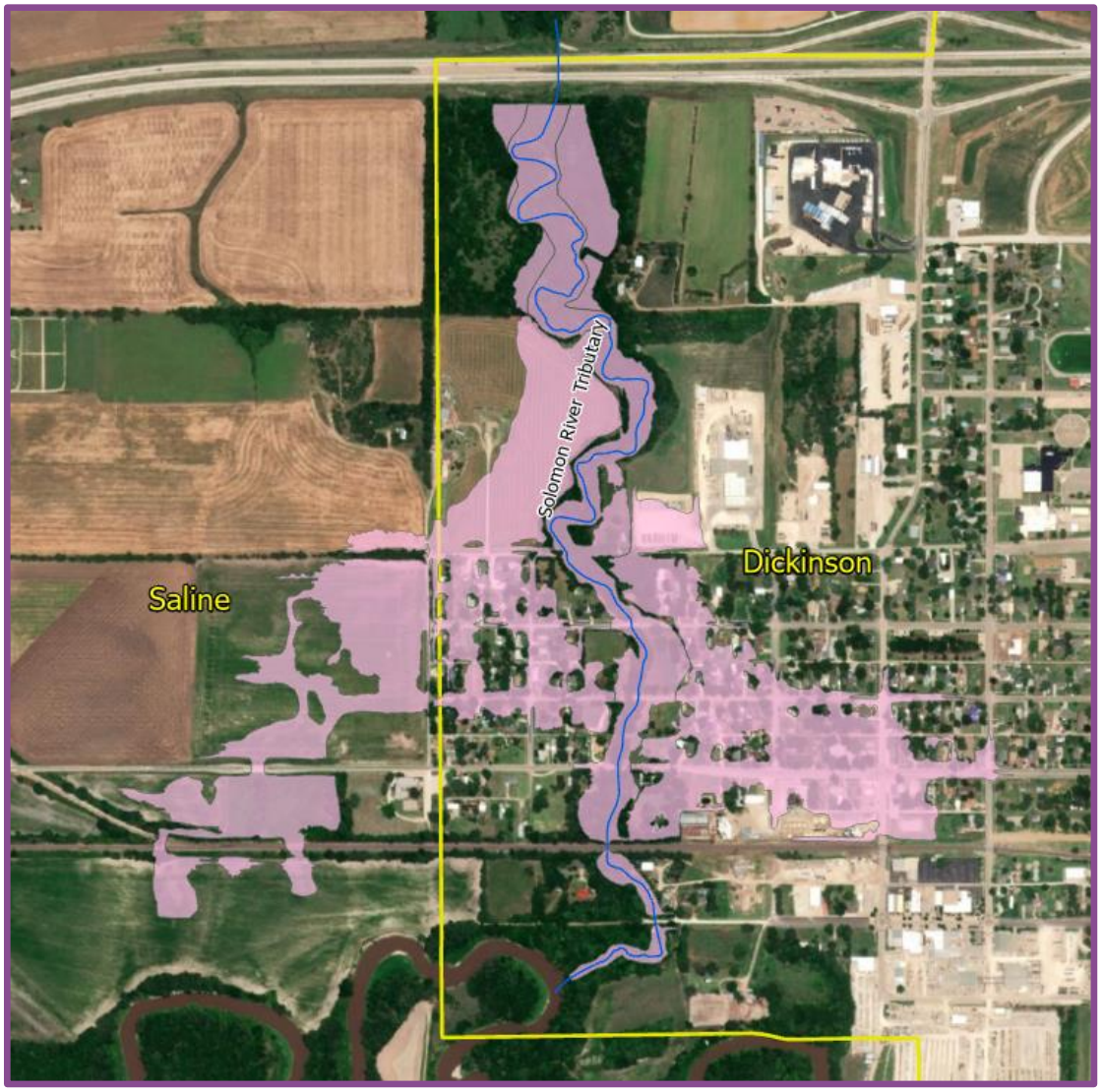
City of Solomon, Kansas

Technical Assistance Project

October 2020



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Division of Water Resources
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Introduction

The Kansas Department of Agriculture (KDA) received funding from FEMA to complete a technical assistance project for the City of Solomon, Kansas to investigate and present potential flood mitigation alternatives to reduce flooding issues in Solomon and the surrounding areas. There is no funding match requirement and no cost to the City of Solomon for this project.

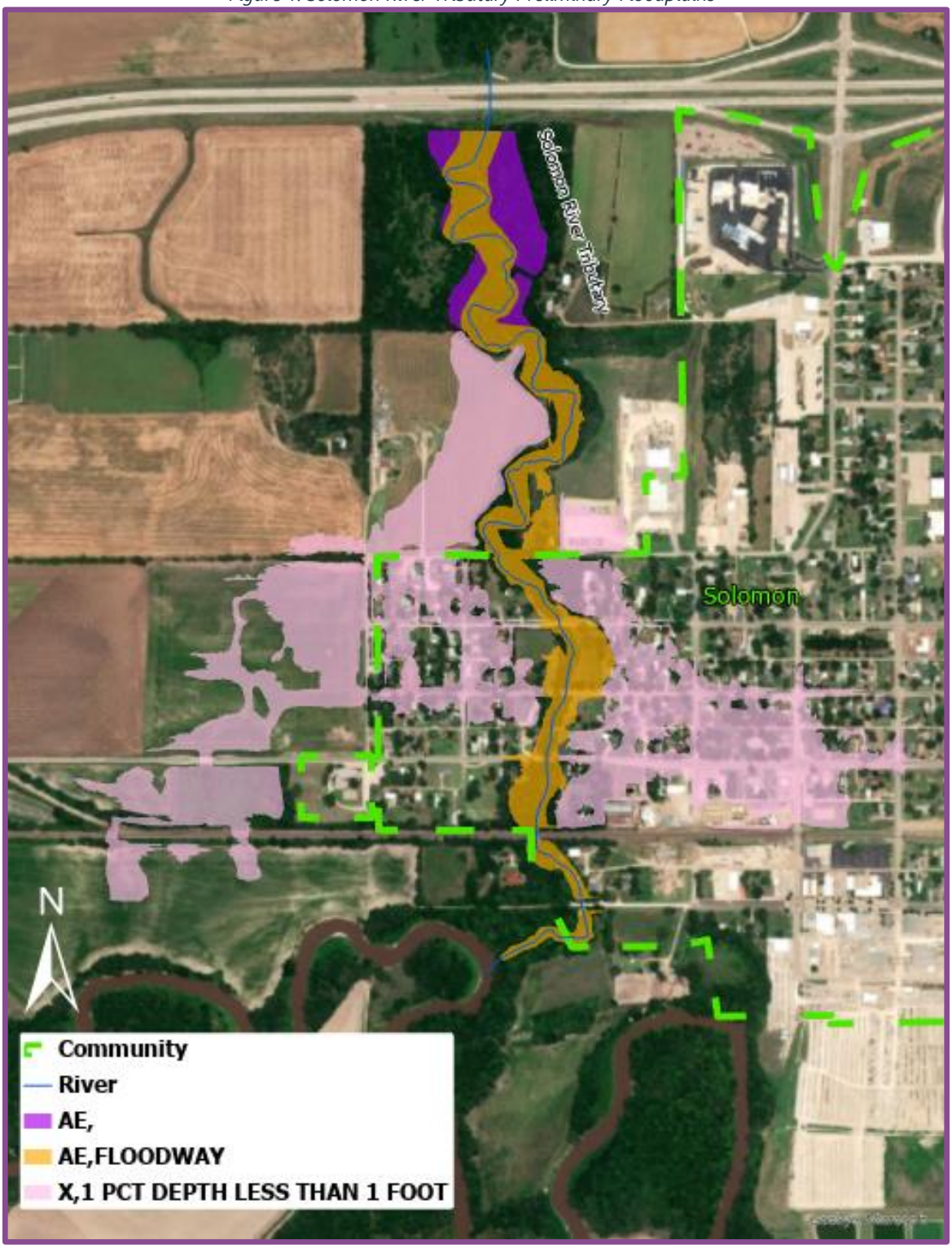
Wood was retained by KDA to provide Technical Assistance to the City of Solomon. The City of Solomon has been impacted by several past flood events including, but not limited to, the 1951 and 1993 flood. In these large events the flooding was primarily a result of backwater from the Solomon River and not headwater flows along the Solomon River Tributary. On May 24, 2007 a significant storm event impacted the areas around and within Solomon, KS. This event did not have significant backwater flooding from the Solomon River and was primarily influenced by headwater contributing flows of the Solomon River Tributary. Updated hydrologic and hydraulic modeling for the Solomon River Tributary was done as part of a floodplain mapping project for Dickinson County (Wood, 2018). The preliminary FIRM Panels are dated August 14, 2019. Due to missing information for the Solomon River, a revised preliminary date is necessary to ensure that all information is properly included. The revised preliminary date is anticipated to be January of 2021.

