SECTION 5

TABLES

FIGURES

5.0 SURFACE WATER RESOURCES IN THE STUDY AREA

Surface water resources in the study area are characterized in this section based on review of USGS stream flow and surface water quality data, the SEO water rights database, information obtained from CDMG files for mines in the area, field observations and studies and other literature sources[3]. Additionally, in order to put water usage in the basin into perspective, a conceptual water balance was developed for Surface Creek, which is one of the key drainages in the study area.

5.1 Stream Flows

As shown in Figure 1 and Exhibit 1, the primary surface water features include numerous lakes and reservoirs on the top of Grand Mesa and multiple tributaries to the North Fork of the Gunnison River and Gunnison River along the south and east flanks of the Grand Mesa. Some of the key tributaries, listed from west to east, include Tongue Creek, Dirty George Creek, Williams Creek, Ward Creek, Cottonwood Creek, Kiser Creek, Youngs Creek, Milk Creek, Surface Creek, Currant Creek, Leroux Creek, Cow Creek, Dever Creek, Jay Creek, Roatcap Creek, Terror Creek, Hubbard Creek, Bear Creek, Elk Creek, Sanborn Creek, Hawksnest Creek, Thompson Creek, Muddy Creek and Anthracite Creek. Streamflows are influenced by a variety of factors such as total amount and distribution of precipitation, irrigation diversions and return flows, soil types and geologic characteristics. Figure 5 shows the watersheds in the study area. Figure 6 shows the extreme variation in precipitation in the study area based on data from the Colorado Climate Center, ranging from approximately 41 to 45 inches/year atop the Grand Mesa to 11 to 20 inches/year along the North Fork of the Gunnison River. Figure 7 shows hydrologic soil groups, which indicate the amount of precipitation and/or irrigation water that infiltrates into the soil or flows back to the stream. Soil type A has a high infiltration rate, whereas soil type D usually consists of clays that are nearly impermeable (low infiltration) and produce higher

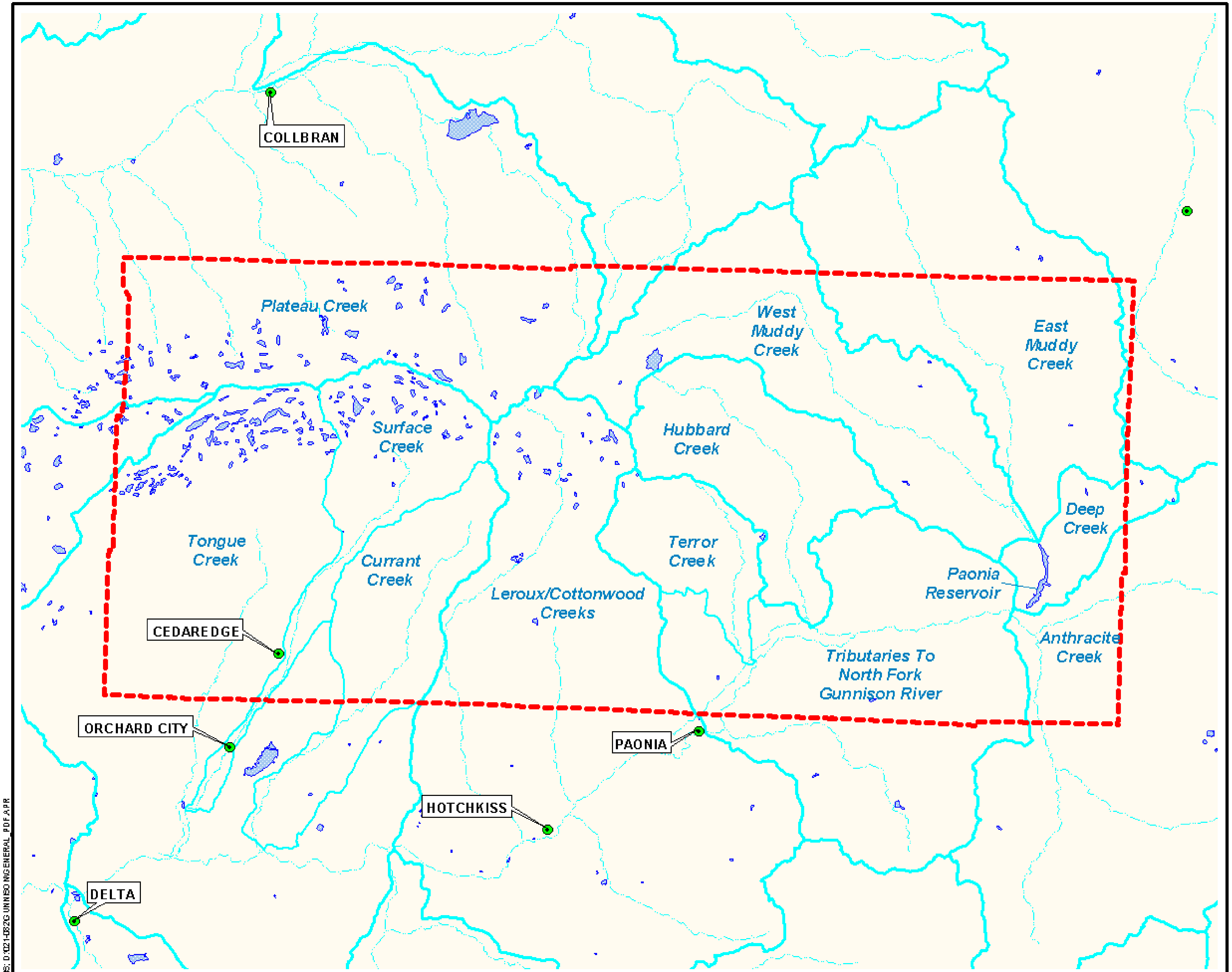
---

[3] Information presented in this section represents data available as of December 2003. Databases, such as those provided on the Internet by the USGS and SEO, are updated periodically and are subject to change.

volumes of runoff. Figure 8 provides a rough distribution of irrigated lands in the study area as of 1999. Exhibits 4 through 6 portray the geologic characteristics of the study area.

Table 2 contains a summary of data available for USGS stream gauges in the study area. Representative average annual flows for minor tributaries in the Cedaredge area such as Kiser, Cottonwood and Youngs Creeks range from 1 to 4 cubic feet per second (cfs). For larger tributaries such as Surface Creek upstream from Cedaredge (and upstream from most diversions), average annual flows are around 45 cfs. (For purposes of comparison, 1 cfs=449 gallons per minute.) Stream flows in the study area are affected by extensive diversions from the streams for irrigation and domestic uses, particularly west of Oak Mesa. Although many USGS stream gauges are present in the study area, only Surface Creek has multiple gauges on the same stream with the same periods of record to enable an assessment of whether the streams typically gain or lose flows along various reaches. Surface Creek flows decrease between the gauge located upstream of Cedaredge and the gauge at Cedaredge. This stream loss is attributed primarily to ditch diversions from the stream, as discussed in Section 5.5.1. In general, however, the key tributaries listed above exhibit highly seasonal flows, which peak in the late spring/early summer during snowmelt and decline to baseflows in the winter. Representative hydrographs showing seasonal variations for Surface Creek and Hubbard Creek are shown in Figures 9 and 10.

Various streams in the study area have minimum instream flows, as administered by the Colorado Water Conservation Board (CWCB), for protection of aquatic life. Representative minimum instream flows for tributaries to the North Fork of the Gunnison River include: East Leroux Creek (1 cfs), Hubbard Creek (3 cfs), Main Hubbard Creek (3 cfs), Middle Leroux Creek (2 cfs), West Leroux Creek (1 cfs), Cunningham Creek (1.5 cfs), Little Dyke Creek (2 cfs), Snowshoe Creek (3 cfs), Milk Creek (1 cfs) and West Muddy Creek (2 cfs). All of these flows are recommended for the entire calendar year. These flows were appropriated May 4, 1984 and were recommended by the Colorado Division of Wildlife. The CWCB indicated that no records were available identifying the fish species present on these reaches (CWCB 2002). The USFS and BLM (2000) identified rainbow, brown, brook and cutthroat trout and other native fish species in Hubbard Creek and the North Fork of the Gunnison River. Colorado "species of special concern" present in the North Fork of the Gunnison River in the study area include the roundtail chub, bluehead sucker, white sucker and flannel mouth sucker (USFS and BLM 2000).



