

## **6.0 UPPER (WEST) FOUNTAIN CREEK**

### **6.1 Watershed Description**

Upper (West) Fountain Creek is a perennial stream located west of the city of Colorado Springs with headwaters in the city of Woodland Park down to its confluence with Monument Creek near I-25 and U.S. Highway 24. Upper (West) Fountain Creek flows southeasterly out of the Rampart Range along U.S. Highway 24. The Upper (West) Fountain Creek watershed has a contributing drainage area of approximately 119 square miles at its confluence with Fountain Creek and Monument Creek near downtown Colorado Springs.

The headwaters of Upper (West) Fountain Creek are part of the Pike National Forest and are dominated by pine and fir forest on very steep slopes until the city of Woodland Park. In the middle portion of the watershed, Pike National Forest continues with pine and fir forest. The lower portion of the Upper (West) Fountain Creek watershed contains the city of Manitou Springs and has been developed with interspersed commercial, industrial, and residential areas.

### **6.2 Scope of Study**

The studied portion of Upper (West) Fountain Creek for the current project is approximately 11.5 miles long. The upper portion of Upper (West) Fountain Creek is approximately 4.9 miles long and is studied from a point just downstream of Green Mountain Falls and extending upstream to Aspen Garden Way Road. The lower portion of Upper (West) Fountain Creek is approximately 6.5 miles long and is studied at its confluence with Monument Creek near I-25 and U.S. Highway 24 extending upstream to the City of Manitou Springs. The detailed modeling of the middle portion of Upper (West) Fountain Creek is not part of this study because the main channel of the middle portion of Upper (West) Fountain Creek is generally narrow and fully contained in the valley/canyon along U.S. Highway 24. Therefore, the middle portion of Upper (West) Fountain Creek is modeled by placing the cross sections approximately 1 mile apart. A location map of the studied reach of Upper Fountain Creek is provided in Figure 6-1.

### **6.3 Channel Description**

The upstream portion of the creek is a mountain stream with boulders, cobbles, and gravel in a narrow valley. Through the city of Woodland Park, the creek transitions to a wide sand-bed channel. Downstream of the city of Woodland Park, the channel becomes a mountain stream with

boulders and natural drops and pools along U.S. Highway 24. The main channel is generally narrow and contained in the valley/canyon along State Highway 24. Downstream of the canyon and through the city of Manitou Springs, the stream has been channelized and is diverted underground in many places. Downstream of the city of Manitou Springs, the channel flattens out to a wide sand-bed channel with some meanders down to the confluence with Monument Creek.

### **6.4 Hydrology**

The Upper (West) Fountain Creek HEC-HMS model was run for both existing and future conditions applying a 24-hour storm event with 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals. The details related to hydrologic analysis of Upper (West) Fountain Creek are provided in a separate study report *Fountain Creek Watershed Preliminary Hydrology Report, URS, 2005*.

Table 6-1 summarizes URS-modeled peak discharges at points of interest throughout the Upper (West) Fountain Creek watershed.

### **6.5 Hydraulics**

Hydraulic conditions and water surface profiles for Upper (West) Fountain Creek were determined by HEC-RAS modeling. The average channel slope for Upper (West) Fountain Creek was determined to be approximately 2.4%. Below is a brief description of different parameters involved in the modeling of Upper (West) Fountain Creek.

#### **6.5.1 Manning's n-Values**

Manning's n-values for the main channel and overbank portions of Upper (West) Fountain Creek were determined by field observations and aerial photographs. In the upper portion of Upper (West) Fountain Creek and through the City of Woodland Park, the creek is a wide sand-bed channel with sparse brush and few trees in the overbank areas. Therefore, for the upper portion of Upper (West) Fountain Creek, Manning's n-values of 0.02-0.03 and 0.07-0.09 were used for the main channel and overbank portions, respectively.

The middle portion of Upper (West) Fountain Creek is generally narrow and the streambed consists of boulders and natural drops. Therefore, for the middle portion of Upper (West) Fountain Creek, Manning's n-values of 0.05 and 0.09 were used for the main channel and overbank areas, respectively.

**Table 6-1. Peak Discharges at Points of Interest Along Upper (West) Fountain Creek**

Location	HEC-HMS Element	Area (mi <sup>2</sup> )	Existing Peak Discharge (cfs)							Future Peak Discharge (cfs)						
			2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
Downstream of Sheridan Ave	JUF010	1.1	2.1	5.4	27	110	180	270	490	3.0	8.4	39	130	210	310	540
At CR 21	JUF020	3.1	2.1	5.4	27	110	210	330	650	3.0	8.4	39	130	230	350	660
Downstream of Crystola Canyon Rd	JUF030	5.5	2.1	7.3	27	140	290	500	1,100	3.0	8.4	39	160	310	520	1,100
-	JUF040	-	2.1	7.1	27	150	340	620	1,400	3.0	8.4	38	160	350	630	1,400
At Hotel St	JUF050	16.9	7.6	24	110	440	850	1,400	2,800	8.1	30	120	470	880	1,400	2,800
-	JUF125	-	11	43	170	630	1100	1800	3,500	12	47	170	640	1100	1800	3,500
-	JUF130	-	11	43	170	630	1100	1800	3,500	12	47	170	640	1100	1800	3,500
At Fountain Ave	JUF160	43.4	32	260	710	1,900	2,800	4,200	7,200	33	260	710	1,900	2,800	4,200	7,200
At Manitou Ave	JUF260	68.5	50	390	1,200	3,300	5,200	7,800	14,000	50	390	1,200	3,300	5,200	7,800	14,000
-	JUF270	-	52	410	1200	3400	5300	8000	14,000	52	410	1200	3400	5300	8000	14,000
At Arcade	JUF340	87.5	64	490	1,500	4,100	7,000	10,000	19,000	64	490	1,500	4,100	7,000	10,000	19,000
At Old Man Tr	JUF350	91.1	69	530	1,600	4,500	7,600	11,000	20,000	70	530	1,600	4,500	7,600	11,000	20,000
-	JUF360	-	350	570	1,700	4,600	7,700	11,000	20,000	350	570	1,700	4,600	7,700	11,000	20,000
At US Hwy 24 near Manitou Bypass	JUF390	97.0	350	630	1,800	4,900	8,200	12,000	22,000	350	630	1,800	4,900	8,200	12,000	22,000
-	JUF400	-	340	690	2,000	5,300	8,800	13,000	24,000	340	690	2,000	5,300	8,800	13,000	24,000
At 31 <sup>st</sup> St (USGS near Colorado Springs Gauge)	RUF410	100.2	330	690	2,000	5,300	8,800	13,000	24,000	330	690	2,000	5,300	8,800	13,000	24,000
-	JUF410	-	340	750	2,100	5,600	9,200	14,000	24,000	340	750	2,100	5,600	9,200	14,000	24,000
At US Hwy 24	JUF470	116.2	1,100	2,000	3,500	7,800	12,000	17,000	30,000	1,100	2,000	3,500	7,800	12,000	17,000	30,000
At confluence with Monument Creek	Wftn	118.7	1,400	2,700	4,300	9,100	13,000	19,000	32,000	1,500	2,800	4,400	9,200	13,000	19,000	32,000

Notes:  
mi<sup>2</sup> = square miles  
cfs = cubic feet per second  
yr = year  
USGS = United States Geological Survey

Downstream of the canyon and through the city of Manitou Springs, the stream has been channelized and is diverted underground in many places. This portion the creek generally contains boulders, cobbles, and gravel within the main channel with moderate-to-high vegetation within overbank areas. For the lower portion of Upper (West) Fountain Creek, Manning's n-values of 0.045-0.07 and 0.09-0.12 were used for the main channel and overbank areas, respectively. It should be noted that the n-values within overbank areas were lowered for those portions of the creek where it was channelized and diverted underground.

