Preliminary Review of City of Aspen's Proposed Castle Creek Hydroelectric Project

Prepared for

Pitkin County, Colorado

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1 Introduction

At the request of Pitkin County, we have reviewed the Castle Creek Hydropower Project (the Project) as proposed by the City of Aspen (Aspen) to determine if the Project would be consistent with and would advance the goals of the County's Healthy Streams Initiative. Our review focused on the Project's hydrologic and operational aspects. We considered the scope of Aspen's analysis; assumptions made regarding available water supply, Project capacities and operations; the Project's stream flow impacts; the adequacy of the proposed monitoring plan; and trade-offs between hydropower generation/revenue and bypass options.

In conducting our review, we examined Project-related documents provided by Aspen, which we understand are available for review at the Pitkin County Library. We also requested and received a copy of the spreadsheet model developed by Grand River Consulting and used by Aspen to simulate the operation of the Project. We also participated in discussions with other members of the County's consultant team: Greg Espegren, Kurt Johnson and Sarah Klahn.

2 Summary of Aspen's Proposed Castle Creek Hydropower Project

The Project would utilize portions of Aspen's existing municipal raw water supply diversion and conveyance system to divert water from Castle and Maroon Creeks for hydropower generation at a proposed new hydropower plant that would be located about 4,000 downstream of Thomas Reservoir and adjacent to Castle Creek. The Project is designed to be to be a run-of-river diversion (no storage) with relatively modest diversion capacities compared to available stream flows. The Project would reduce stream flows in approximately 2.4 miles of Castle Creek and 2.7 miles of Maroon Creek, Stream flows would be increased in approximately 0.7 miles of Castle Creek and approximately 1.2 miles of the Roaring Fork River due to return of water to Castle Creek that would be diverted from Maroon Creek.

Aspen currently diverts most of its municipal water supplies from Castle Creek via the Midland Flume Ditch (also known as the Castle Creek intake), which has a reported capacity of 25 cfs. The Midland Flume Ditch delivers water to Thomas Reservoir. Thomas Reservoir has a reported storage capacity of approximately 15 acre-feet and is a re- regulating forebay reservoir for Aspen's water treatment plant. On occasions when the divertible supply in Castle Creek is insufficient, Aspen diverts additional water for municipal use from Maroon Creek via the Maroon Creek Pipeline and Diversion Dam (also known as the Maroon Creek Intake), which is principally used to divert water for hydropower generation at the existing Maroon Creek hydropower plant. The Maroon Creek Pipeline has a reported capacity of 68 cfs. A bifurcation in the Maroon Creek Pipeline allows for water to be diverted to Thomas Reservoir. The capacity of the Maroon Creek Pipeline segment to Thomas Reservoir is reported to be 27 cfs.

Water to be used for hydropower generation by the Project would be diverted from Castle and Maroon Creeks, using the remaining flow capacity of the Midland Flume Ditch and the Maroon Creek Pipeline after Aspen's municipal water supply diversions, to Thomas Reservoir. Water delivered to Thomas Reservoir would either be delivered to Aspen's water treatment plant or to the new Castle Creek hydro plant via a recently constructed 42" diameter penstock. Outflow from the Castle Creek hydro plant would be discharged to Castle Creek at a point approximately 2.4 miles downstream of the Midland Flume Ditch intake.

According to Aspen, Maroon Creek diversions for hydropower generation by the Project would come from water currently diverted to the existing Maroon Creek hydropower plant. The Maroon Creek Pipeline currently diverts up to 68 cfs for hydropower generation at the Maroon Creek hydropower plant, subject to maintaining a minimum bypass of 14 cfs at the Maroon Creek Diversion Dam. Water to be diverted from Maroon Creek for hydropower generation by the Project would be subject to maintaining the 14 cfs bypass at the Maroon Creek Diversion Dam and to providing the first 10 cfs of flow in excess of the 14 cfs bypass for continued hydropower generation at the Maroon Creek hydropower plant. When the stream flow at the Maroon Creek diversion dam is greater than 24 cfs (14 cfs for stream bypass plus 10 cfs for the Maroon Creek hydropower plant), Aspen would make additional diversions of up to 27 cfs for hydropower diversions by the Project. To the degree that additional water is available, Aspen would continue to divert up to an additional 31 cfs for hydropower generation at the Maroon Creek hydropower plant, for a cumulative hydropower diversion amount of 68 cfs.

3 Water Available for Hydropower Generation

Aspen's environmental and financial assessments of the Project are based on a simulation model of the Project developed by Grand River Consulting. The Grand River model simulates the daily operation of the Project over a hydrologic study period of water years 1970 through 1994. Stream flows at the Project's diversion points were not historically measured. Therefore, the Grand River model estimates stream flows at the diversion points based upon stream flow data historically recorded at two USGS gages: Maroon Creek above Aspen, Colorado (#09075700), and Castle Creek above Aspen, Colorado (#09074800), which operated from 1969 to 1994. Each of these gages was located several miles upstream of the Project's respective diversion points, and stream flows recorded at these gage locations are not indicative of water available at the diversion points because there are significant inflows between the gage locations and the diversion points.

The Grand River model estimates stream flows at the Project's diversion points by multiplying daily stream flows recorded at the gages by monthly coefficients. As shown in Figure 1 (which is a screen capture of the Grand River model's "Set-up" page), the Grand River model uses a coefficient of 265% for all months of the year to convert flows at the Castle Creek gage to flows at the Castle Creek diversion, and a coefficient of 140% for all months of the year to convert flows at the Maroon Creek gage to flows at the Maroon Creek diversion. The origin and basis for these coefficients were not described. These coefficients appear to be partially based upon a 1994 report by Enartech[1]. Pages 3 through 5 of the Enartech report describe the derivation of a simulation model of Aspen's Castle Creek and Maroon Creek diversion system (possibly a precursor of the Grand River model), including eight paired stream flow measurements taken during January, February, March and October of 1994 in order to develop coefficients for converting stream flows recorded at the Castle Creek and

[1] City of Aspen - Evaluation of Raw Water Availability - October 1994 Update, Enartech, Inc.

Maroon Creek gages into stream flows at the Castle Creek and Maroon Creek diversion points. According to Table 1 of the Enartech report, the average ratio of stream flows measured at the Castle Creek diversion to stream flows measured at the Castle Creek gage was 267%, which is nearly identical to the 265% coefficient used in the Grand River model. There was only one set of paired measurements taken on Maroon Creek, which produced a ratio of 158%, which is slightly greater than the 140% coefficient used in the Grand River model. It should be noted that the Enartech report described the period during which stream flow measurements were taken as being "an above average base flow period, following one of the wettest years in recent history". The Enartech report adopted coefficients of 230% for Castle Creek and 125% for Maroon Creek in recognition of the non-representative nature of the stream flow monitoring period.

In Rocky Mountain streams, stream flow at a given location is primarily a function of the size of the tributary drainage area and the amount of precipitation in that drainage area. Stream flow per unit area generally increases with elevation because precipitation increases with elevation. This differential effect of elevation and precipitation is greater during the non-base flow period due to the influence of snowmelt from the higher elevation areas. During the winter months, there is often no increase in unit runoff from higher elevations because of increased snowmelt and occasional rains at lower elevations due to generally warmer temperatures. Therefore, coefficients developed from winter season stream flow measurements are generally not representative of other months. Given the non-representative nature of stream flows during the 1994 winter season, it is likely that the coefficients reported by Enartech for Castle and Maroon Creeks (even the lower adopted coefficients of 230% for Castle Creek and 125% for Maroon Creek) would result in overestimation of stream flows at the Castle and Maroon Creek diversion points.