GIS: D:\021-082\GUNNISON\GENERAL_PDF.APR

FIGURE 5

WATERSHED LOCATION MAP

MAP LEGEND

STUDY AREA BOUNDARY

WATERSHED BOUNDARY

DATA / MAPPING SOURCE: COLORADO CDSS

N
W E
S

4 0 4 Miles

1" = 4 MILES

WWE

WRIGHT WATER ENGINEERS, INC.
2490 W. 26TH AVE. 100A
DENVER, CO. 80211
(303) 480-1700

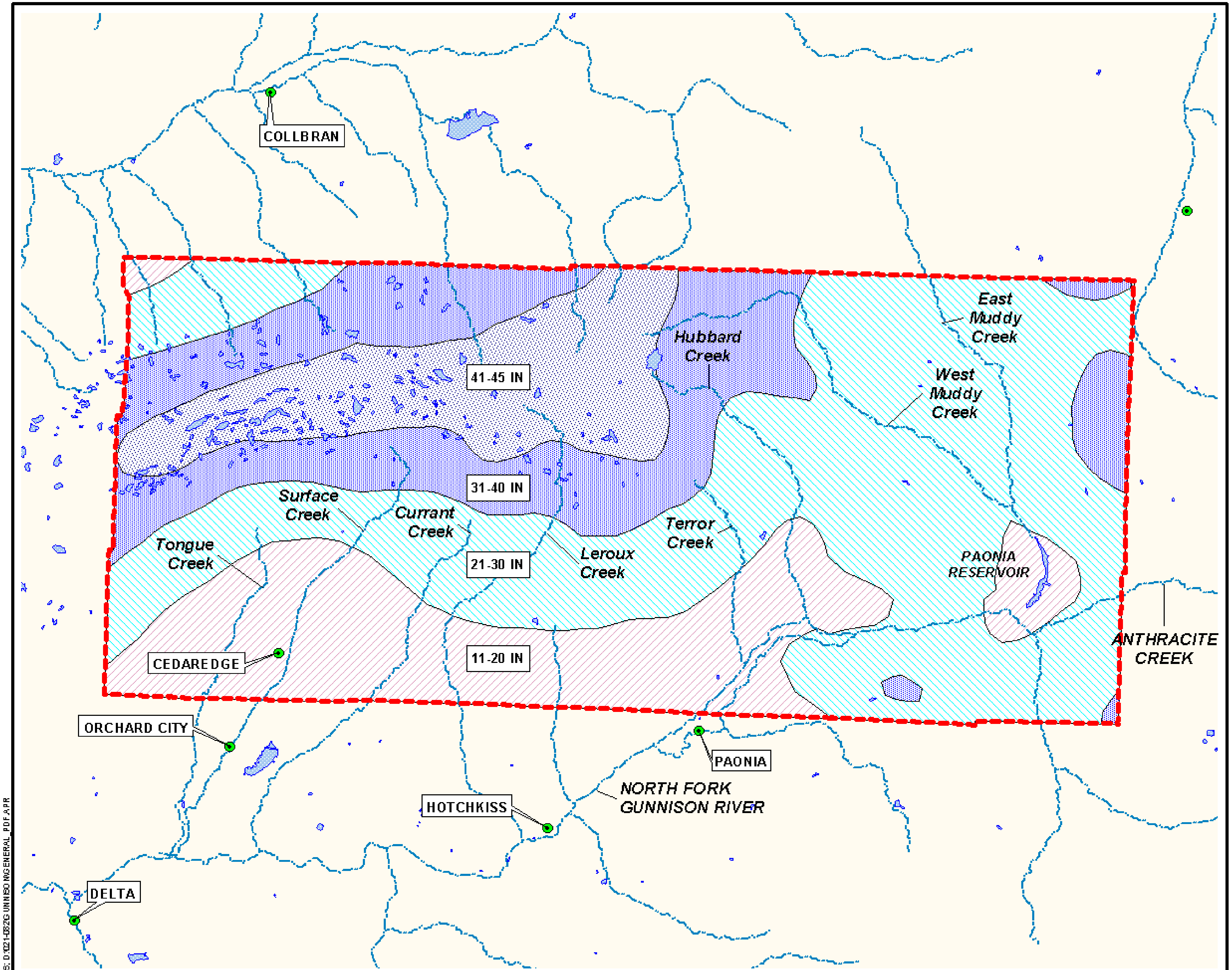


FIGURE 6
AVERAGE ANNUAL PRECIPITATION IN STUDY AREA

MAP LEGEND

STUDY AREA BOUNDARY

PRECIPITATION (IN)

- 11 - 20
- 21 - 30
- 31 - 40
- 41 - 45

N
W E
S

4 0 4 Miles

1" = 4 MILES

WWE

WRIGHT WATER ENGINEERS, INC.
2490 W. 26TH AVE. 100A
DENVER, CO. 80211
(303) 480-1700

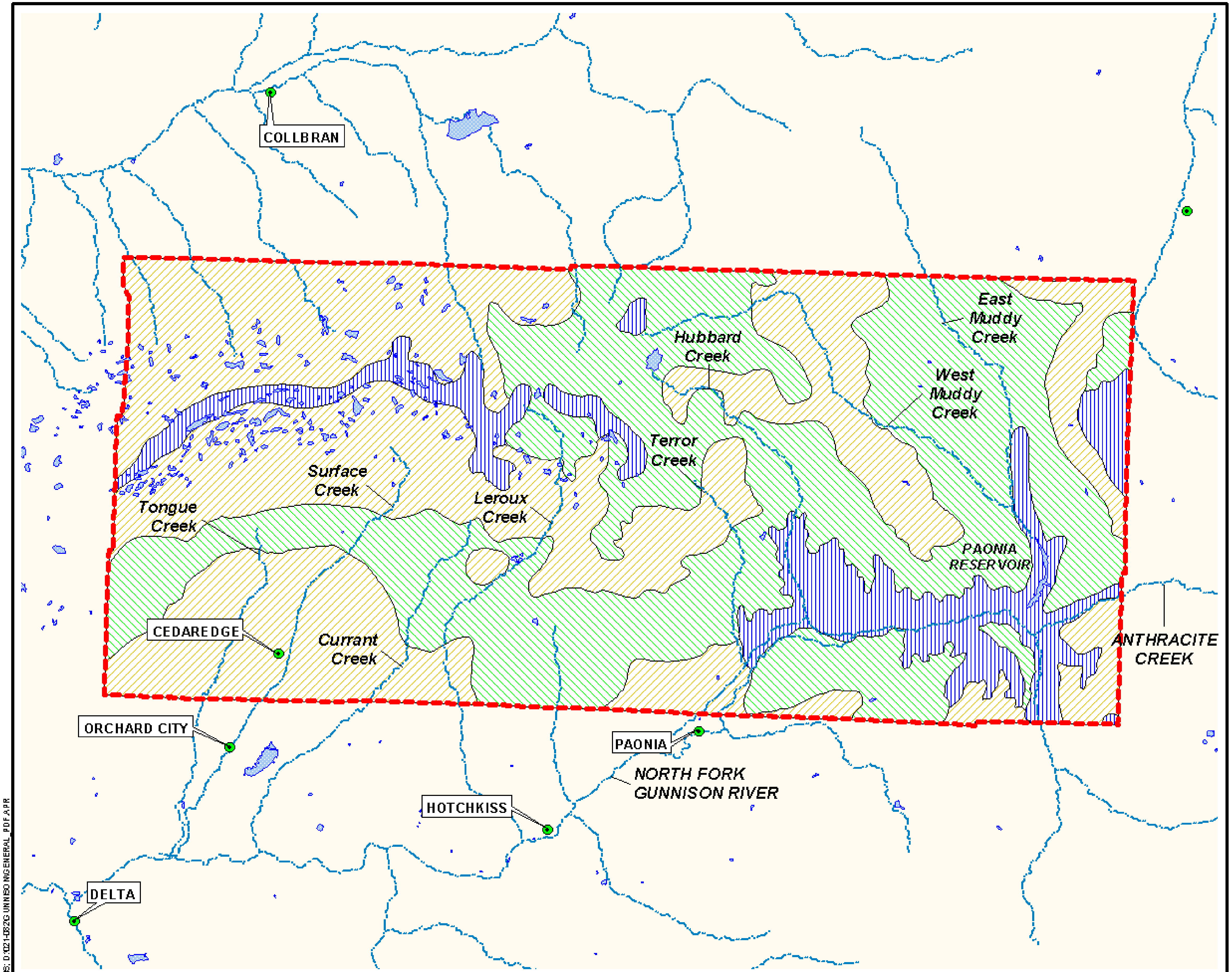


FIGURE 7
HYDROLOGIC SOIL GROUPS* FOR STUDY AREA

MAP LEGEND

STUDY AREA BOUNDARY

HYDROLOGIC SOIL GROUP

B

C

D

*AS DEFINED BY THE NATURAL RESOURCES CONSERVATION SERVICE, NRCS

SOIL DATA / MAPPING SOURCE: COLORADO CDSS

N S W E

4 0 4 Miles

1" = 4 MILES

WWE
WRIGHT WATER ENGINEERS, INC.
2490 W. 26TH AVE. 100A
DENVER, CO. 80211
(303) 480-1700

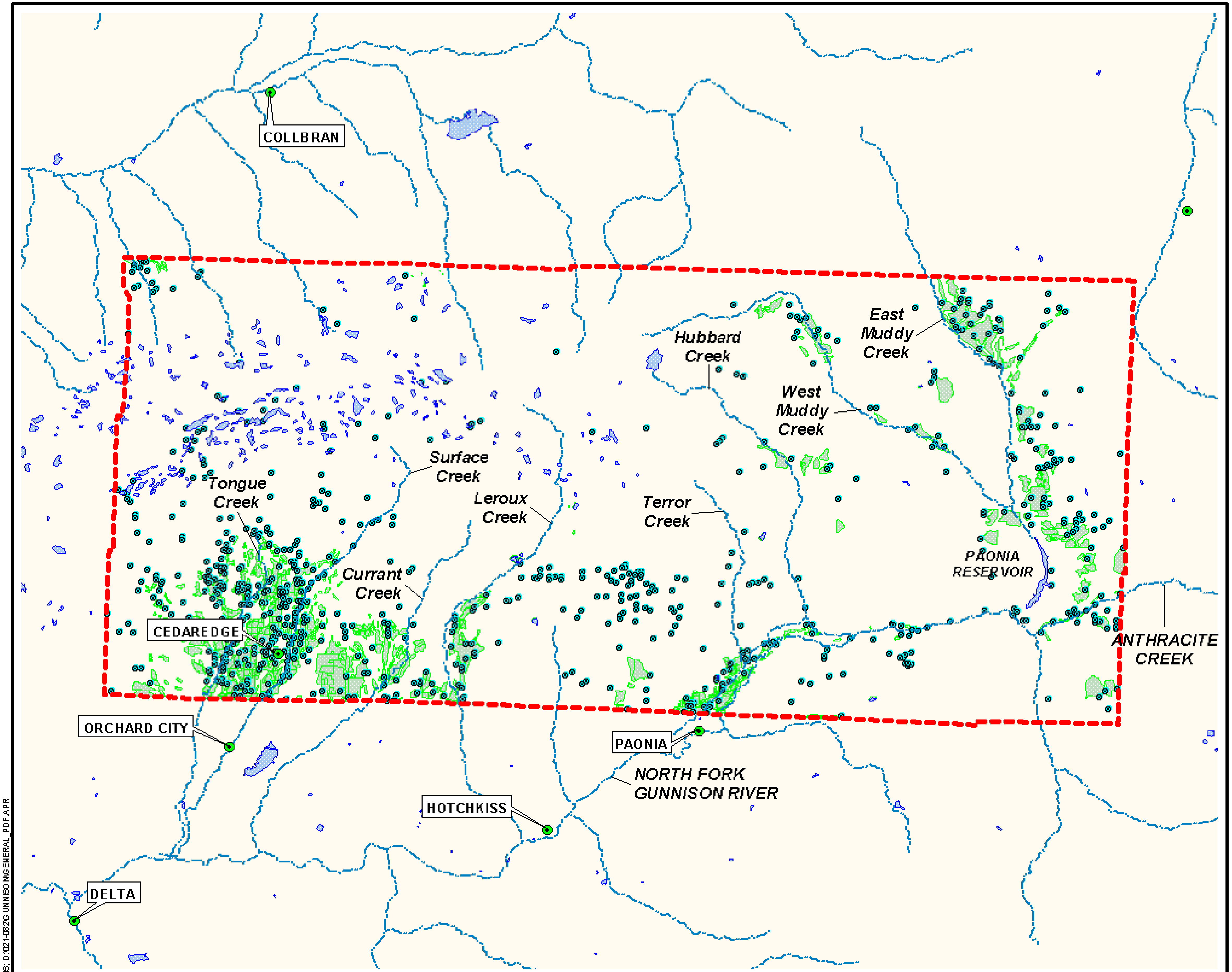


FIGURE 8
IRRIGATED AREAS AND DIVERSION STRUCTURES

MAP LEGEND

STUDY AREA BOUNDARY

DIVERSION LOCATIONS (INCLUDING SPRINGS AND DITCH HEADGATES)

IRRIGATED AREAS

DATA / MAPPING SOURCE: COLORADO CDSS

N
W E
S

4 0 4 Miles

1" = 4 MILES

WWE

WRIGHT WATER ENGINEERS, INC.
2490 W. 26TH AVE. 100A
DENVER, CO. 80211
(303) 480-1700

Table 2

Average Annual Precipitation and Snowfall at Cedaredge (inches) and Mean Annual Streamflows (cfs) at USGS Gauging Stations in the Study Area (USGS 2002)

