Section 5
Storage Area Conceptual Design

5.1 Introduction

The results of the hydrologic, hydraulic, and storage area site evaluation discussed in the previous sections of this report formed the foundation for developing conceptual storage basin designs. The conceptual design depends on local drainage, existing FEMA floodways, and the City of Lincoln design criteria for storage facilities as stated in the City's Drainage Criteria Manual.

5.2 Background

The storage area site evaluation identified two of the four proposed locations (Middle Creek and Oak Creek sites) as being the most effective storage areas. The initial site evaluation found that these sites ultimately have a significant impact reducing local flooding, as well as flooding along Salt Creek. One of the two identified sites is along Middle Creek, south of A Street, between SW 27th and SW 40th Streets. The second identified site is on Oak Creek, near the airport and includes an upstream and downstream storage area. The Oak Creek upstream storage area is located west of the airport runway and south of Lincoln Air Park. The downstream Oak Creek area is south of the Air National Guard base. Figure 5-1 shows site selections for conceptual design.

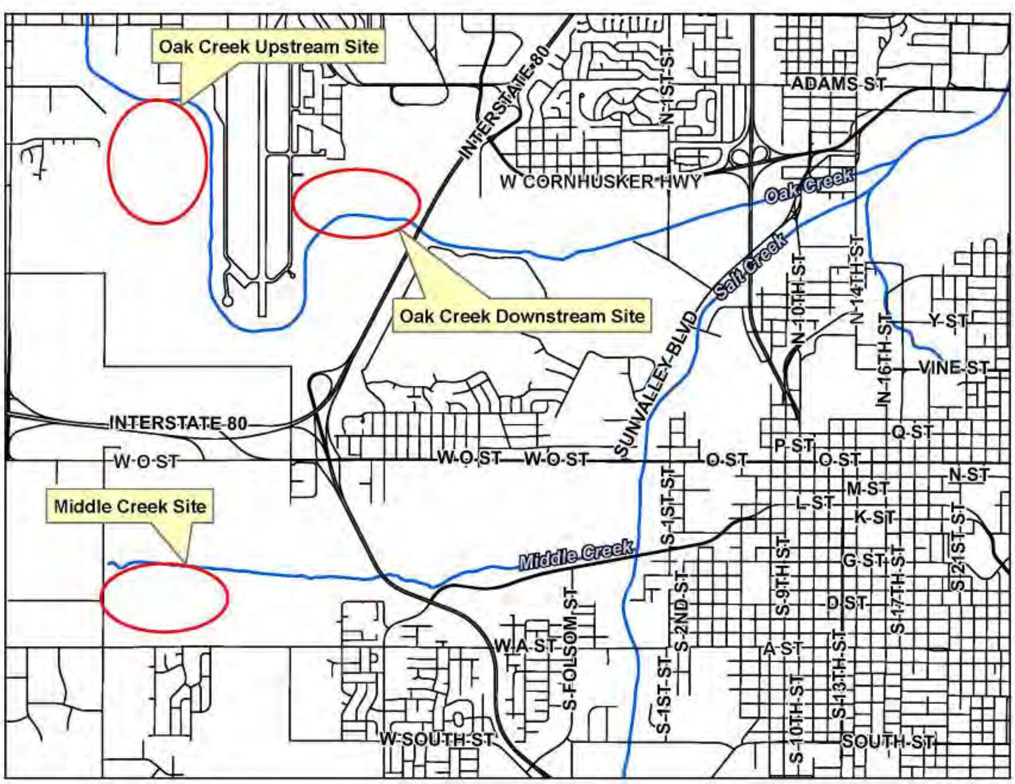

Figure 5-1 Offline Storage Sites Analyzed

For all these sites, local drainage and local drainage routing were taken into account. Local drainage needed to be routed around or through the proposed storage basins in such a manner that storage volume in the basins was not reduced from local runoff. In the City of Lincoln, drainage that is rerouted must be replaced with twice the original length. Also, it is important to consider existing floodways. Locating storage areas within the floodway results in a loss of conveyance area and will leads to water surface elevation and flow problems upstream of the intended storage areas.

As far as storage facility design, the City of Lincoln Drainage Criteria Manual states:

> *The bottom area of storage facilities shall be graded toward the outlet to prevent standing water conditions. A minimum 2 percent bottom slope is required on unpaved areas. A low flow or pilot channel constructed across the facility bottom from the inlet to the outlet is required to convey low flows, and prevent standing water conditions.*

The Middle Creek and upstream Oak Creek storage sites are near residential and developing residential areas. Considering this, the design incorporates some recreational areas, where possible. In order to incorporate recreational areas, some exception was made to the 2 percent minimum bottom slope.

5.3 Conceptual Design

The main goal of the storage area evaluation was to develop storage areas that reduce future flood damages along Salt Creek based on the 10-, 50-, 100-, and 500-year storm events. An iterative process was used to balance the storage basin design versus the cost/benefit analysis of the design. The goal was to maximize the storage volume at the minimum cost.

5.3.1 Preliminary Design

ArcMap was employed for storage layout for preliminary and final conceptual design. This was accomplished by laying out contours and using 3D Analyst to convert the contours into a Triangular Irregular Network (TIN). This TIN was then used to find an elevation volume curve, which will be described in more detail below.

During this process, CDM completed a site visit to gain a better understanding of the site layout, as well as to make sure that all utilities were accounted for. Appendix E contains the site visit photos.