The drainage areas and average precipitation for the Castle and Maroon Creek gage locations and diversion points are shown in Table 1. On the basis of relative drainage area alone, the coefficients for Castle and Maroon Creek should be 216% and 118%, respectively. The average precipitation for the Castle and Maroon Creek diversion points is less than that for the Castle and Maroon Creek gage locations, so if precipitation effects are considered, the coefficients for Castle and Maroon Creek should be less than 216% and 118%, respectively.

The effects of drainage area and precipitation on mean monthly and annual stream flow are well-captured by regional models developed by the USGS to estimate natural stream flow statistics in Colorado[2]. We applied the USGS models specifically designed to estimate mean monthly and mean annual stream slows to the four Castle Creek and Maroon Creek drainage areas. The results are shown in Table 2. The USGS model-derived coefficients for mean monthly stream flows for Castle Creek range from 185% to 216%, with an annual flow coefficient of 193%. The USGS model-derived coefficients for mean monthly stream flows for Maroon Creek range from 102% to 111%, with an annual flow coefficient of 106%.

In order to explore the effect of stream flow coefficients upon Aspen's analysis of the Project, we ran the Grand River model with the USGS-derived monthly coefficients for Castle and

[2] Capesius , Joseph P. and Verlin C. Stephens. Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado. Scientific Investigations Report 2009−5136, U.S. Geological Survey.

Maroon Creek. This resulted in reductions in average annual stream flow of 25% at the Maroon Diversion and 26% at the Castle Creek diversion. Average annual hydropower production was reduced by 19%. The number of years that stream flows downstream of the Castle Creek diversion were continuously reduced to the 13.3 cfs bypass level for more than 6 months increased from 6 years to 13 years out of the 25-year model study period. The flow depletions to both Castle and Maroon Creeks resulting from the operation of the Project, expressed as percent flow depletion, would be significantly greater in all months.

It should be recognized that stream flows at the Castle and Maroon Creek diversions produced by the USGS model and the Grand River model are just estimates. Actual stream flows at those locations are a function of the unique characteristics and processes of those drainage areas. However, the drainage area sizes and precipitation data for those drainage areas argue for significantly lower coefficients than those included in the Grand River model.

Given the importance of accurate stream flow estimates in assessing project feasibility and impacts, Aspen should conduct a more thorough study of water availability at the Project's diversion points, including paired stream flow measurements at the Project's diversion points and at the stream gage locations during all months of the year and during a range of wet, average and dry year conditions.

4 Range of Stream Flow Impacts

The Miller Report[3] portrayed the Project's stream flow impacts for three year types: average year (1980), dry year (1977) and wet year (1984), based upon output from the Grand River model. While these years are representative of average, dry and wet years, the full range and extent of The Project's stream flow impacts are not adequately disclosed by limiting the presentation of impacts to those three years.

The stream flow impacts that would result from the Project's proposed operation would be more variable, and in some aspects more serious, than those shown in the average year, dry year and wet year hydrographs presented in the Miller report. For example, in one year of the study period (1978), post-project stream flows downstream of the Castle Creek intake would be continuously reduced to Aspen's proposed 13.3 cfs bypass level for more than 7 months. In 6 of the 25 years of the hydrologic study period, stream flows downstream of the Castle Creek intake would be continuously reduced to 13.3 cfs for more than 6 months. The full statistical dimensions of the Project's stream flow impacts should be reported and considered in formulating appropriate bypasses.

To illustrate this point, we utilized the Grand River model to generate three tables (Tables 3 through 5 of this report) that show the statistical distribution of stream flow impacts to Castle Creek downstream of the Castle Creek intake, expressed as percent flow reductions, and that compare the flow reductions shown in Figures 14 through 16 of the Miller Report to this statistical distribution. The individual values in the main portion of the tables are color-formatted in proportion to their magnitude. The flow reductions shown in Figures 14 through 16 of the Miller Report are shown in the right column of each table. The individual values in

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[3] Miller Ecological Consultants, Inc. Castle Creek Hydroelectric Plant Environmental Report, October 8, 2010.

the main portion of the tables that bracket the values shown in the Miller report are outlined on boxes. As these tables show, the range of stream flow impacts that would result from the Project's operation, expressed as percent flow reductions, is much greater than what was shown in the Miller Report. The frequency and duration of stream flow impacts during each season of the year are meaningful and should be considered in formulating appropriate bypass schedules that would protect stream health.

5 Potential Effects of Climate Change

As previously discussed, Aspen's analysis of the Project was based upon 25 years of historical hydrology as represented by the Castle Creek and Maroon Creek stream gages. In its analysis, Aspen has not considered the potential effects of climate change upon stream flows available for the Project, Project hydropower revenues and Project stream flow impacts. While there is considerable uncertainty in climate change science, most climate models point to warmer temperatures throughout the year. Stream flow patterns are likely to change as warmer temperatures reduce the storage effect of snowpack, resulting in earlier onset of runoff, earlier peak flows, shorter runoff periods, reduced flows in late summer and fall, and extended periods of base flow. These trends are likely to take longer than 10 years to become evident, but are projected to be noticeable by 2040.

The Colorado River Water Availability Study examined the potential effects of climate change upon stream flows on the West Slope of Colorado. The Study used five alternative climate projections for the 2040 and 2070 planning horizons, and a physical hydrology model (the Variable Infiltration Capacity, or 'VIC' model) to translate changes in temperature and precipitation to changes in natural flows throughout the Colorado river basin. The Study's model results for year 2040 natural flows on the Roaring Fork River near Aspen and at Glenwood Springs are shown in Attachment B. The trends toward earlier onset of runoff, earlier peak flows, shorter runoff periods, reduced flows in late summer and fall, and extended periods of base flow are evident in these figures.

6 No Protection for Flows Greater Than Specified Bypass Flows

The Miller report's finding that the stream health of Castle and Maroon Creeks would not be impaired by the Project assumes the continuation of all historical stream flows not diverted by the Project. Aspen proposes to bypass flows needed to protect base flows as defined by the State of Colorado's R2Cross methodology, which was designed to quantify the minimum amounts needed to protect the natural environment to a reasonable degree. No protection is proposed for flows greater than Aspen's specified bypass flows. A significant portion of the post-project flow regime could be diverted by other entities under new water rights. Additional future diversions by others, while not attributable to the Project, could result in significant additional stream flow depletions. As discussed below, it may be possible for Aspen to commit a portion of its Castle Creek hydropower rights to protect instream flows in Castle Creek at levels greater than 13.3 cfs through change of use and donation to the CWCB under the County's trust agreement.

7 Potential for Expansion of Hydropower Diversions

Aspen owns existing absolute hydropower water rights for the Castle Creek pipeline in amounts totaling 160cfs, although portions of these rights are subject to other commitments including providing up to 33 cfs of municipal water supply for Aspen, providing up to 0.075 cfs to an augmentation plan decreed in Case No. 90CW244 (Division 5), and maintaining the CWCB's 12 cfs instream flow right. By comparison, the reported capacity of the Castle Creek pipeline is 25 cfs. Thus, Aspen's hydropower water rights greatly exceed the stated capacity of that pipeline. In the future, Aspen could decide to fully utilize its Castle Creek hydropower rights by enlarging the capacity of the Castle Creek pipeline and installing a second penstock and turbine. This would result in additional impacts to Castle Creek. As an alternative, it may be possible for Aspen to commit the remaining unused portion of its Castle Creek hydropower rights to protect instream flows in Castle Creek at levels greater than 13.3 cfs through change of use and donation to the CWCB.

8 Monitoring Plan and Memorandum of Agreement

Our review of Aspen's proposed Memorandum of Understanding (MOU) with the Colorado Division of Wildlife and the associated Monitoring Program suggests several areas where the MOU and Monitoring Program should be modified.