Year	Avg. Annual Precip. (inches) Cedaredge	Avg. Annual Snowfall (inches) Cedaredge	Dirty George Creek	Ward Cr. Near Grand Mesa	Ward Cr. Near Cedaredge	Kiser Cr Near Grand Mesa	Kiser Cr Near Cedaredge	Cottonwood Cr Near Grand Mesa	Cotonwood Cr Near Cedaredge	Youngs Cr Near Cedaredge	Youngs Cr Near Grand Mesa	Ward Cr Below Kiser Cr Near Cedaredge	Surface Creek Nr Cedaredge	Surface Creek At Cedaredge	Surface Creek At Eckert	Tongue Cr at Cory	Currant Cr Nr Cedaredge	Currant Cr Nr Read
1918														24				
1919														17				
1920														48.9				
1921														45.2				
1922														45.9				
1923														30.3				
1924														20.1				
1925	11.81	13												25.7				
1926	14.05	16.6												34.6				
1927	18.77	58.2												32.8				
1928	11.97	21.7												29.4				
1929	12.88	51.3												41.4				
1930	12.84	66.8												25.7				
1931	12.07	42.4												17.1				
1932	9.54	42.4												33.6				
1933	9.2	48												18				
1934	10.23	37.6												11				
1935	9.25	36.5												22.5				
1936	10.67	47.7												20.9				
1937	11.74	42.3												30.5				
1938	13.92	38.2												38.4				
1939	8.97	29.7												16.7				
1940	15.9	45.7											35.1	18.9				
1941	18.05	60.8											62.6	43.4				
1942	9.81	50											53.8	32.6				
1943	13.17	27.7			0.63		1.21		0.22	0.38			36.3	18	2.25			
1944	12.62	41.6			6.21		3.01		2	3.42			52.4	32.9	14.2			
1945	9.39	16.3			4.07		1.93		0.97	2.84		12.9	49.4	24.1	4.91			
1946												4.33	30.2	15.3	1.71			
1947	13.83											9.64	51.7	28.8	4.1			
1948												14.1	44.3	25.3	6.22			
1949	10.03	62.3										8.29	44.5	22.1	3.42		8.31	
1950	7.33	39.5										3.89	41.2	20.8	2.17		5.55	
1951	10.09	56										2.32	31.6	16.1			3.21	
1952	11.16	78.5											68.8	35.7			12	
1953	12.01	33.5											30.7	16.9			3.95	
1954	10.06	29											27.4	18.4				
1955	10.46	55											38.8	23.5				
1956	8.57	53											29.2	18.9				
1957	20.44	51.5											60.2	40.8				
1958	11.3	42.5	12.2	20.7		15		2.41			12		56.9	34		76		
1959	11.39	33.5	3.72	7.27		6.03		0.7			3.96		25.7	16.3		12.3		
1960	9.23	44.5	5.31	9.86		6.6		1.33			5.97		32.5	21.4		13.6		
1961	12.24	42.7	5.01	8.77		7.39		1.1			4.58		28.7	20.8		11		
1962	11.85	45.5	8.48	12.9		8.8		1.92			9.78		48.2	32.3		35.4		
1963	10.43	35.5	3.7	8.42		5.34		0.56			4.03		23.8	16.6		12.9		
1964	13.09	57	4.49	10		6.59		1			5.25		30.1	19.9		11.5		
1965	17.86	38.5	9.13	14		7.05		1.89			8.93		46	29.7		45.7		
1966	8.94	28	7.58	11.8		9.39		1.06			7.03		38	24.7		26.9		
1967	10.12	33	4.45	11.5		7.36		0.98			6.47		36.6	24.3		17.8		
1968	10.97	34.2	5.75	13.3		7.76					6.45		37.8	23.1				
1969	13.97	40.1											52.6	32.2				
1970	14.4	35.6											41.3	26.2				
1971	12.72	55.2											40	24.3				
1972	11.13	26.7											34.5	22.3				
1973		50.2											58.6	40.3				
1974	8.59	48.4											33.6	18.5				
1975	7.86	44.4											47.3	29.8				
1976	7.5	24.5											29.8	20.3				
1977	7.48	14.5											9.59	7.41		6.76		1.29
1978	15.49	59.2											47.9	31.8		41.5		4.62
1979	9.42												49.5	34.6		58		13.1
1980	15.67	59.7											55.8	42.3		80.4		17.1
1981	13.9	38.3											25.5	17.4		19.5		2.46
1982													56.4	33.9		49		9.54
1983	19.98	94.2											73.7	61.2		159		24.7
1984	15.61	60.3											59.7	49.5		97.8		22.6
1985	18.27	77.4											57.5	40.1		99.2		23.6
1986	18.68	48.3											71.8	47.8		112		25.8
1987	13.52	65.5											54.9	33.3				
1988	13.84	54.8											35.2	18.8				
1989	10.57	34.5											30.8	18.4				
1990	12.61	48.8											23.7	15				
1991	13.9	87.3											35.4	21.3				
1992	14.71	42.4											31.9	18.5				
1993	16.84	83.5											63.2	49.3				
1994													35.5	21.7				
1995													66.9	45.6				
1996													32.4	21.7				
1997													62.1	40.7				
Averages	12.4	45.6	6.3	11.7	3.6	7.9	2.1	1.3	1.1	2.2	6.8	7.9	43.3	27.9	4.9	49.3	6.6	14.5

Table 2 (continued)

Year	EAST MUDDY CREEK NEAR BARDINE	WEST MUDDY CREEK NEAR RAGGED MOUNTAIN	09130800 WEST MUDDY CREEK NEAR BOWIE	COW CREEK NEAR PAONIA, CO.	WEST MUDDY CREEK NEAR SOMERSET, CO.	MUDDY CREEK AT BARDINE, CO.	ANTHRACITE CREEK NEAR SOMERSET, CO.	NORTH FORK GUNNISON RIVER NEAR SOMERSET	MAIN HUBBARD CREEK NEAR PAONIA, CO.	MIDDLE HUBBARD CREEK NEAR PAONIA	WEST HUBBARD CREEK NEAR PAONIA, CO.	HUBBARD CREEK NEAR BOWIE, CO.	NORTH FORK GUNNISON RIVER NEAR PAONIA, CO.	MINNESOTA CREEK NEAR PAONIA, CO.	MINNESOTA CREEK AT PAONIA, CO.	NORTH FORK GUNNISON RIVER BELOW PAONIA	COTTONWOOD CREEK NEAR HOTCHKISS, CO.	LEROUX CREEK NEAR CEDAREDGE, CO.	COW CREEK NEAR CEDAREDGE, CO.	LEROUX CREEK NEAR LAZEAR, CO.	LEROUX CREEK AT HOTCHKISS, CO.
1918																				51.53	
1919																				35.78	
1920																				87.16	
1921																				76.89	
1922													592.70							71.04	
1923													614.19							52.41	
1924													432.26							42.32	
1925													406.96							44.77	
1926													496.46							55.41	
1927													630.45								
1928													637.26								
1929													848.18								
1930													638.58								
1932													1313.88								
1933								86.63													
1934	10.66							179.72													
1935	73.62							425.09													
1936	74.21							455.90						5.42				7.00			
1937	69.35							409.24						25.91				50.00			
1938	135.10							618.98						28.47				77.06			
1939	58.03							356.79						17.60				39.40			
1940	54.20							333.30						18.56				41.25			
1941	121.47							561.42						27.79				73.46			
1942	112.99							587.56						37.00				63.69			
1943	69.83							423.78						21.42				43.43			
1944	129.63							547.97						25.21				52.19			
1945	98.55							489.02						28.10				49.59			
1946	61.52							342.59						16.58				29.14			
1947	100.55							484.95						25.62				54.32			
1948	106.15							523.76										46.33			
1949	90.62					23.97		470.31										55.50			
1950	80.47					158.06		461.57										47.65			
1951	57.13					89.96		354.62										35.56			
1952	126.40					243.85		654.04										74.24			
1953	75.30					91.98		339.99										32.46			
1954						49.88		202.88										31.21			
1955		0.18				125.10		324.07										41.94			
1956		3.25						336.43										46.04			
1957		7.99						839.62													
1958		6.44						490.81													
1959		2.58						275.73													
1960		3.23						341.93	0.28	0.38	0.49							6.52	0.00		
1961		3.21			13.24			292.07	1.20	1.30	2.59							31.29	10.24		
1962		8.56			56.86			612.31	2.43	2.56	5.04							63.59	15.62		
1963		2.35			10.31			233.78	1.27	1.31	2.18							28.32	9.82		
1964		4.12			18.42			372.14	1.33	1.45	2.98							39.16	11.07		
1965		7.77			37.86			618.69	2.21	2.47	4.99							55.84	14.47		
1966					23.46			312.22	1.17	1.54	2.64							36.38	12.41		
1967					17.90			342.04	1.66	2.11	3.70							44.12	13.82		
1968			2.66	2.64	31.23			479.16	2.39	2.39	3.13	2.82						45.66	15.78		
1969			25.06	11.06	42.95			498.85			4.47	26.68						80.74	20.42		
1970			22.14	8.64	36.78			481.97			4.18	19.72									
1971			22.67	7.72	35.57			433.18			3.32	14.98									
1972			11.55	5.69	16.61			307.66			2.20	10.12									
1973			22.25	12.73	63.38			588.18			5.92	19.01									
1974			16.11	3.54				431.61				13.79									
1975				9.72				506.22													
1976				5.16				319.66							4.96		5.21				7.67
1977				0.79			20.71	107.86							2.59		2.61				3.26
1978				8.13			206.72	483.99							15.36		5.11				29.76
1979				10.80			236.52	621.35							30.68		13.83				33.74
1980				11.41			209.07	675.67													49.97
1981				3.33			126.73	241.38													8.14
1982				14.93				564.67													36.91
1983								764.41													42.92
1984								838.58													58.87
1985								818.20						9.55							52.44
1986								823.53						40.40							56.28
1987								465.13						26.31							36.94
1988								309.72						12.88							8.12
1989								335.44						12.95							7.89
1990								215.93						8.07							5.42
1991								397.10						17.92							11.23
1992								344.88						21.04							11.82
1993								786.69						47.53							54.24
1994								365.01						15.97							9.61
1995								819.79						38.15							47.83
1996								482.04						15.64							12.01
1997								694.49						36.58							
1998								547.18						22.56							
1999								363.22						12.33							
2000								315.16						9.91		323.43					
2001								346.15						12.00		303.35					
Average	85.29	4.52	17.49	7.75	31.12	111.83	159.95	456.17	1.55	1.72	3.42	15.30	661.09	21.98	13.40	313.39	6.69	45.91	12.37	57.48	27.86

Figure 9
Annual Hydrograph for USGS Gauge
Surface Creek At Cedaredge (1917-2001)

