Iowa Flood Resilient Communities Cohort: Potential Flood Mitigation Solutions for Short Creek Watershed near Columbus Junction, Tributary A in Manchester, IA

by

Daniel Gilles, Nathan Young, Kate Giannini

Sponsored by
The American Flood Coalition

IIHR Technical Report No. 544

IIHR—Hydroscience and Engineering
College of Engineering
The University of Iowa
Iowa City, Iowa 52242-158 USA

December 2024

IOWA FLOOD RESILIENT COMMUNITIES COHORT: POTENTIAL FLOOD MITIGATION SOLUTIONS FOR SHORT CREEK WATERSHED NEAR COLUMBUS JUNCTION, IOWA

In December 2023, the American Flood Coalition (AFC) launched the Iowa Flood Resilient Communities Cohort, which provides support in accessing federal funding for flood projects. The cohort includes local officials and community partners from four Iowa communities: Columbus Junction, Dubuque, Manchester and Muscatine. AFC partnered with the Iowa Flood Center (IFC) to provide technical support in exploring flood mitigation alternatives and to assist in conceptualizing project designs that could be further pursued.

IFC provided technical assistance to the City of Columbus Junction in exploring potential options to reduce flooding caused by Short Creek Watershed. IFC evaluated broadscale land use changes within the watershed including converting portions to native vegetation or long-term implementation of cover crops and no-till practices to improve soil properties. Additionally, IFC explored implementation of distributed storage ponds within the watershed to attenuate flood peaks.

1. Background

The City of Columbus Junction is located at the confluence of the Cedar and Iowa Rivers. The community is subjected to flooding originating on either large river. The community came together to fight the devastating 2008 flood event, building a large temporary levee, shown in Figure 1, to hold back flood waters. However, despite their valiant efforts, the temporary levee failed and flooded several businesses and community buildings, shown in Figure 2. This flood event profoundly changed Columbus Junction, and its effects are still felt today.

Additionally, the city is subjected to local flash flooding that can quickly develop from smaller drainage areas like Monkey Run and Short Creek, shown in Figure 3. Short Creek frequently overtops bridges that disrupt major transportation routes for the community and businesses like Tyson Foods, located just north of Columbus Junction. One pathway to mitigating the effects of flooding would be to add flood resiliency within the upstream Short Creek Watershed. Potential projects include broadscale land use changes by converting cultivated land to native vegetation or implementing cover crops/no-till farming practices. Another approach would be to construct a system of distributed storage ponds throughout the watershed to capture and slowly release runoff. These approaches would require significant funding and landowner participation.

IFC developed a hydrologic model to investigate the potential benefits of these mitigation efforts. First, the model was used to establish baseline flow estimates across a range of storm events for the existing watershed. Then, soil infiltration properties were modified to simulate converting agricultural lands to native prairie and implementing cover crops and no-till practices. A distributed network of storage ponds was incorporated into the watershed model to simulate runoff detention. These hypothetical scenarios were compared with the baseline conditions to evaluate their respective flood reduction benefits. This conceptual analysis can be leveraged by stakeholders to begin engaging with landowners and seeking funds for targeted implementation of these practices.

Figure 1. Columbus Junction on June 14, 2008. A temporary levee held back floodwaters until it failed, inundating several business and community buildings. Photo Credit: https://www.kenpurdy.com/FloodWeb/Flood.html

Figure 2. Columbus Junction during the 2008 Flood. The outlined area was protected by a temporary levee before its failure. Photo Credit: https://www.kenpurdy.com/FloodWeb/Flood.html

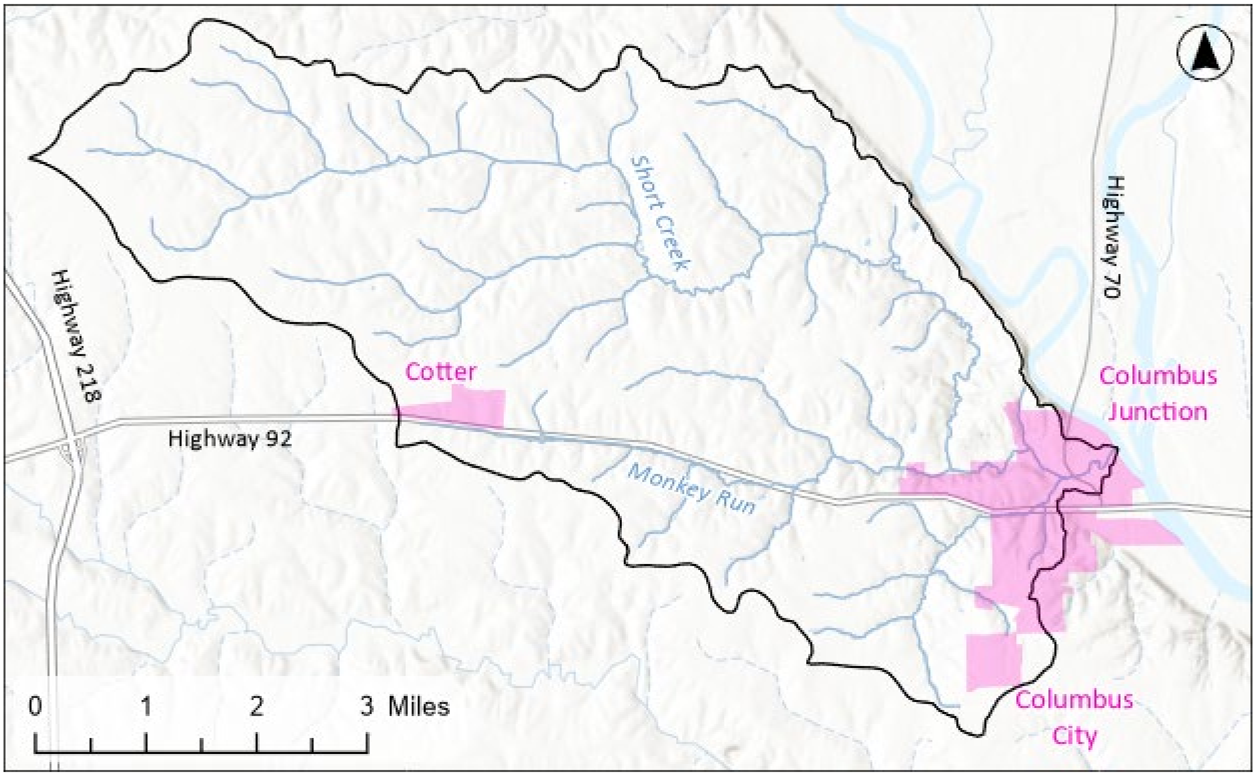

Figure 3. Study area near Columbus Junction, Iowa. Short Creek watershed has a drainage area of 31 square miles.

2. Model Development

IFC utilized the U.S. Army Corps of Engineers Hydrologic Engineering Center's Hydrologic Modeling System (HMS) Version 4.12 software to develop a lumped parameter hydrologic model (Hydrologic Engineering Center, 2023). One important dataset used to develop the model was LiDAR elevation data provided by State of Iowa partners (Iowa Geospatial Data Clearinghouse, 2024). The elevation data, shown in Figure 4, was used to divide Short Creek watershed into 77 smaller units, called subbasins in HMS. These have an average area of approximately 250 acres (0.4 sq mi) but can be as large as 1200 acres (1.8 sq mi). Within each subbasin, model parameters are lumped, meaning physical characteristics of the watershed, such as land use and soil type, are averaged together into a single representative value for each subbasin.