5.3.1.1 Middle Creek

Initially, the Middle Creek storage area was modeled as a single basin. The storage was then designed outward from the culvert inlet using a 2 percent bottom slope, with side slopes no steeper than 4:1 (horizontal to vertical). The bottom slope of 2 percent allowed for proper drainage of water during an event; however, it did not allow for all available land to be used for storage. In order to increase the volume of storage, two hydraulically connected basins were designed. This allowed storage to expand along Middle Creek with an East Middle Creek and West Middle Creek storage basin as shown on Figure 5-2. Several options for conveying flow between the basins were considered, and culverts were found to be the most cost-effective solution. As refinements were made to the storage basin themselves, consideration was also given to the best method for filling and draining these basins.

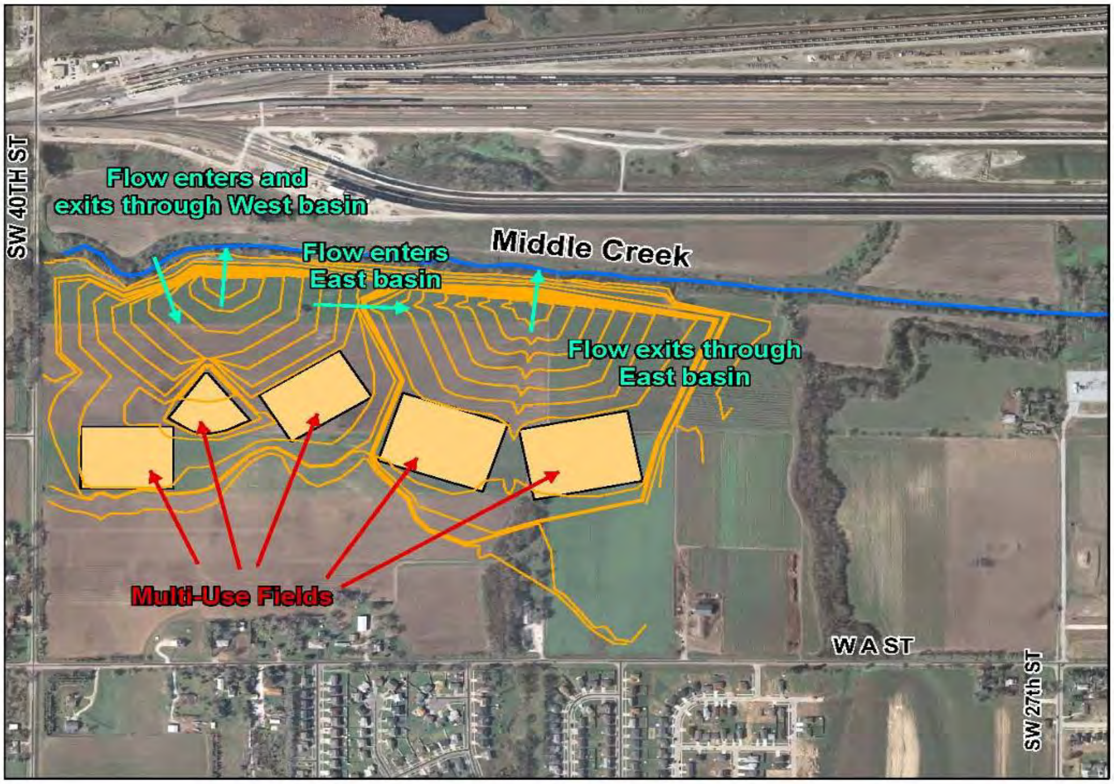

Figure 5-2 Middle Creek Offline Storage Fill and Drain Operation

Initially, weir inlets were modeled to gain an initial understanding of basin function. However, weir inlets did not allow the basin to reach the full storage capacity. Alternatively, gates were modeled for inlet and outlet structures. In the unsteady HEC-RAS model, gates are controlled by water surface elevations. In reality, these gates will be culverts with spring tension flap gates controlled by the pressure head between the creek and the basin. The conceptual design allows for the possibility of the inclusion of five multi-use fields to utilize the site area during dry conditions.

5.3.1.2 Oak Creek -Upstream

The Oak Creek design followed a similar process to that of Middle Creek. The storage was at first designed outward from the culvert inlet using a 2 percent slope for the bottom slope, with side slopes no steeper than 4:1 (horizontal to vertical). The bottom slope of 2 percent allowed for proper drainage of water during an event; however, as with the Middle Creek storage basins, it did not allow for all available land to be used for storage. In order to increase the volume of storage, two hydraulically connected basins were designed as well as a third, separate basin. This allowed storage to expand along Oak Creek, producing a Northwest (NW) upstream Oak Creek storage basin, a Northeast (NE) upstream Oak Creek storage basin, and a South (S) upstream Oak Creek storage basin, as shown in Figure 5-3. Several options for conveying flow between the basins were considered, and culverts were found to be the most cost-effective solution.