As part of the Project, Aspen should provide real-time measurement and publicly accessible reporting of daily flow bypasses at the Castle Creek and Maroon Creek diversion structures and flows below the Castle Creek and Maroon Creek hydropower discharge points.

Given the uncertainties of Aspen's estimates of Project water availability, the Monitoring Plan should include paired stream flow measurements at the Project's diversion points and at the stream gage locations during all months of the year and during a range of wet, average and dry years. Because potential changes in stream flows due climate change may take longer than 10 years to become evident, the Monitoring Plan should run for at least 20 years. The draft MOU and Monitoring plan should also be strengthened to address problems pointed out by Espegren related to establishing an adequate baseline condition, the practical impossibility of demonstrating causality as a requisite for modification of Project operations, and overall enforceability.

Aspen's proposed approach to adaptive management begins with Aspen's proposed bypasses (which are based on the State of Colorado's R2 Cross minimum protection criteria) and relies on post-project monitoring to demonstrate both significant impairment and clear causality as prerequisites to the modifying the Project's operation. As an alternative, Aspen should consider taking a more precautionary approach, which could include adopting variable and proportional bypasses, and/or seasonal limits to diversions, as an alternative to fixed bypasses, in order to protect other biologically important aspects of the hydrograph.

Aspen has explored the trade-offs between project revenues and alternative fixed amounts of bypass on Castle Creek ranging from 12 cfs to 19 cfs. Aspen should also explore the financial implications of adopting a variable bypass schedule that would be proportional to stream flows during a specified period, or limiting the project's Castle Creek diversions to a specified non-base flow season. Either of these alternatives would provide for continued variability in stream flow during the base flow period. As discussed by Espegren and others, stream flow variability is an important element of stream health.

Figure 1: Set-Up Page in Grand River Model

SIMULATION OF RAW WATER AVAILABILITY - CITY OF ASPEN

SIMULATION ID: CASTLE CREEK HYDROELECTRIC PLANT

20-Jan-11 11:33 PM

PRIMARY FACILITIES

CASTLE CREEK DIVERSION CAPACITY (CFS) =	25
MAX MAROON DIVERSION CAP TO CC (CFS) =	27
CASTLE CREEK HYDROPLANT CAPACITY (CFS) =	60
OBLIGATED FLOW TO MAROON HYDRO (CFS) =	10
MAROON CK PUMPBACK (0=NO, 1=YES) =	0
PUMPBACK SITE (0=BELOW HYDROPLANT) =	0
CAPACITY OF PUMPBACK (CFS) =	0

NON-CITY DIVERSIONS

CASTLE CREEK DEPLETIONS (NON-CITY)

ABOVE INTAKE (CFS)	1.0
BELOW CITY INTAKE - WINTER (CFS)	0.0
BELOW CITY INTAKE - SUMMER (CFS)	1.0

MAROON CREEK DEPLETIONS (NON-CITY)

HERRICK DITCH (CFS)	9.3
BELOW CITY INTAKE - WINTER (CFS)	2
BELOW CITY INTAKE - SUMMER (CFS)	8

INSTREAM FLOW CRITERIA

CASTLE CREEK (CFS) =	13.3
MAROON CREEK (CFS) =	14
BYPASS OPERATION =	2

1 = Bypass Instream Flow at Intakes Only
2 = Castle Ck Tailrace below Marolt Ditch
3 = Castle Ck Tailrace abv Marolt Ditch

WATER SUPPLY ASSUMPTIONS

	MUNICIPAL DEMAND (MGD)	CASTLE CK IRRIGATION DEMANDS (CFS)	WELL FIELD DIVERSIONS (CFS)	ASPEN HIGHLANDS (CFS)
Jan =	2.250		1.0	0.0
Feb =	1.800		1.0	0.0
Mar =	1.800		0.0	0.0
Apr =	1.530		0.0	0.0
May =	2.850	15	0.0	0.0
Jun =	4.350	15	0.0	0.0
Jul =	5.550	14	0.0	0.0
Aug =	5.550	15	0.0	0.0
Sep =	3.600	13	0.0	0.0
Oct =	1.800	10	0.0	0.0
Nov =	2.400		1.0	0.0
Dec =	2.850		1.0	0.0

Castle Mun Diversion (cfs) = 5.0
ALLOCATION OF CASTLE CK IRRIGATION
% from Holden Ditch = 70%
% from Marolt Ditch = 30%

DISCHARGE COEFFICIENTS (% OF GAGED FLOW)

	Castle Ck	Maroon Ck	Willow Ck
Oct	265%	140%	5%
Nov	265%	140%	35%
Dec	265%	140%	35%
Jan	265%	140%	35%
Feb	265%	140%	35%
Mar	265%	140%	35%
Apr	265%	140%	35%
May	265%	140%	35%
Jun	265%	140%	35%
Jul	265%	140%	20%
Aug	265%	140%	10%
Sep	265%	140%	5%

PENSTOCK DESIGN

Dia (in) =	36
Length (ft) =	3825
E0 (ft) =	7850
E1 (ft) =	8180

CC HYDRO ASSUMPTIONS

Limit 0=0,1=Q,P=2	0
Up lim	100%
low lim	20%
Generation cap (kW)	1000
Peak	0
Plant eff	85%
Capacity factor	95%

SIMULATION PERIOD

	Year	Sim Year
Start	1970	1994
End	1994	
Initialize		1

KWH ADJUSTMENTS

Head Increase (20') =	6.25%
Penstock Friction Adjust (36" to 42")	
June - August =	2.00%
May & October =	1.00%

Drawing all from Castle and Maroon Creeks

				Q	Power
TOTAL NET KWH PRODUCTION (GENERATION MINUS PUMPING) =	7,866,103	KWH per year			
MAROON CREEK HYDROELECTRIC PLANT - TOTAL KWH PRODUCTION =	701,016	KWH per year	**Avg**	35.65	813.81
CASTLE CREEK HYDROELECTRIC PLANT - TOTAL KWH PRODUCTION =	7,165,087	KWH per year	**max**	49.45	1,117.23
MAROON CREEK PUMPBACK - TOTAL KWH USAGE =	-	KWH per year	**min**	1.94	-

Castle Ck blw Marolt Ditch Flow Requirement (cfs)

Oct =	12	Apr =	12
Nov =	12	May =	12
Dec =	12	Jun =	12
Jan =	12	Jul =	12
Feb =	12	Aug =	12
Mar =	12	Sep =	12

Grand River Consulting Corporation 718 Cooper Avenue Glenwood Springs, CO 81601 Tel (970) 945-2377 Fax(970) 945-2977

Table 1: Castle Creek and Maroon Creek Drainage areas and Average Precipitation

Drainage Area	USGS Recorded Area (sq. mi)	GIS Calculations Drainage Area (sq. mi.)	GIS Calculations Minimum Elevation (ft.)	GIS Calculations Maximum Elevation (ft.)	GIS Calculations Average Elevation (ft.)	GIS Calculations Average Annual Precipitation (in.)	Drainage Area Ratio	Precip-itation Ratio
Castle Creek Gauge	32.2	32.1	9,098	14,233	11,435	35.9		
Castle Creek Intake		69.2	8,216	14,246	11,148	35.5	216%	99%
Maroon Creek Gauge	35.4	35.5	8,734	14,082	11,375	43.4		
Maroon Creek Intake		41.8	8,212	14,082	11,172	41.2	118%	95%

Castle Creek Intake / Gauge Drainage Area Ratio	216%
Maroon Creek Intake / Gauge Drainage Area Ratio	118%

Castle Creek Coefficient Used in Grand River Model	265%
Maroon Creek Coefficient Used in Grand River Model	140%

