Exhibit 1

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

1313 Sherman Street
Denver, CO 80203

P (303) 866-3441
F (303) 866-4474

John Hickenlooper, Governor

Mike King, DNR Executive Director

James Eklund, CWCB Director

TO: Colorado Water Conservation Board Members

FROM: Linda Bassi, Chief
Jeff Baessler, Deputy Section Chief
Stream and Lake Protection Section

DATE: January 25, 2015

AGENDA ITEM: **13. Instream Flow and Natural Lake Level Appropriation Recommendations in Water Divisions 1, 4 , 5 and 6**

Introduction
This memo provides an overview of the technical analyses that were performed by both the recommending entities and CWCB staff to provide the Board with sufficient information to declare its intent to appropriate instream flow and natural lake level water rights in accordance with the Rules Concerning the Colorado Instream Flow and Natural Lake Level Program ("ISF Rules"). An executive summary for each stream and lake recommendation and appendices of the supporting scientific data, which provides the technical basis for each appropriation, was mailed to the Board separately.

Staff Recommendation
Staff recommends that, pursuant to ISF Rule 5d., the Board declare its intent to appropriate an instream flow ("ISF") water right on each stream segment listed and a natural lake level ("NLL") water right for each lake listed on the attached Tabulation of Instream Flow and Natural Lake Level Recommendations, and direct Staff to publicly notice the Board's declaration of its intent to appropriate.

Background
Pursuant to ISF Rule 5d., staff is requesting the Board to declare its intent to appropriate ISF and NLL water rights on the stream segments and lakes identified in the attached table. Staff has reviewed each proposed stream segment and lake to ensure that for each ISF and NLL recommendation, the data set is complete and standard methods and procedures were followed. In addition, staff has completed its water availability studies. Staff has identified 16 stream segments, and four natural lakes in Water Divisions 1, 4, 5 and 6 for which sufficient information has been compiled and analyses performed upon which the Board can base its intent to appropriate. These stream segments and lakes are located in Larimer, Delta, Gunnison, Garfield, Rio Blanco, and Routt Counties.

Technical Investigations
Staff's executive summary and technical analysis of each stream and lake are contained in the Instream Flow Recommendation Reports and form the basis for staff's recommendations. In addition to the reports, the scientific data and technical analyses performed by the recommending entity are

accessible on the Board's web site at: http://cwcb.state.co.us/environment/instream-flow-program/Pages/2015ProposedISFAppropriations.aspx

Natural Environment Studies
The Bureau of Land Management (BLM), Colorado Parks and Wildlife (CPW), the United States Forest Service, and the City of Fort Collins have conducted field surveys of the natural environment resources on these streams and lakes and have found natural environments that can be preserved. To quantify the resources and to evaluate instream flow requirements, the BLM and CPW collected biologic and hydraulic data and performed R2CROSS modeling on all segments. The CWCB staff analyzed and/or reviewed all of the data and models used to support the recommendations, and worked with the recommending entities to prepare final recommendations of the amount of water necessary to preserve the natural environment to a reasonable degree for each of the streams listed on the attached Tabulation of Instream Flow and Natural Lake Level Recommendations.

Water Availability Studies
Staff has conducted an evaluation of water availability for the streams and lakes listed. To determine the amount of water physically available for the Board's instreamflow appropriations, staff analyzed available USGS gage records, available streamflow models, and/or utilized appropriate standard methods to develop a hydrograph of median daily and/or mean monthly flows for each stream flow recommendation. To determine water availability for the lakes, staff reviewed hydrology, analyzed historical aerial photos, and obtained information from people familiar with the proposed NLL to assess the long term persistence of the lakes. In addition, staff analyzed the water rights tabulation for each stream and lake and consulted with the Division Engineer's Office in the relevant water division to identify any potential water availability problems. Based upon its analyses, staff has determined that water is available for appropriation on each stream and lake to preserve the natural environment to a reasonable degree without limiting or foreclosing the exercise of valid water rights.

Stakeholder Outreach
Staff provided public notice of the recommendations in both March and November of 2014 and contacted or met with the County Commissioners for each county where the stream segments are located. In addition, water commissioners and local land owners were contacted when possible to further discuss the recommendations.

Instream Flow Rule 5d.
Rule 5d. provides that the Board may declare its intent to appropriate ISF water rights after reviewing Staff's recommendations for the proposed appropriations. Rule 5d. also sets forth the activities that take place after the Board declares its intent that initiate the public notice and comment procedure for the ISF appropriations. Specifically,

5d. Board's Intent to Appropriate. Notice of the Board's potential action to declare its intent to appropriate shall be given in the January Board meeting agenda and the Board will take public comment regarding its intent to appropriate at the January meeting.

(1) After reviewing Staff's ISF recommendations for proposed ISF appropriations, the Board may declare its intent to appropriate specific ISF water rights. At that time, the Board shall direct the Staff to publicly notice the Board's declaration of its intent to appropriate.

(2) After the Board declares its intent to appropriate, notice shall be published in a mailing to the ISF Subscription Mailing Lists for the relevant water divisions and shall include:

(a) A description of the appropriation (e.g. stream reach, lake location, amounts, etc.);
(b) Availability (time and place) for review of Summary Reports and Investigations Files for each recommendation; and,
(c) Summary identification of any data, exhibits, testimony or other information in addition to the Summary Reports and Investigations Files supporting the appropriation.

(3) Published notice shall also contain the following information:
   (a) The Board may change flow amounts of contested ISF appropriations based on information received during the public notice and comment period.
   (b) Staff will maintain, pursuant to Rule 5e.(3), an ISF Subscription Mailing List for each water division composed of the names of all persons who have sent notice to the Board Office that they wish to be included on such list for a particular water division. Any person desiring to be on the ISF Subscription Mailing List(s) must send notice to the Board Office.
   (c) Any meetings held between Staff and members of the public will be open to the public. Staff may provide Proper Notice prior to any such meetings and may provide notice to persons on the ISF Subscription Mailing List(s).
   (d) Any Notice to Contest must be received at the Board office no later than March 31st, or the first business day thereafter. All Notices of Party status and Contested Hearing Participant status must be received at the Board office no later than April 30th, or the first business day thereafter.
   (e) Staff will announce its Final Staff ISF Recommendation concerning contested appropriations at the September Board meeting and will send notice of the Final Staff Recommendation to all persons on the Contested Hearing Mailing List.
   (f) The Board may take final action on any uncontested ISF appropriations at the May Board meeting.

(4) After the Board declares its intent to appropriate, notice of the Board's action shall be mailed within five working days to the County Commissioners of the county(ies) in which the proposed reach or lake is located.

Attachment

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

Instream Flow Tabulation

Water Division 1

Case Number	Stream	Watershed	County	Upper Terminus	Lower Terminus	Length (miles)	USGS QUADS	Amount(dates) (CFS)	Approp Date
13/1/A-001	Graves Creek	Lonetree Creek-Owl Creek	Larimer	Colorado - Wyoming border at lat 40 59 54N long 105 01 05W	confl unnamed trib at lat 40 58 12N long 104 59 33W	2.76	Carr West Round Butte	0.17 (1/1 - 12/31)	
13/1/A-003	Spottlewood Creek	Cache la Poudre	Larimer	a point located at lat 40 59 33N long 105 03 12W	a point located at lat 40 57 55N long 105 00 57W	3.53	Round Butte	0.1 (1/1 - 12/31)	

Totals for Water Division 1

Total # of Stream Miles = 6.29

Total # of Appropriations = 2

(Totals do not include donated/acquired water rights)

Instream Flow Tabulation - Water Division 4

Case Number	Stream	Watershed	County	Upper Terminus	Lower Terminus	Length (miles)	USGS QUADS	Amount(dates) (CFS)	Approp Date
15/4/A-001	Alkali Creek	Lower Gunnison	Delta	headwaters in the vicinity of lat 38 53 45N long 108 09 34W	confl Lone Starr Ditch hdgt at lat 38 50 08N long 108 09 20W	5.10	Indian Point Point Creek	0.3 (11/1 - 5/15) 2 (5/16 - 7/31) 1.5 (8/1 - 8/31) 0.8 (9/1 - 10/31)	
15/4/A-002	Hubbard Creek	North Fork Gunnison	Delta	US Forest Service Boundary at lat 38 57 23N long 107 31 45W	Deertrail Ditch hdgt at lat 38 56 03N long 107 31 06W	1.88	Bowie	8.3 (4/1 - 6/10) 2.6 (6/11 - 8/15) 1.8 (8/16 - 3/31)	
15/4/A-006	Schaefer Creek	North Fork Gunnison	Gunnison	headwaters in the vicinity of lat 38 51 12N long 107 15 17W	confl Grouse Spring Creek at lat 38 55 03N long 107 16 49W	5.92	Anthracite Range Marcellina Mountain Paonia Reservoir West Beckwith Mountain	1.7 (12/1 - 4/15) 4.6 (4/16 - 7/31) 2.9 (8/1 - 11/30)	
15/4/A-007	Terror Creek	North Fork Gunnison	Delta	confl East & West Terror Creeks at lat 38 56 54N long 107 34 29W	Terror Ditch hdgt at lat 38 55 36N long 107 34 24W	1.55	Bowie	1.5 (10/1 - 3/31) 4.8 (4/1 - 9/30)	
15/4/A-008	Terror Creek	North Fork Gunnison	Delta	Terror Ditch hdgt at lat 38 55 36N long 107 34 24W	Fire Mountain Canal at lat 38 54 23N long 107 34 02W	1.52	Bowie	4.2 (4/1 - 5/31)	

Totals for Water Division 4

Total # of Stream Miles = 15.97

Total # of Appropriations = 5

(Totals do not include donated/acquired water rights)

Instream Flow Tabulation - Water Division 5

Case Number	Stream	Watershed	County	Upper Terminus	Lower Terminus	Length (miles)	USGS QUADS	Amount(dates) (CFS)	Approp Date
15/5/A-001	Timber Springs Gulch	Eagle	Eagle	Spring Complex at lat 39 40 27N long 106 37 39W	BLM Property Boundary at lat 39 40 03N long 106 37 41W	0.47	Edwards Wolcott	1 (11/1 - 3/31) 1.3 (4/1 - 10/31)	

Totals for Water Division 5

Total # of Stream Miles = **0.47**

Total # of Appropriations = **1**

(Totals do not include donated/acquired water rights)

Instream Flow Tabulation - Water Division 6

Case Number	Stream	Watershed	County	Upper Terminus	Lower Terminus	Length (miles)	USGS QUADS	Amount(dates) (CFS)	Approp Date
15/6/A-001	Armstrong Creek	Upper Yampa	Routt	LT of ISF case # 06CW035 at lat 40 44 40N long 107 08 08W	confl Elkhead Creek at lat 40 44 43N long 107 08 12W	0.10	Quaker Mountain	1 (4/1 - 6/30) 0.5 (7/1 - 7/31) 0.22 (8/1 - 3/31)	
15/6/A-003	Brush Creek	Lower White	Rio Blanco Garfield	headwaters in the vicinity of lat 39 36 09N long 108 45 23W	confl East Douglas Creek at lat 39 39 16N long 108 42 26W	5.31	Calf Canyon Douglas Pass	0.5 (11/1 - 3/31) 0.65 (4/1 - 10/31)	
15/6/A-004 (increase)	East Douglas Creek	Lower White	Rio Blanco Garfield	confl Bear Park Creek at lat 39 38 13N long 108 41 43W	confl Brush Creek at lat 39 39 16N long 108 42 26W	1.56	Brushy Point	2.1 (5/1 - 7/15) 0.5 (7/16 - 10/15)	
15/6/A-005 (increase)	East Douglas Creek	Lower White	Rio Blanco	confl Brush Creek at lat 39 39 16N long 108 42 26W	confl Cathedral Creek at lat 39 46 59N long 108 38 35W	14.22	Brushy Point White Coyote Draw	0.5 (5/1 - 10/15)	
15/6/A-006	Elkhead Creek	Upper Yampa	Routt	LT of ISF Case # 06CW034 at lat 40 45 04N long 107 07 60W	confl First Creek at lat 40 44 02N long 107 10 01W	3.68	Bears Ears Peaks Quaker Mountain	7.6 (4/1 - 6/30) 4.1 (7/1 - 7/31) 1.7 (8/1 - 3/31)	
15/6/A-010 (increase)	Soldier Creek	Lower White	Rio Blanco	confl RF & MF Solider Creek at lat 39 42 57N long 108 34 31W	confl Cathedral Creek at lat 39 45 36N long 108 33 48W	3.67	Black Cabin Gulch Razorback Ridge	0.4 (4/1 - 9/30)	
13/6/A-005	Yellow Creek	Piceance Creek-Yellow Creek	Rio Blanco	confl Barcus Creek at lat 40 07 04N long 108 21 40W	confl Lambert Springs at lat 40 08 35N long 108 23 09W	3.66	Barcus Creek Barcus Creek SE Rough Gulch	1.5 (3/1 - 6/15) 0.6 (6/16 - 2/29)	
13/6/A-006	Yellow Creek	Piceance Creek-Yellow Creek	Rio Blanco	confl Lambert Springs at lat 40 08 35N long 108 23 09W	confl White River at lat 40 10 22N long 108 24 11W	3.45	Rough Gulch	2.3 (3/1 - 6/15) 1.1 (6/16 - 2/29)	

Totals for Water Division 6

Total # of Stream Miles = 35.65

Total # of Appropriations = 8

(Totals do not include donated/acquired water rights)

Instream Flow Tabulation - Water Division 6

Case Number	Stream	Watershed	County	Upper Terminus	Lower Terminus	Length (miles)	USGS QUADS	Amount(dates) (CFS)	Approp Date

Report Totals

Total # of Stream Miles = 58.38

Total # of Appropriations = 16

(Totals do not include donated/acquired water rights)

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

Natural Lake Tabulation

Water Division 1

Case Number	Name of Lake	Watershed	County	Lake Location	Surface Acres	Elevation (ft)	Volume (AF)	Approp Date	USGS Map Name
15/1/A-001	Spottlewood Lake 1	Cache la Poudre	Larimer	lat 40 52 16N long 104 59 56W	0.053	5,635	0.19		Carr SW
15/1/A-002	Spottlewood Lake 2	Cache la Poudre	Larimer	lat 40 52 28N long 104 59 53W	0.045	5,646	0.12		Carr SW
15/1/A-003	Spottlewood Lake 3	Cache la Poudre	Larimer	lat 40 52 27N long 104 59 50W	0.192	5,648	0.17		Carr SW
15/1/A-004	Spottlewood Lake 4	Cache la Poudre	Larimer	lat 40 52 31N long 104 59 37W	0.089	6,659	0.16		Carr West

Exhibit 2

United States Department of the Interior

BUREAU OF LAND MANAGEMENT
Colorado State Office
2850 Youngfield Street
Lakewood, Colorado 80215-7210
www.co.blm.gov

In Reply Refer To:
7250 (CO-930)

DEC 2 2 2014

Ms. Linda Bassi
Colorado Water Conservation Board
1313 Sherman Street, Room 721
Denver, CO 80203

Dear Ms Bassi:

The Bureau of Land Management (BLM) is writing this letter to formally update its instream flow recommendation for Yellow Creek, located in Water Division 6. The BLM originally made a recommendation on this stream in a letter dated December 18, 2012. This letter makes minor adjustments to the recommended flow rates and corrects minor errors to the data sets used to support the instream flow recommendations.

Location and Land Status. Yellow Creek is tributary to the White River approximately 27 miles northwest of Meeker, CO. This recommendation covers two stream reaches. The first reach begins at the confluence with Barcus Creek and extends downstream to the confluence with Lambert Springs, located in the SE ¼ NE ¼, Section 16, T2N R98W, Sixth P.M. The second reach begins at the confluence with Lambert Spring and extends to the confluence with the White River.

The first reach is 3.72 miles in length and is located entirely on public lands. The second reach is 3.45 miles in length. Of this length, 2.29 miles are on public lands and 1.16 miles are on private lands.

Biological Summary. Yellow Creek is a small, moderate gradient stream with a variable substrate size and a stable channel. Water quality, food sources and physical habitat characteristics are suitable for native species. Because of the small stream size, protection of flows is extremely important for continued existence of the fishery and riparian community.

Fishery surveys indicate that the creek supports self-sustaining populations of speckled dace and native mountain suckers, with density of mountain suckers slightly exceeding densities of speckled dace. The creek also provides habitat for northern leopard frogs. It is important to note that both mountain suckers and northern leopard frog appear on the BLM's sensitive species list.

The riparian community is in stable condition and comprised primarily of willows and grasses. Riparian community health has been impaired by historic grazing practices and invasion of tamarisk. The BLM is taking actions to modify management and place the riparian community on an upward trend.

R2Cross Analysis. The BLM's data analysis, coordinated with the Division of Parks and Wildlife, indicates that the following flows are needed to protect the fishery and natural environment to a reasonable degree.

Reach 1 – Confluence with Barcus Creek to confluence with Lambert Spring

Cross Section Date	Discharge Rate	Top Width	Winter Flow Recommendation (meets 2 of 3 hydraulic criteria)	Summer Flow Recommendation (meets 3 of 3 hydraulic criteria)
09/09/2004 #1	0.49 cfs	5.18 feet	0.32 cfs	Out of confidence interval
09/09/2004 #2	0.57 cfs	4.58 feet	0.44 cfs	Out of confidence interval
06/21/2005 #1	0.82 cfs	6.03 feet	0.55 cfs	1.50 cfs
09/27/2011 #3	0.39 cfs	7.50 feet	1.00 cfs *See note below.*	Out of confidence interval
		Averages:	0.58 cfs	1.50 cfs

Note: 1.0 cfs provides 47.5% wetted perimeter and exceeds the depth criteria. The flow rate that fully meets all three instream flow criteria – 1.26 cfs is outside the confidence interval of the modeled data set.

Reach 2 – Confluence with Lambert Spring to confluence with White River

Cross Section Date	Discharge Rate	Top Width	Winter Flow Recommendation (meets 2 of 3 hydraulic criteria)	Summer Flow Recommendation (meets 3 of 3 hydraulic criteria)
09/27/2011 #1	1.19 cfs	12.19 feet	1.18 cfs	2.90 cfs *See note below.*
09/27/2011 #2	1.04 cfs	8.56 feet	0.91 cfs	1.65 cfs
		Averages:	1.05 cfs	2.28 cfs

Note: 2.90 cfs does not meet all three instream flow criteria, but it does meet the average depth criteria, average velocity criteria, and provides 46.3 percent wetted perimeter, which is very close to meeting the third instream flow criteria. The flow rate that fully meets all three instream,flow criteria – 3.31cfs-- is slightly outside the confidence interval of the modeled data set.

The BLM's analysis of this data, coordinated with the Division of Parks and Wildlife, indicates that the following flows are needed to protect the fishery and natural environment to a reasonable degree:

Reach 1 – Confluence with Barcus Gulch to confluence with Lambert Spring

> 1.50 cubic feet per second is recommended for the snowmelt runoff period from March 1 through June 15. This recommendation is driven by the average velocity criteria.
>
> 0.60 cubic feet per second is recommended from June 16 through February 28. This recommendation is driven by the average depth and wetted perimeter criteria. Many portions of this reach have a high width-to-depth ratio, so it is important to maintain sufficient depth for fish passage and overwintering of fish. Since this creek is very small and has limited physical habitat, meeting the wetted perimeter and depth criteria will ensure that the limited usable habitat is available to the native fish population.

Reach 2 – Confluence with Lambert Spring to confluence with White River

> 2.30 cubic feet per second is recommended for the snowmelt runoff period from March 1 through June 15. Each surveyed reach had distinctly different hydraulic characteristics, so this recommendation is driven by both the average velocity and wetted perimeter criteria. Since this creek is very small and has limited physical habitat, it is important to meet all three instream flow criteria during the spawning season to insure the survival of the native fish population.
>
> 1.10 cubic feet per second is recommended for the remainder of year, from June 16 through February 28. This recommendation is driven by a variety of the instream flow criteria, since each surveyed reach had distinctly different hydraulic characteristics. Many portions of this reach have a high width-to-depth ratio, so it is important to maintain sufficient depth for fish passage and overwintering of fish. This flow rate also protects the inflow to the creek from Lambert Spring, which is critical in maintaining water quality and quantity that is capable of supporting a native fishery.

Water Availability. The BLM is not aware of any decreed surface diversions within this reach. However, there are numerous decreed diversions, reservoirs, springs, and wells located upstream on Yellow Creek and its tributaries. A high percentage of these water rights are in conditional status. It is important to note that Yellow Creek has dry portions upstream from the reaches recommended in this letter, so diversions in upstream locations will not have a direct relationship to the flow rate in downstream locations. Specifically, the BLM is aware of the following absolute water rights in upstream locations:

Lathan Ditch – 2.0 cfs – irrigation use
WH Violett Ditch – 5.0 cfs – irrigation use
Wilson Ditch – 2.4 cfs – irrigation use

The BLM recommends using U.S. Geological Survey (USGS) Gage 09306255, Yellow Creek near White River, as an indicator of water availability. This gage has a long period of record, and indicates that water is available for the proposed appropriations.

Relationship to Management Plans. The White River Field Office Resource Management Plan identifies management of streams supporting native fish species as a priority for the BLM. The plan specifies that the BLM will work to improve riparian and aquatic conditions in these streams, and will also work to prevent surface disturbances close to them. In addition, the plan specifies that BLM will work with the Colorado Water Conservation Board to appropriate instream flow water rights to protect these fisheries.

Data sheets, R2Cross output, fishery survey information, and photographs of the cross section are to support this recommendation were provided with our previous letter. We thank both the Division of Parks and Wildlife and the Water Conservation Board for their cooperation in this effort.

If you have any questions regarding our instream flow recommendation, please contact Roy Smith at 303-239-3940.

Sincerely,

Acting

Brian St. George
Deputy State Director
Resources and Fire Management

cc: Keith Sauter, White River Field Office
Kent Walter, White River Field

Uncompahgre Field Office Stream Surveys
August 2007

Terror Creek - Water Code #43593

Terror Creek, located northeast of Paonia, Colorado on BLM lands managed by the Uncompahgre Field Office was sampled on August 22, 2007. Terror Creek is tributary to North Fork Gunnison River. Presence/absence sampling was done in support of the Colorado BLM in-stream flow program. Sampling was conducted via backpack electro-shocker and approximately 150 feet of stream was sampled. Personnel present were Tom Fresques, Dennis Murphy, and Malia Boyum.

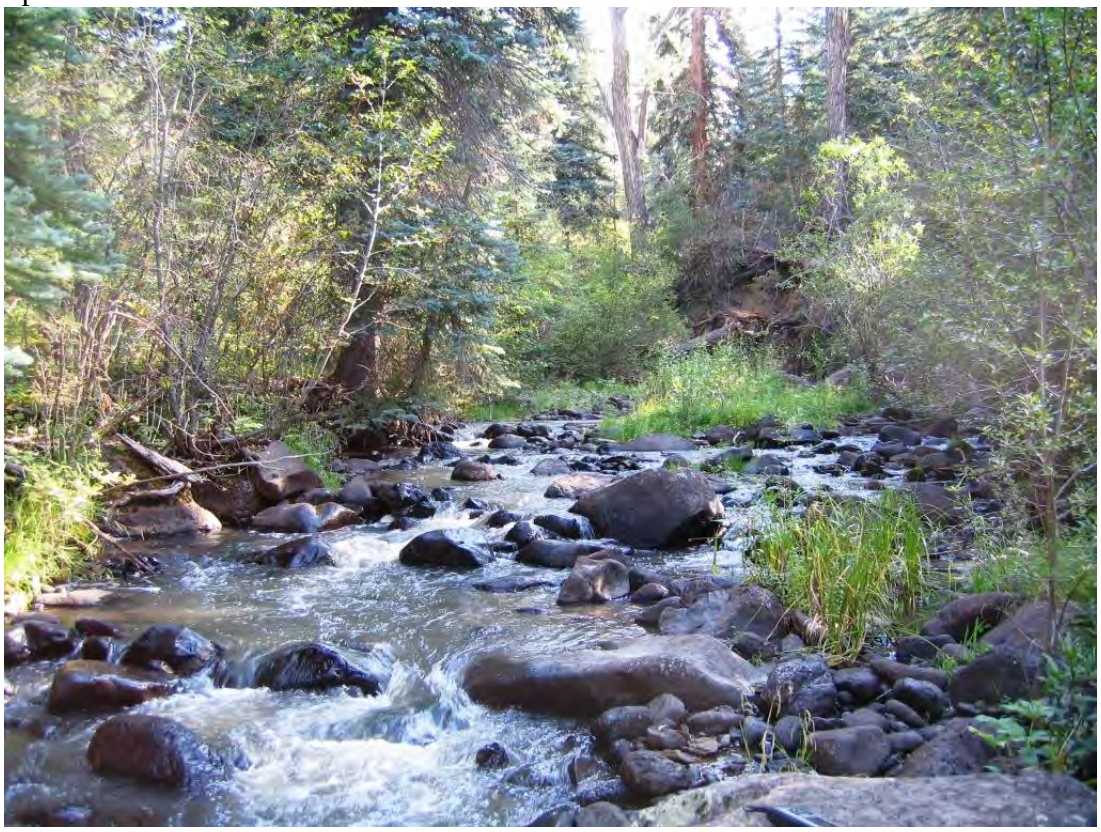
Fish weights and lengths cannot be reported because data sheets were misplaced after the initial effort to identify fish species and fish numbers were completed.

Fish

Colorado River cutthroat trout - adult

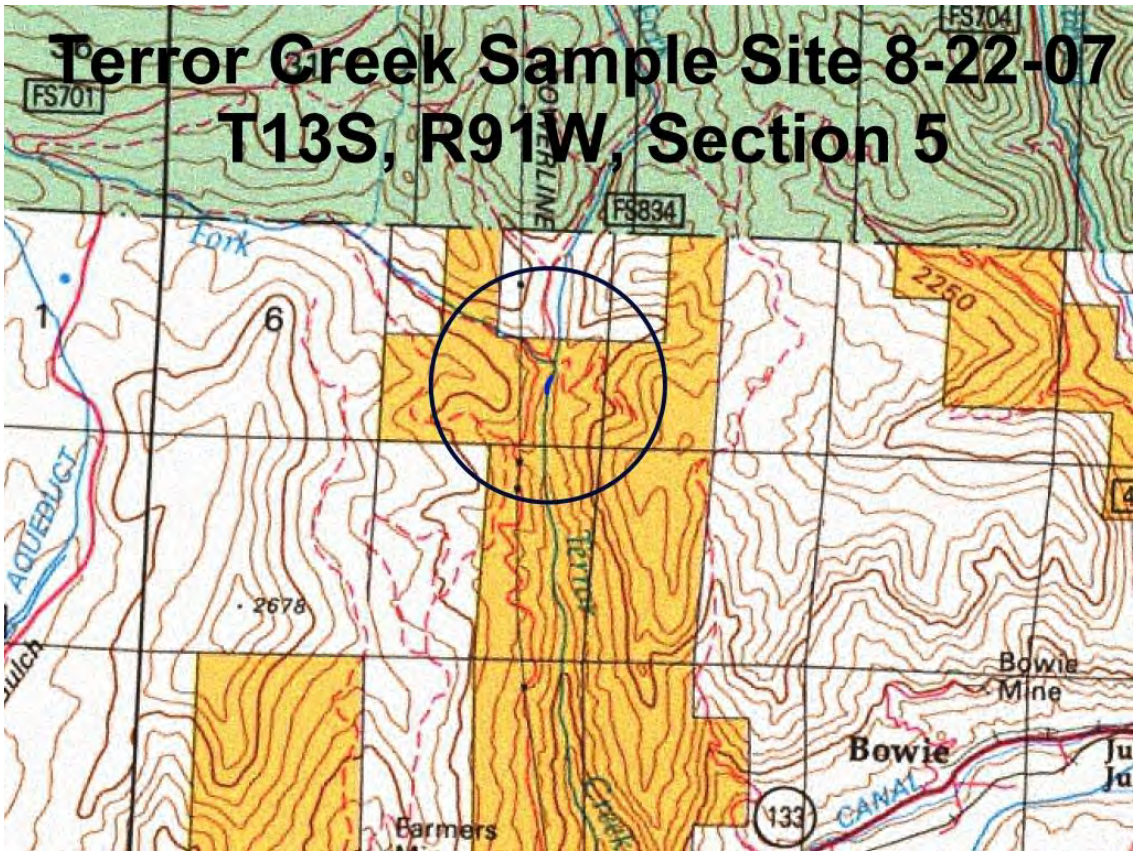
Colorado River cutthroat trout – juvenile

Speckled Dace



Terror Creek

Terror Creek



Map of Sample Site

STREAM SURVEY FISH SAMPLING FORM

WATER_Terror Creek_____ H2O CODE_43593_DATE_8-22-07

GEAR_Backpack Electroshocker EFFORT_150 ft._____ STATION #_1_ PASS 1

CREW Fresques, Murphy, Boyum DRAINAGE N. F. Gunnison River LOCATION Just below confluence of West and East Fork Terror Creek

Pass	species	length	weight		species	length	weight	Pass
1	CRCT							
	CRCT							
	CRCT							
	CRCT							
	CRCT							
	CRCT							
	CRCT							
	CRCT							
	CRCT							
	CRCT							
	SPD							
	SPD							
	SPD							
	SPD							

GPS Location:

Notes: Stream Width_18-22_ft. Sample Reach__150___ft.
Conductivity: Electroshocker settings

Notes: Stream was running approximately 5-7 cfs. Riparian habitat looked vigorous and good pools were present. Water was slightly off color. Good aquatic insect assemblage with stone, caddis, and mayflies noted. These cutthroat are likely pure given the pure population residing upstream in W. Fork Terror Creek. Fish appeared healthy. May want to collect fin clips from the mainstem of Terror Creek to determine genetic status and identify cutthroat upper and lower distribution limits. An instream flow recommendation on this creek would be valuable in maintaining this fishery.

*Note: Fish lengths and weights were taken but data sheets were misplaced.

COLORADO WATER CONSERVATION BOARD
INSTREAM FLOW / NATURAL LAKE LEVEL PROGRAM
STREAM CROSS-SECTION AND FLOW ANALYSIS

LOCATION INFORMATION

STREAM NAME:	Terror Creek
XS LOCATION:	Approx. 650' downstream fr. W. Fk.
XS NUMBER:	1
DATE:	21-Oct-08
OBSERVERS:	R. Smith, D. Murphy
1/4 SEC:	SE
SECTION:	5
TWP:	13S
RANGE:	91W
PM:	Sixth
COUNTY:	Delta
WATERSHED:	N. Fk. Gunnison
DIVISION:	4
DOW CODE:	43593
USGS MAP:	Bowie 7.5'
USFS MAP:	0

SUPPLEMENTAL DATA

		*** NOTE ***
		Leave TAPE WT and TENSION
		at defaults for data collected
TAPE WT:	0.0106	with a survey level and rod
TENSION:	99999	

CHANNEL PROFILE DATA

SLOPE:	0.021

INPUT DATA CHECKED BY: .....DATE.....

ASSIGNED TO: ….....……..…….....DATE.....

STREAM NAME: Terror Creek
XS LOCATION: Approx. 650' downstream fr. W. Fk.
XS NUMBER: 1

DATA POINTS= 23

VALUES COMPUTED FROM RAW FIELD DATA

FEATURE	DIST	VERT DEPTH	WATER DEPTH	VEL	WETTED PERIM.	WATER DEPTH	AREA (Am)	Q (Qm)	% Q CELL
1 RS & G	10.00	3.54			0.00		0.00	0.00	0.0%
W	13.00	4.75			0.00		0.00	0.00	0.0%
	13.50	4.95	0.20	0.00	0.54	0.20	0.10	0.00	0.0%
	14.00	5.05	0.30	0.70	0.51	0.30	0.15	0.11	4.9%
	14.50	5.15	0.40	0.61	0.51	0.40	0.20	0.12	5.7%
	15.00	5.05	0.30	1.84	0.51	0.30	0.15	0.28	12.9%
	15.50	4.80	0.05	0.00	0.56	0.05	0.03	0.00	0.0%
	16.00	4.80	0.05	0.00	0.50	0.05	0.03	0.00	0.0%
	16.50	5.05	0.35	2.23	0.56	0.35	0.18	0.39	18.2%
	17.00	5.15	0.40	2.46	0.51	0.40	0.20	0.49	22.9%
	17.50	4.90	0.10	2.40	0.56	0.10	0.05	0.12	5.6%
	18.00	5.00	0.20	1.62	0.51	0.20	0.10	0.16	7.5%
	18.50	4.90	0.10	1.87	0.51	0.10	0.05	0.09	4.4%
	19.00	5.10	0.30	1.92	0.54	0.30	0.15	0.29	13.4%
	19.50	4.90	0.10	1.64	0.54	0.10	0.05	0.08	3.8%
	20.00	4.85	0.05	0.00	0.50	0.05	0.03	0.00	0.0%
	20.50	4.85	0.05	0.65	0.50	0.05	0.03	0.02	0.8%
W	21.00	4.80			0.50		0.00	0.00	0.0%
	21.70	4.85			0.00		0.00	0.00	0.0%
	22.30	4.75			0.00		0.00	0.00	0.0%
	24.50	4.62			0.00		0.00	0.00	0.0%
	29.00	4.18			0.00		0.00	0.00	0.0%
1 LS & G	32.00	3.55			0.00		0.00	0.00	0.0%
TOTALS ----------					8.36	0.4 (Max.)	1.48	2.15	100.0%

Manning's n = 0.0465
Hydraulic Radius= 0.17649875

STREAM NAME: Terror Creek
XS LOCATION: Approx. 650' downstream fr. W. Fk.
XS NUMBER: 1

WATER LINE COMPARISON TABLE

WATER LINE	MEAS AREA	COMP AREA	AREA ERROR
	1.48	1.49	1.0%
4.53	1.48	4.27	189.7%
4.55	1.48	4.02	172.2%
4.57	1.48	3.76	155.1%
4.59	1.48	3.51	138.3%
4.61	1.48	3.27	121.8%
4.63	1.48	3.03	105.7%
4.65	1.48	2.80	90.1%
4.67	1.48	2.58	75.0%
4.69	1.48	2.37	60.4%
4.71	1.48	2.16	46.3%
4.73	1.48	1.96	32.8%
4.74	1.48	1.86	26.2%
4.75	1.48	1.77	19.8%
4.76	1.48	1.67	13.5%
4.77	1.48	1.58	7.2%
4.78	1.48	1.49	1.0%
4.79	1.48	1.40	-5.1%
4.80	1.48	1.31	-11.2%
4.81	1.48	1.22	-17.0%
4.82	1.48	1.14	-22.4%
4.83	1.48	1.07	-27.6%
4.85	1.48	0.93	-37.2%
4.87	1.48	0.80	-45.5%
4.89	1.48	0.69	-53.2%
4.91	1.48	0.58	-60.4%
4.93	1.48	0.49	-67.0%
4.95	1.48	0.40	-72.9%
4.97	1.48	0.32	-78.2%
4.99	1.48	0.25	-82.9%
5.01	1.48	0.20	-86.8%
5.03	1.48	0.15	-90.2%

WATERLINE AT ZERO
AREA ERROR = 4.777

STREAM NAME: Terror Creek
XS LOCATION: Approx. 650' downstream fr. W. Fk.
XS NUMBER: 1 Constant Manning's n

GL = lowest Grassline elevation corrected for sag
STAGING TABLE *WL* = Waterline corrected for variations in field measured water surface elevations and sag

	DIST TO WATER (FT)	TOP WIDTH (FT)	AVG. DEPTH (FT)	MAX. DEPTH (FT)	AREA (SQ FT)	WETTED PERIM. (FT)	PERCENT WET PERIM (%)	HYDR RADIUS (FT)	FLOW (CFS)	AVG. VELOCITY (FT/SEC)
GL	3.55	21.98	1.00	1.60	21.93	22.67	100.0%	0.97	99.26	4.53
	3.78	20.33	0.84	1.37	17.14	20.96	92.5%	0.82	69.33	4.05
	3.83	19.97	0.81	1.32	16.13	20.58	90.8%	0.78	63.43	3.93
	3.88	19.61	0.77	1.27	15.14	20.20	89.1%	0.75	57.79	3.82
	3.93	19.25	0.74	1.22	14.17	19.83	87.5%	0.71	52.39	3.70
	3.98	18.89	0.70	1.17	13.21	19.45	85.8%	0.68	47.25	3.58
	4.03	18.52	0.66	1.12	12.28	19.07	84.1%	0.64	42.36	3.45
	4.08	18.16	0.63	1.07	11.36	18.70	82.5%	0.61	37.72	3.32
	4.13	17.80	0.59	1.02	10.46	18.32	80.8%	0.57	33.33	3.18
	4.18	17.44	0.55	0.97	9.58	17.94	79.2%	0.53	29.18	3.05
	4.23	16.82	0.52	0.92	8.73	17.31	76.4%	0.50	25.57	2.93
	4.28	16.18	0.49	0.87	7.90	16.66	73.5%	0.47	22.22	2.81
	4.33	15.55	0.46	0.82	7.11	16.02	70.7%	0.44	19.13	2.69
	4.38	14.91	0.43	0.77	6.35	15.37	67.8%	0.41	16.28	2.57
	4.43	14.28	0.39	0.72	5.62	14.72	65.0%	0.38	13.67	2.43
	4.48	13.64	0.36	0.67	4.92	14.07	62.1%	0.35	11.29	2.30
	4.53	13.01	0.33	0.62	4.25	13.43	59.2%	0.32	9.14	2.15
	4.58	12.37	0.29	0.57	3.62	12.78	56.4%	0.28	7.21	1.99
	4.63	11.69	0.26	0.52	3.01	12.09	53.3%	0.25	5.53	1.83
	4.68	10.72	0.23	0.47	2.45	11.11	49.0%	0.22	4.15	1.69
	4.73	9.75	0.20	0.42	1.94	10.12	44.7%	0.19	2.99	1.54
WL	4.78	9.07	0.16	0.37	1.47	9.43	41.6%	0.16	1.98	1.34
	4.83	7.40	0.14	0.32	1.06	7.73	34.1%	0.14	1.29	1.23
	4.88	5.61	0.13	0.27	0.74	5.90	26.0%	0.12	0.85	1.16
	4.93	4.60	0.10	0.22	0.48	4.83	21.3%	0.10	0.48	0.99
	4.98	3.36	0.08	0.17	0.28	3.52	15.5%	0.08	0.24	0.86
	5.03	2.32	0.06	0.12	0.14	2.42	10.7%	0.06	0.10	0.69
	5.08	1.36	0.03	0.07	0.05	1.41	6.2%	0.03	0.02	0.48
	5.13	0.40	0.01	0.02	0.00	0.41	1.8%	0.01	0.00	0.23

STREAM NAME: Terror Creek
XS LOCATION: Approx. 650' downstream fr. W. Fk.
XS NUMBER: 1

SUMMARY SHEET

MEASURED FLOW (Qm)=	2.15	cfs
CALCULATED FLOW (Qc)=	1.98	cfs
(Qm-Qc)/Qm * 100 =	7.8	%
MEASURED WATERLINE (WLm)=	4.78	ft
CALCULATED WATERLINE (WLc)=	4.78	ft
(WLm-WLc)/WLm * 100 =	0.0	%
MAX MEASURED DEPTH (Dm)=	0.40	ft
MAX CALCULATED DEPTH (Dc)=	0.37	ft
(Dm-Dc)/Dm * 100	6.7	%
MEAN VELOCITY=	1.34	ft/sec
MANNING'S N=	0.047	
SLOPE=	0.021	ft/ft
.4 * Qm =	0.9	cfs
2.5 * Qm=	5.4	cfs

RECOMMENDED INSTREAM FLOW:
============================

FLOW (CFS)	PERIOD
___________________	__________________
___________________	__________________
___________________	__________________
___________________	__________________

RATIONALE FOR RECOMMENDATION:
============================

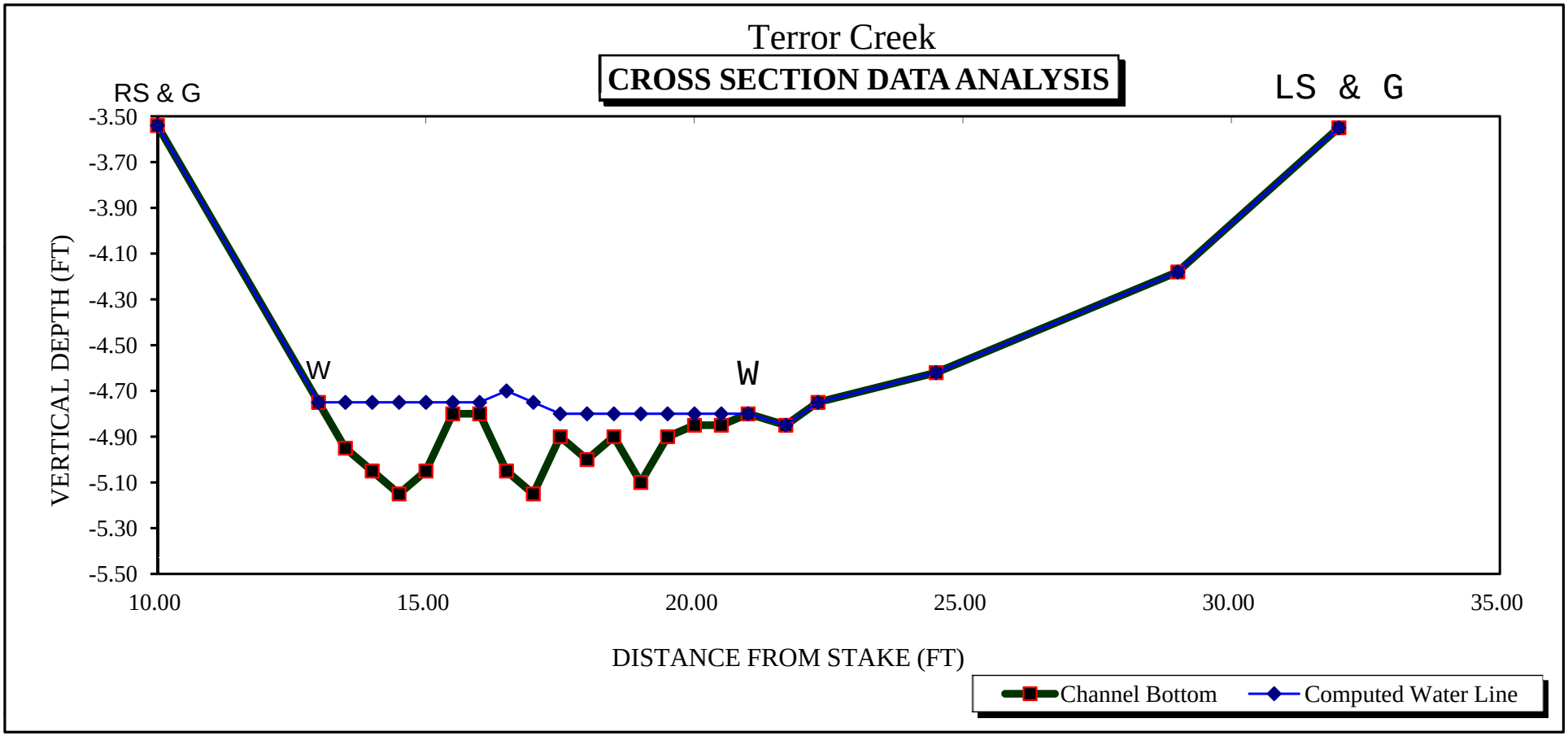
RECOMMENDATION BY: ………………....……..…….............................. AGENCY..……………………......…....…...……...... DATE:......…...….......……………

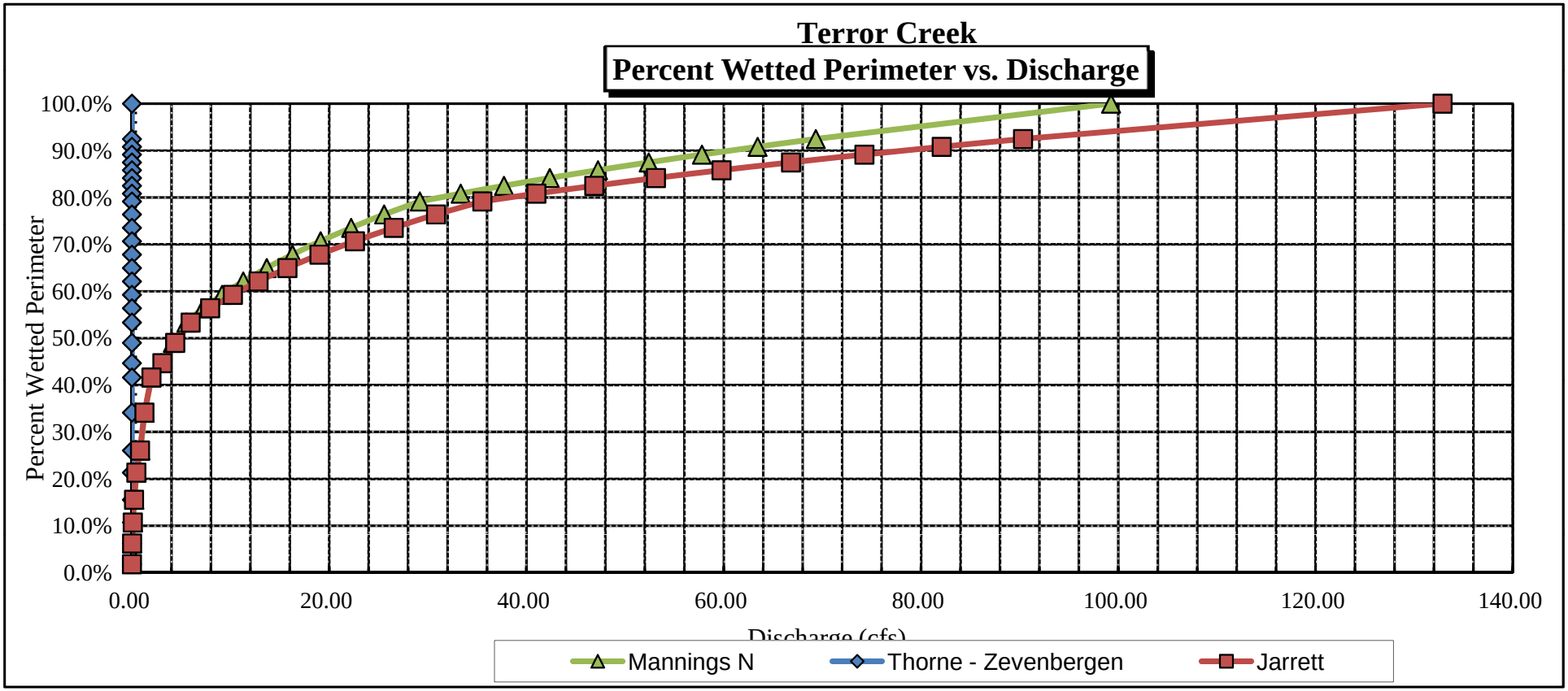
CWCB REVIEW BY: ..……………………….....………………………………………………...…............. DATE:..................……………...….

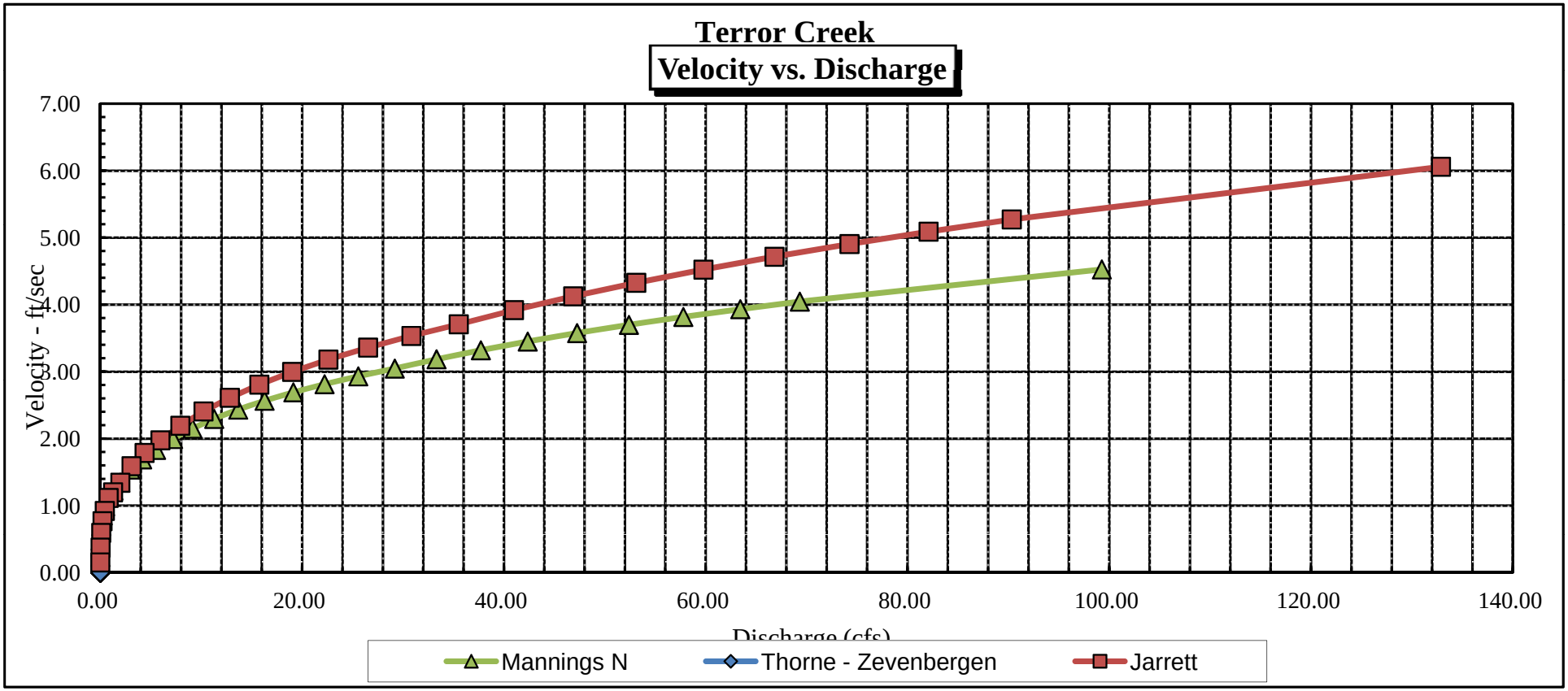
STREAM NAME: Terror Creek
XS LOCATION: Approx. 650' downstream fr. W. Fk.
XS NUMBER: 1 Jarrett Variable Manning's n Correction Applied

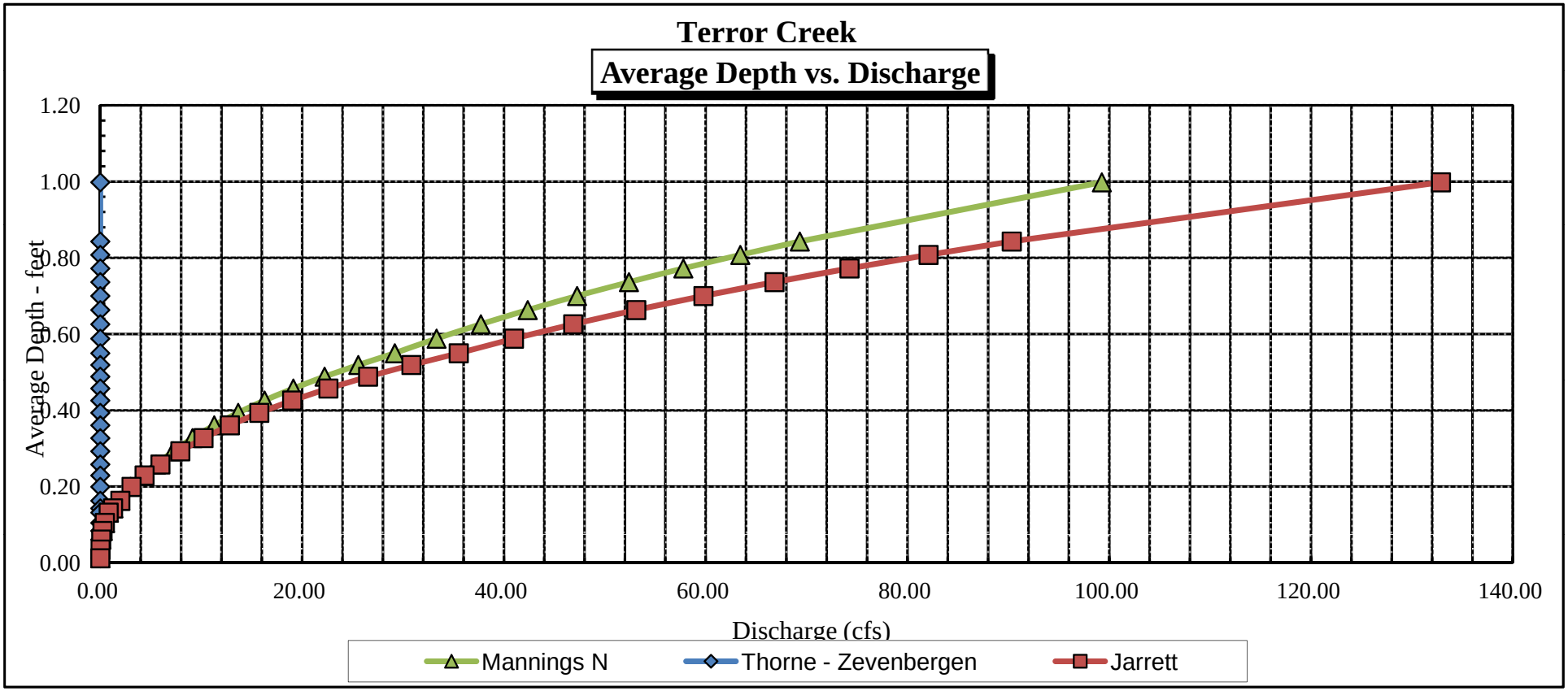
GL = lowest Grassline elevation corrected for sag
STAGING TABLE *WL* = Waterline corrected for variations in field measured water surface elevations and sag

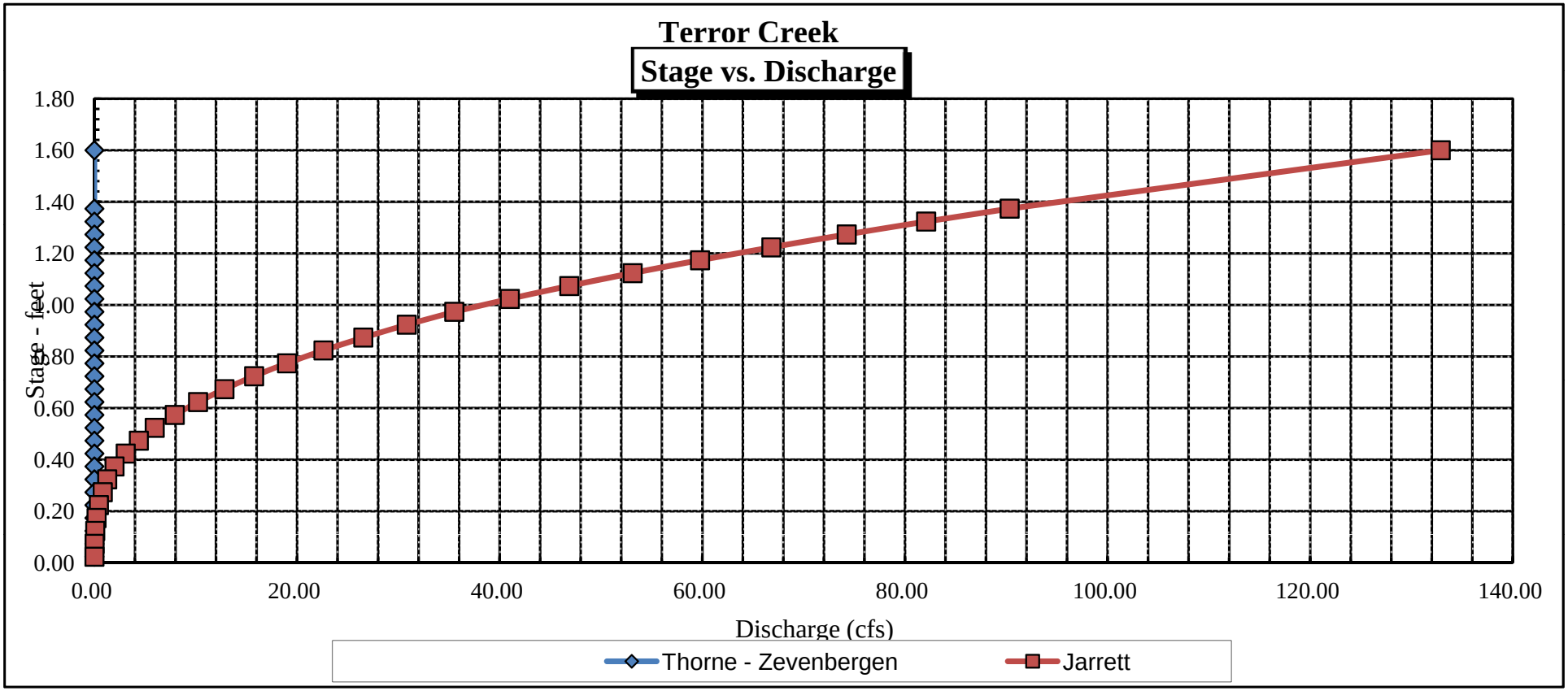
	DIST TO WATER (FT)	TOP WIDTH (FT)	AVG. DEPTH (FT)	MAX. DEPTH (FT)	AREA (SQ FT)	WETTED PERIM. (FT)	PERCENT WET PERIM (%)	HYDR RADIUS (FT)	FLOW (CFS)	AVG. VELOCITY (FT/SEC)
GL	3.55	21.98	1.00	1.60	21.93	22.67	100.0%	0.97	132.88	6.06
	3.78	20.33	0.84	1.37	17.14	20.96	92.5%	0.82	90.34	5.27
	3.83	19.97	0.81	1.32	16.13	20.58	90.8%	0.78	82.09	5.09
	3.88	19.61	0.77	1.27	15.14	20.20	89.1%	0.75	74.25	4.90
	3.93	19.25	0.74	1.22	14.17	19.83	87.5%	0.71	66.81	4.72
	3.98	18.89	0.70	1.17	13.21	19.45	85.8%	0.68	59.77	4.52
	4.03	18.52	0.66	1.12	12.28	19.07	84.1%	0.64	53.12	4.33
	4.08	18.16	0.63	1.07	11.36	18.70	82.5%	0.61	46.87	4.12
	4.13	17.80	0.59	1.02	10.46	18.32	80.8%	0.57	41.00	3.92
	4.18	17.44	0.55	0.97	9.58	17.94	79.2%	0.53	35.52	3.71
	4.23	16.82	0.52	0.92	8.73	17.31	76.4%	0.50	30.83	3.53
	4.28	16.18	0.49	0.87	7.90	16.66	73.5%	0.47	26.54	3.36
	4.33	15.55	0.46	0.82	7.11	16.02	70.7%	0.44	22.60	3.18
	4.38	14.91	0.43	0.77	6.35	15.37	67.8%	0.41	19.01	3.00
	4.43	14.28	0.39	0.72	5.62	14.72	65.0%	0.38	15.76	2.81
	4.48	13.64	0.36	0.67	4.92	14.07	62.1%	0.35	12.84	2.61
	4.53	13.01	0.33	0.62	4.25	13.43	59.2%	0.32	10.23	2.41
	4.58	12.37	0.29	0.57	3.62	12.78	56.4%	0.28	7.93	2.19
	4.63	11.69	0.26	0.52	3.01	12.09	53.3%	0.25	5.95	1.98
	4.68	10.72	0.23	0.47	2.45	11.11	49.0%	0.22	4.39	1.79
	4.73	9.75	0.20	0.42	1.94	10.12	44.7%	0.19	3.09	1.59
WL	4.78	9.07	0.16	0.37	1.47	9.43	41.6%	0.16	1.98	1.34
	4.83	7.40	0.14	0.32	1.06	7.73	34.1%	0.14	1.27	1.20
	4.88	5.61	0.13	0.27	0.74	5.90	26.0%	0.12	0.82	1.11
	4.93	4.60	0.10	0.22	0.48	4.83	21.3%	0.10	0.44	0.92
	4.98	3.36	0.08	0.17	0.28	3.52	15.5%	0.08	0.21	0.77
	5.03	2.32	0.06	0.12	0.14	2.42	10.7%	0.06	0.08	0.59
	5.08	1.36	0.03	0.07	0.05	1.41	6.2%	0.03	0.02	0.37
	5.13	0.40	0.01	0.02	0.00	0.41	1.8%	0.01	0.00	0.15


Terror Creek
CROSS SECTION DATA ANALYSIS
RS & G
LS & G
W
W
-3.50
-3.70
-3.90
-4.10
-4.30
-4.50
-4.70
-4.90
-5.10
-5.30
-5.50
VERTICAL DEPTH (FT)
10.00
15.00
20.00
25.00
30.00
35.00
DISTANCE FROM STAKE (FT)
Channel Bottom
Computed Water Line


Terror Creek
Percent Wetted Perimeter vs. Discharge
Percent Wetted Perimeter
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
Discharge (cfs)
Mannings N
Thorne - Zevenbergen
Jarrett


Terror Creek
Velocity vs. Discharge
Velocity - ft/sec
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
Discharge (cfs)
Mannings N
Thorne - Zevenbergen
Jarrett


Terror Creek
Average Depth vs. Discharge
Average Depth - feet
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
Discharge (cfs)
Mannings N
Thorne - Zevenbergen
Jarrett


Terror Creek
Stage vs. Discharge
Stage - feet
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
Discharge (cfs)
Thorne - Zevenbergen
Jarrett

COLORADO WATER CONSERVATION BOARD

FIELD DATA FOR INSTREAM FLOW DETERMINATIONS

COLORADO DIVISION OF WILDLIFE

LOCATION INFORMATION

STREAM NAME: Terror Creek						CROSS-SECTION NO.: 1	
CROSS-SECTION LOCATION: Approx 650 downstream from cont. w/ West Fork							
DATE: 10-21-08	OBSERVERS: R. Smith, D. Murphy						
LEGAL DESCRIPTION	¼ SECTION: SE	SECTION: 5	TOWNSHIP: 13 N/S	RANGE: 91 E/W	PM: 6th		
COUNTY: Delta	WATERSHED: N Ft. Gunnison	WATER DIVISION: 4	DOW WATER CODE: 43593				
MAP(S): USGS: Bowie 7.5'	USFS:						

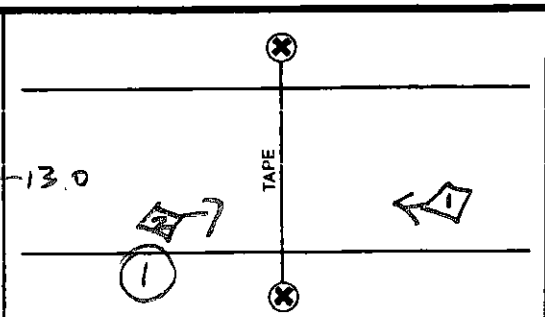
SUPPLEMENTAL DATA

SAG TAPE SECTION SAME AS DISCHARGE SECTION: YES / NO	METER TYPE: M-M			
METER NUMBER:	DATE RATED:	CALIB/SPIN: ____ sec	TAPE WEIGHT: surveyed ____ lbs/foot	TAPE TENSION: surveyed ____ lbs
CHANNEL BED MATERIAL SIZE RANGE: 6" to 18"	PHOTOGRAPHS TAKEN: YES/NO	NUMBER OF PHOTOGRAPHS: 3		

CHANNEL PROFILE DATA

STATION	DISTANCE FROM TAPE (ft)	ROD READING (ft)
⊗ Tape @ Stake LB	0.0	surveyed
⊗ Tape @ Stake RB	0.0	
① WS @ Tape LB/RB	0.0	4.80 / 4.75
② WS Upstream	4.0	4.68
③ WS Downstream	4.0	4.85
SLOPE	0.17/8.0 = 0.021	

SKETCH



LEGEND: Stake ⊗ Station ① Photo ① Direction of Flow

AQUATIC SAMPLING SUMMARY

STREAM ELECTROFISHED: YES/NO	DISTANCE ELECTROFISHED: ____ ft	FISH CAUGHT: YES/NO	WATER CHEMISTRY SAMPLED: YES/NO

LENGTH - FREQUENCY DISTRIBUTION BY ONE-INCH SIZE GROUPS (1.0-1.9, 2.0-2.9, ETC.)