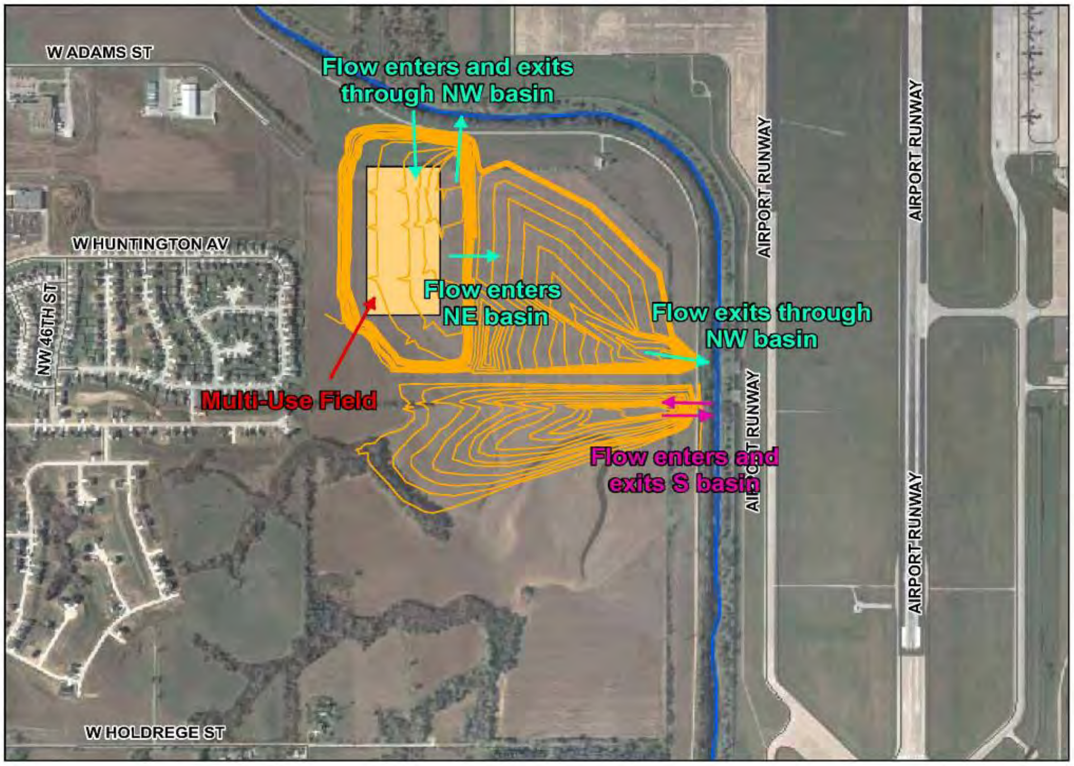

Figure 5-3 Upstream Oak Creek Offline Storage Fill and Drain Operation

The site is currently open space in agricultural production. The site contains above ground powerlines identified during field investigation and by utility maps. The utility maps provided by the LAA are provided in Appendix F. An abandoned radar station is located in the northeast corner of the Oak Creek upstream storage area; however, the Project team was informed that it will be removed in the near future.

5.3.1.3 Oak Creek - Downstream

At the downstream Oak Creek storage area, no additional utilities were discovered. The Project Team recommended that the storage area at this site be expanded compared to the previous design developed by HDR. This expansion created a west basin and an east basin, as shown in Figure 5-4. This was necessary to maximize the flood benefit by providing more storage than previously designed.

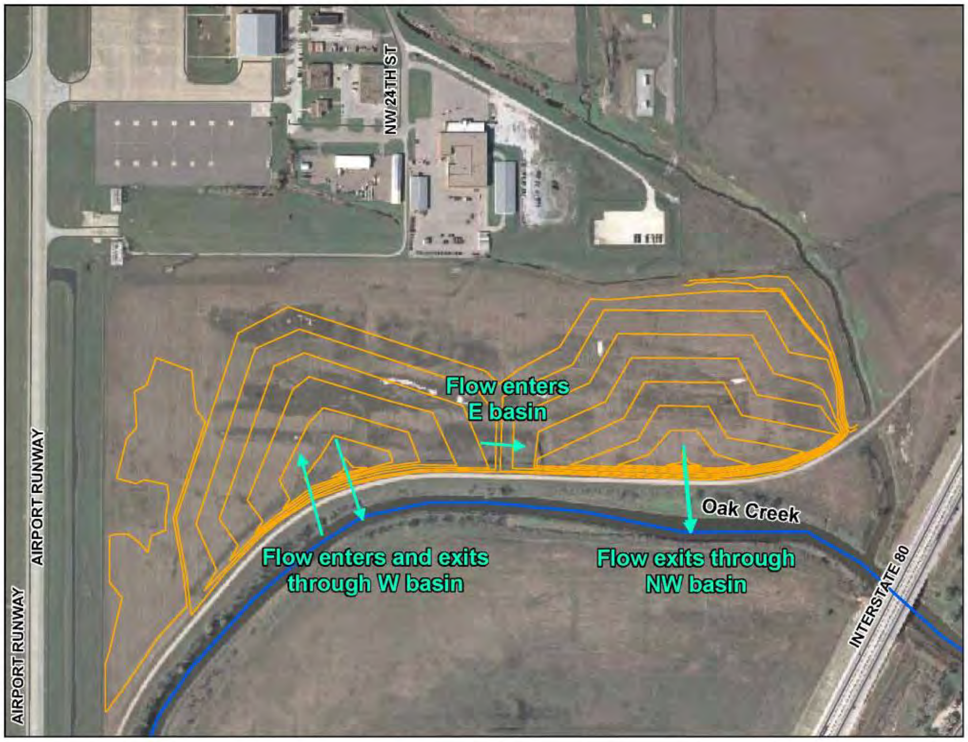

Figure 5-4 Downstream Oak Creek Fill and Drain Operation

5.3.2 Conceptual Design

5.3.2.1 Middle Creek

Based upon the considerations stated in the previous section, the final conceptual design for Middle Creek is shown in Figure 5-2, with additional details provided in Appendix G. The Middle Creek storage area consists of two storage cells, east (E) and west (W), connected by 7 – 3-foot x 4-foot concrete box culverts at an invert elevation of 1,158 feet. The W storage cell is divided such that it has an upper and lower storage area. The City indicated a desire for multi-use fields to be located in the basins so as to more fully utilize the site under dry conditions. These fields were included and designed with a 1 percent slope and underdrains to allow the fields to fully drain after an event. The W storage cell upper storage area includes two multi-use fields and a baseball diamond and drains into the lower storage through a 4-foot corrugated metal pipe (CMP) culvert. From the lower west cell water drains into the E cell and back into Middle Creek. The E storage cell also includes two multi-use fields.