Note: average annual precipitation data are from PRISM 800 meter grid data (1971-2000 mean) (http://www.prism.oregonstate.edu/)

Table 2: Application of USGS Regional Model

	Castle Gage	Castle Intake	Maroon Gage	Maroon Intake
Measured Area (square miles)	32.1	69.2	35.5	41.8
PRISM Average Precipitation (inches)	35.9	35.5	43.4	41.2

	USGS Model exponents		
	10	A	P
Annual	-2.31	0.88	1.71
Oct	-3.29	0.97	1.98
Nov	-3.14	0.98	1.78
Dec	-2.9	1	1.52
Jan	-2.99	1.02	1.53
Feb	-2.92	1.02	1.46
Mar	-2.87	1.06	1.42
Apr	-2.95	1.14	1.64
May	-1.6	0.94	1.44
Jun	-1.29	0.82	1.52
Jul	-2.8	0.84	2.23
Aug	-2.73	0.85	1.91
Sep	-2.93	0.92	1.84

	USGS Model Estimated Mean Flows (cfs)				Coefficients Derived from USGS Model	
	Castle Gage	Castle Intake	Maroon Gage	Maroon Intake	Castle Creek	Maroon Creek
Annual	47	91	72	76	193%	106%
Oct	18	37	29	30	207%	106%
Nov	13	26	20	21	209%	107%
Dec	9	20	14	15	212%	109%
Jan	8	18	12	14	216%	109%
Feb	8	17	11	12	216%	110%
Mar	9	19	13	14	223%	111%
Apr	21	49	32	35	236%	111%
May	113	230	164	178	203%	108%
Jun	203	376	295	312	185%	106%
Jul	85	159	143	146	186%	102%
Aug	33	62	52	54	188%	104%
Sep	21	41	32	34	199%	106%

Table 3: Stream Flow Reductions Downstream of Castle Creek Intake, Dry Year

	Percentile											
Week	Min	10%	20%	30%	40%	50%	60%	70%	80%	90%	Max	1977
24-Sep	0.0%	21.1%	23.8%	28.0%	30.5%	33.2%	36.4%	38.2%	38.2%	40.3%	45.1%	5.2%
1-Oct	5.8%	22.6%	24.6%	28.0%	33.2%	34.7%	37.8%	40.3%	41.7%	42.6%	45.1%	39.6%
8-Oct	0.0%	27.2%	28.2%	31.8%	35.7%	38.2%	41.7%	42.6%	45.1%	52.4%	59.3%	43.5%
15-Oct	26.3%	29.8%	31.8%	38.2%	42.6%	45.1%	48.0%	48.0%	53.3%	57.2%	59.3%	57.5%
22-Oct	29.3%	33.2%	34.7%	40.3%	42.6%	45.1%	48.0%	51.2%	53.3%	57.2%	59.3%	57.2%
29-Oct	29.7%	35.6%	38.2%	42.5%	45.1%	48.0%	48.4%	51.2%	53.3%	54.9%	59.3%	53.8%
5-Nov	9.3%	36.4%	42.5%	42.6%	48.0%	48.4%	51.2%	53.3%	54.9%	57.2%	59.3%	49.1%
12-Nov	16.8%	38.2%	45.1%	48.0%	48.4%	51.2%	53.3%	54.9%	57.2%	59.3%	59.3%	49.1%
19-Nov	10.9%	38.2%	44.6%	48.4%	48.4%	51.2%	53.3%	54.6%	54.9%	58.4%	59.3%	46.5%
26-Nov	0.0%	40.3%	42.5%	48.4%	51.2%	53.3%	53.3%	54.9%	57.2%	59.3%	59.3%	39.8%
3-Dec	7.7%	40.3%	42.5%	48.1%	48.4%	51.2%	53.3%	53.3%	57.2%	59.3%	59.3%	42.5%
10-Dec	5.9%	35.1%	42.5%	42.5%	48.0%	48.4%	49.6%	53.3%	54.9%	57.2%	59.3%	42.5%
17-Dec	0.0%	30.6%	35.1%	42.5%	42.5%	48.4%	48.4%	51.2%	53.3%	57.2%	59.3%	36.2%
24-Dec	0.0%	12.5%	31.9%	35.1%	42.5%	48.4%	48.4%	53.3%	53.3%	57.2%	59.3%	31.4%
1-Jan	0.0%	10.9%	12.5%	30.8%	35.1%	42.5%	45.1%	48.4%	53.3%	57.2%	59.3%	27.6%
2-Jan	0.0%	10.9%	25.3%	35.1%	42.5%	42.5%	48.0%	48.4%	48.4%	53.3%	59.3%	21.4%
9-Jan	0.0%	9.3%	20.3%	35.1%	42.5%	42.5%	42.5%	42.5%	48.4%	53.3%	59.3%	13.7%
16-Jan	0.0%	4.1%	20.5%	28.7%	35.1%	42.5%	42.5%	42.5%	48.4%	53.3%	59.3%	5.2%
23-Jan	0.0%	5.9%	25.5%	30.6%	35.1%	35.1%	35.1%	42.5%	42.5%	53.3%	59.3%	4.4%
30-Jan	0.0%	2.3%	16.8%	28.7%	30.6%	35.1%	35.1%	35.1%	42.5%	53.3%	59.3%	1.7%
6-Feb	0.0%	10.9%	19.5%	23.2%	29.7%	33.4%	35.1%	35.1%	42.5%	55.6%	59.3%	1.2%
13-Feb	0.0%	2.3%	17.9%	19.5%	25.5%	31.6%	35.1%	41.1%	42.5%	53.3%	59.3%	3.1%
20-Feb	0.0%	4.1%	19.3%	23.2%	25.5%	30.6%	33.4%	42.5%	42.5%	53.3%	57.2%	5.9%
27-Feb	0.0%	7.7%	18.2%	24.4%	28.7%	31.1%	34.3%	35.1%	42.5%	48.4%	57.2%	7.2%
5-Mar	0.0%	7.7%	15.4%	24.4%	28.7%	31.6%	35.1%	35.1%	42.5%	48.4%	59.3%	5.9%
12-Mar	0.0%	7.7%	13.7%	24.4%	28.7%	35.1%	35.1%	35.1%	42.5%	48.4%	59.3%	9.5%
19-Mar	0.0%	6.6%	12.5%	19.5%	25.5%	31.6%	35.1%	42.5%	42.5%	48.4%	59.3%	8.9%
26-Mar	0.0%	5.6%	10.9%	19.5%	25.0%	34.3%	42.5%	42.5%	43.6%	48.4%	59.3%	11.4%
2-Apr	0.0%	9.3%	14.0%	23.4%	28.3%	35.1%	42.5%	42.5%	48.4%	53.3%	59.3%	19.9%
9-Apr	0.0%	17.5%	25.5%	30.5%	35.0%	36.4%	42.5%	45.1%	48.4%	54.9%	59.3%	33.1%
16-Apr	14.9%	28.7%	31.6%	35.1%	38.2%	42.5%	45.1%	48.4%	53.3%	56.3%	59.3%	44.2%
23-Apr	0.0%	0.0%	14.3%	22.3%	28.5%	35.1%	38.9%	48.0%	51.6%	54.9%	59.3%	55.4%
30-Apr	0.0%	8.1%	9.7%	12.5%	16.1%	21.7%	25.4%	28.2%	33.5%	38.2%	40.3%	31.2%
7-May	4.0%	8.0%	10.8%	12.9%	14.9%	17.7%	22.3%	27.0%	31.9%	36.3%	40.3%	16.6%
14-May	2.6%	5.8%	7.3%	8.1%	9.3%	10.5%	11.7%	14.0%	21.1%	32.6%	40.3%	31.6%
21-May	2.3%	4.6%	5.6%	6.8%	7.7%	8.6%	9.6%	11.3%	13.8%	18.5%	36.4%	28.3%
28-May	1.7%	3.6%	4.1%	5.0%	5.5%	6.3%	6.9%	7.5%	8.8%	11.4%	26.3%	12.2%
4-Jun	1.7%	2.8%	3.2%	3.5%	4.0%	4.4%	4.9%	6.0%	6.8%	8.1%	14.3%	8.2%
11-Jun	1.9%	2.7%	3.2%	3.6%	3.9%	4.1%	4.7%	5.2%	6.2%	8.0%	15.2%	12.9%
18-Jun	1.7%	2.5%	2.7%	3.1%	3.4%	4.3%	4.7%	5.1%	6.0%	6.9%	23.8%	20.9%
25-Jun	1.8%	2.7%	3.2%	3.7%	4.3%	5.0%	6.0%	6.7%	7.7%	9.9%	29.3%	25.0%
2-Jul	1.7%	3.4%	4.4%	4.8%	5.3%	6.0%	7.6%	9.0%	10.4%	12.0%	34.7%	29.4%
9-Jul	2.6%	4.1%	5.1%	6.0%	7.1%	8.5%	9.8%	12.2%	13.4%	15.5%	40.3%	37.9%
16-Jul	3.4%	5.8%	6.8%	7.9%	9.2%	10.7%	11.5%	13.5%	16.9%	20.0%	39.8%	33.5%
23-Jul	4.6%	7.6%	9.3%	10.3%	11.6%	13.3%	14.6%	17.4%	20.0%	23.5%	39.8%	35.6%
30-Jul	4.7%	8.9%	11.6%	12.9%	14.3%	15.5%	18.1%	20.5%	23.1%	27.4%	36.2%	28.6%
6-Aug	6.1%	10.2%	12.8%	14.0%	16.5%	18.5%	20.5%	23.1%	25.0%	27.2%	33.2%	20.0%
13-Aug	7.8%	12.5%	14.6%	16.9%	18.3%	21.1%	24.7%	28.2%	31.8%	33.2%	40.3%	27.0%
20-Aug	9.6%	12.6%	16.1%	19.1%	21.1%	23.1%	26.6%	30.5%	33.9%	38.2%	41.9%	33.9%
27-Aug	11.3%	15.6%	18.5%	21.1%	24.6%	27.2%	29.3%	30.5%	36.4%	40.3%	41.9%	16.9%
3-Sep	4.0%	15.8%	18.5%	20.5%	23.1%	25.0%	27.2%	30.5%	34.5%	38.2%	41.9%	6.4%
10-Sep	5.4%	18.3%	20.5%	24.6%	27.2%	30.1%	31.8%	33.2%	34.7%	38.2%	41.9%	31.3%
17-Sep	4.0%	18.3%	20.0%	25.0%	28.2%	31.8%	33.7%	34.7%	36.4%	38.4%	41.9%	8.5%