This report presents the alternative scenarios analyzed for the Solomon River Tributary as part of the technical assistance project. The project area covers portions of Dickinson and Saline Counties. The recent flood risk study update of the Solomon River Tributary indicates that the primary channel does not have enough capacity to convey the 1% annual chance design storm event. This would result in shallow overland flow, which could impact numerous existing structures. Figure 1 depicts the preliminary 1% annual chance floodplain through the City of Solomon from the Solomon River Tributary. The floodplains shown in figure 1 do not show the backwater effects from Solomon River.

Much of the area was noted as having average flood depths less than 1 ft, and therefore designated as Shaded Zone X – 1 percent depth less than 1-foot, which does not carry Flood Insurance requirements. However, given the potential flood risk in the community, it was identified by key stakeholders of the City of Solomon, Dickinson County, and KDA that flood mitigation studies would be beneficial for the community. On April 23, 2019, representatives of the KDA, City of Solomon, Dickinson County, and Wood Environment and Infrastructure Solutions, Inc (Wood) met to discuss the identified flood risk areas, identify goals for the project, and possible mitigation options.

In this study, cost effective mitigation improvements were identified that could potentially reduce the flood risk areas within the City of Solomon and not cause adverse impacts to the community.

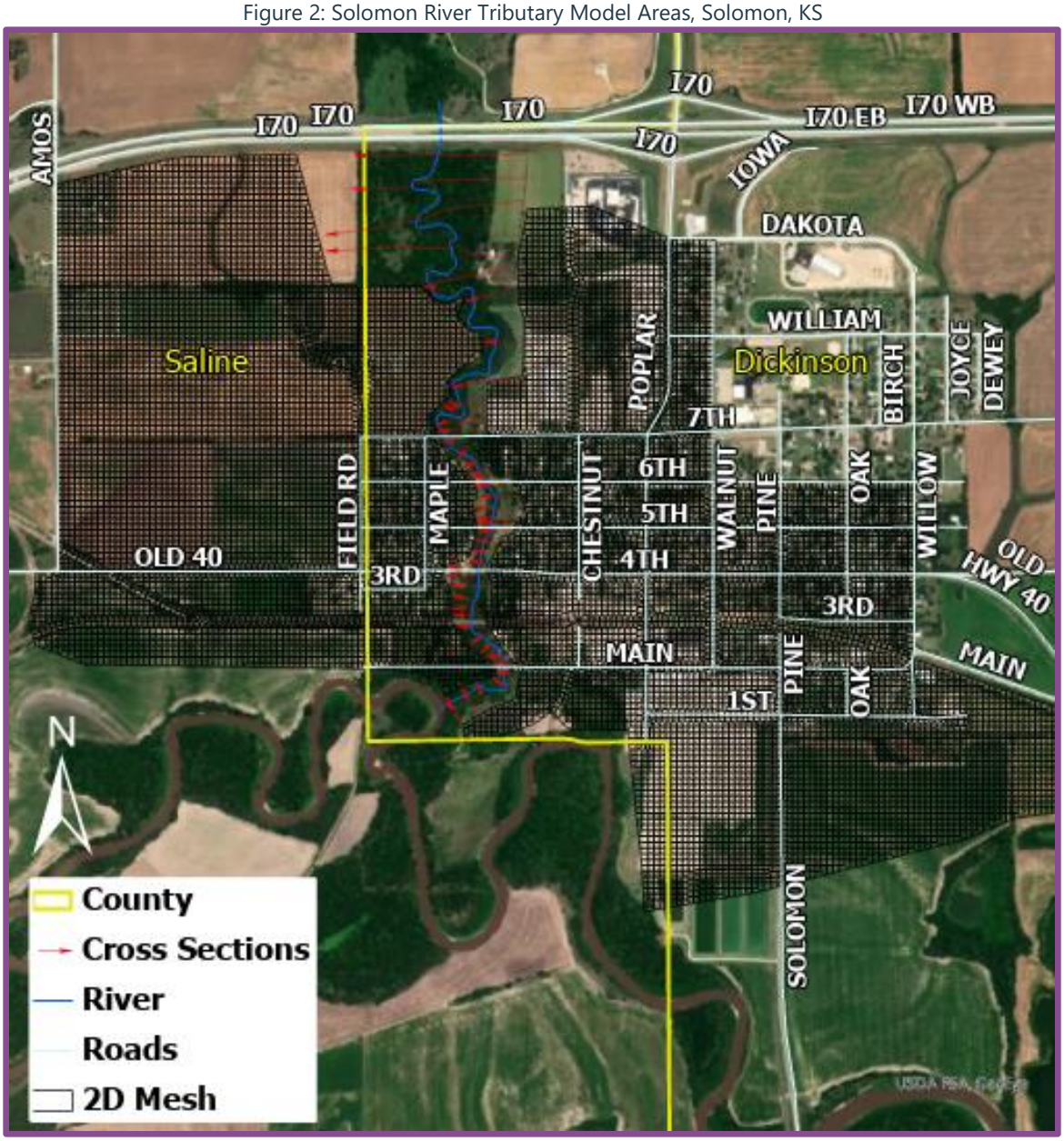
Figure 1: Solomon River Tributary Preliminary Floodplains



Existing Conditions Analysis

An unsteady-state, combined one-dimensional (1-D) and two-dimensional (2-D), Hydrologic Engineering Center's River Analysis System (HEC-RAS), version 5.0.5 (Hydrologic Engineering Center (HEC), 2019) model published by the United States Army Corps of Engineers (USACE) was used to analyze approximately 1.6 miles of the Solomon River Tributary, extending from its confluence with the Solomon River to Interstate 70. The Manning's n value used in the channel sections of the 1-D area ranged from 0.035 to 0.05. The Manning's n values used in the overbanks of the 1-D area ranged from 0.013 to 0.12. The Manning's n values in the 2-D area ranged from 0.013 to 0.12. The downstream boundary condition (starting water surface elevation) was established using the natural stream bed slope and normal depth methods.

Figure 2: Solomon River Tributary Model Areas, Solomon, KS



Initial results indicated there would be complex overland flow between the channel and overbanks; therefore, a combined 1-D and 2-D model was developed. As shown in Figure 2, 1-D analysis was used to compute water surface elevations within the channel areas while 2-D analysis were used to compute water surface elevations adjacent to the channel areas and those overland flow paths that drain away from the channel. Lateral weirs were utilized to represent flow going between the 1-D and 2-D areas. The area north of W 7th Street and the area inside the stream banks extending from the confluence of the Solomon River to 680 feet upstream of W 7th Street was modeled as a 1-D area, resulting in a Zone AE floodplain on the preliminary maps. The area outside of these boundaries south of W 7th Street was modeled as a 2-D area.

Boundary conditions for water exiting the 2-D areas were established on the southern edge of the 2-D boundary along the Solomon River using the natural ground slope and normal depth methods.

Generally, the overflow in the 2-D areas is sheet flow and shallow ponding water. An average area depth analysis was performed for the overflow areas within the 2-D areas. The average depths were 0.3 feet in the west overbank area and 0.5 feet in the east overbank areas. Given these shallow depths, it was agreed upon through discussions with the KDA and FEMA to designate these areas as shaded Zone X- 1 percent depth less than 1-foot floodplains on the preliminary maps, while the main channel conveyance would remain as Zone AE. Figure 1 depicts the preliminary floodplains for the City of Solomon in Dickinson and Saline Counties, with the sheet and shallow ponding areas shown in light pink. This figure does not show the backwater effects from Solomon River.