Soil infiltration and storage capacity are major factors in hydrologic response of the existing watershed. Soil properties are available in the Soil Survey Geographic Database (SSURGO). This database has been developed by the National Cooperative Soil Survey over the course of a century and is made available through the U.S. Department of Agriculture (USDA) and the Natural Resources Conservation Service (NRCS) (Soil Survey Staff, NRCS, USDA, 2024).

The NRCS classifies SSURGO soils into four hydrologic soil groups (HSG) based on the soil's runoff potential. The four HSGs are A, B, C, and D, where A-type soils have the lowest runoff potential, and D-type have the highest. In addition, there are dual code soil classes A/D, B/D, and C/D that are assigned to certain wet soils. For these soil groups, even though the soil properties may be favorable to allow infiltration (water passing from the surface into the ground), a shallow groundwater table (within 24 inches of the surface) typically prevents much from doing so. For example, a B/D soil will have the runoff potential of a B-type soil if the shallow water table were to be drained away, but the higher runoff potential of a D-type soil if it is not. The spatial distribution of HSGs in Short Creek watershed are shown in Figure 5. Short Creek watershed is dominated by type C soils which have a moderately high runoff potential with a soil texture of loam containing silt and clay slowing downward movement of water.

Along with soil properties, land cover and land use are also important components of rainfall infiltration. Land cover across the watershed is described by the 2023 National Land Cover Database (NLCD) in Figure 6 (U.S. Geological Survey, 2023). The majority of the watershed is cultivated crop, covering 65%, followed by forest at 16%, and hay/pasture at 12%.

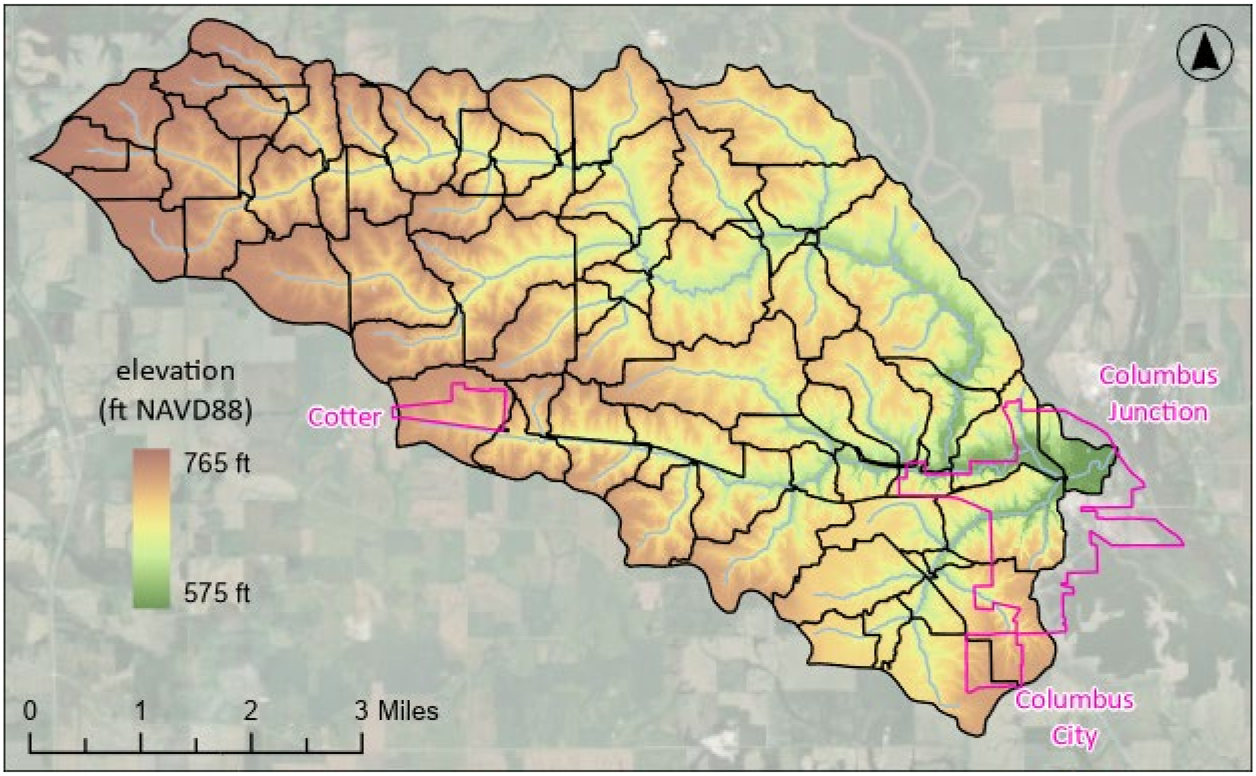

Figure 4. LiDAR elevations within the Short Creek Watershed shown with subbasin units of the watershed used to model hydrology.

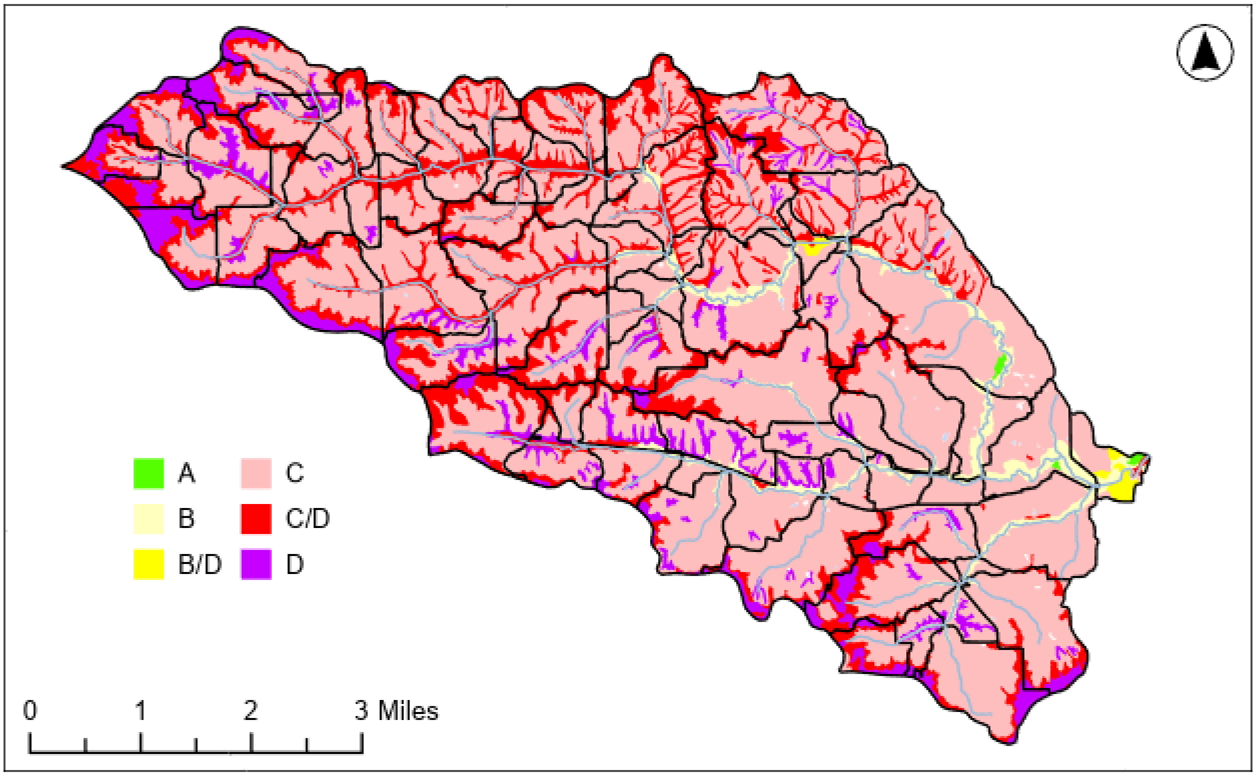

Figure 5. Distribution of Hydrologic Soil Groups. Hydrologic Soil Groups reflect the degree of runoff potential a particular soil has, with Type A representing the lowest runoff potential and Type D representing the highest runoff potential.