SPECIES (FILL IN)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	>15	TOTAL

AQUATIC INSECTS IN STREAM SECTION BY COMMON OR SCIENTIFIC ORDER NAME:
mayfly, caddisfly

COMMENTS

Ph: 8.6
Temp: 5° C
TDS: 160
High silt load, with some algae.

DISCHARGE/CROSS SECTION NOTES

STREAM NAME: Temp Creek	CROSS-SECTION NO.: 1	DATE: 10-21-08	SHEET ___ OF ___
BEGINNING OF MEASUREMENT	EDGE OF WATER LOOKING DOWNSTREAM: (0.0 AT STAKE) LEFT / RIGHT	Gage Reading: _____ ft	TIME: 1:20 pm

Features (Stake (S), Grassline (G), Waterline (W), Rock (R))	Distance From Initial Point (ft)	Width (ft)	Total Vertical Depth From Tape/Inst (ft)	Water Depth (ft)	Depth of Observation (ft)	Revolutions	Time (sec)	Velocity (ft/sec) At Point	Velocity (ft/sec) Mean in Vertical	Area (ft^2)	Discharge (cfs)
RSt—	10.0		3.54								
W	13.0		4.75								
	13.5		4.95	.2				0			
	14.0		5.05	.3				.7			
	14.5		5.15	.4				.61			
	15.0		5.05	.3				1.84			
	15.5		4.80	.05				0			
	16.0		4.80	.05				0			
	16.5		5.05	.35				2.23			
	17.0		5.15	.40				2.46			
	17.5		4.90	.10				2.40			
	18.0		5.00	.20				1.62			
	18.5		4.90	.10				1.87			
	19.0		5.10	.30				1.92			
	19.5		4.90	.10				1.64			
	20		4.85	.05				0			
	20.5		4.85	.05				.65			
W	21.0		4.80								
	21.7		4.95								
12	22.3		4.75								
	24.5		4.62								
	29.0		4.18								
LS/G	32.0		3.55								
TOTALS:											

End of Measurement	Time:	Gage Reading: _____ ft	CALCULATIONS PERFORMED BY:	CALCULATIONS CHECKED BY:

COLORADO WATER CONSERVATION BOARD
INSTREAM FLOW / NATURAL LAKE LEVEL PROGRAM
STREAM CROSS-SECTION AND FLOW ANALYSIS

LOCATION INFORMATION

STREAM NAME:	Terror Creek
XS LOCATION:	450' downstream from W. Fk.
XS NUMBER:	2
DATE:	21-Oct-08
OBSERVERS:	R. Smith, D. Murphy
1/4 SEC:	SE
SECTION:	5
TWP:	13S
RANGE:	91W
PM:	Sixth
COUNTY:	Delta
WATERSHED:	N. Fk. Gunnison
DIVISION:	4
DOW CODE:	43593
USGS MAP:	Bowie 7.5'
USFS MAP:	0

SUPPLEMENTAL DATA

*** NOTE ***
Leave TAPE WT and TENSION at defaults for data collected with a survey level and rod

TAPE WT:	0.0106
TENSION:	99999

CHANNEL PROFILE DATA

SLOPE:	0.01

INPUT DATA CHECKED BY: .....DATE.....

ASSIGNED TO: ….....……..…….....DATE.....

STREAM NAME: Terror Creek
XS LOCATION: 450' downstream from W. Fk.
XS NUMBER: 2

DATA POINTS= 26

VALUES COMPUTED FROM RAW FIELD DATA

	FEATURE	DIST	VERT DEPTH	WATER DEPTH	VEL	WETTED PERIM.	WATER DEPTH	AREA (Am)	Q (Qm)	% Q CELL
1	RS & G	5.60	4.26			0.00		0.00	0.00	0.0%
	W	6.20	5.49			0.00		0.00	0.00	0.0%
		6.50	5.55	0.05	0.00	0.31	0.05	0.02	0.00	0.0%
		7.00	5.55	0.05	0.00	0.50	0.05	0.04	0.00	0.0%
		8.00	5.55	0.05	0.00	1.00	0.05	0.04	0.00	0.0%
		8.50	5.65	0.15	0.11	0.51	0.15	0.06	0.01	0.3%
		8.75	5.80	0.30	1.21	0.29	0.30	0.08	0.09	5.0%
		9.00	5.80	0.35	2.63	0.25	0.35	0.09	0.23	12.7%
		9.25	5.65	0.15	2.56	0.29	0.15	0.04	0.10	5.3%
		9.50	5.65	0.15	2.44	0.25	0.15	0.06	0.14	7.5%
		10.00	5.65	0.15	2.29	0.50	0.15	0.06	0.13	7.1%
		10.25	5.70	0.20	2.26	0.25	0.20	0.05	0.11	6.2%
		10.50	5.70	0.20	2.50	0.25	0.20	0.05	0.13	6.9%
		10.75	5.70	0.20	2.17	0.25	0.20	0.05	0.11	6.0%
		11.00	5.70	0.20	2.03	0.25	0.20	0.05	0.10	5.6%
		11.25	5.75	0.25	1.94	0.25	0.25	0.06	0.12	6.7%
		11.50	5.55	0.05	0.00	0.32	0.05	0.01	0.00	0.0%
		11.75	5.70	0.20	1.80	0.29	0.20	0.05	0.09	4.9%
		12.00	5.70	0.20	1.56	0.25	0.20	0.08	0.12	6.4%
		12.50	5.85	0.35	1.37	0.52	0.35	0.18	0.24	13.2%
		13.00	5.80	0.30	0.67	0.50	0.30	0.15	0.10	5.5%
		13.50	5.80	0.30	0.07	0.50	0.30	0.15	0.01	0.6%
		14.00	5.75	0.25	0.02	0.50	0.25	0.13	0.00	0.1%
		14.50	5.55	0.05	0.00	0.54	0.05	0.02	0.00	0.0%
	W	14.80	5.50			0.30		0.00	0.00	0.0%
1	LS & G	28.70	4.23			0.00		0.00	0.00	0.0%
	TOTALS ----------					8.89	0.35 (Max.)	1.48	1.82	100.0%

Manning's n = 0.0367
Hydraulic Radius= 0.16689723

STREAM NAME: Terror Creek
XS LOCATION: 450' downstream from W. Fk.
XS NUMBER: 2

WATER LINE COMPARISON TABLE

WATER LINE	MEAS AREA	COMP AREA	AREA ERROR
	1.48	1.51	2.0%
5.25	1.48	4.03	171.8%
5.27	1.48	3.81	156.5%
5.29	1.48	3.58	141.4%
5.31	1.48	3.36	126.7%
5.33	1.48	3.15	112.2%
5.35	1.48	2.94	98.1%
5.37	1.48	2.73	84.3%
5.39	1.48	2.53	70.8%
5.41	1.48	2.34	57.6%
5.43	1.48	2.15	44.7%
5.45	1.48	1.96	32.1%
5.46	1.48	1.87	25.9%
5.47	1.48	1.78	19.8%
5.48	1.48	1.69	13.8%
5.49	1.48	1.60	7.8%
5.50	1.48	1.51	2.0%
5.51	1.48	1.43	-3.8%
5.52	1.48	1.34	-9.5%
5.53	1.48	1.26	-15.1%
5.54	1.48	1.18	-20.6%
5.55	1.48	1.10	-26.1%
5.57	1.48	0.96	-35.3%
5.59	1.48	0.84	-43.7%
5.61	1.48	0.71	-51.8%
5.63	1.48	0.60	-59.7%
5.65	1.48	0.49	-67.3%
5.67	1.48	0.39	-73.8%
5.69	1.48	0.30	-79.6%
5.71	1.48	0.23	-84.8%
5.73	1.48	0.17	-88.6%
5.75	1.48	0.12	-91.9%

WATERLINE AT ZERO
AREA ERROR = 5.498

STREAM NAME: Terror Creek
XS LOCATION: 450' downstream from W. Fk.
XS NUMBER: 2

Constant Manning's n

GL = lowest Grassline elevation corrected for sag
STAGING TABLE *WL* = Waterline corrected for variations in field measured water surface elevations and sag

	DIST TO WATER (FT)	TOP WIDTH (FT)	AVG. DEPTH (FT)	MAX. DEPTH (FT)	AREA (SQ FT)	WETTED PERIM. (FT)	PERCENT WET PERIM (%)	HYDR RADIUS (FT)	FLOW (CFS)	AVG. VELOCITY (FT/SEC)
GL	4.26	22.77	0.92	1.59	20.92	23.89	100.0%	0.88	77.42	3.70
	4.50	20.05	0.79	1.35	15.81	21.00	87.9%	0.75	52.92	3.35
	4.55	19.47	0.76	1.30	14.83	20.40	85.4%	0.73	48.46	3.27
	4.60	18.90	0.73	1.25	13.87	19.79	82.9%	0.70	44.23	3.19
	4.65	18.33	0.71	1.20	12.93	19.19	80.3%	0.67	40.21	3.11
	4.70	17.76	0.68	1.15	12.03	18.58	77.8%	0.65	36.42	3.03
	4.75	17.19	0.65	1.10	11.16	17.98	75.3%	0.62	32.84	2.94
	4.80	16.62	0.62	1.05	10.31	17.37	72.7%	0.59	29.46	2.86
	4.85	16.04	0.59	1.00	9.50	16.77	70.2%	0.57	26.29	2.77
	4.90	15.47	0.56	0.95	8.71	16.16	67.7%	0.54	23.32	2.68
	4.95	14.90	0.53	0.90	7.95	15.55	65.1%	0.51	20.55	2.58
	5.00	14.33	0.50	0.85	7.22	14.95	62.6%	0.48	17.97	2.49
	5.05	13.76	0.47	0.80	6.52	14.34	60.1%	0.45	15.57	2.39
	5.10	13.19	0.44	0.75	5.84	13.74	57.5%	0.43	13.36	2.29
	5.15	12.61	0.41	0.70	5.20	13.13	55.0%	0.40	11.33	2.18
	5.20	12.04	0.38	0.65	4.58	12.53	52.5%	0.37	9.47	2.07
	5.25	11.47	0.35	0.60	3.99	11.92	49.9%	0.33	7.79	1.95
	5.30	10.90	0.32	0.55	3.43	11.32	47.4%	0.30	6.27	1.83
	5.35	10.33	0.28	0.50	2.90	10.71	44.9%	0.27	4.92	1.69
	5.40	9.76	0.25	0.45	2.40	10.11	42.3%	0.24	3.73	1.55
	5.45	9.18	0.21	0.40	1.93	9.50	39.8%	0.20	2.69	1.40
WL	5.50	8.58	0.17	0.35	1.48	8.86	37.1%	0.17	1.82	1.23
	5.55	8.02	0.13	0.30	1.07	8.30	34.7%	0.13	1.10	1.03
	5.60	6.00	0.13	0.25	0.75	6.23	26.1%	0.12	0.75	0.99
	5.65	5.47	0.09	0.20	0.47	5.66	23.7%	0.08	0.36	0.77
	5.70	4.04	0.06	0.15	0.25	4.16	17.4%	0.06	0.15	0.61
	5.75	2.27	0.05	0.10	0.11	2.32	9.7%	0.05	0.06	0.54
	5.80	1.44	0.01	0.05	0.02	1.45	6.1%	0.01	0.00	0.22
	5.85	0.02	0.00	0.00	0.00	0.02	0.1%	0.00	0.00	0.03

STREAM NAME: Terror Creek
XS LOCATION: 450' downstream from W. Fk.
XS NUMBER: 2

SUMMARY SHEET

MEASURED FLOW (Qm)=	1.82	cfs
CALCULATED FLOW (Qc)=	1.82	cfs
(Qm-Qc)/Qm * 100 =	-0.2	%
MEASURED WATERLINE (WLm)=	5.50	ft
CALCULATED WATERLINE (WLc)=	5.50	ft
(WLm-WLc)/WLm * 100 =	-0.1	%
MAX MEASURED DEPTH (Dm)=	0.35	ft
MAX CALCULATED DEPTH (Dc)=	0.35	ft
(Dm-Dc)/Dm * 100	-0.5	%
MEAN VELOCITY=	1.23	ft/sec
MANNING'S N=	0.037	
SLOPE=	0.01	ft/ft
.4 * Qm =	0.7	cfs
2.5 * Qm=	4.5	cfs

RECOMMENDED INSTREAM FLOW:
=============================

FLOW (CFS)	PERIOD
___________	___________
___________	___________
___________	___________
___________	___________

RATIONALE FOR RECOMMENDATION:
=============================

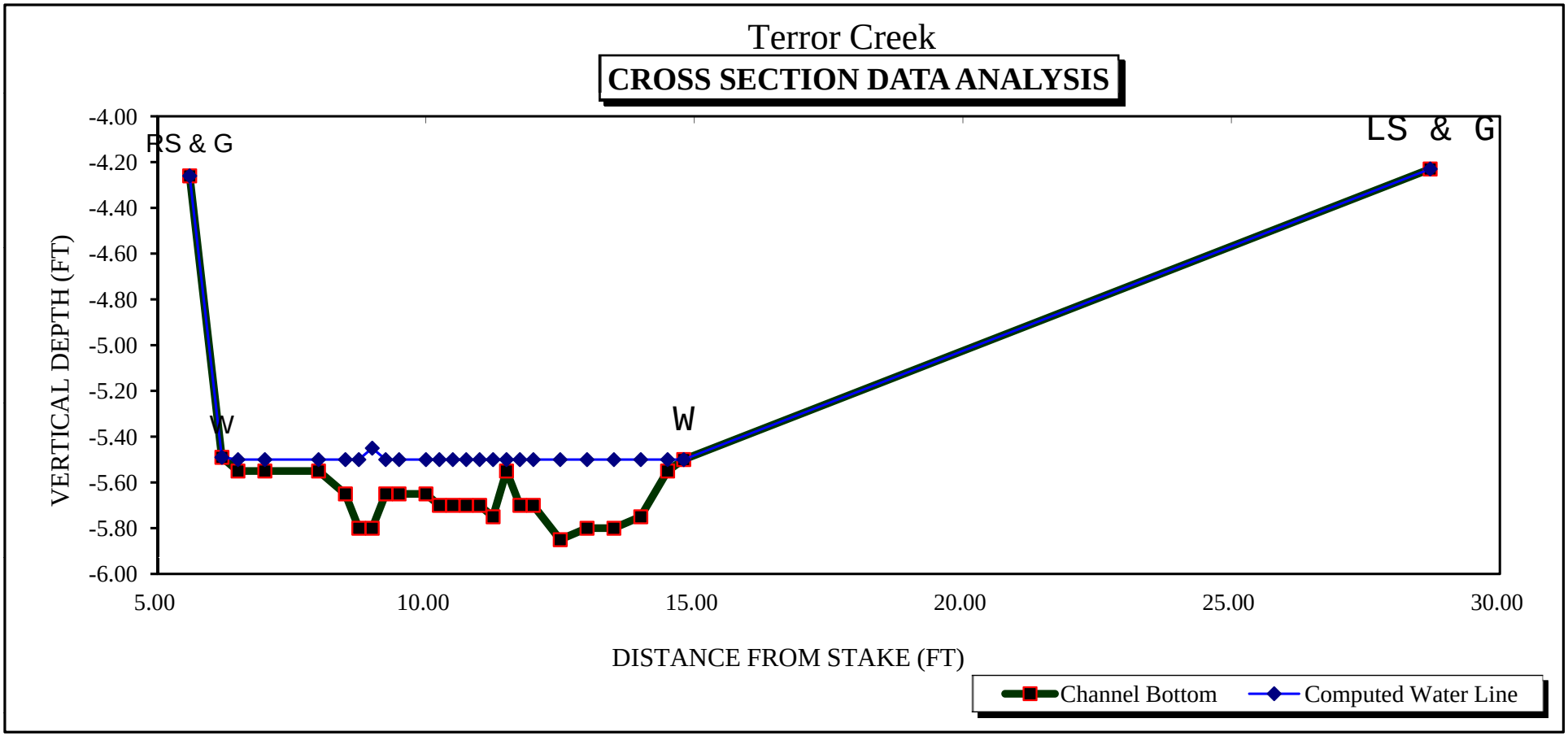
RECOMMENDATION BY: ……………………..………..……................................ AGENCY..………………………......……..…...…….…...... DATE:.......…..…......……………

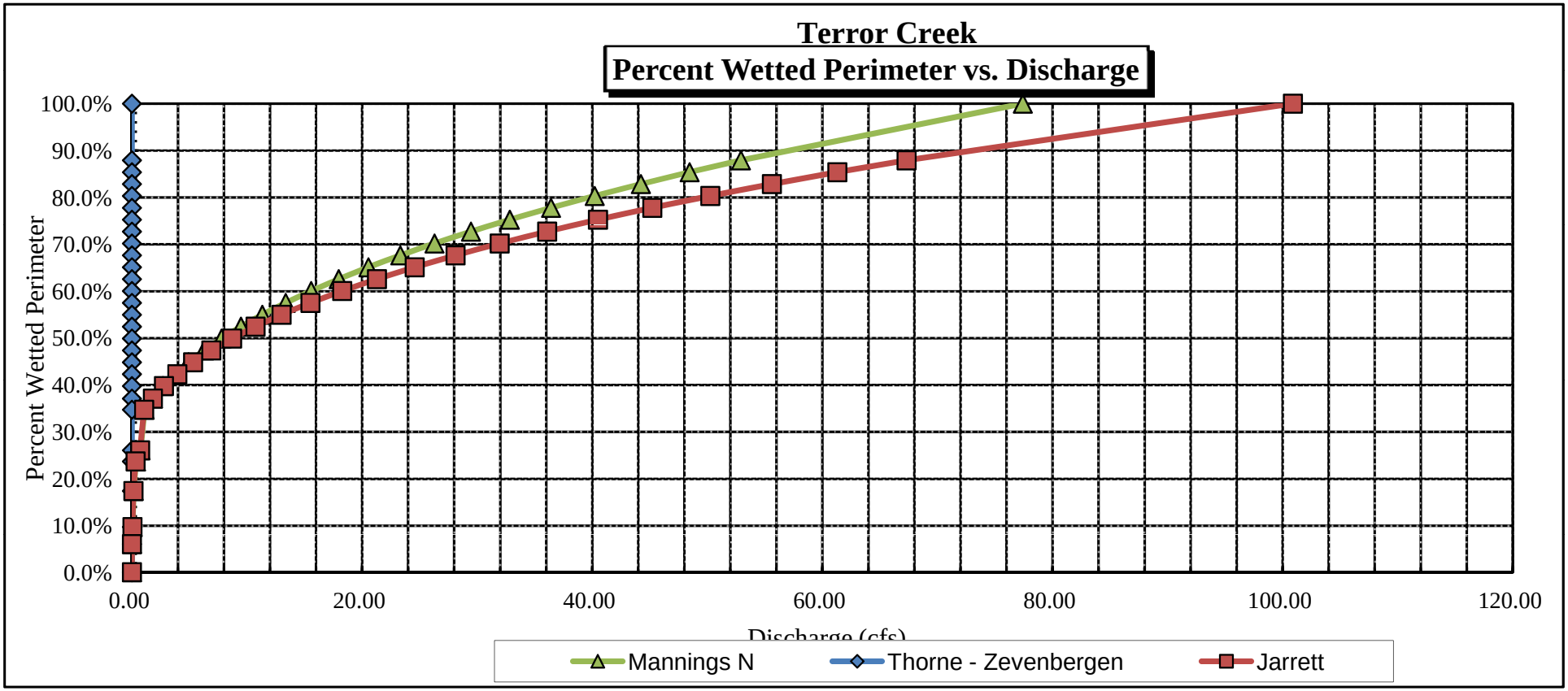
CWCB REVIEW BY: ..……………………………....…………………………………………………...…............. DATE:.................…………….....

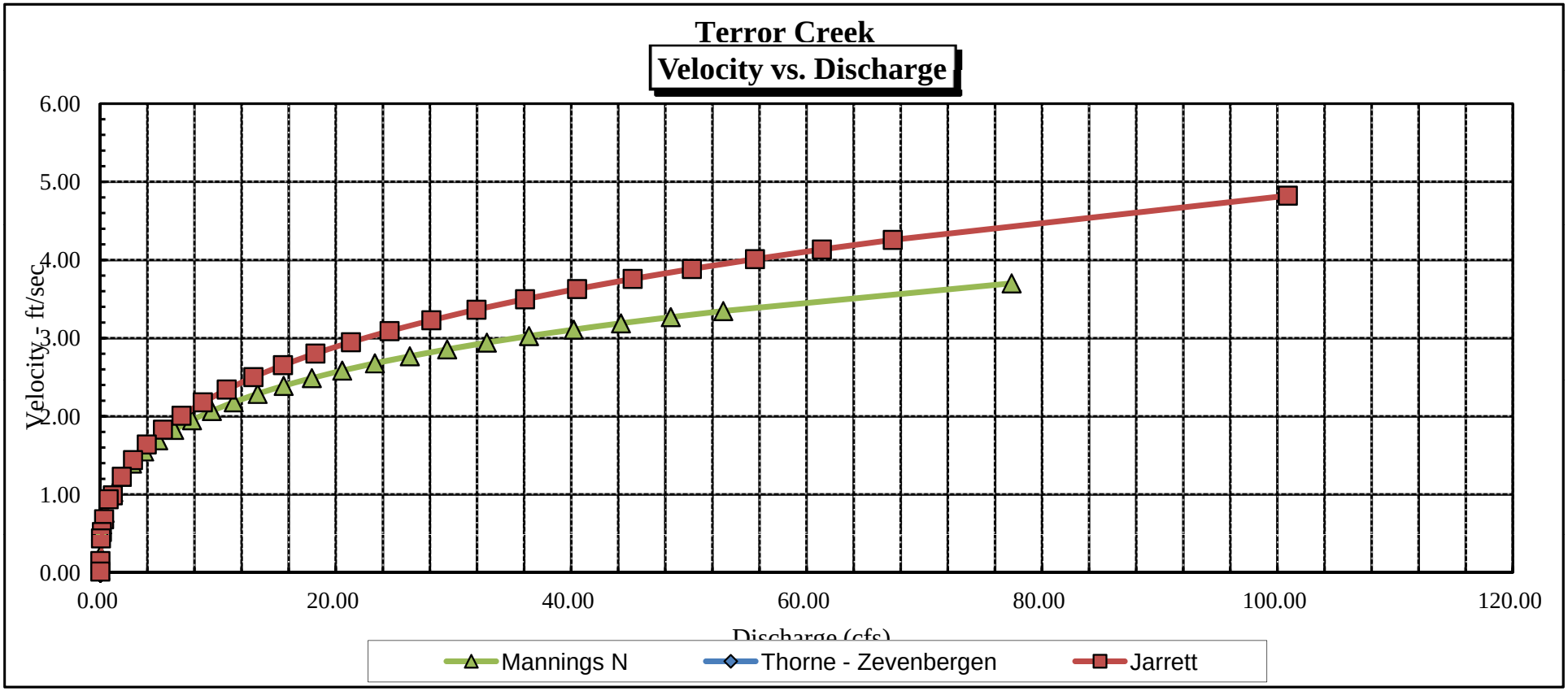
STREAM NAME: Terror Creek
XS LOCATION: 450' downstream from W. Fk.
XS NUMBER: 2 Jarrett Variable Manning's n Correction Applied

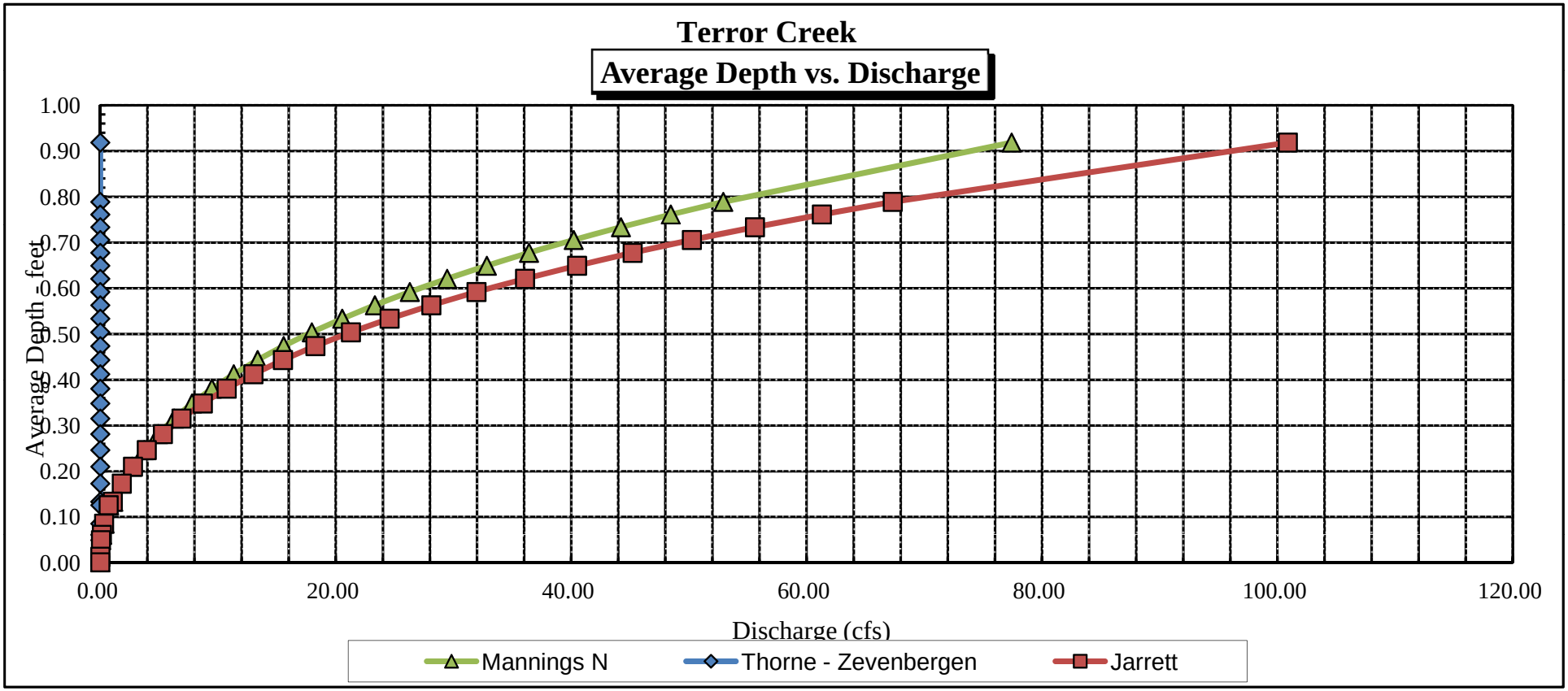
GL = lowest Grassline elevation corrected for sag
STAGING TABLE *WL* = Waterline corrected for variations in field measured water surface elevations and sag

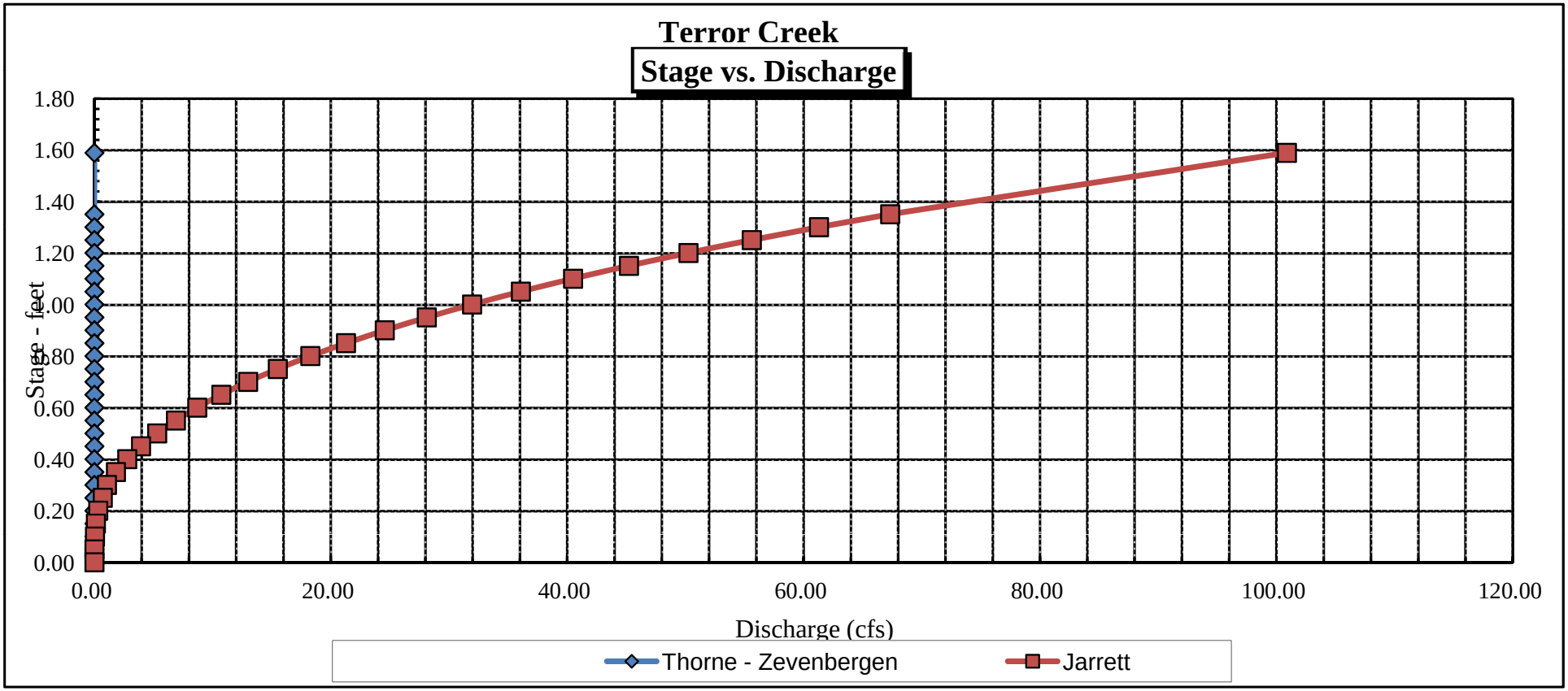
	DIST TO WATER (FT)	TOP WIDTH (FT)	AVG. DEPTH (FT)	MAX. DEPTH (FT)	AREA (SQ FT)	WETTED PERIM. (FT)	PERCENT WET PERIM (%)	HYDR RADIUS (FT)	FLOW (CFS)	AVG. VELOCITY (FT/SEC)
GL	4.26	22.77	0.92	1.59	20.92	23.89	100.0%	0.88	100.89	4.82
	4.50	20.05	0.79	1.35	15.81	21.00	87.9%	0.75	67.32	4.26
	4.55	19.47	0.76	1.30	14.83	20.40	85.4%	0.73	61.30	4.13
	4.60	18.90	0.73	1.25	13.87	19.79	82.9%	0.70	55.61	4.01
	4.65	18.33	0.71	1.20	12.93	19.19	80.3%	0.67	50.26	3.89
	4.70	17.76	0.68	1.15	12.03	18.58	77.8%	0.65	45.22	3.76
	4.75	17.19	0.65	1.10	11.16	17.98	75.3%	0.62	40.50	3.63
	4.80	16.62	0.62	1.05	10.31	17.37	72.7%	0.59	36.08	3.50
	4.85	16.04	0.59	1.00	9.50	16.77	70.2%	0.57	31.96	3.36
	4.90	15.47	0.56	0.95	8.71	16.16	67.7%	0.54	28.12	3.23
	4.95	14.90	0.53	0.90	7.95	15.55	65.1%	0.51	24.57	3.09
	5.00	14.33	0.50	0.85	7.22	14.95	62.6%	0.48	21.29	2.95
	5.05	13.76	0.47	0.80	6.52	14.34	60.1%	0.45	18.27	2.80
	5.10	13.19	0.44	0.75	5.84	13.74	57.5%	0.43	15.51	2.65
	5.15	12.61	0.41	0.70	5.20	13.13	55.0%	0.40	13.00	2.50
	5.20	12.04	0.38	0.65	4.58	12.53	52.5%	0.37	10.74	2.34
	5.25	11.47	0.35	0.60	3.99	11.92	49.9%	0.33	8.70	2.18
	5.30	10.90	0.32	0.55	3.43	11.32	47.4%	0.30	6.90	2.01
	5.35	10.33	0.28	0.50	2.90	10.71	44.9%	0.27	5.31	1.83
	5.40	9.76	0.25	0.45	2.40	10.11	42.3%	0.24	3.94	1.64
	5.45	9.18	0.21	0.40	1.93	9.50	39.8%	0.20	2.78	1.44
WL	5.50	8.58	0.17	0.35	1.48	8.86	37.1%	0.17	1.82	1.23
	5.55	8.02	0.13	0.30	1.07	8.30	34.7%	0.13	1.06	0.99
	5.60	6.00	0.13	0.25	0.75	6.23	26.1%	0.12	0.71	0.94
	5.65	5.47	0.09	0.20	0.47	5.66	23.7%	0.08	0.32	0.68
	5.70	4.04	0.06	0.15	0.25	4.16	17.4%	0.06	0.13	0.52
	5.75	2.27	0.05	0.10	0.11	2.32	9.7%	0.05	0.05	0.44
	5.80	1.44	0.01	0.05	0.02	1.45	6.1%	0.01	0.00	0.15
	5.85	0.02	0.00	0.00	0.00	0.02	0.1%	0.00	0.00	0.01


Terror Creek
CROSS SECTION DATA ANALYSIS
RS & G
LS & G
W
W
-4.00
-4.20
-4.40
-4.60
-4.80
-5.00
-5.20
-5.40
-5.60
-5.80
-6.00
VERTICAL DEPTH (FT)
5.00
10.00
15.00
20.00
25.00
30.00
DISTANCE FROM STAKE (FT)
Channel Bottom
Computed Water Line


Terror Creek
Percent Wetted Perimeter vs. Discharge
Percent Wetted Perimeter
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
0.00
20.00
40.00
60.00
80.00
100.00
120.00
Discharge (cfs)
Mannings N
Thorne - Zevenbergen
Jarrett


Terror Creek
Velocity vs. Discharge
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Velocity - ft/sec
0.00
20.00
40.00
60.00
80.00
100.00
120.00
Discharge (cfs)
Mannings N
Thorne - Zevenbergen
Jarrett


Terror Creek
Average Depth vs. Discharge
Average Depth - feet
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
Discharge (cfs)
Mannings N
Thorne - Zevenbergen
Jarrett


Terror Creek
Stage vs. Discharge
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Stage - feet
0.00
20.00
40.00
60.00
80.00
100.00
120.00
Discharge (cfs)
Thorne - Zevenbergen
Jarrett

COLORADO WATER CONSERVATION BOARD

FIELD DATA FOR INSTREAM FLOW DETERMINATIONS

COLORADO DIVISION OF WILDLIFE

LOCATION INFORMATION

STREAM NAME: Terror Creek						CROSS-SECTION NO.: 2	
CROSS-SECTION LOCATION: 450 ft. downstream from confluence with West Fk. Terror Creek							
DATE: 10-21-08	OBSERVERS: R. Smith, R. Murphy						
LEGAL DESCRIPTION	¼ SECTION: SE	SECTION: 5	TOWNSHIP: 13 N/S	RANGE: 91 E/W	PM: 6th		
COUNTY: Delta	WATERSHED: N. Fk. Gunnison	WATER DIVISION: 4	DOW WATER CODE: 43593				
MAP(S):	USGS: Bowie 7.5'						
	USFS:						

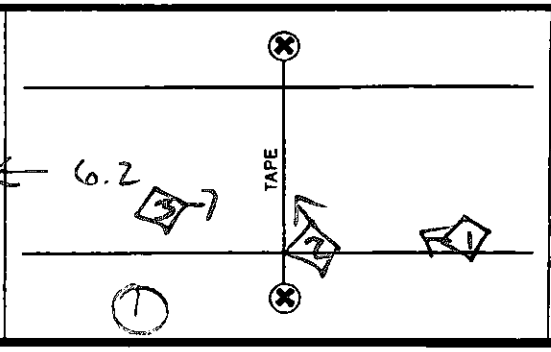
SUPPLEMENTAL DATA

SAG TAPE SECTION SAME AS DISCHARGE SECTION: (YES/NO)	METER TYPE: M-M			
METER NUMBER:	DATE RATED:	CALIB/SPIN. ____ sec	TAPE WEIGHT: surveyed ____ lbs/foot	TAPE TENSION: surveyed ____ lbs
CHANNEL BED MATERIAL SIZE RANGE: 4" - 18"	PHOTOGRAPHS TAKEN (YES/NO)	NUMBER OF PHOTOGRAPHS: 3		

CHANNEL PROFILE DATA

STATION	DISTANCE FROM TAPE (ft)	ROD READING (ft)
⊗ Tape @ Stake LB	0.0	surveyed
⊗ Tape @ Stake RB	0.0	surveyed
① WS @ Tape LB/RB	0.0 14.8	5.49/5.50
② WS Upstream	11.0	5.55
③ WS Downstream	4.0	5.40
SLOPE	0.15/15.0 = .01	

SKETCH



LEGEND:
- Stake ⊗
- Station ①
- Photo ◇→
- Direction of Flow

AQUATIC SAMPLING SUMMARY

STREAM ELECTROFISHED: YES/NO	DISTANCE ELECTROFISHED: ____ ft	FISH CAUGHT: YES/NO	WATER CHEMISTRY SAMPLED: (YES/NO)

LENGTH - FREQUENCY DISTRIBUTION BY ONE-INCH SIZE GROUPS (1.0-1.9, 2.0-2.9, ETC.)

SPECIES (FILL IN)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	>15	TOTAL

AQUATIC INSECTS IN STREAM SECTION BY COMMON OR SCIENTIFIC ORDER NAME:

mayfly, caddisfly (abundant)

COMMENTS

TDS = 160
Ph = 8.6
Temp = 5°C

DISCHARGE/CROSS SECTION NOTES

STREAM NAME: Terror Creek | CROSS-SECTION NO.: 2 | DATE: 10-21-08 | SHEET ___ OF ___

BEGINNING OF MEASUREMENT | EDGE OF WATER LOOKING DOWNSTREAM: (0.0 AT STAKE) LEFT / RIGHT | Gage Reading: _____ ft | TIME: 2 pm

Features: Stake (S) Grassline (G) Waterline (W) Rock (R)	Distance From Initial Point (ft)	Width (ft)	Total Vertical Depth From Tape/Inst (ft)	Water Depth (ft)	Depth of Observation (ft)	Revolutions	Time (sec)	Velocity (ft/sec) At Point	Velocity (ft/sec) Mean in Vertical	Area (ft^2)	Discharge (cfs)
RS/G	5.6		4.26								
W	6.7		5.49								
	6.5		5.55	.05				∅			
	7.0		5.55	.05				∅			
	8.0		5.55	.05				∅			
	8.5		5.65	.15				.11			
	8.75		5.80	.30				1.21			
	9.00		5.80	.35				2.63			
	9.25		5.65	.15				2.56			
	9.50		5.65	.15				2.44			
	10.0		5.65	.15				2.29			
	10.25		5.70	.20				2.26			
	10.50		5.70	.20				2.50			
	10.75		5.70	.20				2.17			
	11.00		5.70	.20				2.03			
	11.25		5.75	.25				1.94			
	11.50		5.55	.05				∅			
	11.75		5.70	.20				1.80			
	12.0		5.70	.20				1.56			
	12.5		5.85	.35				1.37			
	13.0		5.80	.30				0.67			
	13.5		5.80	.30				0.07			
	14.0		5.75	.25				0.02			
	14.5		5.55	.05				∅			
W	14.8		5.50								
LS/G	28.7		4.23								
TOTALS:											

End of Measurement | Time: | Gage Reading: _____ ft | CALCULATIONS PERFORMED BY: | CALCULATIONS CHECKED BY

COLORADO WATER CONSERVATION BOARD
INSTREAM FLOW / NATURAL LAKE LEVEL PROGRAM
STREAM CROSS-SECTION AND FLOW ANALYSIS

LOCATION INFORMATION

STREAM NAME:	Terror Creek
XS LOCATION:	700' DS from confluence w/ W. Fk.
XS NUMBER:	1
DATE:	27-Sep-07
OBSERVERS:	R. Smith, M. Eberle
1/4 SEC:	SE
SECTION:	5
TWP:	13S
RANGE:	91W
PM:	Sixth
COUNTY:	Delta
WATERSHED:	Gunnison
DIVISION:	4
DOW CODE:	43593
USGS MAP:	Bowie 7.5'
USFS MAP:	0

SUPPLEMENTAL DATA

TAPE WT:	0.0106
TENSION:	99999

*** NOTE ***
Leave TAPE WT and TENSION at defaults for data collected with a survey level and rod

CHANNEL PROFILE DATA

SLOPE:	0.0278

INPUT DATA CHECKED BY: .....DATE.....

ASSIGNED TO: ….....……..…….....DATE.....

STREAM NAME: Terror Creek
XS LOCATION: 700' DS from confluence w/ W. Fk.
XS NUMBER: 1

DATA POINTS= 22

VALUES COMPUTED FROM RAW FIELD DATA

	FEATURE	DIST	VERT DEPTH	WATER DEPTH	VEL	WETTED PERIM.	WATER DEPTH	AREA (Am)	Q (Qm)	% Q CELL
1	RS & GL	0.00	4.78			0.00		0.00	0.00	0.0%
		5.00	5.42			0.00		0.00	0.00	0.0%
	W	6.60	6.00			0.00		0.00	0.00	0.0%
		7.00	6.30	0.30	0.00	0.50	0.30	0.21	0.00	0.0%
		8.00	6.60	0.60	0.24	1.04	0.60	0.60	0.14	2.4%
		9.00	6.30	0.30	0.36	1.04	0.30	0.30	0.11	1.8%
		10.00	6.40	0.40	0.00	1.00	0.40	0.40	0.00	0.0%
		11.00	6.30	0.30	0.21	1.00	0.30	0.30	0.06	1.0%
		12.00	6.30	0.30	0.74	1.00	0.30	0.38	0.28	4.5%
		13.50	6.15	0.15	0.91	1.51	0.15	0.19	0.17	2.8%
		14.50	6.30	0.30	0.59	1.01	0.30	0.29	0.17	2.7%
		15.40	6.20	0.20	1.15	0.91	0.20	0.25	0.29	4.7%
		17.00	5.90	0.00	0.00	1.63		0.00	0.00	0.0%
		18.00	6.50	0.50	0.96	1.17	0.50	0.75	0.72	11.8%
		20.00	6.70	0.70	3.09	2.01	0.70	1.05	3.24	53.0%
		21.00	5.95	0.00	0.00	1.25		0.00	0.00	0.0%
		22.00	6.40	0.40	0.42	1.10	0.40	0.40	0.17	2.7%
		23.00	6.30	0.30	1.85	1.00	0.30	0.30	0.56	9.1%
		24.00	6.40	0.40	0.46	1.00	0.40	0.48	0.22	3.6%
	W	25.40	5.96			1.47		0.00	0.00	0.0%
1	GL	28.60	4.64			0.00		0.00	0.00	0.0%
	LS	29.00	4.52			0.00		0.00	0.00	0.0%
	TOTALS ----------					19.65	0.7 (Max.)	5.89	6.13	100.0%

Manning's n = 0.1066
Hydraulic Radius= 0.29961273

STREAM NAME: Terror Creek
XS LOCATION: 700' DS from confluence w/ W. Fk.
XS NUMBER: 1

WATER LINE COMPARISON TABLE

WATER LINE	MEAS AREA	COMP AREA	AREA ERROR
	5.89	6.08	3.3%
5.73	5.89	10.92	85.5%
5.75	5.89	10.52	78.7%
5.77	5.89	10.12	71.9%
5.79	5.89	9.72	65.2%
5.81	5.89	9.33	58.4%
5.83	5.89	8.94	51.8%
5.85	5.89	8.55	45.1%
5.87	5.89	8.16	38.5%
5.89	5.89	7.77	32.0%
5.91	5.89	7.39	25.5%
5.93	5.89	7.01	19.0%
5.94	5.89	6.82	15.8%
5.95	5.89	6.63	12.6%
5.96	5.89	6.45	9.5%
5.97	5.89	6.26	6.4%
5.98	5.89	6.08	3.3%
5.99	5.89	5.90	0.2%
6.00	5.89	5.72	-2.8%
6.01	5.89	5.54	-5.8%
6.02	5.89	5.37	-8.8%
6.03	5.89	5.19	-11.8%
6.05	5.89	4.85	-17.6%
6.07	5.89	4.51	-23.3%
6.09	5.89	4.18	-29.0%
6.11	5.89	3.86	-34.5%
6.13	5.89	3.54	-39.9%
6.15	5.89	3.22	-45.3%
6.17	5.89	2.92	-50.4%
6.19	5.89	2.63	-55.4%
6.21	5.89	2.35	-60.1%
6.23	5.89	2.08	-64.6%

WATERLINE AT ZERO
AREA ERROR = 5.991

STREAM NAME: Terror Creek
XS LOCATION: 700' DS from confluence w/ W. Fk.
XS NUMBER: 1 Constant Manning's n

STAGING TABLE *GL* = lowest Grassline elevation corrected for sag
WL = Waterline corrected for variations in field measured water surface elevations and sag

	DIST TO WATER (FT)	TOP WIDTH (FT)	AVG. DEPTH (FT)	MAX. DEPTH (FT)	AREA (SQ FT)	WETTED PERIM. (FT)	PERCENT WET PERIM (%)	HYDR RADIUS (FT)	FLOW (CFS)	AVG. VELOCITY (FT/SEC)
GL	4.78	28.26	1.18	1.92	33.39	29.49	100.0%	1.13	84.32	2.53
	4.99	26.10	1.06	1.71	27.66	27.28	92.5%	1.01	64.91	2.35
	5.04	25.59	1.03	1.66	26.37	26.75	90.7%	0.99	60.72	2.30
	5.09	25.08	1.00	1.61	25.10	26.23	88.9%	0.96	56.68	2.26
	5.14	24.57	0.97	1.56	23.86	25.70	87.2%	0.93	52.79	2.21
	5.19	24.06	0.94	1.51	22.65	25.18	85.4%	0.90	49.06	2.17
	5.24	23.54	0.91	1.46	21.46	24.65	83.6%	0.87	45.47	2.12
	5.29	23.03	0.88	1.41	20.29	24.13	81.8%	0.84	42.03	2.07
	5.34	22.52	0.85	1.36	19.15	23.60	80.0%	0.81	38.74	2.02
	5.39	22.01	0.82	1.31	18.04	23.08	78.3%	0.78	35.59	1.97
	5.44	21.60	0.78	1.26	16.95	22.65	76.8%	0.75	32.48	1.92
	5.49	21.34	0.74	1.21	15.88	22.38	75.9%	0.71	29.36	1.85
	5.54	21.08	0.70	1.16	14.82	22.10	74.9%	0.67	26.39	1.78
	5.59	20.82	0.66	1.11	13.77	21.82	74.0%	0.63	23.55	1.71
	5.64	20.57	0.62	1.06	12.74	21.54	73.1%	0.59	20.85	1.64
	5.69	20.31	0.58	1.01	11.71	21.26	72.1%	0.55	18.30	1.56
	5.74	20.05	0.53	0.96	10.71	20.99	71.2%	0.51	15.88	1.48
	5.79	19.79	0.49	0.91	9.71	20.71	70.2%	0.47	13.62	1.40
	5.84	19.53	0.45	0.86	8.73	20.43	69.3%	0.43	11.50	1.32
	5.89	19.27	0.40	0.81	7.76	20.15	68.3%	0.38	9.54	1.23
	5.94	18.73	0.36	0.76	6.81	19.57	66.4%	0.35	7.82	1.15
WL	5.99	17.95	0.33	0.71	5.89	18.74	63.6%	0.31	6.32	1.07
	6.04	17.18	0.29	0.66	5.01	17.90	60.7%	0.28	4.98	0.99
	6.09	16.43	0.25	0.61	4.17	17.08	57.9%	0.24	3.78	0.91
	6.14	15.67	0.21	0.56	3.37	16.26	55.1%	0.21	2.74	0.81
	6.19	14.24	0.18	0.51	2.62	14.75	50.0%	0.18	1.92	0.73
	6.24	12.51	0.16	0.46	1.95	12.94	43.9%	0.15	1.28	0.66
	6.29	10.74	0.13	0.41	1.37	11.09	37.6%	0.12	0.79	0.58
	6.34	7.16	0.13	0.36	0.93	7.45	25.3%	0.12	0.54	0.58
	6.39	4.41	0.15	0.31	0.64	4.62	15.7%	0.14	0.40	0.62
	6.44	3.51	0.13	0.26	0.45	3.67	12.4%	0.12	0.26	0.57
	6.49	3.02	0.10	0.21	0.29	3.14	10.6%	0.09	0.14	0.47
	6.54	2.20	0.07	0.16	0.16	2.28	7.7%	0.07	0.06	0.39
	6.59	1.30	0.05	0.11	0.07	1.35	4.6%	0.05	0.02	0.32
	6.64	0.67	0.03	0.06	0.02	0.69	2.4%	0.03	0.00	0.22
	6.69	0.11	0.00	0.01	0.00	0.11	0.4%	0.00	0.00	0.06

STREAM NAME: Terror Creek
XS LOCATION: 700' DS from confluence w/ W. Fk.
XS NUMBER: 1

SUMMARY SHEET

MEASURED FLOW (Qm)=	6.13	cfs
CALCULATED FLOW (Qc)=	6.32	cfs
(Qm-Qc)/Qm * 100 =	-3.2	%
MEASURED WATERLINE (WLm)=	5.98	ft
CALCULATED WATERLINE (WLc)=	5.99	ft
(WLm-WLc)/WLm * 100 =	-0.2	%
MAX MEASURED DEPTH (Dm)=	0.70	ft
MAX CALCULATED DEPTH (Dc)=	0.71	ft
(Dm-Dc)/Dm * 100	-1.3	%
MEAN VELOCITY=	1.07	ft/sec
MANNING'S N=	0.107	
SLOPE=	0.0278	ft/ft
.4 * Qm =	2.5	cfs
2.5 * Qm=	15.3	cfs

RECOMMENDED INSTREAM FLOW:
=============================

FLOW (CFS)	PERIOD
___________	________
___________	________
___________	________
___________	________

RATIONALE FOR RECOMMENDATION:
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____
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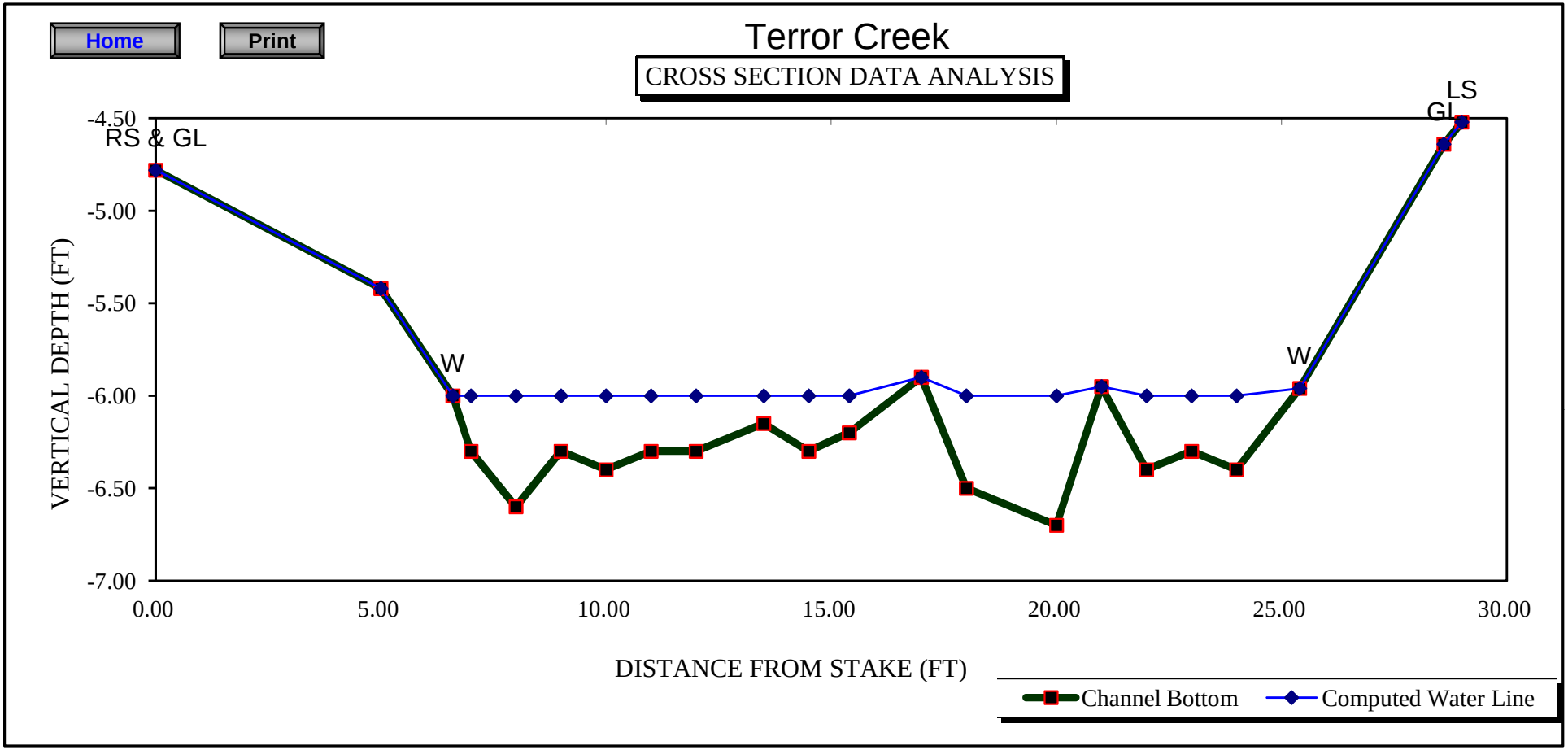
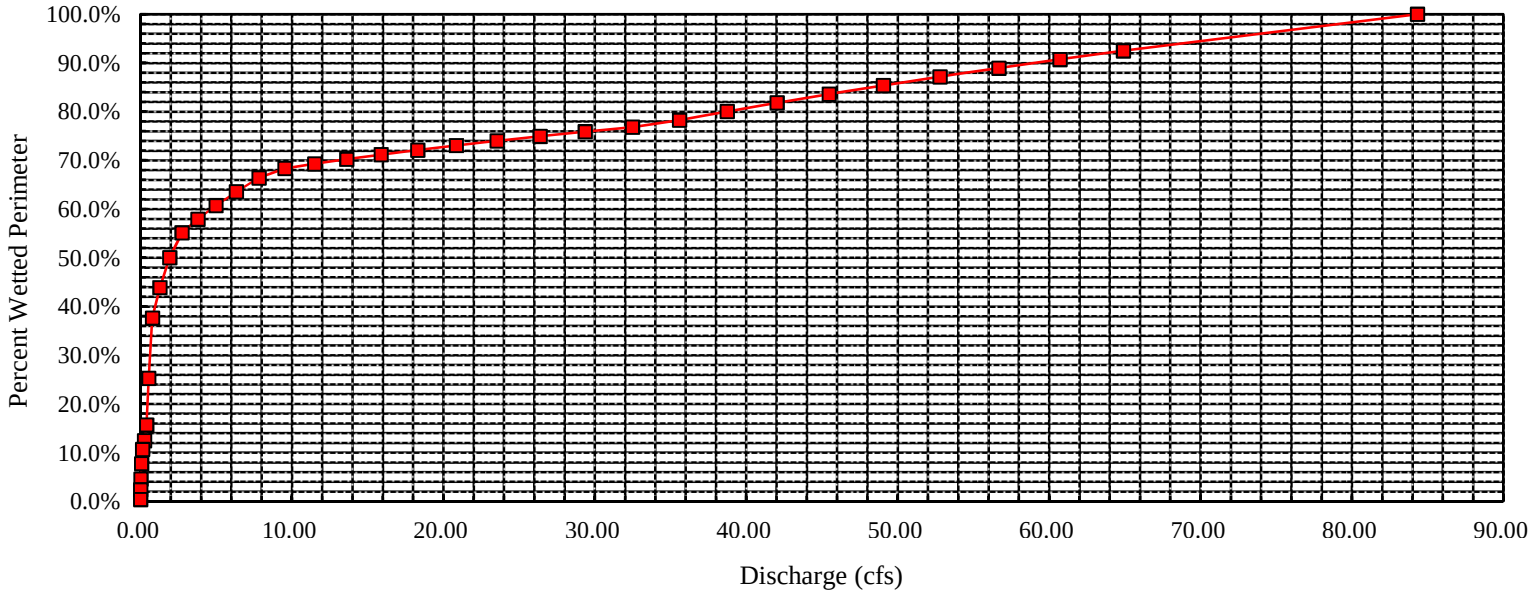
RECOMMENDATION BY: .... AGENCY.. DATE:..................................

