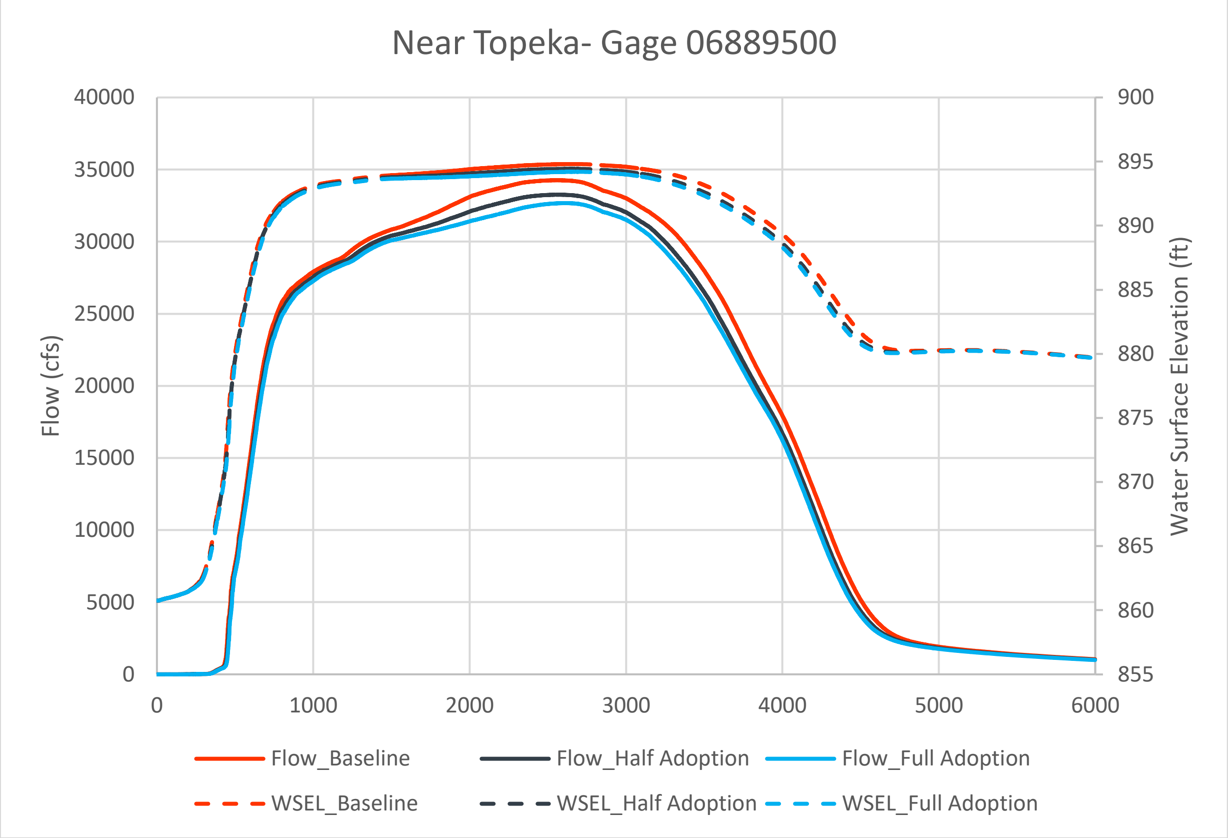


**Figure 12. 100-year 24-hour current conditions floodplain plots at gage 06889500 near Topeka, KS**

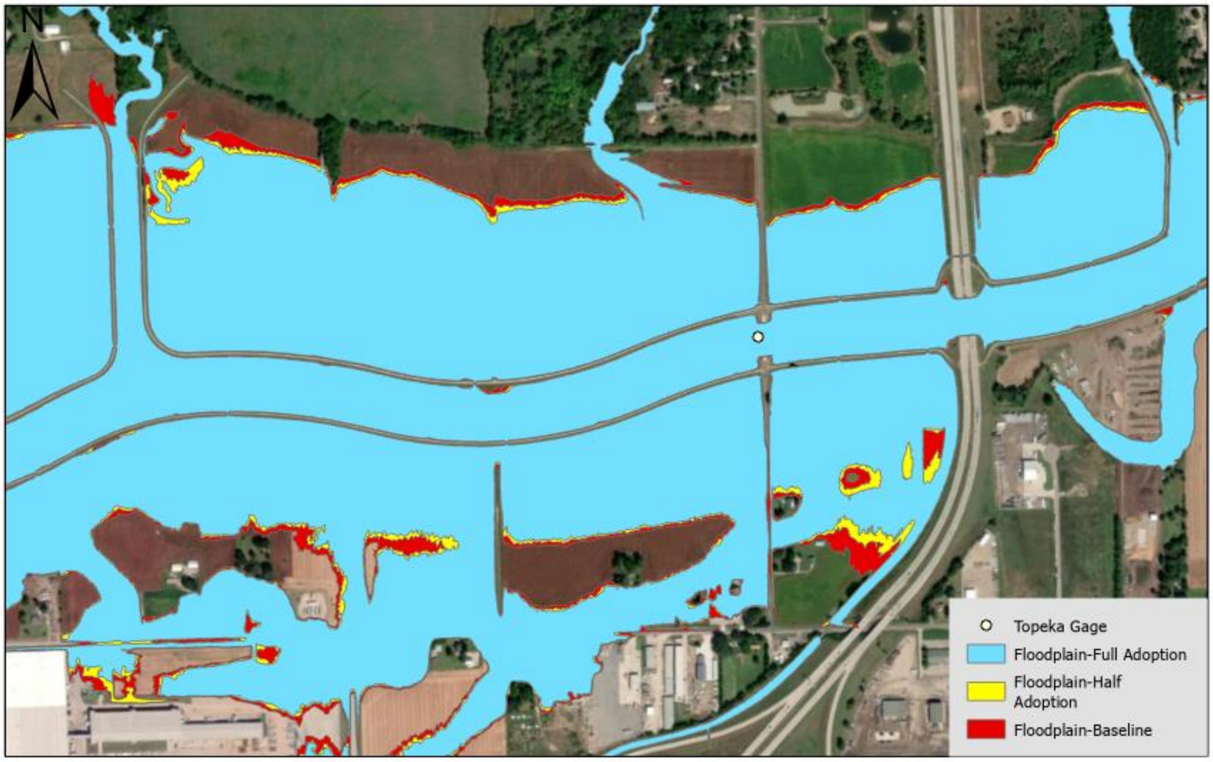


**Figure 13. The change in water surface elevation between the baseline and 100% adoption scenarios for the 24-hour duration 10% and 1% annual chance storms along the Soldier Creek levee**