As previously mentioned, ArcMap was used to process TIN data, from which the elevation volume curve was developed. An elevation volume curve describes the relationship between the elevation of the water surface in the basin and the storage volume of the basin at a given elevation. This curve was used as input into the HEC-RAS model and is provided in Table 5-1.

Table 5-1 Middle Creek Offline Storage Elevation Volume Curves

W offline storage		E offline storage	
Elevation	**Volume (ac-ft)**	**Elevation**	**Volume (ac-ft)**
1144	0	1144	0
1146	0	1146	0.2
1148	0.3	1148	2.2
1150	1.9	1150	7.6
1152	6.4	1152	18
1154	16	1154	35
1156	31.7	1156	60.3
1158	56.6	1158	100.6
1160	93.4	1160	163.7
1162	148.7	1162	245.2
1164	222.9	1164	334.1

Inlet and outlet culverts were designed with gates to allow flow from Middle Creek into the basin only after a predetermined head on the gates from the creek had been reached, as shown in Figure 5-5. The gates then closed as the Middle Creek flood wave passed downstream, trapping the water in the basin.

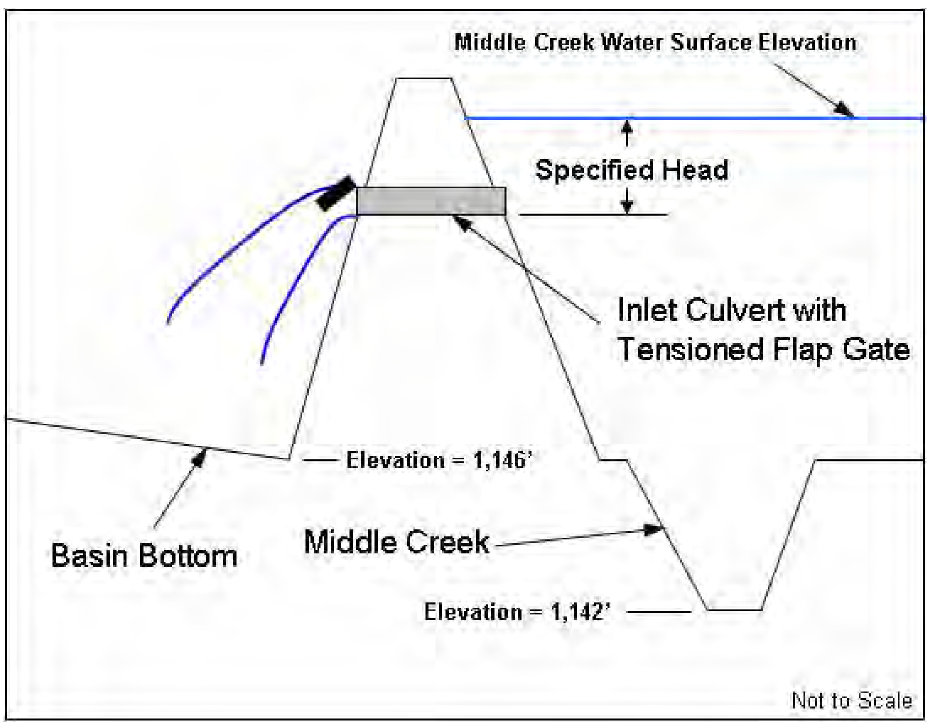

Figure 5-5 Middle Creek Inlet Tension Control

In a similar manner, outlet culverts with tensioned flap gates on the creek side end of the structure were used to control flow out of the storage basin. These were located above the basin bottom elevation to allow the basin to gradually drain as the water surface elevation in Middle Creek recedes, as shown in Figure 5-6.

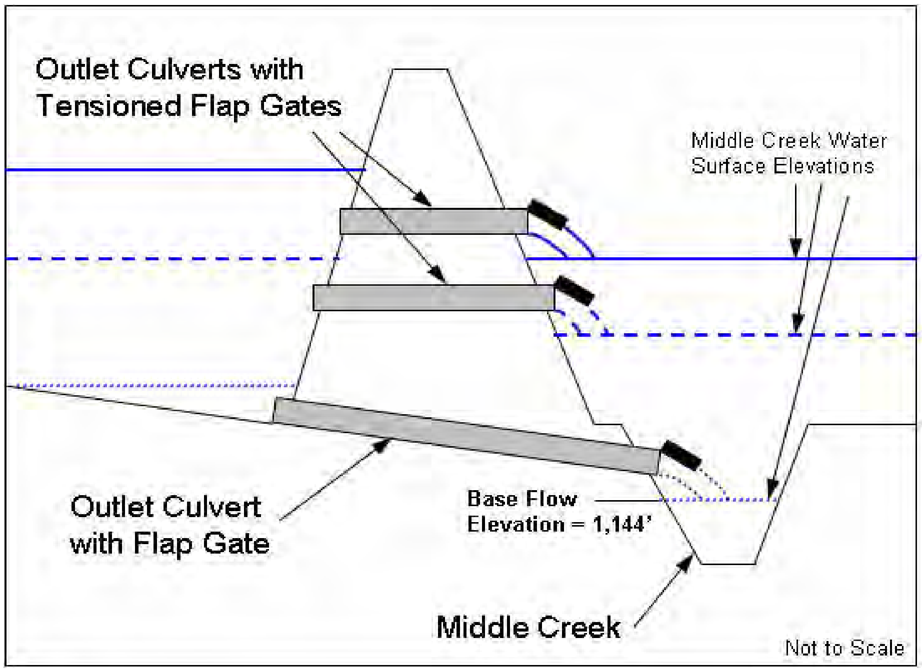

Figure 5-6 Middle Creek Outlet Tension Control

These inlet and outlet culverts were simulated in unsteady HEC-RAS using gates which were opened and closed during the model run at specified Middle Creek water surface elevations. These elevations and gate input data pertinent to Middle Creek are shown in Tables 5-2 and 5-3.