CWCB REVIEW BY: .... DATE:..................................


Home
Print
Terror Creek
CROSS SECTION DATA ANALYSIS
RS & GL
LS
GL
W
W
-4.50
-5.00
-5.50
-6.00
-6.50
-7.00
VERTICAL DEPTH (FT)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
DISTANCE FROM STAKE (FT)
Channel Bottom
Computed Water Line

Home Print

Percent Wetted Perimeter vs. Discharge



COLORADO WATER CONSERVATION BOARD

FIELD DATA FOR INSTREAM FLOW DETERMINATIONS

COLORADO DIVISION OF WILDLIFE

LOCATION INFORMATION

STREAM NAME: Terror Creek					CROSS-SECTION NO.: 1	
CROSS-SECTION LOCATION: 700 ft. downstream from confluence w/ West Fork						
DATE: 9-27-07	OBSERVERS: R. Smith, M. Fberle					
LEGAL DESCRIPTION	¼ SECTION: SE	SECTION: 5	TOWNSHIP: 13 N/S	RANGE: 9 E/W	PM: 6th	
COUNTY: Delta	WATERSHED: Gunnison	WATER DIVISION: 4	DOW WATER CODE: 43593			
MAP(S): USGS: Bowie 7.5'	GPS Z13 276905					
USFS:	4313845					

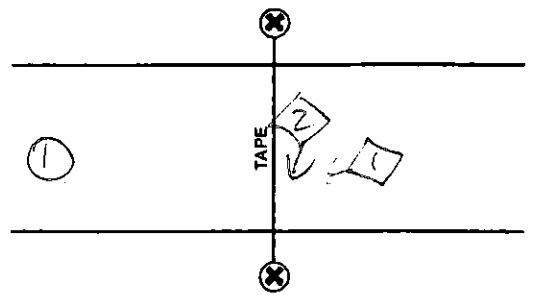
SUPPLEMENTAL DATA

SAG TAPE SECTION SAME AS DISCHARGE SECTION: YES / NO	METER TYPE: Marsh-McBirney			
METER NUMBER:	DATE RATED:	CALIB/SPIN: ____ sec	TAPE WEIGHT: surveyed ____ lbs/foot	TAPE TENSION: surveyed ____ lbs
CHANNEL BED MATERIAL SIZE RANGE: 4" cobbles to 2-foot boulders	PHOTOGRAPHS TAKEN: YES/NO	NUMBER OF PHOTOGRAPHS: 3		

CHANNEL PROFILE DATA

STATION	DISTANCE FROM TAPE (ft)	ROD READING (ft)
⊗ Tape @ Stake LB	0.0	surveyed
⊗ Tape @ Stake RB	0.0	surveyed
① WS @ Tape LB/RB	0.0	
② WS Upstream	14.0	5.70
③ WS Downstream	14.0	6.48
SLOPE	0.78 / 28.0 =	0.0278

SKETCH



LEGEND:
- Stake ⊗
- Station ①
- Photo ③→
- Direction of Flow

AQUATIC SAMPLING SUMMARY

STREAM ELECTROFISHED: YES/NO	DISTANCE ELECTROFISHED: ____ ft	FISH CAUGHT: YES/NO	WATER CHEMISTRY SAMPLED: YES/NO

LENGTH - FREQUENCY DISTRIBUTION BY ONE-INCH SIZE GROUPS (1.0-1.9, 2.0-2.9, ETC.)

SPECIES (FILL IN)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	>15	TOTAL
see attached																	

AQUATIC INSECTS IN STREAM SECTION BY COMMON OR SCIENTIFIC ORDER NAME:

mayfly, caddisfly

COMMENTS

TDS: 100
Temp: 48°F
Ph: 8.2

DISCHARGE/CROSS SECTION NOTES

STREAM NAME: Terror Creek	CROSS-SECTION NO.: 1	DATE: 9-27-07	SHEET ___ OF ___
BEGINNING OF MEASUREMENT	EDGE OF WATER LOOKING DOWNSTREAM: (0.0 AT STAKE) LEFT / RIGHT	Gage Reading: ____ ft	TIME: 3:05 pm

Features: Stake (S) Grassline (G) Waterline (W) Rock (R)	Distance From Initial Point (ft)	Width (ft)	Total Vertical Depth From Tape/Inst (ft)	Water Depth (ft)	Depth of Observation (ft)	Revolutions	Time (sec)	Velocity (ft/sec) At Point	Velocity (ft/sec) Mean in Vertical	Area (ft^2)	Discharge (cfs)
12.5/G	0.0		4.78								
	5.0		5.42								
W	6.6		6.00								
	7.0		6.30	.3				Ø			
	8.0		6.60	.6				.24			
	9.0		6.30	.3				.36			
	10.0		6.40	.4				Ø			
	11.0		6.30	.3				.21			
	12.0		6.30	.3				.74			
	13.5		6.15	.15				.91			
	14.5		6.30	.3				.59			
17.0 R >	15.4	5.90 >	6.20	.2	< Ø			1.15	< Ø		
	18.0		6.50	.5				.96			
21.0 R >	20.0	5.95 >	6.70	.7	< Ø			3.09	< Ø		
	22.0		6.40	.4				.42			
	23.0		6.30	.3				1.85			
	24.0		6.40	.4				.46			
W	25.4		5.96								
G	26.6		4.64								
	29.0		4.52								
TOTALS:											

End of Measurement	Time: 3:30	Gage Reading: ____ ft	CALCULATIONS PERFORMED BY:	CALCULATIONS CHECKED BY:

COLORADO WATER CONSERVATION BOARD
INSTREAM FLOW / NATURAL LAKE LEVEL PROGRAM
STREAM CROSS-SECTION AND FLOW ANALYSIS

LOCATION INFORMATION

STREAM NAME:	Terror Creek
XS LOCATION:	1000 ft. ds from conf. w/ W. Frk.
XS NUMBER:	2
DATE:	27-Sep-07
OBSERVERS:	R. Smith, M. Eberle
1/4 SEC:	SE
SECTION:	5
TWP:	13N
RANGE:	91W
PM:	Sixth
COUNTY:	Delta
WATERSHED:	Gunnison
DIVISION:	4
DOW CODE:	43593
USGS MAP:	Bowie 7.5'
USFS MAP:	0

SUPPLEMENTAL DATA

TAPE WT:	0.0106
TENSION:	99999

*** NOTE ***
Leave TAPE WT and TENSION at defaults for data collected with a survey level and rod

CHANNEL PROFILE DATA

SLOPE:	0.035

INPUT DATA CHECKED BY: .....DATE.....

ASSIGNED TO: ….....……..…….....DATE.....

STREAM NAME: Terror Creek
XS LOCATION: 1000 ft. ds from conf. w/ W. Frk.
XS NUMBER: 2

DATA POINTS= 26

VALUES COMPUTED FROM RAW FIELD DATA

	FEATURE	DIST	VERT DEPTH	WATER DEPTH	VEL	WETTED PERIM.	WATER DEPTH	AREA (Am)	Q (Qm)	% Q CELL
1	LS & GL	3.10	5.20			0.00		0.00	0.00	0.0%
		3.80	5.59			0.00		0.00	0.00	0.0%
	W	4.00	6.22			0.00		0.00	0.00	0.0%
		5.00	6.50	0.30	0.02	1.04	0.30	0.30	0.01	0.1%
		6.00	6.70	0.50	0.08	1.02	0.50	0.50	0.04	0.7%
		7.00	6.90	0.70	1.20	1.02	0.70	0.70	0.84	14.7%
		8.00	6.50	0.30	0.73	1.08	0.30	0.33	0.24	4.2%
		9.20	6.95	0.75	1.21	1.28	0.75	0.75	0.91	15.8%
		10.00	6.80	0.60	0.47	0.81	0.60	0.84	0.39	6.9%
	R	12.00	6.25	0.00	0.00	2.07		0.00	0.00	0.0%
		13.50	6.50	0.30	0.17	1.52	0.30	0.45	0.08	1.3%
		15.00	6.50	0.30	1.00	1.50	0.30	0.44	0.44	7.6%
		16.40	6.40	0.20	0.80	1.40	0.20	0.28	0.22	3.9%
		17.80	6.40	0.20	0.67	1.40	0.20	0.26	0.17	3.0%
	R	19.00	6.10	0.00	0.00	1.24		0.00	0.00	0.0%
		21.00	6.40	0.25	1.61	2.02	0.25	0.38	0.60	10.5%
		22.00	6.45	0.30	1.60	1.00	0.30	0.45	0.72	12.6%
		24.00	6.90	0.75	0.06	2.05	0.75	1.13	0.07	1.2%
		25.00	7.05	0.90	0.62	1.01	0.90	0.90	0.56	9.7%
		26.00	6.55	0.40	0.15	1.12	0.40	0.40	0.06	1.0%
		27.00	6.55	0.40	0.18	1.00	0.40	0.40	0.07	1.3%
		28.00	6.45	0.30	1.00	1.00	0.30	0.30	0.30	5.2%
		29.00	6.35	0.20	0.05	1.00	0.20	0.20	0.01	0.2%
	W	30.00	6.12			1.03		0.00	0.00	0.0%
1	G	33.00	5.15			0.00		0.00	0.00	0.0%
	RS	34.00	4.01			0.00		0.00	0.00	0.0%
	TOTALS ----------					26.63	0.9 (Max.)	9.00	5.73	100.0%

Manning's n = 0.2117
Hydraulic Radius= 0.33784027

STREAM NAME: Terror Creek
XS LOCATION: 1000 ft. ds from conf. w/ W. Frk.
XS NUMBER: 2

WATER LINE COMPARISON TABLE

WATER LINE	MEAS AREA	COMP AREA	AREA ERROR
	9.00	7.28	-19.1%
6.00	9.00	13.65	51.7%
6.02	9.00	13.12	45.9%
6.04	9.00	12.59	40.0%
6.06	9.00	12.07	34.2%
6.08	9.00	11.54	28.3%
6.10	9.00	11.02	22.5%
6.12	9.00	10.50	16.7%
6.14	9.00	9.99	11.0%
6.16	9.00	9.48	5.4%
6.18	9.00	8.98	-0.2%
6.20	9.00	8.48	-5.7%
6.21	9.00	8.24	-8.4%
6.22	9.00	8.00	-11.1%
6.23	9.00	7.75	-13.8%
6.24	9.00	7.51	-16.5%
6.25	9.00	7.28	-19.1%
6.26	9.00	7.04	-21.7%
6.27	9.00	6.81	-24.3%
6.28	9.00	6.58	-26.9%
6.29	9.00	6.35	-29.4%
6.30	9.00	6.12	-31.9%
6.32	9.00	5.68	-36.8%
6.34	9.00	5.25	-41.6%
6.36	9.00	4.84	-46.2%
6.38	9.00	4.43	-50.7%
6.40	9.00	4.04	-55.1%
6.42	9.00	3.70	-58.9%
6.44	9.00	3.37	-62.5%
6.46	9.00	3.07	-65.8%
6.48	9.00	2.79	-69.0%
6.50	9.00	2.53	-71.9%

WATERLINE AT ZERO
AREA ERROR = 6.179

STREAM NAME: Terror Creek
XS LOCATION: 1000 ft. ds from conf. w/ W. Frk.
XS NUMBER: 2 Constant Manning's n

GL = lowest Grassline elevation corrected for sag
STAGING TABLE *WL* = Waterline corrected for variations in field measured water surface elevations and sag

	DIST TO WATER (FT)	TOP WIDTH (FT)	AVG. DEPTH (FT)	MAX. DEPTH (FT)	AREA (SQ FT)	WETTED PERIM. (FT)	PERCENT WET PERIM (%)	HYDR RADIUS (FT)	FLOW (CFS)	AVG. VELOCITY (FT/SEC)
GL	5.20	29.75	1.21	1.85	36.00	31.08	100.0%	1.16	52.16	1.45
	5.23	29.60	1.19	1.82	35.13	30.92	99.5%	1.14	50.24	1.43
	5.28	29.36	1.15	1.77	33.66	30.66	98.6%	1.10	47.04	1.40
	5.33	29.11	1.11	1.72	32.20	30.39	97.8%	1.06	43.94	1.36
	5.38	28.87	1.07	1.67	30.75	30.13	96.9%	1.02	40.93	1.33
	5.43	28.62	1.02	1.62	29.31	29.86	96.1%	0.98	38.02	1.30
	5.48	28.38	0.98	1.57	27.88	29.60	95.2%	0.94	35.20	1.26
	5.53	28.14	0.94	1.52	26.47	29.33	94.4%	0.90	32.47	1.23
	5.58	27.89	0.90	1.47	25.07	29.06	93.5%	0.86	29.84	1.19
	5.63	27.70	0.85	1.42	23.68	28.84	92.8%	0.82	27.27	1.15
	5.68	27.53	0.81	1.37	22.30	28.62	92.1%	0.78	24.80	1.11
	5.73	27.36	0.76	1.32	20.93	28.41	91.4%	0.74	22.42	1.07
	5.78	27.19	0.72	1.27	19.56	28.19	90.7%	0.69	20.14	1.03
	5.83	27.02	0.67	1.22	18.21	27.98	90.0%	0.65	17.96	0.99
	5.88	26.85	0.63	1.17	16.86	27.76	89.3%	0.61	15.88	0.94
	5.93	26.68	0.58	1.12	15.52	27.55	88.6%	0.56	13.91	0.90
	5.98	26.51	0.54	1.07	14.19	27.33	88.0%	0.52	12.04	0.85
	6.03	26.34	0.49	1.02	12.87	27.12	87.3%	0.47	10.29	0.80
	6.08	26.17	0.44	0.97	11.56	26.90	86.6%	0.43	8.64	0.75
	6.13	25.67	0.40	0.92	10.26	26.36	84.8%	0.39	7.18	0.70
WL	6.18	24.91	0.36	0.87	8.99	25.54	82.2%	0.35	5.89	0.65
	6.23	24.11	0.32	0.82	7.77	24.70	79.5%	0.31	4.72	0.61
	6.28	22.90	0.29	0.77	6.59	23.46	75.5%	0.28	3.71	0.56
	6.33	21.49	0.26	0.72	5.48	22.01	70.8%	0.25	2.85	0.52
	6.38	19.91	0.22	0.67	4.44	20.40	65.6%	0.22	2.11	0.48
	6.43	16.13	0.22	0.62	3.54	16.60	53.4%	0.21	1.66	0.47
	6.48	13.73	0.20	0.57	2.80	14.17	45.6%	0.20	1.25	0.45
	6.53	10.54	0.21	0.52	2.20	10.94	35.2%	0.20	0.99	0.45
	6.58	8.36	0.21	0.47	1.74	8.72	28.1%	0.20	0.78	0.45
	6.63	7.35	0.18	0.42	1.35	7.66	24.7%	0.18	0.55	0.41
	6.68	6.34	0.16	0.37	1.00	6.60	21.2%	0.15	0.38	0.37
	6.73	5.32	0.13	0.32	0.71	5.54	17.8%	0.13	0.24	0.33
	6.78	4.31	0.11	0.27	0.47	4.48	14.4%	0.11	0.14	0.29
	6.83	3.25	0.09	0.22	0.28	3.37	10.9%	0.08	0.07	0.25
	6.88	2.15	0.07	0.17	0.15	2.23	7.2%	0.07	0.03	0.21
	6.93	1.21	0.05	0.12	0.06	1.25	4.0%	0.05	0.01	0.18
	6.98	0.61	0.04	0.07	0.02	0.63	2.0%	0.03	0.00	0.14
	7.03	0.18	0.01	0.02	0.00	0.19	0.6%	0.01	0.00	0.06

STREAM NAME: Terror Creek
XS LOCATION: 1000 ft. ds from conf. w/ W. Frk.
XS NUMBER: 2

SUMMARY SHEET

MEASURED FLOW (Qm)=	5.73	cfs
CALCULATED FLOW (Qc)=	5.89	cfs
(Qm-Qc)/Qm * 100 =	-2.8	%
MEASURED WATERLINE (WLm)=	6.25	ft
CALCULATED WATERLINE (WLc)=	6.18	ft
(WLm-WLc)/WLm * 100 =	1.1	%
MAX MEASURED DEPTH (Dm)=	0.90	ft
MAX CALCULATED DEPTH (Dc)=	0.87	ft
(Dm-Dc)/Dm * 100	3.3	%
MEAN VELOCITY=	0.65	ft/sec
MANNING'S N=	0.212	
SLOPE=	0.035	ft/ft
.4 * Qm =	2.3	cfs
2.5 * Qm=	14.3	cfs

RECOMMENDED INSTREAM FLOW:
==========

FLOW (CFS)	PERIOD
==========	========
_____	_____
_____	_____
_____	_____
_____	_____

RATIONALE FOR RECOMMENDATION:
==========

_____
_____
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_____

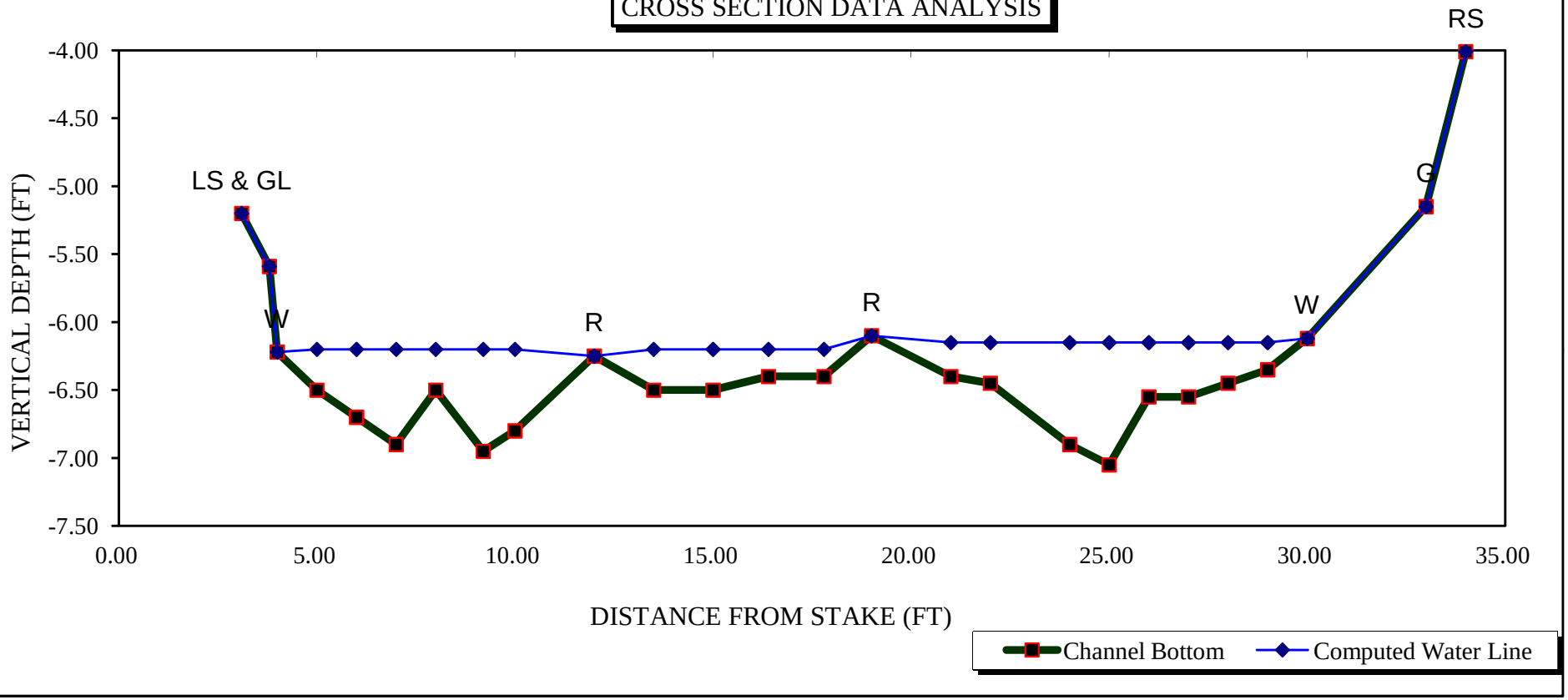
RECOMMENDATION BY: ..... AGENCY..... DATE:.....

CWCB REVIEW BY: ..... DATE:.....

Home Print

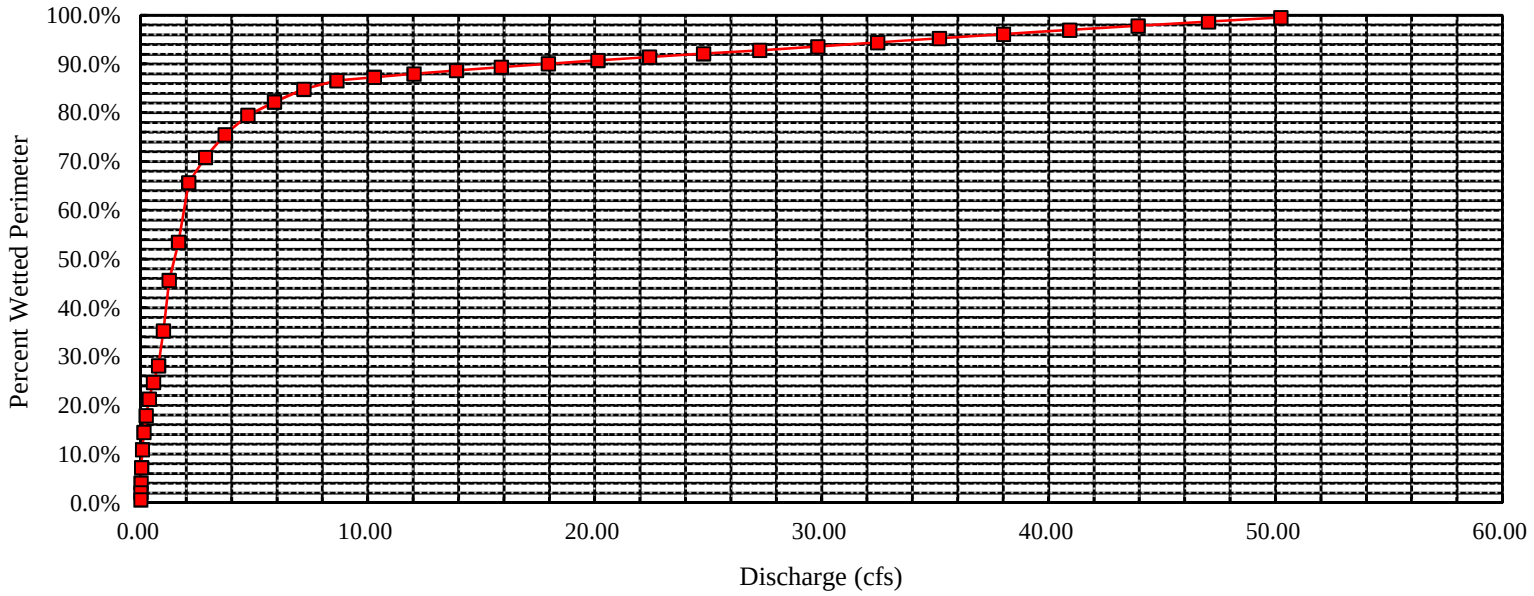
Terror Creek

CROSS SECTION DATA ANALYSIS



Home Print

Percent Wetted Perimeter vs. Discharge



COLORADO WATER CONSERVATION BOARD

FIELD DATA FOR INSTREAM FLOW DETERMINATIONS

COLORADO DIVISION OF WILDLIFE

LOCATION INFORMATION

STREAM NAME: Terror Creek						CROSS-SECTION NO.: 2	
CROSS-SECTION LOCATION: 1,000 ft. downstream from confluence w/ West Fork							
DATE: 9-27-07	OBSERVERS: R. Smith, M. Eberle						
LEGAL DESCRIPTION	¼ SECTION: SE	SECTION: 5	TOWNSHIP: 13 N/S	RANGE: 91 E/W	PM: 6 PL		
COUNTY: Delta	WATERSHED: Gunnison	WATER DIVISION: 4	DOW WATER CODE: 43593				
MAP(S): USGS: Bowie 7.5'	USFS:						

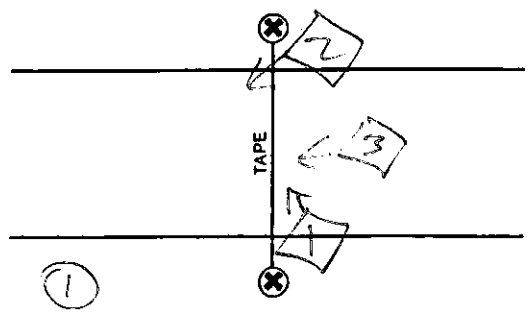
SUPPLEMENTAL DATA

SAG TAPE SECTION SAME AS DISCHARGE SECTION: (YES/NO)	METER TYPE: Marsh-McBirney			
METER NUMBER:	DATE RATED:	CALIB/SPIN: ____ sec	TAPE WEIGHT: surveyed ____ lbs/foot	TAPE TENSION: surveyed ____ lbs
CHANNEL BED MATERIAL SIZE RANGE: inch cobble to 3-foot boulder	PHOTOGRAPHS TAKEN: (YES/NO)	NUMBER OF PHOTOGRAPHS: 5		

CHANNEL PROFILE DATA

STATION	DISTANCE FROM TAPE (ft)	ROD READING (ft)
⊗ Tape @ Stake LB	0.0	surveyed
⊗ Tape @ Stake RB	0.0	surveyed
① WS @ Tape LB/RB	0.0	6.22 / 0.12
② WS Upstream	17.0	5.61
③ WS Downstream	17.0	6.80
SLOPE	1.21 / 34.0 = .035	

SKETCH



LEGEND:
Stake ⊗
Station ①
Photo ①→
Direction of Flow

AQUATIC SAMPLING SUMMARY

STREAM ELECTROFISHED: (YES/NO)	DISTANCE ELECTROFISHED: ____ ft	FISH CAUGHT: (YES/NO)	WATER CHEMISTRY SAMPLED: (YES/NO)

LENGTH - FREQUENCY DISTRIBUTION BY ONE-INCH SIZE GROUPS (1.0-1.9, 2.0-2.9, ETC.)

SPECIES (FILL IN)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	>15	TOTAL
See attached survey																	

AQUATIC INSECTS IN STREAM SECTION BY COMMON OR SCIENTIFIC ORDER NAME:
mayfly, caddisfly

COMMENTS

TDS = 100
Ph = 8.2
Temp: 48°
Very difficult to find riffles.

FORM #ISF FD 1-85

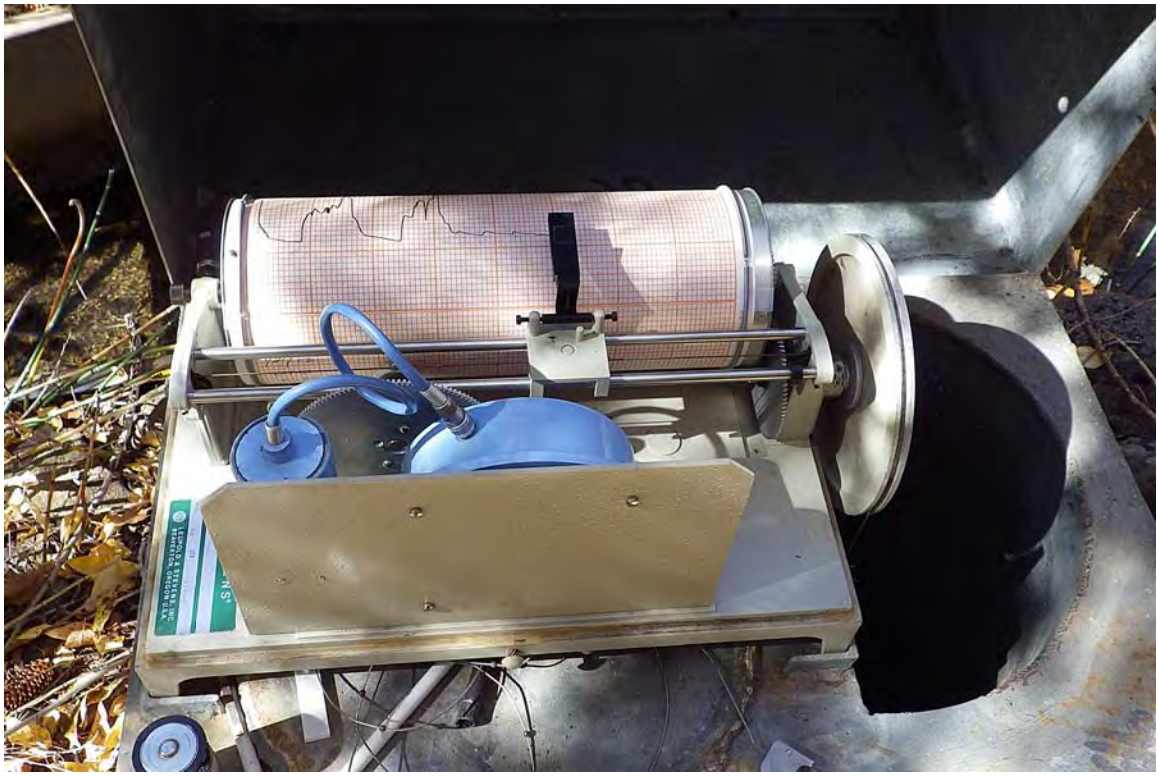
DISCHARGE/CROSS SECTION NOTES

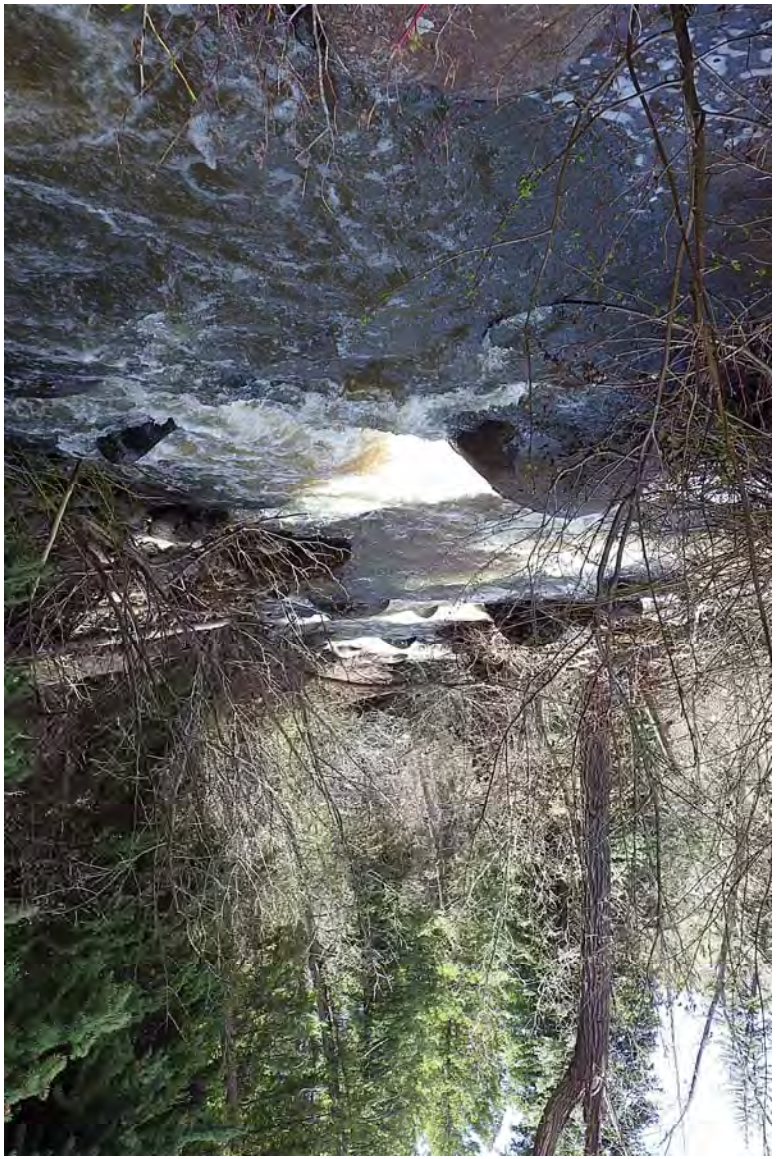
STREAM NAME:	CROSS-SECTION NO.:	DATE:	SHEET ___ OF ___
Terror Creek	2	9-27-07	

BEGINNING OF MEASUREMENT	EDGE OF WATER LOOKING DOWNSTREAM: (0.0 AT STAKE) LEFT / RIGHT	Gage Reading: ____ ft	TIME: 3:45

Features: Stake (S) Grassline (G) Waterline (W) Rock (R)	Distance From Initial Point (ft)	Width (ft)	Total Vertical Depth From Tape/Inst (ft)	Water Depth (ft)	Depth of Observation (ft)	Revolutions	Time (sec)	Velocity (ft/sec) At Point	Velocity (ft/sec) Mean in Vertical	Area (ft^2)	Discharge (cfs)
LS/G	3.1		5.20								
	3.8		5.59								
W	4.0		6.02								
	5.0		6.50	.30				.02			
	6.0		6.70	.50				.08			
	7.0		6.90	.70				1.20			
	8.0		6.50	.30				.73			
	9.2		6.95	.75				1.21			
	10.0		6.80	.60				.47			
R	12.0		6.25	0				0			
	13.5		6.50	.30				.17			
	15.0		6.50	.30				1.00			
	16.4		6.40	.20				.80			
	17.8		6.40	.20				.67			
R	19.0		6.30	0				0			
	21.0		6.40	.25				1.61			
	22.0		6.45	.30				1.60			
	24.0		6.90	.75				0.06			
	25.0		7.05	.90				0.62			
	26.0		6.55	.40				0.15			
	27.0		6.55	.40				0.18			
	28.0		6.45	.30				1.00			
	29.0		6.35	.20				0.05			
W	30.0		6.12								
G	33.0		5.15								
RS	34.0		4.01								
TOTALS:											

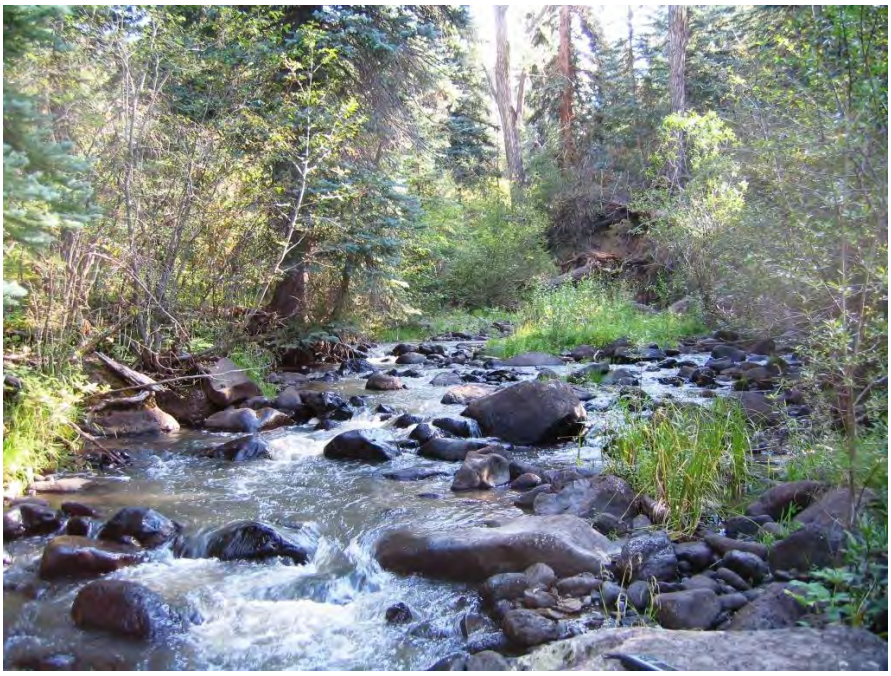
End of Measurement	Time: 4:15	Gage Reading: ____ ft	CALCULATIONS PERFORMED BY:	CALCULATIONS CHECKED BY:





COLORADO
Colorado Water Conservation Board
Department of Natural Resources

Terror Creek (Upper)
Executive Summary



CWCB STAFF INSTREAM FLOW RECOMMENDATION

UPPER TERMINUS:	Confluence of East Fork Terror Creek and West Fork Terror Creek at UTM North: 4314191.79 UTM East: 276880.59
LOWER TERMINUS:	Terror Ditch Headgate at UTM North: 4311776.78 UTM East: 276931.58
WATER DIVISION:	4
WATER DISTRICT:	40
COUNTY:	Delta
WATERSHED:	North Fork Gunnison (HUC#:14020004)
CWCB ID:	15/4/A-007
RECOMMENDER	Bureau of Land Management
LENGTH:	1.55 miles
FLOW RECOMMENDATION:	4.8 cfs (4/1 – 9/30) 1.5 cfs (10/1 – 3/31)

TERROR CREEK (UPPER)

Introduction

Colorado's General Assembly created the Instream Flow and Natural Lake Level Program in 1973, recognizing "the need to correlate the activities of mankind with some reasonable preservation of the natural environment" (see 37-92-102 (3), C.R.S.). The statute vests the Colorado Water Conservation Board (CWCB or Board) with the exclusive authority to appropriate and acquire instream flow (ISF) and natural lake level water rights. Before initiating a water right filing, the Board must determine that: 1) there is a natural environment that can be preserved to a reasonable degree with the Board's water right if granted, 2) the natural environment will be preserved to a reasonable degree by the water available for the appropriation to be made, and 3) such environment can exist without material injury to water rights.

The Bureau of Land Management (BLM) recommended that the CWCB appropriate an ISF water right on a reach of Terror Creek. This reach is located within Delta County about 3.5 miles northeast of the town of Paonia (See Vicinity Map). Terror Creek originates at the confluence of East Fork Terror Creek and West Fork Terror Creek at an elevation of 7,070 feet. It flows in a southerly direction as it drops to an elevation of 5,750 feet where it joins the North Fork Gunnison River. The proposed reach extends from the confluence of East Fork Terror Creek and West Fork Terror Creek downstream to the Terror Ditch headgate. One-hundred percent of the land on the 1.55 mile proposed reach is publicly owned and managed by the US Forest Service (See Land Ownership Map). The BLM recommended this reach of Terror Creek because it has a natural environment that can be preserved to a reasonable degree with an ISF water right.

The information contained in this report and the associated supporting data and analyses (located at http://cwcb.state.co.us/environment/instream-flow-program/Pages/2015ProposedISFAppropriations.aspx) form the basis for staff's ISF recommendation to be considered by the Board. This report provides sufficient information to support the CWCB findings required by ISF Rule 5i on natural environment, water availability, and material injury.

Natural Environment

CWCB staff relies on the recommending entity to provide information about the natural environment. In addition, staff reviews information and conducts site visits for each recommended ISF appropriation. This information is used to provide the Board with a basis for determining that a natural environment exists.

Terror Creek is a cold-water, high gradient stream. It flows through a narrow canyon with a floor approximately one-eight mile in width. The stream is generally constrained by bedrock, especially in locations where the streams come close to the canyon walls. The stream generally has large-sized substrate, ranging from four-inch cobbles to boulders up to two feet in diameter. The stream has a high percentage of pool habitat, but sufficient riffle and side channel habitat exists to support salmonid and

other fish reproduction. Fisheries surveys have revealed self-sustaining populations of speckled dace and native cutthroat trout. The BLM plans to collect fin samples from the cutthroat trout population to determine the genetic quality of the population.

The riparian community in this part of Terror Creek is generally comprised of willow species, alder, blue spruce, and narrowleaf cottonwood. In general, the riparian community is in very good condition, provides adequate shading and cover for fish habitat, and provides stream stability during flood events

Table 1. List of species identified in upper Terror Creek.

Species Name	Scientific Name	Status
native cutthroat trout	*Oncorhynchus clarkii**	State Species of Special Concern BLM Sensitive Species
speckled dace	*Rhinichthys osculus*	none

**Identification of subspecies / lineage of native cutthroat trout in Colorado is ongoing through genetic testing and research*.

ISF Quantification

CWCB staff relies upon the biological expertise of the recommending entity to quantify the amount of water required to preserve the natural environment to a reasonable degree. CWCB staff performs a thorough review of the quantification analyses completed by the recommending entity to ensure consistency with accepted standards.

Methodology

BLM staff used the R2Cross methodology to develop the initial ISF recommendation. The R2Cross method is based on a hydraulic model and uses field data collected in a stream riffle (Espegren, 1996). Riffles are most easily visualized as the stream habitat types that would dry up first should streamflow cease. The field data collected consists of streamflow measurements and surveys of channel geometry at a transect and of the longitudinal slope of the water surface.

The field data is used to model three hydraulic parameters: average depth, average velocity, and percent wetted perimeter. Maintaining these hydraulic parameters at adequate levels across riffle habitat types also will maintain aquatic habitat in pools and runs for most life stages of fish and aquatic invertebrates (Nehring, 1979). BLM staff interprets the model results to develop an initial recommendation for summer and winter flows. The summer flow recommendation is based on meeting 3 of 3 hydraulic criteria. The winter flow recommendation is based on meeting 2 of 3 hydraulic criteria. The model's suggested accuracy range is 40% to 250% of the streamflow measured in the field. Recommendations that fall outside of the accuracy range may not give an accurate estimate of the hydraulic parameters necessary to determine an ISF rate.

The R2Cross methodology provides the biological quantification of the amount of water needed for summer and winter periods based on empirical studies of fish species preferences. The recommending entity uses the R2Cross results and its biological expertise to develop an initial ISF recommendation. CWCB staff then evaluates water availability for the reach typically based on median hydrology (see the Water Availability section below for more details). The water availability analysis may indicate less water is available than the initial recommendation. In that case, the recommending entity either modifies the magnitude and/or duration of the recommended ISF rates if the available flows will preserve the natural environment to a reasonable degree, or withdraws the recommendation.

Data Analysis

R2Cross data was collected at four transects for this proposed ISF reach (Table 2). Results obtained at more than one transect are averaged to determine the R2Cross flow rate for the reach of stream. The R2Cross model results in a summer flow of 4.8 cfs, which meets 3 of 3 criteria and is within the accuracy range of the R2Cross model. The R2Cross model results in a winter flow of 3.9 cfs, which meets 2 of 3 criteria and is within the accuracy range of the R2Cross model.

Table 2. Summary of R2Cross transect measurements and results for upper Terror Creek.

Entity	Date Measured	Streamflow (cfs)	Accuracy Range (cfs)	Winter Rate (cfs)	Summer Rate (cfs)
BLM	9/27/2007	6.13	2.5 – 15.3	4.68	5.15
BLM	9/27/2007	5.73	2.3 – 14.3	4.08	Out of Range
BLM	10/21/2008	2.15	0.9 – 5.4	3.76	4.46
BLM	10/21/2008	1.82	0.7 – 4.5	3.21	Out of Range
			Mean	**3.93**	**4.80**

ISF Recommendation

The BLM recommends flows of 4.8 cfs (4/1 – 9/30) and 1.5 cfs (10/1 – 3/31) based on R2Cross modeling analyses, biological expertise and staff's water availability analysis.

4.8 cfs is recommended for the snowmelt runoff and summer period from April 1 through September 30. This recommendation is driven by the wetted perimeter criteria. Wetting at least 50% of the channel will provide important physical habitat during a time of year when the fish population is completing key life cycle functions.

1.5 cubic feet per second is recommended during the fall and winter period between October 1 and March 31. This recommendation is driven by limited water availability during the fall and winter. This flow rate generally provides between 0.15 and 0.20 feet depth, 40 to 50% wetted perimeter, and an average 0.9 feet per second velocity. This flow rate should prevent icing in pools and allow fish to successfully overwinter.

Water Availability

CWCB staff conducts hydrologic analyses for each recommended ISF appropriation to provide the Board with a basis for making the determination that water is available.

Methodology

Each recommended ISF reach has a unique flow regime that depends on variables such as the timing, magnitude, and location of water inputs (such as rain, snow, and snowmelt) and water losses (such as diversions, reservoirs, evaporation and transpiration, groundwater recharge, etc). Although extensive and time-consuming investigations of all variables may be possible, staff takes a pragmatic and cost-effective approach to analyzing water availability. This approach focuses on streamflows and the influence of flow alterations, such as diversions, to understand how much water is physically available in the recommended reach.

Staff's hydrologic analysis is data-driven, meaning that staff gathers and evaluates the best available data and uses the best available analysis method for that data. Whenever possible, long-term stream gage data (period of record 20 or more years) will be used to evaluate streamflow. Other streamflow information such as short-term gages, temporary gages, spot streamflow measurements, diversion records, and StreamStats will be used when long-term gage data is not available. StreamStats, a statistical hydrologic program, uses regression equations developed by the USGS (Capesius and Stephens, 2009) to estimate mean flows for each month based on drainage basin area and average drainage basin precipitation. Diversion records will also be used to evaluate the effect of surface water diversions when necessary. Interviews with water commissioners, landowners, and ditch or reservoir operators can provide additional information. A range of analytical techniques may be employed to extend gage records, estimate streamflow in ungaged locations, and estimate the effects of diversions. The goal is to obtain the most detailed and reliable estimate hydrology using the most efficient analysis technique.

The final product of the hydrologic analysis used to determine water availability is a hydrograph, which shows streamflow and the proposed ISF rate over the course of one year. The hydrograph will show median daily values when daily data is available; otherwise, it will present mean-monthly streamflow values. Staff will calculate 95% confidence intervals for the median streamflow if there is sufficient data.

Basin Characteristics

The proposed ISF reach of Terror Creek has a 28.1 square mile drainage basin. The average elevation of the basin is 8,880 ft and the average annual precipitation is 26.41 inches. The drainage basin tributary to the lower terminus has several surface water diversions with active records (see Table 3). The Overland Ditch (See Table 3 for details) can divert from the headwaters of Muddy Creek, Hubbard Creek, Terror Creek, and Leroux Creek. This ditch appears to be able to divert a maximum of 150 cfs from each basin; however, the total from all basins cannot exceed 150 cfs. Mesa Pipeline has a total of 2.5 cfs in decreed rights. Bruce Reservoir located on the East Fork of Terror Creek, has a decreed

volume of 631.99 AF and is used to supplement diversions. The Terror Ditch Extension (appropriation 1894, 6 cfs; appropriation 1976, 23 cfs) diverts water from the headwaters of Hubbard Creek into Terror Creek. Due to surface water diversions, transbasin imports and exports, and the reservoir, hydrology in this drainage basin does not represent natural flow conditions.

Table 3. List of diversion structures located within in the Terror Creek drainage basin.

Name	WDID	Adjudication Date	Appropriation Date	Administration Number	Amount
Overland Ditch	4001739	6/23/1914	8/1/1893	21263.15919	75.00
		8/28/1919	4/10/1919	25301.00000	75.00
Pitkin Mesa Pipeline	4001191	6/17/1889	11/13/1883	12370.00000	0.4850
		1/31/1964	8/13/1961	40767.00000	2.0150
Terror Ditch*	4001208	4/12/1901	12/11/1884	14413.12764	6.00
		2/10/1930	5/01/1901	25807.18748	6.00
		3/20/1954	12/11/1884	31924.12764	1.50
Holybee Ditch*	4001155	6/17/1989	11/13/1883	12370.00000	0.40
Fire Mt Canal*	4001809	2/10/1930	7/1/1903	25807.19539	70.00
Fawcett Ditch*	4001130	6/17/1889	11/13/1883	12370.00000	0.1150
		3/20/1954	4/15/1944	34438.00000	1.25
		12/31/2005	5/1/1986	56613.49794	0.1250
				Total	**237.89**

**These diversions are located below the proposed ISF reach, but impact the Terror Creek gage.*

Available Data

There are two historic streamflow gages in the vicinity of the proposed ISF reach. The East Fork Terror Creek below Cottonwood Stomp near Bowie gage (USGS 09132985) is located upstream from the proposed lower terminus. This gage measures streamflow on the East Fork of Terror Creek and therefore is not representative of flow in the ISF reach which receives tributary inflow from the West Fork of Terror Creek. The Terror Creek at mouth near Bowie, CO gage (USGS 09132995) is located approximately 3.4 miles downstream from the proposed lower terminus. The Terror Creek at mouth gage (Terror Creek gage) was operated from 2001 to 2013 and discontinued in 2014 due to funding issues. The Terror Creek gage has a 29.5 square miles drainage basin and is influenced by the same diversions that affect the proposed ISF reach as well as four additional diversions that total 85.39 cfs.

In some cases, diversion records can be used to provide an indication of water availability in a stream reach. Terror Ditch is located at the lower terminus and diverts up to 13.5 cfs. According to the Water Commissioner, Steve Tuck, this structure often diverts the majority of the creek during irrigation season with the exception of spring runoff. This structure has diversion records from 1969 to present

which provide valuable information about the amount of streamflow that reaches the lower terminus of the proposed ISF.

Data Analysis

Due to the short period of record available at the Terror Creek gage, staff took additional steps to evaluate the record. Staff examined other gages in the region in an attempt to find a gage that could be used to extend the record through regression analysis. However, none of the gages evaluated produced a reasonable regression coefficient and none were found suitable for regression extension.

Staff also examined streamflow gages and climate stations and found that the Paonia climate station (Paonia 1 SW, Station ID USC00056306, downloaded 11/7/2014) has a relatively long period of record and is located about 7 miles from the lower terminus. The average annual precipitation at the Paonia Station for the period of record (1893 to 1930, 1957 to 2014) is 15.14 inches. During the 13 years the Terror Creek gage operated (2001 to 2013), only two years (2005 and 2007) had above average precipitation at the Paonia Station and all others were below average. Therefore, the Terror Creek gage record likely represents below average streamflow conditions and likely underestimates the amount of water typically available in this drainage.

The Terror Creek gage was analyzed using the approved period of record (6/28/2001 to 12/10/2013) available through HydroBase on 5/20/2014. The gage record was scaled by 0.969 to the lower terminus using the area-precipitation method. The area-precipitation method estimates streamflow based on the ratio of the precipitation weighted drainage area at the lower terminus location to that of the gage location. Diversions from Terror Ditch and Fawcett Ditch diversions were added to the scaled record because these flows are available in the proposed ISF reach, but do not reach the gage. Fire Mountain Canal diversions were not added because there were no recorded diversions during the period analyzed. Holybee Ditch diversions were not added to avoid double counting flow because it was unclear if return flows accrue to Terror Creek. Median streamflow was calculated using the adjusted Terror Creek gage record. 95% confidence intervals were not calculated due to the short period of record at the Terror Creek gage.

Terror Ditch diversions were analyzed by calculating the median diversion and 95% confidence intervals for the median diversion for the diversion record (11/1/1969 to 10/31/2013) available through HydroBase on 5/20/2014.

Summary

The hydrographs (Figure 1 and 2) show the median streamflow based on the adjusted Terror Creek gage data and the median diversion and 95% confidence intervals for the median diversion for Terror Ditch. The proposed ISF is greater than the median adjusted streamflow for 10 days in September. However, on those days the 95% confidence interval for the median diversion on Terror Ditch was greater than the proposed ISF flow rate. Staff has concluded that water is available for appropriation.

Material Injury

Because the proposed ISF on Terror Creek is a new junior water right, the ISF can exist without material injury to other water rights. Under the provisions of section 37-92-102(3)(b), C.R.S. (2014), the CWCB will recognize any uses or exchanges of water in existence on the date this ISF water right is appropriated.

Citations

Archfield, S.A., and R.M. Vogel, 2009, Map correlation method: selection of reference streamgage to estimate daily streamflow at ungaged catchments, Water Resources Research, vol 46, W10513, doi:10.10/29/2009WR008481.

Capesius, J.P. and V.C. Stephens, 2009, Regional regression equations for estimation of natural streamflow statistics in Colorado, Scientific Investigations Report 2009-5136.

Espegren, G.D., 1996, Development of Instream Flow Recommendations in Colorado Using R2CROSS, Colorado Water Conservation Board.

Nehring, B.R., 1979, Evaluation of Instream Flow Methods and Determination of Water Quantity Needs for Streams in the State of Colorado, Colorado Division of Wildlife.

Metadata Descriptions

The UTM locations for the upstream and downstream termini were derived from CWCB GIS using the National Hydrography Dataset (NHD).

Projected Coordinate System: NAD 1983 UTM Zone 13N.

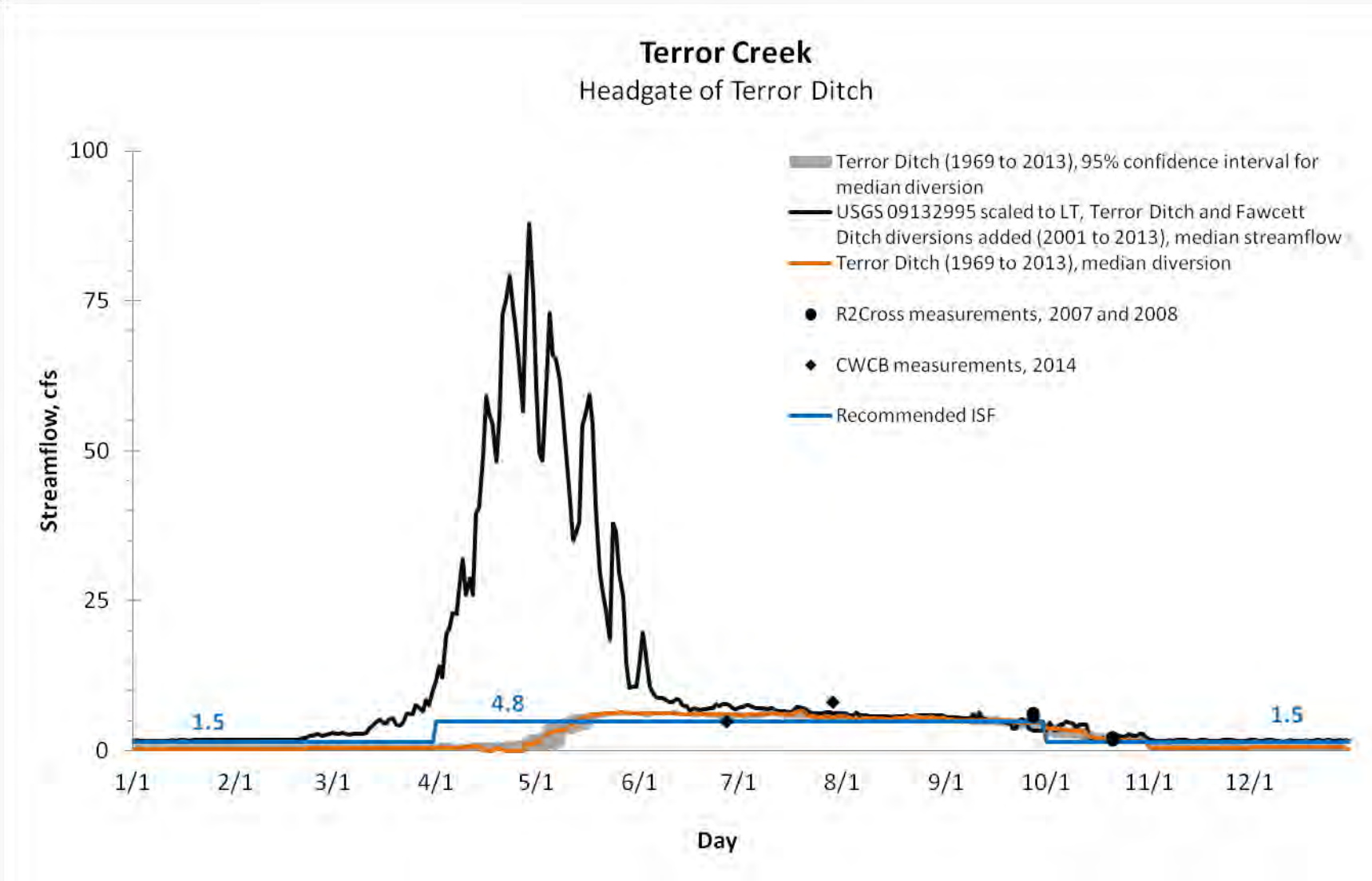


Figure 1. Complete hydrograph showing streamflow data and the proposed ISF rate on upper Terror Creek.