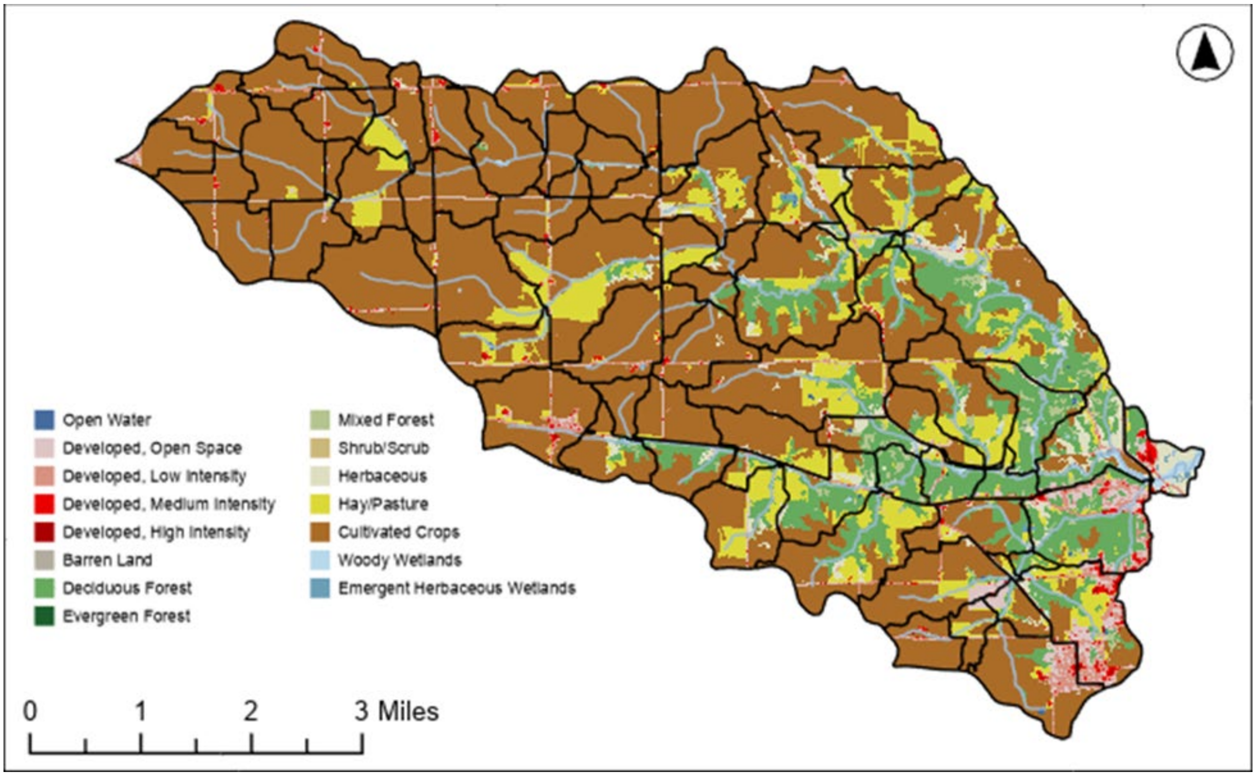

Figure 6. 2023 National Land Cover Database classifications (U.S. Geological Survey, 2023).

SCS curve numbers are used to parameterize runoff potential using spatial intersections of SSURGO hydrological soil groups (HSGs) and NLCD land cover data. The SCS curve number is a simple, widely used method for determining runoff potential. Curve number values for these intersections of soil and land cover were provided by the NRCS TR-55 publication (Natural Resources Conservation Service, USDA, 1986). The SCS curve number grid used to parameterize the HMS model is shown in Figure 7. Areas with higher runoff potential have higher curve numbers. Generally, upland agricultural areas have the highest curve numbers.

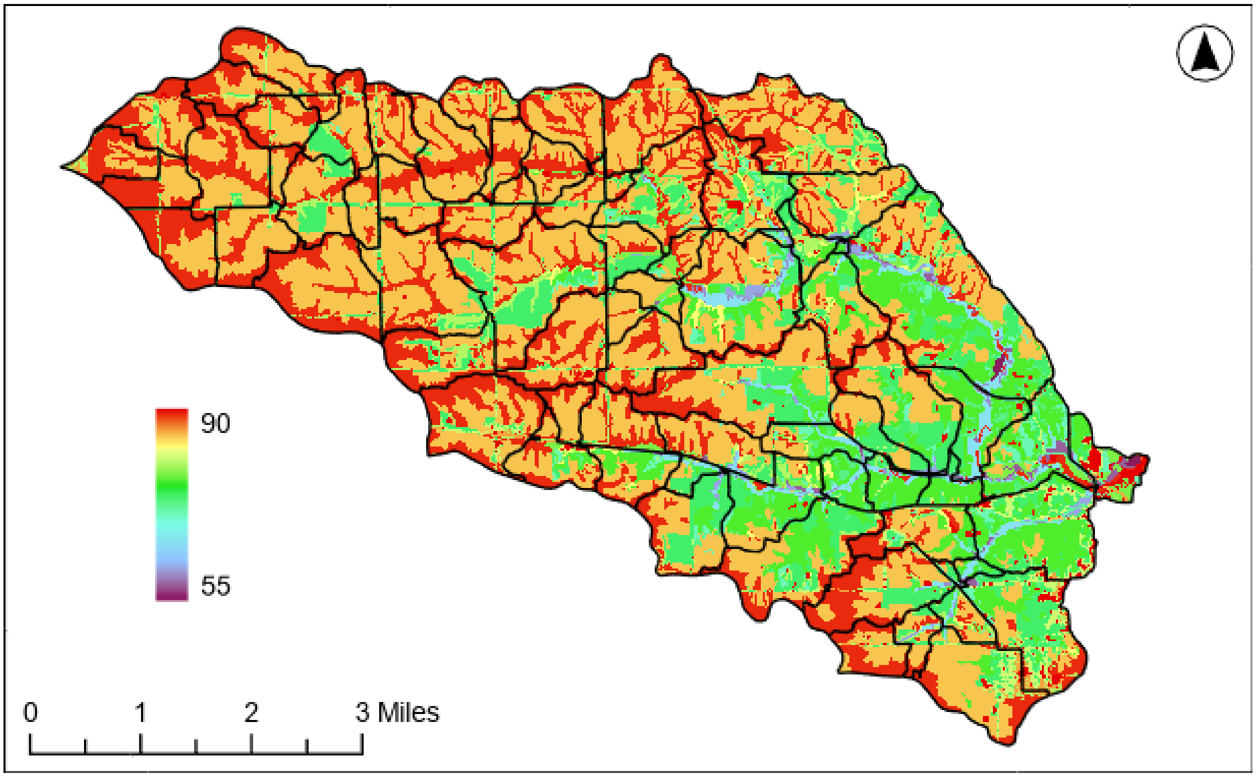

Figure 7. SCS curve numbers generated using hydrologic soil groups and land cover data.

The SCS unit hydrograph method was used to transform runoff to an outflow hydrograph for each subbasin. The lag time for each subbasin was used to parameterize this transform method. The Muskingum-Cunge routing method was used to model how flood waves move through the drainage network. This routing method requires stream slope, Manning's channel roughness, and an assumed trapezoidal channel cross-section to route flows downstream.