Table 5-2 Middle Creek Modeled Inlet Gates

HEC-RAS Station	Invert (ft)	Number	Height (ft)	Width (ft)	Open Elevation (ft)	Close Elevation (ft)
12900	1162.0	8	4	20	1146.0	1164.0
	1150.0	4	4	10	1146.0	1159.6
12300	1159.0	6	4	15	1146.0	1162.3

Table 5-3 Middle Creek Modeled Outlet Gates

HEC-RAS Station	Invert (ft)	Number	Height (ft)	Width (ft)	Open Elevation (ft)	Close Elevation (ft)
12000	1148.0	1	6	10	1146.0	1147.0
	1154.0	1	6	10	1152.0	1153.0
10400	1148.0	1	6	10	1146.0	1147.0
	1154.0	1	6	10	1152.0	1153.0

The West Middle Creek basin contained inlet gates and outlet gates and culverts, and the East Middle Creek basin contained only outlet gates and culverts. With this design, the West basin fills first, and when the water surface reaches the invert of the culverts between the basins, the East basin begins to fill. This fill and drain operation is shown in Figure 5-2.

Total estimated construction costs associated with the storage basins at the Middle Creek site are given in Table 5-4. A more detailed estimate is given in Appendix H.

Table 5-4 Middle Creek Storage Basins Construction Costs

Property Acquisition=	**$5,160,000**
Construction Subtotal=	**$5,900,000**
General Conditions, Overhead Profit, Insurance, Utility Relocation 28%	$1,652,000
Construction with Percent Allowances Subtotal=	**$7,552,000**
Contingency 20%	$1,510,400
Probable Cost Estimate=	**$9,062,400**
Engineering / Permitting / Survey / Geotech 12%	$1,087,500
Project Subtotal	$10,149,900
Total Conceptual Cost Estimate=	**$15,400,000**

5.3.2.2 Oak Creek Upstream

Optimizing storage on Oak Creek presented some additional challenges. The final conceptual design for Oak Creek is shown in Figure 5-3, and additional detail is provided in Appendix G. The upstream storage area site had the aforementioned utilities running through it. Therefore, this location was divided into three separate storage basins. Two storage cells are located next to each other and are referred to as the northeast (NE) and northwest (NW) basins, while the third basin is south (S) of these.

A relatively large portion of the available upstream storage site was located in the existing FEMA floodway. Due to this floodway encroachment, modeled water surface elevations upstream of the project site were greater than existing water surface elevations. In order to mitigate this problem while maintaining the offline storage benefits, the extent of the NE storage basin was reduced and levees were modeled along Oak Creek from Mathis Street to Interstate 80, as shown in Figure 5-7. The exception to the levee system is just downstream of Mathis Street on the right overbank, where an agricultural field exists that is inundated during large events. The available overbank storage of this floodprone area was assumed in the evaluation of the storage basins, which helped mitigate modifications to the floodway downstream. For modeling purposes, the levees were set to an elevation which allowed 4-feet of freeboard.

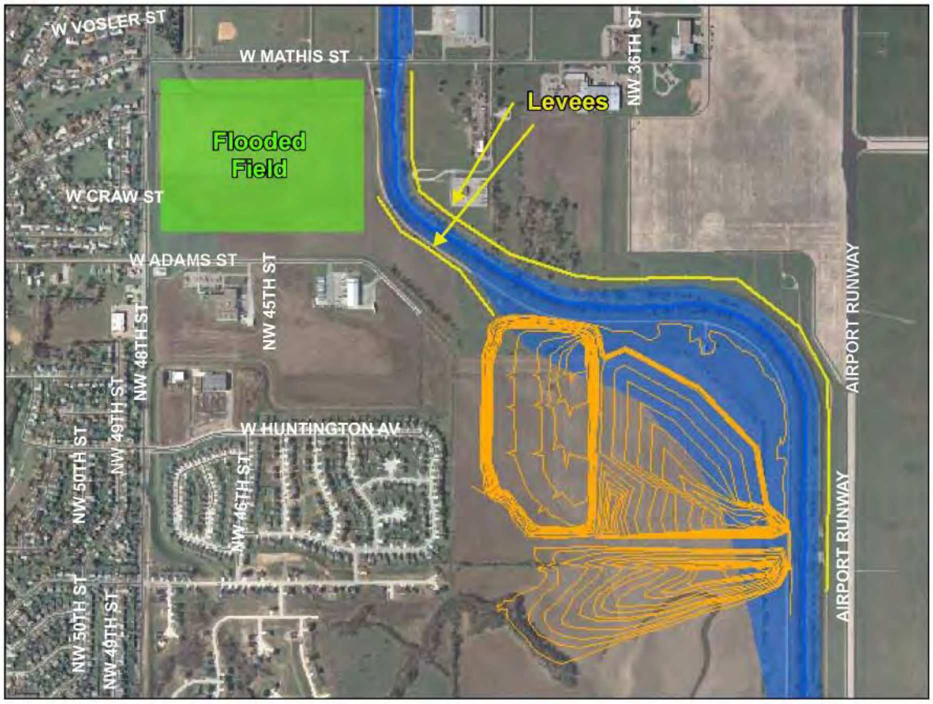

Figure 5-7. Oak Creek Floodway and Conceptual Design

The NE and NW storage cells have a greater storage volume than the S storage cell. The elevation-volume curve for each is shown in Table 5-5.