Downstream of the city of Manitou Springs, the channel flattens out to a wide sand- and gravel-bed channel with some meanders down to the confluence with Monument Creek. Therefore, Manning's n-values of 0.03-0.04 and 0.09-0.12 were used for the main channel and overbank areas, respectively.

Table 6-2 outlines the extent of n-values along Upper (West) Fountain Creek's main channel and overbank areas.

**Table 6-2. Summary of Manning's Roughness n-Values Along Upper (West) Fountain Creek**

	Manning's n-Values (Overbank Portions)	Manning's n-Values (Main Channel)
Minimum	0.07	0.02
Maximum	0.12	0.07

### 6.5.2 Boundary Conditions

The Upper (West) Fountain Creek modeling was performed under the mixed-flow regime that allows the HEC-RAS model to model both the supercritical and subcritical regimes. The downstream boundary condition for all the profiles for the Upper (West) Fountain Creek was set at normal depth based on the downstream channel slope of 0.013 feet/feet. The upstream boundary condition for all the profiles for Upper (West) Fountain Creek was also set at the normal depth based on the upstream channel slope of 0.02 feet/feet.

### 6.5.3 Culvert Data

The information related to FHWA Chart and Scale numbers and entrance and exit loss coefficients for Upper (West) Fountain Creek is summarized in Table 6-3.

**Table 6-3. Summary of Culvert Data for Upper (West) Fountain Creek**

Culvert Location	FHWA Chart Number	FHWA Scale Number	Entrance Loss Coefficient	Exit Loss Coefficient
Aspen Garden Way	8	1	0.4	1
Off Woodland Ave	8	1	0.4	1
Crystola Canyon Rd	29	1	0.5	1
Creekside Dr	34	3	0.9	1
Private ranch	29	1	0.5	1
Off Green Mountain Falls Rd	34	3	0.9	1
El Paso Ave	34	3	0.9	1
Under Penny Arcade	8	1	0.4	1
W Lovers Lane	8	1	0.4	1
SW Lovers Lane	8	1	0.4	1
El Paso Blvd	29	1	0.5	1

### 6.5.4 Study Results

Water surface profiles for the Upper (West) Fountain Creek for the return intervals of 2-, 5-, 10-, 25-, 50-, 100-, and 500-years for the existing and future conditions are presented in Appendix C. Complete HEC-RAS output tables for the Upper (West) Fountain Creek for the existing and future conditions are also provided in Appendix C. Tables 6-4 and 6-5 summarize hydraulic conditions from the Upper (West) Fountain Creek model results. This includes average channel velocity, average flow depth, average top width, and average Froude number for existing and future conditions, respectively. The average value for each of these parameters was computed by dividing the total sum of each parameter by the total number of cross sections at Upper (West) Fountain Creek.

**Table 6-4. Hydraulic Conditions in Upper (West) Fountain Creek  
from HEC-RAS Results (Existing Conditions)**

Hydraulic Parameter	10-Year Event	100-Year Event	500-Year Event
Average channel velocity (ft/sec)	7.0	12.2	14.2
Average water surface depth in channel (ft)	5.1	10.7	13.5
Average top width (ft)	115.8	333.7	420.7
Average Froude number	1.0	0.9	0.9

Note:

ft/s = feet per second

**Table 6-5. Hydraulic Conditions in Upper (West) Fountain Creek  
from HEC-RAS Results (Future Conditions)**

Hydraulic Parameter	10-Year Event	100-Year Event	500-Year Event
Average channel velocity (ft/sec)	7.0	12.2	14.2
Average water surface depth in channel (ft)	5.1	10.7	13.5
Average top width (ft)	117.1	333.4	420.7
Average Froude number	0.8	0.9	0.9

Note:

ft/s = feet per second

Table 7-1 summarizes URS-modeled peak discharges at points of interest throughout the Sutherland Creek watershed.

## **7.0 SUTHERLAND CREEK**

### **7.1 Watershed Description**

Sutherland Creek is an intermittent stream located in the southern portion of the Upper (West) Fountain Creek watershed and flows northeasterly from the Pike National Forest. The Sutherland Creek watershed has a contributing drainage area of approximately 5.1 square miles at its confluence with Upper (West) Fountain Creek just west of the U.S. Highway 24 and the Manitou Springs bypass interchange.

The headwaters of Sutherland Creek are part of the Pike National Forest and are dominated by pine and fir forest on very steep slopes. The middle and lower portions of the Sutherland Creek watershed contains undeveloped large-acreage tracts and some rural residential lots in the city of Manitou Springs.

### **7.2 Scope of Study**

The portion of Sutherland Creek studied for this project is approximately 1.4 miles long. The scope of study starts at its confluence with Upper (West) Fountain Creek just west of the U.S. Highway 24 and the Manitou Springs bypass interchange and extending upstream to a point approximately 1 mile upstream of Sutherland Road. A location map of the studied reach of Sutherland Creek is provided in Figure 7-1.

### **7.3 Channel Description**

Sutherland Creek has a low-flow channel and a relatively narrow floodplain. Throughout the studied reach, the channel has been confined between residential lots but remains a narrow grass and boulder channel with heavy vegetation on the floodplains at several locations. The riparian vegetation in the floodplain contains mainly grass, willows, and trees, and is dense in some areas.

### **7.4 Hydrology**

The Sutherland Creek HEC-HMS model was run for both existing and future conditions applying a 24-hour storm event with 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals. The details related to hydrologic analysis of Sutherland Creek are provided in a separate study report *Fountain Creek Watershed Preliminary Hydrology Report, URS, 2005*.

**Table 7-1. Peak Discharges at Points of Interest Along Sutherland Creek**

Location	HEC-HMS Element	Area (mi <sup>2</sup> )	Existing Peak Discharge (cfs)							Future Peak Discharge (cfs)						
			2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
At intersection of Sutherland Creek Rd and Crystal Park Rd	JSU050	4.58	460	1,200	1,900	2,500	3,300	4,600	6,600	460	1,200	1,900	2,500	3,300	4,600	6,600
At Sandra Lane	JSU060	4.99	510	1,300	2,100	2,800	3,700	5,000	7,300	510	1,300	2,100	2,800	3,700	5,000	7,300
At confluence with Upper (West) Fountain Creek	Sthrlnd	5.08	520	1,400	2,100	2,800	3,700	5,100	7,300	520	1,400	2,100	2,800	3,700	5,100	7,300

Notes:  
mi<sup>2</sup> = square miles  
cfs = cubic feet per second  
yr = year

## 7.5 Hydraulics

Hydraulic conditions and water surface profiles for Sutherland Creek were determined by HEC-RAS modeling. The average channel slope for Sutherland Creek was determined to be approximately 4.5%. Below is a brief description of different parameters involved in the modeling of Sutherland Creek.

### 7.5.1 Manning's n-Values

Manning's n-values for the main channel and overbank portions of Sutherland Creek were determined by field observation and aerial photographs. For most part of the scope of study, the channel has been confined between residential lots but remains a narrow grass and boulder channel with heavy vegetation on the floodplains at several locations. At some locations vegetation is also present at the bottom of the channel. The riparian vegetation in the floodplain contains mainly grass, willows, and trees, and is dense in some areas. Manning's n-values of 0.045-0.05 and 0.08-0.12 were used for the main channel and overbank portions, respectively.