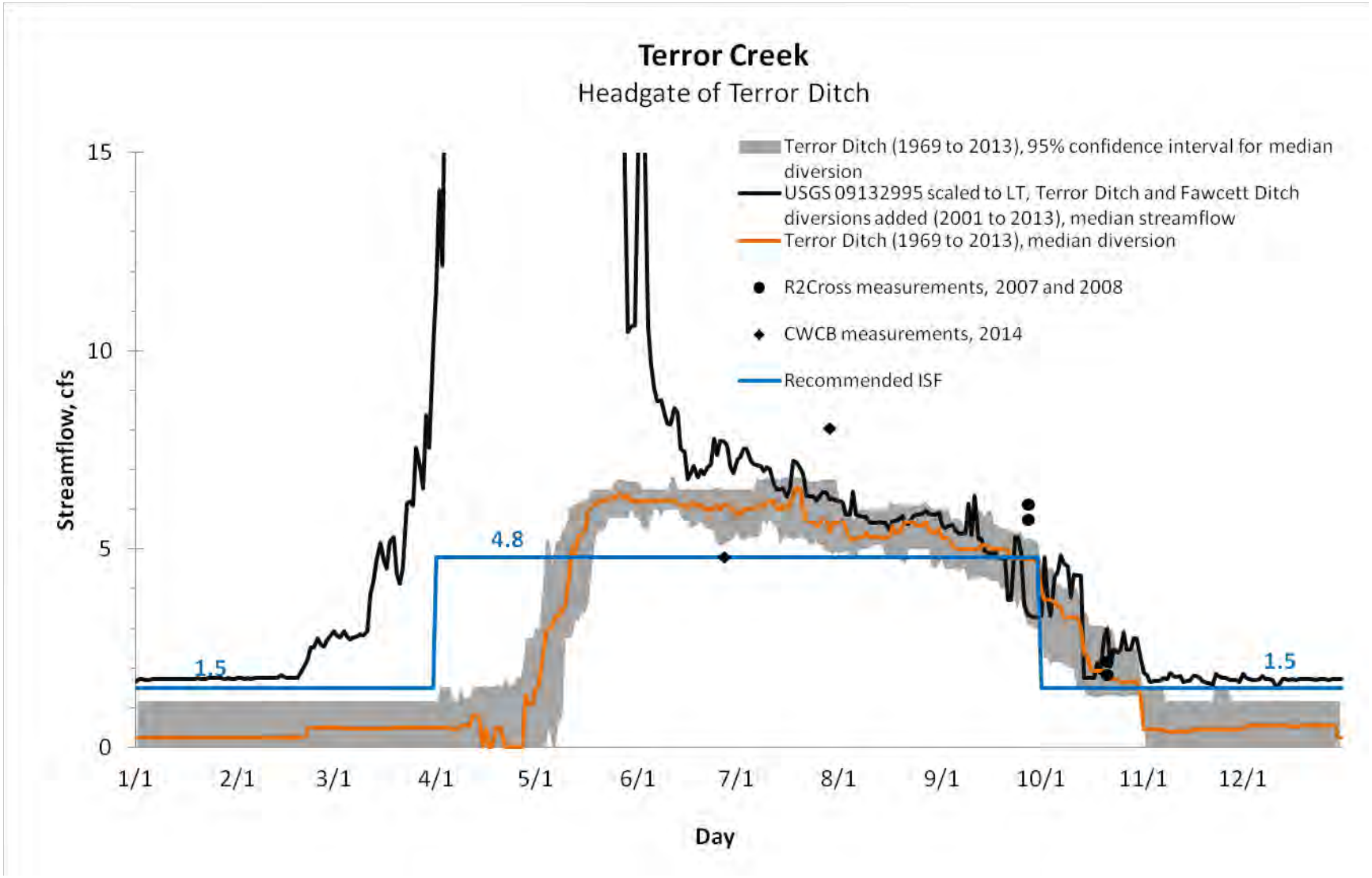
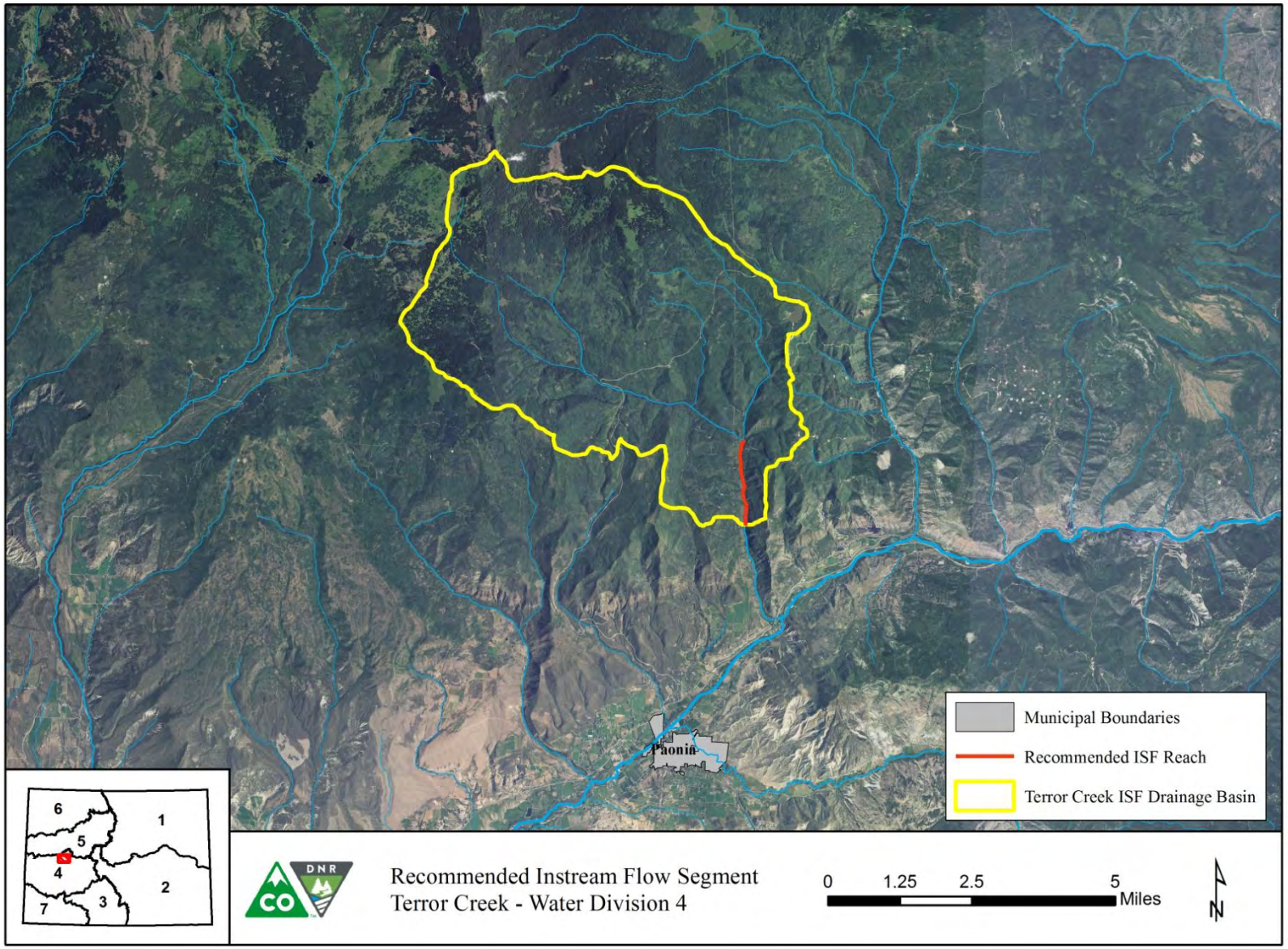
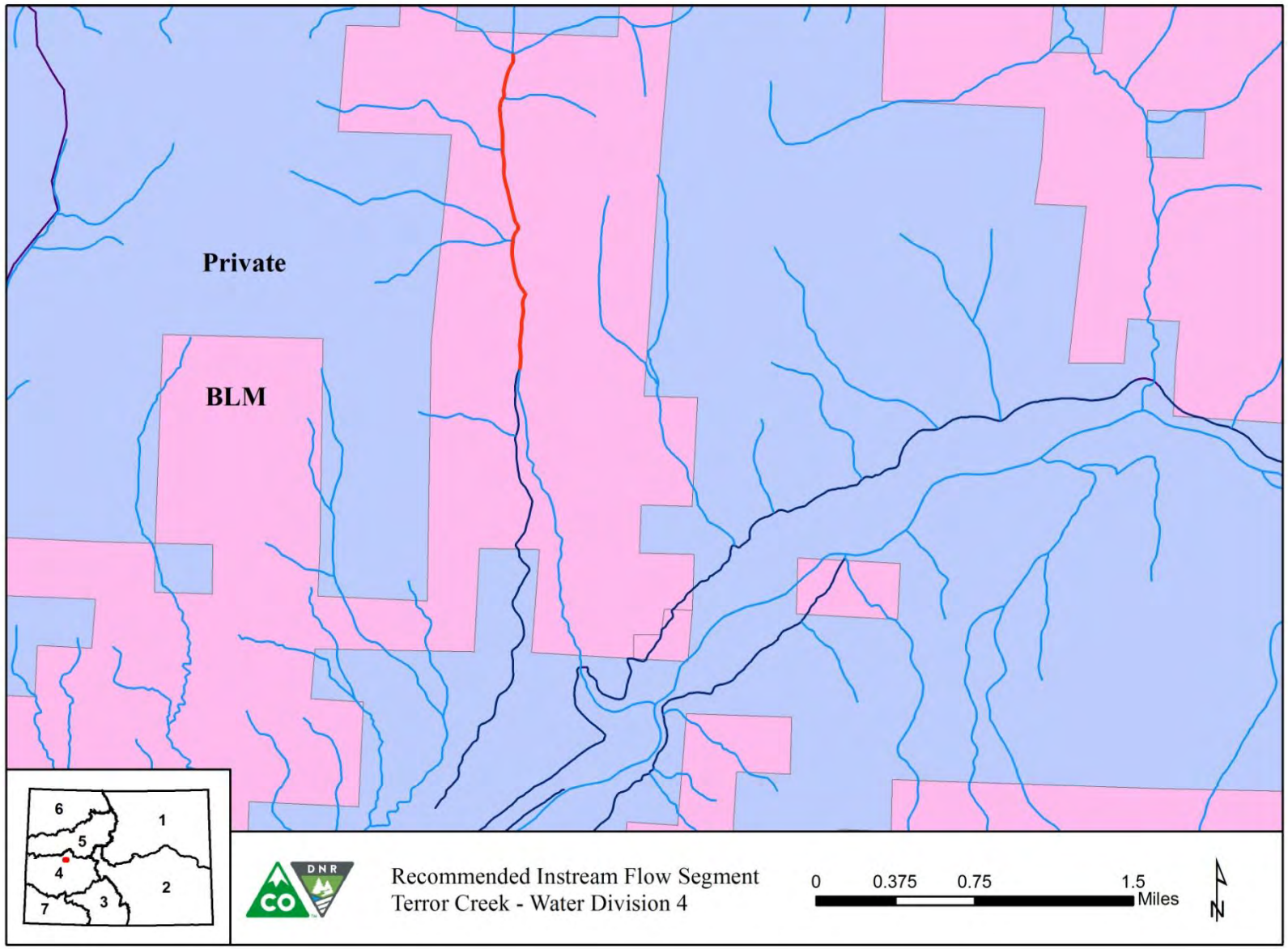


Figure 2. Detailed hydrograph showing streamflow data and the proposed ISF rate on upper Terror Creek.

Vicinity Map



Land Use Map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BLM
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DNR
Recommended Instream Flow Segment
Terror Creek - Water Division 4
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Miles
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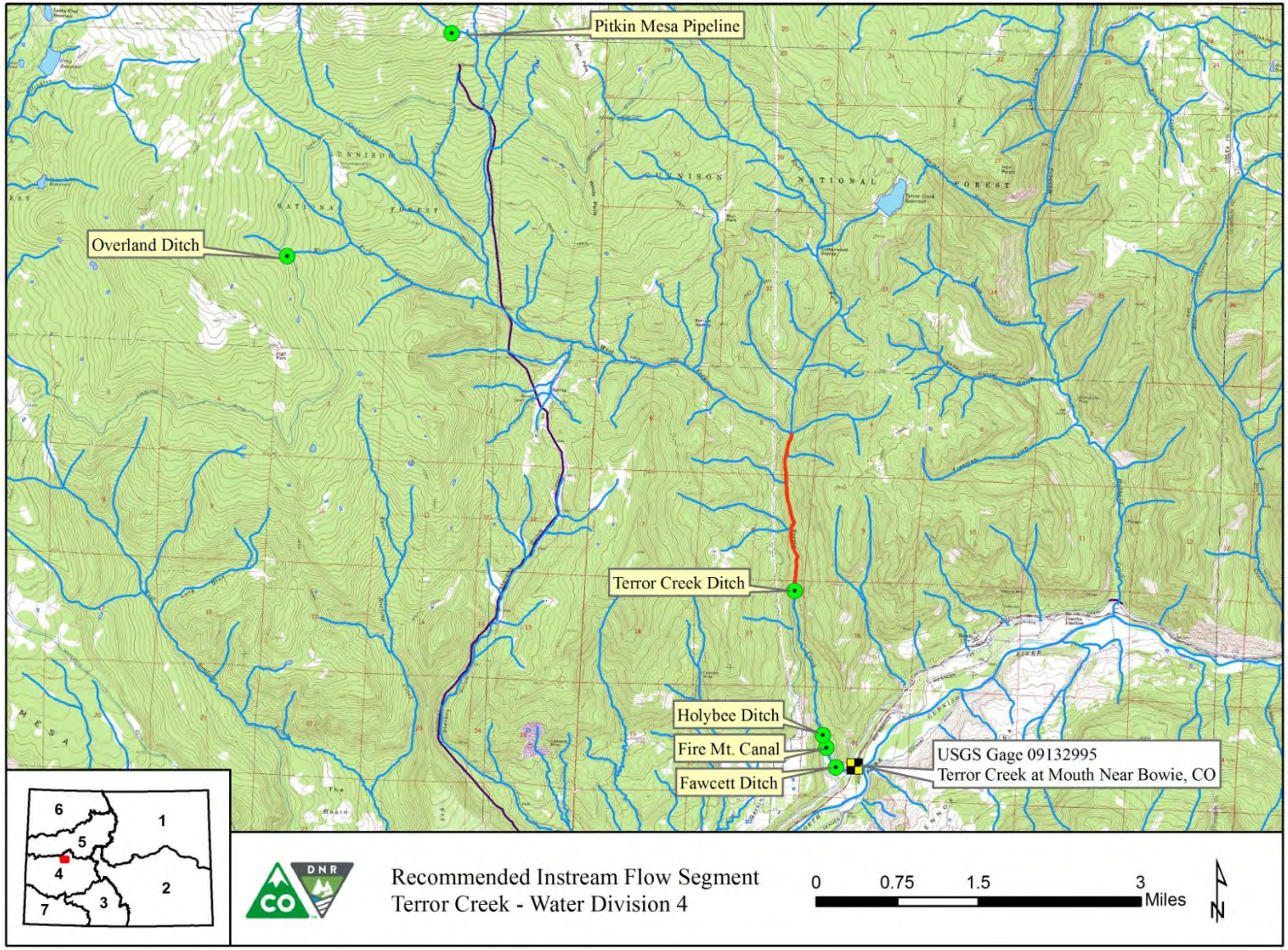
Water Rights Map



COLORADO
Colorado Water Conservation Board
Department of Natural Resources

Terror Creek (Lower)
Executive Summary

CWCB STAFF INSTREAM FLOW RECOMMENDATION

UPPER TERMINUS:	Terror Ditch Headgate at UTM North: 4311776.78	UTM North: 276931.58
LOWER TERMINUS:	Fire Mountain Canal at UTM North: 4309509.78	UTM East: 277393.55
WATER DIVISION:	4	
WATER DISTRICT:	40	
COUNTY:	Delta	
WATERSHED:	North Fork Gunnison (HUC#:14020004)	
CWCB ID:	12/4/A-008	
RECOMMENDER	Bureau of Land Management	
LENGTH:	1.52 miles	
FLOW RECOMMENDATION:	4.2 cfs (4/1 – 5/31)	

TERROR CREEK (LOWER)

Introduction

Colorado's General Assembly created the Instream Flow and Natural Lake Level Program in 1973, recognizing "the need to correlate the activities of mankind with some reasonable preservation of the natural environment" (see 37-92-102 (3), C.R.S.). The statute vests the Colorado Water Conservation Board (CWCB or Board) with the exclusive authority to appropriate and acquire instream flow (ISF) and natural lake level water rights. Before initiating a water right filing, the Board must determine that: 1) there is a natural environment that can be preserved to a reasonable degree with the Board's water right if granted, 2) the natural environment will be preserved to a reasonable degree by the water available for the appropriation to be made, and 3) such environment can exist without material injury to water rights.

The Bureau of Land Management (BLM) recommended that the CWCB appropriate an ISF water right on a reach of Terror Creek. This reach is located within Delta County about 2.5 miles northeast of the town of Paonia (See Vicinity Map). Terror Creek originates at the confluence of East Fork Terror Creek and West Fork Terror Creek at an elevation of 7,070 feet. It flows in a southerly direction as it drops to an elevation of 5,750 feet where it joins the North Fork Gunnison River. The proposed reach extends from the Terror Ditch headgate downstream to the Fire Mountain Canal. Ninety-six percent of the land on the 1.52 mile proposed reach is publicly owned and managed by the BLM (See Land Ownership Map). The BLM recommended this reach of Terror Creek because it has a natural environment that can be preserved to a reasonable degree with an ISF water right.

The information contained in this report and the associated supporting data and analyses (located at http://cwcb.state.co.us/environment/instream-flow-program/Pages/2015ProposedISFAppropriations.aspx) form the basis for staff's ISF recommendation to be considered by the Board. This report provides sufficient information to support the CWCB findings required by ISF Rule 5i on natural environment, water availability, and material injury.

Natural Environment

CWCB staff relies on the recommending entity to provide information about the natural environment. In addition, staff reviews information and conducts site visits for each recommended ISF appropriation. This information is used to provide the Board with a basis for determining that a natural environment exists.

Terror Creek is a cold-water, high gradient stream. It flows through a narrow canyon with a floor approximately one-eight mile in width. The stream is generally constrained by bedrock, especially in locations where the streams come close to the canyon walls. The stream generally has large-sized substrate, ranging from four-inch cobbles to boulders up to two feet in diameter. The stream has a high percentage of pool habitat, but sufficient riffle and side channel habitat exists to support salmonid and other fish reproduction. Fisheries surveys have revealed self-sustaining populations of speckled dace

and native cutthroat trout. The BLM plans to collect fin samples from the cutthroat trout population to determine the genetic quality of the population.

The riparian community in this part of Terror Creek is generally comprised of willow species, alder, blue spruce, and narrowleaf cottonwood. In general, the riparian community is in very good condition, provides adequate shading and cover for fish habitat, and provides stream stability during flood events.

Table 1. List of species identified in lower Terror Creek.

Species Name	Scientific Name	Status
native cutthroat trout	*Oncorhynchus clarkii**	State Species of Special Concern BLM Sensitive Species
speckled dace	*Rhinichthys osculus*	none

**Identification of subspecies / lineage of native cutthroat trout in Colorado is ongoing through genetic testing and research.*

ISF Quantification

CWCB staff relies upon the biological expertise of the recommending entity to quantify the amount of water required to preserve the natural environment to a reasonable degree. CWCB staff performs a thorough review of the quantification analyses completed by the recommending entity to ensure consistency with accepted standards.

Methodology

BLM staff used the R2Cross methodology to develop the initial ISF recommendation. The R2Cross method is based on a hydraulic model and uses field data collected in a stream riffle (Espegren, 1996). Riffles are most easily visualized as the stream habitat types that would dry up first should streamflow cease. The field data collected consists of streamflow measurements and surveys of channel geometry at a transect and of the longitudinal slope of the water surface.

The field data is used to model three hydraulic parameters: average depth, average velocity, and percent wetted perimeter. Maintaining these hydraulic parameters at adequate levels across riffle habitat types also will maintain aquatic habitat in pools and runs for most life stages of fish and aquatic invertebrates (Nehring, 1979). BLM staff interprets the model results to develop an initial recommendation for summer and winter flows. The summer flow recommendation is based on meeting 3 of 3 hydraulic criteria. The winter flow recommendation is based on meeting 2 of 3 hydraulic criteria. The model's suggested accuracy range is 40% to 250% of the streamflow measured in the field. Recommendations that fall outside of the accuracy range may not give an accurate estimate of the hydraulic parameters necessary to determine an ISF rate.

The R2Cross methodology provides the biological quantification of the amount of water needed for summer and winter periods based on empirical studies of fish species preferences. The recommending

entity uses the R2Cross results and its biological expertise to develop an initial ISF recommendation. CWCB staff then evaluates water availability for the reach typically based on median hydrology (see the Water Availability section below for more details). The water availability analysis may indicate less water is available than the initial recommendation. In that case, the recommending entity either modifies the magnitude and/or duration of the recommended ISF rates if the available flows will preserve the natural environment to a reasonable degree, or withdraws the recommendation.

Data Analysis

R2Cross data was collected at four transects for this proposed ISF reach (Table 2). Results obtained at more than one transect are averaged to determine the R2Cross flow rate for the reach of stream. The R2Cross model results in a summer flow of 4.8 cfs, which meets 3 of 3 criteria and is within the accuracy range of the R2Cross model. The R2Cross model results in a winter flow of 3.9 cfs, which meets 2 of 3 criteria and is within the accuracy range of the R2Cross model.

Table 2. Summary of R2Cross transect measurements and results for lower Terror Creek.

Entity	Date Measured	Streamflow (cfs)	Accuracy Range (cfs)	Winter Rate (cfs)	Summer Rate (cfs)
BLM	9/27/2007	6.13	2.5 – 15.3	4.68	5.15
BLM	9/27/2007	5.73	2.3 – 14.3	4.08	Out of Range
BLM	10/21/2008	2.15	0.9 – 5.4	3.76	4.46
BLM	10/21/2008	1.82	0.7 – 4.5	3.21	Out of Range
			Mean	**3.93**	**4.80**

ISF Recommendation

The BLM recommends flows of 4.2 cfs (4/1 – 5/31) based on R2Cross modeling analyses, biological expertise, and staff's water availability analysis.

4.2 cubic feet per second is recommended for the snowmelt runoff period from April 1 through May 31. This recommendation is driven by limited water availability, but comes close to meeting the wetted perimeter and velocity criteria. Wetting at least 50% of the channel will provide important physical habitat during a time of year when the fish population moves into this reach and completes key life cycle functions. This flow rate will also assist in recharging stream-side aquifers. Storage in and discharge from these aquifers will assist in maintaining the riparian community during the June 1 to December 31 period, when flows are very low because of diversions.

The BLM has not made an instream flow recommendation for the period between June 1 and March 31. Because of diversions from senior water rights, there is insufficient water available in this reach to meet any of the instream flow criteria. If flows do become available because of changes in management

of diversions, the BLM recommends that the CWCB reconsider this stream for an appropriation during the June 1 to March 31 period.

Water Availability

CWCB staff conducts hydrologic analyses for each recommended ISF appropriation to provide the Board with a basis for making the determination that water is available.

Methodology

Each recommended ISF reach has a unique flow regime that depends on variables such as the timing, magnitude, and location of water inputs (such as rain, snow, and snowmelt) and water losses (such as diversions, reservoirs, evaporation and transpiration, groundwater recharge, etc). Although extensive and time-consuming investigations of all variables may be possible, staff takes a pragmatic and cost-effective approach to analyzing water availability. This approach focuses on streamflows and the influence of flow alterations, such as diversions, to understand how much water is physically available in the recommended reach.

Staff's hydrologic analysis is data-driven, meaning that staff gathers and evaluates the best available data and uses the best available analysis method for that data. Whenever possible, long-term stream gage data (period of record 20 or more years) will be used to evaluate streamflow. Other streamflow information such as short-term gages, temporary gages, spot streamflow measurements, diversion records, and StreamStats will be used when long-term gage data is not available. StreamStats, a statistical hydrologic program, uses regression equations developed by the USGS (Capesius and Stephens, 2009) to estimate mean flows for each month based on drainage basin area and average drainage basin precipitation. Diversion records will also be used to evaluate the effect of surface water diversions when necessary. Interviews with water commissioners, landowners, and ditch or reservoir operators can provide additional information. A range of analytical techniques may be employed to extend gage records, estimate streamflow in ungaged locations, and estimate the effects of diversions. The goal is to obtain the most detailed and reliable estimate hydrology using the most efficient analysis technique.

The final product of the hydrologic analysis used to determine water availability is a hydrograph, which shows streamflow and the proposed ISF rate over the course of one year. The hydrograph will show median daily values when daily data is available; otherwise, it will present mean-monthly streamflow values. Staff will calculate 95% confidence intervals for the median streamflow if there is sufficient data.

Basin Characteristics

The proposed ISF reach of Terror Creek has a 29.4 square mile drainage basin. The average elevation of the basin is 8,790 ft and the average annual precipitation is 26.00 inches. The drainage basin tributary to the lower terminus has several surface water diversions with active records (see Table 3). The Overland Ditch can divert from the headwaters of Muddy Creek, Hubbard Creek, Terror Creek,

and Leroux Creek. This ditch appears to be able to divert a maximum of 150 cfs from each basin; however, the total from all basins cannot exceed 150 cfs. Terror Ditch diverts up to 13.50 cfs out of basin just above the proposed ISF reach. Bruce Reservoir, located on the East Fork of Terror Creek, has a decreed volume of 631.99 AF and is used to supplement diversions. The Terror Ditch Extension (appropriation date 1894, 6 cfs; appropriation date 1976, 23 cfs) diverts water from the headwaters of Hubbard Creek into Terror Creek. Due to surface water diversions, transbasin imports and exports, and the reservoir, hydrology in this drainage basin does not represent natural flow conditions.

Table 3. List of diversion structures located within the lower Terror Creek drainage basin.

Name	WDID	Adjudication Date	Appropriation Date	Administration Number	Amount
Overland Ditch	4001739	6/23/1914	8/1/1893	21263.15919	75.00
		8/28/1919	4/10/1919	25301.00000	75.00
Pitkin Mesa Pipeline	4001191	6/17/1889	11/13/1883	12370.00000	0.4850
		1/31/1964	8/13/1961	40767.00000	2.0150
Terror Ditch	4001208	4/12/1901	12/11/1884	14413.12764	6.00
		2/10/1930	5/01/1901	25807.18748	6.00
		3/20/1954	12/11/1884	31924.12764	1.50
Holybee Ditch	4001155	6/17/1989	11/13/1883	12370.00000	0.40
Fire Mt Canal*	4001809	2/10/1930	7/1/1903	25807.19539	70.00
Fawcett Ditch*	4001130	6/17/1889	11/13/1883	12370.00000	0.1150
		3/20/1954	4/15/1944	34438.00000	1.25
		12/31/2005	5/1/1986	56613.49794	0.1250
				Total	237.89

**This diversion is located below the proposed ISF reach, but impacts the Terror Creek gage.*

Available Data

There are two historic gages in the vicinity of the proposed ISF reach. The East Fork Terror Creek below Cottonwood Stomp near Bowie gage (USGS 09132985) is located upstream from the proposed lower terminus. This gage measures streamflow on the East Fork of Terror Creek and therefore is not representative of flow in the ISF reach, which receives tributary inflow from the West Fork of Terror Creek. The Terror Creek at mouth near Bowie, CO gage (USGS 09132995) is located less than a half mile downstream from the proposed lower terminus. The Terror Creek at mouth gage (Terror Creek gage) was operated from 2001 to 2013 and discontinued in 2014 due to funding issues. The Terror Creek gage has a 29.5 square miles drainage basin and is influenced by the same diversions that affect the proposed ISF reach as well as four additional diversions that total 85.39 cfs.

Data Analysis

Due to the short period of record available at the Terror Creek gage, staff took additional steps to evaluate the record. Staff examined other gages in the region in an attempt to find a gage that could be

used to extend the record through regression analysis. However, none of the gages evaluated produced a reasonable regression coefficient and none were found suitable for regression extension.

Staff also examined streamflow gages and climate stations and found that the Paonia climate station (Paonia 1 SW, Station ID USC00056306, downloaded 11/7/2014) has a relatively long period of record and is located about 7 miles from the lower terminus. The average annual precipitation at the Paonia Station for the period of record (1893 to 1930, 1957 to 2014) is 15.14 inches. During the 13 years the Terror Creek gage operated (2001 to 2013), only two years (2005 and 2007) had above average precipitation at the Paonia Station and all others were below average. Therefore, the Terror Creek gage record likely represents below average streamflow conditions and likely underestimates the amount of water typically available in this drainage.

The Terror Creek gage was analyzed using the approved period of record (6/28/2001 to 12/10/2013) available through HydroBase on 5/20/2014. The gage record was not scaled because there was negligible difference (0.2%) in drainage basin area between the lower terminus and the gage location. The diversions from Fawcett Ditch were added to the gage record because these flows are available in the proposed ISF reach, but do not reach the gage. 95% confidence intervals were not calculated due to the short period of record at the Terror Creek gage.

Water Availability Summary

The hydrographs (Figure 1 and 2) show the median streamflow based on the adjusted Terror Creek gage record. The proposed ISF is less than the median adjusted streamflow. Staff has concluded that water is available for appropriation.

Material Injury

Because the proposed ISF on Terror Creek is a new junior water right, the ISF can exist without material injury to other water rights. Under the provisions of section 37-92-102(3)(b), C.R.S. (2014), the CWCB will recognize any uses or exchanges of water in existence on the date this ISF water right is appropriated.

Citations

Capesius, J.P. and V.C. Stephens, 2009, Regional regression equations for estimation of natural streamflow statistics in Colorado, Scientific Investigations Report 2009-5136.

Espegren, G.D., 1996, Development of Instream Flow Recommendations in Colorado Using R2CROSS, Colorado Water Conservation Board.

Nehring, B.R., 1979, Evaluation of Instream Flow Methods and Determination of Water Quantity Needs for Streams in the State of Colorado, Colorado Division of Wildlife.

Metadata Descriptions

The UTM locations for the upstream and downstream termini were derived from CWCB GIS using the National Hydrography Dataset (NHD).

Projected Coordinate System: NAD 1983 UTM Zone 13N.

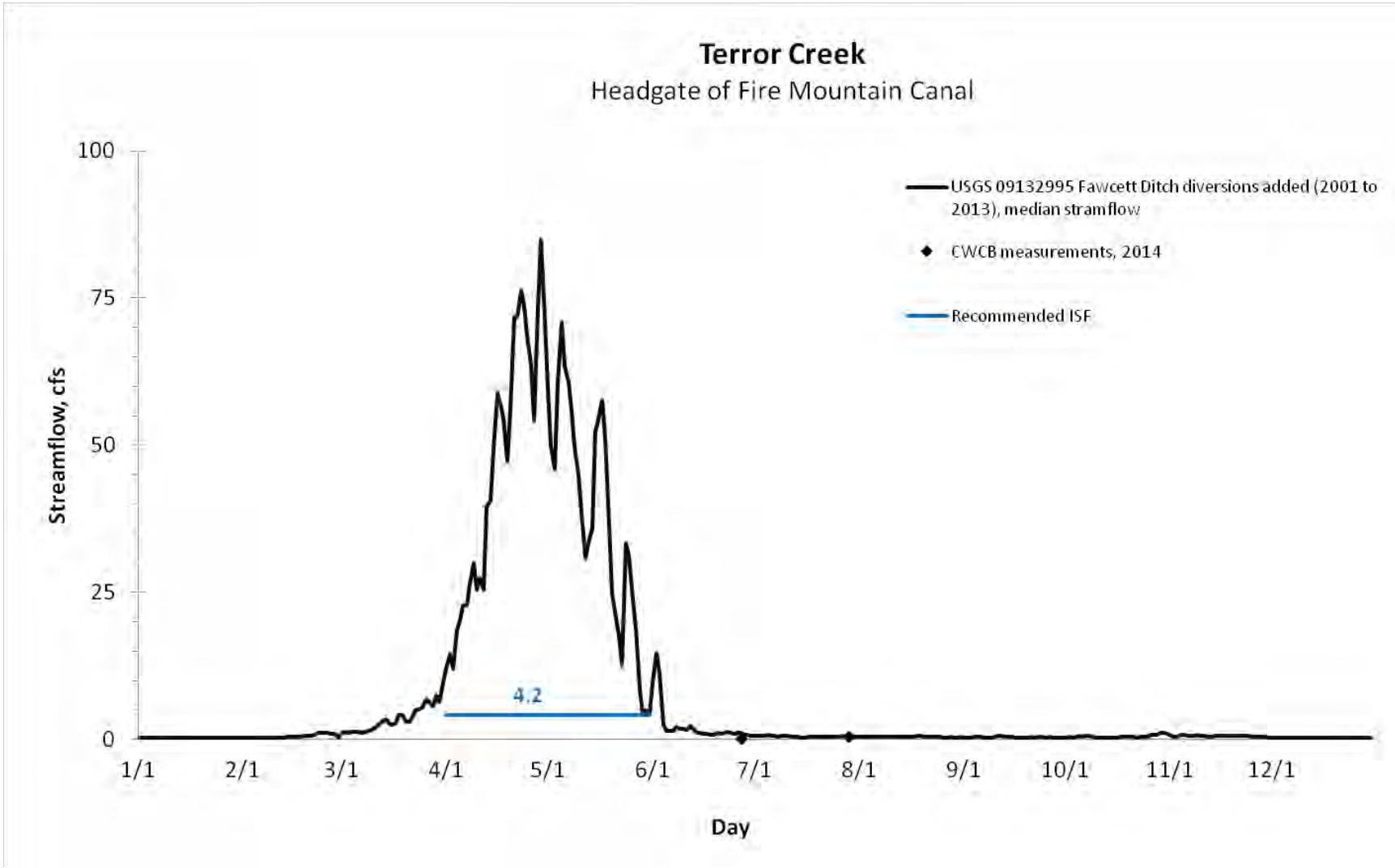


Figure 1. Complete hydrograph showing streamflow data and the proposed ISF rate on lower Terror Creek.

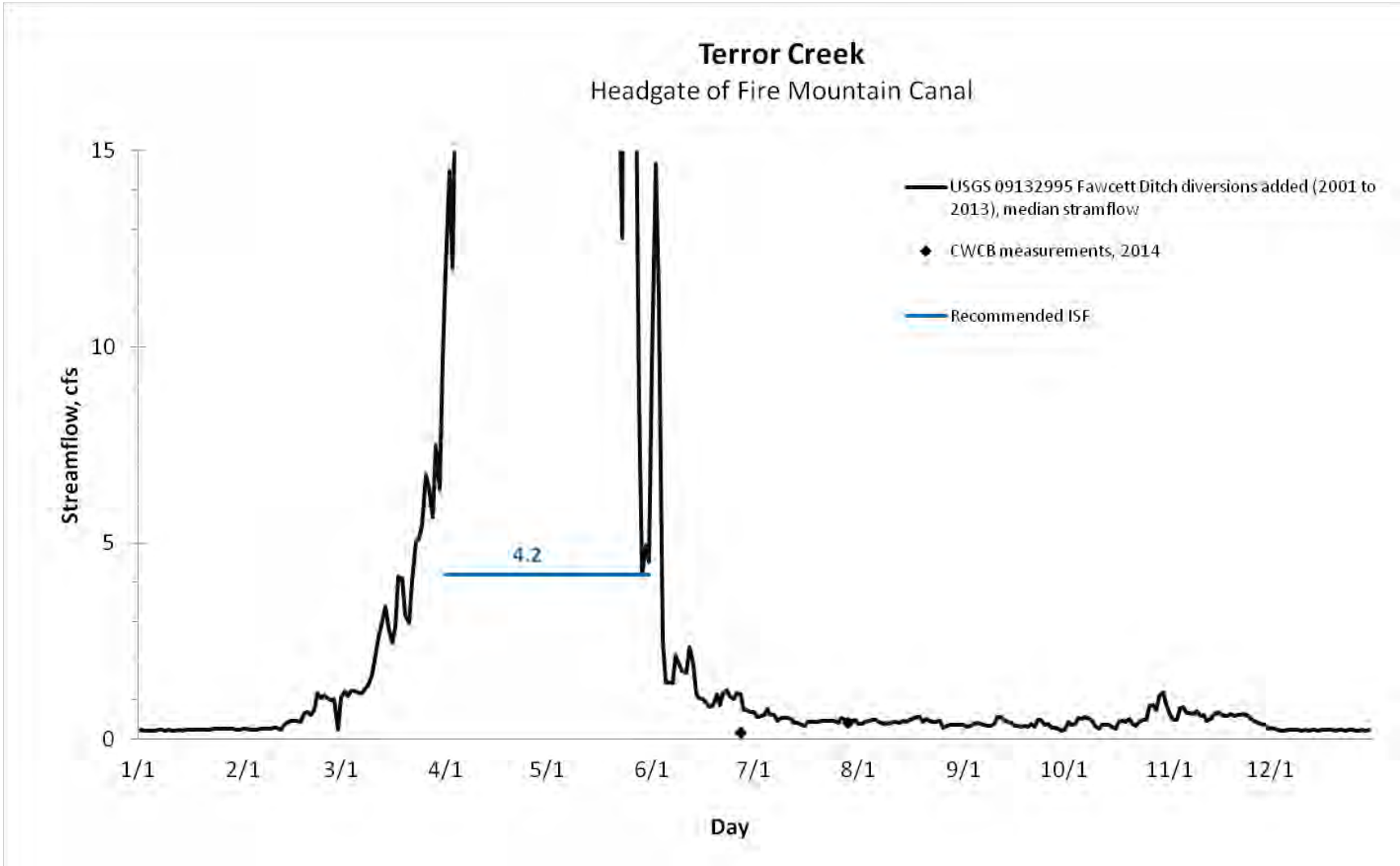
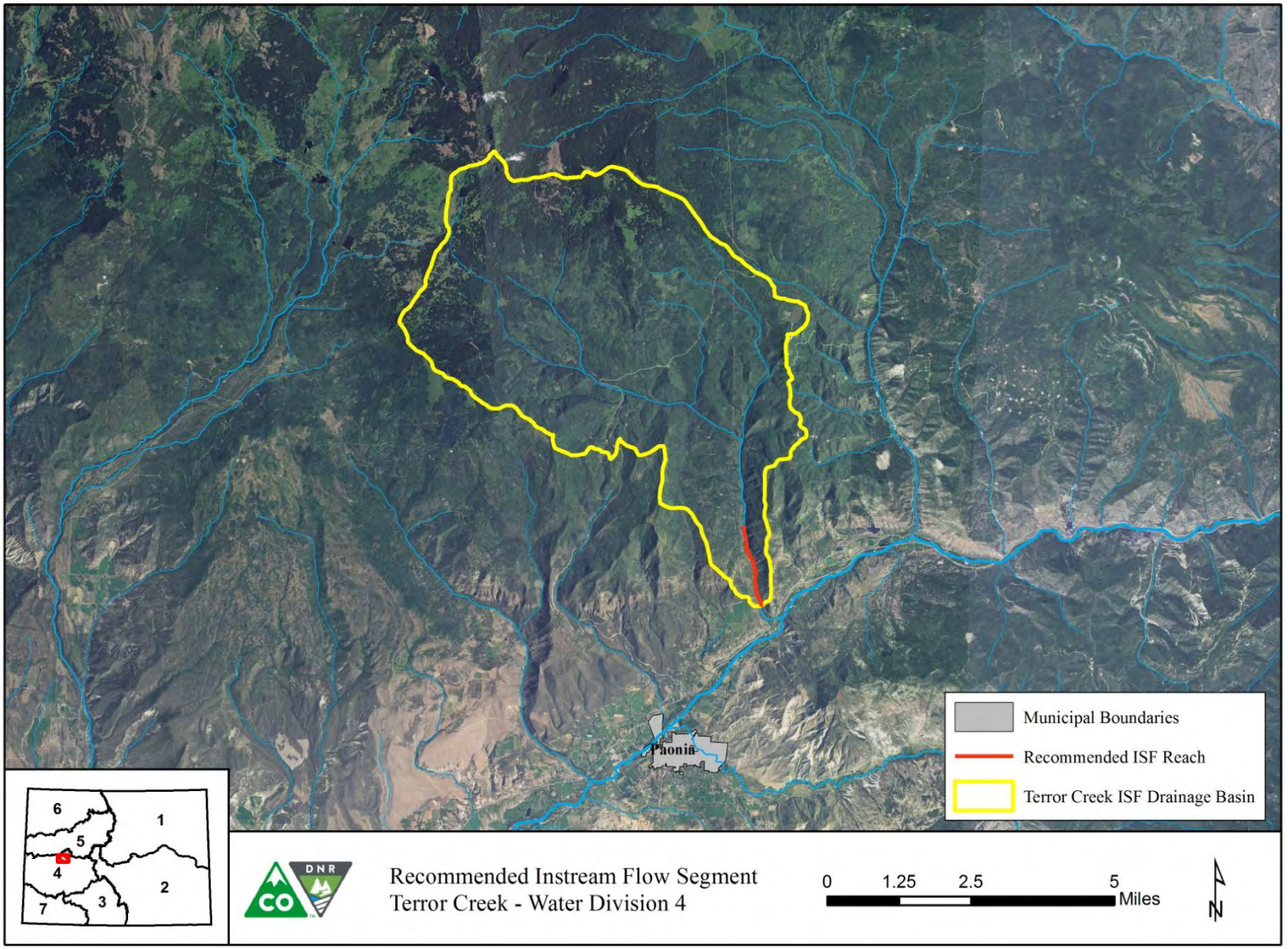
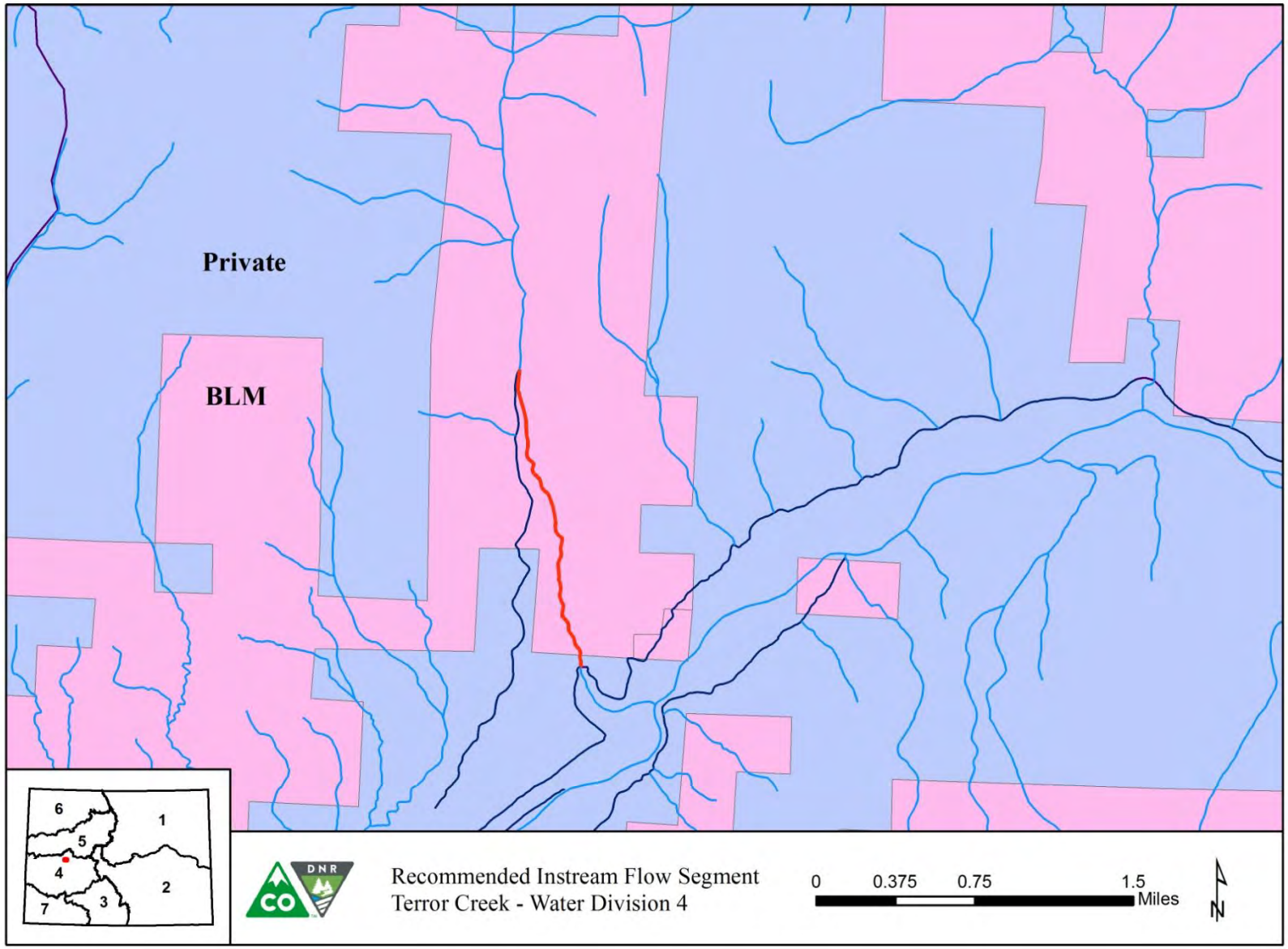


Figure 2. Detailed hydrograph showing streamflow data and the proposed ISF rate on lower Terror Creek.

Vicinity Map



Land Use Map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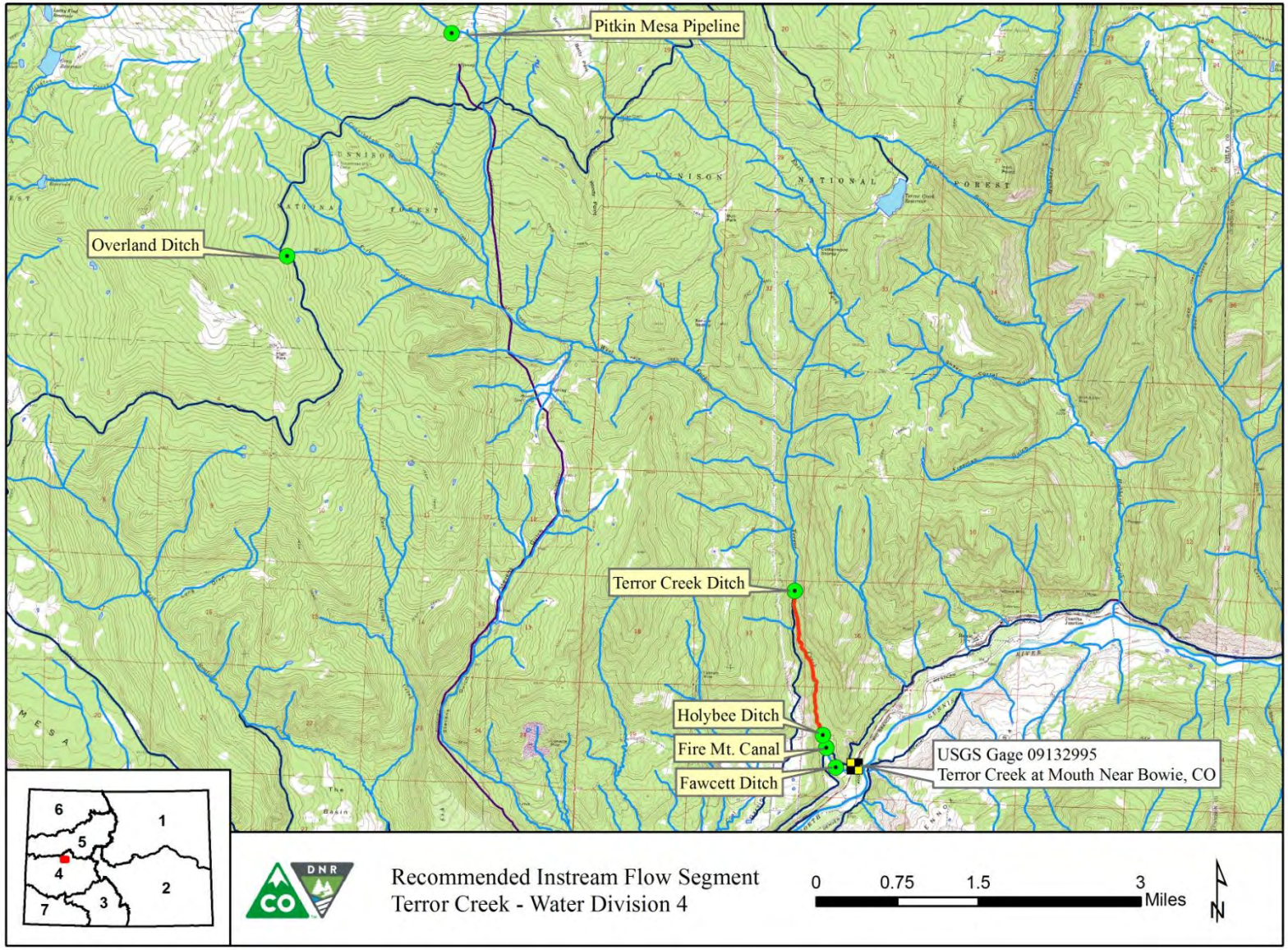

Exhibit 4

RULES CONCERNING THE COLORADO INSTREAM FLOW AND NATURAL LAKE LEVEL PROGRAM

Adopted by the
Colorado Water Conservation Board
January 27, 2009

Statement of Basis and Purpose

In 1973, the General Assembly enacted Senate Bill 97, creating the Colorado Instream Flow and Natural Lake Level Program ("ISF Program"), to be administered by the Colorado Water Conservation Board ("Board"). The statutory authority for these Rules is found at sections 37-60-108 and 37-92-102(3), C.R.S. (2008). The purpose of these Rules, initially adopted in 1993, is to codify and establish procedures for the Board to implement the ISF Program.

The Board has amended the Rules several times since 1993 to reflect changes in the statutes related to the ISF Program. Notably, in 1999, the Board repealed the existing Rule 5 in its entirety, and, among other things, adopted a new Rule 5 to establish a public notice and comment process for instream flow water right appropriations. In 2003, the Board amended Rule 6 to implement the provisions of Senate Bill 02-156 by identifying factors that the Board will consider when determining whether to acquire water, water rights, or interests in water, and by establishing procedures for notice, public input, and, if necessary, hearings. In 2004, the Board amended Rule 6 to implement House Bill 03-1320, codified at section 37-83-105, C.R.S. (2003), to allow for emergency loans of water for instream flows. The Board also amended Rule 6 to enable the Board to finalize an acquisition within a two-meeting time frame, if necessary. In 2005, the Board amended Rule 6 to implement House Bill 05-1039, establishing how the Board and its staff will respond to offers of water for temporary instream flow use and expedite use of loaned water for instream flow purposes.

In 2009, the Board amended Rule 6 to adopt criteria specified in House Bill 08-1280 (codified at sections 37-92-102(3), 37-92-103 and 37-92-305, C.R.S.) for evaluating proposed leases or loans of water, and to incorporate H.B. 1280's requirements for: (1) specific conditions that must be met as part of the CWCB's approval of a proposed loan or lease of water; (2) provisions that must be included in all agreements for loans or leases of water under section 37-92-102(3); and (3) actions that the Board must take in connection with loans or leases of water. Rule 6 does not incorporate those provisions of H.B. 1280 that direct the water courts or the Division of Water Resources to take certain actions in regard to water acquisitions by the Board for instream flow use.

Specifically, the 2009 Rules 6a., 6c., 6e, 6j., 6k., 6l., and 6m. clarify the Board's evaluation process, Board funding for water leases and purchases, and public input for proposed acquisitions of water, water rights or interests in water for instream flow use. Rule 6f. identifies additional factors for loans and leases of water, and Rules 6g. and 6h. describe recording requirements and water reuse provisions to be included in contracts or agreements for water acquisitions. Rule 6i. incorporates H.B 1280's requirements regarding water court applications filed by the Board to obtain a decreed right to use acquired water for instream flow purposes. Regarding the historical consumptive use quantification referred to in Rule 6i.(1), the Board will not object to a water rights owner requesting a term and condition from the water court that the historical consumptive use determination shall not apply to the water right at the expiration of the lease or loan.

In 2009, the Board also amended Rules 8e.—h. (De Minimis Rule) to recognize priority administration of the CWCB's instream flow water rights and clarify that the

decision not to file a statement of opposition under this Rule does not constitute: (1) acceptance by the CWCB of injury to any potentially affected instream flow water right; or (2) a waiver of the CWCB's right to place an administrative call for any instream flow water right. Rule 8e.(1) sets forth what type of notice the CWCB will provide to water court applicants and to the Division Engineer when it elects not to file a statement of opposition to a water court application under this Rule.

Finally, in 2009, the Board amended Rule 8i.(3) (Injury Accepted with Mitigation) to provide notice to water users of: (1) the information they must submit to the CWCB when requesting that the CWCB enter into a pretrial resolution under which it will accept injury with mitigation; (2) the factors the CWCB will consider in evaluating an injury with mitigation proposal; and (3) the terms and conditions the CWCB will require in decrees incorporating injury with mitigation.

In general, it is the policy of the CWCB to consider injury with mitigation proposals only when no other reasonable water supply alternatives can be implemented. Exceptions to the policy may be granted when the proponent can demonstrate that the proposed mitigation will result in significant and permanent enhancements to the natural environment of the subject stream or lake existing at the time the proponent proposes the injury with mitigation.

DEPARTMENT OF NATURAL RESOURCES

Colorado Water Conservation Board

RULES CONCERNING THE COLORADO INSTREAM FLOW AND NATURAL LAKE LEVEL PROGRAM

2 CCR 408-2

1. TITLE.

Rules Concerning the Colorado Instream Flow and Natural Lake Level Program, hereafter referred to as the Instream Flow ("ISF") Program as established in §37-92-102 (3) C.R.S., shall be hereinafter referred to as the "ISF Rules."

2. PURPOSE OF RULES.

The purpose of the ISF Rules is to set forth the procedures to be followed by the Board and Staff when implementing and administering the ISF Program. By this reference, the Board incorporates the Basis and Purpose statement prepared and adopted at the time of rulemaking. A copy of this document is on file at the Board office.

3. STATUTORY AUTHORITY.

The statutory authority for the ISF Rules is found at §37-60-108, C.R.S. and §37-92-102 (3), C.R.S. Nothing in these rules shall be construed as authorizing the Board to deprive the people of the state of Colorado of the beneficial use of those waters available by law and interstate compact.

4. DEFINITIONS.

4a. Agenda Mailing List.

The agenda mailing list consists of all Persons who have sent a notice to the Board Office that they wish to be included on such list. These Persons will be mailed a Board meeting agenda prior to each scheduled Board meeting.

4b. Board.

Means the Colorado Water Conservation Board as defined in §§37-60-101, 103 and 104, C.R.S.

4c. Board Office.

The Colorado Water Conservation Board's office is located at 1313 Sherman Street, 7th Floor, Denver, CO 80203. The phone number is (303) 866-3441. The facsimile number is (303) 866-4474. The Board's website is http://www.cwcb.state.co.us.

4d. Contested Hearing Mailing List.

The Contested Hearing Mailing List shall consist of all Persons who have received Party status or Contested Hearing Participant status pursuant to Rules 5l. or 5m. This mailing list is specific to a contested appropriation.

4e. Contested Hearing Participant.

Any Person who desires to participate in the contested ISF process, but not as a Party, may obtain Contested Hearing Participant status pursuant to Rule 5m. A Person with such status will receive all Party documents. Contested Hearing Participants may comment on their own behalf, but may not submit for the record technical evidence, technical witnesses or legal memoranda.

4f. CWCB Hearing Officer.

The Hearing Officer is appointed by the Board and is responsible for managing and coordinating proceedings related to contested ISF appropriations, acquisitions or modifications, such as setting prehearing conferences and adjusting deadlines and schedules to further the Parties' settlement efforts or for other good cause shown. The Hearing Officer does not have the authority to rule on substantive issues.

4g. Final Action.

For purposes of Rule 5, final action means a Board decision to (1) file a water right application, (2) not file a water right application or (3) table action on an ISF appropriation; however, tabling an action shall not be construed as abandonment of its intent to appropriate.

4h. Final Staff ISF Recommendation.

Staff's ISF recommendation to the Board is based on Staff's data and report, and public comments and data contained in the official record.

4i. ISF.

Means any water, or water rights appropriated by the Board for preservation of the natural environment to a reasonable degree, or any water, water rights or interests in water acquired by the Board for preservation or improvement of the natural environment to a reasonable degree. “ISF” includes both instream flows between specific points on a stream and natural surface water levels or volumes for natural lakes.

4j. ISF Subscription Mailing List(s).

The ISF Subscription Mailing List(s) are specific to each water division. The ISF Subscription Mailing List(s) shall consist of all Persons who have subscribed to the list(s) by sending notice(s) to the Board Office that they wish to be included on such list for a particular water division. The Staff shall, at such times as it deems appropriate, mail to all Persons on the water court resume mailing list in each water division an invitation to be included on the ISF Subscription Mailing List for that water division. Persons on the list are responsible for keeping Staff apprised of address changes. Persons on the ISF Subscription Mailing List(s) shall receive agendas and other notices describing activities related to ISF recommendations, appropriations and acquisitions in the particular water division. Persons may be required to pay a fee in order to be on the ISF Subscription Mailing List(s).

4k. Mail.

For the purposes of the ISF Rules, mail refers to regular or special delivery by the U.S. Postal Service or other such services, electronic delivery (e-mail), or delivery by FAX transmission.

4l. Party.

Any Person may obtain Party status pursuant to Rule 5l. Only a Person who has obtained Party status may submit, for the record, technical evidence, technical witnesses or legal memoranda. Each Party is responsible for mailing copies of all documents to all other Parties and Contested Hearing Participants.

4m. Person.

Means any human being, partnership, association, corporation, special district, water conservancy district, water conservation district, municipal entity, county government, state government or agency thereof, and federal government or agency thereof.

4n. Proper Notice.

Means the customary public notice procedure that is provided each year by the Board in the preamble to the Board's January Board meeting agenda. This customary public notice procedure may include posting of the agenda at the Board office, filing legal notices when required, mailing to Persons on the Board mailing lists and posting notices on the Board's website.

4o. Stacking.

As used in Rule 6, the terms “stack” or “stacking” refer to an instance in which the Board holds more than one water right for the same lake or reach of stream and exercises the rights independently according to their decrees.

4p. Staff.

Means the Director of the Colorado Water Conservation Board (“CWCB Director”) and other personnel employed by the Board.

5. ORIGINAL APPROPRIATION PROCEDURE.

5a. Recommendation of Streams and Lakes for Protection.

All Persons interested in recommending certain stream reaches or natural lakes for inclusion in the ISF Program may make recommendations to the Board or Staff at any time. Staff will provide a preliminary response to any Person making such a recommendation within 30 working days after receipt of the recommendation at the Board Office. Staff will collaborate with State and Federal agencies and other interested Persons to plan and coordinate collection of field data necessary for development of ISF recommendations. The Staff shall advise the Board, at least annually, of all new recommendations received and of streams and lakes being studied for inclusion in the ISF Program.

5b. Method of Making Recommendations.

All recommendations transmitted to the Board or Staff for water to be retained in streams or lakes to preserve the natural environment to a reasonable degree must be made with specificity and in writing.

5c. Board Approval Process.