3. Design Storms

Precipitation frequency estimates over a 24-hour storm duration were provided by NOAA Atlas 14 and are shown in Table 1 (Perica, et al., 2013). These precipitation depths were distributed on a Midwest Region 3 first quartile case, 50% occurrence storm. This storm distribution was used to develop a rainfall time series for each return period.

Table 1. NOAA Atlas 14 precipitation frequency estimates for 24-hour duration.

Return Period	2-yr	5-yr	10-yr	50-yr	100-yr	500-yr
Annual Exceedance Probability, AEP	50	20	10	2	1	0.2
Total Depth (in)	3.09	3.87	4.57	6.51	7.45	9.91

4. Simulation Results – Conversion to Native Prairie

All the agricultural land in Short Creek watershed was mostly native prairie or forest prior to European settlement. An analysis to quantify the impact of this conversion to agricultural use was developed by assuming 25-, 50-, and 100-percent conversion to native prairie. While the 100-percent (as well as 50-percent) conversion is not feasible as a flood mitigation strategy, it provides a baseline for how the watershed would handle runoff at its most resilient state. This scenario will typically have much lower flood flow peaks, however, there is still flooding that occurs, just not as severe. Once the watershed is saturated, runoff will still occur.

To simulate these conversions to native prairie, curve numbers were decreased by assuming row crop have curve numbers corresponding to native prairie according to the conversion percentages and are shown in Figure 8. Using the design storms, we simulated these watershed scenarios along with the existing conditions as a baseline. Simulated flow at the outlet of Short Creek for each design storm and watershed scenario is shown in Figure 9. Peak flow reductions are summarized in Table 2. As expected, the 100-percent conversion to native prairie has the largest peak flow reductions, averaging 31 percent across the range of design storms. The 25- and 50-percent conversion scenarios have average peak flow reductions of 10 and 17 percent, respectively. These reductions come from increased infiltration rates via the curve number and slowing the travel time to each subbasin outlet.

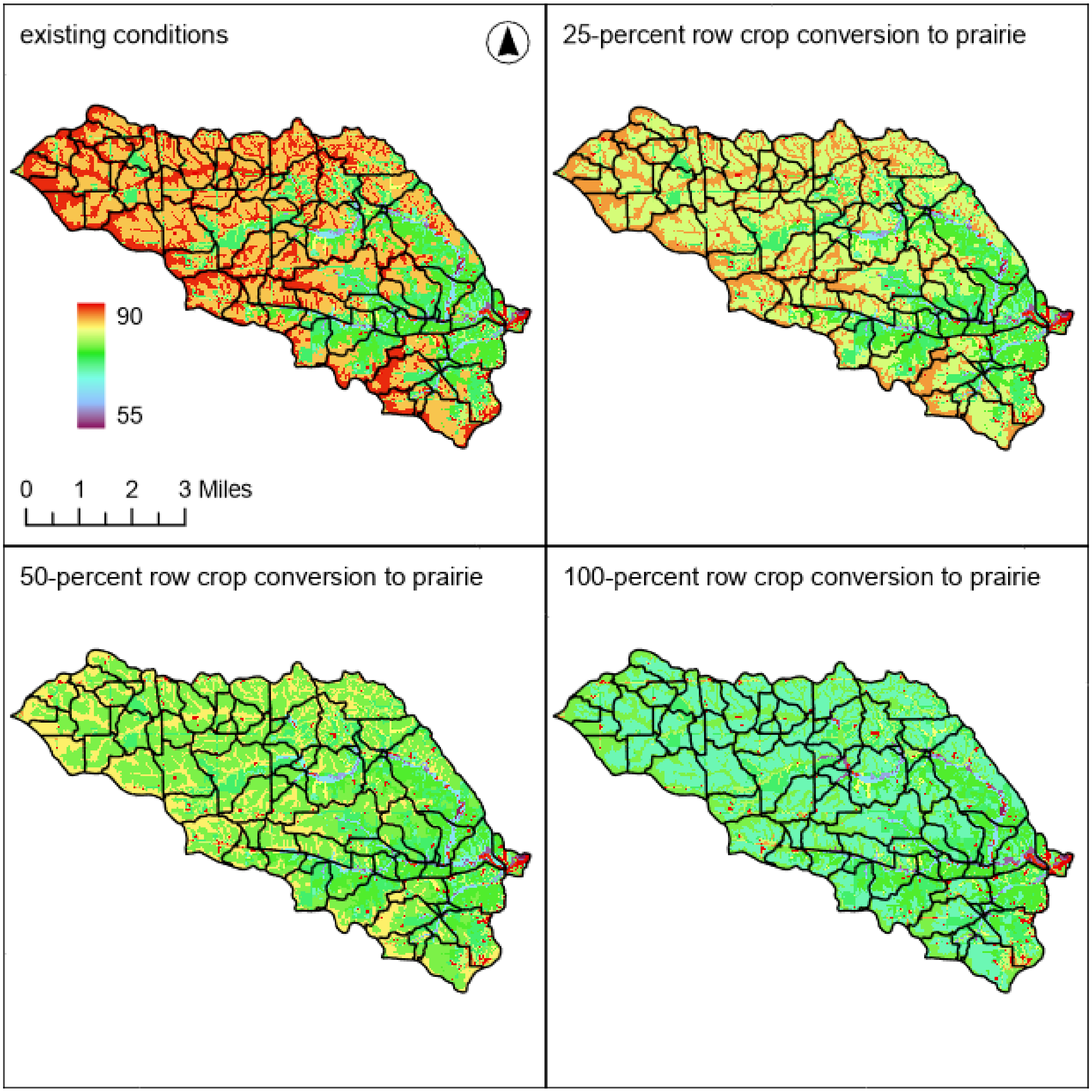

Figure 8. The existing SCS curve numbers were adjusted assuming a 25-, 50-, and 100-percent conversion of row crop agriculture to native prairie.