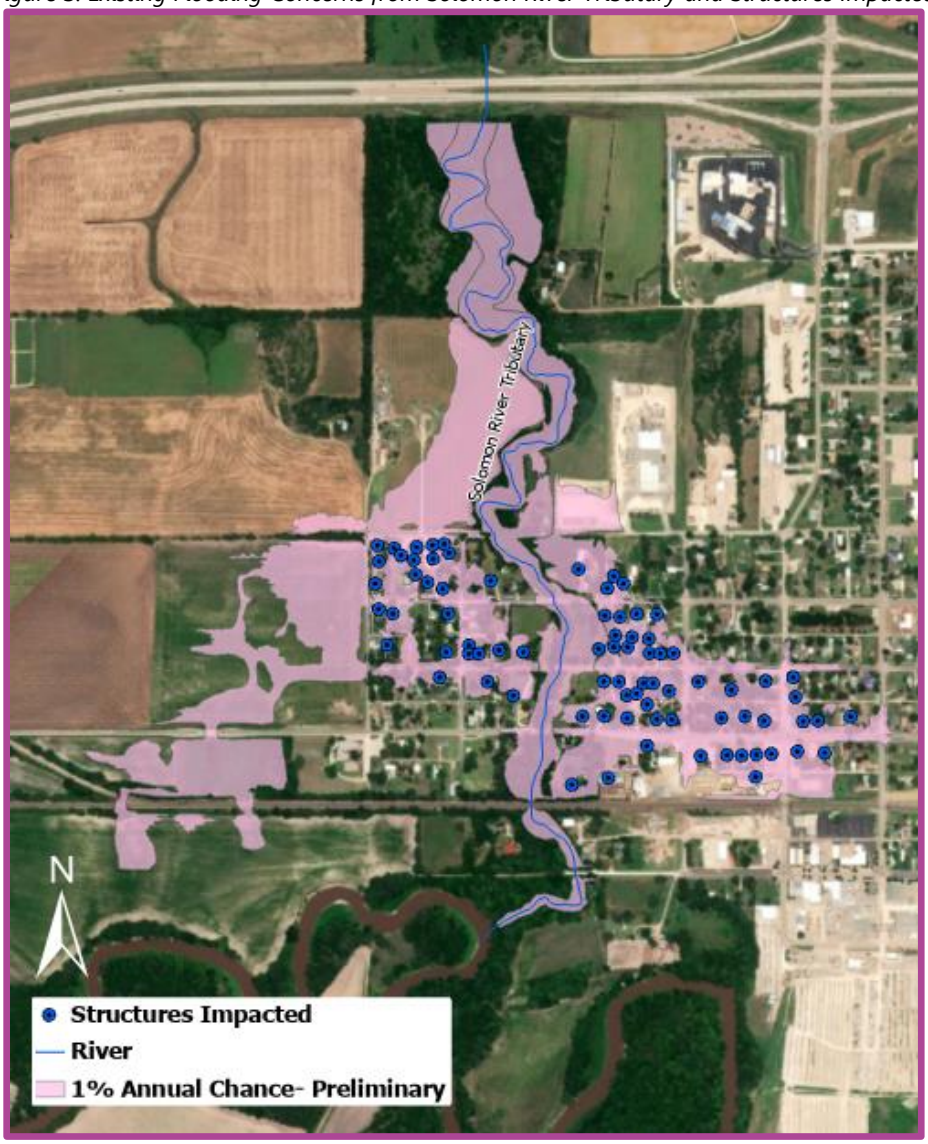
A floodway was also developed for the designated Zone AE 1-D areas. While a floodway was developed and shown in the 1-D areas between the 2-D overbank areas, extreme caution should be taken before developing adjacent to the Solomon River Tributary channel. In general, the 1% annual chance event exceeds the Solomon River Tributary channel and would normally overflow away from the channel into adjacent low-lying areas, reducing downstream impacts. Should development in these areas occur, it is possible that adverse impacts upstream, due to backwater, or downstream, due to increased flows, could result by blockages in the overflow paths.

Existing Conditions Flooding Concerns

The recent flood risk study update of the Solomon River Tributary indicates that the primary channel does not have enough capacity to convey the 1% annual chance design storm event. This would result in shallow overland flow, which could impact numerous existing structures.

In the City of Solomon, there are approximately 80 structures that are within the shaded Zone X- 1 percent depth less than 1-foot floodplains on the preliminary maps. These structures are shown in Figure 3. Approximately half of the town is included within the preliminary 1% annual chance floodplain.

Figure 3: Existing Flooding Concerns from Solomon River Tributary and Structures Impacted



Conceptual Mitigation Alternatives Analysis

Project Goals

Goals and objectives to identify flood mitigation alternatives were collectively agreed upon by representatives of Wood, KDA and representatives from the City of Solomon and Dickinson County and are listed below:

1. Remove as many structures as possible from the 1% annual chance floodplain and ultimately reduce the risk of flooding to these properties.
2. Avoid proposing detention or structures on land identified for future development.
3. Minimize long term and expensive maintenance costs.

Mitigation Alternatives

Conceptual flood mitigation alternatives, or scenarios, were developed by Wood as the analyses progressed and often built upon one another. The scenarios were evaluated predominately on their ability to reduce the 1% annual chance floodplain, but also on their ability to reduce impacts from headwater. An overview of the final five scenarios evaluated is shown in Table 1. In addition to analysing the improvement alternatives, Wood also produced budget level cost estimates for the improvements, which are discussed in sections to follow.

Table 1: Overview of Alternative Scenarios

Scenario	Description	Comments
0	Base model for existing conditions	The channel does not have enough capacity to convey the 1% annual chance design storm event. This scenario results in shallow overland flooding that impacts numerous structures.
1	Inline detention- Upstream of I-70	Wood will evaluate adding inline detention upstream of Interstate 70 to reduce flood frequency flows through the City of Solomon and ultimately reduce the flood risk areas. This will include for the evaluation of any upstream impacts and risks.
2	Bypass channel- Upstream of 7th Street	Wood will evaluate the construction of a bypass channel at/or just upstream of 7th Street. This bypass channel would take overflows from Solomon River Tributary to the west along 7th Street and to the south along Field Road, ultimately entering the Solomon River. The intent of this improvement would be to reduce the flood frequency flows and flood risk areas through the City of Solomon.
3	Bypass channel- Upstream of Railroad	Wood will evaluate the construction of a bypass channel at/or just upstream of the Railroad downstream of Old Highway 40. This bypass channel would take overflows from Solomon River Tributary to the west along the Railroad, ultimately entering the Solomon River. The intent of this improvement would be to reduce the flood frequency flows through the Railroad, reduce the headwater ponding caused by the railroad, and therefore reduce flood risk areas through the City of Solomon.
4	Channel improvements	Wood will evaluate enlargement of the existing channel capacity of the Solomon River Tributary and any structures along the channel, including the Railroad. The intent of these improvements would be to increase the natural channel capacity, reduce the hydraulic water surface elevations and therefore reduce the flood risk areas in the City of Solomon.
5	Buyouts	Wood will evaluate the cost effectiveness of buying out those structures within the 1% annual chance floodplain, both separately and in combination with the prior stated improvements. This is only within the AE zone, and not within the Shaded Zone X – 1% depth less than 1-foot zone.

Alternatives Analyses

The base model for existing conditions was used to create conceptual flood mitigation alternatives. The different scenarios are described in detail in the sections that follows.

Scenario 1- Inline Detention – Upstream of I-70

The rainfall-runoff model HEC-HMS version 4.2.1 (Hydrologic Engineering Center (HEC), 2017) was used to develop a conceptual dam north of town, behind Solomon Road. The goal of this scenario was to provide inline detention thereby reducing the flood frequency flows through the City of Solomon and ultimately reduce flood risk areas. This also included the evaluation of any upstream impacts and risks.

A detention pond was not considered just north of I-70 to avoid any potential adverse impact to the structure that is present there. The conceptual dam was modeled behind the Solomon Road and the area of the land that needs to be purchased for the detention facility was about 200 acres. The top of dam footprint for the modeled dam was approximately 120 acres. The top of dam elevation was set to 1,228 (NAVD88). The primary spillway is a 48-inch diameter pipe culvert, with a length of 120 feet, an inlet elevation of 1207.8 (NAVD88) and an outlet elevation of 1207.2 (NAVD88). A broad crested auxiliary spillway spanning 100 feet in length and set at an elevation of 1225 (NAVD88) was also added to the dam. The 100-year and 500-year peak elevations were determined as 1224.7 (NAVD88) and 1226.2 (NAVD88), respectively, based on the modeling performed.

In addition to the dam, the 4th Street structure was found to be a restriction to flood flows and was modified within the HEC-RAS model to reduce the restriction and thus reduce localized flooding within the city. The current structure, a 20-feet wide bridge opening, was modified to a triple 10 ft by10 ft box culvert structure. Note that similar benefits would be seen with a 30-feet wide bridge opening. Figure 4 shows the location that was chosen for the conceptual dam and the 4th Street structure described above. Figure 5 shows the resulting 1% annual chance floodplain for Scenario 1 compared to the preliminary floodplain. All 80 structures that were impacted were removed from the floodplain in this scenario.