Table 7-2 outlines the extent of n-values along Sutherland Creek's main channel and overbank areas.

**Table 7-2. Summary of Manning's Roughness n-Values Along Sutherland Creek**

	Manning's n-Values (Overbank Portions)	Manning's n-Values (Main Channel)
Minimum	0.08	0.045
Maximum	0.12	0.05

### 7.5.2 Boundary Conditions

The Sutherland Creek modeling was performed under the mixed-flow regime that allows the HEC-RAS model to model both the supercritical and subcritical regimes. The downstream boundary condition for all the profiles for Sutherland Creek was set at normal depth based on the downstream channel slope of 0.016 feet/feet. The upstream boundary condition for all the profiles for Sutherland Creek was also set at the normal depth based on the upstream channel slope of 0.06 feet/feet.

### 7.5.3 Culvert Data

The information related to FHWA Chart and Scale numbers and entrance and exit loss coefficients for Sutherland Creek is summarized in Table 7-3.

**Table 7-3. Summary of Culvert Data for Sutherland Creek**

Culvert Location	FHWA Chart Number	FHWA Scale Number	Entrance Loss Coefficient	Exit Loss Coefficient
Sutherland Rd	34	1	0.5	1
Willa Lane	34	1	0.5	1
Crystal Park Rd	1	3	0.2	1
Ramp Highway 24 Southbound	8	1	0.4	1

### 7.5.4 Study Results

Water surface profiles for Sutherland Creek for the return intervals of 2-, 5-, 10-, 25-, 50-, 100-, and 500-years for the existing and future conditions are presented in Appendix D. Complete HEC-RAS output tables for Sutherland Creek for the existing and future conditions are also provided in Appendix D. Tables 7-4 and 7-5 summarize hydraulic conditions from the Sutherland Creek model results. This includes average channel velocity, average flow depth, average top width, and average Froude number for existing and future conditions, respectively. The average value for each of these parameters was computed by dividing the total sum of each parameter by the total number of cross sections at Sutherland Creek.

**Table 7-4. Hydraulic Conditions in Sutherland Creek from HEC-RAS Results  
(Existing Conditions)**

Hydraulic Parameter	10-Year Event	100-Year Event	500-Year Event
Average channel velocity (ft/sec)	14.2	18.7	21.0
Average water surface depth in channel (ft)	6.6	9.2	10.5
Average top width (ft)	136.9	202.7	236.2
Average Froude number	1.1	1.2	1.2

Note:  
ft/s = feet per second

**Table 7-5. Hydraulic Conditions in Sutherland Creek from HEC-RAS Results  
(Future Conditions)**

Hydraulic Parameter	10-Year Event	100-Year Event	500-Year Event
Average channel velocity (ft/sec)	14.2	18.7	21.0
Average water surface depth in channel (ft)	6.6	9.2	10.5
Average top width (ft)	136.9	202.7	236.2
Average Froude number	1.1	1.2	1.2

Note:  
ft/s = feet per second

## 8.0 MONUMENT CREEK

### 8.1 Watershed Description

Monument Creek is a perennial stream located in the upper portion of the Fountain Creek watershed and is the primary tributary to Fountain Creek. Monument Creek flows easterly out of the Rampart Range and then southerly from the southern slope of the Palmer Divide. The Monument Creek watershed has a contributing drainage area of approximately 237 square mile at its confluence with Fountain Creek near downtown Colorado Springs. The headwaters of Monument Creek are part of the Pike National Forest and are dominated by pine and fir forest on very steep slopes until the slope decreases near the town of Palmer Lake. The headwaters of the eastern tributaries are dominated by grassland on undeveloped large-acreage tracts, interspersed with single-family homes, schools, commercial centers, and large commercial parks in portions of the town of Monument and unincorporated El Paso County. The USAF Academy occupies the middle reach of Monument Creek with undeveloped large-acreage tracts, cadet housing, military training areas, and business developments. The lower portion of the Monument Creek watershed is contained within the limits of the city of Colorado Springs and has been almost completely developed with commercial, industrial, and residential areas.

### 8.2 Scope of Study

The scope of study length for Monument Creek is approximately 20 miles long and consists of Upper Monument Creek and Lower Monument Creek. Upper Monument Creek is approximately 9 miles long and is studied from the USAF Academy boundary and extending upstream to a point approximately 1,100 feet upstream of Walnut Road. Lower Monument Creek is approximately 11 miles long and is studied at its confluence with Fountain Creek to a point that is approximately 2.5 miles upstream of Woodman Road. It should be noted that both Upper and Lower Monument creeks have separate HEC-RAS models. The middle portion of Monument Creek that lies within the USAF Academy boundary is beyond the scope of this study. A location map of the studied reach of Monument Creek is provided in Figure 8-1.

### 8.3 Channel Description

Monument Creek varies greatly from the headwaters to its confluence with Fountain Creek. The upstream portion of Upper Monument Creek is a mountain stream with boulders, cobbles, and gravel in a narrow valley. Downstream from the town of Monument, the creek transitions to a meandering stream with some weeds and stones. Downstream of the USAF Academy boundary, Lower Monument Creek gradually widens until its confluence with Fountain Creek, where it is a wide sand-bed channel.

### 8.4 Site-Specific Issues

There currently exists a reservoir, Monument Lake, upstream of Mount Herman Road on Upper Monument Creek. The reservoir is impounded by an embankment with an emergency spillway set at 6915.0 feet. In the absence of actual surveying information, the Monument Lake embankment structure (hereafter referenced as embankment structure) was modeled using the available topography as an in-line structure within the HEC-RAS model. Also, three additional cross sections were manually added at the embankment structure. These three cross sections included a cross section at the downstream face of the embankment structure, a cross section at the upstream face of the embankment structure, and a cross section at the top of the embankment structure. No natural cross section was placed within Monument Lake except the one placed at the upstream face of the embankment structure. It should also be noted that the HEC-HMS model for Monument Creek does contain Monument Lake. Therefore, the hydrologic flows at the downstream end of the embankment structure are reduced taking into account the storage available at Monument Lake. Further details related to the hydrologic modeling of Monument Lake are provided in a separate study report *Fountain Creek Watershed Preliminary Hydrology Report, URS, 2005*. The WSELs for different storm events determined at the embankment structure using HEC-RAS model were in close agreement with the WSELs provided in the hydrology report at the outlet of Monument Lake.

There currently exists a drop structure at Lower Monument Creek approximately 0.9 mile downstream of Northbound I-25 and 0.4 mile upstream of Garden of Gods Road. In order to determine a more accurate profile upstream of and through the drop structure, the drop structure was modeled in HEC-RAS by incorporating a series of cross sections at the drop structure. The actual surveying information was available only at the upstream and the downstream ends of the drop structure. Additional cross sections were added at the slope and further downstream of the drop

structure using the available topographic sources to accurately predict the location of hydraulic jump.

## **8.5 Hydrology**

The Monument Creek HEC-HMS model was run for both existing and future conditions applying a 24-hour storm event with 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals. The details related to hydrologic analysis of Monument Creek are provided in a separate study report *Fountain Creek Watershed Preliminary Hydrology Report, URS, 2005*.

Tables 8-1 and 8-2 summarize URS-modeled peak discharges at points of interest throughout the Monument Creek watershed along Upper Monument Creek and Lower Monument Creek, respectively.