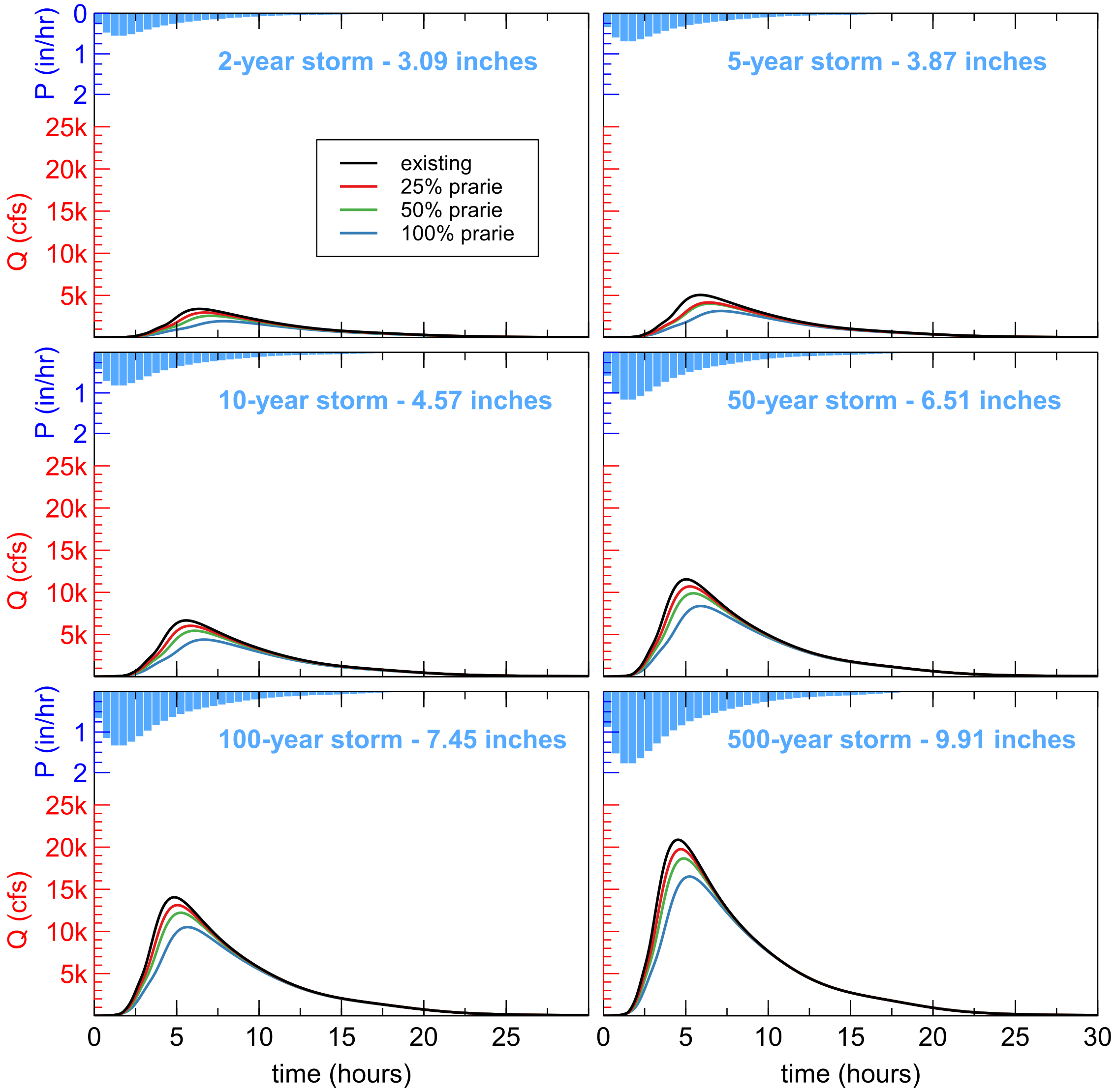

Figure 9.Simulation results from 25-, 50-, and 100-percent conversion of agricultural land to native prairie, shown with results from existing conditions. Rainfall time series shown on upper axis.

Table 2. Simulation results tabulated for the 25-, 50-, and 100-percent conversion of agricultural land to native prairie.

return period			2-year	5-year	10-year	50-year	100-year	500-year
annual exceedance probability			50%	20%	10%	2%	1%	0.20%
existing flow (cfs)			3,396	5,055	6,669	11,545	14,052	20,871
prairie restoration	25% *	flow (cfs)	2,967	4,165	6,033	10,698	13,118	19,759
		% change	-13%	-18%	-10%	-7%	-7%	-5%
	50% *	flow (cfs)	2,585	4,016	5,444	9,887	12,218	18,658
		% change	-24%	-21%	-18%	-14%	-13%	-11%
	100% *	flow (cfs)	1,941	3,154	4,396	8,379	10,513	16,512
		% change	-43%	-38%	-34%	-27%	-25%	-21%

* percentage of row crop area adopting cover crops or converted to prairie

5. Simulation Results – Cover Crops / No Till

One feasible way to increase infiltration at the watershed scale while keeping agricultural land in production is to utilize cover crops and no-till farming practices. Farmers typically plant cover crops after the harvest of either corn or soybeans and "cover" the ground through the winter until the next growing season begins. The cover crop can be killed off in the spring by rolling it or herbicide application; afterwards, row crops can be planted directly into the remaining cover crop residue. Cover crops provide a variety of benefits, including improved soil quality and fertility, increased organic matter content, increased infiltration and percolation, reduced soil compaction, and reduced erosion and soil loss.

To be clear, this scenario does not represent the conversion of the existing agricultural landscape (primarily row crops) to cover crops. Rather, the existing agricultural landscape is still mostly intact, but its runoff potential during the growing season has been slightly reduced by planting cover crops during the dormant season. To reap the full benefits of cover crops it is important that cover crops and no-till farming practices are implemented consistently for many years.

Like the native prairie scenarios, curve numbers were decreased by assuming row crop have curve numbers corresponding to the use of cover crops and no-till farming according to the conversion percentages and are shown in Figure 10. Using the design storms, we simulated these watershed scenarios along with the existing conditions as a baseline. Simulated flow at the outlet of Short Creek for each design storm and watershed scenario is shown in Figure 11. Peak flow reductions are summarized in Table 3. The peak flow reductions are less than those from the conversion to native prairie. The 100-percent utilization of cover crops has the largest peak flow reductions, averaging 11 percent across all the range of design storms. The 25- and 50-percent conversion scenarios have average peak flow reductions of 3 and 6 percent, respectively. These reductions come from increased infiltration rates via the curve number and slowing the travel time to each subbasin outlet. However, it should be noted these simulations are a single event over 24 hours. Typically, cover crops grown during the dormant season dry the soil during the spring over several weeks, adding capacity for rainfall events. This effect is not captured in these simulation results.