Table 4: Stream Flow Reductions Downstream of Castle Creek Intake, Average Year

						Percentile						
Week	**Min**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**Max**	1980
24-Sep	0.0%	21.1%	23.8%	28.0%	30.5%	33.2%	36.4%	38.2%	38.2%	40.3%	45.1%	41.3%
1-Oct	5.8%	22.6%	24.6%	28.0%	33.2%	34.7%	37.8%	40.3%	41.7%	42.6%	45.1%	43.7%
8-Oct	0.0%	27.2%	28.2%	31.8%	35.7%	38.2%	41.7%	42.6%	45.1%	52.4%	59.3%	45.9%
15-Oct	26.3%	29.8%	31.8%	38.2%	42.6%	45.1%	48.0%	48.0%	53.3%	57.2%	59.3%	46.4%
22-Oct	29.3%	33.2%	34.7%	40.3%	42.6%	45.1%	48.0%	51.2%	53.3%	57.2%	59.3%	49.9%
29-Oct	29.7%	35.6%	38.2%	42.5%	45.1%	48.0%	48.4%	51.2%	53.3%	54.9%	59.3%	48.9%
5-Nov	9.3%	36.4%	42.5%	42.6%	48.0%	48.4%	51.2%	53.3%	54.9%	57.2%	59.3%	54.5%
12-Nov	16.8%	38.2%	45.1%	48.0%	48.4%	51.2%	53.3%	54.9%	57.2%	59.3%	59.3%	56.3%
19-Nov	10.9%	38.2%	44.6%	48.4%	48.4%	51.2%	53.3%	54.6%	54.9%	58.4%	59.3%	53.6%
26-Nov	0.0%	40.3%	42.5%	48.4%	51.2%	53.3%	53.3%	54.9%	57.2%	59.3%	59.3%	52.4%
3-Dec	7.7%	40.3%	42.5%	48.1%	48.4%	51.2%	53.3%	53.3%	57.2%	59.3%	59.3%	47.6%
10-Dec	5.9%	35.1%	42.5%	42.5%	48.0%	48.4%	49.6%	53.3%	54.9%	57.2%	59.3%	42.5%
17-Dec	0.0%	30.6%	35.1%	42.5%	42.5%	48.4%	48.4%	51.2%	53.3%	57.2%	59.3%	41.5%
24-Dec	0.0%	12.5%	31.9%	35.1%	42.5%	48.4%	48.4%	53.3%	53.3%	57.2%	59.3%	35.1%
1-Jan	0.0%	10.9%	12.5%	30.8%	35.1%	42.5%	45.1%	48.4%	53.3%	57.2%	59.3%	35.1%
2-Jan	0.0%	10.9%	25.3%	35.1%	42.5%	42.5%	48.0%	48.4%	48.4%	53.3%	59.3%	34.7%
9-Jan	0.0%	9.3%	20.3%	35.1%	42.5%	42.5%	42.5%	42.5%	48.4%	53.3%	59.3%	34.7%
16-Jan	0.0%	4.1%	20.5%	28.7%	35.1%	42.5%	42.5%	42.5%	48.4%	53.3%	59.3%	32.9%
23-Jan	0.0%	5.9%	25.5%	30.6%	35.1%	35.1%	35.1%	42.5%	42.5%	53.3%	59.3%	33.8%
30-Jan	0.0%	2.3%	16.8%	28.7%	30.6%	35.1%	35.1%	35.1%	42.5%	53.3%	59.3%	30.3%
6-Feb	0.0%	10.9%	19.5%	23.2%	29.7%	33.4%	35.1%	35.1%	42.5%	55.6%	59.3%	30.8%
13-Feb	0.0%	2.3%	17.9%	19.5%	25.5%	31.6%	35.1%	41.1%	42.5%	53.3%	59.3%	31.2%
20-Feb	0.0%	4.1%	19.3%	23.2%	25.5%	30.6%	33.4%	42.5%	42.5%	53.3%	57.2%	31.2%
27-Feb	0.0%	7.7%	18.2%	24.4%	28.7%	31.1%	34.3%	35.1%	42.5%	48.4%	57.2%	30.8%
5-Mar	0.0%	7.7%	15.4%	24.4%	28.7%	31.6%	35.1%	35.1%	42.5%	48.4%	59.3%	28.9%
12-Mar	0.0%	7.7%	13.7%	24.4%	28.7%	35.1%	35.1%	35.1%	42.5%	48.4%	59.3%	24.3%
19-Mar	0.0%	6.6%	12.5%	19.5%	25.5%	31.6%	35.1%	42.5%	42.5%	48.4%	59.3%	17.8%
26-Mar	0.0%	5.6%	10.9%	19.5%	25.0%	34.3%	42.5%	42.5%	43.6%	48.4%	59.3%	11.6%
2-Apr	0.0%	9.3%	14.0%	23.4%	28.3%	35.1%	42.5%	42.5%	48.4%	53.3%	59.3%	6.4%
9-Apr	0.0%	17.5%	25.5%	30.5%	35.0%	36.4%	42.5%	45.1%	48.4%	54.9%	59.3%	8.8%
16-Apr	14.9%	28.7%	31.6%	35.1%	38.2%	42.5%	45.1%	48.4%	53.3%	56.3%	59.3%	32.3%
23-Apr	0.0%	0.0%	14.3%	22.3%	28.5%	35.1%	38.9%	48.0%	51.6%	54.9%	59.3%	22.9%
30-Apr	0.0%	8.1%	9.7%	12.5%	16.1%	21.7%	25.4%	28.2%	33.5%	38.2%	40.3%	28.4%
7-May	4.0%	8.0%	10.8%	12.9%	14.9%	17.7%	22.3%	27.0%	31.9%	36.3%	40.3%	34.0%
14-May	2.6%	5.8%	7.3%	8.1%	9.3%	10.5%	11.7%	14.0%	21.1%	32.6%	40.3%	18.2%
21-May	2.3%	4.6%	5.6%	6.8%	7.7%	8.6%	9.6%	11.3%	13.8%	18.5%	36.4%	11.7%
28-May	1.7%	3.6%	4.1%	5.0%	5.5%	6.3%	6.9%	7.5%	8.8%	11.4%	26.3%	7.0%
4-Jun	1.7%	2.8%	3.2%	3.5%	4.0%	4.4%	4.9%	6.0%	6.8%	8.1%	14.3%	3.3%
11-Jun	1.9%	2.7%	3.2%	3.6%	3.9%	4.1%	4.7%	5.2%	6.2%	8.0%	15.2%	3.2%
18-Jun	1.7%	2.5%	2.7%	3.1%	3.4%	4.3%	4.7%	5.1%	6.0%	6.9%	23.8%	3.0%
25-Jun	1.8%	2.7%	3.2%	3.7%	4.3%	5.0%	6.0%	6.7%	7.7%	9.9%	29.3%	3.7%
2-Jul	1.7%	3.4%	4.4%	4.8%	5.3%	6.0%	7.6%	9.0%	10.4%	12.0%	34.7%	5.3%
9-Jul	2.6%	4.1%	5.1%	6.0%	7.1%	8.5%	9.8%	12.2%	13.4%	15.5%	40.3%	8.8%
16-Jul	3.4%	5.8%	6.8%	7.9%	9.2%	10.7%	11.5%	13.5%	16.9%	20.0%	39.8%	11.4%
23-Jul	4.6%	7.6%	9.3%	10.3%	11.6%	13.3%	14.6%	17.4%	20.0%	23.5%	39.8%	14.4%
30-Jul	4.7%	8.9%	11.6%	12.9%	14.3%	15.5%	18.1%	20.5%	23.1%	27.4%	36.2%	17.4%
6-Aug	6.1%	10.2%	12.8%	14.0%	16.5%	18.5%	20.5%	23.1%	25.0%	27.2%	33.2%	19.4%
13-Aug	7.8%	12.5%	14.6%	16.9%	18.3%	21.1%	24.7%	28.2%	31.8%	33.2%	40.3%	22.9%
20-Aug	9.6%	12.6%	16.1%	19.1%	21.1%	23.1%	26.6%	30.5%	33.9%	38.2%	41.9%	23.8%
27-Aug	11.3%	15.6%	18.5%	21.1%	24.6%	27.2%	29.3%	30.5%	36.4%	40.3%	41.9%	28.8%
3-Sep	4.0%	15.8%	18.5%	20.5%	23.1%	25.0%	27.2%	30.5%	34.5%	38.2%	41.9%	21.5%
10-Sep	5.4%	18.3%	20.5%	24.6%	27.2%	30.1%	31.8%	33.2%	34.7%	38.2%	41.9%	27.7%
17-Sep	4.0%	18.3%	20.0%	25.0%	28.2%	31.8%	33.7%	34.7%	36.4%	38.4%	41.9%	33.7%