## **8.6 Hydraulics**

Hydraulic conditions and water surface profiles for Upper Monument Creek and Lower Monument Creek were determined by HEC-RAS modeling. The average channel slopes for Upper Monument Creek and Lower Monument Creek were determined to be approximately 1.2% and 0.6 % respectively. Below is a brief description of different parameters involved in the modeling of Upper and Lower Monument Creek.

### **8.6.1 Manning's n-Values**

Manning's n-values for the main channel and overbank portions of Upper and Lower Monument creek were determined by field observation and aerial photographs. Monument Creek varies greatly from the headwaters to its confluence with Fountain Creek. The upper portion of Upper Monument Creek is a mountain stream with boulders, cobbles, and gravel in a narrow valley and moderate-to-high vegetation along overbank areas. Downstream from the town of Monument, the creek transitions to a meandering stream with some weeds and stones. Therefore, for the major portion of Upper Monument Creek, Manning's n-values of 0.04-0.06 and 0.08-0.14 are used for the main channel and overbank portions, respectively. Downstream of the USAF Academy boundary, Lower Monument Creek gradually widens until its confluence with Fountain Creek where it is a wide sand-bed channel with gravel. Lower Monument Creek experiences minor to moderate vegetation along overbank areas. Therefore, for the major portion of Lower Monument Creek, Manning's n-values of 0.03-0.045 and 0.07-0.10 are used for the main channel and overbank

portions, respectively. Table 8-3 outlines the extent of n-values along Monument Creek's main channel and overbank areas.

**Table 8-1. Peak Discharges at Points of Interest Along Upper Monument Creek**

Location	HEC-HMS Element	Area (mi <sup>2</sup> )	Existing Peak Discharge (cfs)							Future Peak Discharge (cfs)						
			2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
Downstream of Spring St	JMC030	16	45	390	860	2,200	3,100	4,100	6,600	45	390	860	2,200	3,100	4,100	6,600
Downstream of Red Rock Ranch Rd (USGS Palmer Lake Gauge)	JMC050	27	63	520	1,100	2,900	4,100	5,300	8,500	63	520	1,100	2,900	4,100	5,300	8,500
At outlet of Monument Lake	JMC060	30	71	570	1,200	3,100	4,400	5,700	9,200	74	580	1,200	3,200	4,400	5,700	9,200
At Arnold Ave	JMC110	39	60	180	470	2,400	3,700	5,100	8,600	140	330	490	2,400	3,700	5,100	8,700
Upstream of Baptist Rd	JMC130	40	60	180	470	2,400	3,700	5,100	8,700	140	340	510	2,500	3,800	5,200	8,800
At north boundary of USAF Academy	JMC240	75	82	310	820	3,800	5,600	7,800	14,000	220	730	1,300	4,000	5,900	8,100	15,000
Upstream of North Gate Blvd (USGS North Gate Blvd Gauge)	RMC285	81	92	330	850	3,900	5,800	8,100	15,000	220	780	1,400	4,100	6,000	8,400	15,000

Notes:  
mi<sup>2</sup> = square miles  
cfs = cubic feet per second  
yr = year

**Table 8-2. Peak Discharges at Points of Interest Along Lower Monument Creek**

Location	HEC-HMS Element	Area (mi <sup>2</sup> )	Existing Peak Discharge (cfs)							Future Peak Discharge (cfs)						
			2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
At south boundary of USAF Academy	JMC540	168	94	350	910	4,200	6,400	9,200	18,000	200	850	1,600	4,800	7,200	10,000	20,000
Downstream of Woodmen Rd (USGS Woodmen Rd Gauge)	JMC590	180	570	1,600	2,500	4,600	6,800	9,700	19,000	570	1,600	2,500	5,200	7,700	11,000	21,000
Upstream of I-25 (USGS Pikeview Gauge)	JMC630	203	750	2,300	3,700	7,000	8,900	11,000	21,000	750	2,300	3,700	7,100	10,000	14,000	25,000
Downstream of Austin Bluffs Pkwy	JMC650	211	1,400	4,300	6,700	12,000	16,000	19,000	27,000	1,400	4,300	6,700	13,000	16,000	19,000	27,000
Upstream of Filmore St	JMC710	230	2,300	7,100	11,000	21,000	27,000	32,000	46,000	2,300	7,100	11,000	21,000	27,000	33,000	47,000
Upstream of Uintah St	JMC730	235	2,400	7,400	12,000	22,000	28,000	35,000	50,000	2,400	7,400	12,000	22,000	28,000	35,000	50,000
At confluence with Fountain Creek	MonCrk	237	2,400	7,600	12,000	23,000	29,000	36,000	52,000	2,500	7,600	12,000	23,000	29,000	36,000	52,000

Notes:  
mi<sup>2</sup> = square miles  
cfs = cubic feet per second  
yr = year

**Table 8-3. Summary of Manning's Roughness n-Values Along Monument Creek**

	Manning's n-Values (Overbank Portions)	Manning's n-Values (Main Channel)
Minimum	0.07	0.03
Maximum	0.14	0.06

**8.6.2 Boundary Conditions**

The modeling for Upper and Lower Monument creeks was performed under the mixed-flow regime that allows the HEC-RAS model to model both the supercritical and subcritical regimes. The downstream boundary condition for all the profiles for both Upper and Lower Monument creek was set at normal depth based on the downstream channel slope of 0.007 feet/feet and 0.005 feet/feet, respectively. The upstream boundary condition for all the profiles for both Upper and Lower Monument creek was also set at the normal depth based on the upstream channel slope of 0.06 feet/feet and 0.008 feet/feet, respectively.

**8.6.3 Culvert Data**

The information related to FHWA Chart and Scale numbers and entrance and exit loss coefficients for Upper and Lower Monument creeks is summarized in Table 8-4.

**Table 8-4. Summary of Culvert Data for Upper Monument Creek**

Culvert Location	FHWA Chart Number	FHWA Scale Number	Entrance Loss Coefficient	Exit Loss Coefficient
Walnut Rd	34	3	0.9	1
Redrock Ranch culverts #1, 2, 4, 5	1	3	0.2	1
Redrock Ranch culvert #3	29	3	0.2	1
Private drive culverts #1, 2	34	1	0.5	1
Private drive culvert #3	2	1	0.5	1
Mt Herman Rd	34	3	0.9	1

**Table 8-5. Summary of Culvert Data for Lower Monument Creek**

Culvert Location	FHWA Chart Number	FHWA Scale Number	Entrance Loss Coefficient	Exit Loss Coefficient
NA	NA	NA	NA	NA

**8.6.4 Study Results**

Water surface profiles for both Upper Monument Creek and Lower Monument Creek, for the return intervals of 2-, 5-, 10-, 25-, 50-, 100-, and 500-years for the existing and future conditions are presented in Appendix E. Complete HEC-RAS output tables for both Upper Monument Creek and Lower Monument Creek for the existing and future conditions are also provided in Appendix E. Tables 8-6 and 8-7 summarize hydraulic conditions from the Upper Monument Creek model results. Tables 8-8 and 8-9 summarize hydraulic conditions from the Lower Monument Creek model results. This includes average channel velocity, average flow depth, average top width, and average Froude number for existing and future conditions, respectively. The average value for each of these parameters was computed by dividing the total sum of each parameter by the total number of cross sections at Upper Monument Creek and Lower Monument Creek respectively.