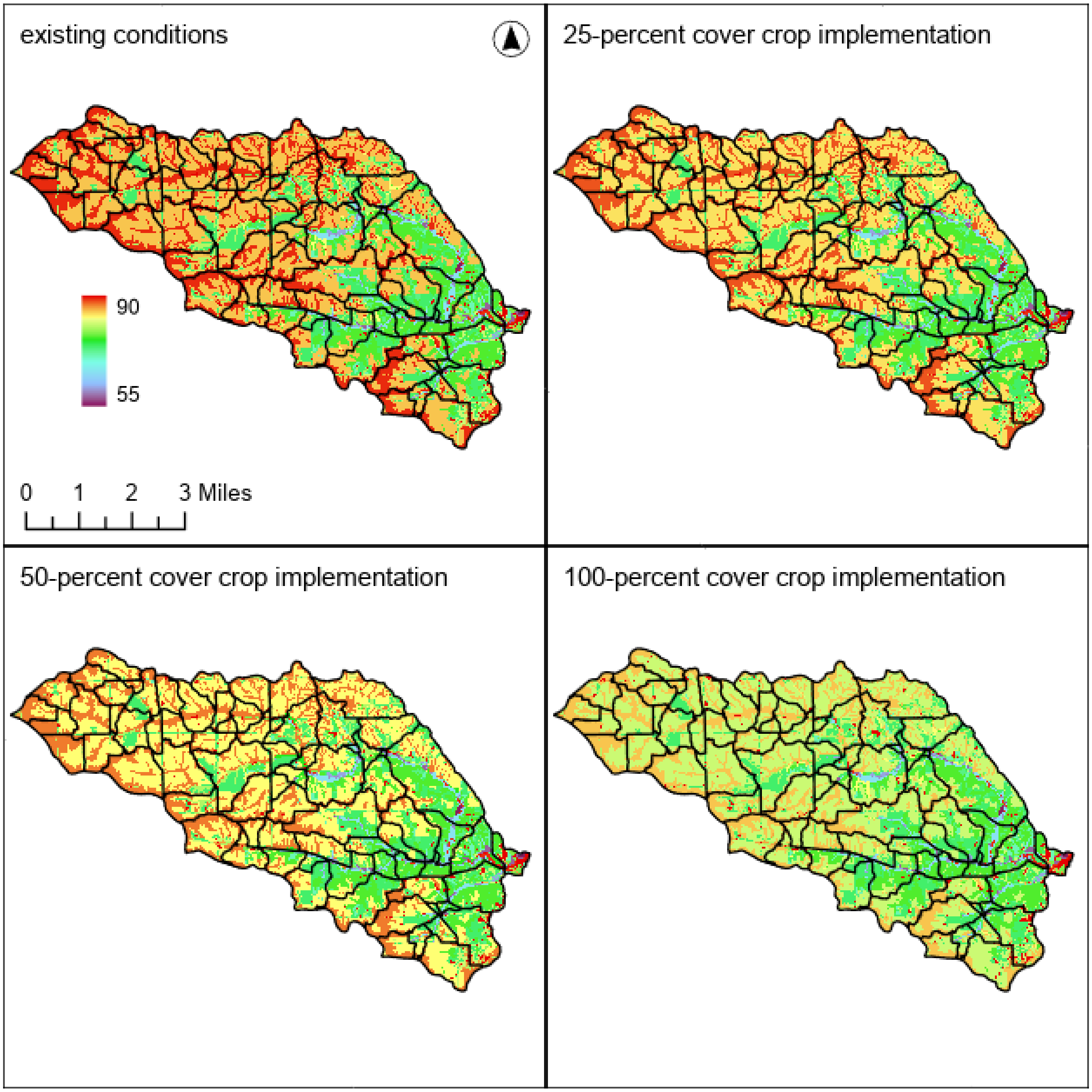

Figure 10. The existing SCS curve numbers were adjusted assuming a 25-, 50-, and 100-percent adoption of cover crops and no-till farming practices.

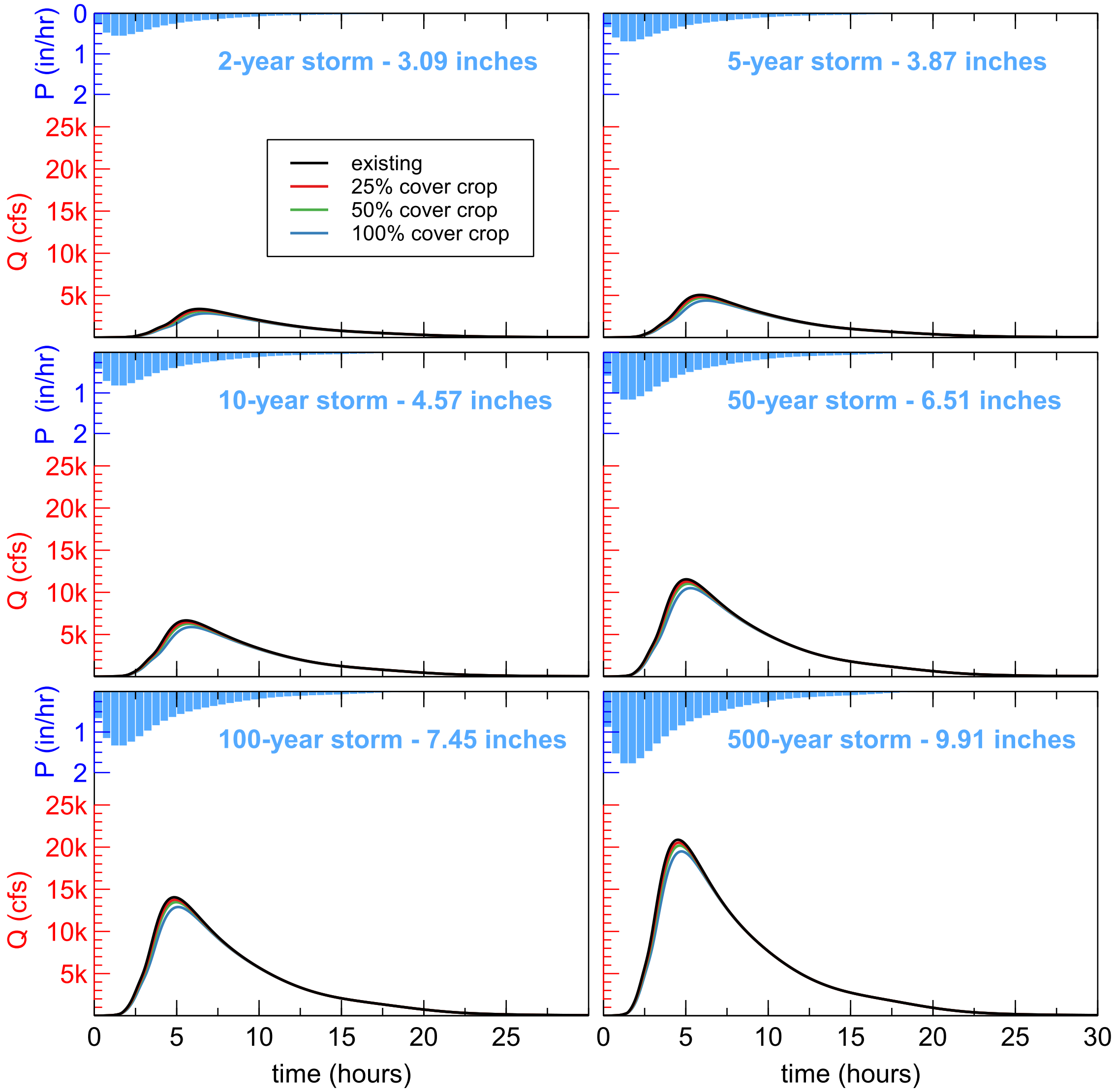

Figure 11. Simulation results from 25-, 50-, and 100-percent utilization of cover crops and no-till practices on agricultural land, shown with results from existing conditions. Rainfall time series shown on upper axis.

Table 3. Simulation results tabulated for 25-, 50-, and 100-percent utilization of cover crops and no-till practices on agricultural land.

return period			2-year	5-year	10-year	50-year	100-year	500-year
annual exceedance probability			50%	20%	10%	2%	1%	0.20%
existing flow (cfs)			3,396	5,055	6,669	11,545	14,052	20,871
cover crops	25% *	flow (cfs)	3,258	4,882	6,468	11,281	13,762	20,528
		% change	-4%	-3%	-3%	-2%	-2%	-2%
	50% *	flow (cfs)	3,125	4,713	6,271	11,017	13,471	20,183
		% change	-8%	-7%	-6%	-5%	-4%	-3%
	100% *	flow (cfs)	2,871	4,388	5,887	10,498	12,897	19,490
		% change	-15%	-13%	-12%	-9%	-8%	-7%

* percentage of row crop area adopting cover crops or converted to prairie

6. Simulation Results – Distributed Storage

In general, a system providing distributed storage, does not change the volume of water that runs off the landscape. Instead, storage ponds hold floodwater temporarily and release it at a slower rate, lowering the peak flood discharge downstream of the storage pond. The effectiveness of any one storage pond depends on its size (storage volume) and how quickly water is released.

This scenario assumed a typical detention pond was placed at the outlet of several selected headwater subbasins, shown in Figure 12. If implemented across the watershed, there would be site specific pond storage and outlet design details, but the typical ponds provide a convenient method to investigate impacts. The typical ponds have 20 acre-feet of storage available for flood storage below the emergency spillway. A smaller principal spillway pipe with a diameter of 12 inches releases lower flows while also attenuating flood peaks by throttling flows and consuming pond storage. The relationship between the pond storage and the dictated outflow is shown in Figure 13. Low flows are throttled until the emergency spillway is activated at 20 acre-feet. Additionally, the detention ponds were assumed to intercept 50% of the flow generated from their respective upstream subbasin. This was accomplished using a diversion structure within HEC-HMS.

Simulated flow at the outlet of Short Creek for each design storm with and without detention ponds are shown in Figure 14. Peak flow reductions are summarized in Table 4 for with and without detention ponds. Overall, the detention ponds provided similar flow reductions as the 100 percent utilization of cover crops but were still smaller than the 100 percent conversion to native prairie. The average peak flow reduction across all the design storms was 15 percent. The ponds typically provide the largest flow reductions immediately downstream of the pond project. Example simulation results showing inflow, storage and outflow at a single pond location are shown in Figure 15. This is an example of a large flow reduction of 60 percent. The flow reductions provided by ponds generally decrease moving downstream as more unregulated drainage area accumulates.