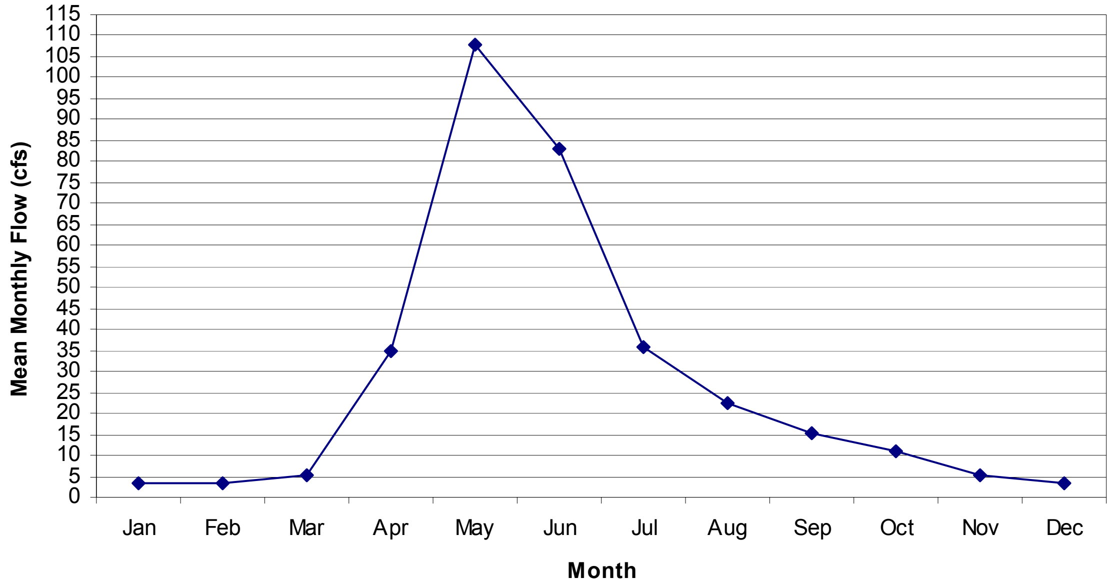
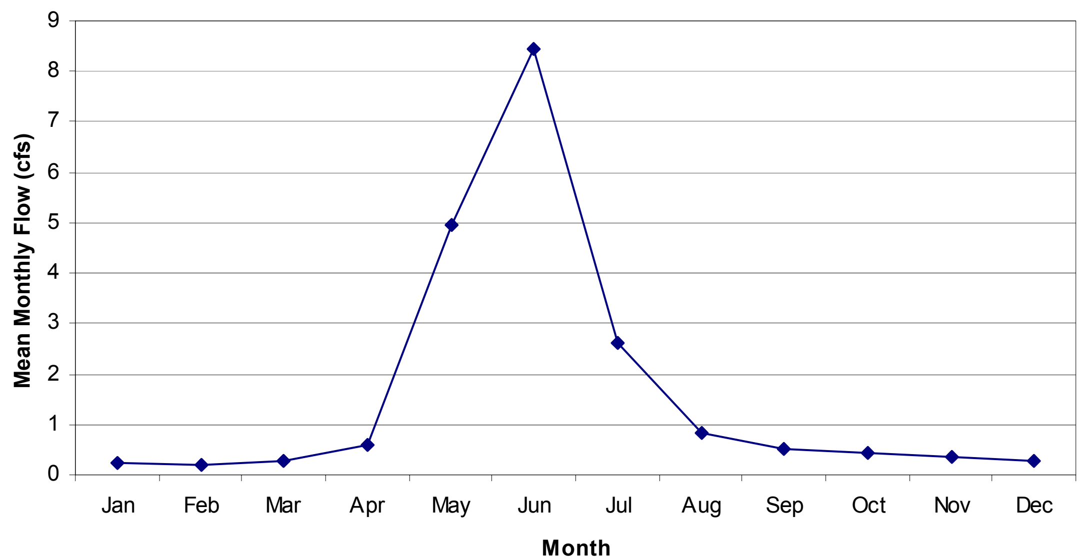


Figure 10
Annual Hydrograph for USGS Gauge
Main Hubbard Creek (1960-1968)



5.2 Surface Water Quality

In order to establish baseline water quality conditions in the study area, both a literature review and a field monitoring program have been conducted (field monitoring is on-going as of January 2003). Although a variety of data sources were pursued and reviewed, the primary published data sources include:

- Colorado Department of Public Health and Environment (CDPHE) Water Quality Control Commission (CWQCC) and Division (CWQCD)
- USGS National Water Information System database (http://waterdata.usgs.gov/nwis)
- CDMG permit files for mines in the vicinity
- Oxbow Mining water quality database

In addition to the literature review, Cordilleran, working closely with WWE, collected field data at multiple locations in the study area, as shown on Exhibit 1 and as summarized in Appendix B. Mr. Greg Lazear provided additional field data for springs in the vicinity of Cedaredge that are discussed in Section 5.2.6, along with follow-up samples obtained by Cordilleran at some of these springs.

The findings of each of these key data sources are outlined below.

5.2.1 Colorado Department of Public Health and Environment Water Quality Control Commission and Division Data

Surface water quality can be assessed by comparing water quality data to stream standards assigned by the CWQCC to protect beneficial uses for streams and lakes throughout Colorado. This assessment indicates that, in general, surface water quality is good in the study area.

The study area includes stream segments within both the North Fork of the Gunnison and Lower Gunnison River sub-basins of the Colorado River. In the study area, the CWQCC has assigned numeric standards to protect the following designated beneficial stream uses: Aquatic Life

Cold-1, Recreation-1, Water Supply and Agriculture, with a few exceptions to the Aquatic Life designation. A general overview of these designated uses as provided in the "Basic Standards and Methodologies for Surface Water" (5 CCR 1002-31) includes:

- Recreation Class 1: This classification is intended to protect "primary contact" with the surface water where ingestion of small quantities of the water is likely to occur. For example, recreational activities conducted on these waters could include swimming, rafting, kayaking, tubing, etc.

- Agriculture: This classification is intended to protect waters that would be used for irrigation of crops usually grown in Colorado and used for drinking water for livestock.

- Aquatic Life Class 1 (Cold): This classification is intended to protect waters that: 1) are currently capable of sustaining a wide variety of cold water biota, including sensitive species such as trout, or 2) could sustain such biota if water quality conditions were corrected. These waters are considered capable of sustaining such biota where physical habitat, water flows or levels, and water quality conditions result in no substantial impairment of the abundance and diversity of species.

- Aquatic Life Class 2 (Cold or Warm): This classification is intended to protect waters that are not capable of sustaining a wide variety of biota due to physical habitat, water flows or levels, or uncorrectable water quality conditions that result in substantial impairment of the abundance and diversity of species.

- Water Supply: This classification is intended to protect waters suitable or intended to become suitable for potable water supplies. After receiving standard drinking water treatment, these waters would meet Colorado drinking water regulations.

Some tributaries to the North Fork of the Gunnison River that are not on National Forest lands or specifically identified in the CWQCC stream classifications have the less stringent Aquatic Life Warm-2 designation, instead of the Aquatic Life-Cold-1 Designation. Surface Creek, Ward Creek, Tongue Creek and Youngs Creek have an Aquatic Life Cold-2 standard, which is also less stringent than the Aquatic Life Cold-1 standard. Although a comprehensive review of aquatic life species was not completed for purposes of this report, sensitive species such as trout are known to be present in many of the streams in the study area, particularly the streams with the Aquatic Life Class 1 (Cold) designation (CWQCC 2002) and some of the streams with minimum instream flow allocations (CWCD 2002), as discussed in Section 5.1.

Based on the CWQCD's review of these streams in 2001, as reported in the state's 305(b) report "Status of Water Quality in Colorado-2002," all of the segments reviewed within the study area shown in Figure 1 were considered to "fully support" their designated uses (i.e., attain stream standards) with the exception of segment COGUNF05, which includes Hubbard, Terror, Minnesota and Leroux Creeks. As summarized in Table 3, these creeks supported all uses except the Aquatic Life Cold-1 designation due to elevated levels of selenium and other metals, particularly in areas overlying or downstream of Mancos Shale outcrops.

The CWQCD identified agricultural activities as the source of these elevated constituents. These stream segments were identified as being targeted for the Total Maximum Daily Load (TMDL) process for 2004 (CWQCD 2002). This process allocates loads of the contaminant of concern among various sources discharging to the stream, naturally occurring background sources and a safety margin in order to help the stream meet its stream standard and designated uses.

Table 3

2001 CWQCD Assessment of Designated Use Support for Streams Within Study Area[1]

Water Body ID	Segment	Channel Length	Assessed Uses	Comments
COGULG07	Surface Creek, Ward Creek, Tongue Creek, Youngs Creek	43 miles	FS-AqLife Cold 2 FS-Rec 1 ND-Water Supply FS-Ag	
COGULG08	Mainstream of Surface Creek and Kannah Creek, including all tributaries, from the boundary of national forest lands to the point of diversion for public water supply; Fruita Water Supply Reservoirs I and II	17 miles	FS-AqLife Cold 1 FS-Rec 1 FS-Water Supply FS-Ag	
COGUNF01	North Fork of the Gunnison River including all tributaries within the West Elk and Raggeds Wilderness Areas	134 miles	FS-AqLife Cold 1 FS-Rec 1 FS-Water Supply FS-Ag	
COGUNF02	Mainstem of North Fork of the Gunnison River from the confluence of Muddy Creek and Coal Creek to the Black Bridge	17 miles	FS-AqLife Cold 1 FS-Rec 1 FS-Water Supply FS-Ag	
COGUNF04	All tributaries to the North Fork of the Gunnison River including all lakes, reservoirs, and wetlands from source of Muddy Creek to a point just below confluence w/Coal Creek	516 miles	FS-AqLife Cold 1 FS-Rec 1 FS-Water Supply FS-Ag	
COGUNF05	Hubbard, Terror, Minnesota, and Leroux Creeks	30 miles	NS-AqLife Cold 1 FS-Rec 1 FS-Water Supply FS-Ag	TMDL pending in 2004 due to metals and selenium; agriculture identified as the source
COGUNF06	All tributaries to the North Fork of the Gunnison River including all lakes, reservoirs, and wetlands which are not on national forest lands, except for the specific listings	240 miles	FS-AqLife Warm 2 FS-Rec 1 FS-Water Supply FS-Ag	
COGUNF07	Paonia Reservoir	318 acres	FS-AqLife Cold 1 FS-Rec 1 FS-Water Supply FS-Ag	

[1] NOTES:
FS = fully supporting designated use
NS = not supporting designated use
ND = not determined
AqLife = aquatic life
Rec = recreation
Ag = agriculture

5.2.2 USGS National Water Information System

The USGS has collected water quality samples at multiple locations in the study area, as shown in Table 4. At each sample location, periods of record and number of samples vary significantly, which limits the conclusions and trends that can be identified based on the data. This is particularly relevant in the study area, which is significantly influenced by seasonal variations such as irrigation return flows. However, the data set does demonstrate the significant variability in water quality conditions. For example, total dissolved solids (TDS) concentrations vary from 70 mg/L at “Cow Creek near Paonia” to 3,023 mg/L at “Cottonwood Creek near Hotchkiss.” As explained in Section 5.2.6, TDS is a widely used water quality metric, and can be useful for comparing the similarity of samples from different locations. Average hardness (another common parameter which is the sum of calcium and magnesium expressed as calcium carbonate equivalent) varies from 42 mg/L on “Cow Creek near Paonia” to 2,000 mg/L on “Cottonwood Creek near Hotchkiss.”