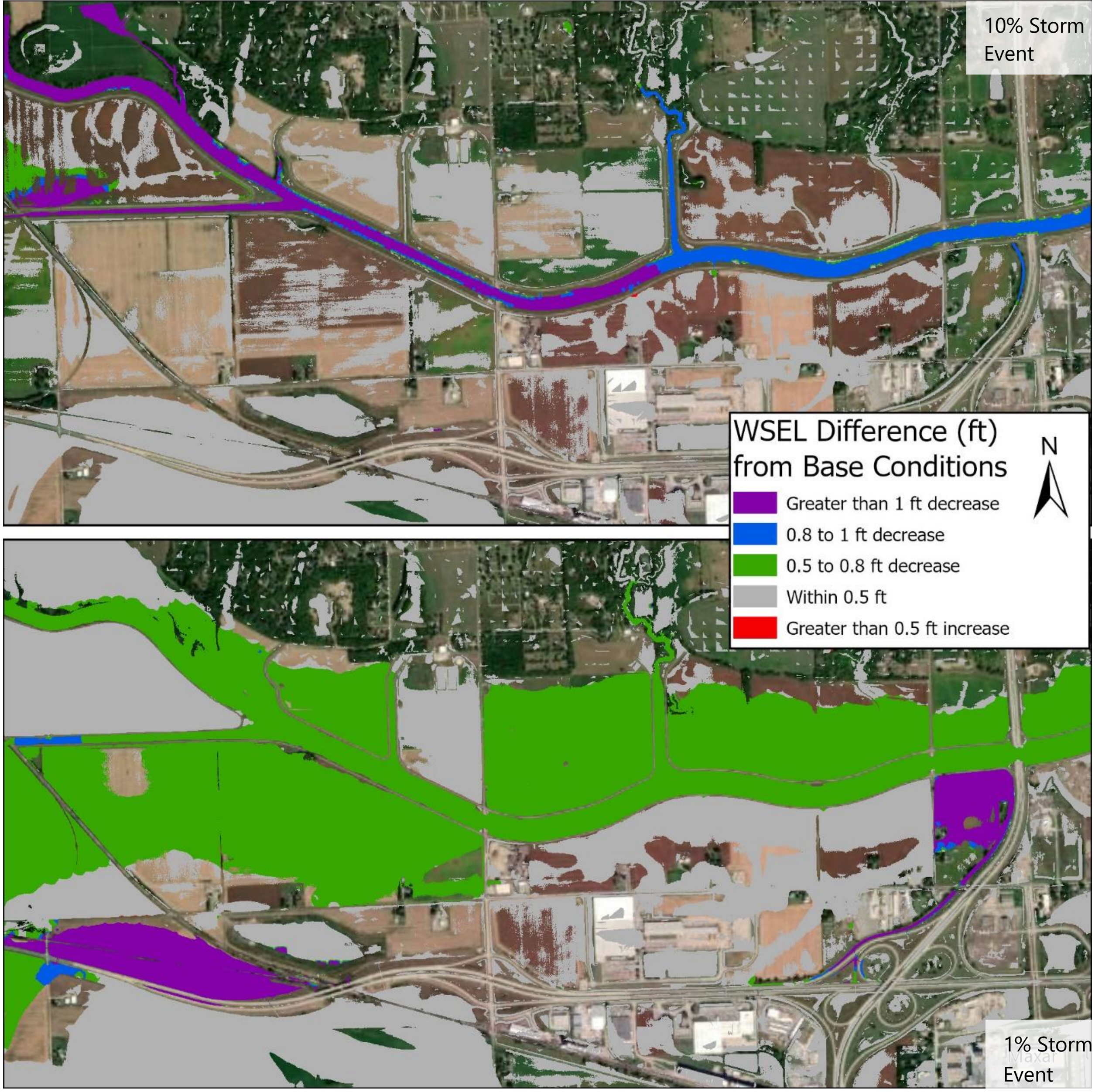


Figure 13 provides another visual representation of the resulting decrease in water surface elevation between the baseline and 100% adoption scenarios for the 10% and 1% annual chance storm frequencies. The images shown are along the levee running through North Topeka and near the outlet of the Soldier Creek watershed. Both images show a decrease of more than 0.5 feet along the streamline and in some of the surrounding area.

In comparison, Figure 14 shows the same decrease in water surface elevation between the baseline and 100% adoption scenarios for the 10% and 1% annual chance storms but focusing on a small rural drainage area along Soldier Creek closer to the headwaters. This shows that the benefits of the increase in hydraulic conductivity are seen primarily in the main Soldier Creek channel even in the 10% chance storm. The 1% chance storm shows no significant change in this headwater area since a difference within 0.5 ft is negligible. The locations of Figures 13 and 14 are shown in Figure 15.

**Figure 14. The change in water surface elevation between the baseline and 100% adoption scenarios for the 24-hour duration 10% and 1% annual chance storms in small drainage area**