Table 5: Stream Flow Reductions Downstream of Castle Creek Intake, Wet Year

	Percentile											
Week	Min	10%	20%	30%	40%	50%	60%	70%	80%	90%	Max	1984
24-Sep	0.0%	21.1%	23.8%	28.0%	30.5%	33.2%	36.4%	38.2%	38.2%	40.3%	45.1%	27.9%
1-Oct	5.8%	22.6%	24.6%	28.0%	33.2%	34.7%	37.8%	40.3%	41.7%	42.6%	45.1%	33.0%
8-Oct	0.0%	27.2%	28.2%	31.8%	35.7%	38.2%	41.7%	42.6%	45.1%	52.4%	59.3%	35.9%
15-Oct	26.3%	29.8%	31.8%	38.2%	42.6%	45.1%	48.0%	48.0%	53.3%	57.2%	59.3%	37.8%
22-Oct	29.3%	33.2%	34.7%	40.3%	42.6%	45.1%	48.0%	51.2%	53.3%	57.2%	59.3%	40.3%
29-Oct	29.7%	35.6%	38.2%	42.5%	45.1%	48.0%	48.4%	51.2%	53.3%	54.9%	59.3%	41.6%
5-Nov	9.3%	36.4%	42.5%	42.6%	48.0%	48.4%	51.2%	53.3%	54.9%	57.2%	59.3%	43.4%
12-Nov	16.8%	38.2%	45.1%	48.0%	48.4%	51.2%	53.3%	54.9%	57.2%	59.3%	59.3%	48.4%
19-Nov	10.9%	38.2%	44.6%	48.4%	48.4%	51.2%	53.3%	54.6%	54.9%	58.4%	59.3%	52.4%
26-Nov	0.0%	40.3%	42.5%	48.4%	51.2%	53.3%	53.3%	54.9%	57.2%	59.3%	59.3%	56.8%
3-Dec	7.7%	40.3%	42.5%	48.1%	48.4%	51.2%	53.3%	53.3%	57.2%	59.3%	59.3%	56.9%
10-Dec	5.9%	35.1%	42.5%	42.5%	48.0%	48.4%	49.6%	53.3%	54.9%	57.2%	59.3%	55.7%
17-Dec	0.0%	30.6%	35.1%	42.5%	42.5%	48.4%	48.4%	51.2%	53.3%	57.2%	59.3%	45.8%
24-Dec	0.0%	12.5%	31.9%	35.1%	42.5%	48.4%	48.4%	53.3%	53.3%	57.2%	59.3%	54.9%
1-Jan	0.0%	10.9%	12.5%	30.8%	35.1%	42.5%	45.1%	48.4%	53.3%	57.2%	59.3%	51.8%
2-Jan	0.0%	10.9%	25.3%	35.1%	42.5%	42.5%	48.0%	48.4%	48.4%	53.3%	59.3%	48.3%
9-Jan	0.0%	9.3%	20.3%	35.1%	42.5%	42.5%	42.5%	42.5%	48.4%	53.3%	59.3%	45.9%
16-Jan	0.0%	4.1%	20.5%	28.7%	35.1%	42.5%	42.5%	42.5%	48.4%	53.3%	59.3%	44.2%
23-Jan	0.0%	5.9%	25.5%	30.6%	35.1%	35.1%	35.1%	42.5%	42.5%	53.3%	59.3%	40.4%
30-Jan	0.0%	2.3%	16.8%	28.7%	30.6%	35.1%	35.1%	35.1%	42.5%	53.3%	59.3%	35.0%
6-Feb	0.0%	10.9%	19.5%	23.2%	29.7%	33.4%	35.1%	35.1%	42.5%	55.6%	59.3%	36.2%
13-Feb	0.0%	2.3%	17.9%	19.5%	25.5%	31.6%	35.1%	41.1%	42.5%	53.3%	59.3%	39.4%
20-Feb	0.0%	4.1%	19.3%	23.2%	25.5%	30.6%	33.4%	42.5%	42.5%	53.3%	57.2%	35.3%
27-Feb	0.0%	7.7%	18.2%	24.4%	28.7%	31.1%	34.3%	35.1%	42.5%	48.4%	57.2%	26.1%
5-Mar	0.0%	7.7%	15.4%	24.4%	28.7%	31.6%	35.1%	35.1%	42.5%	48.4%	59.3%	19.2%
12-Mar	0.0%	7.7%	13.7%	24.4%	28.7%	35.1%	35.1%	35.1%	42.5%	48.4%	59.3%	25.2%
19-Mar	0.0%	6.6%	12.5%	19.5%	25.5%	31.6%	35.1%	42.5%	42.5%	48.4%	59.3%	26.1%
26-Mar	0.0%	5.6%	10.9%	19.5%	25.0%	34.3%	42.5%	42.5%	43.6%	48.4%	59.3%	16.3%
2-Apr	0.0%	9.3%	14.0%	23.4%	28.3%	35.1%	42.5%	42.5%	48.4%	53.3%	59.3%	21.6%
9-Apr	0.0%	17.5%	25.5%	30.5%	35.0%	36.4%	42.5%	45.1%	48.4%	54.9%	59.3%	28.7%
16-Apr	14.9%	28.7%	31.6%	35.1%	38.2%	42.5%	45.1%	48.4%	53.3%	56.3%	59.3%	28.7%
23-Apr	0.0%	0.0%	14.3%	22.3%	28.5%	35.1%	38.9%	48.0%	51.6%	54.9%	59.3%	-9.4%
30-Apr	0.0%	8.1%	9.7%	12.5%	16.1%	21.7%	25.4%	28.2%	33.5%	38.2%	40.3%	-10.0%
7-May	4.0%	8.0%	10.8%	12.9%	14.9%	17.7%	22.3%	27.0%	31.9%	36.3%	40.3%	7.0%
14-May	2.6%	5.8%	7.3%	8.1%	9.3%	10.5%	11.7%	14.0%	21.1%	32.6%	40.3%	3.4%
21-May	2.3%	4.6%	5.6%	6.8%	7.7%	8.6%	9.6%	11.3%	13.8%	18.5%	36.4%	2.6%
28-May	1.7%	3.6%	4.1%	5.0%	5.5%	6.3%	6.9%	7.5%	8.8%	11.4%	26.3%	4.0%
4-Jun	1.7%	2.8%	3.2%	3.5%	4.0%	4.4%	4.9%	6.0%	6.8%	8.1%	14.3%	3.9%
11-Jun	1.9%	2.7%	3.2%	3.6%	3.9%	4.1%	4.7%	5.2%	6.2%	8.0%	15.2%	2.2%
18-Jun	1.7%	2.5%	2.7%	3.1%	3.4%	4.3%	4.7%	5.1%	6.0%	6.9%	23.8%	1.9%
25-Jun	1.8%	2.7%	3.2%	3.7%	4.3%	5.0%	6.0%	6.7%	7.7%	9.9%	29.3%	2.1%
2-Jul	1.7%	3.4%	4.4%	4.8%	5.3%	6.0%	7.6%	9.0%	10.4%	12.0%	34.7%	2.3%
9-Jul	2.6%	4.1%	5.1%	6.0%	7.1%	8.5%	9.8%	12.2%	13.4%	15.5%	40.3%	3.5%
16-Jul	3.4%	5.8%	6.8%	7.9%	9.2%	10.7%	11.5%	13.5%	16.9%	20.0%	39.8%	4.2%
23-Jul	4.6%	7.6%	9.3%	10.3%	11.6%	13.3%	14.6%	17.4%	20.0%	23.5%	39.8%	5.6%
30-Jul	4.7%	8.9%	11.6%	12.9%	14.3%	15.5%	18.1%	20.5%	23.1%	27.4%	36.2%	7.5%
6-Aug	6.1%	10.2%	12.8%	14.0%	16.5%	18.5%	20.5%	23.1%	25.0%	27.2%	33.2%	7.9%
13-Aug	7.8%	12.5%	14.6%	16.9%	18.3%	21.1%	24.7%	28.2%	31.8%	33.2%	40.3%	8.6%
20-Aug	9.6%	12.6%	16.1%	19.1%	21.1%	23.1%	26.6%	30.5%	33.9%	38.2%	41.9%	11.3%