**Table 8-6. Hydraulic Conditions in Upper Monument Creek from HEC-RAS Results (Existing Conditions)**

Hydraulic Parameter	10-Year Event	100-Year Event	500-Year Event
Average channel velocity (ft/sec)	6.1	11.2	13.0
Average water surface depth in channel (ft)	3.4	8.1	10.0
Average top width (ft)	129.4	297.3	363.3
Average Froude number	0.7	0.8	0.8

Note:  
ft/s = feet per second

**Table 8-7. Hydraulic Conditions in Upper Monument Creek from HEC-RAS Results (Future Conditions)**

Hydraulic Parameter	10-Year Event	100-Year Event	500-Year Event
Average channel velocity (ft/sec)	6.4	11.2	13.1
Average water surface depth in channel (ft)	3.7	8.2	10.1
Average top width (ft)	134.9	299.4	365.2
Average Froude number	0.7	0.8	0.8

Note:

ft/s = feet per second

**Table 8-8. Hydraulic Conditions in Lower Monument Creek from HEC-RAS Results (Existing Conditions)**

Hydraulic Parameter	10-Year Event	100-Year Event	500-Year Event
Average channel velocity (ft/sec)	9.8	14.1	16.0
Average water surface depth in channel (ft)	8.6	15.7	19.3
Average top width (ft)	181.5	380.7	525.0
Average Froude number	0.7	0.7	0.7

Note:

ft/s = feet per second

**Table 8-9. Hydraulic Conditions in Lower Monument Creek from HEC-RAS Results (Future Conditions)**

Hydraulic Parameter	10-Year Event	100-Year Event	500-Year Event
Average channel velocity (ft/sec)	10.0	14.2	16.2
Average water surface depth in channel (ft)	8.8	16.0	19.6
Average top width (ft)	185.4	400.5	529.3
Average Froude number	0.7	0.7	0.7

Note:

ft/s = feet per second

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## **9.0 COTTONWOOD CREEK**

### **9.1 Watershed Description**

Cottonwood Creek is a perennial stream located in the eastern portion of the Monument Creek subwatershed that flows southwesterly from the southern slope of the Black Forest. The Cottonwood Creek Watershed has a contributing drainage area of approximately 19.2 square miles at its confluence with Monument Creek. The Cottonwood Creek Watershed consists of undeveloped land in the upper basin and densely developed land in the lower basin. In the upper basin are private parcels or homes on large lots, and in the lower basin are generally single-family homes.

### **9.2 Scope of Study**

The portion of Cottonwood Creek investigated for this study is approximately 8 miles long starting at its confluence with Monument Creek about 0.5 mile south of the I-25 and Woodmen Road interchange in north-central Colorado Springs and extending upstream to Black Forest Road. A location map of the studied reach of Cottonwood Creek is provided in Figure 9-1.

### **9.3 Channel Description**

Cottonwood Creek has a low-flow channel and a wide connected floodplain in the upper portion of the watershed. In the upper portion of the watershed on private lands, the channel appears to be a grass swale. In the middle portion of the watershed, the channel is well developed with heavy vegetation on both the channel bottom and the floodplains. The floodplain is narrowed toward the lower basin because of urban development. The lower Cottonwood Creek becomes deeply incised with sand beds and dense vegetation along the channel. Channel side slopes change constantly along the main channel. In the upper and middle reaches of the creek, the low-flow channel is 8 to 15 feet wide with variable side slopes from 3 foot horizontal to 1 foot vertical (3H:1V) to 2H:1V. In the lower reaches of the creek, the low-flow channel becomes wider, up to 30 feet, with a depth of several feet and various side slopes. The riparian vegetation in the floodplain contains mainly grass and willows and is dense in some areas.

### **9.4 Site-Specific Issues**

There currently exists a drop structure at Cottonwood Creek approximately 0.3 mile downstream of Union Boulevard. The main channel invert for Cottonwood Creek drops by approximately 7.4 feet at the drop structure. In order to determine a more accurate profile upstream

of and through the drop structure, the drop structure was modeled in HEC-RAS by incorporating a series of cross sections along the drop structure. The actual surveying information was available only at the upstream and the downstream ends of the drop structure. Additional cross sections were added at the slope and further downstream of the drop structure using the available topographic sources to accurately predict the location of hydraulic jump.

### **9.5 Hydrology**

The Cottonwood Creek HEC-HMS model was run for both existing and future conditions applying a 24-hour storm event with 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals. The details related to hydrologic analysis of Cottonwood Creek are provided in a separate study report *Fountain Creek Watershed Preliminary Hydrology Report, URS, 2005*.

Table 9-1 summarizes URS-modeled peak discharges at points of interest throughout the Cottonwood Creek watershed.

**Table 9-1. Peak Discharges at Points of Interest Along Cottonwood Creek**

Location	HEC-HMS Element	Area (mi <sup>2</sup> )	Existing Peak Discharge (cfs)							Future Peak Discharge (cfs)						
			2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
At Black Forest Rd	JCC050	3.4	12	70	140	350	480	620	1,000	15	71	140	350	480	630	1,000
Downstream of Powers Blvd	JCC090	7.1	40	200	370	820	1,100	1,400	2,300	280	620	900	1,600	2,000	2,400	3,300
At Austin Bluffs Pkwy	JCC120	9.4	170	380	650	1,300	1,600	2,000	3,000	540	1,000	1,400	2,200	2,700	3,200	4,400
At Woodmen Rd (USGS Woodmen Rd Gauge)	RCC140	10.3	330	680	960	1,700	2,100	2,500	3,600	620	1,100	1,600	2,500	3,100	3,700	5,000
At Rangewood Dr	JCC180	14.3	700	1,600	2,200	3,800	4,700	5,700	7,900	820	1,900	2,700	4,500	5,500	6,600	9,000
At Union Blvd	JCC190	16.2	910	2,200	3,200	5,500	6,800	8,100	11,000	1,000	2,400	3,600	6,100	7,500	9,000	12,000
At Academy Blvd	JCC200	17.3	940	2,300	3,300	5,800	7,100	8,600	12,000	1,100	2,500	3,700	6,400	7,900	9,400	13,000
At confluence with Monument Creek (USGS mouth at Pikeview Gauge)	Ctnwd	19.2	1,100	2,700	4,000	6,900	8,400	10,000	14,000	1,300	3,000	4,400	7,500	9,200	11,000	15,000

Notes:  
mi<sup>2</sup> = square miles  
cfs = cubic feet per second  
yr = year  
USGS = United States Geological Survey

## 9.6 Hydraulics

Hydraulic conditions and water surface profiles for Cottonwood Creek were determined by HEC-RAS modeling. The average channel slope for Cottonwood Creek was determined to be approximately 1.7%. Below is a brief description of different parameters involved in the modeling of Cottonwood Creek.

### 9.6.1 Manning's n-Values

Manning's n-values for the main channel and overbank portions of Cottonwood Creek were determined by field observation and aerial photographs. A shallow grassed channel and wide connected floodplain exists in the upper portion of the watershed. In the upper portion of the watershed on private lands, the channel appears to be a grass swale. In the middle portion of the watershed, the channel is well developed with heavy vegetation on both the channel bottom and the floodplains. In the lower portions of the watershed, the channel becomes deeply incised with a sand bed and highly eroded banks through residential and commercial developments. The n-values for Cottonwood Creek vary from 0.025 to 0.05 for the main channel portion and from 0.07 to 0.12 for the overbank portions. Table 9-2 outlines the extent of n-values along Cottonwood Creek's main channel and overbank areas.