Table 4.
USGS Water Quality Data Relevant to Gunnison Energy

SITE #	STATION #	ARSENIC DISSOLVED (UG/L AS AS)	ARSENIC SUSPENDED TOTAL (UG/L AS AS)	BARIUM DISSOLVED (UG/L AS BA)	BERYLLIUM DISSOLVED (UG/L AS BE)	BICARBONATE, WATER, DISSOLVED, INCREMENTAL TITRATION, FIELD, MG/	BORON DISSOLVED (UG/L AS B)	CALCIUM DISSOLVED (MG/L AS CA)	CHLORIDE DISSOLVED (MG/L AS CL)	FLUORIDE DISSOLVED (MG/L AS F)	HARDNESS TOTAL (MG/L AS CAC03)	MAGNESIUM DISSOLVED (MG/L AS MG)	PH, WATER, WHOLE, FIELD, STANDARD UNITS	PH, WATER, WHOLE, LABORATORY, STANDARD UNITS	POTASSIUM DISSOLVED (MG/L AS K)	SILICA DISSOLVED (MG/L AS SIO2)	SODIUM ADSORPTION RATIO	SODIUM DISSOLVED (MG/L AS NA)	SODIUM PLUS POTASSIUM DISSOLVED (MG/L AS NA)	SPECIFIC CONDUCTANCE (MICROSIEMENS/CM AT 25 DEG. C)	SULFATE DISSOLVED (MG/L AS SO4)
9131100	COW CREEK NEAR PAONIA, CO.	1.00						11.40	0.83	0.11	41.60	2.73	7.87	7.66	0.95	7.95	0.16	1.89		124.71	6.83
9132050	ANTHRACITE CREEK NEAR SOMERSET, CO.	0.93	0.25	53.57	2.29		14.82	17.31	1.01	0.11	53.71	2.58	7.58	7.78	0.57	6.62	0.20	3.51	15.51	126.21	12.56
9132500	NORTH FORK GUNNISON RIVER NEAR SOMERSET, CO.	1.07	0.38	70.00	3.25		26.72	19.38	1.65	0.12	61.68	3.32	7.79	7.99	0.80	8.74	0.37	6.70	7.63	155.94	9.76
9132940	HUBBARD CREEK ABOVE IRON POINT GULCH NEAR BOWIE, CO																			274.00	
9132985	E FORK TERROR CREEK BELOW COTTONWOOD STOMP NEAR BOWIE, CO																			97.00	
9132995	TERROR CREEK AT MOUTH NEAR BOWIE, CO																			332.00	
9134000	MINNESOTA CREEK NEAR PAONIA, CO.																			454.62	
9134050	MINNESOTA CREEK AT PAONIA, CO.												8.26							1007.91	
9134100	NORTH FORK GUNNISON RIVER BELOW PAONIA, CO																			426.80	
9134200	COTTONWOOD CREEK NEAR HOTCHKISS, CO.							310.00	26.42	0.54	2000.00	188.20	8.07	7.93	7.87	13.08	4.00	287.40		3310.79	1794.00
9134500	LEROUX CREEK NEAR CEDAREDGE, CO.												8.00							91.00	
9134700	COW CREEK NEAR CEDAREDGE, CO.												8.10							102.00	
9135000	LEROUX CREEK NEAR LAZEAR, CO.												9.00							280.00	
9135900	LEROUX CREEK AT HOTCHKISS, CO.							155.00	11.70	0.60	690.00	74.50	8.32		6.95	31.00	1.00	71.00		1129.84	550.00
9135950	NORTH FORK GUNNISON RIVER BELOW LEROUX CREEK, NEAR HOTCHKISS, CO																			929.79	
9136200	GUNNISON RIVER NEAR LAZEAR, CO.	0.90		39.10	0.06		27.00	43.80	2.70	0.20		14.20	8.30	8.15	2.00	11.80		14.10		841.69	96.10
9137050	CURRANT CREEK NEAR READ, CO.	1.25				168.00	740.00	242.95	38.00	0.48		180.58	8.12	8.13	14.13	21.25		261.38		4162.44	1677.50
9139500	WARD CREEK NEAR CEDAREDGE, CO.																				
9143000	SURFACE CREEK NEAR CEDAREDGE, CO.						10.00	11.35	0.58	0.10	56.00	3.08	7.50	8.15	1.30	15.25	0.20	2.55		110.34	5.45
9143500	SURFACE CREEK AT CEDAREDGE, CO.																			146.90	
9144200	TONGUE CREEK AT CORY, CO.	2.00				174.00	320.00	126.41	8.01	0.48	700.00	70.21	8.31	8.10	7.71	28.83	2.00	90.53		1336.02	504.00

SITE #	STATION #	ALKALINITY, WATER, DISSOLVED, TOTAL, INCREMENTAL TITRATION, FIELD	ALPHA, GROSS, DISSOLVED AS U NATURAL (UG/L)	ALUMINUM DISSOLVED (UG/L AS AL)	ANTIMONY DISSOLVED (UG/L AS SB)	BETA, GROSS, DISSOLVED AS STRONTIUM/TRITIUM-90 (PCI/L)	GROSS ALPHA DISSOLVED (PCI/L AS U-NAT)	GROSS BETA DISSOLVED (PCI/L AS CS-137)	IRON DISSOLVED (UG/L AS FE)	IRON SUSPENDED (UG/L AS FE)	IRON, TOTAL, (UG/L AS FE)	LITHIUM DISSOLVED (UG/L AS LI)	MANGANESE DISSOLVED (UG/L AS MN)	MERCURY, DISSOLVED (UG/L AS HG)	MOLYBDENUM DISSOLVED (UG/L AS MO)	POTASSIUM 40 DISSOLVED(PCI /L AS K40)	SELENIUM DISSOLVED (UG/L AS SE)	SILVER DISSOLVED (UG/L AS AG)	SOLIDS, SUM OF CONSTITUENTS, DISSOLVED (MG/L)	STRONTIUM DISSOLVED (UG/L AS SR)	THALLIUM DISSOLVED (UG/L AS TL)	URANIUM, NATURAL, 2 SIGMA PRECISION ESTIMATE, WATER, WHOLE, TOTAL	VANADIUM DISSOLVED (UG/L AS V)	ZINC SUSPENDED (UG/L AS ZN)
9131100	COW CREEK NEAR PAONIA, CO.			101.43					122.86	432.50	452.86		8.29	0.14			1.00		70.00					10.00
9132050	ANTHRACITE CREEK NEAR SOMERSET, CO.		1.18	53.43		1.10	0.86	1.15	27.89			5.79	3.21	0.06	7.50	0.36	0.43		71.14	178.17			2.56	7.50
9132500	NORTH FORK GUNNISON RIVER NEAR SOMERSET, CO.			49.29					53.75		895.00		10.13	0.08		0.54	0.69		91.28				0.54	11.43
9132940	HUBBARD CREEK ABOVE IRON POINT GULCH NEAR BOWIE, CO																							
9132985	E FORK TERROR CREEK BELOW COTTONWOOD STOMP NEAR BOWIE, CO																							
9132995	TERROR CREEK AT MOUTH NEAR BOWIE, CO																							
9134000	MINNESOTA CREEK NEAR PAONIA, CO.																							
9134050	MINNESOTA CREEK AT PAONIA, CO.																1.52							
9134100	NORTH FORK GUNNISON RIVER BELOW PAONIA, CO																							
9134200	COTTONWOOD CREEK NEAR HOTCHKISS, CO.								45.00				105.00				7.97		3022.50					
9134500	LEROUX CREEK NEAR CEDAREDGE, CO.																0.70							
9134700	COW CREEK NEAR CEDAREDGE, CO.																0.70							
9135000	LEROUX CREEK NEAR LAZEAR, CO.																0.70							
9135900	LEROUX CREEK AT HOTCHKISS, CO.								15.00		280.83		24.29	0.10			11.61	0.20	1050.00					
9135950	NORTH FORK GUNNISON RIVER BELOW LEROUX CREEK, NEAR HOTCHKISS, CO																							
9136200	GUNNISON RIVER NEAR LAZEAR, CO.			2.00	0.14							12.70	6.50		1.20		0.80	1.00		277.00	0.04		0.90	
9137050	CURRANT CREEK NEAR READ, CO.	138.00							10.00				44.20	0.10	10.00		22.79		2695.00			4.30	4.30	
9139500	WARD CREEK NEAR CEDAREDGE, CO.																8.50							
9143000	SURFACE CREEK NEAR CEDAREDGE, CO.								115.00		360.00								82.00					
9143500	SURFACE CREEK AT CEDAREDGE, CO.																							
9144200	TONGUE CREEK AT CORY, CO.	143.00							36.67				43.33	0.10	8.00		5.41		1059.80			3.20	2.90	

Notes: Averages provided for period of record, which may vary signicantly among sites.
For purposes of averages, values below detection limits replaced with detection limit.

5.2.3 CDMG Mining Files

In addition to information on groundwater conditions, the Cumulative Hydrologic Impact Analyses (CHIAs) and permit documents for mining activities at CDMG contain relevant surface water quality data and characterizations. For example, the *Cumulative Hydrologic Impact Study—North Fork of the Gunnison* (CDMG 2001) characterizes the North Fork of the Gunnison River water as being of a calcium-bicarbonate type. This was also the case for surface water in the vicinity of the Bowie #1 and #2 mines, Red Canyon Mine and the Terror Creek Loadout area.

The mines generally characterize surface waters in their study areas as having lower TDS concentrations and better overall water quality than Mesaverde Formation water which was encountered during mining. For example, the Red Canyon Mine reported average TDS for undisturbed sites on Dirty George, Sand, Williams and Ward Creeks at 194, 310, 161 and 99 mg/L, respectively. Near Somerset, the Bowie Mines described surface water with TDS ranging from 100 to 400 mg/L. In the vicinity of the Somerset and Sanborn Creek mines, the North Fork of the Gunnison was identified as having TDS of about 70 mg/L. By contrast, and as discussed in more detail in Section 6.5, TDS concentrations of Mesaverde water samples exceeding 10,000 mg/L are observed. (Note: various wells in the study area which draw water from the Mesaverde Formation have much lower TDS concentrations, because in these locations, the Mesaverde Formation is recharged by water-rich overlying surficial deposits which are permeable. TDS concentrations of 10,000 mg/L or larger are normally associated with Mesaverde Formation water, which is older, deeper [further away from the outcrop] and less likely to have been recently influenced by surface water.)

5.2.4 Oxbow Mining Water Quality Database

Oxbow Mining, L.L.C., provided an electronic copy of their water quality database with surface water sampling locations including sites on Elk Creek, Thompson Creek, Sanborn Creek, Hawksnest Creek, Hubbard Creek and Bear Creek. Samples were collected over a 14-year period. The average concentrations for collected data are summarized in Appendix C, with monitoring locations identified on Exhibit 2.

Examination of these data sources indicates that surface waters in the Oxbow Mining study area are variable. Overall, calcium, magnesium, and bicarbonate are the most abundant ions but, at some locations, significant sulfate and sodium levels occur. Higher sulfate and sodium levels tend to occur together, suggesting that runoff from coal piles, abandoned mines or formation waters contribute to these surface waters. Surface water TDS levels in this area vary between 77 and 530 mg/L.