Table 5-5 Upstream Oak Creek Offline Storage Elevation Volume Curves

Upstream NE offline storage		Upstream NW offline storage		Upstream S offline storage	
Elevation	**Volume (ac-ft)[1]**	**Elevation**	**Volume (ac-ft)**	**Elevation**	**Volume (ac-ft)**
1140	0.0	1140	0.0	1140	0.0
1142	0.1	1142	0.1	1142	0.2
1144	0.5	1144	3.3	1144	2.2
1146	1.1	1146	11.9	1146	5.9
1148	2.0	1148	31.2	1148	11.7
1150	9.9	1150	67.2	1150	21.3
1152	23.5	1152	121.6	1152	36.8
1154	45.6	1154	184.7	1154	58.0
1156	78.5	1156	249.8	1156	84.6
1158	125.0	1158	317.0	1158	118.5
1160	187.8	1160	386.7	1160	161.4
1162	262.1	1162	462.8	1162	216.0
1164	343.3	1164	545.0	1164	288.8

[1] Storage volumes listed below elevation 1,154 feet are available storage values

The NE storage cell fills from the NW storage cell. These storage cells are connected by 3-foot x 4-foot concrete box culverts at elevation 1,154 feet.

Inlet structures included both weirs and culverts with tensioned flap gates, and outlet structures used were culverts with tensioned flap gates. Flap gates were employed on the basin-side end of inlet culverts to control the timing of flow into the storage basin. They were designed as being tensioned flap gates to allow flow from Oak Creek into the basin only after a predetermined head on the gates from the creek had been reached, as shown in Figure 5-8. Conceptual design details are provided in Appendix G. The gates then closed as the Oak Creek flood wave passed downstream, trapping the water in the basin. For unsteady HEC-RAS modeling purposes, complexity of the Oak Creek hydrograph, and in order to fully utilize these storage areas, the culverts were modeled using gates which were opened and closed during the model run at specified Oak Creek water surface elevations, as well as storage area water surface elevations.

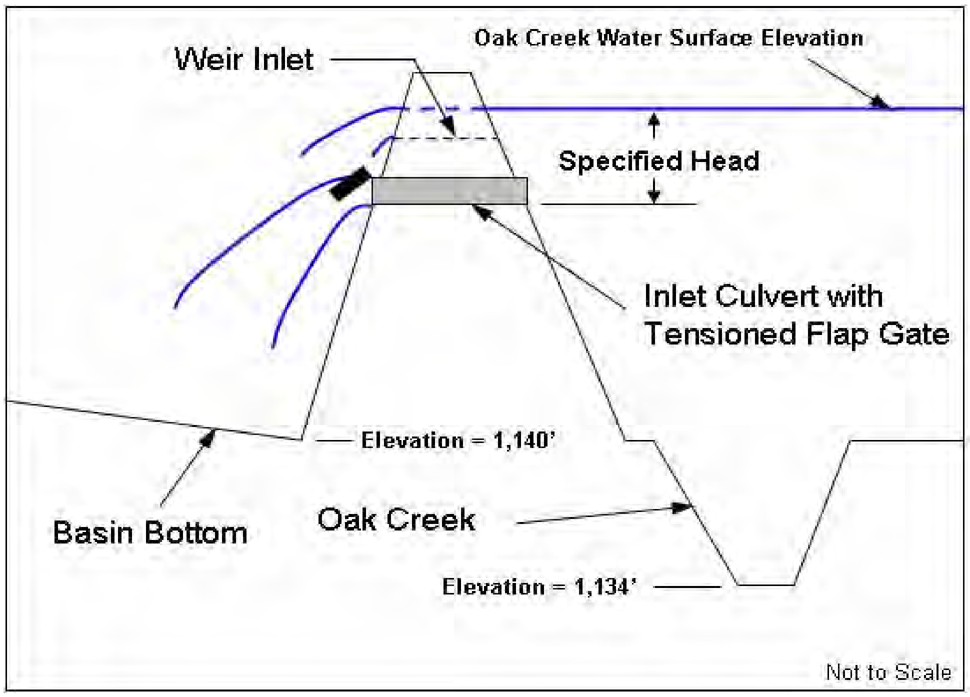

Figure 5-8 Oak Creek Inlet Tension Control

In a similar manner, outlet culverts with tensioned flap gates on the creek side end of the structure were used to control flow out of the storage basin (Figure 5-9).