**Table 9-2. Summary of Manning's Roughness n-Values Along Cottonwood Creek**

	Manning's n-Values (Overbank Portions)	Manning's n-Values (Main Channel)
Minimum	0.07	0.025
Maximum	0.12	0.050

### 9.6.2 Boundary Conditions

The Cottonwood Creek modeling was performed under the mixed-flow regime that allows the HEC-RAS model to model both the supercritical and subcritical regimes. The downstream boundary condition for all the profiles for Cottonwood Creek was set at normal depth based on the downstream channel slope of 0.004 feet/feet. The upstream boundary condition for all the profiles for Cottonwood Creek was also set at the normal depth based on the upstream channel slope of 0.04 feet/feet.

### 9.6.3 Culvert Data

The information related to FHWA Chart and Scale numbers and entrance and exit loss coefficients for Cottonwood Creek is summarized in Table 9-3.

**Table 9-3. Summary of Culvert Data for Cottonwood Creek**

Culvert Location	FHWA Chart Number	FHWA Scale Number	Entrance Loss Coefficient	Exit Loss Coefficient
Current St	1	1	0.5	1
N Academy Blvd	8	1	0.4	1
Union Blvd	8	1	0.4	1
Rangewood Rd	36	1	0.9	1

### 9.6.4 Study Results

Water surface profiles for Cottonwood Creek for the return intervals of 2-, 5-, 10-, 25-, 50-, 100-, and 500-years for the existing and future conditions are presented in Appendix F. Complete HEC-RAS output tables for Cottonwood Creek for the existing and future conditions are also provided in Appendix F. Tables 9-4 and 9-5 summarize hydraulic conditions from the Cottonwood Creek model results. This includes average channel velocity, average flow depth, average top width, and average Froude number for existing and future conditions, respectively. The average value for each of these parameters was computed by dividing the total sum of each parameter by the total number of cross sections at Cottonwood Creek.

**Table 9-4. Hydraulic Conditions in Cottonwood Creek from HEC-RAS Results  
(Existing Conditions)**

Hydraulic Parameter	10-Year Event	100-Year Event	500-Year Event
Average channel velocity (ft/sec)	10.7	14.9	16.8
Average water surface depth in channel (ft)	4.1	7.2	8.8
Average top width (ft)	77.3	108.4	124.5
Average Froude number	1.2	1.2	1.2

Note:

ft/s = feet per second

**Table 9-5. Hydraulic Conditions in Cottonwood Creek from HEC-RAS Results  
(Future Conditions)**

Hydraulic Parameter	10-Year Event	100-Year Event	500-Year Event
Average channel velocity (ft/sec)	12.1	16.2	18.0
Average water surface depth in channel (ft)	4.7	8.0	9.5
Average top width (ft)	84.7	116.8	132.8
Average Froude number	1.2	1.2	1.2

Note:

ft/s = feet per second

## **10.0 DRY CREEK**

### **10.1 Watershed Description**

Dry Creek is an ephemeral stream located in the western portion of the Monument Creek subwatershed and flows easterly from the eastern slope of the Rampart Range. The Dry Creek watershed has a contributing drainage area of approximately 3.5 square miles at its confluence with Monument Creek. The Dry Creek watershed consists of undeveloped land in the upper basin and densely developed land in the middle and lower basins. In the upper basin are private parcels or homes on large lots, and in the lower basin are generally single-family homes.

### **10.2 Scope of Study**

The portion of Dry Creek studied for the current project is approximately 2.3 miles long starting at its confluence with Monument Creek and extending upstream to a point 0.25 mile upstream of Dairy Ranch Road. A location map of the studied reach of Dry Creek is provided in Figure 10-1.

### **10.3 Channel Description**

In the upper portion of the studied reach, the channel floodplain narrows through dense development with a well-defined channel and heavy vegetation and has also been channelized in some areas. In the lower portion of the studied reach, the channel is deeply incised with a gravel and cobble bed and dense vegetation on the streambed and floodplains.

### **10.4 Hydrology**

The Dry Creek HEC-HMS model was run for both existing and future conditions applying a 24-hour storm event with 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals. The hydrologic flows for both existing and future conditions are same for Dry Creek. The details related to hydrologic analysis of Dry Creek are provided in a separate study report *Fountain Creek Watershed Preliminary Hydrology Report, URS, 2005*.

Table 10-1 summarizes URS-modeled peak discharges at points of interest throughout the Dry Creek watershed.

**Table 10-1. Peak Discharges at Points of Interest Along Dry Creek**

Location	HEC-HMS Element	Area (mi <sup>2</sup> )	Existing Peak Discharge (cfs)							Future Peak Discharge (cfs)						
			2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
At Orchard Valley Rd	RDC070	2.24	230	460	630	1,200	1,500	1,900	2,800	230	460	630	1,200	1,500	1,900	2,800
Downstream of Carlson Dr	JDC070	2.53	270	520	710	1,300	1,700	2,200	3,200	270	520	710	1,300	1,700	2,200	3,200
Upstream of Wintery Loop	JDC080	2.78	320	580	790	1,400	1,900	2,300	3,500	320	580	790	1,400	1,900	2,300	3,500
Upstream of Rockrimmon Blvd	JDC100	3.30	490	840	1,100	1,700	2,200	2,800	4,200	490	840	1,100	1,700	2,200	2,800	4,200
At confluence with Monument Creek	DryCrk	3.46	510	880	1,200	1,800	2,300	2,900	4,300	510	880	1,200	1,800	2,300	2,900	4,300

Notes:

mi<sup>2</sup> = square miles

cfs = cubic feet per second

yr = year

(The hydrologic flows for both existing and future conditions are same for Dry Creek)

## 10.5 Hydraulics

Hydraulic conditions and water surface profiles for Dry Creek were determined by HEC-RAS modeling. The average channel slope for Dry Creek was determined to be approximately 2.4%. Below is a brief description of different parameters involved in the modeling of Dry Creek.

### 10.5.1 Manning's n-Values

Manning's n-values for the main channel and overbank portions of Dry Creek were determined by field observation and aerial photographs. In the upper portion of the studied reach, the channel floodplain narrows through dense development with a well-defined channel and heavy vegetation and has also been channelized in some areas. In the lower portion of the studied reach, the channel is deeply incised with a gravel and cobble bed and dense vegetation on the streambed and floodplains. Manning's n-values of 0.045-0.07 and 0.08-0.15 were used for the main channel and overbank portions, respectively. For some isolated portions where the main channel was obstructed with heavy stands of willows and timber, n-values of 0.08-0.10 were used for the main channel itself. In addition, a small section of the main channel at the downstream end of the culvert at Dawson Drive was channelized, and therefore an n-value of 0.015 was used for the concrete section accordingly. Table 10-2 outlines the extent of n-values along Dry Creek's main channel and overbank areas.

**Table 10-2. Summary of Manning's Roughness n-Values Along Dry Creek**

	Manning's n-Values (Overbank Portions)	Manning's n-Values (Main Channel)
Minimum	0.08	0.015
Maximum	0.15	0.10

### 10.5.2 Boundary Conditions

The Dry Creek modeling was performed under the mixed-flow regime that allows the HEC-RAS model to model both the supercritical and subcritical regimes. The downstream boundary condition for all the profiles for Dry Creek was set at normal depth based on the downstream channel slope of 0.048 feet/feet. The upstream boundary condition for all the profiles for Dry Creek was also set at the normal depth based on the upstream channel slope of 0.02 feet/feet.

### 10.5.3 Culvert Data

The information related to FHWA Chart and Scale numbers and entrance and exit loss coefficients for Dry Creek is summarized in Table 10-3.