27-Aug	11.3%	15.6%	18.5%	21.1%	24.6%	27.2%	29.3%	30.5%	36.4%	40.3%	41.9%	14.4%
3-Sep	4.0%	15.8%	18.5%	20.5%	23.1%	25.0%	27.2%	30.5%	34.5%	38.2%	41.9%	17.8%
10-Sep	5.4%	18.3%	20.5%	24.6%	27.2%	30.1%	31.8%	33.2%	34.7%	38.2%	41.9%	19.1%
17-Sep	4.0%	18.3%	20.0%	25.0%	28.2%	31.8%	33.7%	34.7%	36.4%	38.4%	41.9%	21.1%

City of Aspen

Evaluation of RAW WATER AVAILABILITY

OCTOBER 1994 UPDATE

Prepared by

ENARTECH Inc.
Consulting Engineers and Hydrologists

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TABLES

ATTACHMENTS

SIMULATION MODEL

A computer model of the City's integrated diversion system has been developed to simulate long-term water availability. The operation of this integrated system is complex and many factors that affect the City's diversions are not completely understood. For example, the amount of stream flow occurring at the primary intake facilities on Castle Creek and Maroon Creek has not been historically measured. As a result, estimates of the amount of stream flow occurring at the diversion sites have been made. Many other critical estimates and assumptions have been used in the simulation efforts, including assumptions regarding the timing and amount of the City's future water demands. These estimates and assumptions significantly influence the results and conclusions of the water availability simulation.

Users of the City's water system rely on a dependable year-round supply of water, even during critical drought periods. As a result, it is important that the amount of water available to the City is not overestimated or overcommitted, and that interruptions in water supply do not occur. Accordingly, several conservative assumptions and estimates have been applied in the simulation model, particularly for those issues that are not well understood (such as stream flow during drought periods).

Data collection has been initiated to improve the accuracy of the estimates and assumptions used in the model. As additional data and information becomes available, the evaluation of water availability should be periodically updated in order to improve the accuracy of water supply forecasts.

A partial printout of the simulation model, for one year of simulation, is presented in Attachment 1. A general description of the operation of the model, and the primary assumptions used in the model, occurs below.

SIMULATION PERIOD

The model simulates daily operation of City facilities for a 23-year historic period extending from the 1970 water year through the 1992 water year. This period coincides with the historic operation of U.S. Geological Survey (USGS) streamgages in the upper Castle Creek and Maroon Creek watersheds. The study period is generally representative of long-term conditions and contains some of the driest as well as the wettest individual years that have occurred within the last century. However, the study period does not contain a worst-case consecutive dry year period such as that which occurred in the 1950's.

STREAM FLOW PROJECTIONS

Stream flow gaging has not occurred at the primary City diversion facilities on Castle Creek and Maroon Creek. Gaging sites are located a considerable distance upstream of the facilities and are not accurate indicators of water availability at the diversion sites.

Measurements of stream flow at the intake facilities, and at the upstream USGS stream gages, were periodically made during the winter of 1994 in order to better define the relationship between stream flow occurring at these sites. These measurements were made jointly for the City of Aspen and for the Aspen Highlands Ski Company. The measurements were made during an above average baseflow period, following one of the wettest years in recent history. An additional Castle Creek measurement was made during early October of 1994.