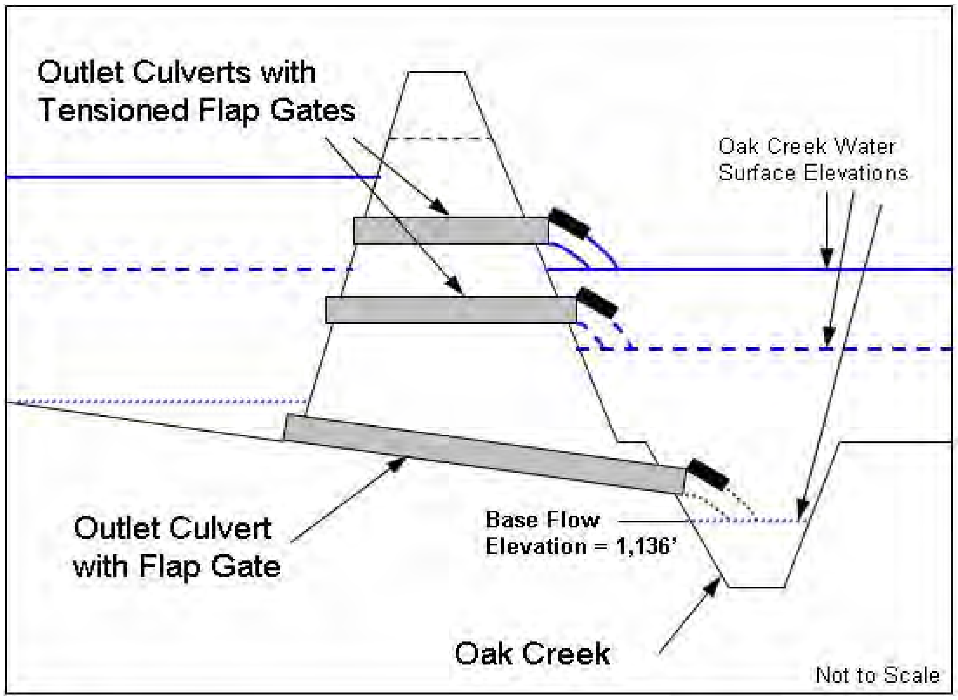

Figure 5-9 Oak Creek Outlet Tension Control

The NW basin has a 150-foot wide weir inlet at invert 1,161 feet and includes inlet gates. The NE and NW storage cells each empty through an outlet gate with an outlet invert of 1,158 feet. The S storage cell fills through a 100-foot inlet weir, as well as inlet gates. This function is show in Figure 5-3. Detailed gate dimensions and inverts used to model the Oak Creek upstream storage area are shown in Tables 5-6 and 5-7. A multi-use field was also included as part of the design in the NW storage area. This field was designed with a 1 percent slope and underdrains to allow the fields to fully drain after an event.

Table 5-6 Oak Creek Upstream Modeled Inlet Gates

HEC-RAS Station	Invert (ft)	Number	Height (ft)	Width (ft)	Open Elevation (ft)	Close Elevation (ft)
30200 (weir 1161 ft)	1158.0	1	2	20	1161.0	1160.5
	1153.0	1	2	20	1160.0	1159.5
25858 (weir 1158 ft)	1157.0	1	1	75	1154.0	1159.0
	1155.5	1	1	30	1150.0	1154.0
	1152.0	1	1	30	1158.1	1187.5
	1138.0	1	2	10	1127.0	1127.5

Table 5-7 Oak Creek Upstream Modeled Outlet Gates

HEC-RAS Station	Invert (ft)	Number	Height (ft)	Width (ft)	Open Elevation (ft)	Close Elevation (ft)
30200	1140.0	1	2	16	1130.0	1130.1
26222	1140.0	1	4	20	1130.0	1131.0
25858	1138.0	1	2	10	1127.0	1127.5

The South basin contained both inlet and outlet gates and operated independently of the North basins. Included in the inlet gate design were gates which allow flow into the basin for the 10-, 50-, and 100-year design storms.

Total estimated construction costs associated with the storage basins at the upstream Oak Creek site are given in Table 5-8. A more detailed estimate is given in Appendix H.

Table 5-8 Oak Creek Upstream Storage Basins Construction Costs

Property Acquisition=	**$3,025,000**
Construction Subtotal=	**$8,744,912**
General Conditions, Overhead Profit, Insurance, Utility Relocation 28%	$2,448,500
Construction with Percent Allowances Subtotal=	**$11,193,412**
Contingency 20%	**$2,238,700**
Probable Cost Estimate=	**$13,432,112**
Engineering / Permitting / Survey / Geotech 12%	**$1,611,800**
Project Subtotal	**$15,043,900**
Total Conceptual Cost Estimate with Property Acquisition =	**$18,200,000**

5.3.2.3 Oak Creek Downstream

The downstream storage area was also divided into two cells, east and west. The elevation volume curves are shown in Table 5-9.

Table 5-9 Downstream Oak Creek Offline Storage Elevation Volume Curves

Downstream West offline storage		Downstream East offline storage	
Elevation	**Volume (ac-ft)**	**Elevation**	**Volume (ac-ft)**
1140	0.0	1140	0.0
1142	0.7	1142	0.8
1144	3.3	1144	4.3
1146	7.7	1146	13.3
1148	16.5	1148	29.5
1150	33.0	1150	53.8
1152	59.0	1152	86.9
1154	95.4	1154	127.7

These offline storage sites are relatively small compared to the upstream sites. The west cell has a 60-foot inlet weir with invert 1151.5 feet and a 60-foot inlet gate. Inlet gate and weir operation is shown in Figure 5-8, and outlet gate operation is shown in Figure 5-9. Basin bottom and base flow water surface elevations for the downstream site are similar to the elevations for the upstream site.

The east cell is filled by flow from the west cell through five 3-foot x 4-foot concrete box culverts. Both cells drain separately through outlet gates. The fill and drain operation is shown in Figure 5-4, and additional detail is provided in Appendix G. Detailed gate dimensions and inverts used to model the Oak Creek downstream storage area are shown in Tables 5-10 and 5-11.

Table 5-10 Oak Creek Downstream Modeled Inlet Gates

HEC-RAS Station	Invert (ft)	Number	Height (ft)	Width (ft)	Open Elevation (ft)	Close Elevation (ft)
17000	1151.5	1	1	60	1151.0	1150.0
	1148.5	1	2	30	1148.5	1151.5
	1147.0	1	1	30	1148.0	1152.0

Table 5-11 Oak Creek Downstream Modeled Outlet Gates

HEC-RAS Station	Invert (ft)	Number	Height (ft)	Width (ft)	Open Elevation (ft)	Close Elevation (ft)
17000	1138.0	1	2	10	1130.0	1131.0
16000	1138.0	1	2	10	1130.5	1131.0

Total estimated construction costs associated with the storage basins at downstream Oak Creek site are given in Table 5-12. A more detailed estimate is given in Appendix H.