**Table 10-3. Summary of Culvert Data for Dry Creek**

Culvert Location	FHWA Chart Number	FHWA Scale Number	Entrance Loss Coefficient	Exit Loss Coefficient
Rockrimmon Elementary School	2	2	0.7	1
Rockrimmon Blvd	8	1	0.4	1
Dawson Dr	8	1	0.4	1
Mark Dabling	8	1	0.4	1

### 10.5.4 Study Results

Water surface profiles for Dry Creek for the return intervals of 2-, 5-, 10-, 25-, 50-, 100-, and 500-years for the existing and future conditions are presented in Appendix G. The hydrologic flows for both existing and future conditions are same for Dry Creek. Complete HEC-RAS output tables for Dry Creek for the existing and future conditions are also provided in Appendix G. Table 10-4 summarize hydraulic conditions from the Dry Creek model results. This includes average channel velocity, average flow depth, average top width, and average Froude number for existing and future conditions, respectively. The average value for each of these parameters was computed by dividing the total sum of each parameter by the total number of cross sections at Dry Creek.

**Table 10-4. Hydraulic Conditions in Dry Creek from HEC-RAS Results  
(Existing and Future Conditions)**

<b>Hydraulic Parameter</b>	<b>10-Year Event</b>	<b>100-Year Event</b>	<b>500-Year Event</b>
Average channel velocity (ft/sec)	10.2	12.4	14.3
Average water surface depth in channel (ft)	6.6	9.8	11.3
Average top width (ft)	85.2	153.1	178.2
Average Froude number	0.7	0.8	0.9

Note:

ft/s = feet per second

## **11.0 DIRTY WOMAN CREEK**

### **11.1 Watershed Description**

Dirty Woman Creek is an intermittent stream located in the northeastern portion of the Monument Creek watershed and flows westerly from an area northeast of the I-25 and Hwy 105 interchange. The Dirty Woman Creek watershed has a contributing drainage area of approximately 5.0 square miles at its confluence with Monument Creek about 0.5 mile west of the Mitchell Avenue and Mount Herman Road intersection near the town of Monument. The Dirty Woman Creek watershed consists of developed land in the upper basin and less densely developed land in the lower basin. In the upper basin are private parcels or homes on large lots, and in the lower basin is generally open field and industrial development. A large commercial development and the I-25 and Hwy 105 interchange are located near the mouth of Dirty Woman Creek.

### **11.2 Scope of Study**

The portion of Dirty Woman Creek investigated for this study is approximately 1.3 miles long starting at its confluence with Monument Creek and extending upstream to a point just upstream of I-25. A location map of the studied reach of Dirty Woman Creek is provided in Figure 11-1.

### **11.3 Channel Description**

For most of the studied reach, the main channel of Dirty Woman Creek consists of a more defined grass swale with low-to-moderate vegetation over the channel overbanks.

### **11.4 Hydrology**

The Dirty Woman Creek HEC-HMS model was run for both existing and future conditions applying a 24-hour storm event with 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals. The details related to hydrologic analysis of Dirty Woman Creek are provided in a separate study report *Fountain Creek Watershed Preliminary Hydrology Report, URS, 2005*.

Table 11-1 summarizes URS-modeled peak discharges at points of interest throughout the Dirty Woman Creek watershed.

**Table 11-1. Peak Discharges at Points of Interest Along Dirty Woman Creek**

Location	HEC-HMS Element	Area (mi <sup>2</sup> )	Existing Peak Discharge (cfs)							Future Peak Discharge (cfs)						
			2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
At Hwy 105	JDW100	3.99	42	300	450	820	1,000	1,300	1,800	120	300	450	820	1,000	1,300	1,800
At I-25	JDW120	4.44	54	290	440	800	1,000	1,200	1,800	120	300	450	820	1,000	1,200	1,800
At Old Denver Hwy	JDW130	4.61	57	300	450	810	1,000	1,200	1,800	140	310	460	830	1,000	1,300	1,800
At Railroad Bridge	JDW140	4.92	66	310	460	840	1,000	1,300	1,800	200	360	490	860	1,100	1,300	1,900
At confluence with Monument Creek	DrtyWmn	5.02	70	310	470	840	1,100	1,300	1,900	220	400	550	860	1,100	1,300	1,900

Notes:  
mi<sup>2</sup> = square miles  
cfs = cubic feet per second  
yr = year

## 11.5 Hydraulics

Hydraulic conditions and water surface profiles for Dirty Woman Creek were determined by HEC-RAS modeling. The average channel slope for Dirty Woman Creek was determined to be approximately 1.3%. Below is a brief description of different parameters involved in the modeling of Dirty Woman Creek.

### 11.5.1 Manning's n-Values

Manning's n-values for the main channel and overbank portions of Dirty Woman Creek were determined by field observation and aerial photographs. For most of the studied reach, the main channel of Dirty Woman Creek consists of a more defined grass swale with low-to-moderate vegetation over the channel overbanks. Therefore, Manning's n-values of 0.07-0.08 and 0.04-0.05 were used for the main channel and overbank portions, respectively. For some isolated portions of Dirty Woman Creek where the main channel is obstructed with heavy stands of willows and timber and overbank areas consist of trees, dense willows, and thick vegetation, n-values of 0.10-0.12 and 0.06-0.07 were used for the main channel and overbank portions, respectively. Table 11-2 outlines the extent of n-values along Dirty Woman Creek's main channel and overbank areas.

**Table 11-2. Summary of Manning's Roughness n-Values Along Dirty Woman Creek**

	Manning's n-Values (Overbank Portions)	Manning's n-Values (Main Channel)
Minimum	0.07	0.04
Maximum	0.12	0.07

### 11.5.2 Boundary Conditions

The Dirty Woman Creek modeling was performed under the mixed-flow regime that allows the HEC-RAS model to model both the supercritical and subcritical regimes. The downstream boundary condition for all the profiles for Dirty Woman Creek was set at normal depth based on the downstream channel slope of 0.014 feet/feet. The upstream boundary condition for all the profiles for Dirty Woman Creek was also set at the normal depth based on the upstream channel slope of 0.013 feet/feet.

### 11.5.3 Culvert Data

The information related to FHWA Chart and Scale numbers and entrance and exit loss coefficients for Dirty Woman Creek is summarized in Table 11-3.

**Table 11-3. Summary of Culvert Data for Dirty Woman Creek**

Culvert Location	FHWA Chart Number	FHWA Scale Number	Entrance Loss Coefficient	Exit Loss Coefficient
Santa Fe Trail	8	3	0.7	1
Old Denver Hwy	34	3	0.9	1
Railroad	8	1	0.4	1
Mitchell Ave	2	2	0.7	1

### 11.5.4 Study Results

Water surface profiles for Dirty Woman Creek for the return intervals of 2-, 5-, 10-, 25-, 50-, 100-, and 500-years for the existing and future conditions are presented in Appendix H. Complete HEC-RAS output tables for Dirty Woman Creek for the existing and future conditions are also provided in Appendix H. Tables 11-4 and 11-5 summarize hydraulic conditions from the Dirty Woman Creek model results. This includes average channel velocity, average flow depth, average top width, and average Froude number for existing and future conditions, respectively. The average value for each of these parameters was computed by dividing the total sum of each parameter by the total number of cross sections at Dirty Woman Creek.