A summary of the discharge measurements occurs in Table 1. The measurements reflect a large amount of variability, even during the winter baseflow period. On Castle Creek, stream flow at the City intake averaged about 270% of the flow occurring at the upstream gage. Discharge at this location varied between 229% and 330% of stream flow at the upstream site. Given the variability of the measurements, and the wetter than average nature of the period monitored, Castle Creek stream flow has been conservatively estimated to be 230% of the upstream USGS gage data.

TABLE 1

STREAMFLOW MONITORING RESULTS

DATE	CASTLE CREEK Above Intake	CASTLE CREEK USGS Gage	CASTLE CREEK % of USGS	MAROON CREEK Above Intake	MAROON CREEK USGS Gage	MAROON CREEK % of USGS
26-Jan-94	35.9	12.4	290%	27.0		
06-Feb-94	38.6	11.8	327%	32.8	20.8	158%
11-Feb-94	33.5	13.9	241%	28.3		
18-Feb-94	35.7			31.1		
25-Feb-94	32.5	11.2	290%	24.3		
04-Mar-94	35.7	13.5	264%	31.0		
11-Mar-94	33.4	14.4	232%	28.5		
17-Mar-94	30.6	11.7	262%	26.7		
04-Oct-94	49.5	21.6	229%			
Average	34.5	12.7	267%	28.7	20.8	158%

Maroon Creek streamflow was measured to closely coincide with Castle Creek discharge. One measurement determined the discharge at the intake to be 158% of flow at the upstream USGS gage on Maroon Creek. This measurement coincided with a Castle Creek discharge that was greater than average in relation to the USGS gage (327% of the Castle Creek USGS gage). The watershed area at the Maroon Creek intake is about 116% of the area at the upstream gage. For purposes of this study, stream flow at the Maroon Creek intake is estimated to be 125% of the flow at the Maroon Creek USGS Gage.

Willow Creek is an important non-gaged tributary that influences stream flow of lower Maroon Creek. The area of the Willow Creek watershed is approximately 37% of the area at the upstream Maroon Creek gage, and the watershed is of similar aspect and elevation. Accordingly, Willow Creek inflow is estimated to be 35% of the flow at the Maroon Creek gage. An exception to this assumption is the July through October period when it is assumed that upstream irrigation diversions on Willow Creek totally deplete the flow of this tributary.

Stream flow occurring during critical drought periods has not been measured at the City intake facilities on either Castle Creek or Maroon Creek. If actual dry year discharge is less than projected above, the amount of water available for diversion by the City may have been overestimated in this study.

INSTREAM FLOW CONSIDERATIONS

The stream flow that exceeds the CWCB instream flow rights is assumed to be available for diversion. The instream flow right for Castle Creek is 12 cubic feet per second (cfs), 14 cfs for Maroon Creek, and 32 cfs for the Roaring Fork River.

The model can be operated to either (1) maintain the instream flow right below City diversion facilities, or (2) maintain instream flow rights below City facilities and below downstream diversion facilities operated by other parties. The latter method of operation (which was used in this study) can result in an increased bypass at City facilities in order to maintain instream flow conditions below a downstream diversion structure.

It is assumed that the instream flow rights represent a rate of stream flow adequate to protect the environment to a reasonable degree at and downstream of the intake facilities on lower Castle Creek and lower Maroon Creek. If the CWCB quantified these instream flow values at sites upstream of the City intake structures (where the stream channel and amount of natural stream flow is smaller), the instream flow rights may underestimate the amount of water desired to maintain environmental conditions. If the instream flow bypass rates desired for environmental purposes are greater than those identified by the CWCB, the amount of water available for City use would be decreased.

OPERATION OF FACILITIES

The City facilities are operated in accordance with the following priorities. The purpose of this method of operation is to optimize water supply at the City's intake facilities and to maximize instream flow conditions. This priority of operation may not conform with actual historic practices of the City, but represents an increased efficiency of operation.

Potable Water Supplies. Potable water demands are first supplied by available water from Castle Creek. All stream flow that exceeds the instream flow bypass requirements is available for diversion. This operation maximizes water available for hydroelectric use on Maroon Creek. Maroon Creek is only used for potable purposes if insufficient supply is available from Castle Creek. The existing well field is only used when potable demands cannot be supplied by combined diversions from Castle Creek and Maroon Creek.

Figure D7 – 2040 Roaring Fork River near Aspen Average Monthly Natural Flow Comparison

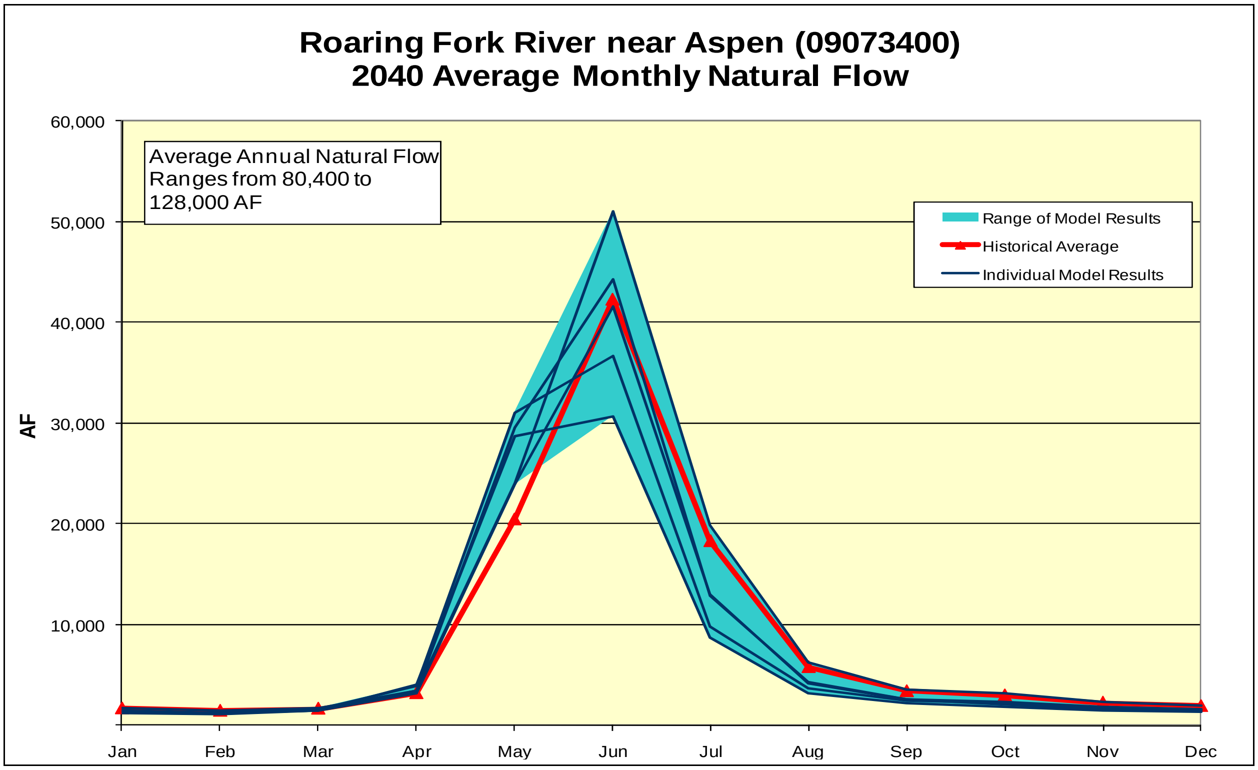

Figure D8 – 2040 Roaring Fork River at Glenwood Average Monthly Natural Flow Comparison