Table 5-12 Oak Creek Downstream Storage Basins Construction Costs

Construction Subtotal=	**$2,903,400**
General Conditions, Overhead Profit, Insurance, Utility Relocation 28%	$813,000
Construction with Percent Allowances Subtotal=	**$3,716,400**
Contingency 20%	$743,300
Probable Cost Estimate=	**$4,459,700**
Engineering / Permitting / Survey / Geotech 12%	$535,200
Project Subtotal	$4,994,900
Total Conceptual Cost Estimate=	**$5,000,000**

5.4 Spoils Locations

Due the large amount of excavation necessary, removal and disposal of excess cut (spoils) is one of the biggest costs. The project team identified locations which could store the spoils in close proximity to the offline storage sites. These locations were either government- or Lincoln Airport Authority-owned. They were analyzed by drawing new contours at each site representing maximum feasible fill, based on engineering judgment. Fill elevations were not allowed above one foot of the average maximum height of surrounding roadways. Existing drainage conditions were taken into account, and the resulting contours minimize changes to these conditions.

Shown in Figure 5-10 are the estimated amounts of excess cut from each storage basin, the location of site which could store the excess cut, and the estimated amount of excess cut that each site can store. As shown in Figure 5-10, potential fill sites are available within 1-mile of the excavation sites. This assumption was used in developing the cost estimates that are presented above.

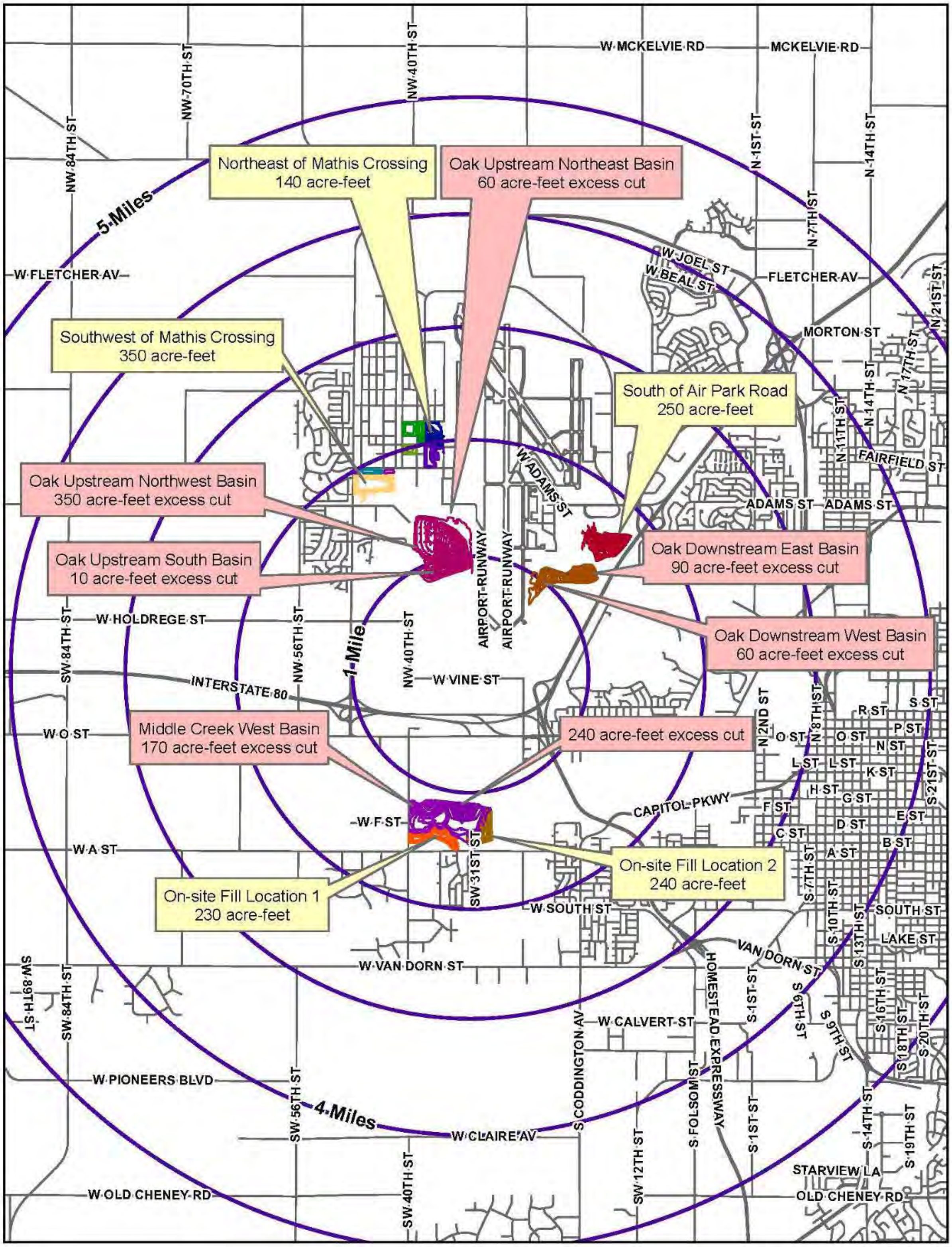

Figure 5-10 Identified Potential Fill Locations