**Table 11-4. Hydraulic Conditions in Dirty Woman Creek from HEC-RAS Results  
(Existing Conditions)**

Hydraulic Parameter	10-Year Event	100-Year Event	500-Year Event
Average channel velocity (ft/sec)	5.1	6.8	7.3
Average water surface depth in channel (ft)	6.0	7.8	9.2
Average top width (ft)	151.5	195.5	229.1
Average Froude number	0.6	0.6	0.5

Note:

ft/s = feet per second

**Table 11-5. Hydraulic Conditions in Dirty Woman Creek from HEC-RAS Results  
(Future Conditions)**

Hydraulic Parameter	10-Year Event	100-Year Event	500-Year Event
Average channel velocity (ft/sec)	6.8	7.3	7.3
Average water surface depth in channel (ft)	7.8	9.2	9.3
Average top width (ft)	195.5	229.1	229.8
Average Froude number	0.6	0.5	0.5

Note:

ft/s = feet per second

Table 12-1 summarizes URS-modeled peak discharges at points of interest throughout the Teachout Creek watershed.

## **12.0 TEACHOUT CREEK**

### **12.1 Watershed Description**

Teachout Creek is an ephemeral stream located in the northeastern portion of the Monument Creek watershed and flows westerly from an area southeast of the I-25 and Hwy 105 interchange. The Teachout Creek watershed has a contributing drainage area of approximately 2.5 square miles at its confluence with Monument Creek about 0.75 miles northwest of the I-25 and Baptist Road interchange. The headwaters of Teachout Creek are dominated by undeveloped large-acreage tracts and 2- to 5-acre rural residential lots in unincorporated El Paso County. Just below the pines is grassland on undeveloped large-acreage tracts. The middle portion of Teachout Creek watershed contains a large development with single-family homes on small lots. I-25 crosses the lower portion of the watershed surrounded by grassland on undeveloped large-acreage tracts.

### **12.2 Scope of Study**

The portion of Teachout Creek investigated for this study is approximately 1.7 miles long starting from its confluence with Monument Creek and extending upstream to a point approximately 0.20 mile upstream of Jackson Creek Parkway. A location map of the studied reach of Teachout Creek is provided in Figure 12-1.

### **12.3 Channel Description**

For the upper portion of the studied reach, the channel appears to be well defined. In the upper portion, the channel bottom is sand, and the banks are grass-lined in this area. In the lower portion of the studied reach, the channel becomes wider with a bottom width of approximately 30 feet. In the lower portion, the channel bottom and the banks are also grass-lined. The riparian vegetation in the floodplain contains mainly grass.

### **12.4 Hydrology**

The Teachout Creek HEC-HMS model was run for both existing and future conditions applying a 24-hour storm event with 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals. The details related to hydrologic analysis of Teachout Creek are provided in a separate study report *Fountain Creek Watershed Preliminary Hydrology Report, URS, 2005*.

**Table 12-1. Peak Discharges at Points of Interest Along Teachout Creek**

Location	HEC-HMS Element	Area (mi <sup>2</sup> )	Existing Peak Discharge (cfs)							Future Peak Discharge (cfs)						
			2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
At Higby Rd	JTC010	0.53	59	130	180	300	370	450	620	59	130	180	300	370	450	620
-	JTC020	-	65	140	200	350	430	510	720	72	150	220	370	460	540	760
Downstream of I-25	JTC050	1.70	140	310	460	790	980	1,200	1,700	260	490	670	1,100	1,300	1,500	2,100
At Old Denver Hwy	JTC060	1.87	150	340	490	860	1,100	1,300	1,800	290	550	760	1,200	1,500	1,700	2,300
-	JTC070	-	150	350	520	910	1100	1400	1900	300	580	800	1300	1500	1800	2400
At Railroad Bridge	JTC080	2.22	190	420	610	1,100	1,300	1,600	2,200	360	690	930	1,500	1,800	2,100	2,800
At confluence with Monument Creek	Teachout	2.46	200	450	660	1,100	1,400	1,700	2,400	380	720	980	1,600	1,900	2,200	3,000

Notes:  
mi<sup>2</sup> = square miles  
cfs = cubic feet per second  
yr = year

## 12.5 Hydraulics

Hydraulic conditions and water surface profiles for Teachout Creek were determined by HEC-RAS modeling. The average channel slope for Teachout Creek was determined to be approximately 1.9%. Below is a brief description of different parameters involved in the modeling of Teachout Creek.

### 12.5.1 Manning's n-Values

Manning's n-values for the main channel and overbank portions of Teachout Creek were determined by field observation and aerial photographs. For the upper portion of the studied reach, the channel bottom is sand, and the banks are grass-lined. Therefore, for the upper portion of Teachout Creek, Manning's n-values of 0.03-0.035 and 0.07-0.08 were used for the main channel and overbank portions, respectively. In the lower portion, the channel bottom and the banks are grass-lined and, therefore, Manning's n-values of 0.04-0.045 were used for the main channel. Table 12-2 outlines the extent of n-values along Teachout Creek's main channel and overbank areas.

**Table 12-2. Summary of Manning's Roughness n-Values Along Teachout Creek**

	Manning's n-Values (Overbank Portions)	Manning's n-Values (Main Channel)
Minimum	0.07	0.03
Maximum	0.08	0.045

### 12.5.2 Boundary Conditions

The Teachout Creek modeling was performed under the mixed-flow regime that allows the HEC-RAS model to model both the supercritical and subcritical regimes. The downstream boundary condition for all the profiles for Teachout Creek was set at normal depth based on the downstream channel slope of 0.012 feet/feet. The upstream boundary condition for all the profiles for Teachout Creek was also set at the normal depth based on the upstream channel slope of 0.018 feet/feet.

### 12.5.3 Culvert Data

The information related to FHWA Chart and Scale numbers and entrance and exit loss coefficients for Teachout Creek is summarized in Table 12-3.

**Table 12-3. Summary of Culvert Data for Teachout Creek**

Culvert Location	FHWA Chart Number	FHWA Scale Number	Entrance Loss Coefficient	Exit Loss Coefficient
Jackson Creek Pkwy	8	3	0.2	1
Struthers Rd	1	3	0.2	1
I-25	8	1	0.4	1
Santa Fe Trail	29	1	0.5	1
Old Denver Hwy	34	3	0.9	1

### 12.5.4 Study Results

Water surface profiles for Teachout Creek for the return intervals of 2-, 5-, 10-, 25-, 50-, 100-, and 500-years for the existing and future conditions are presented in Appendix I. Complete HEC-RAS output tables for Teachout Creek for the existing and future conditions are also provided in Appendix I. Tables 12-4 and 12-5 summarize hydraulic conditions from the Teachout Creek model results. This includes average channel velocity, average flow depth, average top width, and average Froude number for existing and future conditions, respectively. The average value for each of these parameters was computed by dividing the total sum of each parameter by the total number of cross sections at Teachout Creek.

**Table 12-4. Hydraulic Conditions in Teachout Creek from HEC-RAS Results  
(Existing Conditions)**

Hydraulic Parameter	10-Year Event	100-Year Event	500-Year Event
Average channel velocity (ft/sec)	7.5	8.7	9.1
Average water surface depth in channel (ft)	2.6	4.2	4.9
Average top width (ft)	132.3	229.8	249.1
Average Froude number	1.0	1.0	0.8

Note:  
ft/s = feet per second

**Table 12-5. Hydraulic Conditions in Teachout Creek from HEC-RAS Results  
(Future Conditions)**

Hydraulic Parameter	10-Year Event	100-Year Event	500-Year Event
Average channel velocity (ft/sec)	8.1	9.2	9.2
Average water surface depth in channel (ft)	3.1	4.6	5.5
Average top width (ft)	165.1	242.5	271.7
Average Froude number	1.0	1.0	0.8

Note:  
ft/s = feet per second