Figure 4: Location of Scenario 1 Modifications

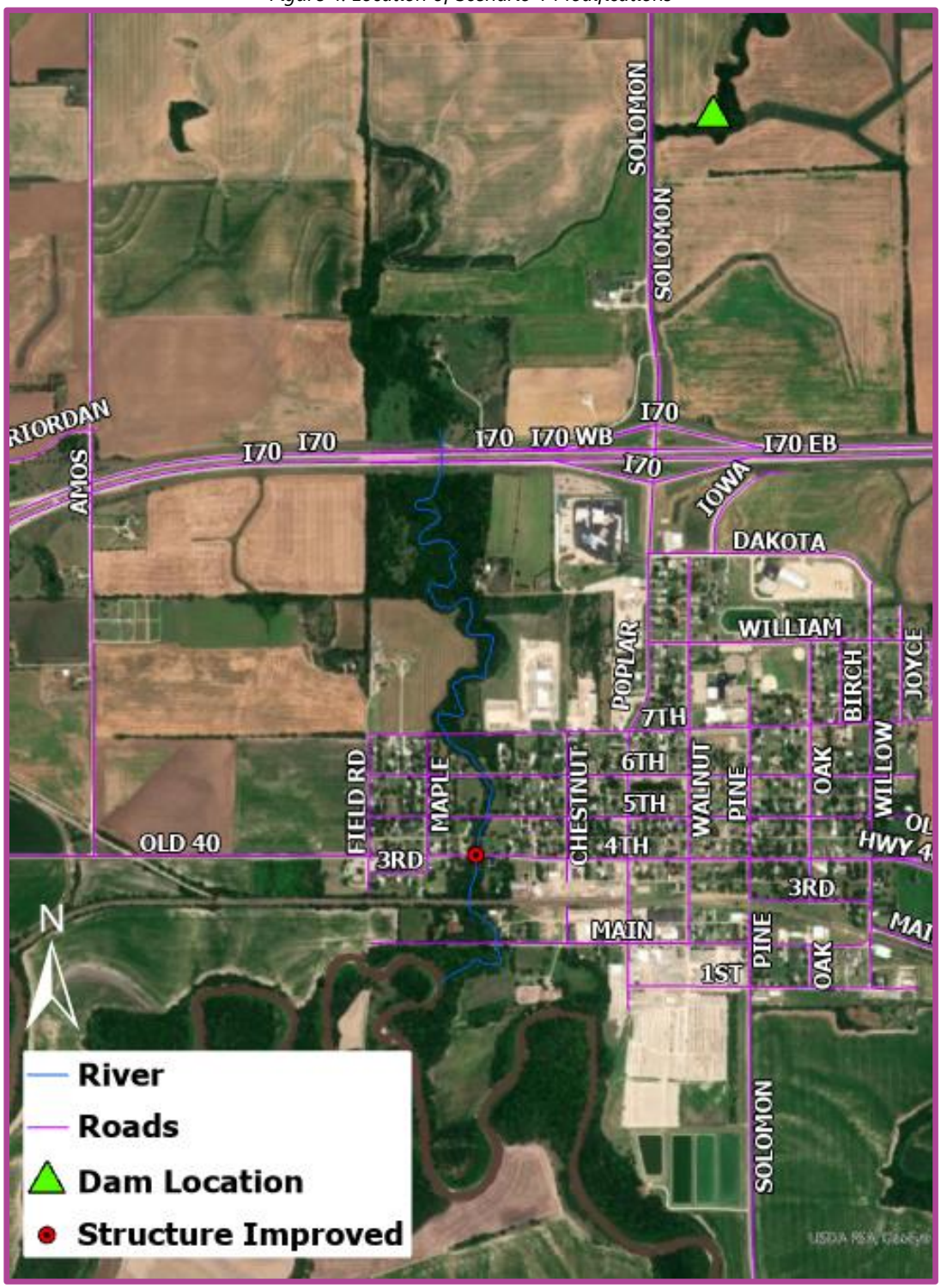
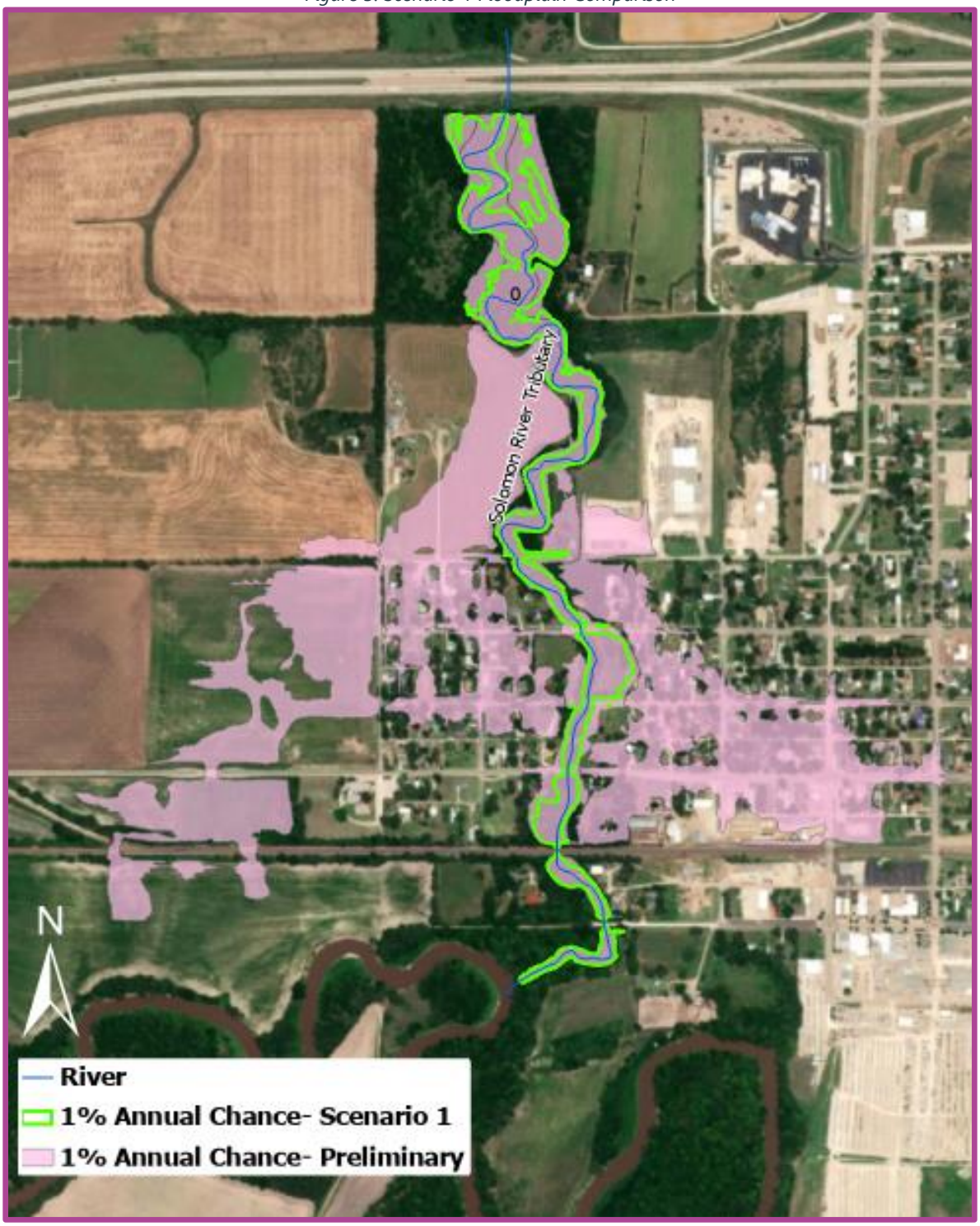


Figure 5: Scenario 1 Floodplain Comparison



Scenario 2- Bypass Channel – Upstream of 7th Street

A conceptual bypass channel was built in the HEC-RAS model, beginning upstream of 7th Street, to convey overflows from Solomon River Tributary to the west along 7th Street and to the south along Field Road, allowing water to ultimately enter the Solomon River to the south. The channel was developed utilizing a 4:1 slope with a top width of 50 feet and a bottom width of 20 feet. One structure, including a triple 8 ft by 8 ft box culvert, was added at N. Field Road. Additionally, the 5th Street and 4th Street structures, a triple 10 ft by 10 ft box culvert and a 20-feet wide bridge, respectively, were modified to allow more conveyance capacity, thus reducing flooding in the town. The existing 5th Street structure was modified to a quadruple 10 ft by 10 ft box culvert structure and the existing structure at 4th Street was modified to a triple 10 ft by 10 ft box culvert structure. Figure 6 shows the location of the bypass channel and the structures improvements included in Scenario 2. Figure 7 shows the resulting 1% annual chance floodplain for Scenario 2 compared to the preliminary floodplain. All 80 structures that were impacted were removed from the floodplain in this scenario.