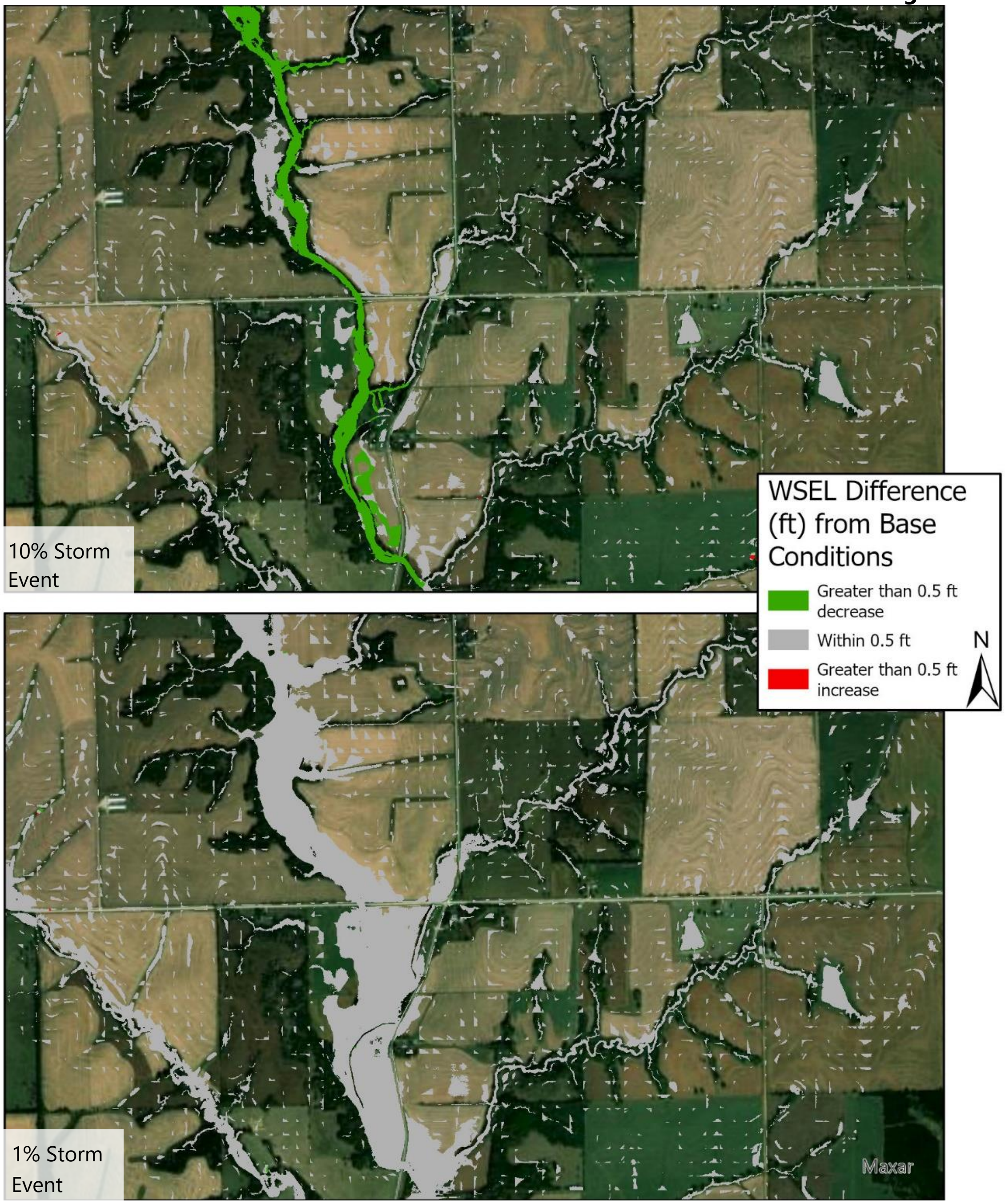
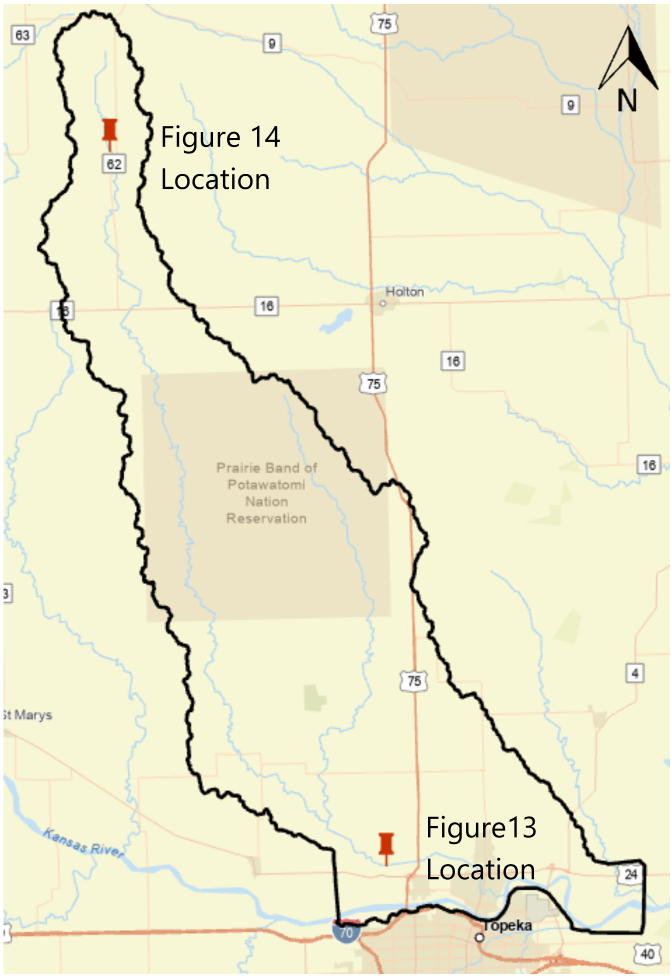