Periodically, after studying streams and lakes for inclusion in the ISF Program, Staff will recommend that the Board appropriate ISF rights. The Board and Staff will use the following annual schedule for initiating, processing and appropriating ISF water rights:

January

- The January Board meeting agenda will list proposed ISF appropriations to be appropriated that year.

- Staff will provide data, engineering and other information supporting each proposed ISF appropriation to the Board prior to or at the January Board meeting.

- Staff will present its information and recommendation for each proposed ISF appropriation at the January Board meeting.

- The Board will take public comment on the proposed ISF appropriations at the January Board meeting.

- The Board may declare its intent to appropriate for each proposed ISF appropriation at the January Board meeting, provided that the particular ISF appropriation has been listed as being under consideration in a notice, mailed at least 60 days prior to the January Board meeting, to the ISF Subscription Mailing List for the relevant water division(s).

- Notice of the Board having declared its intent to appropriate will be distributed through the ISF Subscription Mailing List for the relevant water division(s).

March

- The Board will take public comment on all ISF appropriations at the March Board meeting.

- Notice to Contest an ISF appropriation, pursuant to Rule 5k, must be submitted to the Board Office by March 31st, or the first business day thereafter.

April

- Staff will notify all Persons on the ISF Subscription Mailing List(s) of contested ISF appropriations by April 10th, or the first business day thereafter.

- Notice of Party status or Contested Hearing Participant status, pursuant to Rules 5l. or 5m., must be submitted to the Board Office by April 30th, or the first business day thereafter.

May

- Staff will report to the Board which ISF appropriations are being contested.

- The Board may set hearing dates for contested ISF appropriations.

- At the May Board meeting, the Board may take final action on all uncontested ISF appropriations.

July

- A prehearing conference will be held prior to the July Board meeting for all contested ISF appropriations (Date specific to be determined by the Hearing Officer).

- Five working days before the prehearing conference, all Parties shall file at the Board office, for the record, any and all legal memoranda, engineering data, biological data and reports or other information upon which the Party will rely.

August

- All Parties must submit written rebuttal statements, including testimony and exhibits, by August 15th, or the first business day thereafter. Except for such rebuttal and testimony provided at the hearing pursuant to Rule 5p.(2), the Board will not accept any statements,

related documentation or exhibits submitted by any Party after the prehearing conference, except for good cause shown or as agreed upon by the Parties.

September

- Staff will make its final recommendations to the Board, based upon its original report, all public comments, documents submitted by the Parties and all data contained in the official record, at the September Board meeting.
- Notice of the Final Staff ISF Recommendations will be sent to all Persons on the Contested Hearing Mailing List prior to the September Board meeting.
- Parties may choose to continue or withdraw their Notice to Contest an ISF appropriation at or before the September Board Meeting.
- The Board will hold hearings on all contested ISF appropriations.

November

- The Board shall update the public on the results of any hearings through its agenda and may take final action on contested ISF appropriations.

When necessary, the Board may modify or delay this schedule or any part thereof as it deems appropriate.

5d. Board's Intent to Appropriate.

Notice of the Board's potential action to declare its intent to appropriate shall be given in the January Board meeting agenda and the Board will take public comment regarding its intent to appropriate at the January meeting.

(1) After reviewing Staff's recommendations for proposed ISF appropriations, the Board may declare its intent to appropriate specific ISF water rights. At that time, the Board shall direct the Staff to publicly notice the Board's declaration of its intent to appropriate.

(2) After the Board declares its intent to appropriate, notice shall be published in a mailing to the ISF Subscription Mailing Lists for the relevant water divisions and shall include:

(a) A description of the appropriation (e.g. stream reach, lake location, amounts, etc.);

(b) Availability (time and place) for review of Summary Reports and Investigations Files for each appropriation; and,

(c) Summary identification of any data, exhibits, testimony or other information in addition to the Summary Reports and Investigations Files supporting the appropriation.

(3) Published notice shall also contain the following information:

(a) The Board may change flow amounts of contested ISF appropriations based on information received during the public notice and comment period.

(b) Staff will maintain, pursuant to Rule 5e.(3), an ISF Subscription Mailing List for each water division composed of the names of all Persons who have sent notice to the Board Office that they wish to be included on such list for a particular water division. Any Person

desiring to be on the ISF Subscription Mailing List(s) must send notice to the Board Office.

(c) Any meetings held between Staff and members of the public will be open to the public. Staff may provide Proper Notice prior to any such meetings and may provide notice to Persons on the ISF Subscription Mailing List(s).

(d) Any Notice to Contest must be received at the Board office no later than March 31st, or the first business day thereafter. All Notices of Party status and Contested Hearing Participant status must be received at the Board office no later than April 30th, or the first business day thereafter.

(e) Staff will announce its Final Staff ISF Recommendation concerning contested appropriations at the September Board meeting and will send notice of the Final Staff ISF Recommendations to all Persons on the Contested Hearing Mailing List.

(f) The Board may take final action on any uncontested ISF appropriations at the May Board meeting.

(4) After the Board declares its intent to appropriate, notice of the Board's action shall be mailed within five working days to the County Commissioners of the county(ies) in which the proposed reach or lake is located.

(5) Final action by the Board on ISF appropriations will occur no earlier than the May Board meeting.

5e. Public Comment.

(1) The Board will hear comment on the recommended action to declare its intent to appropriate at the January Board Meeting.

(2) ISF appropriations will be noticed in the Board agenda for each regularly scheduled subsequent meeting until the Board takes final action. Prior to March 31st, at each regularly scheduled Board meeting, time will be allocated for public comment. Subsequent to March 31st, the Board will accept public comment on any contested ISF appropriations or lake levels only at the hearings held on those appropriations pursuant to Rule 5j.

(3) Staff will maintain an ISF Subscription Mailing List for each water division. Any Person desiring to receive information concerning proposed ISF appropriations for that water division must contact the Board Office to request inclusion on that ISF Subscription Mailing List.

5f. Date of Appropriation.

The Board may select an appropriation date that may be no earlier than the date the Board declares its intent to appropriate. The Board may declare its intent to appropriate when it concludes that it has received sufficient information that reasonably supports the findings required in Rule 5i.

5g. Notice.

Agenda and ISF Subscription Mailing List(s) notice shall be given pursuant to Rule 5d. and the public shall be afforded an opportunity to comment pursuant to Rule 5e. Notice of the date of final action on uncontested ISF appropriations shall be mailed to Persons on the ISF Subscription Mailing Lists for the relevant water divisions, maintained pursuant to Rule 5e.(3).

5h. Final Board Action on an ISF Appropriation.

The Board may take final action on any uncontested ISF appropriation(s) at the May Board meeting or any Board meeting thereafter. If a Notice to Contest has been filed, the Board shall proceed under Rules 5j. - 5q.

5i. Required Findings.

Before initiating a water right filing to confirm its appropriation, the Board must make the following determinations:

(1) Natural Environment.

That there is a natural environment that can be preserved to a reasonable degree with the Board's water right if granted.

(2) Water Availability.

That the natural environment will be preserved to a reasonable degree by the water available for the appropriation to be made.

(3) Material Injury.

That such environment can exist without material injury to water rights.

These determinations shall be subject to judicial review in the water court application and decree proceedings initiated by the Board, based on the Board's administrative record and utilizing the criteria of §§24-4-106(6) and (7), C.R.S.

5j. Procedural Rules for Contested ISF Appropriations.

(1) Whenever an ISF appropriation is contested, the Board shall hold a hearing at which any Party may present evidence, witnesses and arguments for or against the appropriation and any Contested Hearing Participant or member of the public may comment. The hearing shall be a notice and comment hearing as authorized in §37-92-102(4)(a), C.R.S., and shall not be a formal agency adjudication under §24-4-105, C.R.S.

(2) These rules are intended to assure that information is received by the Board in a timely manner. Where these rules do not address a procedure or issue, the Board shall determine the procedures to be followed on a case-by-case basis. The Board may waive the requirements of these rules whenever the Board determines that strict adherence to the rules is not in the best interests of fairness, unless such waiver would violate applicable statutes. For any such waiver, the Board shall provide appropriate justification, in writing, to Persons who have Party or Contested Hearing Participant status.

(3) In a hearing on a contested ISF appropriation, a Party may raise only those issues relevant to the statutory determinations required by §37-92-102(3)(c), C.R.S. and the required findings in Rule 5i.

5k. Notice to Contest.

(1) To contest an ISF appropriation, a Person must comply with the provisions of this section. The Board must receive a Notice to Contest the ISF appropriation by March 31st, or the first business day thereafter.

(2) A Notice to Contest an ISF appropriation shall be made in writing and contain the following information:

(a) Identification of the Person(s) requesting the hearing;

(b) Identification of the ISF appropriation(s) at issue; and,

(c) The contested facts and a general description of the data upon which the Person will rely to the extent known at that time.

(3) After a Party has filed a Notice to Contest an ISF appropriation, any other Person may participate as a Party or a Contested Hearing Participant pursuant to Rules 5l. or 5m.

(4) Staff will notify all Persons on the relevant ISF Subscription Mailing List(s) of contested ISF appropriations by April 10th, or the first business day thereafter.

5l. Party Status.

(1) Party status will be granted to any Person who timely files a Notice of Party Status with the Staff. Any Person filing a Notice to Contest shall be granted Party status and need not also file a Notice of Party Status. A Notice of Party status must be received by April 30th, or the first business day thereafter. A Notice of Party status shall set forth a brief and plain statement of the reasons for obtaining Party status, the contested facts, the matters that the Person claims should be decided and a general description of the data to be presented to the Board. The Board will have discretion to grant or deny Party status to any Person who files a Notice of Party Status after April 30th or the first business day thereafter, for good cause shown.

(2) Only a Party may submit for the record technical evidence, technical witnesses or file legal memoranda. Each Party is responsible for mailing copies of all documents submitted for Board consideration to all other Parties and Contested Hearing Participants.

(3) The Staff shall automatically be a Party in all proceedings concerning contested ISF appropriations.

(4) Where a contested ISF appropriation is based fully or in part on another agency's recommendation pursuant to Rule 5a., that agency shall automatically be a Party in any proceeding.

(5) All Parties, whether they achieved such status by filing a Notice to Contest or a Notice of Party Status, shall be afforded the same rights in the contested ISF appropriation proceedings. Specifically, but without limiting the generality of the foregoing sentence, any Person who filed a Notice of Party Status is entitled to raise issues not raised by any Person who filed a Notice to Contest.

5m. Contested Hearing Participant Status.

(1) Any Person who desires to participate in the process, but not as a Party, may obtain Contested Hearing Participant status by filing a notice thereof at the Board Office prior to April 30th. A Person with such status will receive all Party documents specific to the contested appropriation. Contested Hearing Participants may comment on their own behalf, but may not submit for the record technical evidence, technical witnesses or legal memoranda. The Board will have discretion to grant or deny Contested Hearing Participant status to any Person who filed a Notice of Contested Hearing Participant Status after April 30th or the first business day thereafter, for good cause shown.

(2) The request for Contested Hearing Participant status must be received by April 30th, or the first business day thereafter.

(3) Staff shall notify all Parties and Contested Hearing Participants of the list of Contested Hearing Participants prior to May 31st. Thereafter, Parties shall also mail their prehearing statements and any other documents to Contested Hearing Participants.

5n. <u>Prehearing Conference.</u>

(1) The Board will designate a Hearing Officer, who shall schedule and preside over prehearing conferences and assist the Parties with procedural matters, such as setting prehearing conferences and adjusting deadlines and schedules to further the Parties' settlement efforts or for other good cause shown. All prehearing conferences will be scheduled and held prior to the July Board meeting.

(2) On or before five working days before the prehearing conference, each Party shall file 25 copies of its prehearing statement with the Board, and provide an electronic version when possible. The prehearing statement shall identify all exhibits, engineering data, biological data and reports or other information that the Party will rely upon at the hearing and shall contain:

(a) A specific statement of the factual and legal claims asserted (issues to be resolved) and the legal basis upon which the Party will rely;

(b) Copies of all exhibits to be introduced at the hearing;

(c) A list of witnesses to be called and a brief description of their testimony;

(d) Any alternative proposal to the proposed ISF appropriation;

(e) All written testimony to be offered into evidence at the hearing;

and

(f) Any legal memoranda.

Each Party shall deliver a copy of its prehearing statement to all other Parties, Contested Hearing Participants, the Hearing Officer and directly to the Assistant Attorneys General representing Staff and the Board five working days before the prehearing conference. The Board will not consider information, other than rebuttal statements and testimony provided at the hearing pursuant to Rule 5p.(2), submitted by the Parties after this deadline except for good cause shown or as agreed upon by the Parties.

(3) Any Contested Hearing Participant may also submit written comments 5 working days prior to the prehearing conference. Contested Hearing Participants who submit written comments for the Board's consideration shall provide 25 copies to the Board, and a copy to all other Contested Hearing Participants, Parties, the Hearing Officer and the Assistant Attorneys General representing Staff and Board, and provide an electronic version when possible.

(4) The prehearing conference will afford the Parties the opportunity to address such issues as time available for each Party at the hearing, avoiding presentation of duplicative information, consolidation of concerns, etc. The Parties may formulate stipulations respecting the issues to be raised, witnesses and exhibits to be presented, and/or any other matters which may be agreed to or admitted by the Parties. At the prehearing conference, the Parties shall make known any objections to the procedures or evidence that they may raise at the hearing unless such objections could not have been reasonably determined at that time.

(5) August 15th, or the first business day thereafter, is the last day for submission of written rebuttal statements, including testimony, legal memoranda, and exhibits. Twenty-five copies of such

materials must be provided to the Board, and an electronic version also provided, when possible. Except for such rebuttal and testimony provided at the hearing pursuant to Rule 5p.(2), the Board will not accept any statements, related documentation or exhibits submitted by any Party after the deadline set forth in Rules 5n.(2) and 5n.(3), except for good cause shown or as agreed upon by the Parties. The scope of rebuttal is limited to issues and evidence presented in the prehearing statements. Any documentation to be submitted pursuant to this subsection (5) shall be delivered to the Board and mailed to all Parties and Contested Hearing Participants by August 15th, or the first business day thereafter, unless the Parties agree otherwise.

5o. Notice of Hearings on Contested ISF Appropriations.

(1) Staff shall mail notice of prehearing conference(s) on contested ISF appropriations to all Persons on the Contested Hearing Mailing List for the particular ISF appropriation. The notice shall specify the time and place of the prehearing conference and any procedural requirements that the Board deems appropriate.

(2) The Board may postpone a hearing to another date by issuing written notice of the postponement no later than 7 calendar days prior to the original hearing date.

5p. Conduct of Hearings.

(1) In conducting any hearing, the Board shall have authority to: administer oaths and affirmations; regulate the course of the hearing; set the time and place for continued hearing; limit the number of technical witnesses; issue appropriate orders controlling the subsequent course of the proceedings; and take any other action authorized by these Rules.

(2) At the hearing, the Board shall hear arguments, concerns or rebuttals from Parties, Contested Hearing Participants and interested members of the public. The Board may limit testimony at the hearing. Without good cause, the Board will not permit Parties or Contested Hearing Participants to introduce written material at the hearing not previously submitted pursuant to these Rules. The Board, in making its determinations, need not consider any written material not timely presented.

(3) Only the Board may question witnesses at the hearing except where the Board determines that, for good cause shown, allowing the parties to question witnesses may materially aid the Board in reaching its decision, or where such questioning by the Parties relates to the statutory findings required by §37-92-102(3)(c), C.R.S. The Board may terminate questioning where the Board determines that such questioning is irrelevant or redundant or may terminate such questioning for other good cause.

(4) The hearing shall be recorded by a reporter or by an electronic recording device. Any Party requesting a transcription of the hearing shall be responsible for the cost of the transcription.

5q. Final Board Action.

The Board may take final action at the hearing or at a later date.

5r. Statement of Opposition.

In the event that any Person files a Statement of Opposition to an ISF water right application in Water Court, the Staff may agree to terms and conditions that would prevent injury. Where the resolution of the Statement of Opposition does not involve a change regarding the Board's determinations under Rule 5i. (including but not limited to the amount, reach, and season), the Board is not required to review and ratify the resolution. Staff may authorize its counsel to sign any court documents necessary to finalize this type of pretrial resolution without Board ratification.

5s. Withdrawal of Filing.

If the Board elects to withdraw a Water Court filing, notice shall be given in the agenda of the Board meeting at which the action is expected to occur.

6. ACQUISITION OF WATER, WATER RIGHTS OR INTERESTS IN WATER FOR INSTREAM FLOW PURPOSES.

The Board may acquire water, water rights, or interests in water for ISF purposes by the following procedures:

6a. Means of Acquisition.

The Board may acquire, by grant, purchase, donation, bequest, devise, lease, exchange, or other contractual agreement, from or with any Person, including any governmental entity, such water, water rights, or interests in water that are not on the Division Engineer's abandonment list in such amounts as the Board determines are appropriate for stream flows or for natural surface water levels or volumes for natural lakes to preserve or improve the natural environment to a reasonable degree.

6b. 120 Day Rule.

At the request of any Person, including any governmental entity, the Board shall determine in a timely manner, not to exceed one hundred twenty days, unless further time is granted by the requesting Person, what terms and conditions the Board will accept in a contract or agreement for the acquisition. The 120-day period begins on the day the Board first considers the proposed contract or agreement at a regularly scheduled or special Board meeting.

6c. Stacking Evaluation.

The Board shall evaluate whether to combine or stack the acquired water right with any other ISF appropriation or acquisition, based upon the extent to which the acquired water will provide flows or lake levels to preserve or improve the natural environment to a reasonable degree.

If the Board elects to combine or stack the acquired water right, the details of how the water rights are to be combined or stacked with other existing ISF appropriations or acquisitions must be set forth in the application for a decree to use the acquired right for instream flow purposes.

6d. Enforcement of Acquisition Agreement.

Pursuant to section 37-92-102(3), C.R.S., any contract or agreement executed between the Board and any Person which provides water, water rights, or interests in water to the Board shall be enforceable by either party thereto as a water matter in the water court having jurisdiction over the water right according to the terms of the contract or agreement.

6e. Appropriateness of an Acquisition.

The Board shall evaluate the appropriateness of any acquisition of water, water rights, or interests in water to preserve or improve the natural environment. Such evaluation shall include, but need not be limited to consideration of the following factors:

(1) The reach of stream or lake level for which the use of the acquired water is proposed, which may be based upon any one or a combination of the following: the historical location of return flow; the length of the existing instream flow reach, where applicable; whether an existing instream flow water right relies on return flows from the water right proposed for acquisition; the environment to

be preserved or improved by the proposed acquisition; or such other factors the Board may identify;

(2) The natural flow regime;

(3) Any potential material injury to existing decreed water rights;

(4) The historical consumptive use and historical return flows of the water right proposed for acquisition that may be available for instream flow use;

(5) The natural environment that may be preserved or improved by the proposed acquisition, and whether the natural environment will be preserved or improved to a reasonable degree by the water available from the proposed acquisition;

(6) The location of other water rights on the subject stream(s);

(7) The effect of the proposed acquisition on any relevant interstate compact issue, including whether the acquisition would assist in meeting or result in the delivery of more water than required under compact obligations;

(8) The effect of the proposed acquisition on the maximum utilization of the waters of the state;

(9) Whether the water acquired will be available for subsequent use or reuse downstream;

(10) The cost to complete the transaction or any other associated costs; and

(11) The administrability of the acquired water right when used for instream flow purposes.

The Board shall determine how to best utilize the acquired water, water rights or interest in water to preserve or improve the natural environment.

6f. <u>Factors Related to Loans and Leases.</u>

In addition to considering the factors listed above, for loans and leases of water, water rights and interests in water for ISF purposes under section 37-92-102(3),

(1) The Board shall consider the extent to which the leased or loaned water will preserve or improve the natural environment to a reasonable degree, including but not limited to:

  (a) Whether the amount of water available for acquisition is needed to provide flows to meet a decreed ISF amount in below average years; and

  (b) Whether the amount of water available for acquisition could be used to and would improve the natural environment to a reasonable degree, either alone or in combination with existing decreed ISF water rights.

(2) In considering the extent to which the leased or loaned water will preserve or improve the natural environment to a reasonable degree, the Board will request and review a biological analysis from the Colorado Division of Wildlife, and will review any other biological or scientific evidence presented to the Board.

(3) If other sources of water are available for acquisition on the subject stream reach(es) by purchase or donation, the Board shall fully consider each proposed acquisition and give preference first to the donation and then to a reasonable acquisition by purchase.

(4) The Board shall obtain confirmation from the Division Engineer that the proposed lease or loan is administrable and is capable of meeting all applicable statutory requirements.

(5) The Board shall determine, through negotiation and discussion with the lessor, the amount of compensation to be paid to the lessor of the water based, in part, upon the anticipated use of the water during and after the term of the lease.

(6) The Board shall consider evidence of water availability based upon the historical record(s) of diversion, the beneficial use of the subject water right, the location and timing of where return flows have historically returned to the stream, and the reason(s) the water is available for lease or loan.

6g. Recording Requirements.

(1) All contracts or agreements for leases or loans of water, water rights or interests in water under section 37-92-102(3) shall require the Board to:

(a) Maintain records of how much water the Board uses under the contract or agreement each year it is in effect; and

(b) Install any measuring device(s) deemed necessary by the Division Engineer (1) to administer the lease or loan of water, (2) to measure and record how much water flows out of the reach after use by the Board under the lease or loan; and (3) to meet any other applicable statutory requirements.

(2) All contracts or agreements for leases or loans of water shall provide for the recording of the actual amount of water legally available and capable of being diverted under the leased or loaned water right during the term of the lease or loan, with such records provided to the Division of Water Resources for review and publication.

6h. Water Reuse.

All contracts or agreements for the acquisition of water, water rights or interests in water under section 37-92-102(3) shall provide that the Board or the seller, lessor, lender or donor of the water may bring about beneficial use of the historical consumptive use of the acquired water right downstream of the ISF reach as fully consumable reusable water, pursuant to the water court decree authorizing the Board to use the acquired water.

(1) The bringing about of beneficial use of the historical consumptive use of the water may be achieved by direct use, sale, lease, loan or other contractual arrangement by the Board or the seller, lessor, lender or donor.

(2) The contract or agreement also shall provide that the Division Engineer must be notified of any agreement for such beneficial use downstream of the ISF reach prior to the use.

(3) Prior to any beneficial use by the Board of the historical consumptive use of the acquired water right downstream of the ISF reach, the Board shall find that such use:

(a) Will be consistent with the Board's statutory authority and with duly adopted Board policies and objectives; and

(b) Will not injure vested water rights or decreed conditional water rights.

6i. Applications for a Decreed Right to Use Water for ISF Purposes.

The Board shall file a change of water right application or other applications as needed or required with the water court to obtain a decreed right to use water for ISF purposes under all contracts or agreements for acquisitions of water, water rights or interests in water under section 37-92-102(3), including leases and loans of water. The Board shall file a joint application with the Person from whom the Board has acquired the water or a Person who has facilitated the acquisition, if requested by such Person. The Water Court shall determine matters that are within the scope of section 37-92-305, C.R.S. In a change of water right proceeding, the Board shall request the Water Court to:

(1) Verify the quantification of the historical consumptive use of the acquired water right;

(2) Verify the identification, quantification and location of return flows to ensure that no injury will result to vested water rights and decreed conditional water rights;

(3) Include terms and conditions providing that:

(a) The Board or the seller, lessor, lender, or donor of the water may bring about the beneficial use of the historical consumptive use of the changed water right downstream of the ISF reach as fully consumable reusable water, subject to such terms and conditions as the water court deems necessary to prevent injury to vested water rights and decreed conditional water rights; and

(b) When the Board has not identified such downstream beneficial use at the time of the change of water right, the Board may amend the subject change decree, if required by the Division Engineer, to add such beneficial use(s) of the historical consumptive use downstream of the ISF reach at the time the Board is able to bring about such use or reuse, without requiring requantification of the original historical consumptive use calculation;

and

(4) Decree the method by which the historical consumptive use should be quantified and credited during the term of the agreement for the lease or loan of the water right pursuant to section 37-92-102(3), C.R.S.

6j. Limitation on Acquisitions.

The Board may not accept a donation of water rights that were acquired by condemnation, or that would require the removal of existing infrastructure without approval of the current owner of such infrastructure.

6k. Temporary Loans of Water to the Board.

The Board may accept temporary loans of water for instream flow use for a period not to exceed 120 days in any one year, in accordance with the procedures and subject to the limitations set forth in section 37-83-105, C.R.S.

(1) Within 5 working days after receiving an offer of a temporary loan of water to the Board for temporary instream flow use, the Director will provide a response to the proponent and, unless the proposed loan has no potential value for instream flow use, staff will coordinate with the proponent on preparing and submitting the necessary documentation to the State and Division Engineers required by sections 37-83-105(2)(a)(I) and (2)(b)(I), C.R.S., and providing the public notice required by section 37-83-105(2)(b)(II), C.R.S.

(2) Provided that the State Engineer has made a determination of no injury pursuant to section 37-83-105(2)(a)(III), C.R.S., the Board hereby delegates authority to the CWCB Director to accept temporary loans of water for instream flow use in accordance with the procedures and subject to

the limitations set forth in section 37-83-105 and to take any administrative action necessary to put the loaned water to instream flow use.

(3) Provided that the State Engineer's determination of non-injury is still in effect, the Director shall notify the proponent and the State Engineer whether the temporary loan is to be exercised in subsequent years. Such notification shall be provided within 5 working days of the Director being notified by the proponent that the water is available for use under the temporary loan. The CWCB's use of loaned water for instream flows shall not exceed the CWCB's decreed instream flow amount or extend beyond the CWCB's decreed instream flow reach at any time during the loan term, and shall comply with any terms and conditions imposed by the State Engineer to prevent injury. The purpose of this delegation is to expedite use of temporarily loaned water for instream flows by the Board.

(4) At the first regular or special Board meeting after the Director accepts or rejects an offer of a loan of water to the Board for temporary instream flow use under (1) or (2) above, the Board shall vote either to ratify or overturn the Director's decision.

(5) The Board, Director and staff will expedite all actions necessary to implement Rule 6k.

6l. Funds for Water Right Acquisitions.

The Board may use any funds available to it for costs of the acquisition of water rights and their conversion to ISF use. The Board shall spend available funds for such costs in accordance with section 37-60-123.7, C.R.S. and any other applicable statutory authority, and with applicable Board policies and procedures.

6m. Public Input on Proposed Acquisitions.

The Board shall follow the public review process in Rules 11a. - 11c. when acquiring water, water rights or interests in water, except for temporary loans or leases as provided in Rule 6k. above and except as provided below.

(1) Prior to Board consideration of any proposed acquisition, Staff shall mail notice of the proposed acquisition to all Persons on the ISF Subscription Mailing List and the State Engineer's Substitute Supply Plan Notification List for the relevant water division, and shall provide Proper Notice. Such notice shall include:

(a) The case number adjudicating the water right proposed to be acquired, and the appropriation date, adjudication date, priority, decreed use(s), and flow amount of the water right proposed to be acquired, and approximately how much of the water right the Board will consider acquiring;

(b) The location of the stream reach or lake that is the subject of the proposal, including, when available, the specific length of stream reach to benefit from the proposed acquisition;

(c) Any available information on the purpose of the acquisition, including the degree of preservation or improvement of the natural environment to be achieved;

(d) Any available scientific data specifically supporting the position that the acquisition will achieve the goal of preserving or improving the natural environment to a reasonable degree; and

(e) In addition to (a) - (d) above, for leases and loans of water, water rights or interests in water under section 37-92-102(3), such notice shall include the proposed term of the lease or loan and the proposed season of use of the water under the lease or loan.

(2) At every regularly scheduled Board meeting subsequent to the mailing of notice, and prior to final Board action, Staff will report on the status of the proposed acquisition and time will be reserved for public comment.

(3) Any Person may address the Board regarding the proposed acquisition prior to final Board action. Staff shall provide any written comments it receives regarding the proposed acquisition directly to the Board.

(4) Any Person may request the Board to hold a hearing on a proposed acquisition. Such a request must be submitted to the Board in writing within twenty days after the first Board meeting at which the Board considers the proposed acquisition, and must include a brief statement, with as much specificity as possible, of why a hearing is being requested.

(5) At its next regularly scheduled meeting after receipt of the request for a hearing, or at a special meeting, the Board will consider the request and may, in its sole discretion, grant or deny such a request. All hearings scheduled by the Board shall be governed by the following procedures:

(a) A hearing on a proposed acquisition must be held within the 120 day period allowed for Board consideration of an acquisition pursuant to Rule 6b., unless the Person requesting the Board to consider the proposed acquisition agrees to an extension of time.

(b) The Board shall appoint a Hearing Officer to establish the procedures by which evidence will be offered.

(c) At least thirty days prior to the hearing date(s), the Board shall provide written notice of the hearing(s) to the Person proposing the acquisition, all interested parties known to the Board, and all Persons on the ISF Subscription Mailing List and the State Engineer's Substitute Supply Plan Notification List for the relevant water division. The Board also shall provide Proper Notice, as defined in ISF Rule 4n.

(d) Any Person who desires party status shall become a Party upon submission of a written Notice of Party Status to the Board Office. The Notice shall include the name and mailing address of the Person and a brief statement of the reasons the Person desires party status. The Board Office must receive Notice of Party Status within seven days after notice of the hearing is issued.

(e) The Hearing Officer shall set timelines and deadlines for all written submissions. Prehearing statements will be required, and shall include, but not be limited to, the following: 1) a list of all disputed factual and legal issues; 2) the position of the Party regarding the factual and legal issues; 3) a list identifying all of the witnesses that will testify for the Party, and a summary of the testimony that those witnesses will provide; and 4) copies of all exhibits that the Party will introduce at the hearing(s).

(f) Any Party may present testimony or offer evidence identified in its prehearing statement regarding the proposed acquisition.

(g) The Hearing Officer shall determine the order of testimony for the hearing(s), and shall decide other procedural matters related to the hearing(s). The Hearing Officer does not have authority to rule on substantive issues, which authority rests solely with the Board.

(h) The Board will not apply the Colorado Rules of Evidence at hearings on proposed acquisitions.

(i) The Board may permit general comments from any Person who is not a Party; however, the Board may limit these public comments to five minutes per Person.

(j) The Board may take final action at the hearing(s) or continue the hearing and/or deliberations to a date certain.

(k) Board hearings may be recorded by a reporter or by an electronic recording device. Any Party requesting a transcription of the hearing(s) shall be responsible for the cost of the transcription.

(l) When necessary, the Board may modify this hearing procedure schedule or any part thereof as it deems appropriate.

6n. Board Action to Acquire Water, Water Rights or Interests in Water.

The Board shall consider the acquisition during any regular or special meeting of the Board. At the Board meeting, the Board shall consider all presentations or comments of Staff or any other Person. After such consideration, the Board may acquire, acquire with limitations, or reject the proposed acquisition.

7. INUNDATION OF ISF RIGHTS.

Inundation of all or a portion of an ISF stream reach or lake may be an interference with the Board's usufructuary rights that have been acquired by Board action. “Inundation” as used in this section is the artificial impoundment of water within an ISF or natural lake; “inundation” does not refer to the use of a natural stream as a conveyance channel as long as such use does not raise the waters of the stream above the ordinary high watermark as defined in §37-87-102 (1)(e), C.R.S.

7a. Small Inundations.

Staff may file a Statement of Opposition to inundations described in this section if it determines that the ISF right or natural environment will be adversely affected by the inundation. The Staff shall not be required to file a Statement of Opposition to applications proposing small inundations. Small inundations are those in which the impoundment is 100 acre-feet or less, or the surface acreage of the impoundment is 20 acres or less, or the dam height of the structure is 10 feet or less. The dam height shall be measured vertically from the elevation of the lowest point of the natural surface of the ground, where that point occurs along the longitudinal centerline of the dam up to the flowline crest of the spillway of the dam.

(1) All structures proposed by any applicant on a stream reach shall be accumulated for the purpose of determining whether the inundations proposed by the applicant are small inundations. In the event the cumulative surface acreage, volume impounded, or dam height of all impoundments exceed the definition of a small inundation, Staff may file a Statement of Opposition to that application.

(2) In the event that no Statement of Opposition is filed pursuant to the terms of this section, the Board shall be deemed to have approved the inundation proposed without a request by the applicant.

7b. Application of Rule 7.

The provisions of this rule will not be applied to the following water rights:

(1) any absolute or conditional water right that is senior to an ISF right;

(2) any senior conditional water right that seeks a finding of reasonable diligence;

(3) any junior absolute or conditional water right which was decreed prior to July 10, 1990, or had an application for decree pending prior to July 10, 1990, unless the Board had filed a Statement of Opposition to the absolute or conditional water right application prior to July 10, 1990; or

(4) any inundation of an ISF reach by water that does not have an absolute or conditional water right if the inundation occurred prior to July 10, 1990.

7c. Request to Inundate.

Any Person seeking permission to inundate shall timely submit a written request for permission to inundate to the Board Office. No requests for inundation will be considered or approved until the Person seeking permission to inundate files a water court application outlining their storage plans or files plans and specifications with the State Engineer for a jurisdictional dam pursuant to §37-87-105, C.R.S. The Board will consider the request to inundate in a timely manner.

7d. Staff Investigation.

After receiving the request to inundate, the Staff may seek the recommendations from the Division of Wildlife, Division of Parks and Outdoor Recreation, Division of Water Resources, United States Department of Agriculture and United States Department of Interior.

7e. Required Information.

In any written request to inundate, the requesting Person shall at a minimum include information on the following factors: the location of the inundation, the size of the inundation, impact of the inundation on the natural environment, any unique or rare characteristics of the ISF water right to be inundated, any regulatory requirements or conditions imposed upon the applicant by federal, state and/or local governments, all terms and conditions included in applicant's water court decree, and any compensation or mitigation offered by the Person proposing the inundation.

7f. Determination of Interference.

In response to the request to inundate, the Board shall determine whether the proposed inundation interferes with an ISF right. When making this determination, the Board shall consider, without limitation, the extent of inundation proposed and the impact of the proposed inundation on the natural environment existing prior to the inundation.

7g. Consideration of Request to Inundate.

If the Board determines that a proposed inundation interferes with an ISF right, the Board may then approve, approve with conditions, defer, or deny the request to inundate. In making this decision, the Board shall consider all relevant factors, including, but not limited to (1) the extent of inundation proposed; (2) the impact of the proposed inundation on the natural environment existing prior to the inundation; (3) the degree to which the beds and banks adjacent to the ISF right subject to the inundation are publicly or privately owned; (4) the economic benefits arising from the inundation; (5) the benefits to recreation and downstream ISF segments arising from the inundation; (6) the degree to which the proposed inundation will allow development of Colorado's allotment of interstate waters as determined by compact or adjudication; and, (7) any mitigation or compensation offered to offset adverse impacts on the ISF right. After considering all relevant factors, the Board shall take one of the actions set forth in Rules 7h. - 7k. below.

7h. Approval.

If the Board approves the request to inundate, any Statement of Opposition filed by the Board shall be withdrawn.

7i. Conditional Approval.

The Board may require certain conditions to be performed prior to approval. Failure to perform any condition will be a reason for denial.

7j. Deferral.

When it appears that other governmental agencies may impose terms and conditions upon the issuance of a permit to construct a facility which will cause an inundation, the Board may defer consideration of the request to inundate until all other governmental bodies have finalized the permit or approval conditions.

7k. Denial of Request to Inundate.

Requests for permission to inundate may be denied if in the discretion of the Board the request is inconsistent with the goals of the ISF Program. The Board may decide to deny a request for permission to inundate if it finds:

(1) No compensation or mitigation would be adequate for the injury caused by the inundation; or

(2) No compensation or mitigation acceptable to the Board has been proposed by applicant; or

(3) The proposed inundation is inconsistent with the goals of the ISF Program.

7l. Remedies.

The Board may seek any administrative, legal or equitable remedy through state courts (including water courts), federal courts, city, county, state or federal administrative proceedings to resolve actual or proposed inundation of its ISF rights.

7m. Board Has Sole Right to Protect ISF Rights from Interference.

Only the Board may seek to prevent interference with an ISF right by inundation and only the Board may seek compensation or mitigation for such interference.

7n. Public Review Process.

The Board shall follow the public review process in Rules 11a. - 11c. prior to any Board decision on a request to inundate an ISF right.

8. PROTECTION OF ISF APPROPRIATIONS.

The Board delegates the day-to-day management and administration of the ISF Program to Staff. Staff shall seek ratification of its decisions as set forth in Rules 8c., 8e.(2), 8i., and 8j.

8a. Resume Review.

Staff shall review the monthly resumes of all water divisions. The Staff shall evaluate each resume entry for the possibility of injury or interference to an ISF right.

8b. Statement of Opposition.

In the event Staff identifies a water right application in the resume that may injure an ISF right, Staff shall file a Statement of Opposition to that application. In the event Staff identifies a water right application in the resume that may interfere with an ISF right as contemplated in Rule 7, Staff may file a Statement of Opposition to that application.

8c. Ratification of Statements of Opposition.

At a Board meeting following the filing of the Statement of Opposition, Staff shall apprise the Board of the filing of a Statement of Opposition and the factual basis for the Staff action. At that time, the Board shall ratify the filing, disapprove the filing, or table the decision to a future meeting if more information is needed prior to making a decision.

8d. Notice.

Prior to ratification of a Statement of Opposition, the Staff shall mail the applicant a copy of the Board memorandum concerning the ratification and a copy of the agenda of the meeting in which the ratification will be considered. Following a Board action considering a Statement of Opposition, the Staff shall notify the applicant and/or its attorney in writing of the Board's action.

8e. De Minimis Rule.

In the event that Staff determines a water court application would result in a 1 percent depletive effect or less on the stream reach or lake subject of the ISF right, and the stream reach or lake has not been excluded from this rule pursuant to Rules 8f. or 8h., Staff shall determine whether to file a Statement of Opposition. Staff's decision not to file a Statement of Opposition does not constitute: (1) acceptance by the Board of injury to any potentially affected ISF water right; or (2) a waiver of the Board's right to place an administrative call for any ISF water right.

(1) If Staff does not file a Statement of Opposition, Staff shall notify the Division Engineer for the relevant water division that it has not filed a Statement of Opposition, but that it may place an administrative call for the potentially affected ISF water right(s). Such a call could be enforced against the water right(s) subject of the application by the Division Engineer in his or her enforcement discretion. Staff also shall mail a letter to the applicant at the address provided on the application notifying the applicant: (a) of Staff's decision not to file a Statement of Opposition pursuant to this Rule; (b) that the CWCB may place a call for its ISF water rights to be administered within the prior appropriation system; and (c) that the Division Engineer's enforcement of the call could result in curtailment or other administration of the subject water right(s).

(2) If Staff files a Statement of Opposition, Staff shall seek Board ratification by identifying and summarizing the Statement of Opposition on the Board meeting consent agenda pursuant to Rule 8c.

8f. Cumulative Impact.

In determining existence of a de minimis impact, Staff shall consider the existence of all previous de minimis impacts on the same stream reach or lake. If the combined total of all such impacts exceeds 1 percent, then Staff will file a Statement of Opposition regardless of the individual depletive effect of an application.

8g. Notification of Staff Action.

At a Board meeting following a Staff determination to apply the De Minimis rule, the Staff shall notify the Board about the factual basis leading to its application of the De Minimis rule.

8h. Exclusion from De Minimis Rule.

The Board may at any time exclude any stream reach or lake, or any portion thereof, from application of the De Minimis rule.

8i. Pretrial Resolution.

Staff may negotiate a pretrial resolution of any injury or interference issue that is the subject of a Statement of Opposition. The Board shall review the pretrial resolution pursuant to the following procedures:

(1) No Injury.

In the event the pretrial resolution includes terms and conditions preventing injury or interference and does not involve a modification, or acceptance of injury or interference with mitigation, the Board is not required to review and ratify the pretrial resolution. Staff may authorize its counsel to sign any court documents necessary to finalize this type of pretrial resolution without Board ratification.

(2) No Injury/Modification.

In the event the pretrial resolution addresses injury or interference through modification of the existing ISF decree, the process set forth in Rule 9 shall be followed prior to any Board decision to ratify the pretrial resolution.

(3) Injury Accepted with Mitigation.

In the event a proposed pretrial resolution will allow injury to or interference with an ISF or natural lake level (NLL) water right, but mitigation offered by the applicant could enable the Board to accept the injury or interference while continuing to preserve or improve the natural environment to a reasonable degree, and if the proposed pretrial resolution does not include a modification under ISF Rule 9, the Board shall:

(a) Conduct a preliminary review of the proposed pretrial resolution during any regular or special meeting to determine whether the natural environment could be preserved or improved to a reasonable degree with the proposed injury or interference if applicant provided mitigation; and

(b) At a later regular or special meeting, take final action to ratify, refuse to ratify or ratify with additional conditions.

(c) No proposed pretrial resolution considered pursuant to this Rule 8i.(3) may receive preliminary review and final ratification at the same Board meeting.

(d) The Board shall not enter into any stipulation or agree to any decretal terms and conditions under this Rule that would result in the Division of Water Resources being unable to administer the affected ISF or NLL water right(s) in accordance with the priority system or with Colorado water law.

(e) To initiate CWCB staff review of an Injury with Mitigation proposal, the proponent must provide the following information in writing:

i. Location of injury to ISF or NLL water right(s) (stream(s) or lake(s) affected, and length of affected reach(es));

ii. Quantification of injury (amount, timing and frequency);

iii. Type of water use that would cause the injury;

iv. Analysis showing why full ISF or NLL protection is not possible;

v. Detailed description of the proposed mitigation, including all measures taken to reduce or minimize the injury;

vi. Detailed description of how the proposed mitigation will enable the Board to continue to preserve or improve the natural environment of the affected stream of lake to a reasonable degree despite the injury;

vii. Identification and feasibility analysis of: (1) all water supply alternatives considered by the proponent in the context of this proposal; (2) all alternatives evaluated by the proponent to fully protect the potentially affected ISF or NLL water right, but rejected as infeasible; and (3) all alternatives evaluated by the proponent and designed to mitigate the injury to or interference with the affected ISF or NLL water right. This information shall address the environmental and economic benefits and consequences of each alternative; and

viii. A discussion of the reasonableness of each alternative considered.

(f) After receipt and review of the required information, staff will consult with the DOW and with the entity that originally recommended the affected ISF or NLL water rights(s) (if other than DOW) to determine whether additional field work is necessary and to identify any scheduling concerns. Staff will request a recommendation from the DOW as to whether the proposed mitigation will enable the Board to continue to preserve or improve the natural environment of the affected stream or lake to a reasonable degree despite the injury, including a discussion of the reasonableness of the alternatives considered. CWCB staff will use best efforts to consult with affected land owners and managers regarding the proposal.

(g) Prior to bringing the proposal to the Board for preliminary consideration, staff will consult with the Division of Water Resources on whether the proposal would result in the Division of Water Resources being unable to administer the affected ISF or NLL water right(s) in accordance with the priority system or with Colorado water law.

(h) At the first meeting of the two-meeting process required by this Rule, staff will bring the proposal to the Board for preliminary consideration after completing its review of the proposal and its consultation with DOW. Staff will work with the proponent and interested parties to address any preliminary concerns prior to bringing a proposal to the Board. Preliminary consideration by the Board may result in requests for more information or for changes to the proposal. Staff will work with the proponent and interested parties to finalize the proposal and bring it back to the Board for final action at a subsequent Board meeting.

(i) The Board will consider the following factors when evaluating Injury with Mitigation proposals. Because Injury with Mitigation proposals may involve unique factual situations, the Board may consider additional factors in specific cases. Further, evaluation of each Injury with Mitigation proposal will require the exercise of professional judgment regarding the specific facts of the proposal.

i. Extent of the proposed injury:

1. Location of injury – affected stream(s) or lake and length of affected reach(es);

2. Amount, timing and frequency of shortage(s) or impacts to the affected ISF of NLL water right(s); and

3. Potential impact to the natural environment of the affected stream reach(es) or lake from the proposed injury.

ii. Benefits of the mitigation to the natural environment:

1. The nature and extent of the benefits the mitigation will provide to the existing natural environment of the affected stream or lake;

2. The scientific justification for accepting the mitigation; and

3. Whether the mitigation will enable the Board to continue to preserve or improve the natural environment of the subject stream or lake to a reasonable degree.

(j) Evaluation of proposed alternatives. The Board shall evaluate: (1) all water supply alternatives considered by the proponent in the context of this proposal; (2) all alternatives evaluated by the proponent to fully protect the potentially affected ISF or NLL water right, but rejected as infeasible; and (3) all alternatives evaluated by the proponent and designed to mitigate the injury to or interference with the affected ISF or NLL water right. In its evaluation, the Board shall consider the following factors:

i. Availability of on-site mitigation alternatives;

ii. Technical feasibility of each alternative;

iii. Environmental benefits and consequences of each alternative;

iv. Economic benefits and consequences of each alternative;

v. Reasonableness of alternatives;

vi. Administrability of proposed alternatives by the Board and the Division Engineer; and

vi. For mitigation alternatives, whether the mitigation was or will be put in place to satisfy a requirement or need unrelated to the Injury with Mitigation proposal.

(k) The Board will consider mitigation on a different reach of stream or another stream ("off-site mitigation") as a last resort and will only consider mitigation in an area other than the affected stream reach if no reasonable alternative exists for mitigation on the affected stream reach. The Board only will consider off-site mitigation on stream(s) located in the same drainage as the affected stream. Factors that the Board may consider in looking at such a proposal include, but are not limited to, the degree and frequency of impact to the affected stream; the environmental benefits provided to the off-site stream by the mitigation; whether the proposal could, in effect, constitute a modification of the ISF water right on the affected stream; or whether the proposal could result in the Division of Water Resources being unable to administer the affected ISF water right(s) in accordance with the priority system or with Colorado water law.

(l) Stipulations and water court decrees that incorporate Injury with Mitigation shall include, but not be limited to inclusion of, the following terms and conditions:

i. A provision that the proponent will not divert water or take any other action that would reduce flows in the affected stream or levels in the affected lake below the decreed ISF or NLL amount until the agreed-upon mitigation measures are in place and fully operational;

ii. A requirement that the structural components of the mitigation be maintained permanently;

iii. A provision allowing CWCB or DOW staff access to the property on which structural components of the mitigation are located to inspect the structures at certain time intervals, and, if necessary, to perform biological stream or lake monitoring. This provision shall clearly define the reasonable nature, extent and timing of such access (i.e, advance notice, dates, times or season of access, coordination with proponent, and location and routes of access);

iv. A term providing that if the proponent ceases to provide the agreed upon mitigation (such as removing structural components or failing to maintain them to a specified level, or ceasing to implement non-structural components), that the proponent will not divert water or take any other action that would reduce flows in the affected stream or levels in the affected lake below the decreed ISF or NLL amount because the Board will no longer accept the injury based upon the mitigation no longer being in effect -- in such case, if the Board places a call for the affected ISF or NLL water right, the Board will notify the Division Engineer that this provision of the decree now is in effect and that the Board is not accepting the injury;

v. A requirement that the proponent install and pay operation and maintenance costs of (or commit to pay operation and maintenance costs if the CWCB installs) any measuring devices deemed necessary by the Division Engineer to administer the terms of the stipulation and decree implementing the Injury with Mitigation pretrial resolution; and

vi. A term providing that the water court will retain jurisdiction to enforce the terms and conditions set forth above in subsections (i) - (vi), and any other terms and conditions specific to the Injury with Mitigation pretrial resolution, as a water matter.

8j. Authorization to Proceed to Trial.

In the event that a Statement of Opposition filed by the Board is not settled prior to the last regularly scheduled Board meeting prior to the trial date, Staff shall seek Board authorization to proceed to trial. In the event that Staff is authorized to proceed to trial, the Board may adjourn to executive session to discuss settlement parameters with its counsel. Staff is authorized to settle any litigation without Board ratification if the settlement terms are consistent with instructions given by the Board to its counsel.

8k. Public Review Process.

The Board shall follow the public review process in Rules 11a. - 11c. prior to consideration of a request to ratify a pretrial resolution pursuant to Rule 8i.(3).

8l. Notice.

At any time Staff verifies that an ISF water right is not being fulfilled as a result of water use against which the ISF water right is entitled to protection, the Staff shall provide Proper Notice, including a description of what the Board is doing in response to the situation.

9. MODIFICATION OF ISF RIGHTS.

The Board may modify any existing decreed ISF right according to the procedures set forth in this Rule. "Modification" of an ISF right within the meaning of this Rule includes a decrease in the rate of flow described in the existing ISF decree, segmenting an existing ISF reach into shorter reaches with the result of decreasing the rate of flow in any portion of an ISF reach, or subtracting water from an ISF right during any particular time period or season.

9a. Need for Modification.

Modification may be requested by the Staff or by any Person who has filed a water right application on an ISF reach or who has applied for any governmental permit for facilities located in or near an ISF reach and who complies with Rules 9b. and 9c. Any request for modification, except by staff, shall be made in writing, submitted to Staff and such writing shall contain the following information:

(1) name, address and telephone number of the Person seeking modification;

(2) stream or lake subject of request;

(3) modification requested;

(4) reason for modification; and

(5) the scientific data supporting the request.

9b. Need for Water.

Any Person who requests a modification of an ISF right must, as a precondition to the Board's consideration of the request, establish a need for the water made available by the modification. Staff does not have to comply with this rule and any governmental entity seeking to implement the terms of an agreement specified in Rule 9f. does not have to comply with this section.

9c. Grounds for Modification.

No request for modification may be considered until the applicant establishes that one of the following reasons for modification exists:

(1) Mistake.

An ISF right may be considered for modification if the requesting Person establishes that an error was made in the calculations upon which the original or supplemental appropriation or enlargement to an original appropriation was made.

(2) Excessive Flow.

An ISF right may be considered for modification if the requesting Person establishes that the ISF flow rate is in excess of the amount of water necessary to accomplish the purpose of the original, supplemental or enlarged ISF right when that right was appropriated.

9d. Recovery Implementation or Other Intergovernmental Agreement.

An ISF right may be modified if such modification was agreed upon by the Board as part of the Recovery Implementation Program for the Endangered Fishes of the Colorado River Basin or any other agreement between the Board and another governmental entity. Modifications made as a part of the Recovery Implementation Program for the Endangered Fishes of the Colorado River Basin need not be subject to the public review process in Rule 9e. Criteria for modifications made in the ISF rights decreed as part of the Recovery Implementation Program for the Endangered Fishes of the Colorado River Basin will be established in the decrees governing such appropriations.

9e. Public Review Process of Requests for Modification.

The Board shall adhere to the following public review process when considering requests for modification:

(1) Notice.

Notice of the proposed modification and the date of the public meeting at which it will first be considered shall be printed in the resume in the Water Court having jurisdiction over the decree that is the subject of the modification. The first public meeting of the Board at which the modification is to be considered shall occur at least sixty days after the month in which the resume is published. Notice shall also be published in a newspaper of statewide distribution within thirty to forty-five days prior to such first public meeting.

(2) Public Meeting.

If the Board decides at such first public meeting to give further consideration to the proposed modification, the Board shall announce publicly the date of a subsequent public meeting for such purpose. If the Board decides that it will not give further consideration to the proposed modification, it shall state, in writing, the basis for its decision.

(3) Request for Delay.

On the written request of any Person made within thirty days after the date of the first public meeting, the Board shall delay the subsequent public meeting for up to one year to allow such Person the opportunity for the collection of scientific data material to the proposed modification. The Board need not grant the request if it determines that the request is made solely to delay the proceedings.

(4) Procedures.

On the written request of any Person made within thirty days after the date of the first public meeting, the Board shall, within sixty days after such request, establish fair and formal procedures for the subsequent public meeting, including the opportunity for reasonable disclosure, discovery, subpoenas, direct examination, and cross examination. Subject to these rights and requirements, where a meeting will be expedited and the interests of the participants will not be substantially prejudiced thereby, the Board may choose to receive all or part of the evidence in written form.

(5) Final Determination.

The Board shall issue a final written determination regarding the modification that shall state its effective date, be mailed promptly to the Persons who appeared by written or oral comment at the Board's proceeding, and be filed promptly with the water court.

10. ENFORCEMENT AGREEMENTS.

The Board may attach conditions to an appropriation, decreased appropriation, or acquisition, and may enter into any enforcement agreements that it determines will preserve or improve the natural environment to a reasonable degree. The Board may enter into enforcement agreements that limit the

Board's discretion in the protection, approval of inundation, modification or disposal of ISF right, and/or may delegate limited authority to act on the Board's behalf.

10a. Ratification of Enforcement Agreements.

No enforcement agreement shall be effective to limit the discretion of the Board until that agreement and all of its terms are reviewed and ratified by the Board. Upon ratification, the Director may execute the agreement and the agreement shall be binding upon the Board for the term set forth in the enforcement agreement.

10b. Public Review Process.

The Board shall follow the public review process set forth in Rules 11a. - 11c. prior to any Board decision to ratify an Enforcement Agreement.

11. PUBLIC REVIEW PROCESS.

Except as otherwise provided in the ISF Rules, the Board shall follow the public review process set forth below prior to any Board decision requiring public review.

11a. Public Notice.

Public notice of all Board actions under these Rules shall be provided through the agenda of each regular or special Board meeting.

11b. Public Comment.

Except as otherwise provided in Rules 5k. and 6m., at a regular or special meeting, the Board shall consider public comment on the recommended ISF action prior to the Board action on the recommendation in any or all of the following manners:

(1) Oral and/or written comments may be directed to Staff. When such comments are made, Staff may summarize these comments to the Board.

(2) Oral and/or written comments, subject to reasonable limitations established by the Board, may be made directly to the Board during the public meeting.

11c. Public Agency Recommendations.

Prior to taking an ISF action pursuant to Rules 5 or 6, the Board shall request recommendations from the Division of Wildlife and the Division of Parks and Outdoor Recreation. The Board shall also request recommendations from the United States Department of Agriculture and the United States Department of Interior. The Board may also request comments from other interested Persons or agencies as it deems appropriate.

Prior to taking an ISF action pursuant to Rules 7, 8, 9, or 10, the Board may request recommendations from the Division of Wildlife, the Division of Parks and Outdoor Recreation, the Division of Water Resources, the United States Department of Agriculture, the United States Department of Interior or other Persons as it deems appropriate.

11d. Board Procedures.

At a regular or special Board meeting, the Board may, as necessary, adopt or amend procedures to supplement these rules.

12. SEVERABILITY.

In the event that any section or subsection of these Rules are judged to be invalid by a court of law or are allowed to expire by the General Assembly, the remaining Rules shall remain in full force and effect.

Exhibit 5

Development of Instream Flow Recommendations In Colorado Using

R2CROSS

Colorado Water Conservation Board
Department of Natural Resources
1313 Sherman Street, Room 721
Denver, Colorado 80203

Water Rights Investigations Section

January 1996

Development of Instream Flow Recommendations In Colorado Using

R2CROSS

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Water Rights Investigations Section

January 1996

Abstract

In 1973, the Colorado State Legislature vested the Colorado Water Conservation Board with the authority to appropriate instream flow water rights in the State of Colorado. Today, the Board holds 1,326 instream flow water rights covering approximately 7,982 miles of Colorado streams. Standardized field and office procedures help to ensure that instream flow recommendations reflect the amount of water required to "preserve the natural environment to a reasonable degree", as prescribed by state statute. R2CROSS is one of the standard techniques employed by state and federal agencies to model instream hydraulic parameters. R2CROSS was chosen because it is time and labor efficient and produces comparable results to more costly techniques, i.e., the Instream Flow Incremental Methodology. This manuscript provides an overview of Colorado's Instream Flow Program and documentation for the Board's R2CROSS Lotus macro. The R2CROSS macro runs efficiently on an IBM-compatible 80486 personal computer equipped with a hard disk drive, and DOS 6.0, Windows 3.1, and Lotus 1-2-3 Release 4 for Windows software.

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The Colorado Water Conservation Board would like to thank everyone involved in the development of the Board's R2CROSS Lotus macro. In addition, the author wishes to acknowledge the persons involved in the review and testing of the R2CROSS macro including R. Barry Nehring and Jay Skinner of the Colorado Division of Wildlife, Dr. Eric P. Bergersen, Dr. Kurt Fausch, and Charles Gowan of Colorado State University, Dennis Murphy of the Bureau of Land Management, Dave Gerhardt of the United States Forest Service, Dan Merriman, Anne Janicki, and Margaret Langdon of the Colorado Water Conservation Board, and Steven O. Sims of the State Attorney General's Office. The Board is very grateful to all of those who participated in the development of the R2CROSS macro and this document.

Disclaimer

The R2CROSS macro is in the public domain, and the recipient may not assert any proprietary rights thereto nor represent it to anyone as other than a Colorado State Government-produced program. R2CROSS is provided "as-is" without warranty of any kind, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose. The user assumes all responsibility for the accuracy and suitability of this program for a specific application. In no event will the Colorado Water Conservation Board or the Colorado Division of Wildlife be liable for any damages, including lost profits, lost savings, or other incidental or consequential damages arising from the use of or the inability to use this program.

The CWCB staff verified the calculations preformed in its R2CROSS program with hand-held calculators and by comparison with other Manning's equation-based hydraulic streamflow models. Based upon this verification process, the staff believes that the instream hydraulic parameters summarized in the R2CROSS staging table are accurate calculations of Manning's equation. However, the CWCB does not suggest that the predicted hydraulic parameters will necessarily be realized at any particular stream discharge.

On November 10, 1993, the Colorado Water Conservation Board adopted Rules and Regulations that codified the procedures the Board follows in appropriating instream flow water rights. This document is intended to conform to the procedures presented in the Rules and Regulations.

Table of Contents

List of Tables and Figures

Tables

Figures

Introduction

Colorado's Instream Flow Program originated in 1973 with the passage of Senate Bill 97 (SB 97). Under SB 97, the Colorado Water Conservation Board (CWCB) was vested with the authority to appropriate instream flow water rights in the State of Colorado (§ 37-92-102(3), C.R.S. (1990)). Instream flow water rights are held by the CWCB on behalf of the people of the State of Colorado to "preserve the natural environment to a reasonable degree." Today, the CWCB holds 1,326 instream flow water rights covering approximately 7,982 miles of Colorado streams.

Determining the quantity of water required to preserve the natural environment to a reasonable degree can be a difficult task. The CWCB, in cooperation with the Colorado Division of Wildlife (DOW), has developed standard field and office procedures to ensure that each instream flow appropriation is necessary and reasonable and that the amount of water recommended is available for appropriation.

The R2CROSS methodology described in this document is a valuable tool in developing these instream flow recommendations. The CWCB uses R2CROSS because it is time and labor efficient and produces results which are comparable to more data intensive techniques (Nehring 1979).

This manuscript is divided into two sections. The first section describes Colorado's Instream Flow Program, including some of the statutory guidelines that have shaped the program. It also describes the standard field techniques and office procedures that are used by the CWCB staff in the development of R2CROSS-based instream flow recommendations. This section is intended to provide an understanding of the procedural and technical aspects of Colorado's Instream Flow Program.

The second section of the manuscript is a users' manual for the CWCB's R2CROSS macro. The CWCB has received many requests for its R2CROSS macro from both the public and private sectors but has been hesitant to release the program without proper documentation. The second section of the manuscript is intended to provide that documentation.