Figure 6: Location of Scenario 2 Modifications

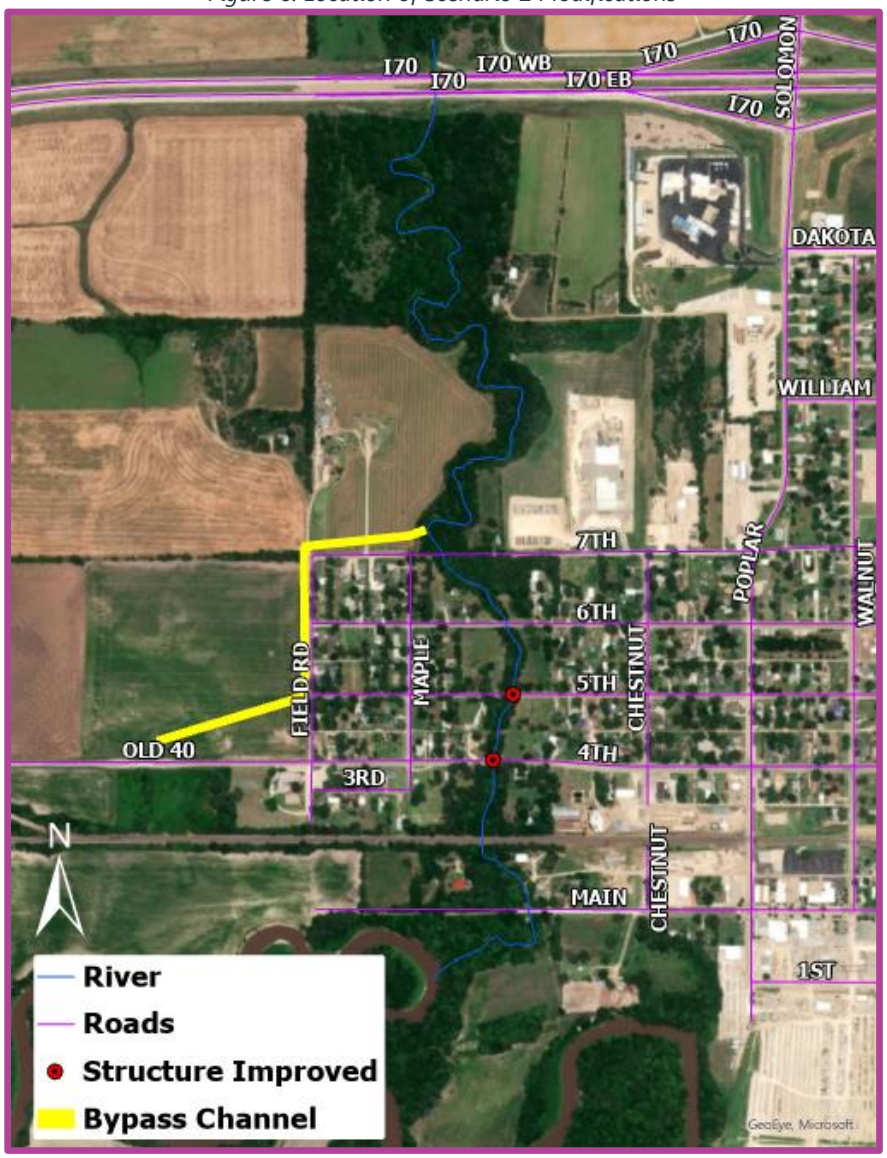
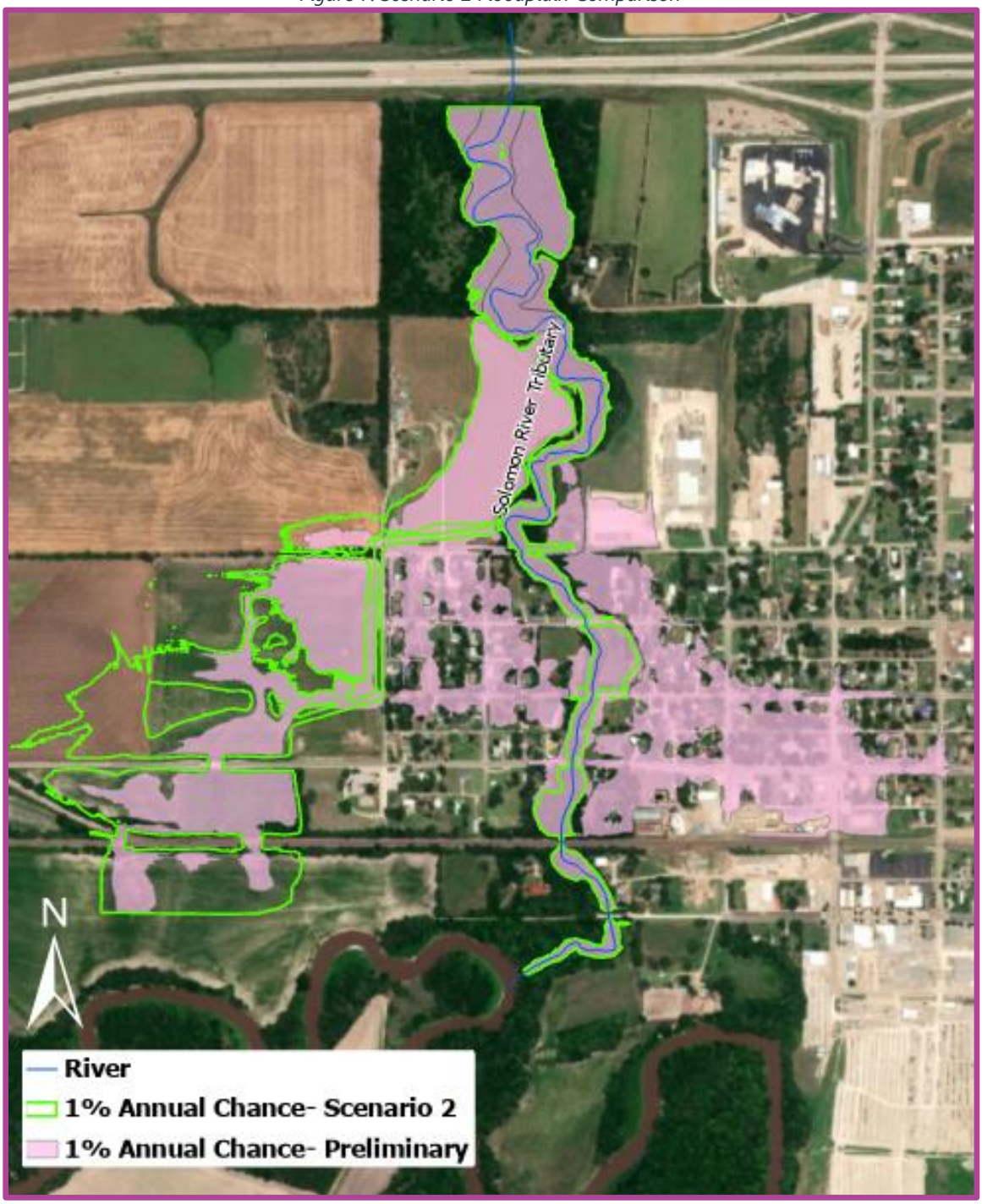


Figure 7: Scenario 2 Floodplain Comparison



Scenario 3- Bypass channel- Upstream of railroad

In this conceptual scenario, a bypass channel, 20 feet wide at the bottom and 50 feet wide at the top, was included in the HEC-RAS model, just upstream of the railroad downstream of Old Highway 40. The intent of this improvement was to reduce the flood frequency through the railroad, reduce the headwater ponding caused by the railroad, and therefore reduce the flood risk areas through the city. Additionally, the railroad structure was also modified with three additional 6 feet diameter CMP culverts. Figure 8 shows the location of the bypass channel and railroad structure. However, this conceptual scenario did not reduce the risk of flooding in the city, as shown in Figure 9 and only 8 structures were removed from the floodplain so it was determined that associated construction costs would not be evaluated for this Scenario.