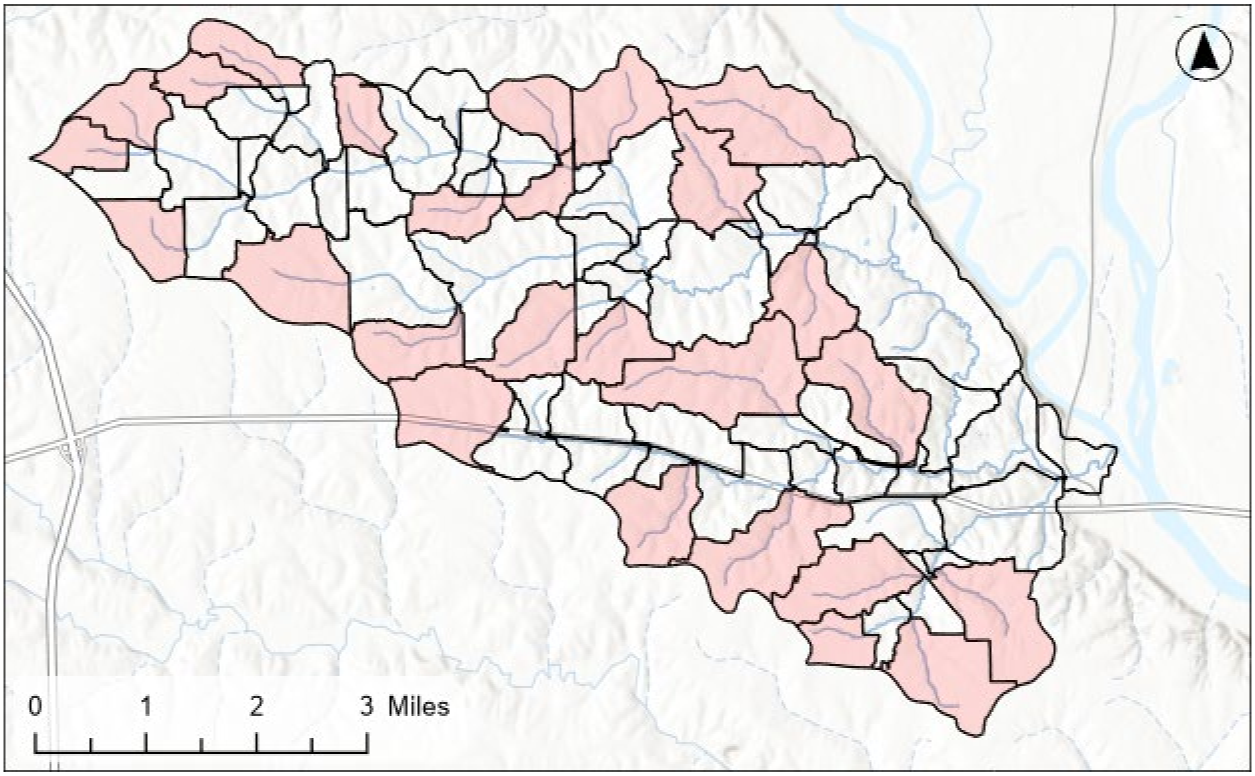

Figure 12. Detention ponds were implemented at the outlet of selected headwater subbasins (shown in pink).

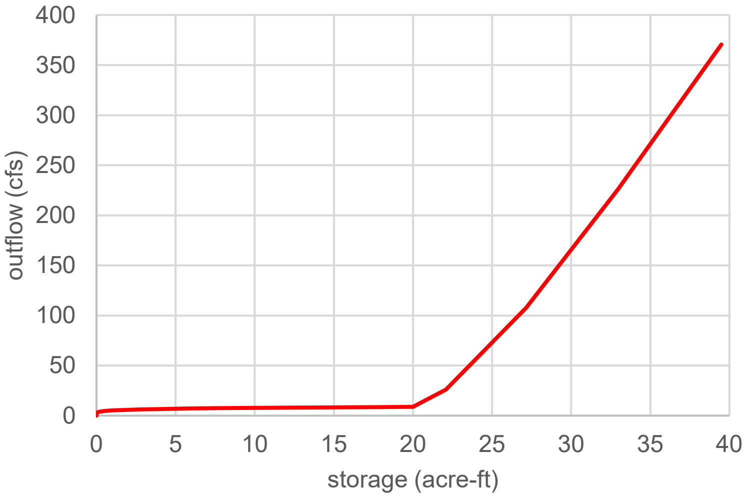

Figure 13. Detention pond behavior is dictated by a relationship between storage and outflow from a typical 20 acre-feet pond

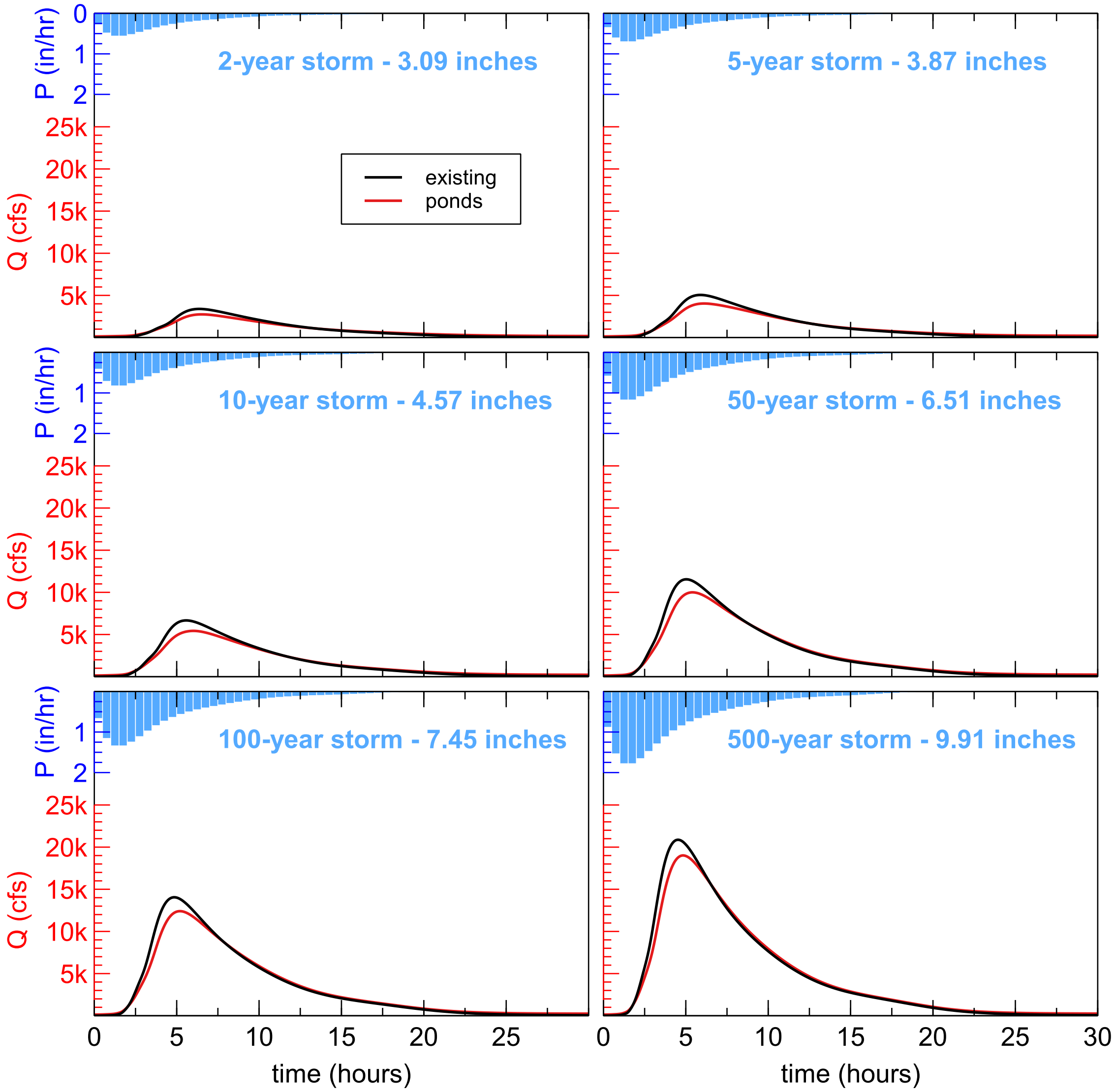

Figure 14. Simulation results using distributed pond storage, shown with results from existing conditions. Rainfall time series shown on upper axis.