Colorado's Instream Flow Program

Instream Flow Legislation

The CWCB was created in 1937 to serve as the State's chief water planning agency (§ 37-60-101 through 123, C.R.S. (1990)). Today, the CWCB is responsible for the administration of the State's Instream Flow Program, protection of endangered aquatic species, identification of flood plains, funding of new water development and water conservation projects, and negotiation of inter- and intra-state water planning issues.

The CWCB is a fourteen-member board. The board consists of one Governor-appointee from each of the eight major river drainages in the State and one from the City and County of Denver. Each Governor-appointee must also be confirmed by the Colorado State Senate. Ex-officio members of the board include the

Executive Director of the Department of Natural Resources, the Directors of the CWCB and DOW, the State Attorney General, and the State Engineer. The diverse backgrounds of its board members provides the CWCB with an excellent representation of Colorado's various water interests.

Colorado's Instream Flow Program was created in 1973 when the Colorado State Legislature recognized "the need to correlate the activities of mankind with some reasonable preservation of the natural environment" through the passage of SB 97. Within SB 97, the definition of beneficial use was changed to include minimum stream flows and the CWCB was vested with the authority to appropriate "waters of natural streams and lakes ... as may be required ... to preserve the natural environment to a reasonable degree." SB 97 was amended by Senate Bill 414 in 1981, Senate Bill 91 in 1986, Senate Bill 212 in 1987, and Senate Bill 54 in 1994. These changes and amendments are consolidated within § 37-92-102(3), C.R.S. (1990), the Instream Flow statute.

The Instream Flow statute sets forth the guidelines for the administration of Colorado's Instream Flow Program. The statute vests the CWCB with the exclusive authority to appropriate and acquire instream flow and natural lake level water rights. In order to encourage other entities to participate in Colorado's Instream Flow Program, the statute directs the CWCB to request instream flow recommendations from other state and federal agencies prior to initiating an instream flow appropriation. The CWCB routinely requests instream flow recommendations from the DOW, Colorado Division of Parks and Outdoor Recreation, United States Department of Agriculture, and United States Department of Interior (the "cooperating agencies").

Prior to appropriating an instream flow water right, the statute requires the CWCB to: (1) "determine that the natural environment will be preserved to a reasonable degree by the water available for the appropriation to be made; (2) determine that there is a natural environment that can be preserved to a reasonable degree with the CWCB's water right, if granted; and (3) determine that such environment can exist without material injury to water rights" (§ 37-92-102(3c), C.R.S. (1990)). The CWCB makes these determinations based upon a review of the supporting technical data and a final instream flow recommendation prepared by the CWCB staff.

Standardized field and office procedures have been developed to help ensure that final instream flow recommendations meet statutory guidelines and are consistent. The standard field procedures that were established concern selection of transect sites and collection of hydraulic and biologic data. Standard office procedures have been established for determining biological instream flow recommendations using output from R2CROSS and for analyzing water availability.

Field Procedures

Instream flow recommendations are typically based on hydraulic and biologic data collected during a single field visit. Hydraulic data collection consists of setting up a transect, surveying stream channel geometry, and measuring stream discharge. Biologic data is gathered to document the existence of a natural environment. The biologic data usually consists of a fish sample, collected by electrofishing, and an aquatic invertebrate sample.

Field Data Site Selection

The R2CROSS method requires that stream discharge and channel profile data be collected in a riffle stream habitat-type. A riffle is a stream segment that is controlled by channel geometry rather than a downstream

flow control. Riffles are most easily visualized as the stream reaches which would dry up most quickly should streamflow cease.

Biologically, riffles are essential to the production of benthic invertebrates and the passage, spawning, egg incubation, feeding, and protective cover of fish. Riffles are also the stream habitat-type most sensitive to changes in hydraulic parameters with variation in discharge (Nehring 1979). Riffles are critical to a healthy aquatic environment because small reductions in streamflow may result in large reductions in water depth and the amount of wetted perimeter available for aquatic habitat. Maintaining adequate streamflow in riffles also preserves the natural environment in other important stream habitat-types such as pools and runs (Nehring 1979).

Hydraulic engineers have developed several mathematical models and equations to predict instream hydraulic parameters (Chow 1959). Manning's equation is one such model that is well-suited to the riffle stream habitat-type (Grant et al. 1992). In order to maximize the reliability of Manning's equation, transects are placed within a riffle so that streamflow is uniform across the transect (Grant et al. 1992). The transect represents the average stream width, depth, and cross-sectional area within the riffle being characterized. Transects should be located in areas that exhibit natural banks or grasslines and concentrated water flow, free from braiding. They should not be located on eroded or undercut streambanks.

Hydraulic Data Collection

Stream discharge is measured using standardized procedures established by the United States Geological Survey (USGS) (Buchanan and Somers 1969). On streams less than 50 feet in width, channel geometry is typically measured using sag-tape methodology (Silvey 1976; Ray and Megahan 1979). Larger streams typically require the use of a land survey level and stadia rod (Benson and Dalrymple 1967). A list of required field equipment for making streamflow measurements is provided in Table 1.

The sag-tape methodology consists of suspending a steel tape from bank to bank across the stream channel, perpendicular to the streamflow (Figure A). Metal cross section stakes are driven into the ground above the grassline. The steel tape is suspended by attaching the zero-end of the tape to one of the metal stakes, stretching the tape across the stream, and then attaching the other end to a tape clamp and spring scale fastened to the metal stake on the opposite streambank. A minimum of 15 pounds of tension is applied to the tape, as the tape is drawn up and clamped. A survey level and stadia rod are used to adjust the ends of the tape up or down until they are level, thereby producing a consistent datum from which vertical distance measurements can be read.

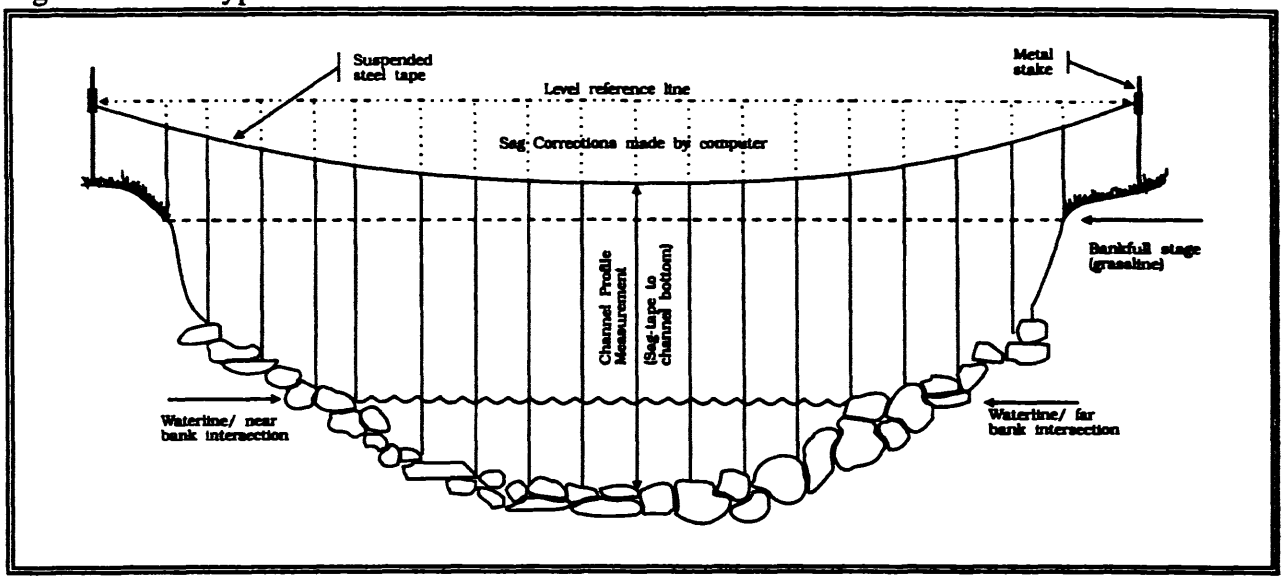
The R2CROSS program uses the standard weight of a one-foot section of the steel tape, tape tension, and the length of tape in suspension to correct horizontal distance and vertical depth measurements made from the sagging tape. The program adjusts the coordinates at each cross section vertical so that the corrected measurements correspond to a level datum from stake to stake and not the curved datum created by the sagging tape (Figure A).

On larger streams, vertical measurements between the suspended tape and the stream channel may be replaced with readings using a survey level and stadia rod. The suspended tape is then used to measure only the horizontal location of each cell vertical. There is no need to precisely level the ends of the suspended tape or to record the tape tension as no sag corrections are required.

Table 1. Field equipment list for making streamflow measurements

Equipment	Description
100' Steel Survey tape	Stretched between cross section stakes. (Obtain standard weight of a 1.0 foot section of tape from manufacturer)
Spring Tension Scale	Used to measure pounds of tension on steel tape when stretched between stakes.
Tape Clamp Handle	Holds tape in tension.
Cross Section Stakes	Two 24"-36" metal stakes used to maintain tape tension and to level steel tape. Must be strong enough to be driven into rocky stream bank.
Discharge Wading Rod (or Stadia Rod)	Used to measure vertical depths from suspended tape to stream channel.
Level, Tripod, and Stadia Rod	Used to level ends of suspended tape and to measure slope.
Current Meter	Pygmy, Price AA, Marsh-McBirney or similar devise used to measure stream velocity.
Hand Sledge Hammer	Used to drive cross section stakes into streambank.
Staging Pin	Used to detect changes in discharge during the streamflow measurement.
100' Fiberglass Tape	Used to measure horizontal distance from suspended tape to water-slope stadia rod readings.
Field Forms and Clipboard	Standardized form to ensure complete set of field data.
Miscellaneous Items	Camera, film, maps, waders, stopwatch and calculator.

Figure A. Typical stream cross section



Biologic Data Collection

Biologic sampling is conducted to document the existence of a natural environment. Coldwater fish species, particularly salmonids, have been used to indicate the existence of such a natural environment in the majority of the CWCB's instream flow appropriations to date. Warmwater fish species and other aquatic life forms may be used to document the existence of a natural environment in more downstream, low-elevation stream segments. In addition to salmonids, the CWCB has used amphibians, such as frogs and salamanders, and warmwater fish species, including the endangered fishes of the Colorado River basin, as the biologic basis for instream flow appropriations.

Biologic data typically consists of a fish sample, collected by electrofishing, and an aquatic invertebrate sample. Captured fish are identified and measured and a length-frequency distribution is constructed for each species. The sample is not tied directly to the R2CROSS hydraulic modeling but it may be used to refine the biologic instream flow recommendation to meet the specific habitat requirements of unique populations.

The Field Form

The CWCB and DOW use a standardized field form to record all field data. The use of this form helps to ensure that all instream flow recommendations are based upon a uniform set of field data. The front page of the form provides space for cross section "Location Information", "Supplemental Data", "Channel Profile Data", an "Aquatic Sampling Summary", and "Comments" (Figure B). The back page is dedicated to "Discharge/Cross Section Notes" (Figure C).

The "Location Information" section of the field form is used to describe the location of the cross section as well as the date and names of the members of the field crew. Geographic information can be obtained from either USGS or United States Forest Service (USFS) maps. Water divisions and DOW water codes can be obtained from the State Engineers' Office, the CWCB, or the DOW.

The "Supplemental Data" section is used to provide supporting documentation of the field data collection effort. Most importantly, this section is used to record the tape manufacturer's standard weight (lbs/ft) and tape tension (lbs). The R2CROSS program uses this information, together with the length of tape in suspension, to adjust vertical distances measured from the sagging tape to a level reference datum.

The "Channel Profile Data" section of the form is used to establish the relationship between the sag-tape cross section and the stream. Stadia rod readings are taken at each end of the suspended tape and at the water surface on the right and left streambanks. These readings are recorded within the "Rod Reading (ft)" column. They are used to assure that the ends of the tape are level and to quantify the vertical distance between the suspended tape and the water surface. Water surface readings and horizontal distances are also recorded upstream and downstream of the suspended tape. These observations are used to establish the water surface slope for input into Manning's equation.

The right side of the "Channel Profile Data" section is used to graphically depict the relative locations of the suspended tape and survey level, the direction of streamflow, and any photographic documentation of the field data collection effort. Photographs of the suspended tape are taken looking up, down, and across the stream.

Biologic sampling is summarized in the "Aquatic Sampling Summary" portion of the field form. Biologic data typically consists of a fish sample, collected by electrofishing, and an aquatic invertebrate sample. Captured fish are identified by species and measured to the nearest inch. A species-specific length-frequency distribution is created by placing a hashmark in the appropriate cell of the table as each fish is measured. Aquatic invertebrate sampling is summarized within the space provided at the bottom of this section.

All other pertinent field data is recorded in the "Comments" section of the field form. This section is often used to record weather conditions, water turbidity, or species-specific biomass estimates. This additional information helps characterize the field data when it is being analyzed in the office.

The "Discharge/Cross Section Notes" portion of the field form is used to record all of the hydraulic measurements associated with the discharge measurement (Figure C). A heading is provided to record the stream name, cross section number, date, edge of water looking downstream, the staging pin reading, and time at the beginning of the stream discharge measurement. The table below the heading is used to record "Features", "Distance From Initial Point", "Width", "Total Vertical Depth From Tape/Inst(rument)", and "Water Depth" channel geometry parameters at each cell vertical. Stream velocity measurements are recorded under the columns labeled "Depth of Observation", "Revolutions", "Time", and "Velocity" for each wet cell. All discharge measurement procedures are as outlined by Buchanan and Somers (1969).

The first and last channel geometry measurements are always taken at the cross section stakes. Channel geometry measurements should also be taken at the grassline-streambank and streambank-waterline intersections and at all distinguishable slope breaks between these two intersection points. The horizontal locations of the grassline-streambank and streambank-waterline intersections are also documented by placing a "G" and a "W" in the appropriate row of the "Features" column of the field form. Grassline is identified at the normal high water line, not flood stage, and is generally located below sedges and other plants that may survive submerged under high flows. The "Features"

column is also used to document the horizontal locations of the two cross section stakes ("S") and any rocks ("R") or other features that may have an impact on the discharge measurement.

In streams with uniform bottom profiles (i.e., sand, cobble, etc.), channel geometry and discharge measurements are taken at fixed intervals within the wetted portion of the channel. The interval is varied in streams with boulder substrates to more accurately reflect changes in the velocity distribution with changes in channel bottom profile. The stream discharge measurement is divided into a minimum of 20 to 30 discharge cells, depending upon wetted stream width, with a minimum cell width of 0.3 feet. Sufficient measurements are taken to ensure that no more than 10% of the total streamflow occurs within a single discharge cell. Horizontal and vertical distances are taken from the suspended tape and recorded to the nearest tenth of a foot. Stream velocity (ft/sec) within each cell is averaged and recorded.

The bottom of the "Discharge/Cross Section Notes" section is used to summarize the discharge measurement. Space is also provided to record the names of the persons responsible for the field data calculations, the staging pin reading, and time at the end of the stream discharge measurement.

Figure B. Field data input sheet (Front Page)

COLORADO WATER CONSERVATION BOARD

FIELD DATA FOR INSTREAM FLOW DETERMINATIONS

COLORADO STATE OF MONTANA

LOCATION INFORMATION

STREAM NAME:					CROSS-SECTION NO.:
CROSS-SECTION LOCATION					
DATE	OBSERVERS:				
LEGAL DESCRIPTION	¼ SECTION:	SECTION	TOWNSHIP N/S	RANGE: E/W	PM:
COUNTY:	WATERSHED	WATER DIVISION:	DOW WATER CODE		
MAPS:	USGS:				
	USFS:				

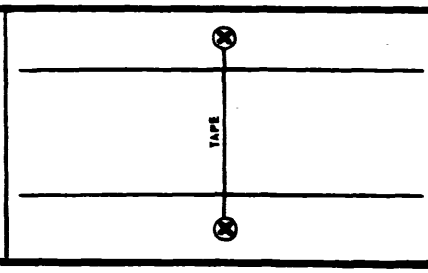
SUPPLEMENTAL DATA

SAG TAPE SECTION SAME AS DISCHARGE SECTION: YES / NO	METER TYPE			
METER NUMBER	DATE RATED	CALIB/SPIN ____ sec	TAPE WEIGHT ____ lbs/foot	TAPE TENSION ____ lbs
CHANNEL BED MATERIAL SIZE RANGE		PHOTOGRAPHS TAKEN YES/NO	NUMBER OF PHOTOGRAPHS	

CHANNEL PROFILE DATA

STATION	DISTANCE FROM TAPE @	ROD READING @
⊗ Tape @ Stake LB	0.0	
⊗ Tape @ Stake RB	0.0	
① WS @ Tape LB/RB	0.0	
② WS Upstream		
③ WS Downstream		
SLOPE		

SKETCH



LEGEND:
Stake ⊗
Station ①
Photo ◇
Direction of Flow

AQUATIC SAMPLING SUMMARY

STREAM ELECTROFISHED YES/NO	DISTANCE ELECTROFISHED ____ft	FISH CAUGHT YES/NO	WATER CHEMISTRY SAMPLED YES/NO

LENGTH - FREQUENCY DISTRIBUTION BY ONE-INCH SIZE GROUPS (1.0-1.9, 2.0-2.9, ETC.)

SPECIES (FILL IN)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	>15	TOTAL

AQUATIC INSECTS IN STREAM SECTION BY COMMON OR SCIENTIFIC ORDER NAME

COMMENTS

FORM #ISF FD 1-85

Figure C. Field data input sheet (Back Page)

DISCHARGE/CROSS SECTION NOTES

STREAM NAME		CROSS-SECTION NO	DATE	SHEET ___ OF ___
BEGINNING OF MEASUREMENT	EDGE OF WATER LOOKING DOWNSTREAM (0.0 AT STAKE) LEFT / RIGHT	Gage Reading. _____ ft	TIME	

Features: Stake (S) Grassline (G) Waterline (W) Rock (R)	Distance From Initial Point (ft)	Width (ft)	Total Vertical Depth From Tape/Inst (ft)	Water Depth (ft)	Depth of Observation (ft)	Revolutions	Time (sec)	Velocity (ft/sec) At Point	Velocity (ft/sec) Mean in Vertical	Area (ft^2)	Discharge (cfs)
TOTALS											

End of Measurement	Time:	Gage Reading _____ ft	CALCULATIONS PERFORMED BY:	CALCULATIONS CHECKED BY:

Office Procedures

The CWCB uses a Lotus 1-2-3 macro, called R2CROSS, to process the field data and model instream hydraulic parameters at streamflows above and below the field-measured discharge. The CWCB relies upon the biologic expertise of the cooperating agencies to interpret the output from R2CROSS and develop an initial, biologic instream flow recommendation. This initial recommendation is designed to address the unique biologic requirements of each stream without regard to water availability. After receiving the cooperating agencies' biologic recommendation, the CWCB staff evaluates stream hydrology to determine whether water is physically available for an instream flow appropriation.

Background on the R2CROSS Methodology

Three instream hydraulic parameters, average depth ($\bar{x}_d$), average velocity ($\bar{x}_v$), and percent wetted perimeter (*%WP*), are used to develop biologic instream flow recommendations in Colorado. The DOW has determined that by maintaining these three hydraulic parameters at adequate levels across riffle habitat-types, aquatic habitat in pools and runs will also be maintained for most life stages of fish and aquatic invertebrates (Nehring 1979).

The R2CROSS methodology uses Manning's equation to predict $\bar{x}_d$, $\bar{x}_v$, *%WP*, and other instream hydraulic parameters, at discharges both above and below the field-measured stream discharge. The methodology is both time and labor efficient, requires data from only a single stream transect, and has been found to produce similar results to more data intensive techniques (Nehring 1979) such as the Instream Flow Incremental Methodology (IFIM) developed by the U.S. Fish and Wildlife Service (Bovee 1982).

In 1973, the CWCB staff performed all Manning's equation calculations with a hand-held calculator. In 1981, the USFS released "*Program Documentation for R2-CROSS-81*" (Weatherred et al. 1981). This Fortran-based, mainframe computer program automated the repetitive task of manipulating and recalculating Manning's equation by hand. The CWCB used the USFS version of R2CROSS on the Colorado State University mainframe computer until 1985.

In 1986, the CWCB staff began development of a personal computer version of R2CROSS using the macro capabilities of Lotus 1-2-3. The CWCB found the R2CROSS macro to be advantageous because it ran on a personal computer and it could be customized to the specific needs of the CWCB. The most recent version of R2CROSS is menu-driven (Figure D) and requires very little experience with Lotus 1-2-3. The macro formats the R2CROSS worksheet, initiates data entry, and performs all calculations and printing automatically.

Figures E through K provide an example of R2CROSS output from a typical Colorado stream. Figure E is a "Proof Sheet" that is printed and inspected for data entry errors prior to performing final R2CROSS calculations. Final output consists of a five page printout (Figures F through J). Page one summarizes most of the stream location information, supplemental data, and channel profile data from the field form (Figure F). Page two summarizes the channel geometry/discharge field data set and values computed from the raw field data, including an estimate of Manning's "n" (Figure G). Page three consists of a water line comparison table which the program uses to interpolate the single water surface elevation that results in a calculated cross-sectional area equal to the field-measured cross-sectional area (Figure H). Page four is the staging table that is used by the cooperating agency to develop an initial, biologic instream flow recommendation

(Figure I). The staging table provides estimates of modeled instream hydraulic parameters at stages above and below the measured discharge. Page five summarizes measured and calculated flows, waterlines, and depths (Figure J). It also presents estimates of mean velocity, Manning's "n", water slope, and upper and lower streamflow limits within which the instream flow recommendation should fall. In general, hydraulic models based upon Manning's equation are most accurate when predicted flows fall within a range of 0.4 to 2.5 times measured flow (Bovee and Milhous 1978; Bovee 1982). Space is also provided for a narrative describing the basis for the initial instream flow recommendation and for the signatures of the personnel involved in making the recommendation. The macro can also be used to generate a plot of the stream cross section (Figure K).

Figure D. The R2CROSS Menu

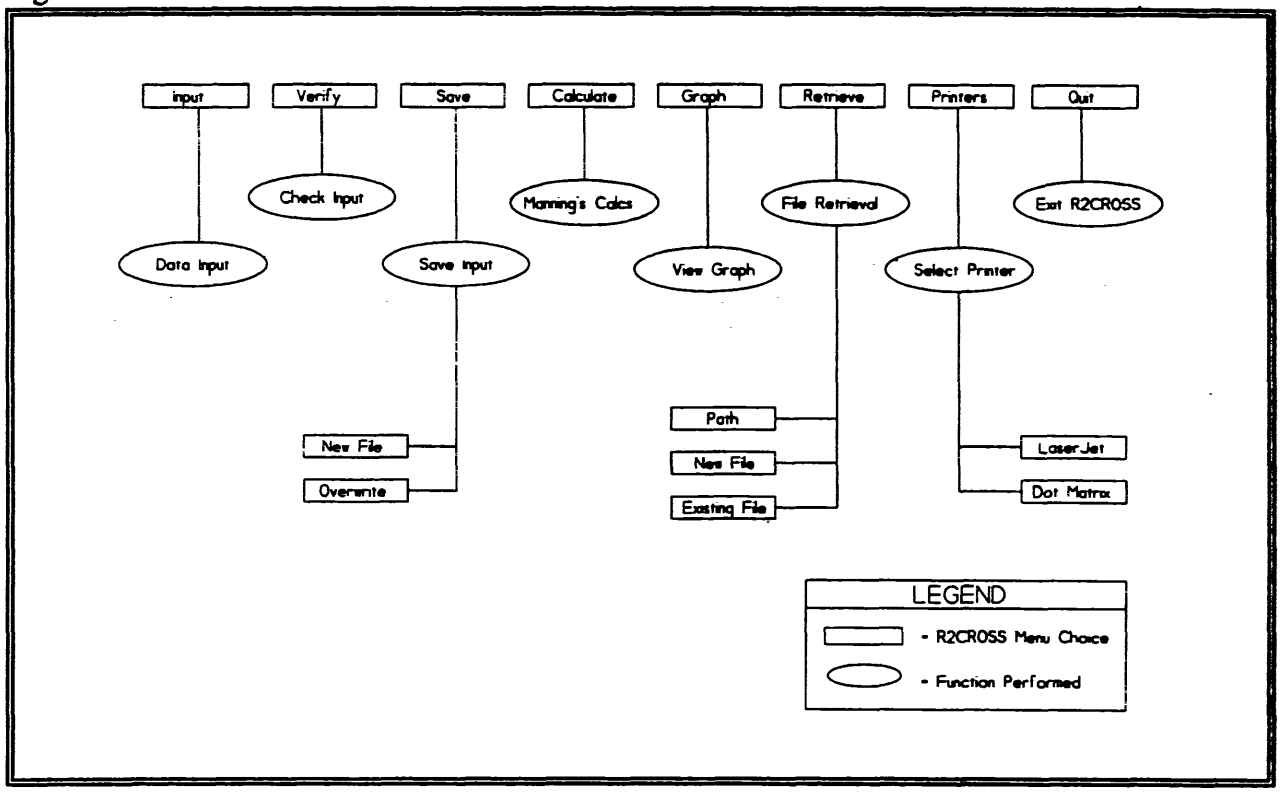


Figure E. R2CROSS proof sheet

PROOF SHEET

LOCATION INFORMATION

STREAM NAME: IRON CREEK
XS LOCATION: 100 YDS U/S DWB DIVERSION
XS NUMBER: 1

DATE: 10/17/86
OBSERVERS: SEAHOLM, PUTTMAN

1/4 SEC:
SECTION: 20
TWP: 2S
RANGE: 76W
PM: 6TH

COUNTY: GRAND
WATERSHED: FRASER
DIVISION: 5
DOW CODE: 25482

USGS MAP: BYERS PEAK
USFS MAP: ARAPAHOE

SUPPLEMENTAL DATA

TAPE WT: 0.0106
TENSION: 28

CHANNEL PROFILE DATA

SLOPE: 0.0055

INPUT DATA # DATA POINTS= 34

FEATURE	DIST	VERT DEPTH	WATER DEPTH	VEL	A	Q	TAPE TO WATER
S	0.00	1.10	0.00	0.00	0.00	0.00	0.00
	0.50	1.30	0.00	0.00	0.00	0.00	0.00
1 G	1.00	1.40	0.00	0.00	0.00	0.00	0.00
	2.00	1.80	0.00	0.00	0.00	0.00	0.00
	2.50	1.95	0.00	0.00	0.00	0.00	0.00
	3.00	2.00	0.00	0.00	0.00	0.00	0.00
R	3.50	1.90	0.00	0.00	0.00	0.00	0.00
	4.00	2.45	0.00	0.00	0.00	0.00	0.00
	4.50	2.45	0.00	0.00	0.00	0.00	0.00
W	5.00	2.60	0.00	0.00	0.00	0.00	0.00
	5.70	3.00	0.40	0.80	0.20	0.16	2.61
	6.00	3.10	0.45	0.45	0.13	0.06	2.66
	6.30	3.00	0.40	1.10	0.12	0.13	2.61
	6.60	3.00	0.40	0.95	0.12	0.11	2.61
	6.90	2.95	0.35	0.95	0.11	0.10	2.61
	7.20	2.85	0.25	0.70	0.07	0.05	2.61
	7.50	3.10	0.50	0.75	0.15	0.11	2.61
	7.80	3.10	0.50	0.65	0.15	0.10	2.61
	8.10	3.10	0.50	0.85	0.15	0.13	2.61
	8.40	3.20	0.60	0.95	0.18	0.17	2.61
	8.70	3.20	0.60	1.10	0.18	0.20	2.61
	9.00	3.20	0.60	1.35	0.18	0.24	2.61
	9.30	3.15	0.55	1.40	0.16	0.23	2.61
	9.60	3.25	0.65	1.50	0.19	0.29	2.61
	9.90	3.30	0.70	1.55	0.21	0.33	2.61
	10.20	3.30	0.70	1.60	0.21	0.34	2.61
	10.50	3.30	0.70	1.25	0.12	0.15	2.61
W	10.55	2.60	0.00	0.00	0.00	0.00	0.00
1 G	11.00	1.30	0.00	0.00	0.00	0.00	0.00
	11.50	0.85	0.00	0.00	0.00	0.00	0.00
	12.00	0.60	0.00	0.00	0.00	0.00	0.00
	12.50	0.55	0.00	0.00	0.00	0.00	0.00
	13.00	0.55	0.00	0.00	0.00	0.00	0.00
S	13.50	0.50	0.00	0.00	0.00	0.00	0.00
				TOTALS	2.65	2.91	

Figure F. Final output from R2CROSS (Page 1)

```
                    ****************************************************
                    *         COLORADO WATER CONSERVATION BOARD        *
                    *     INSTREAM FLOW / NATURAL LAKE LEVEL PROGRAM   *
                    *      STREAM CROSS-SECTION AND FLOW ANALYSIS      *
                    ****************************************************

LOCATION INFORMATION
====================

STREAM NAME:    IRON CREEK
XS LOCATION:    100 YDS U/S DWB DIVERSION
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DATE:           10/17/86
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1/4 SEC:
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PM:             6TH

COUNTY:         GRAND
WATERSHED:      FRASER
DIVISION:       5
DOW CODE:       25482

USGS MAP:       BYERS PEAK
USFS MAP:       ARAPAHOE

SUPPLEMENTAL DATA           *** NOTE ***
=================       Leave TAPE WT and TENSION
                      at defaults for data collected
TAPE WT:        0.0106  with a survey level and rod
TENSION:            28

CHANNEL PROFILE DATA
====================
SLOPE:          0.0055



INPUT DATA CHECKED BY: .....................................DATE.....................

ASSIGNED TO: ...............................................DATE.....................
```

Figure G. Final output from R2CROSS (Page 2)

STREAM NAME: IRON CREEK
XS LOCATION: 100 YDS U/S DWB DIVERSION
XS NUMBER: 1

	INPUT DATA	# DATA POINTS= 34			VALUES COMPUTED FROM RAW FIELD DATA				
	FEATURE	DIST	VERT DEPTH	WATER DEPTH	VEL	WETTED PERIM.	WATER DEPTH	AREA (Am)	Q (Qm)	% Q CELL
	S	0.00	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.0%
		0.50	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.0%
1	G	1.00	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.0%
		2.00	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.0%
		2.50	1.95	0.00	0.00	0.00	0.00	0.00	0.00	0.0%
		3.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0%
	R	3.50	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.0%
		4.00	2.45	0.00	0.00	0.00	0.00	0.00	0.00	0.0%
		4.50	2.45	0.00	0.00	0.00	0.00	0.00	0.00	0.0%
	W	5.00	2.60	0.00	0.00	0.00	0.00	0.00	0.00	0.0%
		5.70	3.00	0.40	0.80	0.81	0.40	0.20	0.16	5.5%
		6.00	3.10	0.45	0.45	0.32	0.45	0.13	0.06	2.1%
		6.30	3.00	0.40	1.10	0.32	0.40	0.12	0.13	4.5%
		6.60	3.00	0.40	0.95	0.30	0.40	0.12	0.11	3.9%
		6.90	2.95	0.35	0.95	0.30	0.35	0.11	0.10	3.4%
		7.20	2.85	0.25	0.70	0.32	0.25	0.07	0.05	1.8%
		7.50	3.10	0.50	0.75	0.39	0.50	0.15	0.11	3.9%
		7.80	3.10	0.50	0.65	0.30	0.50	0.15	0.10	3.4%
		8.10	3.10	0.50	0.85	0.30	0.50	0.15	0.13	4.4%
		8.40	3.20	0.60	0.95	0.32	0.60	0.18	0.17	5.9%
		8.70	3.20	0.60	1.10	0.30	0.60	0.18	0.20	6.8%
		9.00	3.20	0.60	1.35	0.30	0.60	0.18	0.24	8.4%
		9.30	3.15	0.55	1.40	0.30	0.55	0.16	0.23	7.9%
		9.60	3.25	0.65	1.50	0.32	0.65	0.19	0.29	10.1%
		9.90	3.30	0.70	1.55	0.30	0.70	0.21	0.33	11.2%
		10.20	3.30	0.70	1.60	0.30	0.70	0.21	0.34	11.6%
		10.50	3.30	0.70	1.25	0.30	0.70	0.12	0.15	5.3%
	W	10.55	2.60	0.00	0.00	0.70	0.00	0.00	0.00	0.0%
1	G	11.00	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.0%
		11.50	0.85	0.00	0.00	0.00	0.00	0.00	0.00	0.0%
		12.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.0%
		12.50	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.0%
		13.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.0%
	S	13.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.0%
	TOTALS					6.49	0.7 (Max.)	2.65	2.91	100.0%

Manning's n = 0.0552

Figure H. Final output from R2CROSS (Page 3)

STREAM NAME: IRON CREEK
XS LOCATION: 100 YDS U/S DWB DIVERSION
XS NUMBER: 1

WATER LINE COMPARISON TABLE

WATER LINE	MEAS AREA	COMP AREA	AREA ERROR
2.36	2.65	4.21	59.0%
2.38	2.65	4.07	53.9%
2.40	2.65	3.94	48.8%
2.42	2.65	3.81	43.8%
2.44	2.65	3.67	38.8%
2.46	2.65	3.54	33.8%
2.48	2.65	3.42	29.2%
2.50	2.65	3.30	24.7%
2.52	2.65	3.18	20.2%
2.54	2.65	3.07	15.8%
2.56	2.65	2.95	11.4%
2.57	2.65	2.89	9.3%
2.58	2.65	2.84	7.1%
2.59	2.65	2.78	5.0%
2.60	2.65	2.72	2.9%
2.61	2.65	2.67	0.8%
2.62	2.65	2.61	-1.3%
2.63	2.65	2.56	-3.4%
2.64	2.65	2.50	-5.5%
2.65	2.65	2.45	-7.6%
2.66	2.65	2.39	-9.6%
2.68	2.65	2.28	-13.7%
2.70	2.65	2.18	-17.8%
2.72	2.65	2.07	-21.9%
2.74	2.65	1.96	-25.9%
2.76	2.65	1.86	-29.9%
2.78	2.65	1.75	-33.9%
2.80	2.65	1.65	-37.8%
2.82	2.65	1.54	-41.8%
2.84	2.65	1.44	-45.6%
2.86	2.65	1.34	-49.5%

WATERLINE AT ZERO
AREA ERROR = 2.611

Figure I. Final output from R2CROSS (Page 4)

STREAM NAME: IRON CREEK
XS LOCATION: 100 YDS U/S DWB DIVERSION
XS NUMBER: 1

GL = lowest Grassline elevation corrected for sag
STAGING TABLE *WL* = Waterline corrected for variations in field measured water surface elevations and sag

	DIST TO WATER (FT)	TOP WIDTH (FT)	AVG. DEPTH (FT)	MAX. DEPTH (FT)	AREA (SQ FT)	WETTED PERIM. (FT)	PERCENT WET PER (%)	HYDR RADIUS (FT)	FLOW (CFS)	AVG. VELOCITY (FT/SEC)
GL	1.40	**9.97**	1.21	1.90	12.09	12.14	100.0%	1.00	24.07	1.99
	1.61	9.38	1.07	1.70	10.08	11.37	93.6%	0.89	18.57	1.84
	1.66	9.23	1.04	1.65	9.61	11.18	92.0%	0.86	17.36	1.81
	1.71	9.09	1.01	1.60	9.15	10.99	90.5%	0.83	16.18	1.77
	1.76	8.95	0.97	1.55	8.70	10.80	89.0%	0.81	15.04	1.73
	1.81	8.80	0.94	1.50	8.26	10.61	87.4%	0.78	13.95	1.69
	1.86	8.62	0.91	1.45	7.82	10.39	85.5%	0.75	12.93	1.65
	1.91	8.41	0.88	1.40	7.40	10.13	83.5%	0.73	11.97	1.62
	1.96	7.90	0.88	1.35	6.99	9.55	78.6%	0.73	11.33	1.62
	2.01	7.16	0.92	1.30	6.61	8.75	72.0%	0.76	10.96	1.66
	2.06	7.10	0.88	1.25	6.26	8.63	71.0%	0.73	10.08	1.61
	2.11	7.04	0.84	1.20	5.90	8.51	70.0%	0.69	9.24	1.57
	2.16	6.97	0.80	1.15	5.55	8.39	69.1%	0.66	8.42	1.52
	2.21	6.91	0.75	1.10	5.21	8.27	68.1%	0.63	7.64	1.47
	2.26	6.85	0.71	1.05	4.86	8.15	67.1%	0.60	6.88	1.42
	2.31	6.79	0.67	1.00	4.52	8.02	66.1%	0.56	6.16	1.36
	2.36	6.72	0.62	0.95	4.18	7.90	65.1%	0.53	5.47	1.31
	2.41	6.66	0.58	0.90	3.85	7.78	64.1%	0.49	4.81	1.25
	2.46	6.09	0.58	0.85	3.52	7.16	58.9%	0.49	4.38	1.24
	2.51	5.91	0.55	0.80	3.22	6.93	57.1%	0.46	3.86	1.20
	2.56	5.72	0.51	0.75	2.93	6.70	55.2%	0.44	3.37	1.15
WL	2.61	5.55	0.48	0.70	2.65	6.48	53.4%	0.41	2.91	1.10
	2.66	5.45	0.43	0.65	2.37	6.33	52.1%	0.37	**2.46**	**1.04**
	2.71	5.36	0.39	0.60	2.10	6.18	**50.9%**	0.34	**2.04**	**0.97**
	2.76	5.27	0.35	0.55	1.84	6.03	**49.7%**	0.30	**1.66**	0.90
	2.81	5.18	0.30	0.50	1.57	5.88	48.4%	0.27	1.31	0.83
	2.86	5.08	0.26	0.45	1.32	5.72	47.1%	0.23	0.99	0.75
	2.91	4.78	**0.22**	0.40	1.07	5.33	43.9%	0.20	**0.73**	0.68
	2.96	4.47	**0.19**	0.35	0.84	4.94	40.7%	0.17	**0.51**	0.61
	3.01	3.73	0.17	0.30	0.63	4.11	33.8%	0.15	0.36	0.57
	3.06	3.36	0.13	0.25	0.45	3.66	30.2%	0.12	0.22	0.49
	3.11	2.41	0.12	0.20	0.29	2.63	21.6%	0.11	0.14	0.46
	3.16	2.22	0.08	0.15	0.18	2.39	19.7%	0.07	0.06	0.35
	3.21	1.05	0.08	0.10	0.08	1.15	9.4%	0.07	0.03	0.34
	3.26	0.88	0.04	0.05	0.03	0.93	7.6%	0.04	0.01	0.22

** NOTE**: Bold and underlined text within the Iron Creek staging table was added to facilitate explanation of the procedure for developing biologic instream flow recommendations (see Pages 18-19). Standard R2CROSS staging table printouts will not contain these enhancements.

Figure J. Final output from R2CROSS (Page 5)

STREAM NAME: IRON CREEK
XS LOCATION: 100 YDS U/S DWB DIVERSION
XS NUMBER: 1

SUMMARY SHEET

MEASURED FLOW (Qm)=	2.91 cfs	RECOMMENDED INSTREAM FLOW:
CALCULATED FLOW (Qc)=	2.91 cfs	==========
(Qm-Qc)/Qm * 100 =	-0.1 %	
		FLOW (CFS) PERIOD
MEASURED WATERLINE (WLm)=	2.61 ft	========== ======
CALCULATED WATERLINE (WLc)=	2.61 ft	
(WLm-WLc)/WLm * 100 =	-0.1 %	_____ _____
MAX MEASURED DEPTH (Dm)=	0.70 ft	_____ _____
MAX CALCULATED DEPTH (Dc)=	0.70 ft	
(Dm-Dc)/Dm * 100	0.6 %	_____ _____
MEAN VELOCITY=	1.10 ft/sec	_____ _____
MANNING'S n=	0.055	
SLOPE=	0.0055 ft/ft	
.4 * Qm =	1.2 cfs	
2.5 * Qm=	7.3 cfs	

RATIONALE FOR RECOMMENDATION:
==========

_____
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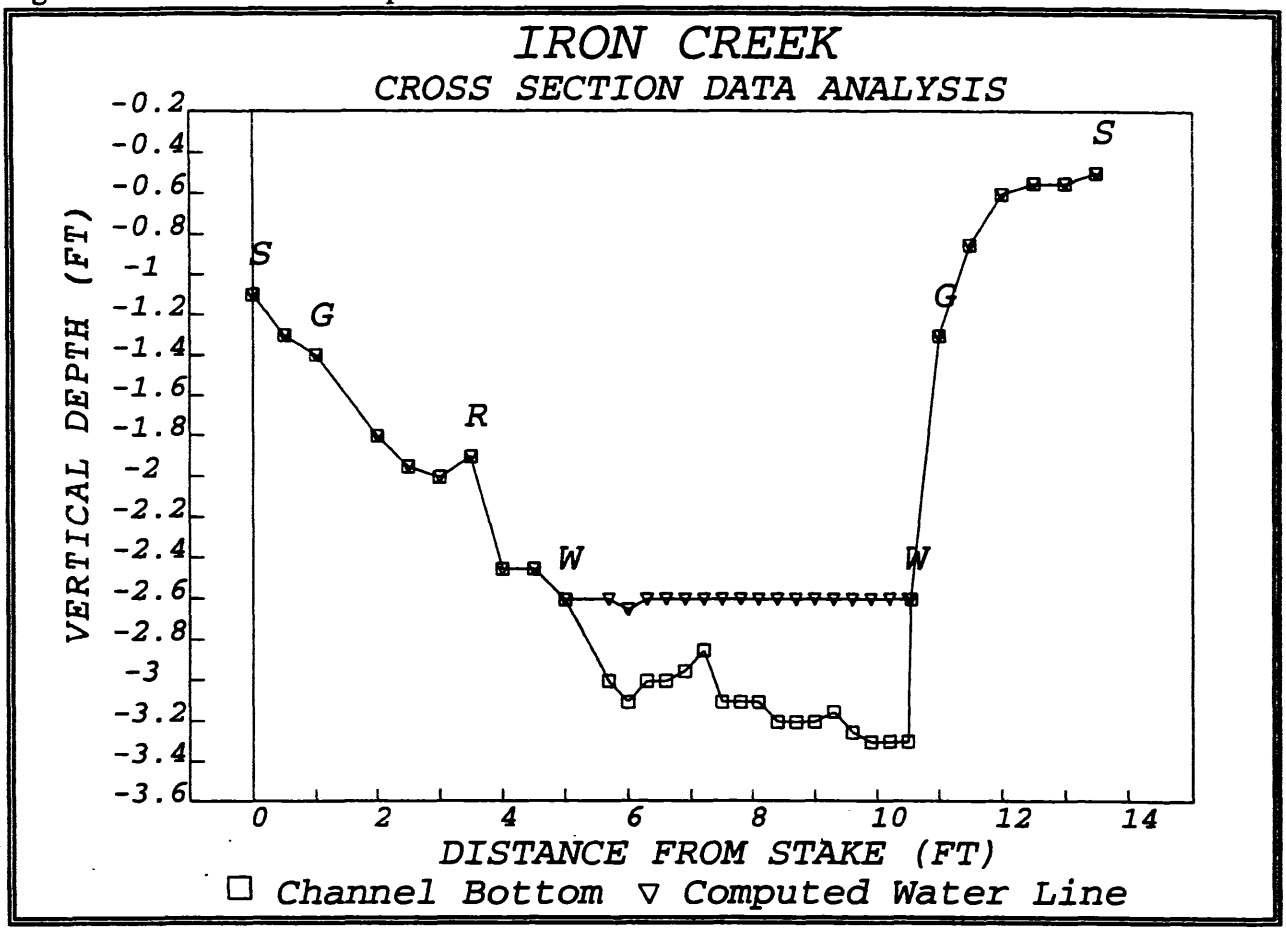
RECOMMENDATION BY: .....AGENCY..... DATE:.....

CWCB REVIEW BY: ..... DATE:.....

Figure K. Cross section plot from R2CROSS



Biologic Instream Flow Recommendations

When using R2CROSS, biologic instream flow recommendations are based on maintaining three principal hydraulic criteria, $\bar{x}_d$, $\bar{x}_v$, and *%WP*, at adequate levels across the stream transect (Table 2). The $\bar{x}_d$ and *%WP* criteria are functions of stream top width and grassline-to-grassline wetted perimeter, respectively. A constant $\bar{x}_v$ of 1 ft/sec is recommended for all streams. The DOW has determined that these three parameters are good indices of flow-related stream habitat quality and that maintenance of these parameters at adequate levels across riffle habitat-types will also result in maintenance of adequate aquatic habitat in pools and runs for most life stages of fish and aquatic invertebrates (Nehring 1979).

The three critical hydraulic parameters are estimated within the R2CROSS staging table at various levels of discharge (Figure I). Biologic instream flow recommendations are developed by locating the modeled streamflow(s) in the R2CROSS staging table that satisfy the three hydraulic criteria summarized in Table 2. The streamflow that meets two of the three criteria is considered as an initial winter flow recommendation. Initial summer flow recommendations are based upon satisfying all three criteria (Skinner, pers. comm). Aquatic biologists may modify summer and winter flow recommendations

Table 2. Criteria used to determine minimum flow requirements using the R2CROSS single transect method (Nehring 1979)

Stream Top Width (ft)[1]	Average Depth (ft)	Percent Wetted Perimeter (%)[1]	Average Velocity (ft/sec)
1-20	0.2	50	1.0
21-40	0.2-0.4	50	1.0
41-60	0.4-0.6	50-60	1.0
61-100	0.6-1.0	≥ 70	1.0

[1] At bankfull discharge.

based upon biologic considerations such as stream conditions, species composition, and aquatic habitat quality.

These hydraulic criteria can be applied to the R2CROSS staging table from the Iron Creek example (Figure I) to develop an initial biologic instream flow recommendation. In this example, the grassline top width of Iron Creek is 9.97 ft. Therefore, the DOW criteria for an $\bar{x}_d$ of 0.2 feet would be satisfied at a flow of approximately 0.6 cfs. The *%WP* criterion of 50% would be met at a flow of around 1.75 cfs and an $\bar{x}_v$ of 1 ft/sec at a flow of 2.25 cfs. Based upon this analysis, a winter flow recommendation of 1.75 cfs would meet the $\bar{x}_d$ and *%WP* criteria and a summer flow recommendation of 2.25 cfs would satisfy all three criteria. These initial recommendations may be adjusted up or down based upon biologic judgment and expertise.

Water Availability Requirements

Once an initial biologic instream flow recommendation has been developed, the CWCB staff must determine whether water is physically available to satisfy the biologic recommendation. The staff uses stream gaging records to analyze physical water availability whenever possible. In the absence of a gage record, the staff may use standardized hydrologic techniques, such as areal apportionment or synthetic streamflow modeling (Kircher et al. 1985), to estimate physical water availability. The staff may also conduct a review of the State Engineer's water rights tabulation and consult with Division Engineers and District Water Commissioners to determine the effect of senior diversions on a stream reach.

The water availability analyses may lead the CWCB staff to conclude that sufficient water is not available to meet the biologic recommendation. In that situation, the CWCB staff may request that the cooperating agency reconsider its biologic recommendation and determine whether the natural environment can be preserved with the amount of water available. If the natural environment can be preserved with the available water, the instream flow recommendation may be revised to reflect the lower available flow amounts. If the statutory water availability requirement cannot be satisfied, the CWCB must reject the instream flow recommendation.

Appropriating and Protecting an Instream Flow Water Right

On November 10, 1993, the CWCB adopted the "Statement of Basis and Purpose and Rules and Regulations Concerning the Colorado Instream Flow and Natural Lake Level Program." These Rules and Regulations codified existing CWCB procedures for implementing the Instream Flow Program and established procedures for handling acquisition of water, water rights, and interests in water including conditional rights, modification of instream flows, and inundation of instream flow water rights. The CWCB's procedural requirements for appropriating and protecting instream flow water rights are also described in great detail within these Rules and Regulations.

The procedural aspects of appropriating and protecting an instream flow water right are beyond the intended scope of this manuscript. Individuals who are interested in learning more about these procedures are encouraged to obtain a copy of the above-referenced Rules and Regulations from the CWCB.

Summary

In 1973, the Colorado State Legislature vested the CWCB with the authority to appropriate instream flow water rights to preserve the natural environment to a reasonable degree. Since that time, the CWCB has completed instream flow appropriations on approximately 7,982 miles of Colorado streams, and the Instream Flow Program is expanding.

The CWCB has adopted standardized field and office procedures for developing instream flow recommendations. This standardization helps to ensure that each instream flow recommendation is "necessary" and "reasonable", as required by state statute.

R2CROSS is one of the standard methodologies employed by the CWCB to model instream hydraulic parameters. The CWCB has chosen to use the R2CROSS methodology because it is both time and labor efficient, requiring data from only a single stream transect. It has also been found to produce similar results to more data intensive techniques like the IFIM. The R2CROSS macro is also easy to use and requires very little in the way of computer hardware or software.

Biologic instream flow recommendations based upon output from R2CROSS are designed to maintain $\bar{x}_v$, $\bar{x}_d$, and *%WP* at critical levels across riffle habitat-types. It is assumed that by maintaining these critical hydraulic parameters across riffles, aquatic habitat in pools and runs is also preserved. In addition to biologic considerations, water must be physically available for the CWCB to file for an instream flow water right.

An instream flow water right requires a coordinated effort between various state and federal agencies, the public, and the CWCB. The culmination of these efforts is a decreed instream flow water right that is held by the CWCB on behalf of the people of Colorado to "preserve the natural environment to a reasonable degree."

The Colorado State Legislature enacted SB 97 in 1973. By "recognizing the need to correlate the activities of mankind with some reasonable preservation of the natural environment" (§ 37-92-102(3), C.R.S. (1990)), the Legislature sought to balance traditional water development with some reasonable protection of Colorado's natural environment. This is not a simple task in the semi-arid Western United States where water is a scarce, and extremely valuable resource. The ongoing success of Colorado's Instream Flow Program assures that coordination between water development and protection of the natural environment will continue -- both now and into the future.

R2CROSS Program Documentation

Program documentation for the R2CROSS macro is divided into four sections. The "Setup and Installation" section describes the hardware and software requirements of the R2CROSS macro and installation of the R2CROSS program on a hard disk drive. The "Iron Creek Example" provides an opportunity for the new user to learn the most common procedures for entering and analyzing typical R2CROSS data sets and to verify that a newly installed version of R2CROSS is operating properly. "The R2CROSS Menu" provides detailed program documentation for each of the menu choices within R2CROSS (Figure D). Instructions for "Terminating and reactivating the R2CROSS macro" are described in the final section.

Appendix A provides a brief description of the "Program Calculations" that are performed within the R2CROSS macro. Rather than emphasizing the technical aspects of these calculations, this appendix is intended to provide a fundamental understanding of the operations being performed within the macro.

Output from the R2CROSS macro was verified against several simple hand-calculated examples. More complex cross sections were verified by comparison with output from the MANSQ option of IFIM (Bovee 1982). Based on this verification process, it is our belief that the instream hydraulic parameters summarized in the R2CROSS staging table are accurate estimations based upon Manning's equation.

To date, the majority of the CWCB's instream flow water rights have been based upon recommendations from an R2CROSS analysis. The CWCB chose the R2CROSS methodology because it is both time and labor efficient. It has also been shown to produce similar results to more costly techniques for modeling streamflows (Nehring 1979).

The CWCB hopes that the release of the R2CROSS macro will foster a greater understanding of this technical aspect of Colorado's Instream Flow Program. It is intended to be user-friendly. If you have any problems running the macro or questions regarding its operation, please feel free to contact the CWCB staff.

Setup and Installation

The R2CROSS macro runs efficiently on an IBM-compatible 80486 personal computer equipped with a hard disk drive, and DOS 6.0, Windows 3.1, and Lotus 1-2-3 Release 4 for Windows software.

Copying R2CROSS to a Hard Disk Drive

To begin installation of the R2CROSS program, create an R2CROSS subdirectory on your computer's hard drive using the DOS command:

md c:\R2CROSS

and press <ENTER>.

Copy the files from the enclosed diskette into this subdirectory using the DOS command:

copy a:*.* c:\R2CROSS.

Press <ENTER> to execute the command.

Loading Lotus 1-2-3 and Retrieving the R2CROSS Macro

To run the R2CROSS macro, load your copy of Lotus 1-2-3 Version 4 for Windows and open the R2CROSS.WK4 file using the Lotus menu commands "File" and "Open". The R2CROSS macro begins with an introductory message screen. Press <ENTER> to continue.

The data entry and data editing routines of the R2CROSS macro were intended to be very user-friendly. In R2CROSS, the <ENTER> key is used to complete the entry of all data within the "Location Information", "Supplemental Data", and "Channel Profile Data" sections of the data input screen (see Figure E). After entering the stream "Slope", the macro moves into the "Input Data" table. The arrow keys are used to complete the entry of all data within the "Input Data" table. After using the arrow keys to complete the entry of all data within the "Input Data" table, simultaneously press "<Ctrl> G" to exit the data entry routine.

After initial data entry, the arrow keys are used to correct and edit all data entry errors, including corrections to the "Location Information", "Supplemental Data", and "Channel Profile Data" (which were initially entered using the <ENTER> key). Table 3 is intended to help clarify the proper use of the <ENTER> key and the arrow keys within the R2CROSS data entry and data editing routines.

Table 3. Data entry and data editing using the <ENTER> key and arrow keys

	Initial data entry	Data correction/ editing
Location Information Supplemental Data Channel Profile Data	<ENTER> key	Arrow keys
Input Data Table	Arrow keys	Arrow keys

The "Iron Creek Example" which follows is a useful exercise. It is intended to familiarize new users with the data entry nuances of the R2CROSS macro and to verify that the newly installed copy of the R2CROSS macro is operating properly. We recommend that new users take a couple of minutes to work through the "Iron Creek Example" in order to gain hands-on experience with the R2CROSS macro prior to entering individual data sets.

Iron Creek Example

Figure E depicts an actual set of R2CROSS field data collected on Iron Creek, a tributary to the Fraser River in Grand County, Colorado. Assuming that the R2CROSS macro has been installed and initiated as described above, highlight the "Printers" menu choice and select either the LaserJet or Dot Matrix menu choice. Other printer-types may require a customized setup (consult your Lotus 1-2-3 reference manual).

In order to ensure that all subsequent data files are stored in the R2CROSS subdirectory, select the "Retrieve" menu choice, choose the "Path" suboption, key-in:

c:\ R2CROSS

and press <ENTER>.

To initiate data entry, select the "Input" menu option. R2CROSS then prompts you to enter the number of data points collected in the stream cross section. Count the number of data points (Iron Creek has 34), key-in this number at the prompt, and press <ENTER>.

Enter the remainder of the data within the "Location Information", "Supplemental Data", and "Channel Profile Data" sections of the R2CROSS macro. Use the <ENTER> key to complete each data entry and move the cursor through each of the data input cells in sequential order. The final use of the <ENTER> key occurs after keying-in the stream "Slope".

After entering the stream "Slope", use the arrow keys to enter all of the "Feature", "Dist", "Vert Depth", "Water Depth", and "Vel" data from the Input Data table of Figure E. The grasslines on each streambank represent a very important piece of information in the R2CROSS analysis. In the Iron Creek example, these grasslines occur at distances of 1.00 and 11.00 feet. It is imperative that these grasslines be identified within R2CROSS by placing the number "1" in the appropriate cell of Column A in the R2CROSS worksheet. This designation is so important that the R2CROSS macro will not proceed until the two grasslines have been specified. After entering all of the data within the Input Data table, including the two grasslines, simultaneously press "<Ctrl> G" to terminate the data entry routine and return to the main R2CROSS menu.

Select the "Verify" option to print a "Proof Sheet" for comparison with Figure E. If data entry errors are found, return to the "Input" menu option and correct them. When editing data, use the arrow keys to move around the worksheet and correct mistakes. When all data entry errors have been corrected, exit the editing routine by pressing "<Ctrl> G". The data editing routine can be repeated until all data entry errors have been corrected.

Once all data entry errors have been corrected, use the "Save" menu choice to store the input data file to the R2CROSS directory on the hard disk drive. Select the "New File" menu option, type an appropriate eight letter file name for the data set, and press <ENTER>. The file will automatically be saved with a .WK4 file extension. **Caution: do not name the file "R2CROSS".**

Select the "Calculate" option and press <ENTER> to initiate staging table calculations and print the final output from R2CROSS. Verify that the printed output is identical to Figures F through J.

Select the "Graph" option to view the cross section plot. Press <ENTER> to exit the view and print the cross section plot.

Exit the R2CROSS macro by selecting the "Quit" option. Answer "No" to the Lotus prompt to exit R2CROSS and remain in Lotus 1-2-3.

This general procedure can be followed to enter, edit, and analyze almost all R2CROSS datasets. To begin data entry on your own R2CROSS data set, select "Retrieve" a "New file" from the R2CROSS menu.

The R2CROSS Menu

The R2CROSS menu consists of eight main menu choices arranged from left to right across the top of the computer screen (Figure D). Use the arrow keys to move between menu choices and the <ENTER> key to select a highlighted menu choice.

Input

The "Input" menu choice is used to enter data in a new R2CROSS.WK4 worksheet or to correct/edit data in an existing worksheet. As depicted in Table 3, the <ENTER> key is used for the initial entry of the information contained within the "Location Information", "Supplemental Data", and "Channel Profile Data" sections of the field form. The arrow keys are used for the initial entry of the "Discharge/Cross Section Notes" within the "Input Data" table. The arrow keys are also used for all subsequent editing of data. This procedure ensures that the cursor is always located within the appropriate cell of the worksheet during the initial entry of the "Location Information", "Supplemental data" and "Channel Profile Data" (not always a one cell movement) and also allows the greatest flexibility in the initial entry of the discharge notes and subsequent editing of data.

Entering data in a new file

To enter data in a new file:

1. *Select the "Input" menu choice.*
2. *Count the number of data points (cell verticals) collected across the stream channel. Key-in that number and press <ENTER>. R2CROSS automatically sizes the worksheet to the proper number of discharge cells.*
3. *Once the worksheet has been sized, the macro prompts for the entry of a "Stream Name". Key-in the "Stream Name" and press the <ENTER> key to complete the data entry. Follow this same procedure for all of the information contained within the "Location Information", "Supplemental Data", and "Channel Profile Data" data entry cells. The final use of the <ENTER> key occurs after the entry of a stream "Slope". The cursor then moves to the upper left corner of the "Input Data" table (cell C50).*
4. *Use the arrow keys to enter all channel geometry and stream velocity data within the "Input Data" table. Key-in the horizontal distance from the zero stake to the cell vertical in the "Dist" column, vertical distance from the suspended tape to the channel bottom in the "Vert Depth" column, water depth in the "Water Depth" column, and water velocity in the "Vel" column for each cell in the cross section. Use the "Feature" column (Column B) to indicate the horizontal locations of the cross section stakes (S), grasslines (G), waterlines (W), and other features such as rocks (R), etc. Finally, enter a "1" in the appropriate cell of Column A to indicate the location of the grassline/streambank intersection on each streambank. R2CROSS uses the grassline locations to determine bankfull wetted perimeter and top width. These grassline locations are integral to the development of biologic instream flow recommendations in Colorado. The R2CROSS macro will not proceed until the grassline/streambank intersection on each streambank has been depicted with a "1" in Column A of the worksheet.*

5. *When all of the field data has been entered in the "Input Data" table, simultaneously press "<Ctrl> G" to exit from the "Input" routine and return to the main R2CROSS menu.*

Editing data in the current worksheet

To correct data entry errors in the current worksheet:

1. *Select the "Input" option.*
2. *Use the arrow keys to edit data. Data editing begins at the top of the "Input Data" table in cell C50. Move the cursor up from cell C50 to edit "Location Information", Supplemental Data", or "Channel Profile Data". Move down to edit data within the "Input Data" table.*
3. *After correcting all data entry errors, simultaneously press "<Ctrl> G" to terminate the "Input" routine and return to the main R2CROSS menu.*

Editing data in an "Existing file"

Previously-saved files can be retrieved, edited and re-run. Use the R2CROSS menu to "Retrieve" an "Existing file" and then following the instructions under "Editing data in the current worksheet" to edit previously-saved data files.