Figure 8: Location of Scenario 3 Modifications

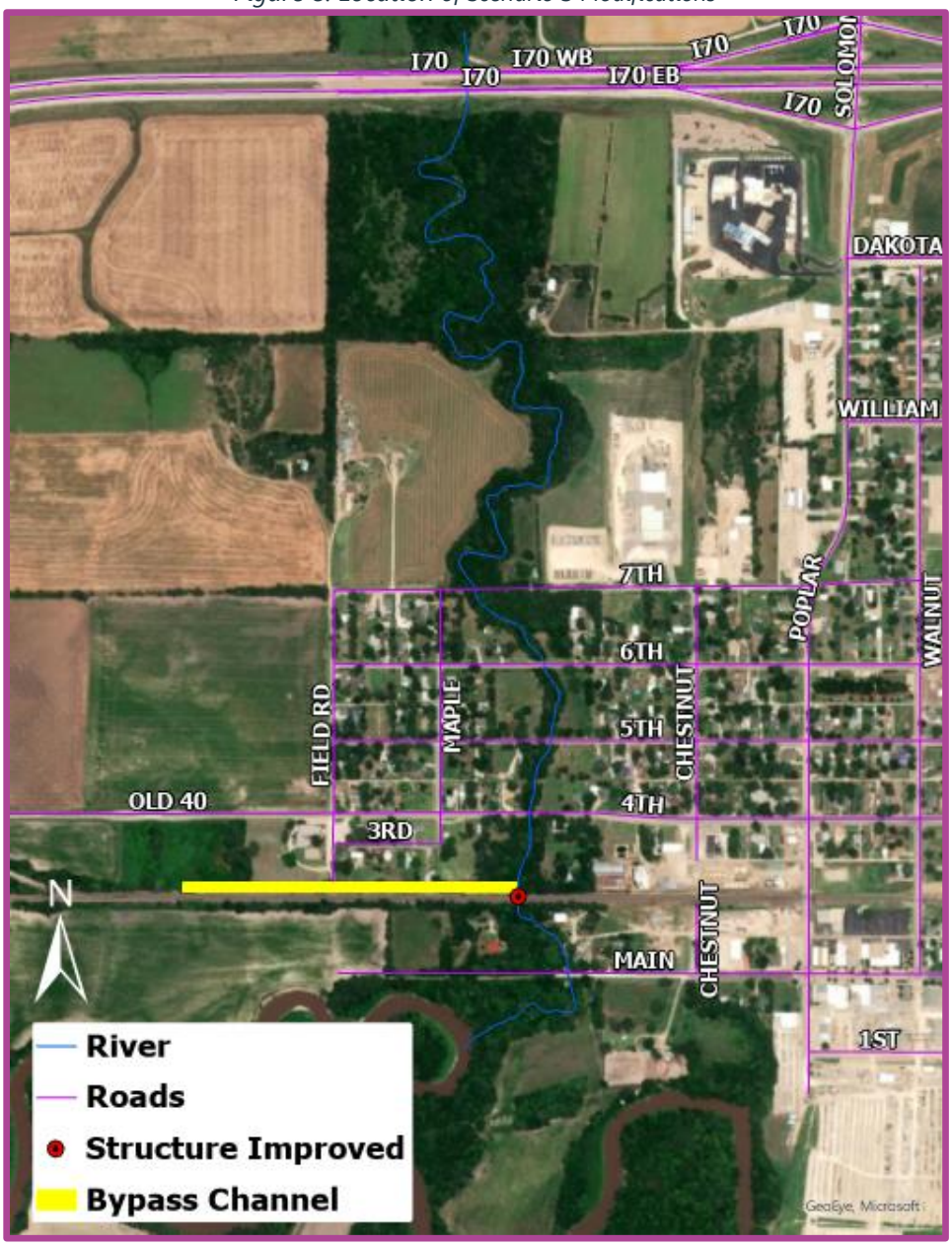
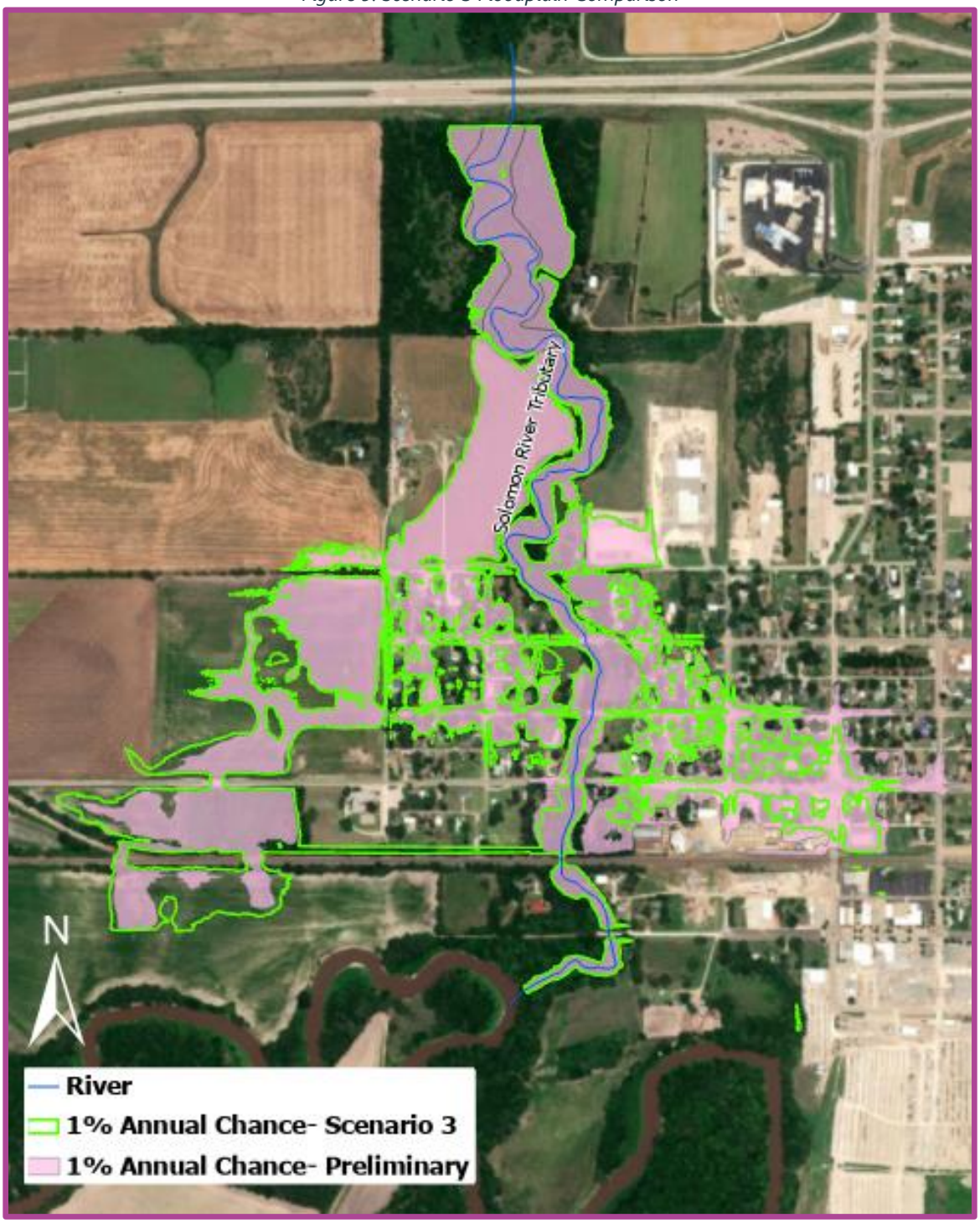