5.2.5 Cordilleran Compliance Services Surface Water Field Data

To develop a baseline of water quality data in the study area, particularly in the vicinity of the proposed natural gas exploration wells, Cordilleran was contracted to obtain both surface and groundwater quality samples. Surface water monitoring locations including streams, ponds and springs are shown on Exhibit 1 and are summarized in Appendix B. (Groundwater samples were also obtained and are discussed in Section 6.3). Table 5 identifies the water quality constituents sampled at each location. As of the time of completion of this report, about 150 surface water and groundwater samples have been collected and analyzed.

Table 5

Summary of Water Quality Constituents Collected by Cordilleran Compliance Services During 2002

Water Quality Constituent
Benzene (µg/L)
Toluene (µg/L)
Ethylbenzene (µg/L)
m,p-Xylene (µg/L)
o-Xylene (µg/L)
MTBE (µg/L)
Methane (mg/L)
TDS (mg/L)
Nitrates + Nitrites (mg/L)
Nitrate (mg/L)
Nitrite (mg/L)
Ammonia-N (mg/L)
Sulphate Reducing Bacteria (approx. CFU/ml)
Iron Bacteria (approx. CFU/ml)
Hydrogen Sulfide (mg/L)
Cations:
Calcium (mg/L)
Iron (mg/L)
Potassium (mg/L)
Magnesium (mg/L)
Manganese (mg/L)
Sodium (mg/L)
Selenium (mg/L)
Anions
Chloride (mg/L)
Fluoride (mg/L)
Sulfate (mg/L)
Bicarbonate (mg/L)
Carbonate (mg/L)
Alkalinity (mg/L CaCO3)
pH
Specific Conductance (µmhos/cm @ 25 °C)
Conductivity (field) (mS/cm)
Turbidity (NTU)
Dissolved Oxygen (mg/L)
Temperature (ºC)
Salinity (percent)

Examination of the initial data set indicates that surface waters in the Dever Creek, Lone Pine and Leon Lake study areas are generally calcium/magnesium-bicarbonate types. Occasionally, sodium is found in significant concentrations. Significant levels of sulfate are found at a few locations, but chloride is consistently negligible. Surface water TDS levels in these areas generally vary from between about 80 to 500 mg/L. One creek sample had a TDS concentration of 726 mg/L.

Surface waters in the Stevens Gulch and Spaulding Peak areas are similar in quality to those in the Dever Creek and Lone Pine areas, with the exception of two springs (SG-SG1 and SP-SG1) where sodium is the dominant cation. Except for these springs, surface waters in the Stevens Gulch and Spaulding Peak areas are also mainly calcium/magnesium-bicarbonate types. The sodium-dominated springs are likely to have contributions from bedrock formations.

5.2.6 Springs Sampled by Mr. Greg Lazear During 2002

Mr. Greg Lazear provided WWE with specific conductivity data from 30 water samples collected from springs and seeps in the general vicinity of Cedaredge between June 26 and November 22, 2002. Prior to evaluating this data set, it is important to understand how specific conductivity data can be used.

Specific conductivity is proportional to the ion concentration in the sample and, therefore, is an indicator of the TDS concentration. The mathematical relation between specific conductivity and TDS is approximate and varies with the concentration and types of ions in the sample; therefore, it is always site specific. For carbonate or sulfate-based groundwater, the relation is:

$$\text{TDS (mg/L)} = (0.55 \text{ to } 0.75) \times (\text{specific conductivity in } \mu\text{S/cm}).$$

The exact value of the proportionality constant should be determined empirically. If the empirically determined proportionality constant is found to be consistent for several samples, seasonally distributed, from the same location, then the simpler conductivity measurement may be substituted for a laboratory TDS analysis. In the absence of an empirical proportionality constant, a rule of thumb often used is to choose a value of 0.55 to 0.75 and recognize that the calculated TDS values are approximate. Approximate TDS values are often useful for comparison purposes. However, a more complete water quality analysis is required in order to evaluate potential water origins of surface springs and seeps.

In order to further interpret Mr. Lazear’s data, Cordilleran obtained more complete water quality data (e.g., major ions) from additional sampling at some of the same sites sampled by Mr. Lazear. Mr. Lazear accompanied Cordilleran to some of these locations. Table 6 contains the results of Mr. Lazear's specific conductivity measurements (column 2) and TDS measurements by Cordilleran from later sampling at six of the same sites sampled by Mr. Lazear (column 4). In addition, WWE calculated the expected range of TDS values for all of Mr. Lazear’s specific conductivity values (column 3), using the highest and lowest proportionality constants (0.55 and 0.75) in the equation above. Water quality type is also shown for the sites where Cordilleran sampled for the major ion composition.

The variability in water type evidenced in Table 6 confirms the experience of WWE from analyzing approximately 450 water quality records from the study area: TDS alone is not sufficient for determining the origins of surface water sources. As discussed elsewhere in this report, water from the Mesaverde Formation is sodium-bicarbonate type with very little calcium, magnesium, chloride, or sulfate. Alluvial waters are mainly calcium and/or magnesium bicarbonate types. The presence of calcium and/or magnesium at relatively significant levels is an indication that alluvial or surface water contributes to the water source. Springs or seeps with TDS greater than about 500 mg/L have often been influenced by nearby mine workings. The influence of mines can sometimes be identified by the presence of sulfate in the water. In the area of interest, sulfate is generally absent in alluvial and Mesaverde waters except where anoxic groundwater, carrying sulfide from the Coal-Bearing Member, becomes exposed to air in mine workings. Oxygen in the air of a mine oxidizes the sulfide to sulfate. Sulfate may also be evidence of a contribution from the Mancos Shale formation.

Conclusions about origins of surface waters, as indicated by Table 6, include:

- Springs at sites 063 and 064 are mainly fed by alluvial water, based on the dominance of calcium and magnesium cations.
- Springs at sites 121 and 124 appear to be influenced by the nearby Landreth and/or Ward mines because of the high sulfate and TDS levels.
- Springs at sites 132 and 150 fit the sodium-bicarbonate water type of Mesaverde water.

Additional discussion regarding the interpretation and significance of available water chemistry data is presented in Section 6.6.

Table 6

Conductivities Reported by Mr. Greg Lazear for Springs and Seeps In the Cedaredge Area, With Calculated and Measured TDS Concentrations and Water Quality Type

1 Measurement Site	2 Sp. Conductivity (μS/cm) Field meas. by Mr. G. Lazear	3 Calc. TDS range (mg/L) Calc. from column 2	4 Measured TDS (mg/L) Laboratory analysis	5 Water Type Based on major ion balance.
001	460	253–345	---	
002	497	273–373	---	
005	515	283–386	---	
006	488	268–366	---	
008	635	349–476	---	
023	511	281–383	---	
044	764	420–573	---	
046	819	450–614	---	
048	938	516–703	---	
055	966	398–724	---	
057	616	339–462	---	
059	0	0	---	
060	865	476–649	---	
062	856	471–642	---	
063	828	455–621	585	Mg-Ca-Na-HCO_3
064	1012	557–759	595	Mg-Ca-Na-HCO_3
069	770	424–577	---	
077	699	384–524	---	
078	920	506–690	---	
096	874	481–655	---	
097	1969	1083–1477	---	
098	3220	1771–2415	---	
120	2576	1417–1932	---	
121	5520	3036–4140	6920	Na-Mg-SO_4
124	7176	3947–5382	7510	Mg-Na-SO_4
131	0	0	---	
132	1288	708–966	915	Na-HCO_3
135	2668	1467–2001	---	
149	1122	617–841	---	
150	1025	564–769	756	Na-HCO_3

Column 1: Site designations assigned by Greg Lazear.

Column 2: Measurements performed and reported by Greg Lazear between 6/26/02 and 11/22/02.

Column 3: TDS values calc. from column 2 using: TDS (mg/L) = 0.55 x Sp. Cond; and TDS (mg/L) = 0.75 x Sp. Cond.

Column 4: Laboratory measurements of TDS values. Samples collected by Cordilleran between 12/12/02 and 12/21/02.

Column 5: Major ions considered to be any ion comprising 10% or more of total ion equivalent weight. Cations and anions separately listed in order of abundance.

5.2.7 Wetlands

As part of the surface water resources review, WWE researched existing information on wetlands and "waters of the U.S." that may be regulated through the U.S. Army Corps of Engineers within the study area. The following federal and state databases were researched in order to determine if wetland information and mapping currently exists within the project area:

- U.S. Fish and Wildlife Service National Wetlands Inventory Mapping
- U.S. Geological Survey National Wetlands Research Center
- Colorado Division of Wildlife GAP Analysis Project
- Colorado Division of Wildlife Riparian and Wetland Mapping
- Colorado Natural Diversity Information Source
- Colorado State University – Natural Heritage Program
- Colorado Riparian Association Wetlands Mapping Project

Although some portions of Colorado have been mapped for existing wetlands, the proposed project area is not currently covered by any of these sources.

5.2.8 Summary of Surface Water Quality Data Review

Based on the review of various surface water data sources, the following conclusions can be drawn:

1. Surface water in the study area can generally be characterized as a calcium-bicarbonate type, with significant sodium and sulfate levels at some locations.

2. Concentrations of constituents such as TDS and trace metals vary in the surface waterbodies in the study area depending on the origin of the water and associated land uses. For example, surface waters originating primarily from overland flow and recharge from shallow, unconsolidated deposits typically have lower TDS concentrations than those receiving water from bedrock sources, including mine discharges. As another example, surface waters in agricultural areas are impacted

by agricultural irrigation return flows, particularly with regard to increased metals (e.g., selenium) concentrations.

3. Mining reports consistently indicate that surface water is generally of better quality than bedrock groundwater sources such as waters of the Mesaverde Formation.

4. Most surface waters in the study area attain the CWQCC's designated uses with the exception of Hubbard, Terror, Minnesota and Leroux Creeks due to elevated concentrations of metals, such as selenium.

5.3 Water Rights and Beneficial Uses

For purposes of developing a general understanding of water sources and usage within the study area, the Colorado Decision Support System (CDSS) database was queried for water rights in the study area (www.cdss.state.co.us). Specifically, Division 4, District 40 absolute water rights within Townships 11 through 13 South and Ranges 89 through 95 West were reviewed. This research was combined with a review of well permit records from the Colorado State Engineer's Office (SEO) in Denver as discussed in Section 6.2. This was important because small capacity water wells are often permitted through the SEO but do not have adjudicated water rights. Water rights in the study area can be characterized as follows:

1. Over 1,540 absolute water rights are decreed.

2. Approximately 4,190 cfs of net absolute flow right decrees are associated with structures such as ditches, springs, wells, etc., as shown in Figure 11. Of this amount, the following is noteworthy:

   - Approximately 97 percent (4,060 cfs) is associated with ditches, over 75 percent of ditch diversions are designated for irrigation use only, with over 99 percent decreed for a combination of irrigation and other uses.