Verify

The "Verify" option is used to initiate R2CROSS discharge calculations and print a proof sheet (Figure E). Prior to running "Verify", be sure that the proper printer has been initialized (see "Printer" menu option).

Printed output consists of the cross section input data, calculated cross-sectional area, and calculated discharge. The proof sheet should be reviewed to verify accurate entry of all field measurements before continuing to the "Save" option. If data entry errors are discovered, return to the instructions for "Editing data in the current worksheet" and correct the errors. Proceed to "Save" only after all field data has been entered correctly.

Save

Use "Save" to store data input files. Data input files should always be saved prior to running the "Calculate" option because they are generally smaller in size and they can be retrieved, edited, and rerun if necessary. The "Calculate" option can not be run twice on the same file!

Prior to saving data input files, be sure to run the "Retrieve" and "Path" menu options to specify the location of data storage.

There are two suboptions under the "Save" menu choice, "New file" and "Overwrite". Choose your option carefully and do not overwrite the original R2CROSS.WK4 file!

New file

The first suboption, "New file", is used to save a newly created R2CROSS data set. This is accomplished by the following procedure:

1. *Select "Save" and then "New file" from the R2CROSS menu. R2CROSS prompts for the name of a new file.*
2. *Enter a name of up to eight characters and press <ENTER>.*

If a filename is selected that already exists in the default directory, the computer will beep and the file will not be saved. Should this happen, either repeat the above procedure and save under a different file name or go to the "Overwrite" suboption.

Overwrite

The "Overwrite" suboption is designed to overwrite an existing data file. Use the following procedure to perform this task:

1. *Select "Save" and then "Overwrite" from the R2CROSS menu. R2CROSS will list the files in the current directory that you may chose to overwrite.*
2. *Select a file from the list using the arrow keys and overwrite it by pressing <ENTER>. The existing file will be replaced with the current file. Do not select the original R2CROSS.WK4 file!*

Calculate

"Calculate" initiates all staging table calculations and prints a five page data summary (Figures F through Figure J). Be sure that you have saved your input data set and that the proper printer type has been specified prior to running "Calculate". This operation may take several minutes depending upon the speed of your computer. A detailed explanation of the four major calculations performed within R2CROSS can be found in "Appendix A - Program Calculations".

Graph

The "Graph" option allows the user to view and print a cross-section plot of the stream transect (Figure K). The cross section plot is useful for revealing potential problems with the input data set or potential errors in data collection or data entry. Errors, such as misread rod readings on waterlines or ground profiles, are often easily detected on a cross section plot.

Retrieve

The "Retrieve" menu option has three suboptions, "Path", "New file", and "Existing file". These suboptions are used to change the current file storage path and to retrieve data files.

Path

The "Path" suboption changes the current data storage location. A valid storage path may be any drive and/or directory which is in existence on the computer's hard drive. To select a new path, follow these steps:

1. *Select "Retrieve" and then "Path" from the R2CROSS menu.*
2. *Type in the name of an existing directory on your hard drive and press <Enter>.*

Subsequent files will be stored and retrieved within this directory. In the event that a non-existent path is entered, the computer will beep and return to the main menu. The default directory will remain in effect until a valid path has been entered.

The "Path" suboption choice is not frequently used. It may be appropriate if you wish to organize R2CROSS data from different streams into separate subdirectories. However, file organization can also be accomplished by simply using descriptive file names. If you do decide to create separate directories for your R2CROSS output files, you should copy the files from the R2CROSS diskette into each of these subdirectories so that they can be retrieved when you want to create a new data set.

New file

The "New file" suboption is used to initiate data entry on a new cross section. It erases the current worksheet from the screen and replaces it with a blank R2CROSS.WK4 worksheet. Read the introductory message and press <ENTER> to initiate data entry.

Existing file

The final suboption, "Existing file", retrieves a previously-saved R2CROSS data set from storage. Simply select the file to be retrieved. Select the "Input" command on the R2CROSS menu to edit the dataset. Staging table calculations are initiated by selecting the "Calculate" option. Remember, the "Calculate" option cannot be run twice on the same file.

Printers

LaserJet

Dot Matrix

The "Printers" menu option is used to format R2CROSS output for either a LaserJet or Dot Matrix type printer. The proper printer-type should be selected prior to running the "Verify" or "Calculate" menu options. Use the arrow keys to highlight the proper printer and press the <ENTER> key. Experienced Lotus 1-2-3 users can setup additional printers prior to retrieving the R2CROSS.WK4 worksheet if necessary. Consult a Lotus manual for specific instructions on setting up other types of printers.

Quit

Select the "Quit" menu option and answer "No" to the Lotus prompt to de-activate the R2CROSS macro and return to normal Lotus 1-2-3 operations. De-activating the R2CROSS macro allows for the use of standard Lotus 1-2-3 commands on all unprotected cells within the current data file. The R2CROSS menu can be reactivated by simultaneously pressing "<Ctrl> M". Alternatively, a new R2CROSS worksheet can be brought up from within Lotus 1-2-3 by retrieving the original R2CROSS.WK4 file from the computer's hard disk drive (see "Installation" section).

Terminating and Reactivating the R2CROSS Macro

Situations may arise where the macro must be terminated during data entry or calculation routines. To terminate the R2CROSS macro and return to the standard Lotus 1-2-3 menu, press <Ctrl><Break>. Then press the <Esc> key several times to clear the Lotus error message screen.

If the R2CROSS macro was terminated due to a data entry error or a problem with the execution of the macro, the integrity of the worksheet may have been compromised. If so, the current worksheet should be erased and a fresh copy of the R2CROSS.WK4 file retrieved from the computer's hard disk drive. The data should definitely be re-entered if the macro failed during the "Calculate" option of R2CROSS. Trying to rerun a compromised dataset may result in additional problems and unreliable output. It is always safer, albeit more time consuming, to start over.

If you do not believe the data in the current worksheet has been compromised, the R2CROSS macro can be re-activated by simultaneously pressing "<Ctrl> M". Macro operation will begin with the standard R2CROSS menu and data entry or calculations may then resume within the existing file.

Literature Cited

Bovee, K.D. 1982. A guide to stream habitat analysis using the Instream Flow Incremental Methodology. Instream Flow Information Paper No. 12. Washington, DC: U.S. Fish and Wildlife Service (FWS/OBS-82/26). 248pp.

Bovee, K.D. and R. Milhous. 1978. Hydraulic simulation in instream flow studies: Theory and techniques. Instream Flow Information Paper No. 5. Washington, DC: U.S. Fish and Wildlife Service (FWS/OBS -78/33). 143pp.

Buchanan, T.J. and W.P. Somers. 1969. Discharge measurements at gaging stations. Techniques of Water-Resources Investigations of the United States Geological Survey, Book 3, Chapter A8. United States Government Printing Office, Washington, D.C. 20402.

Benson, M.A., and T. Dalrymple. 1967. General field and office procedures for indirect discharge measurements. Techniques of Water-Resources Investigations of the United States Geological Survey, Book 3, Chapter A1. United States Government Printing Office, Washington, D.C. 20402.

Chow, V.T. 1959. Open-channel hydraulics. McGraw-Hill Book Company, New York. 680p.

Colorado Water Conservation Board. 1993. Statement of Basis and Purpose and Rules and Regulations Concerning the Colorado Instream Flow and Natural Lake Level Program. Department of Natural Resources. Denver, CO. 80203.

Grant, G.E., J.E. Duval, G.J. Koerper and J.L. Fogg. 1992. XSPRO: A channel cross-section analyzer. Technical Note 387. Bureau of Land Management. Denver, CO. 80225-0047.

Kircher, J.E., A.F. Choquette and B.D. Richter. 1985. Estimation of natural streamflow characteristics in western Colorado. Water-Resources Investigations Report 85-4086. United States Geological Survey. Box 25425, Denver Federal Center. Lakewood, CO 80225.

Laursen, H.I. 1978. Structural analysis. Second edition. New York. McGraw-Hill Book Company.

Nehring, R.B. 1979. Evaluation of instream flow methods and determination of water quantity needs for streams in the State of Colorado. Colorado Division of Wildlife. Fort Collins, CO.

Ray, G.A. and W.F. Megahan. 1979. Measuring cross sections using a sag tape: a generalized procedure. USDA Forest Service General Technical Report INT-47. Intermountain Forest and Range Experiment Station. U.S. Department of Agriculture. Ogden, UT. 84401.

Silvey, L. 1976. R-2 Cross Program: A sag-tape method of channel cross section measurement for use with instream flow determinations. United States Department of Agriculture, Forest Service Region 2. 11177 W. 8th Avenue. Lakewood, CO 80225.

Skinner, J. Instream Flow Coordinator. Colorado Division of Wildlife. Personal communication.

Weatherred, J.D., H.L. Silvey and D.J. Pfankuch. 1981. Program documentation for R2-CROSS-81. Watershed Systems Development Group. United States Department of Agriculture, Forest Service. 3825 East Mulberry Street. Fort Collins, CO 80524.

Appendix A - Program Calculations

Some R2CROSS users may be interested in the operation and layout of the Lotus 1-2-3 macro. Figure L depicts the sequence of operations performed within each R2CROSS menu option. Figure M provides the layout of the R2CROSS macro within the Lotus 1-2-3 worksheet. The four major computations performed within the R2CROSS macro are sag-tape corrections, estimation of Manning's "n", calculation of a water line comparison table, and calculation of a staging table.

Sag-Tape Calculations.

Channel geometry measurements that are taken using the sag-tape methodology must be corrected to a level reference. R2CROSS uses catenary curve formulas to compute these corrections from a sagging tape that has been leveled at each end. The use of the catenary curve solution is based on the assumption that the suspended steel tape is analogous to a suspended cable placed under a unidirectionally distributed load (Laursen 1978).

The derivation of the catenary curve solution is beyond the scope of this manuscript. Basically, R2CROSS uses the length of tape in suspension, the tension applied to the tape, and the standard weight of one foot of tape to apply the necessary vertical distance corrections to each cell vertical within the cross section.

When using a level and stadia rod to survey channel geometry, the tape weight and tension defaults, supplied in the original R2CROSS.WK4 worksheet, will simulate an extremely light tape stretched at very high tension. This results in a sag correction of approximately zero at each cell vertical.

Use of Manning's Equation.

Manning's equation is defined as:

$$Q = \frac{1.486 * A * R^{2/3} * S^{1/2}}{n}$$

where;
Q = discharge (cfs);
A = cross-sectional area (ft^2);
R = hydraulic radius (ft);
S = slope (ft/ft); and
n = Manning's "n", a dimensionless coefficient of roughness.

Manning's equation is used in two separate R2CROSS calculations. It is first used within the "Verify" option to provide an initial estimate of Manning's "n" using the rearranged equation:

$$n = \frac{1.486 * A * R^{2/3} * S^{1/2}}{Q}$$

The parameters Q, A, R, and S are calculated from the raw field data and used to solve directly for "n" (Figures G and J). Once estimated, Manning's "n" remains constant throughout the remainder of the streamflow modeling.

Manning's equation is also used within the "Calculate" option to solve for Q at each simulated water surface elevation within the staging table (Table 4).

Calculation of the Water Line Comparison Table.

R2CROSS uses two techniques for estimating cross-sectional area. One estimate is obtained by summing the product of "measured" water depth and cell width for all cells in the cross section (A_m). This technique allows independent water surface elevations within each cell and provides the most accurate estimate of cross-sectional area at the time the field measurement was made. However, this technique cannot be used to simulate a single, flat water surface elevation at computer-modeled stream discharges.

The second technique used to estimate cross-sectional area involves projecting a single water surface elevation across the stream channel. Channel bottom elevations are subtracted from this projected water surface elevation to obtain a "computed" water depth at each cell vertical. Cross-sectional area is obtained by summing the product of the "computed" water depth and cell width at each cell vertical (A_c). This technique constrains the water surface to a flat plane and is useful for simulating discharges above and below the field-measured discharge.

The water line comparison table (Figure H) iteratively calculates 31 separate estimates of A_c, using projected waterlines ranging from 0.25 feet above to 0.25 feet below the mean waterline measured in the field. The single water surface elevation that results in A_c equal to A_m is interpolated from the water line comparison table and is used in the staging table as the best estimate of the waterline at the field-measured discharge.

Calculation of the Staging Table.

The final product of the R2CROSS macro is the staging table (Figure I). In addition to the three critical biologic criteria ($\bar{x}_d$, *%WP*, and $\bar{x}_v$), R2CROSS also calculates incremental estimates of top width (TW), maximum depth (D_{max}), cross-sectional area (A), wetted perimeter (WP), hydraulic radius (R), and flow (Q) at a number of waterline elevations. The upper limit of the model occurs at bankfull discharge which is defined as the lower of the two grassline elevations measured in the field. The lower limit is either 1.75 feet below the waterline calculated in the water line comparison table or stage of zero flow (the lowest field-measured channel profile), whichever is higher in elevation. The formulae for each of the parameters estimated in the staging table are summarized in Table 4.

Figure L. Sequence of operations performed by R2CROSS macro

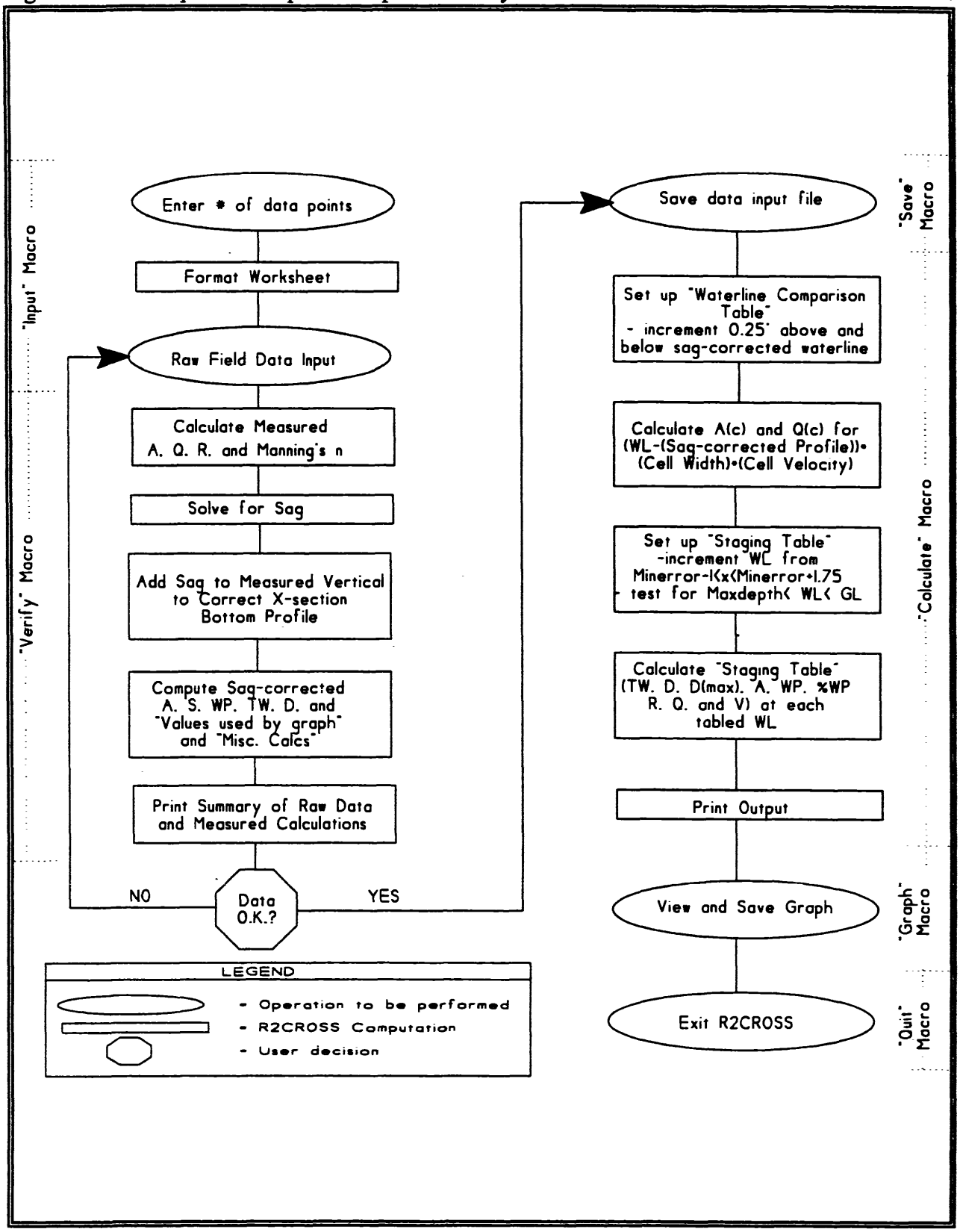


Figure M. Lotus 1-2-3 worksheet layout for R2CROSS macro

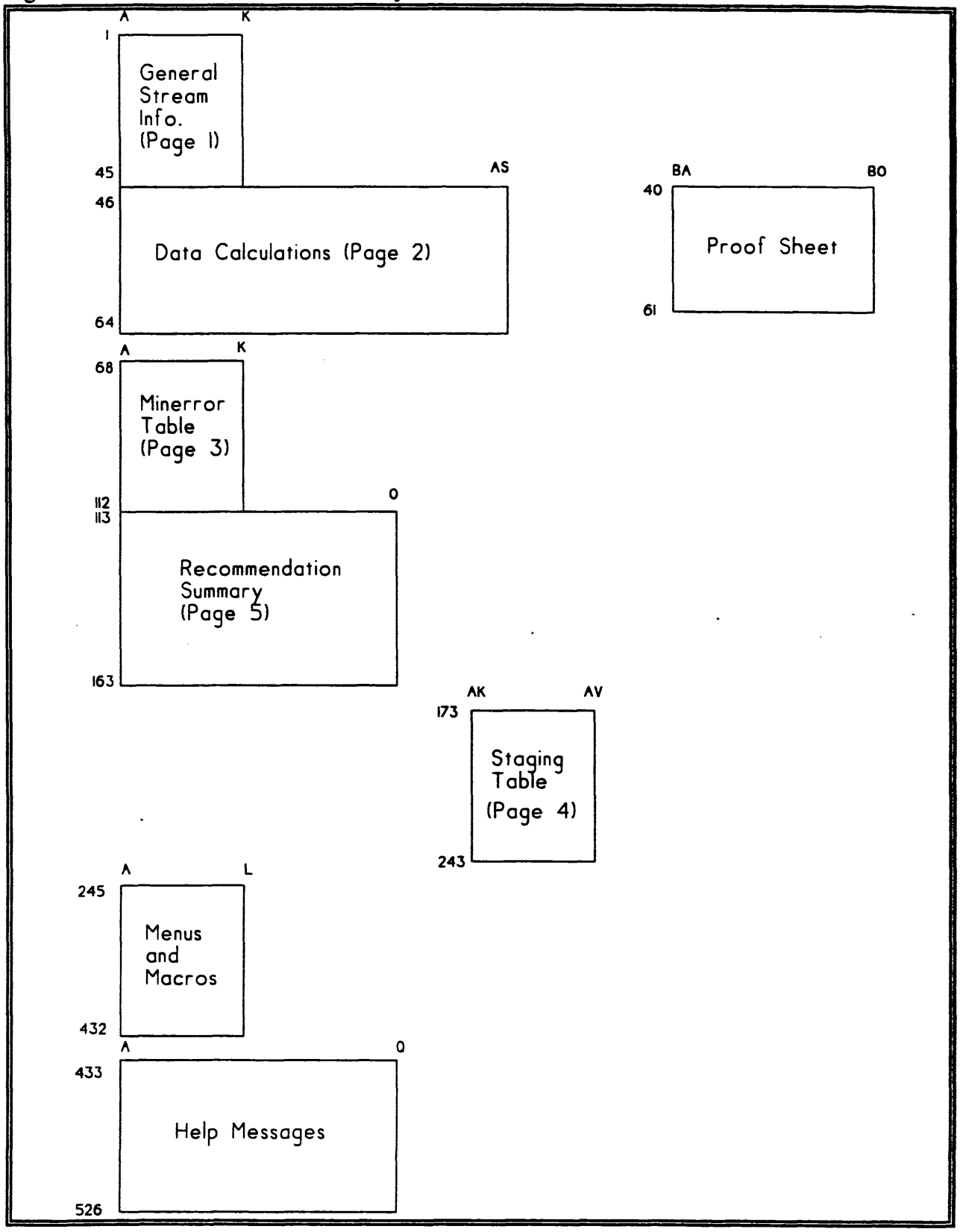


Table 4. Hydraulic Formulas used in R2CROSS staging table

Parameter	Formula
Top Width (TW)	$\sum_{i=1}^{n} TW_i$
Average Depth ($\bar{x}_d$)	$\frac{A}{TW}$
Maximum Depth (D_{max})	$\underset{i=1}{\overset{n}{MAX}}(D_i)$
Area (A)	$\sum_{i=1}^{n} A_i$
Wetted Perimeter (WP)	$\sum_{i=1}^{n} WP_i$
Percent Wetted Perimeter (%WP)	$\frac{WP}{Bankfull\ WP} * 100$
Hydraulic Radius (R)	$\frac{A}{WP}$
Flow (Q)	$\frac{1.486 * A * R^{\frac{2}{3}} * S^{\frac{1}{2}}}{n}$
Average Velocity ($\bar{x}_v$)	$\frac{Q}{A}$

Development of Instream Flow Recommendations In Colorado Using

R2CROSS for Microsoft Excel

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Stream and Lake Protection Section

June 2006

Abstract

In 1973, the Colorado State Legislature vested the Colorado Water Conservation Board with the authority to appropriate instream flow water rights in the State of Colorado. Today, the Board holds over 1,500 instream flow water rights covering approximately 8,500 miles of Colorado streams. Standardized field and office procedures help to ensure that instream flow recommendations reflect the amount of water required to" preserve the natural environment to a reasonable degree", as prescribed by state statute. R2CROSS is one of several instream flow assessment techniques employed by state and federal agencies to model instream hydraulic parameters. R2CROSS was chosen by the State of Colorado because it is time and labor efficient and produces comparable results to more costly instream flow assessment techniques, i.e., the Instream Flow Incremental Methodology. This manuscript provides an overview of Colorado's Instream Flow Program and documentation for the Board's R2CROSS computer macro. The R2CROSS macro requires Microsoft Excel for Windows software to operate.

Acknowledgments

The Colorado Water Conservation Board (CWCB) would like to thank everyone involved in the development of the Board's R2CROSS Excel for Windows macro. The macro was written by Mike Kleypas of MaKro Consulting (www.XLhelp.com/).

In addition, CWCB staff wishes to acknowledge the persons involved in the review and testing of the R2CROSS macro including Mark Uppendahl and Jay Skinner of the Colorado Division of Wildlife and Roy Smith of the Bureau of Land Management.

The Board is very grateful to all of those who participated in the development of the R2CROSS macro and this document.

Disclaimer

The R2CROSS macro is in the public domain, and the recipient may not assert any proprietary rights thereto nor represent it to anyone as other than a Colorado State Government-produced program. R2CROSS is provided "as-is" without warranty of any kind, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose. The user assumes all responsibility for the accuracy and suitability of this program for a specific application. In no event will the Colorado Water Conservation Board (CWCB) or the Colorado Division of Wildlife be liable for any damages, including lost profits, lost savings, or other incidental or consequential damages arising from the use of or the inability to use this program.

The CWCB staff verified the calculations preformed in its R2CROSS program with hand-held calculators and by comparison with other Manning's equation-based hydraulic streamflow models. Based upon this verification process, the staff believes that the instream hydraulic parameters summarized in the R2CROSS staging table are accurate calculations of Manning's equation. However, the CWCB does not suggest that the predicted hydraulic parameters will necessarily be realized at any particular stream discharge.

On November 10, 1993, the CWCB first adopted Rules that codified the procedures the Board follows in appropriating instream flow water rights. The most recent version of the rules can be found on the CWCB website at:
http://cwcb.state.co.us/Streamandlake/Documents/ADOPTEDRULES11-15-2005.pdf

This document is intended to conform to the procedures presented in the Rules.

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List of Tables and Figures

Tables

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Introduction

Colorado's Instream Flow Program originated in 1973 with the passage of Senate Bill 97 (SB 97). Under SB 97, the Colorado Water Conservation Board (CWCB) was vested with the authority to appropriate instream flow water rights in the State of Colorado (§37-92-102(3), C.R.S. (2002)). Instream flow water rights are held by the CWCB on behalf of the people of the State of Colorado to "preserve the natural environment to a reasonable degree." Today, the CWCB holds over 1,500 instream flow water rights covering approximately 8,500 miles of Colorado streams.

Determining the quantity of water required to preserve the natural environment to a reasonable degree can be a difficult task. The CWCB, in cooperation with the Colorado Division of Wildlife (DOW), has developed standard field and office procedures to ensure that each instream flow appropriation is necessary and reasonable and that the amount of water recommended is available for appropriation.

The R2CROSS methodology described in this document is a valuable tool in developing these instream flow recommendations. The CWCB uses R2CROSS because it is time and labor efficient and produces results which are comparable to more data intensive techniques (Nehring 1979).

This manuscript is divided into two sections. The first section describes Colorado's Instream Flow Program, including some of the statutory guidelines that have shaped the program. It also describes the standard field techniques and office procedures that are used by the CWCB staff in the development of R2CROSS-based instream flow recommendations. This section is intended to provide an understanding of the procedural and technical aspects of Colorado's Instream Flow Program.

The second section of the manuscript is a users' manual for the CWCB's R2CROSS macro. The CWCB has received many requests for its R2CROSS macro from both the public and private sectors but has been hesitant to release the program without proper documentation. The second section of the manuscript is intended to provide that documentation.

Colorado's Instream Flow Program

Instream Flow Legislation

The CWCB was created in 1937 to serve as the State's chief water planning agency (§37-60-101 through 130, C.R.S. (2002)). Today, the CWCB is responsible for the administration of the State's Instream Flow Program, identification of flood plains, funding of new water development and water conservation projects, and negotiation of inter- and intra-state water planning issues.

The CWCB is a fourteen-member board. The board consists of one Governor-appointee from each of the eight major river drainages in the State and one from the City and County of Denver. Each Governor-appointee must also be confirmed by the Colorado State Senate. Ex-officio members of

the board include the Executive Director of the Department of Natural Resources, the Directors of the CWCB and DOW, the State Attorney General, and the State Engineer. The diverse backgrounds of its board members provide the CWCB with an excellent representation of Colorado's various water interests.

Colorado's Instream Flow Program was created in 1973 when the Colorado State Legislature recognized "the need to correlate the activities of mankind with some reasonable preservation of the natural environment" through the passage of SB 97. Within SB 97, the definition of beneficial use was changed to include minimum stream flows and the CWCB was vested with the exclusive authority to appropriate "waters of natural streams and lakes ... as may be required ... to preserve the natural environment to a reasonable degree."

The Instream Flow statute sets forth the guidelines for the administration of Colorado's Instream Flow Program. In order to encourage other entities to participate in Colorado's Instream Flow Program, the statute directs the CWCB to request instream flow recommendations from other state and federal agencies prior to initiating an instream flow appropriation. The CWCB routinely requests instream flow recommendations from the DOW, Colorado Division of Parks and Outdoor Recreation, United States Department of Agriculture, and United States Department of Interior (the "cooperating agencies").

Prior to appropriating an instream flow water right, the statute requires the CWCB to: (1) "determine that the natural environment will be preserved to a reasonable degree by the water available for the appropriation to be made; (2) determine that there is a natural environment that can be preserved to a reasonable degree with the CWCB's water right, if granted; and (3) determine that such environment can exist without material injury to water rights" (§37-92-102(3c), C.R.S. (2002)). The CWCB makes these determinations based upon a review of the supporting technical data and a final instream flow recommendation prepared by the CWCB staff.

Standardized field and office procedures have been developed to help ensure that final instream flow recommendations meet statutory guidelines and are consistent. The standard field procedures that were established concern selection of transect sites and collection of hydraulic and biologic data. Standard office procedures have been established for determining biological instream flow recommendations using output from the R2CROSS program and for analyzing water availability.

Merriman and Janicki (2005) provide additional information on the state of Colorado’s Instream Flow Program.

Field Procedures

The R2CROSS Method is a "Standard Setting" hydraulic based instream flow assessment technique. R2CROSS instream flow recommendations are typically based on hydraulic and biologic data collected during single or multiple field visits. Hydraulic data collection consists of setting up atransect, surveying stream channel geometry, water surface elevations, and measuring stream discharge. Biologic data is gathered to document the existence of a natural environment.

Field Data Site Selection

The R2CROSS method requires that stream discharge and channel profile data be collected in a riffle stream habitat-type. A riffle is a stream segment that is controlled by channel geometry rather than a downstream flow control. Riffles are most easily visualized as the stream reaches which would dry up most quickly should streamflow cease.

Biologically, riffles are essential to the production of benthic invertebrates and the passage, spawning, egg incubation, feeding, and protective cover of fish. Riffles are also the stream habitat-type most sensitive to changes in hydraulic parameters with variation in discharge (Nehring 1979). Riffles are critical to a healthy aquatic environment because small reductions in streamflow may result in large reductions in water depth and the amount of wetted perimeter available for aquatic habitat. Maintaining adequate streamflow in riffles also preserves the natural environment in other important stream habitat-types such as pools and runs (Nehring 1979).

Hydraulic engineers have developed several mathematical models and equations to predict instream hydraulic parameters (Chow 1959). Manning's equation is one such model that is well-suited to the riffle stream habitat-type (Grant et al. 1992). In order to maximize the reliability of Manning's equation, transects are placed within a riffle so that streamflow is uniform across the transect (Grant et al. 1992). Each transect should represent the average stream width, depth, and cross-sectional area within the riffle being characterized. Transects should be located in areas that exhibit natural banks or grasslines and concentrated water flow, free from braiding. They should not be located on eroded or undercut streambanks.

Hydraulic Data Collection

Stream discharge is measured using standardized procedures established by the United States Geological Survey (USGS) (Buchanan and Somers 1969). Channel geometry can be measured using sag-tape methodology (Silvey 1976; Ray and Megahan 1979) or by the use of a land survey level and stadia rod (Benson and Dalrymple 1967). A list of recommended field equipment for completing the required streamflow measurement and channel geometry measurements is provided in Table 1.

The sag-tape methodology consists of suspending a steel tape from bank to bank across the stream channel, perpendicular to the streamflow (Figure A). Metal cross section stakes are driven into the ground above the grassline. The steel tape is suspended by attaching the zero-end of the tape to one of the metal stakes, stretching the tape across the stream, and then attaching the other end to a tape

Table 1. Recommended Field Equipment List

Equipment	Description
100' Steel Survey tape	Stretched between cross section stakes. (Obtain standard weight of a 1.0 foot section of tape from manufacturer)
Spring Tension Scale	Used to measure pounds of tension on steel tape when stretched between stakes.
Tape Clamp Handle	Holds tape in tension.
Cross Section Stakes	Two 24"-36" metal stakes used to maintain tape tension and to level steel tape. Must be strong enough to be driven into rocky stream bank.
Discharge Wading Rod (or Stadia Rod)	Used to measure vertical depths from suspended tape to stream channel.
Level, Tripod, and Stadia Rod	Used to level ends of suspended tape and to measure slope.
Current Meter	Pygmy, Price AA, Marsh-McBirney or similar devise used to measure stream velocity.
Hand Sledge Hammer	Used to drive cross section stakes into streambank.
Staging Pin	Used to detect changes in discharge during the streamflow measurement.
100' Fiberglass Tape	Used to measure horizontal distance from suspended tape to water-slope stadia rod readings.
Field Forms and Clipboard	Standardized form to ensure complete set of field data.
Miscellaneous Items	Digital camera, GPS Unit, maps, waders, stopwatch and calculator.

clamp and spring scale fastened to the metal stake on the opposite streambank. A minimum of 15 pounds of tension is applied to the tape, as the tape is drawn up and clamped. A survey level and stadia rod are used to adjust the ends of the tape up or down until they are level, thereby producing a consistent datum from which vertical distance measurements can be read.

The R2CROSS program uses the standard weight of a one-foot section of the steel tape, tape tension, and the length of tape in suspension to correct horizontal distance and vertical depth measurements made from the sagging tape. The program adjusts the coordinates at each cross section vertical so that the corrected measurements correspond to a level datum from stake to stake and not the curved datum created by the sagging tape (Figure A).

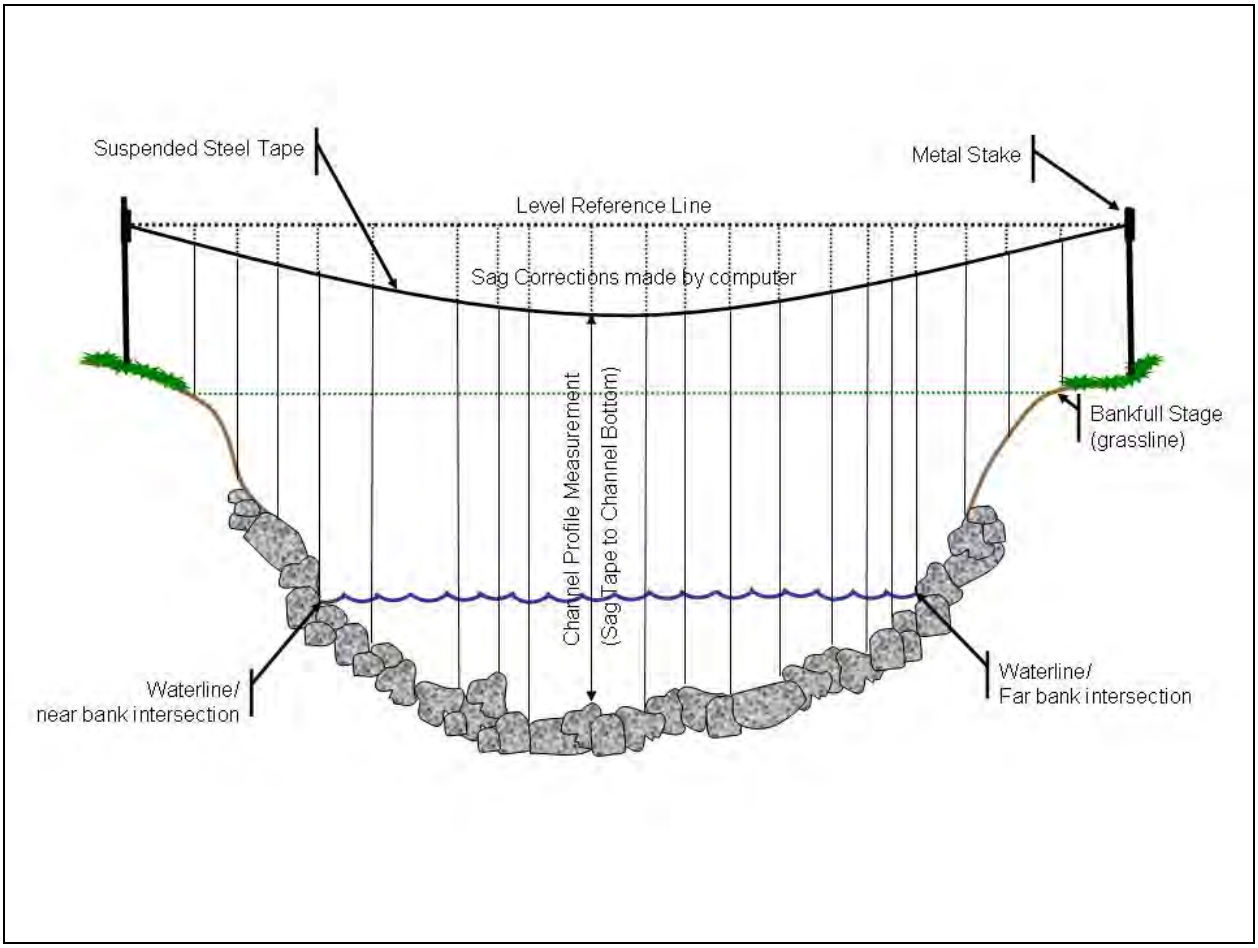


Figure A. Typical stream cross section

Vertical measurements between the suspended tape and the stream channel may be replaced with readings using a survey level and stadia rod. The suspended tape is then used to measure only the horizontal location of each cell vertical. There is no need to precisely level the ends of the suspended tape or to record the tape tension as no sag corrections are required.

Biologic Data Collection

Biologic sampling is conducted to document the existence of a natural environment. Coldwater fish species, particularly salmonids, have been used to indicate the existence of such a natural environment in the majority of the CWCB's instream flow appropriations to date. Warmwater fish species and other aquatic life forms may be used to document the existence of a natural environment in more downstream, low-elevation stream segments. In addition to salmonids, the CWCB has used amphibians, such as frogs and salamanders, and warmwater fish species, including the endangered fishes of the Colorado River basin, as the biologic basis for instream flow appropriations.

Biologic data typically consists of a fish sample, collected by electrofishing, and an aquatic invertebrate sample. Captured fish are identified and measured and a length-frequency distribution is

constructed for each species. The fish sample is not tied directly to the R2CROSS hydraulic modeling but it may be used to refine the biologic instream flow recommendation to meet the specific habitat requirements of unique populations.

Digital Camera and GPS Unit

Digital cameras should be used to record the field data collection effort. A photographic record of the hydraulic data collection process may include pictures of the transect location (upstream, downstream and across stream views) and the stream flow measurement process. These photos can serve as valuable visual evidence that cross sections were properly located in riffles and that standard data collection protocols were met. In addition, photographs may help relocate a transect in the future should additional data be required.

Photos of the biologic data collection effort may also assist the CWCB in making its natural environment findings. Photographs of the biologic sampling process and captured organisms (fish, aquatic insects, etc.) may be used in combination with a statistical summary of the results of biologic sampling to document the existence of a natural environment.

Handheld GPS Units should be used to record field data collection site locations. Geographic coordinate information helps relocate transect locations in the future should additional data be required.

Digital cameras and handheld GPS Units are small in size and light in weight. Digital photos can easily be transferred into written reports and they provide valuable visual evidence. A digital camera and a handheld GPS Unit should be considered standard equipment on any field data collection effort.

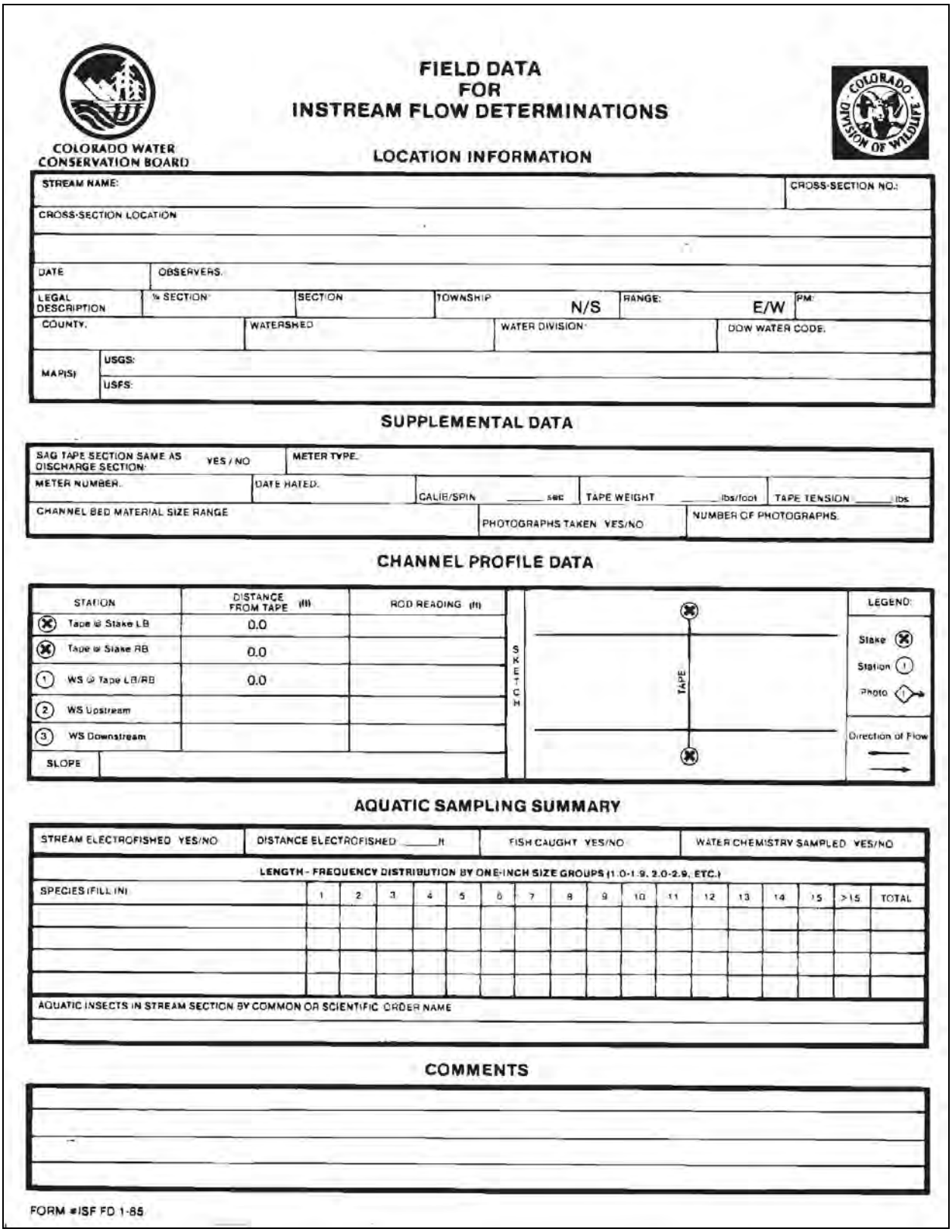
The Field Form

The CWCB and DOW use a standardized field form to record all field data. The use of this form helps to ensure that all instream flow recommendations are based upon a uniform set of field data. The front page of the form provides space for cross section "Location Information", "Supplemental Data", "Channel Profile Data", an "Aquatic Sampling Summary", and "Comments" (Figure B). The back page is dedicated to "Discharge/Cross Section Notes" (Figure C).

The "Location Information" section of the field form is used to describe the location of the cross section as well as the date and names of the members of the field crew. Geographic information can be obtained from USGS maps, United States Forest Service (USFS) maps, or handheld GPS Units. Water divisions and DOW water codes can be obtained from the State Engineers' Office, the CWCB, or the DOW.

The "Supplemental Data" section is used to provide supporting documentation of the field data collection effort. Most importantly, this section is used to record the tape manufacturer's standard weight (lbs/ft) and tape tension (lbs). The R2CROSS program uses this information, together with the length of tape in suspension, to adjust vertical distances measured from the sagging tape to a level reference datum.

The "Channel Profile Data" section of the form is used to establish the relationship between the sag-tape cross section and the stream. Stadia rod readings are taken at each end of the suspended tape and at the water surface on the right and left streambanks. These readings are recorded within the "Rod Reading (ft)" column. They are used to assure that the ends of the tape are level and to quantify the vertical distance between the suspended tape and the water surface. Water surface readings and horizontal distances are also recorded upstream and downstream of the suspended tape. These observations are used to establish the water surface slope for input into Manning's equation.



COLORADO WATER CONSERVATION BOARD

FIELD DATA FOR INSTREAM FLOW DETERMINATIONS

COLORADO DIVISION OF WILDLIFE

LOCATION INFORMATION

STREAM NAME:					CROSS-SECTION NO.:
CROSS-SECTION LOCATION					
DATE	OBSERVERS:				
LEGAL DESCRIPTION	¼ SECTION:	SECTION	TOWNSHIP N/S	RANGE: E/W	PM:
COUNTY:	WATERSHED	WATER DIVISION:	DOW WATER CODE:		
MAP(S)	USGS:				
	USFS:				

SUPPLEMENTAL DATA

SAG TAPE SECTION SAME AS DISCHARGE SECTION: YES / NO	METER TYPE:			
METER NUMBER:	DATE RATED:	CALIB/SPIN ____ sec	TAPE WEIGHT ____ lbs/foot	TAPE TENSION ____ lbs
CHANNEL BED MATERIAL SIZE RANGE		PHOTOGRAPHS TAKEN YES/NO	NUMBER OF PHOTOGRAPHS:	

CHANNEL PROFILE DATA

STATION	DISTANCE FROM TAPE (ft)	ROD READING (ft)
⊗ Tape @ Stake LB	0.0	
⊗ Tape @ Stake RB	0.0	
① WS @ Tape LB/RB	0.0	
② WS Upstream		
③ WS Downstream		
SLOPE		

SKETCH

LEGEND:

Stake ⊗

Station ①

Photo ◇

Direction of Flow

AQUATIC SAMPLING SUMMARY

STREAM ELECTROFISHED YES/NO	DISTANCE ELECTROFISHED ____ ft	FISH CAUGHT YES/NO	WATER CHEMISTRY SAMPLED YES/NO

LENGTH - FREQUENCY DISTRIBUTION BY ONE-INCH SIZE GROUPS (1.0-1.9, 2.0-2.9, ETC.)

SPECIES (FILL IN)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	>15	TOTAL

AQUATIC INSECTS IN STREAM SECTION BY COMMON OR SCIENTIFIC ORDER NAME

COMMENTS

FORM #ISF FD 1-85

Figure B. Field data input sheet (Front Page)

DISCHARGE/CROSS SECTION NOTES

STREAM NAME:	CROSS-SECTION NO	DATE	SHEET ___ OF ___

BEGINNING OF MEASUREMENT	EDGE OF WATER LOOKING DOWNSTREAM (0.0 AT STAKE) LEFT / RIGHT	Gage Reading _____ ft	TIME

Features: Stake (S) Grassline (G) Waterline (W) Rock (R)	Distance From Initial Point (ft)	Width (ft)	Total Vertical Depth From Tape/Inst (ft)	Water Depth (ft)	Depth of Observation (ft)	Revolutions	Time (sec)	Velocity (ft/sec) At Point	Velocity (ft/sec) Mean in Vertical	Area (ft^2)	Discharge (cfs)
TOTALS											

End of Measurement	Time:	Gage Reading _____ ft	CALCULATIONS PERFORMED BY:	CALCULATIONS CHECKED BY:

Figure C. Field data input sheet (Back Page)

The right side of the "Channel Profile Data" section is used to graphically depict the relative locations of the suspended tape and survey level, the direction of streamflow, and any photographic documentation of the field data collection effort. Photographs of the suspended tape are taken looking up, down, and across the stream.

Biologic sampling is summarized in the "Aquatic Sampling Summary" portion of the field form. Biologic data typically consists of a fish sample, collected by electrofishing, and an aquatic invertebrate sample. Captured fish are identified by species and measured to the nearest inch. A species-specific length-frequency distribution is created by placing a hashmark in the appropriate cell of the table as each fish is measured. Aquatic invertebrate sampling is summarized within the space provided at the bottom of this section.

All other pertinent field data is recorded in the "Comments" section of the field form. This section is often used to record weather conditions, water turbidity, or species-specific biomass estimates. This additional information helps characterize the field data when it is being analyzed in the office.

The "Discharge/Cross Section Notes" portion of the field form is used to record all of the hydraulic measurements associated with the discharge measurement (Figure C). A heading is provided to record the stream name, cross section number, date, edge of water looking downstream, the staging pin reading, and time at the beginning of the stream discharge measurement. The table below the heading is used to record "Features", "Distance From Initial Point", "Width", "Total Vertical Depth From Tape/Inst(rument)", and "Water Depth" channel geometry parameters at each cell vertical. Stream velocity measurements are recorded under the columns labeled "Depth of Observation", "Revolutions", "Time", and "Velocity" for each wet cell. All discharge measurement procedures are as outlined by Buchanan and Somers (1969).

The first and last channel geometry measurements are always taken at the cross section stakes. Channel geometry measurements should also be taken at the grassline-streambank and streambank-waterline intersections and at all distinguishable slope breaks between these two intersection points. The horizontal locations of the grassline-streambank and streambank-waterline intersections are also documented by placing a "G" and a "W" in the appropriate row of the "Features" column of the field form. Grassline is identified at the normal high water line, not flood stage, and is generally located below sedges and other plants that may survive submerged under high flows. The "Features" column is also used to document the horizontal locations of the two cross section stakes ("S") and any rocks ("R") or other features that may have an impact on the discharge measurement.

On streams with uniform bottom profiles (i.e., sand, cobble, etc.), channel geometry and discharge measurements are taken at fixed intervals within the wetted portion of the channel. The interval is varied in streams with boulder substrates to more accurately reflect changes in the velocity distribution with changes in channel bottom profile. The stream discharge measurement is divided into a minimum of 20 to 30 discharge cells, depending upon wetted stream width, with a minimum cell width of 0.3 feet. Sufficient measurements are taken to ensure that no more than 10% of the total streamflow occurs within a single discharge cell. Horizontal and vertical distances are taken

from the suspended tape and recorded to the nearest tenth of a foot. Stream velocity (ft/sec) within each cell is averaged and recorded.

The bottom of the "Discharge/Cross Section Notes" section is used to summarize the discharge measurement. Space is also provided to record the names of the persons responsible for the field data calculations, the staging pin reading, and time at the end of the stream discharge measurement.

Office Procedures

The CWCB uses a Microsoft Excel for Windows macro, called R2CROSS, to process the field data and model instream hydraulic parameters at streamflows above and below the field-measured discharge. The CWCB relies upon the biologic expertise of the cooperating agencies to interpret the output from R2CROSS and develop an initial, biologic instream flow recommendation. This initial recommendation is designed to address the unique biologic requirements of each stream without regard to water availability. After receiving the cooperating agencies' biologic recommendation, the CWCB staff evaluates stream hydrology to determine whether water is physically available for an instream flow appropriation.

Background on the R2CROSS Methodology

Three instream hydraulic parameters, average depth ($\bar{x}_d$), average velocity ($\bar{x}_v$), and percent wetted perimeter (*%WP*), are used to develop biologic instream flow recommendations in Colorado. The DOW has determined that by maintaining these three hydraulic parameters at adequate levels across riffle habitat-types, aquatic habitat in pools and runs will also be maintained for most life stages of fish and aquatic invertebrates (Nehring 1979).

The R2CROSS methodology uses Manning's equation to predict $\bar{x}_d$, $\bar{x}_v$, *%WP*, and other instream hydraulic parameters, at discharges both above and below the field-measured stream discharge. The methodology is both time and labor efficient, requires data from only a single stream transect, and has been found to produce similar results to more data intensive techniques (Nehring 1979) such as the Instream Flow Incremental Methodology (IFIM) developed by the U.S. Fish and Wildlife Service (Bovee 1982).

In 1973, the CWCB staff performed all Manning's equation calculations with a hand-held calculator. In 1981, the USFS released "*Program Documentation for R2-CROSS-81*" (Weatherred et al. 1981). This Fortran-based, mainframe computer program automated the repetitive task of manipulating and recalculating Manning's equation by hand. The CWCB used the USFS version of R2CROSS on the Colorado State University mainframe computer until 1985.

In 1986, the CWCB staff began development of a personal computer version of R2CROSS using the macro capabilities of Lotus 1-2-3. The CWCB found the R2CROSS macro to be advantageous because it ran on a personal computer and it could be customized to the specific needs of the CWCB. In February 2002, the CWCB staff upgraded the R2CROSS macro to Microsoft Excel for Windows. This latest version of R2CROSS is menu-driven (Figure D) and requires very little experience with

Microsoft Excel. The macro automatically formats the R2CROSS worksheet, initiates data entry, and performs all calculation and printing tasks.

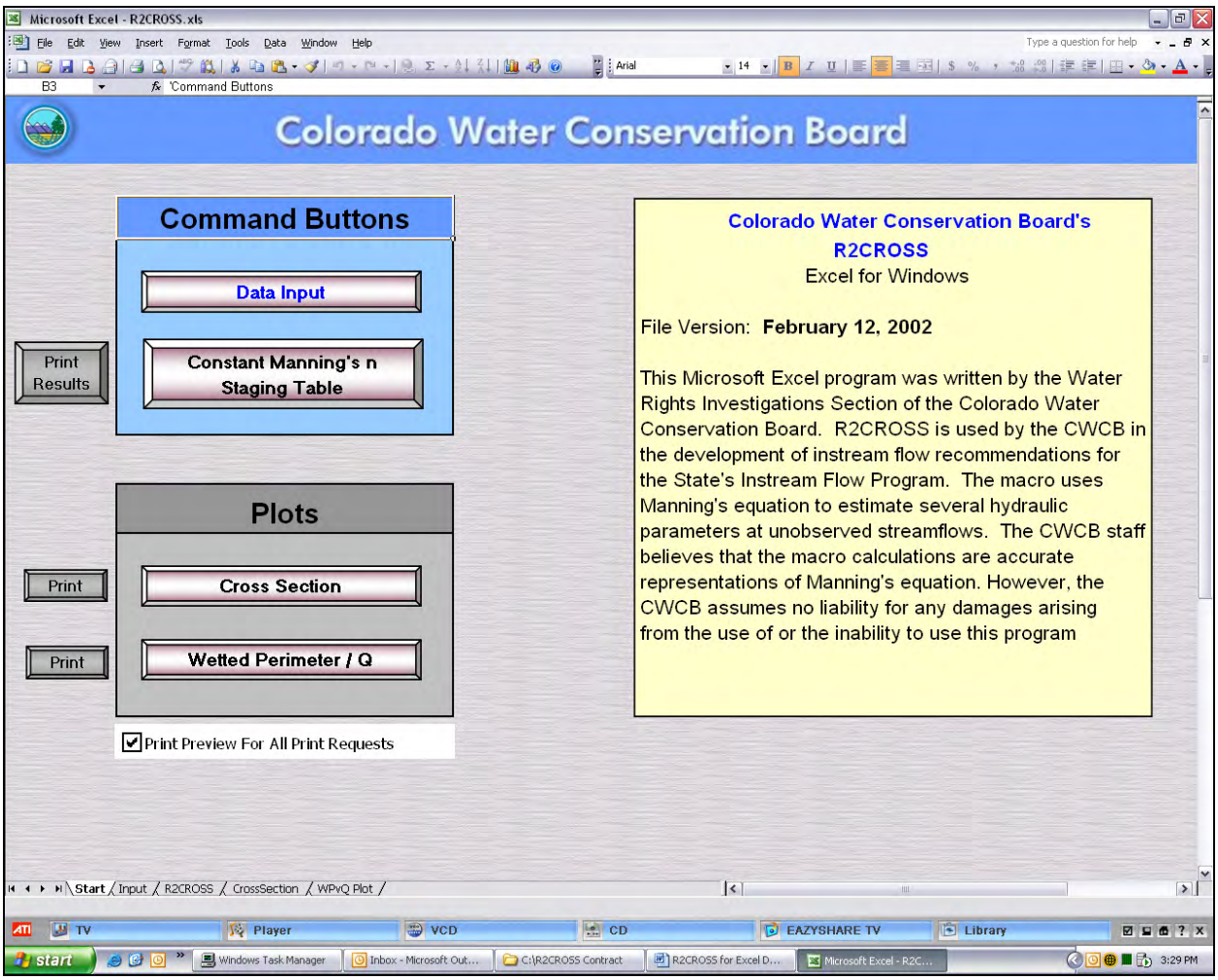
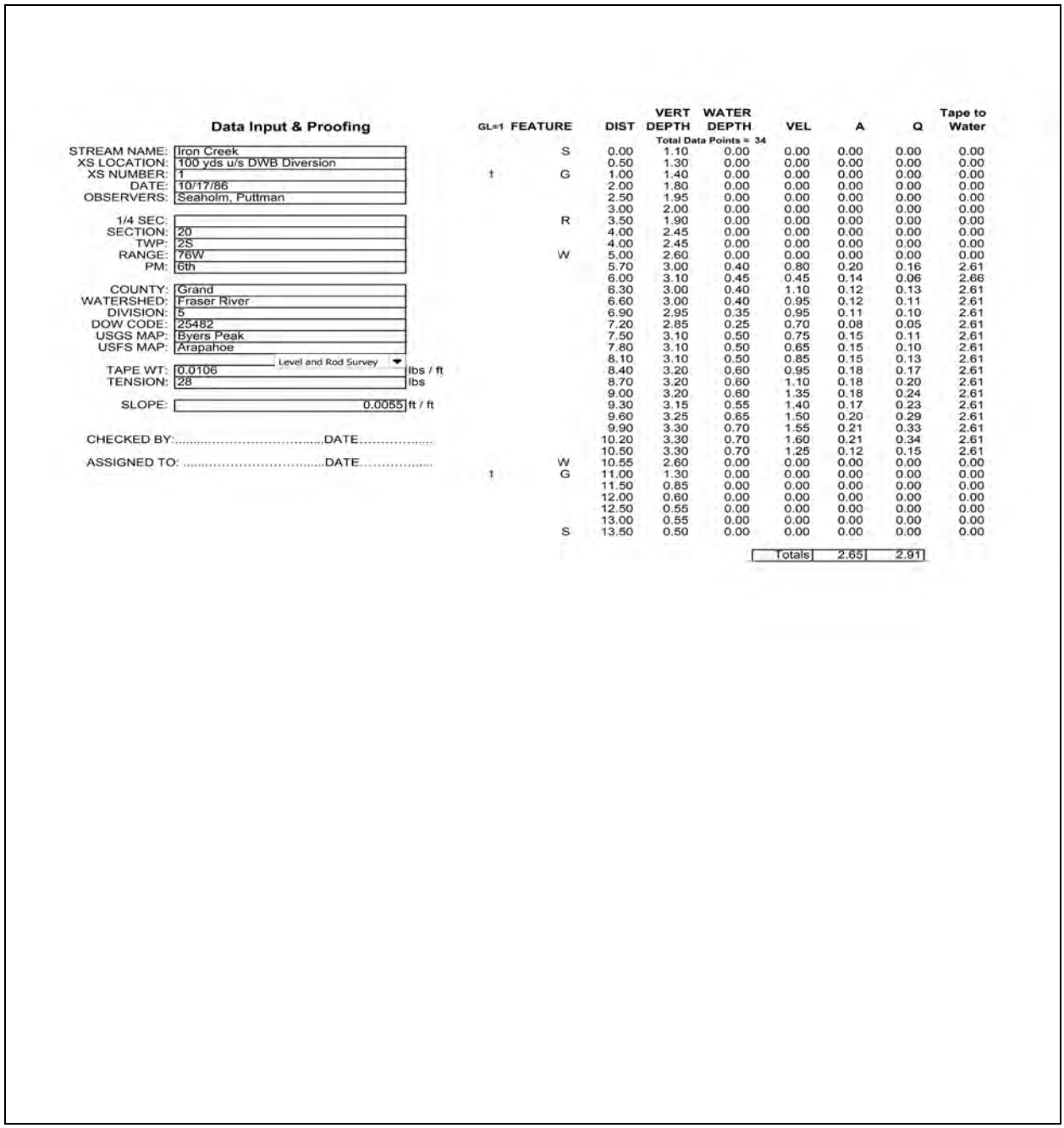


Figure D. R2CROSS menu in Microsoft Excel for Windows

Figures E through K provide an example of R2CROSS output from a typical Colorado stream named Iron Creek. Figure E is a "Proof Sheet" that is printed and inspected for data entry errors prior to performing final R2CROSS calculations. Final output consists of a five page printout (Figures F through J). Page one summarizes most of the stream location information, supplemental data, and channel profile data from the field form (Figure F). Page two summarizes the channel geometry/discharge field data set and values computed from the raw field data, including an estimate of Manning's "n" (Figure G). Page three consists of a water line comparison table which the program uses to interpolate the single water surface elevation that results in a calculated cross-sectional area equal to the field-measured cross-sectional area (Figure H). Page four is the staging table that is used by the cooperating agency to develop an initial, biologic instream flow recommendation (Figure I). The staging table provides estimates of modeled instream hydraulic parameters at stages above and below the measured discharge. Page five summarizes measured and calculated flows, waterlines, and depths (Figure J). It also presents estimates of mean velocity, Manning's "n", water slope, and

upper and lower streamflow limits within which the instream flow recommendation should fall. In general, hydraulic models based upon Manning's equation are most accurate when predicted flows fall within a range of 0.4 to 2.5 times measured flow (Bovee and Milhous 1978; Bovee 1982). Space is also provided for a narrative describing the basis for the initial instream flow recommendation and for the signatures of the personnel involved in making the recommendation. The macro can also be used to generate a plots of the stream cross section (Figure K) and Wetted Perimeter vs. Discharge (Figure L).