Table 4. Simulation results using distributed pond storage.

return period annual exceedance probability		2-year 50%	5-year 20%	10-year 10%	50-year 2%	100-year 1%	500-year 0.20%
existing flow (cfs)		3,396	5,055	6,669	11,545	14,052	20,871
ponds	flow (cfs)	2,750	4,039	5,429	10,000	12,404	19,015
	% change	-19%	-20%	-19%	-13%	-12%	-9%

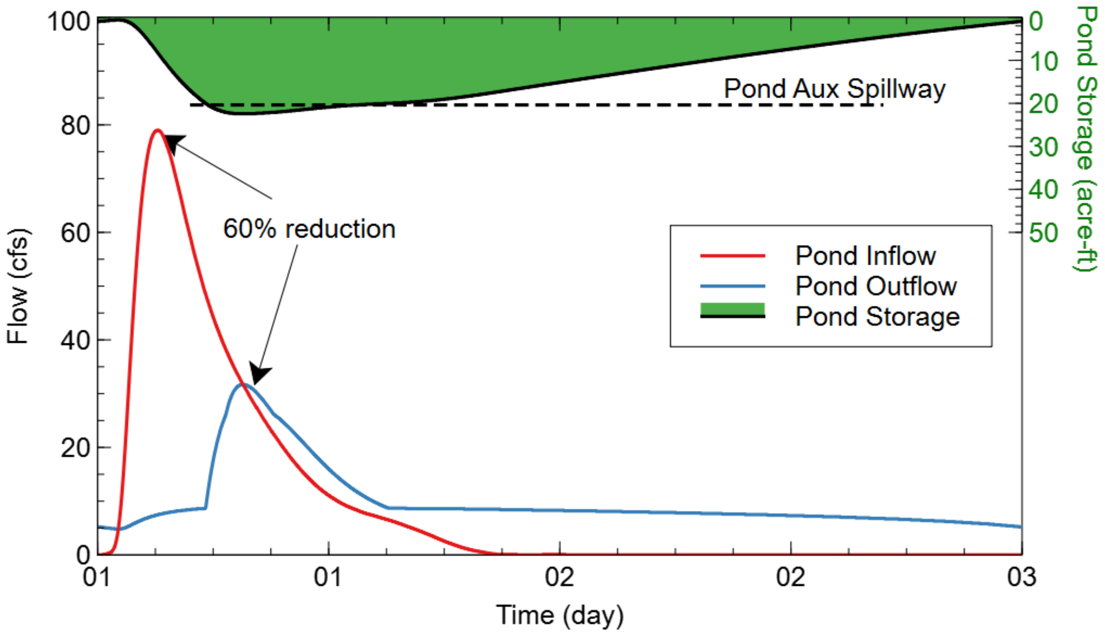

Figure 15. Example of individual detention pond inflow, outflow, and storage behavior for the 100-year design storm.

7. Summary and Recommendations

Our analysis revealed that broadscale changes to infiltration through conversion to native prairie provide significant flow reductions. However, implementing at the 50- or 100-percent conversion rate isn't feasible for many reasons. Utilization of cover crops and no-till farming practices at a watershed scale would be more economically feasible and would enhance soil infiltration and decrease runoff. Additional benefits of cover crops, like drying of the soil during spring, occur over long periods are not captured in presented simulation results. Cover crops would be a pathway to provide water quality benefits while keeping agricultural lands productive. Although the simulated peak flow reductions from cover crops are relatively small, their full range of benefits could be achieved over many years of consistent utilization. Constructing distributed storage ponds would also provide significant peak flow reductions, but like the broad scale land use changes would require significant investment and landowner participation. A summary of all the peak flow reductions is shown in Table 5. Even with any combination of these flood mitigation measures implemented across the watershed, it would be impossible to prevent flooding for most major rainfall events. This conceptual analysis can be leveraged by stakeholders to begin engaging with landowners and seeking funds for targeted implementation of these practices.

Table 5. Simulation results for all scenarios.

return period			2-year	5-year	10-year	50-year	100-year	500-year
annual exceedance probability			50%	20%	10%	2%	1%	0.2%
existing flow (cfs)			3,396	5,055	6,669	11,545	14,052	20,871
cover crops	25% *	flow (cfs)	3,258	4,882	6,468	11,281	13,762	20,528
		% change	-4%	-3%	-3%	-2%	-2%	-2%
	50% *	flow (cfs)	3,125	4,713	6,271	11,017	13,471	20,183
		% change	-8%	-7%	-6%	-5%	-4%	-3%
	100% *	flow (cfs)	2,871	4,388	5,887	10,498	12,897	19,490
		% change	-15%	-13%	-12%	-9%	-8%	-7%
prairie restoration	25% *	flow (cfs)	2,967	4,165	6,033	10,698	13,118	19,759
		% change	-13%	-18%	-10%	-7%	-7%	-5%
	50% *	flow (cfs)	2,585	4,016	5,444	9,887	12,218	18,658
		% change	-24%	-21%	-18%	-14%	-13%	-11%
	100% *	flow (cfs)	1,941	3,154	4,396	8,379	10,513	16,512
		% change	-43%	-38%	-34%	-27%	-25%	-21%
ponds		flow (cfs)	2,750	4,039	5,429	10,000	12,404	19,015
		% change	-19%	-20%	-19%	-13%	-12%	-9%

* percentage of row crop area adopting cover crops or converted to prairie

8. References

Hydrologic Engineering Center. (2023). *HEC-HMS User's Manual Version 4.12.* USACE.

Iowa Geospatial Data Clearinghouse. (2024). *LiDAR for Iowa Project.* Retrieved from https://geodata.iowa.gov/pages/lidar

Natural Resources Conservation Service, USDA. (1986). *TR-55 Urban Hydrology for Small Watersheds.* Washington D.C.: US Department of Agriculture.

Perica, S., Martin, D., Pavlovic, S., Roy, I., St. Laurent, M., Trypaluk, C., . . . Bonnin, G. (2013). *NOAA Atlas 14 Volume 8 Version 2.* Retrieved from Precipitation-Frequency Atlas of the United States, Midwestern States. NOAA, National Weather Service: https://hdsc.nws.noaa.gov/pfds/

Soil Survey Staff, NRCS, USDA. (2024). *Soil Survey Geographic Database (SSURGO).* Retrieved from Web Soil Survey: https://websoilsurvey.nrcs.usda.gov/

U.S. Geological Survey. (2023). *Annual National Land Cover Database (NLCD) Collection 1 Land Cover.* Retrieved from Science Products: U.S. Geological Survey data release: https://doi.org/10.5066/P94UXNTS