- Approximately 0.1 percent (less than 5 cfs) is associated with decreed water wells (again, permitted wells that do not have water rights are not included).
- Approximately 0.1 percent (less than 5 cfs) is associated with springs/seeps.
- The remaining 2.8 percent is associated with mining, pipelines and other structures.

3. Approximately 89,150 acre-feet of net absolute volume rights decrees are associated with reservoirs. Over half of this volume is associated with Paonia Reservoir water rights. WWE infers from the facts presented in #2, above, that the vast majority of the reservoirs are filled with surface rights.

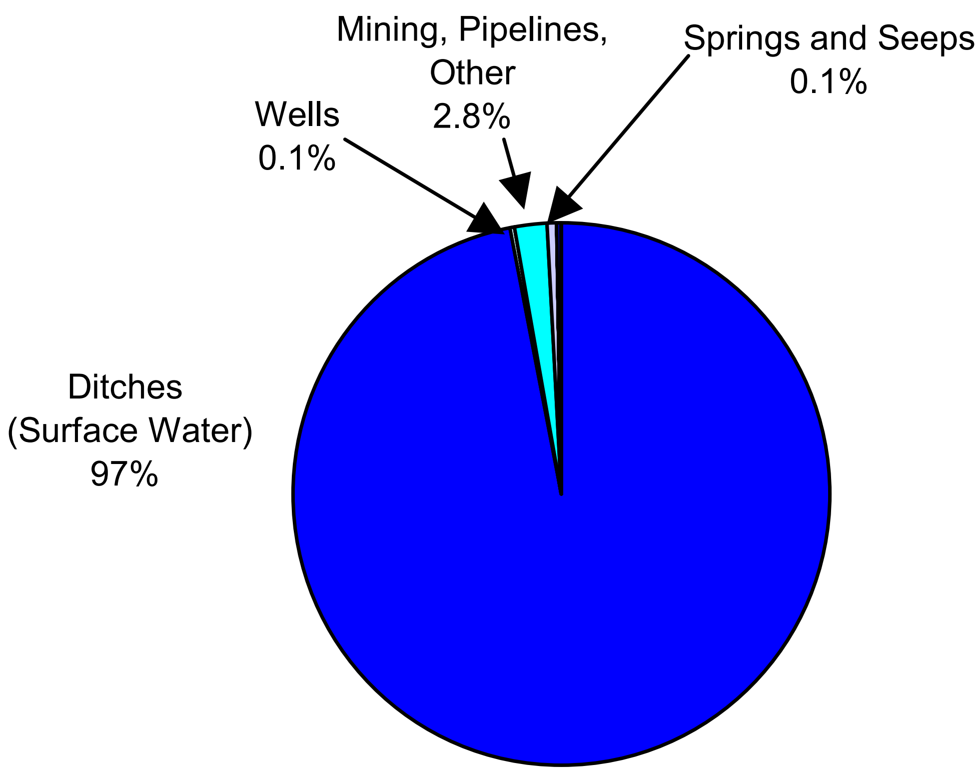
4. For the approximately 90 cfs of water rights with domestic use decrees only, 97 percent of the water is supplied by ditches, 1 percent supplied by water wells and the remainder supplied by other structures.

5. For the approximately 15 cfs of water rights with municipal use listed first among combinations of uses (e.g., the decree may include municipal, domestic and stock uses), 2 percent (0.25 cfs) is associated with water wells and the majority of the remainder is associated with water distribution pipelines.

`

Figure 11

**Distribution of Division 4, District 40 Absolute Flow Rights[4]
Within Study Area**



[4] Permitted wells that do not have water rights are not included in this figure.

These findings were further supported by interviews with Mr. Jim Boyd, one of the eleven water commissioners in District 40, who indicated that the basin is over-appropriated and has so many diversion structures over such a large area that multiple water commissioners are required to handle the work. He confirmed that surface water is the dominant source of irrigation in the area. Most of the land is irrigated by flood irrigation and/or furrows. In areas where pivot sprinklers are used, surface water is pumped to ponds or piped for use in these systems. Typically, the groundwater wells do not have enough water to be useful for irrigation, although water wells do provide some water for domestic purposes.

These findings are also consistent with a 1991 USGS summary of water usage for the entire North Fork of the Gunnison River Basin, which indicated that 99 percent of the water used in the basin is derived from surface water sources. Of the 29,490 irrigated acres in the entire North Fork of the Gunnison River Basin in 1990, less than 0.5 percent (150 acres) used groundwater for irrigation (USGS 1991).

5.4 Municipal Water Supplies

Based on review of Colorado Department of Public Health and Environment (CDPHE) Drinking Water Section records, coupled with literature review and interviews, municipal water use is dependent primarily on surface water sources (CDPHE 2002b). Alluvial groundwater and springs also supply water. Towns in the study area include Cedaredge and Paonia with populations of 1,854 and 1,497, respectively, based on year 2000 census data. To the south of the study area and north of the North Fork of the Gunnison River, Orchard City and Hotchkiss had year 2000 populations of 2,880 and 968, respectively. These towns derive much of their water supplies from water sources within the study area. Table 7 summarizes the public water supply sources for these towns and other population centers of interest. The majority of these water supplies are either surface water sources or alluvial groundwater “under the direct influence of surface water.” Review of Table 7 indicates that the towns do not depend on bedrock groundwater within the study area boundaries. Most of the water supply sources originate from the lakes and springs on top of Grand Mesa. For example, the Town of Paonia derives much of its supply from alluvial wells along the North Fork of the Gunnison River, as noted in the *North Fork Coal EIS* (BLM and USFS 1999). As stated by Bertram (2002):

> Most fresh water springs tapped at the source for domestic water use by the Town of Cedaredge, Colby Canyon, and Orchard City are on Grand Mesa high above the coal interval. They are located in or around the edge of the area formed by the top of large land rotational slump blocks forming the depressions where nearly all the natural lakes exist on Grand Mesa (Bertram 2002).

In Delta County there are also 11 transient, non-community water systems, which are primarily campgrounds and camps that serve between 25 and 391 individuals annually. Records at the SEO and CWQCD indicate that alluvial groundwater is the primary water source for these seasonal users.

Table 7

Summary of Water Sources for Selected Communities In and Near the Study Area

Town	Source Type	Service Pop.	Description	Treatment
Cedaredge	Surface Water	2,200	East Beaver Creek, Kemier Creek, 10 springs on Grand Mesa, Surface Creek Reservoir	Gaseous chlorination with rapid sand filtration
Paonia	Groundwater Under Direct Influence of Surface Water	2,200	3 springs located between latitude 38^{o} 46' 80" and 38^{o} 51' 82" and longitude 107^{o} 29' 71" and 107^{o} 35' 64"	Gaseous chlorination, pressure sand filtration and/or filtration cartridge
Orchard City	Groundwater Under Direct Influence of Surface Water	2,700-3,200	Little Gem Reservoir, Big Ditch (Surface Creek water rights), 15 springs between latitude 39^{o} 00' 24" and 39^{o} 02' 07" and longitude 107^{o} 59' 15" and 117^{o} 59' 46"	Gaseous chlorination with rapid sand filtration upgrade
Hotchkiss	Surface Water	1,200-2,000	Leroux Creek, Highline Canal	Sand filtration/chlorination
Town of Lazear	Groundwater	178	110-foot well, approximately 0.5 miles north of Lazear	Hypochlorination
Other Significant Populations Served in Study Area				
Bone Mesa Water District (Hotchkiss)	Groundwater	300	2 springs near Paonia	Gaseous chlorination
Pitkin Mesa Pipeline (Paonia)	Groundwater	425	8 springs in vicinity of latitude 39^{o} 00' and longitude 107^{o} 37-38', Chalk Mountain area	Gaseous chlorination
Coalby Domestic Water Company (Cedaredge)	Groundwater Under Direct Influence of Surface Water	200	4 springs on Grand Mesa	Gaseous chlorination
Somerset Water District	Groundwater	90	20-foot well in North Fork of the Gunnison alluvium	Gaseous chlorination

5.5 Conceptual Water Balance for Surface Creek

To put hydrologic conditions in the study area into perspective, a portion of the Surface Creek drainage basin was selected to develop a conceptual water balance as summarized in Table 8 and

Figure 12. Surface Creek was selected based on the availability of USGS flow gauges with long periods of record that could be compared with each other and Surface Creek's proximity to the town of Cedaredge. In addition, as presented in Section 6.2.3, the majority of the domestic wells completed in the Mesaverde Formation in the entire study area are located near Cedaredge; thus, the nature and extent of the Mesaverde Formation water supply in this area is important. To better understand the gain/loss characteristics of Surface Creek, itself, as opposed to the adjoining irrigated lands, WWE completed stream flow measurements at multiple locations in December 2002. The results of the hydrologic balance and gain/loss study are discussed below.

5.5.1 Conceptual Hydrologic Balance Procedure

The hydrologic balance study area is defined by two USGS gauges. The Surface Creek at Cedaredge, Colorado gauge (USGS #09143500) defines the downstream extent of the study reach and the Surface Creek near Cedaredge, Colorado (USGS #09143000) defines the upstream extent of the study reach. The Surface Creek at Cedaredge gauge has a drainage area of 39.0 square miles and is located at an elevation of 6,220 feet. The Surface Creek near Cedaredge gauge has a drainage area of 27.4 square miles and an elevation of 8,261 feet. Thus, the drainage area included in this reach of stream is 11.6 square miles, or about 7,400 acres. Some of the flow in Surface Creek results from releases of water from reservoirs on top of Grand Mesa such as Leon Reservoir, based on discussions with the Water Commissioner.

Average annual precipitation in the study area varies from about 11 inches at lower elevations to roughly 45 inches atop the Grand Mesa, as shown in Figure 6. Precipitation, snowfall and temperature data for Cedaredge and Paonia were retrieved from the Colorado State Climate Center. Based on data collected between 1898 through 1994 for Cedaredge and 1905 through 1999 for Paonia, the average annual precipitation is about 12.2 inches (range: 7.3-20.4 inches) and 11.2 inches (range: 0-23.8 inches), respectively. Based on the same data set, the average annual snowfall at Cedaredge is 45.6 inches (range: 13-94.2 inches) and 33.9 inches (range: 0-93.4 inches) at Paonia. By contrast, atop the Grand Mesa, total annual precipitation averages about 41 to 45 inches (see Figure 6).

The period of record available from the two USGS gauges and the Colorado Decision Support System (CDSS) Hydrobase that could be compared for purposes of the hydrologic balance was 1970 through 2001. During the irrigation season, the average volumes of water measured at the two gauges during this time frame were about 28,220 acre-feet for the upper gauge and about 17,820 acre-feet for the lower gauge. (Note: 1 acre-foot = 325,900 gallons.) These data indicated a 37 percent loss between the two gauges. These losses can be attributed primarily to ditch diversions with associated irrigation consumptive use and deep percolation.

The primary tributary inflow to Surface Creek is from Milk Creek, which does not have a USGS gauge in place. In November 2002, WWE measured inflows from Milk Creek at 1 cfs. To develop an approximate inflow value for Milk Creek during the irrigation season, historic gauged flows from Ward, Kiser, Cottonwood and Youngs Creeks were averaged to obtain an estimated irrigation season flow from Milk Creek of about 1,190 acre-feet.