Figure 9: Scenario 3 Floodplain Comparison



Scenario 4- Channel Improvements

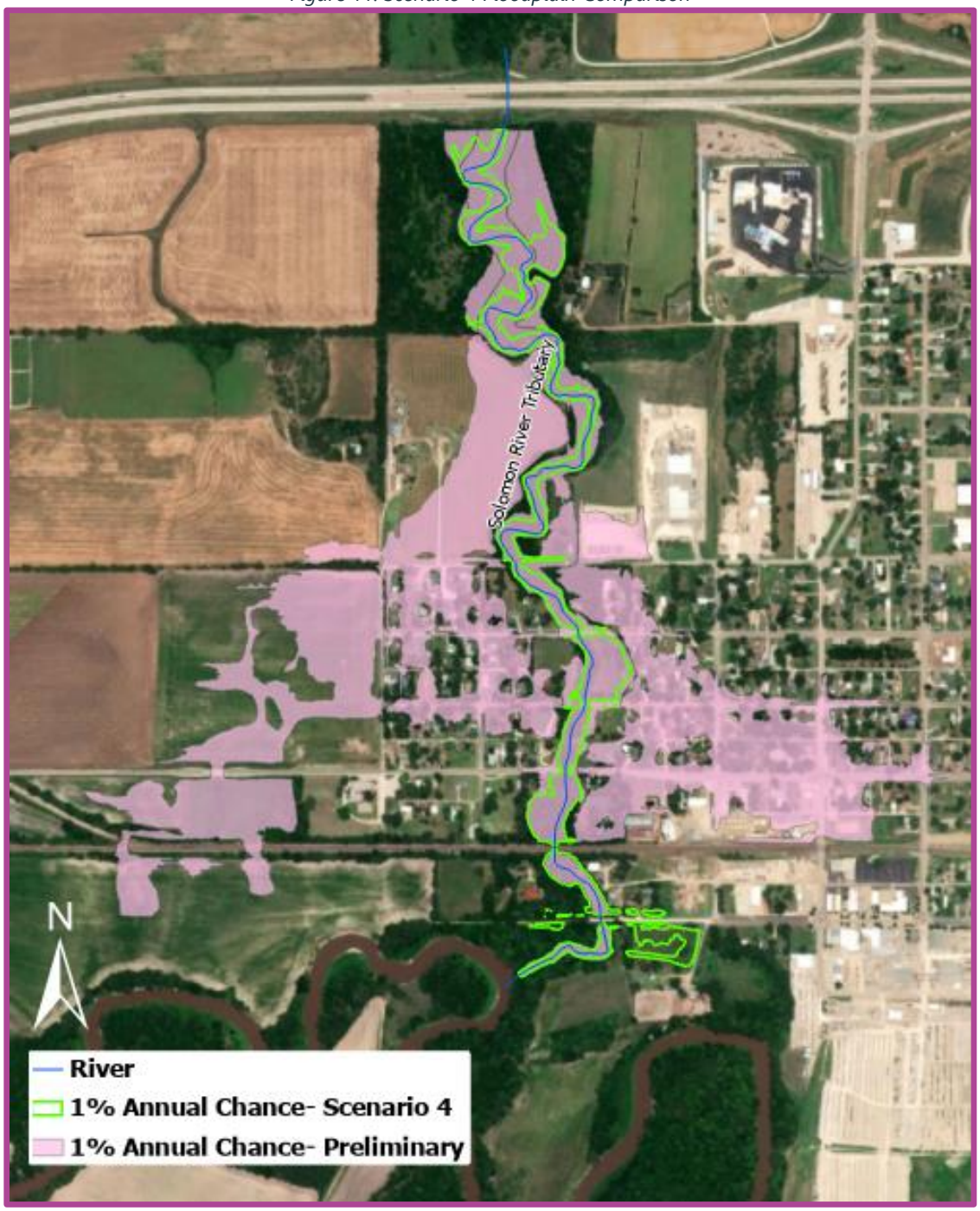
In this conceptual scenario, the existing channel capacity of the Solomon River Tributary was increased, and all the structures at road crossing through town were enlarged. The intent of these improvements was to increase the natural channel capacity, reduce the hydraulic water surface elevations and therefore reduce the flood risk areas in the City of Solomon. The channel was widened to 50 feet with a 3:1 slope and a Manning's n value of 0.035. Table 2 lists the modifications that were made to the structures. Figure 10 shows the extent of the channel modifications and the structures that were improved for this scenario. The impact of channel and structure modifications is shown in Figure 11. All 80 structures that were impacted were removed from the floodplain in this scenario.

Table 2: Structure modifications

S. No.	Structure name	Existing	Modification
1	7th Street	25 feet bridge	4- 12X10 feet box culvert
2	6th Street	3- 10X10 feet box culvert	5- 10X10 feet box culvert
3	5th Street	3- 10X10 feet box culvert	5- 10X10 feet box culvert
4	4th Street	20 feet bridge	5- 10X10 feet box culvert
5	Rail Road	1-10X15 feet box culvert	1-10X15 box culvert + 3- 6 feet CMP culvert
6	Main Street	17 feet CMP culvert	No change

Figure 10: Location of Scenario 4 Modifications

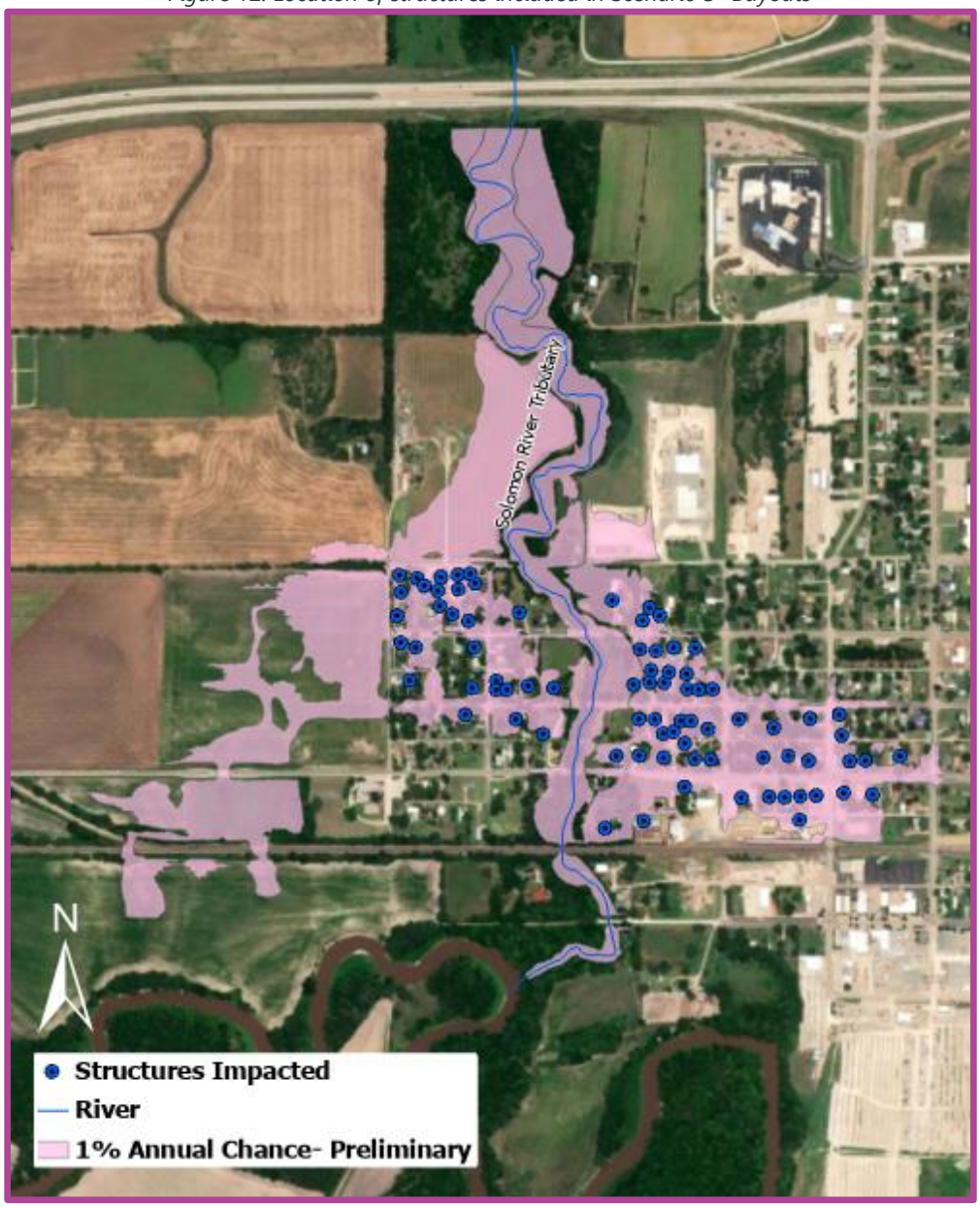
Figure 11: Scenario 4 Floodplain Comparison



Scenario 5- Buyouts

With many flood mitigations projects, buyouts are usually an option. In Solomon, there are approximately 80 structures that are within the shaded Zone X- 1 percent depth less than 1-foot floodplains on the preliminary maps. These structures are shown in Figure 12. Approximately half of the town is included within the preliminary 1% annual chance floodplain. This option would not remove the areas from flood risk, but instead remove structures from the 1% annual chance flooding event, and therefore eliminating the associated damages. However, pursuing buyouts would have a significant economic and social impact to the City of Solomon. The total cost estimates for buyouts was assumed to not be socially & economically feasible, and thus was not determined.