Figure 15. The locations of Figures 13 and 14 within the watershed



## Conclusions

Since the main point of comparison is how the increased saturated hydraulic conductivity effects the water surface elevation, it was predicted that the higher frequency storm events would experience more substantial changes. This prediction aligned with the observed results.

While the improved infiltration rates did yield reductions in flow it did not significantly lower the resulting water surface elevations. As seen in Figure 14 the 1% annual chance storm shows no change in water surface elevation greater than 0.5 feet. A difference of this amount is negligible and is often an acceptable error in floodplain mapping. Even for the 10% annual chance storm frequency most of the benefits are only seen in the main channel and not in the smaller drainage areas.

The reason for the smaller tributaries not seeing the same level of change as the main channel is likely due to the limited effects improving infiltration can provide. Although improving infiltration can be beneficial, it still has a finite storage capacity and once the soil is saturated it will still result in runoff.

However, there is the potential for compounding benefits. The reduction of runoff throughout the watershed results in a measurable change near the outlet of the watershed even in the 1% annual chance storm. While a change in water surface elevation of less than 1 foot doesn’t seem like much, it can have a significant impact downstream in lower lying valley areas. In this particular case it would have a positive impact on the effectiveness of the Soldier Creek levee system, especially when considering mitigating the impacts of climate change in the future.

## Future Improvements

The current Green and Ampt soil infiltration parameters were set based on a sensitivity analysis performed by the US Army Corps of Engineers. Since they were not measured values, the feasibility of achieving the modeled improved infiltration values is unknown. As more measured data on infiltration improvements and the value ranges that can be obtained from these improvements becomes available, the current model parameters can be updated, and the models rerun.

# Works Cited

Hydrologic Engineering Center (HEC). (2022). HEC-RAS Hydraulic Reference Manual. US Army Corps of Engineers (USACE).

Hydrologic Engineering Center (HEC). (2022). River Analysis System (HEC-RAS), Version 6.3.1. US Army Corps of Engineers (USACE).

National Oceanic and Atmospheric Administration (NOAA). (2013). *Atlas 14 - Precipitation-Frequency Atlas of the United States Volume 8.* United States Department of Commerce.

Natural Resources Conservation Service (NRCS). (2020). Gridded Soil Survey Geographic (gSSURGO) Database.

Rawls, W.J, L. Ahuja, D. L. Brakensiek, and A. Shirmohammadi (1982). Infiltration and soil water movement. Handbook of Hydrology.

United States Department of Agriculture (USDA). (2017). National Agriculture Imagery Program (NAIP).

US Army Corps of Engineers (USACE). (2022). Kansas Healthy Watershed Study. Hydrologic Modeling Sensitivity to Soil Parameters (Soldier Creek Watershed)