Based on review of water rights decreed for this reach of Surface Creek as obtained from CDSS, over 99 percent of the decreed absolute flows were associated with ditch diversions. Of these ditch diversions, 85 percent of the decreed flows were designated for irrigation usage, with the remainder for domestic usage. A follow-up discussion with Water Commissioner Jim Boyd indicated that the 26 cfs associated with domestic use may have historically been used to fill cisterns, but currently is used for irrigation. So, for purposes of the water balance, all of the ditch diversions were assumed to be for irrigation use. Ditch diversion records were retrieved from CDSS for the 20 ditches in the study reach which reflected the primary diversions (e.g., ditches with more than 0.5 cfs absolute flow rights decreed). For the irrigation season of May through October, diversion records indicated that these ditches diverted a total of about 12,970 acre-feet on average for the period of record.

In order to determine losses associated with irrigation, an estimate of irrigated land and required irrigation was developed. Two sets of irrigated acreage estimates existed in the CDSS database: 4,696 acres for 1993 and 3,042 acres for 2001. Based on interviews with the Water Commissioner, it was noted that there has been a 90 percent decline over the last 20 years in acres irrigated for orchards due to market conditions, which affects the irrigation consumptive use and return flow estimates for the study area. Given these changes in irrigated land usage, irrigation consumptive use was estimated for each time period and then averaged to develop a reasonable estimate of irrigation usage. For the 1993 estimate, irrigated land usage was considered to be 30 percent orchards with 70 percent pastureland, 20 percent of which was planted with alfalfa. For the 2001 estimate, irrigated land usage was considered to be 10 percent orchards with 90 percent pastureland. The pastureland was estimated to consist of about 20 percent alfalfa mixed with smooth brome orchard grass and other cool season grasses. Using irrigation requirement estimates (consumptive use - effective precipitation = irrigation requirement) developed by the Natural Resources Conservation Service for various crops in the Cedaredge area, an irrigation requirement of about 7,440 acre-feet was calculated. Approximately 10 percent of the diversion, or 1,300 acre-feet, was estimated for return flows resulting from irrigation.

Additionally, field observations and discussions with the Water Commissioner suggest that for pasture land, about 30 percent of the irrigation is by gated pipe into furrows, 60 percent open ditch into furrows and 10 percent sprinkler. A large amount of surface runoff and low field efficiency would be expected; however, the system allows as much as 90 percent reuse of surface runoff, which would substantially increase the system efficiency. For orchards and vineyards, about 90 percent is irrigated by micro-sprinklers and 10 percent is by open ditch and furrow. For the orchards, efficiency is high and runoff is small. Air evaporation would be expected to be low because sprinkler heads are close to the ground with short throw distances and low pressures. The overall system efficiency is estimated to be about 80 percent.

Based on the estimated irrigation required and return flows, the remaining irrigation water that would be expected to contribute to deep percolation totals about 4,220 acre-feet/year. Some portion of this 4,220 acre-feet/year of deep percolation is available for infiltration into the underlying Mesaverde Formation; this subject is discussed in Section 6.

Table 8

Conceptual Hydrologic Balance for Surface Creek Above Cedaredge (May through October)

	1970-2001 Irrigation Season Water Volume (acre-feet)
USGS Gauge Near (upstream of) Cedaredge	28,219
Ditch Diversions (from CDSS Database)	- 12,969
Irrigation Return Flows (10% estimated)	+ 1,300
Milk Creek Tributary inflow	+ 1,186
WWE Calculated Flow at Cedaredge	17,736
Error margin	0.5%
USGS Gauge at Cedaredge	17,823

Diversion Usage (acre-feet)
7,443 irrigation use
4,226 deep percolation (33% of diversion)
11,669 loss
1,300 return flows (10% of diversion)

Notes:
Irrigation season based on May through October.

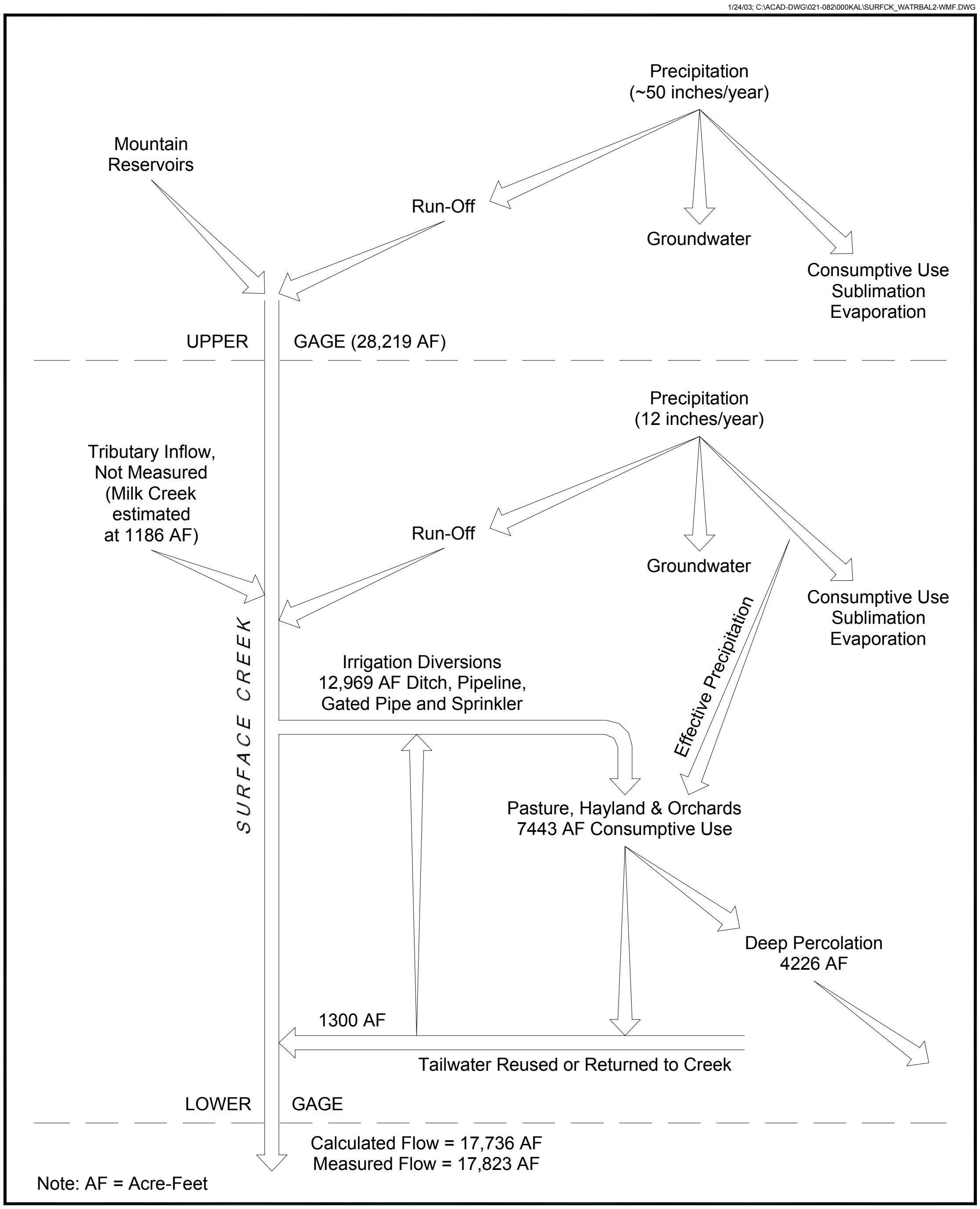
Milk Creek tributary inflow estimated based on average of gauged irrigation season flows on Kiser, Youngs, Cottonwood and Ward Creeks near Cedaredge.

Both the USGS stream gauge and CDSS water diversion records are based on 1970-2001.

Crop irrigation water usage based on NRCS consumptive use tables for Cedaredge.

Irrigation usage calculated based on the average of irrigated land use for 1993 and 2001 as provided in the irrigation structure diversion records from CDSS. Crop types were estimated based on field reconnaissance and interview with water commissioner.

	Irrigated Acres	Irrigation Water Use (inches/yr)	Irrigation Water Use (acre-feet/yr)
1993 Irrigated Acres:	4,696		
30% Orchard	1,409	24.83	2,915
70% Pasture (20% alfalfa pasture)	3,287	22.59	6,188
		Total	9,103
2001 Irrigated Acres:	3,042		
10% Orchard w/cover	304	24.83	629
90% Pasture (20% alfalfa pasture)	2,738	22.59	5,154
		Total	5,783
		Average Irrigation Use	7,443



WRIGHT WATER ENGINEERS, INC.
2490 W. 26TH AVE. 100A
DENVER, CO 80211
(303) 480-1700

FIGURE 12
CONCEPTUAL WATER BALANCE OF SURFACE CREEK DURING IRRIGATION SEASON OF MAY 1 THROUGH OCTOBER 31

(See text for explanation)

5.5.2 Gain/Loss Field Study on Surface Creek

On December 3, 2002 WWE conducted stream flow measurements on Surface Creek. The purpose of the measurements was to gain insight into the gain/loss characteristics of the stream system, itself, under base flow conditions to complement the conceptual water balance calculations provided above.

While both of the previously described USGS gauges are equipped with telemetry for real time data collection, both gauges are currently operated on a seasonal basis and were not operational during the gain/loss study; however, these gauging stations were selected as measurement locations, along with other measurement locations based on access via public roads. Milk Creek is the only significant tributary to Surface Creek within the study reach and, as such, was included as a measurement location. The stream flow measurements were performed using the velocity-area method, which is the standard procedure employed by the USGS. Velocities were determined using a Global flow meter.

The timing of the study presented both advantages and disadvantages. Advantages included lack of tributary inflows with the exception of Milk Creek, which was accounted for, and a lack of irrigation diversions, which have a significant impact on flows during the irrigation season. Disadvantages included the difficulty in obtaining accurate flow measurements during low flows in a stream with large rocks armoring the stream channel, and the fact that ice covered most of the stream in the upper reach of the study area. The latter difficulty was partially addressed by choosing control sections beneath the road crossings, where it was possible to break through the ice and obtain reasonable flow measurements.

At the conclusion of the stream flow measurements, WWE staff returned to the downstream USGS gauge and took a staff gauge reading to determine if conditions had changed throughout the day. It was visually apparent, and confirmed by the staff gauge, that stream flows had increased due to melting during the day. Based on the weather patterns during the day, the majority of this melting most likely occurred after noon since the morning was mostly overcast with temperatures in the 30's. WWE began measurements at the downstream extent of the reach and arrived at the upper stations by afternoon. Based on the significant change in elevation between the upper and lower stations of 2,000 feet, it is believed that most of the melting-induced increases in stream flow occurred in the lower reach. Although the diurnal fluctuation at the lower gauge was significant, it is not thought to have had a significant impact at the upper gauge. Lagged irrigation return flows may have contributed to flows in the reach.

The field data indicated that in the study reach on the date of data collection, there was no discernable gain or loss in the stream channel itself. However, it is likely that the gain-loss regime is highly seasonal and flow-dependent.