Figure 12: Location of structures included in Scenario 5- Buyouts



Conceptual Cost Estimates

Budget level cost estimates were developed for Conceptual Mitigation Scenarios 1, 2, and 4 described in the previous section of the report. These cost estimates are presented in Table 3.

Table 3: Budget level cost estimates for the Conceptual Mitigation Scenarios 1, 2, and 4

Scenario	Preliminary Construction Estimate	Contingency (30%)	Land Purchase	Project Costs	Total Project Probable Cost
1	$ 1,020,250	$ 306,075	$ 600,000	$ 255,062.5	$ 2,181,400
2	$ 889,000	$ 266,700	$ 52,000	$ 266,700	$ 1,474,400
4	$ 1,976,000	$ 592,800	N/A	$ 494,000	$ 3,062,800

The total project cost includes construction cost, contingency cost, land purchase (if any) and project cost, which would include legal, fiscal, financing, engineering design, construction administration, inspection, and staking.

Capital costs were compiled from manufacturer's data and construction bid tabulations from other similar projects. These values include the cost of materials, tools and equipment necessary for construction and installation of the described modifications. Allowances based upon a percentage of the total capital or specific defined portions of the capital work have been used for certain aspects of the work that are not yet well defined. This level of costing is consistent with industry standards and contains a contingency to cover unforeseen items that will develop during the engineering phase of the project.

A full itemized breakdown for the cost estimates for each of these scenarios is presented in Tables 4, 5 and 6.

Table 4: Cost estimates for Scenario 1 i.e. Inline Detention- Upstream of I-70

S. No.	Description	Quantity	Unit	Unit Costs	Total Costs
Detention Dam					
1	Detention Dam and Earthwork	110,000	CY	$5	$550,000
2	Principle Spillway (48" RCP)	145	LF	$350	$50,750
3	Emergency Spillway	100	LF	$150	$15,000
4	Traffic Control	1	LS	$5,000	$5,000
5	Erosion Control	1	LS	$12,000	$12,000
4th Street Structure Improvements					
6	10' X 10' RCB	150	LF	$1,150	$172,500
7	Concrete Headwall for RCB	2	EA	$55,000	$110,000
8	Remove and replace pavement	50	LF	$200	$10,000
9	Utility conflict resolution	1	LS	$5,000	$5,000
Miscellaneous					
10	Site Clearing and Restoration*	1	LS	$90,000	$90,000
PRELIMINARY COSTRUCTION ESTIMATE					**$1,020,250**
Contingency @ 30%					$306,075
Land Purchase for Detention Facility (200 Acres @ $4,500/Acre)					$600,000
Project Costs @ 25%**					$255,062.50
TOTAL PROJECT PROBABLE COSTS					**$2,181,400**

**Includes seeding*
***Does not include any easement acquisitions*

Table 5: Cost estimates for Scenario 2 i.e. Bypass Channel- Upstream of 7th Street

S. No.	Description	Quantity	Unit	Unit Costs	Total Costs
Bypass channel and Field Road (new structure addition)					
1	Channel Excavation	21,000	CY	$9	$189,000
2	8' X 8' RCB	150	LF	$1,000	$150,000
3	Concrete Headwall for RCB	2	EA	$55,000	$110,000
5th Street Structure Improvements					
4	10' X 10' RCB	40	LF	$1,150	$46,000
5	Concrete Headwall for RCB*	2	EA	$18,000	$36,000
6	Remove and Replace Pavement	50	LF	$200	$10,000
4th Street Structure Improvements					
7	10' X 10' RCB	120	LF	$1,150	$138,000
8	Concrete Headwall for RCB	2	EA	$55,000	$110,000
9	Remove and Replace Pavement	50	LF	$200	$10,000
Miscellaneous					
10	Utility Conflict Resolution	1	LS	$15,000	$15,000
11	Traffic Control	1	LS	$10,000	$10,000
12	Erosion Control	1	LS	$15,000	$15,000
13	Site Clearing and Restoration**	1	LS	$50,000	$50,000
PRELIMINARY COSTRUCTION ESTIMATE					**$889,000**
Contingency @ 30%					$266,700
Land Purchase for Detention Facility (8 Acres @ $6,500/Acre)					$52,000
Project Costs @ 30%* **					$266,700
TOTAL PROJECT PROBABLE COSTS					**$1,474,400**

**Since a new headwall is not required for 5th Street, the estimate is provided only for the new cell that will be added.*
***Includes seeding*
****Includes some flood easement acquisition on farm field*

Table 6: Cost estimates for Scenario 4 i.e. Channel Improvements

S. No.	Description	Quantity	Unit	Unit Costs	Total Costs
Channel Excavation					
1	Channel Excavation	19,000	CY	$9	$171,000
7th, 6th, 5th, 4th Streets and Railroad Structure Improvements					
2	12' X 10' RCB	160	LF	$1,350	$216,000
3	10' X 10' RCB	360	LF	$1,150	$414,000
4	Concrete Headwall for RCB	6	EA	$60,000	$360,000
5	Bore & Jack Rail Road Crossing 72" RCP	200	LF	$2,500	$500,000
6	Concrete Headwall for 3-72" RCP's	2	EA	$45,000	$90,000
7	Remove and Replace Pavement	200	LF	$200	$40,000
Miscellaneous					
8	Utility Conflict Resolution	1	LS	$70,000	$70,000
9	Traffic Control	1	LS	$25,000	$25,000
10	Erosion Control	1	LS	$15,000	$15,000
11	Site Clearing and Restoration*	1	LS	$75,000	$75,000
PRELIMINARY COSTRUCTION ESTIMATE					**$1,976,000**
Contingency @ 30%					$592,800
Project Costs @ 25%**					$494,000
TOTAL PROJECT PROBABLE COSTS					**$3,062,800**

**Includes seeding*
***Includes some temporary and permanent easement acquisitions*

Conclusion

The purpose of this project was to investigate and present flood mitigation alternatives to the City of Solomon and the KDA that address flood risk for the preliminary 1% annual chance event associated with the Solomon River Tributary. Five alternative scenarios were evaluated and ultimately three of those scenarios were chosen as feasible options for budget level cost estimating.

The recent modeling performed for the Solomon River Tributary indicates that the primary channel does not have enough capacity to convey the 1% annual chance design storm event. This results in shallow overland flow outside of the channel banks, which impacts numerous existing structures in the City of Solomon.

In this study, cost effective mitigation improvements were identified that could reduce the flood risk areas within the City of Solomon and not cause adverse impacts to the community. The scenarios were evaluated on their ability to reduce the impacts from the 1% annual chance floodplain, but also on their ability to reduce impacts from headwater. Three of the scenarios evaluated would remove all the houses and businesses in the City of Solomon, from the 1% annual chance floodplain that is associated with the

Solomon River Tributary. Also, it should be noted that flood mitigation alternatives were developed without considering the backwater effects from the Solomon River.

While the homes and businesses in the Zone X floodplain are not required to purchase flood insurance, residents should still consider purchasing flood insurance, which could be purchased at a comparatively-cheaper Preferred Risk Policy rate when located outside of the Zone A or Zone AE floodplain. Ultimately, it is up the City of Solomon to determine whether to pursue a Mitigation option, keeping the City's specific needs, concerns, and budgetary requirements in mind.

References

Hydrologic Engineering Center (HEC). (2017, March). Hydrologic Modeling System (HEC-HMS), Version 4.2.1. United States Army Corps of Engineers (USACE).

Hydrologic Engineering Center (HEC). (2019, March). River Analysis System (HEC-RAS), Version 5.0.7. US Army Corps of Engineers (USACE).

Wood. (2018). *Hydraulic Report for the Lower Smoky Hill Watershed (Volume I- Dickinson County, Marion County, and Ottawa County, KS).*

Exhibit A

Digital Data

- HEC-HMS Model developed for the Solomon River Tributary
- HEC-RAS Model developed for the Solomon River Tributary
- 1% Annual Chance Preliminary Floodplain
- 1% Annual Chance Floodplains for the different scenarios