Data Input & Proofing

STREAM NAME:	Iron Creek
XS LOCATION:	100 yds u/s DWB Diversion
XS NUMBER:	1
DATE:	10/17/86
OBSERVERS:	Seaholm, Puttman
1/4 SEC:	
SECTION:	20
TWP:	2S
RANGE:	76W
PM:	6th
COUNTY:	Grand
WATERSHED:	Fraser River
DIVISION:	5
DOW CODE:	25482
USGS MAP:	Byers Peak
USFS MAP:	Arapahoe
	Level and Rod Survey
TAPE WT:	0.0106 lbs / ft
TENSION:	28 lbs
SLOPE:	0.0055 ft / ft

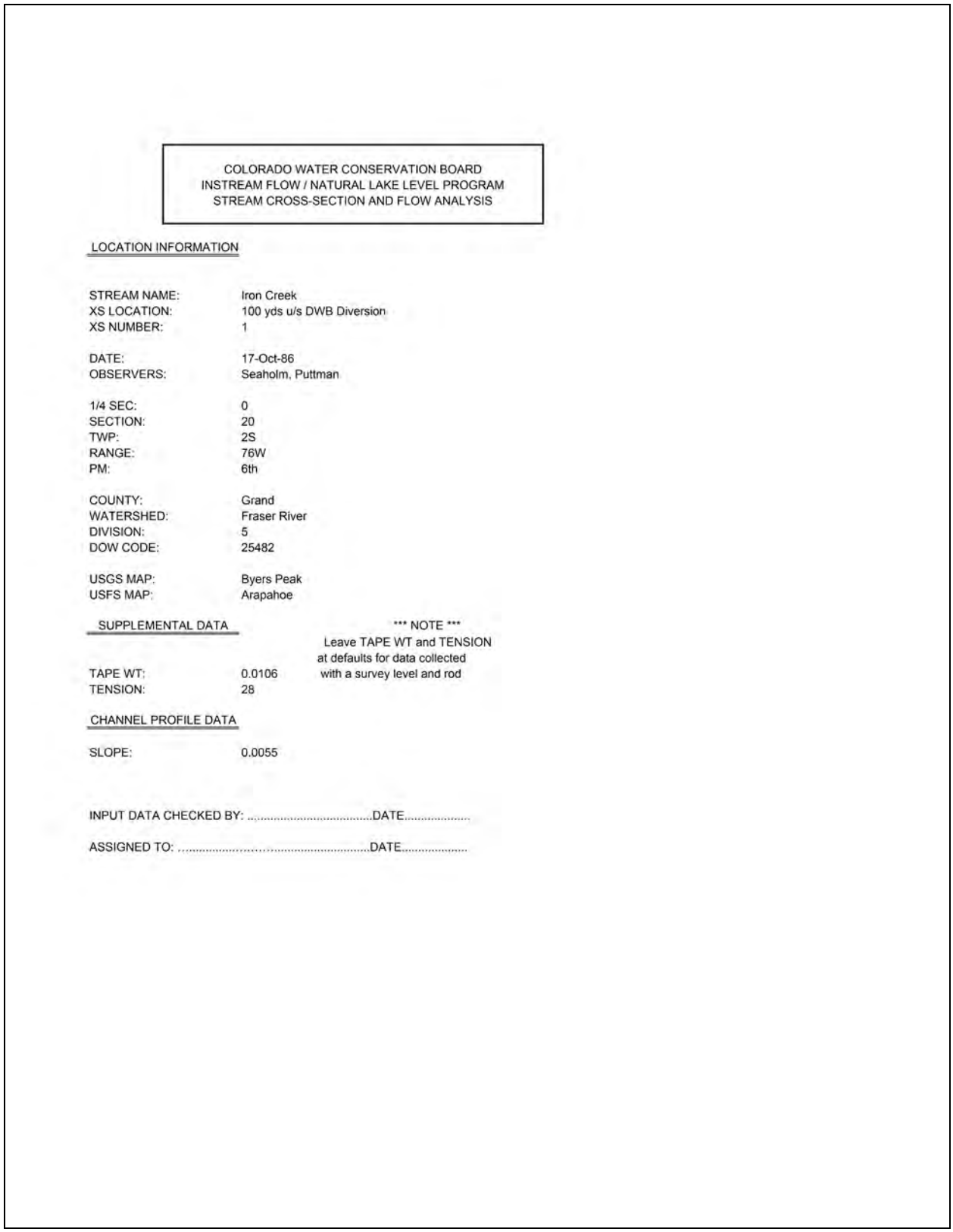
CHECKED BY:.....DATE.....

ASSIGNED TO: .....DATE.....

Total Data Points = 34

GL=1	FEATURE	DIST	VERT DEPTH	WATER DEPTH	VEL	A	Q	Tape to Water
	S	0.00	1.10	0.00	0.00	0.00	0.00	0.00
		0.50	1.30	0.00	0.00	0.00	0.00	0.00
t	G	1.00	1.40	0.00	0.00	0.00	0.00	0.00
		2.00	1.80	0.00	0.00	0.00	0.00	0.00
		2.50	1.95	0.00	0.00	0.00	0.00	0.00
		3.00	2.00	0.00	0.00	0.00	0.00	0.00
	R	3.50	1.90	0.00	0.00	0.00	0.00	0.00
		4.00	2.45	0.00	0.00	0.00	0.00	0.00
		4.00	2.45	0.00	0.00	0.00	0.00	0.00
	W	5.00	2.60	0.00	0.00	0.00	0.00	0.00
		5.70	3.00	0.40	0.80	0.20	0.16	2.61
		6.00	3.10	0.45	0.45	0.14	0.06	2.66
		6.30	3.00	0.40	1.10	0.12	0.13	2.61
		6.60	3.00	0.40	0.95	0.12	0.11	2.61
		6.90	2.95	0.35	0.95	0.11	0.10	2.61
		7.20	2.85	0.25	0.70	0.08	0.05	2.61
		7.50	3.10	0.50	0.75	0.15	0.11	2.61
		7.80	3.10	0.50	0.65	0.15	0.10	2.61
		8.10	3.10	0.50	0.85	0.15	0.13	2.61
		8.40	3.20	0.60	0.95	0.18	0.17	2.61
		8.70	3.20	0.60	1.10	0.18	0.20	2.61
		9.00	3.20	0.60	1.35	0.18	0.24	2.61
		9.30	3.15	0.55	1.40	0.17	0.23	2.61
		9.60	3.25	0.65	1.50	0.20	0.29	2.61
		9.90	3.30	0.70	1.55	0.21	0.33	2.61
		10.20	3.30	0.70	1.60	0.21	0.34	2.61
		10.50	3.30	0.70	1.25	0.12	0.15	2.61
	W	10.55	2.60	0.00	0.00	0.00	0.00	0.00
t	G	11.00	1.30	0.00	0.00	0.00	0.00	0.00
		11.50	0.85	0.00	0.00	0.00	0.00	0.00
		12.00	0.60	0.00	0.00	0.00	0.00	0.00
		12.50	0.55	0.00	0.00	0.00	0.00	0.00
		13.00	0.55	0.00	0.00	0.00	0.00	0.00
	S	13.50	0.50	0.00	0.00	0.00	0.00	0.00
					Totals	2.65	2.91	

Figure E. R2CROSS Proof Sheet – Iron Creek Example



COLORADO WATER CONSERVATION BOARD
INSTREAM FLOW / NATURAL LAKE LEVEL PROGRAM
STREAM CROSS-SECTION AND FLOW ANALYSIS

LOCATION INFORMATION

STREAM NAME:	Iron Creek
XS LOCATION:	100 yds u/s DWB Diversion
XS NUMBER:	1
DATE:	17-Oct-86
OBSERVERS:	Seaholm, Puttman
1/4 SEC:	0
SECTION:	20
TWP:	2S
RANGE:	76W
PM:	6th
COUNTY:	Grand
WATERSHED:	Fraser River
DIVISION:	5
DOW CODE:	25482
USGS MAP:	Byers Peak
USFS MAP:	Arapahoe

SUPPLEMENTAL DATA

*** NOTE ***
Leave TAPE WT and TENSION
at defaults for data collected
with a survey level and rod

TAPE WT:	0.0106
TENSION:	28

CHANNEL PROFILE DATA

SLOPE:	0.0055

INPUT DATA CHECKED BY: .....DATE.....

ASSIGNED TO: .....DATE.....

Figure F. Final R2CROSS Output (Page 1) – Iron Creek Example

STREAM NAME: Iron Creek
XS LOCATION: 100 yds u/s DWB Diversion
XS NUMBER: 1

DATA POINTS= 34

FEATURE	DIST	VERT DEPTH	WATER DEPTH	VEL	VALUES COMPUTED FROM RAW FIELD DATA: WETTED PERIM.	WATER DEPTH	AREA (Am)	Q (Qm)	% Q CELL
S	0.00	1.10	0.00	0.00	0.00		0.00	0.00	0.0%
	0.50	1.30	0.00	0.00	0.00		0.00	0.00	0.0%
1 G	1.00	1.40	0.00	0.00	0.00		0.00	0.00	0.0%
	2.00	1.80	0.00	0.00	0.00		0.00	0.00	0.0%
	2.50	1.95	0.00	0.00	0.00		0.00	0.00	0.0%
	3.00	2.00	0.00	0.00	0.00		0.00	0.00	0.0%
R	3.50	1.90	0.00	0.00	0.00		0.00	0.00	0.0%
	4.00	2.45	0.00	0.00	0.00		0.00	0.00	0.0%
	4.00	2.45	0.00	0.00	0.00		0.00	0.00	0.0%
W	5.00	2.60	0.00	0.00	0.00		0.00	0.00	0.0%
	5.70	3.00	0.40	0.80	0.81	0.40	0.20	0.16	5.5%
	6.00	3.10	0.45	0.45	0.32	0.45	0.14	0.06	2.1%
	6.30	3.00	0.40	1.10	0.32	0.40	0.12	0.13	4.5%
	6.60	3.00	0.40	0.95	0.30	0.40	0.12	0.11	3.9%
	6.90	2.95	0.35	0.95	0.30	0.35	0.11	0.10	3.4%
	7.20	2.85	0.25	0.70	0.32	0.25	0.08	0.05	1.8%
	7.50	3.10	0.50	0.75	0.39	0.50	0.15	0.11	3.9%
	7.80	3.10	0.50	0.65	0.30	0.50	0.15	0.10	3.4%
	8.10	3.10	0.50	0.85	0.30	0.50	0.15	0.13	4.4%
	8.40	3.20	0.60	0.95	0.32	0.60	0.18	0.17	5.9%
	8.70	3.20	0.60	1.10	0.30	0.60	0.18	0.20	6.8%
	9.00	3.20	0.60	1.35	0.30	0.60	0.18	0.24	8.4%
	9.30	3.15	0.55	1.40	0.30	0.55	0.17	0.23	7.9%
	9.60	3.25	0.65	1.50	0.32	0.65	0.20	0.29	10.1%
	9.90	3.30	0.70	1.55	0.30	0.70	0.21	0.33	11.2%
	10.20	3.30	0.70	1.60	0.30	0.70	0.21	0.34	11.6%
	10.50	3.30	0.70	1.25	0.30	0.70	0.12	0.15	5.3%
W	10.55	2.60	0.00	0.00	0.70		0.00	0.00	0.0%
1 G	11.00	1.30	0.00	0.00	0.00		0.00	0.00	0.0%
	11.50	0.85	0.00	0.00	0.00		0.00	0.00	0.0%
	12.00	0.60	0.00	0.00	0.00		0.00	0.00	0.0%
	12.50	0.55	0.00	0.00	0.00		0.00	0.00	0.0%
	13.00	0.55	0.00	0.00	0.00		0.00	0.00	0.0%
S	13.50	0.50	0.00	0.00	0.00		0.00	0.00	0.0%
TOTALS					6.49	0.7 (Max.)	2.65	2.91	100.0%

Manning's n = 0.0552
Hydraulic Radius= 0.407804906

Figure G. Final R2CROSS Output (Page 2) – Iron Creek Example

STREAM NAME: Iron Creek
XS LOCATION: 100 yds u/s DWB Diversion
XS NUMBER: 1

WATER LINE COMPARISON TABLE

WATER LINE	MEAS AREA	COMP AREA	AREA ERROR
	2.65	2.67	0.8%
2.36	2.65	4.25	60.4%
2.38	2.65	4.11	55.3%
2.40	2.65	3.98	50.3%
2.42	2.65	3.84	45.2%
2.44	2.65	3.71	40.2%
2.46	2.65	3.58	35.2%
2.48	2.65	3.45	30.3%
2.50	2.65	3.32	25.5%
2.52	2.65	3.20	20.7%
2.54	2.65	3.07	16.1%
2.56	2.65	2.95	11.6%
2.57	2.65	2.90	9.4%
2.58	2.65	2.84	7.2%
2.59	2.65	2.78	5.0%
2.60	2.65	2.72	2.9%
2.61	2.65	2.67	0.8%
2.62	2.65	2.61	-1.3%
2.63	2.65	2.56	-3.4%
2.64	2.65	2.50	-5.5%
2.65	2.65	2.45	-7.6%
2.66	2.65	2.39	-9.6%
2.68	2.65	2.28	-13.7%
2.70	2.65	2.18	-17.8%
2.72	2.65	2.07	-21.9%
2.74	2.65	1.96	-25.9%
2.76	2.65	1.86	-29.9%
2.78	2.65	1.75	-33.9%
2.80	2.65	1.65	-37.8%
2.82	2.65	1.54	-41.8%
2.84	2.65	1.44	-45.6%
2.86	2.65	1.34	-49.5%

WATERLINE AT ZERO
AREA ERROR = 2.611

Figure H. Final R2CROSS Output (Page 3) – Iron Creek Example

STREAM NAME: Iron Creek
XS LOCATION: 100 yds u/s DWB Diversion
XS NUMBER: 1

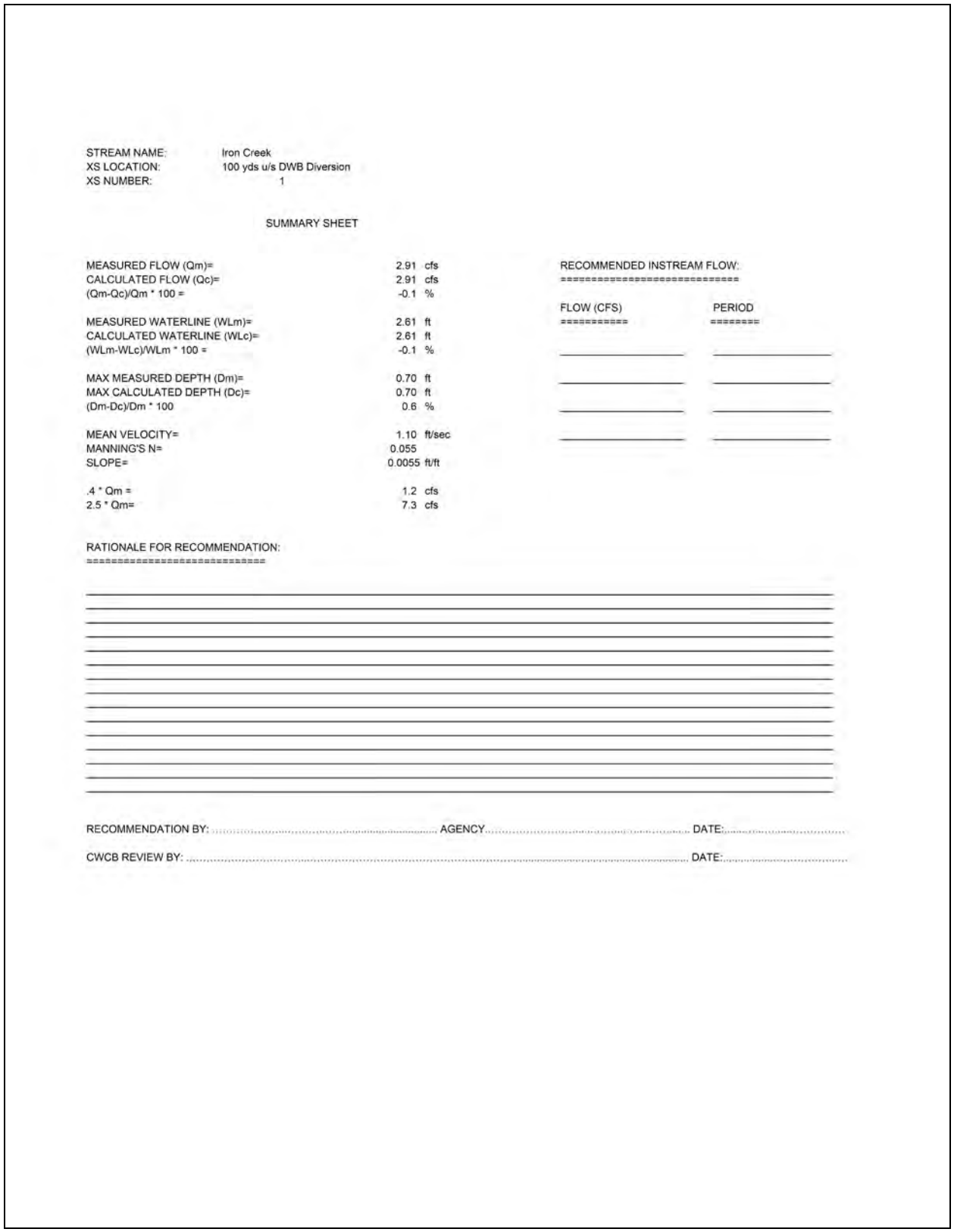
Constant Manning's n

STAGING TABLE

GL = lowest Grassline elevation corrected for sag
WL = Waterline corrected for variations in field measured water surface elevations and sag

	DIST TO WATER (FT)	TOP WIDTH (FT)	AVG. DEPTH (FT)	MAX. DEPTH (FT)	AREA (SQ FT)	WETTED PERIM. (FT)	PERCENT WET PERIM (%)	HYDR RADIUS (FT)	FLOW (CFS)	AVG. VELOCITY (FT/SEC)
GL	1.40	9.97	1.22	1.90	12.13	12.13	100.0%	1.00	24.21	2.00
	1.61	9.38	1.08	1.70	10.12	11.35	93.6%	0.89	18.70	1.85
	1.66	9.23	1.05	1.65	9.65	11.17	92.0%	0.86	17.48	1.81
	1.71	9.09	1.01	1.60	9.19	10.98	90.5%	0.84	16.30	1.77
	1.76	8.95	0.98	1.55	8.74	10.79	89.0%	0.81	15.16	1.73
	1.81	8.80	0.94	1.50	8.30	10.60	87.4%	0.78	14.07	1.70
	1.86	8.62	0.91	1.45	7.86	10.38	85.5%	0.76	13.04	1.66
	1.91	8.41	0.88	1.40	7.43	10.12	83.4%	0.73	12.08	1.63
	1.96	7.90	0.89	1.35	7.03	9.54	78.6%	0.74	11.44	1.63
	2.01	7.16	0.93	1.30	6.65	8.74	72.0%	0.76	11.07	1.66
	2.06	7.10	0.89	1.25	6.29	8.62	71.0%	0.73	10.19	1.62
	2.11	7.04	0.84	1.20	5.94	8.50	70.0%	0.70	9.35	1.57
	2.16	6.97	0.80	1.15	5.59	8.38	69.0%	0.67	8.53	1.52
	2.21	6.91	0.76	1.10	5.24	8.25	68.0%	0.64	7.74	1.48
	2.26	6.85	0.72	1.05	4.90	8.13	67.0%	0.60	6.98	1.42
	2.31	6.79	0.67	1.00	4.56	8.01	66.0%	0.57	6.25	1.37
	2.36	6.72	0.63	0.95	4.22	7.89	65.1%	0.53	5.55	1.32
	2.41	6.66	0.58	0.90	3.89	7.77	64.1%	0.50	4.89	1.26
	2.46	6.58	0.54	0.85	3.56	7.63	62.9%	0.47	4.27	1.20
	2.51	6.23	0.52	0.80	3.24	7.25	59.7%	0.45	3.77	1.17
	2.56	5.88	0.50	0.75	2.93	6.86	56.5%	0.43	3.32	1.13
WL	2.61	5.55	0.48	0.70	2.65	6.48	53.4%	0.41	2.91	1.10
	2.66	5.45	0.43	0.65	2.37	6.33	52.2%	0.37	2.46	1.04
	2.71	5.36	0.39	0.60	2.10	6.18	50.9%	0.34	2.04	0.97
	2.76	5.27	0.35	0.55	1.84	6.03	49.7%	0.30	1.66	0.90
	2.81	5.18	0.30	0.50	1.57	5.88	48.5%	0.27	1.31	0.83
	2.86	5.08	0.26	0.45	1.32	5.72	47.1%	0.23	0.99	0.75
	2.91	4.78	0.22	0.40	1.07	5.33	43.9%	0.20	0.73	0.68
	2.96	4.47	0.19	0.35	0.84	4.94	40.7%	0.17	0.51	0.61
	3.01	3.73	0.17	0.30	0.63	4.11	33.9%	0.15	0.36	0.57
	3.06	3.36	0.13	0.25	0.45	3.66	30.2%	0.12	0.22	0.49
	3.11	2.41	0.12	0.20	0.29	2.63	21.7%	0.11	0.14	0.46
	3.16	2.22	0.08	0.15	0.18	2.39	19.7%	0.07	0.06	0.35
	3.21	1.05	0.08	0.10	0.08	1.15	9.5%	0.07	0.03	0.34
	3.26	0.88	0.04	0.05	0.03	0.93	7.6%	0.04	0.01	0.22

Figure I. Final R2CROSS Output (Page 4) – Iron Creek Example



STREAM NAME: Iron Creek
XS LOCATION: 100 yds u/s DWB Diversion
XS NUMBER: 1

SUMMARY SHEET

MEASURED FLOW (Qm)=	2.91	cfs
CALCULATED FLOW (Qc)=	2.91	cfs
(Qm-Qc)/Qm * 100 =	-0.1	%
MEASURED WATERLINE (WLm)=	2.61	ft
CALCULATED WATERLINE (WLc)=	2.61	ft
(WLm-WLc)/WLm * 100 =	-0.1	%
MAX MEASURED DEPTH (Dm)=	0.70	ft
MAX CALCULATED DEPTH (Dc)=	0.70	ft
(Dm-Dc)/Dm * 100	0.6	%
MEAN VELOCITY=	1.10	ft/sec
MANNING'S N=	0.055	
SLOPE=	0.0055	ft/ft
.4 * Qm =	1.2	cfs
2.5 * Qm=	7.3	cfs

RECOMMENDED INSTREAM FLOW:

FLOW (CFS)	PERIOD

RATIONALE FOR RECOMMENDATION:

RECOMMENDATION BY: ..... AGENCY ..... DATE: .....

CWCB REVIEW BY: ..... DATE: .....

Figure J. Final R2CROSS Output (Page 5) – Iron Creek Example

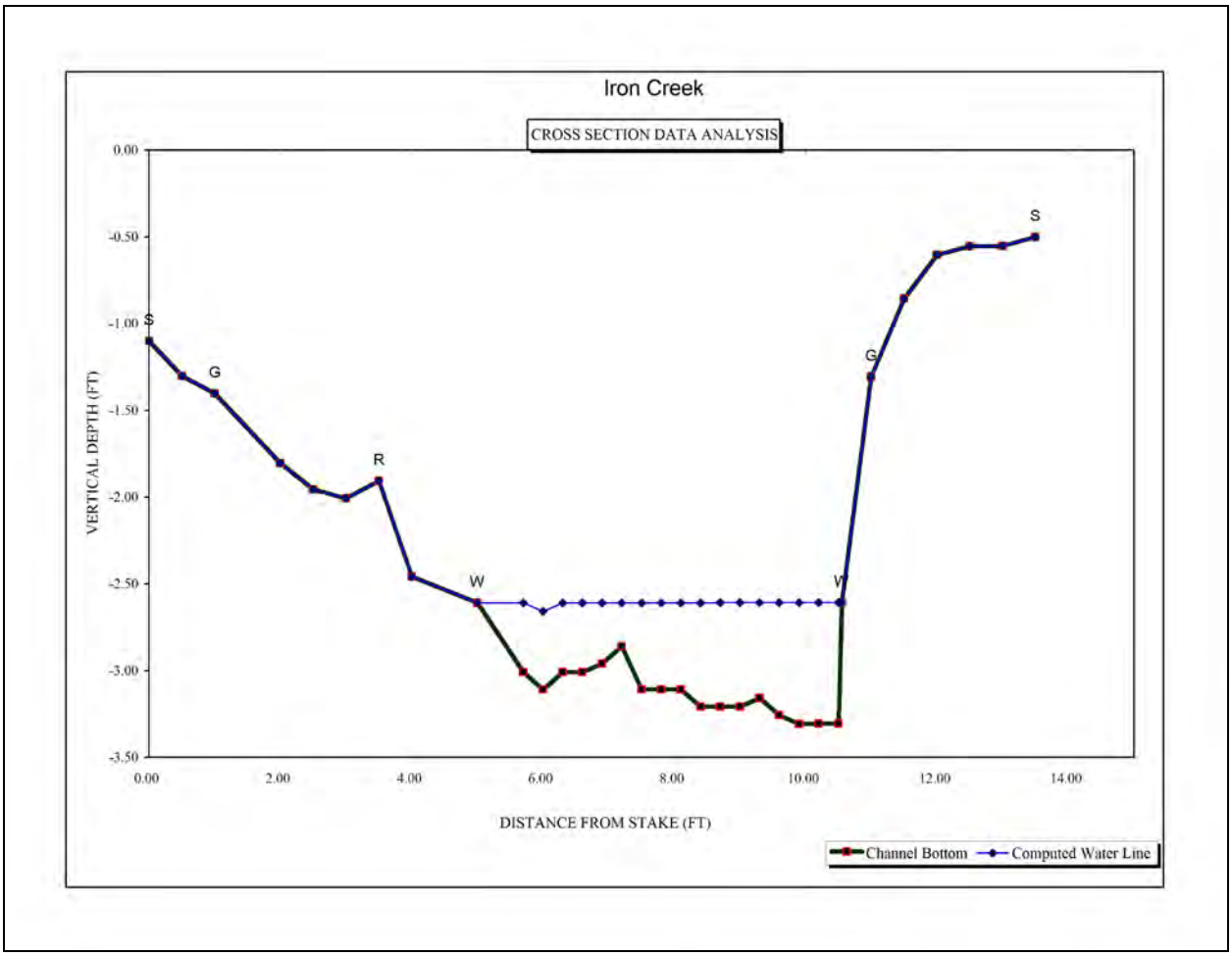


Figure K. Cross Section Plot from R2CROSS – Iron Creek Example

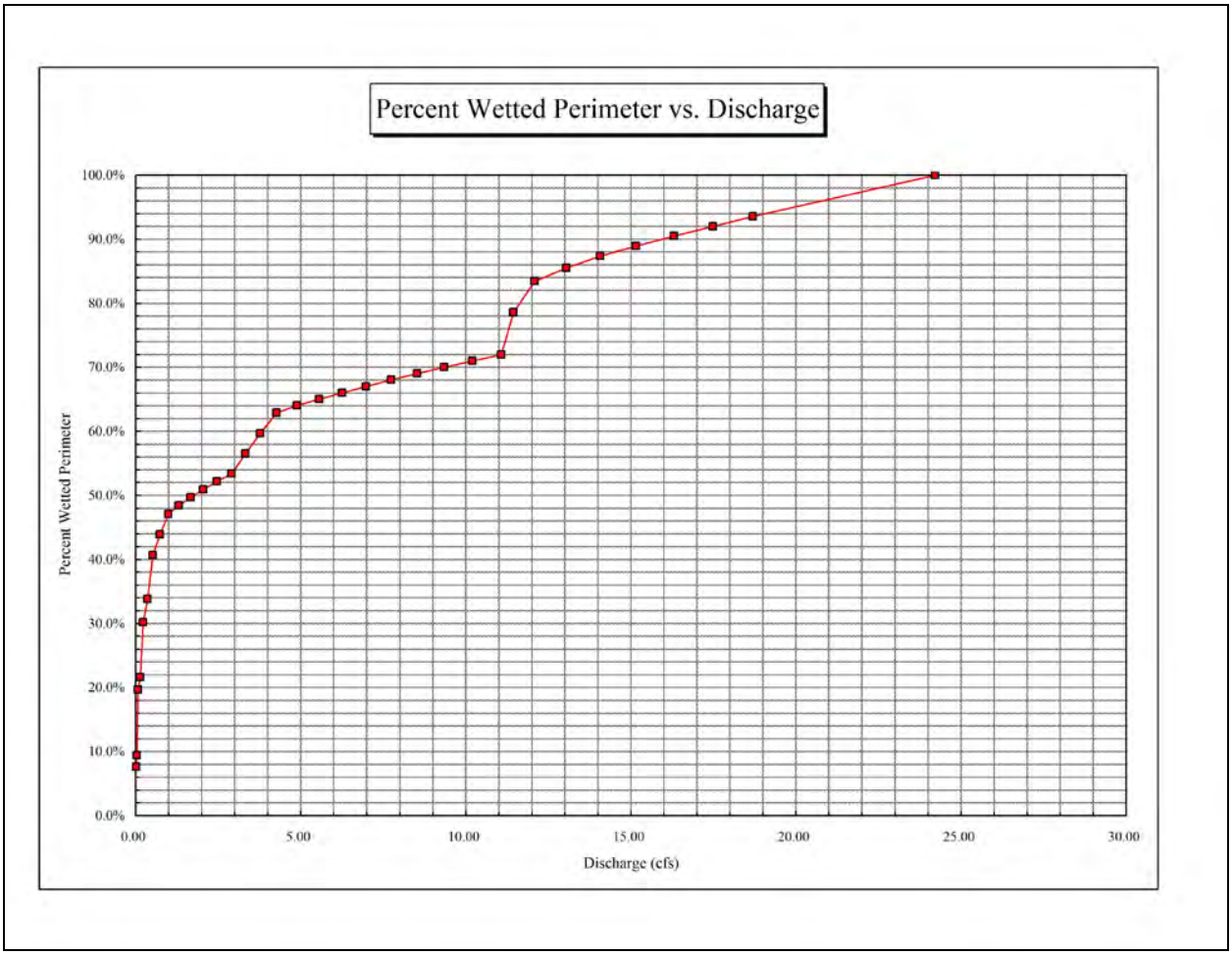


Figure L. Wetted Perimeter Plot from R2CROSS – Iron Creek Example

Biologic Instream Flow Recommendations

When using R2CROSS, biologic instream flow recommendations are based on maintaining three principal hydraulic criteria, $\bar{x}_d$, $\bar{x}_v$, and %WP, at adequate levels across the stream transect (Table 2). The $\bar{x}_d$ and %WP criteria are functions of stream top width and grassline-to-grassline wetted perimeter, respectively. A constant $\bar{x}_v$ of 1 ft/sec is recommended for all streams. The DOW has determined that these three parameters are good indices of flow-related stream habitat quality and that maintenance of these parameters at adequate levels across riffle habitat-types will also result in maintenance of adequate aquatic habitat in pools and runs for most life stages of fish and aquatic invertebrates (Nehring 1979).

The three critical hydraulic parameters are estimated within the R2CROSS staging table at various levels of discharge (Figure I). Biologic instream flow recommendations are developed by locating the modeled streamflow(s) in the R2CROSS staging table that satisfy the three hydraulic criteria summarized in Table 2. As stated above, Colorado's Instream Flow Program was created in 1973, since that time, the Program along with the science of determining instream flows has continued to evolve. For the Instream Flow Program to be successful, instream flow water rights must be able to balance the ever-changing needs and values of the public while honoring existing uses. The greatest asset of the Program, to date, has been its ability to evolve and meet those challenges.

Table 2. Criteria used to determine minimum flow requirements (Nehring 1979)

Stream Top Width (ft)[1]	Average Depth (ft)	Percent Wetted Perimeter (%)[1]	Average Velocity (ft/sec)
1-20	0.2	50	1.0
21-40	0.2-0.4	50	1.0
41-60	0.4-0.6	50-60	1.0
61-100	0.6-1.0	$\geq$ 70	1.0

[1] At bankfull discharge

In the early years of the Program, the DOW's instream flow recommendations consisted of only single year-round flow amounts. These single year-round flow amounts were based on meeting only two of the three critical hydraulic criteria identified by Nehring. For the first third of the Program, these initial flow recommendations were not adjusted due to water availability concerns. It was not until the passage of Senate Bill 414 (SB 414) in 1981, that future instream flow appropriations would require an evaluation of the existing physical water supply. In the mid 1980's, to incorporate these new changes into the Program and address other concerns being raised regarding the R2CROSS model (mainly the tendency of the R2CROSS model to overestimate the $\bar{x}_v$ criteria), DOW biologists modified the original instream flow methodology of recommending single year-round

flows and began developing "seasonal flow recommendations" which would incorporate all 3 of the identified critical criteria into the flow recommendations.

These seasonal flow recommendations are an attempt to mimic the natural flow regime, albeit, on a simplistic and much smaller scale. The DOW currently believes spring/summer flows require flow recommendations which meet all three of the critical hydraulic criteria and fall/winter flows require flow recommendations which meet two of the three critical hydraulic criteria, whenever possible. CDOW believes the development of these seasonal flow recommendations helps address the full range of hydrologic and hydraulic conditions required to maintain important stream characteristics and its associated aquatic community. Research has shown that single year-round minimum flows, when maintained as a long-term condition, cannot be expected to sustain the same fish populations or aquatic life as a natural flow regime, where low flow conditions occur infrequently and for shorter periods (Stalnaker and Wick 2000). Higher spring and summer flows provide the water and resultant habitat required to maintain the adjacent riparian zone, the geomorphology of the stream channel and additional habitat and protection for different life stages of the aquatic community. In addition, protection from increasing recreational uses such as rafting, kayaking, boating, tubing, swimming and fishing is gained during these flow periods. Higher spring and summer flows also provide water quality protection from other outside factors such as effluent discharges, high metal concentrations, excess sedimentation and water temperature increases. Aquatic biologists may modify summer and winter flow recommendations based upon biologic considerations such as stream conditions, species composition, and aquatic habitat quality.

These hydraulic criteria can be applied to the R2CROSS staging table from the Iron Creek example (Figure I) to develop an initial biologic instream flow recommendation. In this example, the grassline top width of Iron Creek is 9.97 ft. Therefore, the DOW criteria for an $\overline{x}_d$ of 0.2 feet would be satisfied at a flow of approximately 0.6 cfs. The *%WP* criterion of 50% would be met at a flow of around 1.75 cfs and an $\overline{x}_v$ of 1 ft/sec at a flow of 2.25 cfs. Based upon this analysis, a winter flow recommendation of 1.75 cfs would meet the $\overline{x}_d$ and *%WP* criteria and a summer flow recommendation of 2.25 cfs would satisfy all three criteria. These initial recommendations may be adjusted up or down based upon biologic judgment and expertise.

Water Availability Requirements

Once an initial biologic instream flow recommendation has been developed, the CWCB staff must determine whether water is physically available to satisfy the biologic recommendation. The staff uses stream gaging records to analyze physical water availability whenever possible. In the absence of a gage record, the staff may use standardized hydrologic techniques, such as basin area apportionment or synthetic streamflow modeling (Kircher et al. 1985), to estimate physical water availability. The staff may also conduct a review of the State Engineer's water rights tabulation and consult with Division Engineers and District Water Commissioners to determine the effect of senior diversions on a stream reach.

The water availability analyses may lead the CWCB staff to conclude that sufficient water is not available to meet the biologic recommendation. If the statutory water availability requirement cannot be satisfied, the CWCB must reject the instream flow recommendation.

Appropriating and Protecting an Instream Flow Water Right

The CWCB has adopted the "Rules Concerning the Colorado Instream Flow and Natural Lake Level Program." These Rules codified existing CWCB procedures for implementing the Instream Flow Program and established procedures for handling acquisition of water, water rights, and interests in water including conditional rights, modification of instream flows, and inundation of instream flow water rights. The CWCB's procedural requirements for appropriating and protecting instream flow water rights are also described in great detail within these Rules and Regulations. The procedural aspects of appropriating and protecting an instream flow water right are beyond the intended scope of this manuscript. Individuals who are interested in learning more about these procedures are encouraged to obtain a copy of the above-referenced Rules from the CWCB website at: http://cwcb.state.co.us/Streamandlake/Documents/ADOPTEDRULES11-15-2005.pdf .

Summary

The Colorado State Legislature enacted SB 97 in 1973. By "recognizing the need to correlate the activities of mankind with some reasonable preservation of the natural environment" (§ 37-92-102(3), C.R.S. (2002)), the Legislature sought to balance traditional water development with some reasonable protection of Colorado's natural environment. This is not a simple task in the semi-arid Western United States where water is a scarce and extremely valuable resource. The ongoing success of Colorado's Instream Flow Program assures that coordination between water development and protection of the natural environment will continue -- both now and into the future. . Since that time, the CWCB has completed instream flow appropriations on approximately 8,500 miles of Colorado streams.

The CWCB has adopted standardized field and office procedures for developing instream flow recommendations. This standardization helps to ensure that each instream flow recommendation is "necessary" and "reasonable", as required by state statute.R2CROSS is one of several instream flow assessment techniques employed by state and federal agencies to model instream hydraulic parameters. R2CROSS was chosen by the State of Colorado because it is time and labor efficient and produces comparable results to more costly instream flow assessment techniques. . The R2CROSS macro is also easy to use and requires very little in the way of computer hardware or software.

Biologic instream flow recommendations based upon output from R2CROSS are designed to maintain $\bar{x}_v$, $\bar{x}_d$, and *%WP* at critical levels across riffle habitat-types. It is assumed that by maintaining these critical hydraulic parameters across riffles, aquatic habitat in pools and runs is also preserved. In addition to biologic considerations, water must be physically available for the CWCB to file for an instream flow water right.

An instream flow water right requires a coordinated effort between various state and federal agencies, the public, and the CWCB. The culmination of these efforts is a decreed instream flow water right that is held by the CWCB on behalf of the people of Colorado to "preserve the natural environment to a reasonable degree."

R2CROSS Program Documentation

Program documentation for the R2CROSS macro is divided into two sections. The "Setup and Installation" section provides a brief description of the hardware and software requirements of the R2CROSS macro and copying the R2CROSS program to folders on a hard drive. "The R2CROSS Menu" provides more detailed program documentation for each of the menu choices within R2CROSS (Figure M). Users who are familiar with Microsoft Excel for Windows should have very little difficulty learning how to operate the R2CROSS macro.

Appendix A provides a brief description of the "Program Calculations" that are performed within the R2CROSS macro. Rather than emphasizing the technical aspects of these calculations, this appendix is intended to provide a fundamental understanding of the operations being performed within the macro.

Output from the R2CROSS macro was verified against several simple hand-calculated examples. More complex cross sections were verified by comparison with output from the MANSQ option of IFIM (Bovee 1982). Based on this verification process, it is our belief that the instream hydraulic parameters summarized in the R2CROSS staging table are accurate estimations based upon Manning's equation.

The CWCB hopes that the release of the R2CROSS macro will foster a greater understanding of this technical aspect of Colorado's Instream Flow Program. It is intended to be user-friendly. If you have any problems running the macro or questions regarding its operation, please feel free to contact the CWCB staff.

Setup and Installation

We have found that the R2CROSS macro runs efficiently on most IBM-compatible personal computers equipped with Microsoft Excel for Windows software. We recommend that an original copy of the R2CROSS.xls spreadsheet be stored in a location where it won't be overwritten. Additional copies can then be placed in other folders where individual stream flow datasets are being evaluated.

To initiate the R2CROSS macro, either double click on the R2CROSS.xls file or start Microsoft Excel for Windows , select "File"" and then "Open" from the Excel menu bar, and then navigate to the location where you saved the working copy of R2CROSS.xls.

Some users may find that the macro runs extremely slow when first installed. This is generally due to the security level setting on an individual's copy of Microsoft Excel. To increase the speed of the R2CROSS macro, it may be necessary to lower the security level of Excel. This can be accomplished by clicking the "Tools" menu choice in Excel and then selecting "Options" from the drop down menu. Click the "Security" tab and then the "Macro Security" button in the lower right hand corner of the graphic user interface. Select "Low" from the list of available macro security

choices. You may want to repeat this procedure and increase the macro security level of your computer back to its original level when you finish an R2CROSS session.

The R2CROSS Menu

Figure M shows the opening screen of R2CROSS. The functionality of the R2CROSS macro is intended to be fairly intuitive. Use the "Data Input" button to initiate and proof data entry. After data entry is complete, use the "Constant Manning's n Staging Table" button to generate and print R2CROSS output. The "Cross Section" and "Wetted Perimeter/Q" buttons can then be used to generate cross section and wetted perimeter vs. discharge plots.

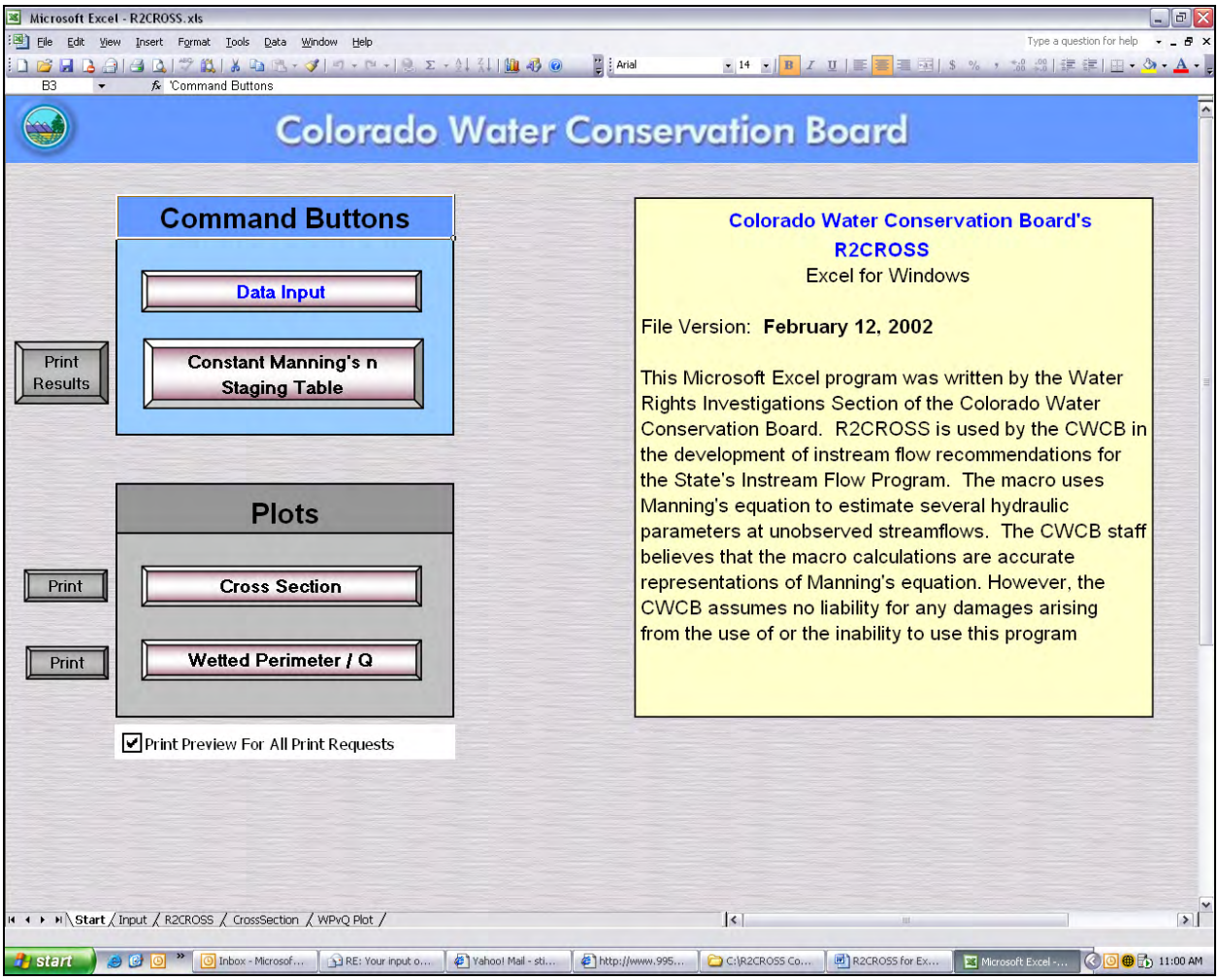


Figure M. R2CROSS Menu

Check the "Print Preview for All Print Requests" option if you want to preview all print requests before sending them to the printer. Uncheck the checkbox if you'd prefer to have all print requests sent directly to the printer without the opportunity to preview.

The "Print Results" and "Print" buttons can be used to send results of plots directly to the printer.

Data Input

Press the "Data Input" button to begin entering cross section data. Figure N shows the R2CROSS data input and proofing screen. Begin by entering the Stream Name, XS Location, etc in the appropriate cells of the spreadsheet. Use the "Enter" key on your keyboard to move the cursor down the column. After entering a Slope, use the Enter key to automatically move the cursor to the top of the "GL=1" column.

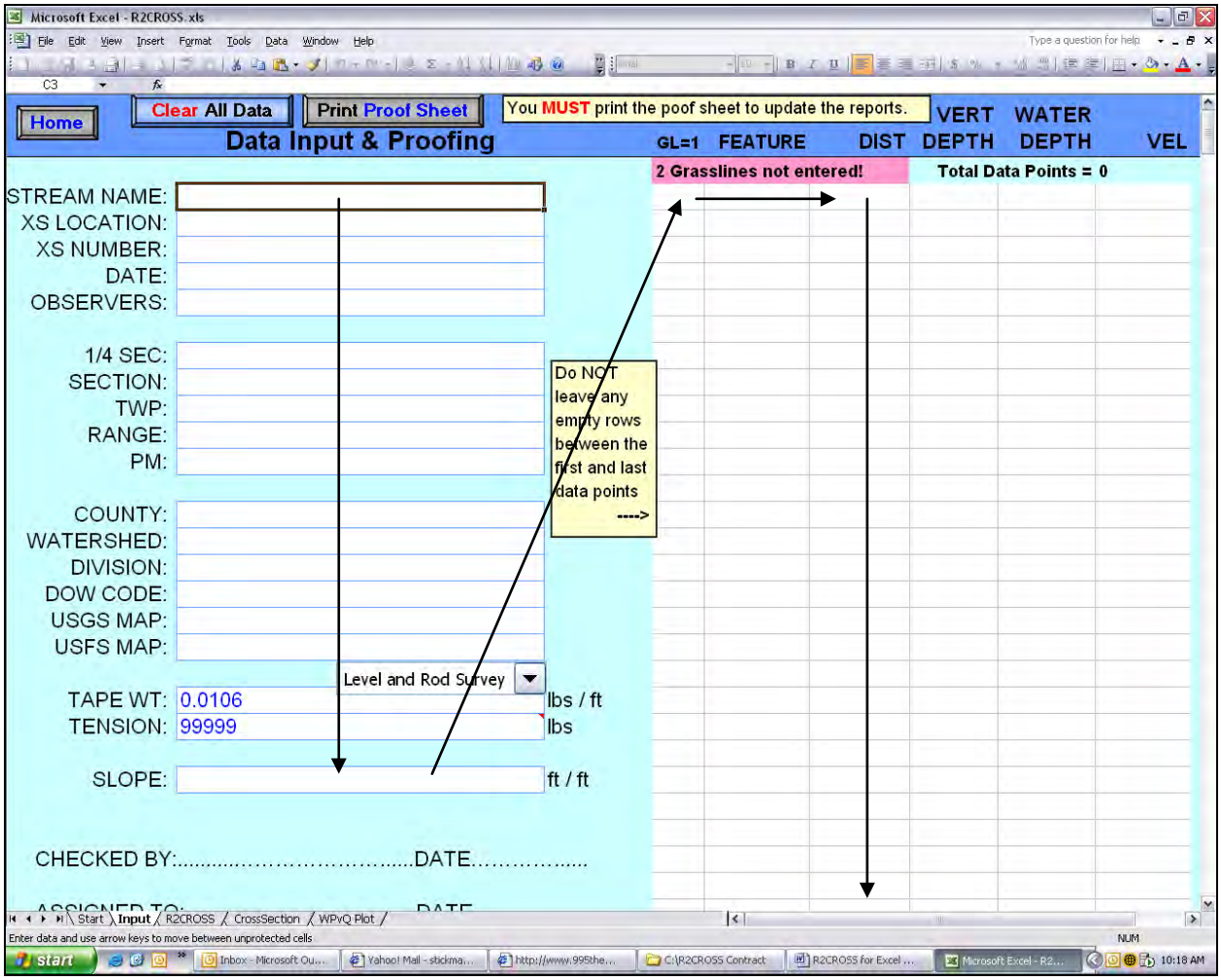


Figure N. R2CROSS Data Input and Proofing Screen

Use the arrow keys on your keyboard to move right into the "Dist" column. Enter all distances from the near bank cross section stake. This is most easily accomplished using the key pad on the right hand side of most computers. Ten-key typing skills will facilitate data entry. After entering the last "Dist" at the far bank cross section stake, scroll or use the arrow keys to move back to the top of the data entry form and verify that the "Total Data Points = *x*" displayed at the top of the data entry form are identical to the number of data points collected in the field. Correct any data entry errors in the "Dist" column.

Use the cursor, arrow keys, or Enter key to navigate through the remainder of the data entry form. R2CROSS requires that you enter a "1" in the "GL=1" for the grasslines on each side of the cross section. The "2 Grasslines not entered" warning will disappear when this requirement has been met.

Note that the standard Microsoft Excel functions like "Cut", "Copy", and "Paste" can be accessed by right-clicking on cells in the worksheet and selecting the desired choice from the Excel menu. In addition, standard Excel "drag and drop" functionality can by used to move single cells or blocks of cells within the data entry worksheet. Experience Excel users may find that using these functions greatly facilitates data entry and editing.

The final data entry screen for Iron Creek is provided as an example in Figure O. Note that the "2 Grasslines not entered" warning is gone and there are 34 Total Data Points on the Iron Creek transect.

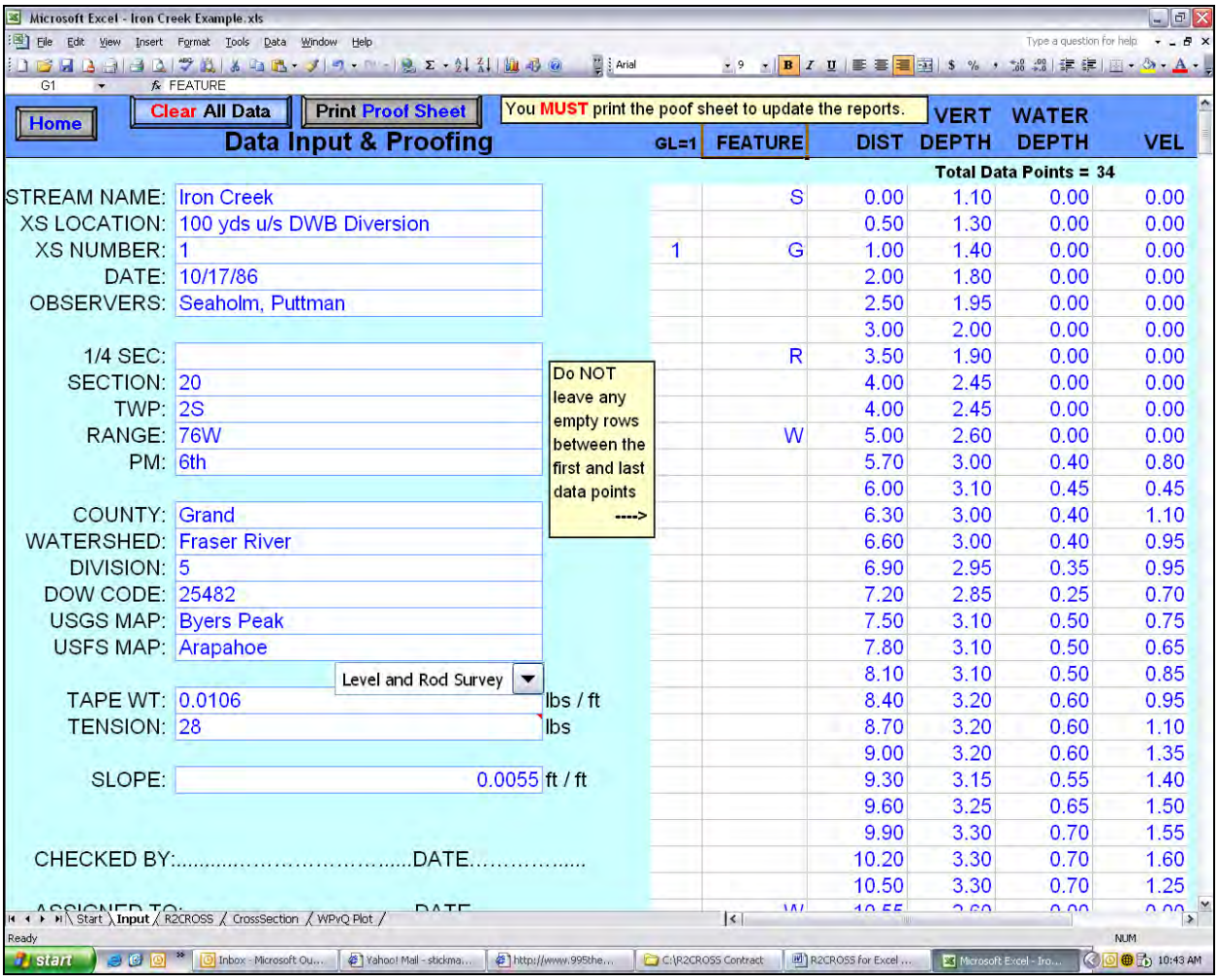


Figure O. Iron Creek Data Entry and Proofing Screen

When you are satisfied that all field data has been entered properly, press the "Print Proof Sheet" button. Pressing this button recalculates all computations in the spreadsheet and cycles to the Print

Proof Sheet option Use the standard Microsoft Windows options to Setup and Print Proof Sheet or Close" the print preview window. R2CROSS returns to the opening screen.

The "Home" button can also be used at anytime to return to the R2CROSS opening screen. However, the user should be aware that any changes made to the data entry form will only be revised in the calculations after pressing the "Print Proof Sheet" button.

Constant Manning's n Staging Table

Press the "Constant Manning's n Staging Table" button to preview the R2CROSS staging table. Press the "Home" key to return to the R2CROSS opening screen.

If the staging table appears to be correct, press the "Print Results" button to the left of the "Constant Manning's n Staging Table" button to print all 5 pages of R2CROSS output. You will be provided with an opportunity to preview the output pages if the "Print Preview For All Print Requests" box is checked. If it is not checked, the print request will go directly to the printer.

If the staging table does not appear to be correct, press the "Home" button and then the "Data Input" button to return to data entry/edit mode. Revise the cross section data as necessary and press the "Print Proof Sheet" button to recalculate the worksheet and inspect the proof sheet. Print the proof sheet if necessary.

The R2CROSS output from the Iron Creek example was presented previously in Figures F through J.

Cross Section and Wetted Perimeter/Q Plots

From the R2CROSS opening screen, press the "Cross Section" or "Wetted Perimeter/Q" buttons to preview these plots. Press "Home" to return to the opening screen or "Print" to send the plots to the printer.

Alternatively, press the "Print" button to the left of the "Cross Section" or "Wetted Perimeter/Q" buttons on the R2CROSS opening screen to send these plots to the printer. As with all print requests, you will have an opportunity to preview the plots if the "Print Preview For All Print Requests" is checked.

Cross Section and Wetted Perimeter plots from the Iron Creek example were presented previously in Figures K and L; respectively.

Starting a new R2CROSS analysis and exiting when finished

There are several ways to start a new R2CROSS analysis. One way is to open the R2CROSS.xls spreadsheet as described earlier and using the Excel "File" and "Save As" commands to rename the file and specify the folder location. Another way would be to press the "Data Input" button and then "Clear All Data" button.

Prior to exiting an R2CROSS analysis, use the Excel "File" and "Save As" commands to rename the file and specify a folder location. Data from an existing file can be retrieved by double clicking the

saved ".xls" file name or by using the Excel "File" and "Open" menu choices to navigate to the location of the a previously-saved R2CROSS data file.

Literature Cited

Bovee, K.D. 1982. A guide to stream habitat analysis using the Instream Flow Incremental Methodology. Instream Flow Information Paper No. 12. Washington, DC: U.S. Fish and Wildlife Service (FWS/OBS-82/26). 248pp.

Bovee, K.D. and R. Milhous. 1978. Hydraulic simulation in instream flow studies: Theory and techniques. Instream Flow Information Paper No. 5. Washington, DC: U.S. Fish and Wildlife Service (FWS/OBS -78/33). 143pp.

Buchanan, T.J. and W.P. Somers. 1969. Discharge measurements at gaging stations. Techniques of Water-Resources Investigations of the United States Geological Survey, Book 3, Chapter A8. United States Government Printing Office, Washington, D.C. 20402.

Benson, M.A., and T. Dalrymple. 1967. General field and office procedures for indirect discharge measurements. Techniques of Water-Resources Investigations of the United States Geological Survey, Book 3, Chapter A1. United States Government Printing Office, Washington, D.C. 20402.

Chow, V.T. 1959. Open-channel hydraulics. McGraw-Hill Book Company, New York. 680p.

Colorado Water Conservation Board. 1993. Statement of Basis and Purpose and Rules and Regulations Concerning the Colorado Instream Flow and Natural Lake Level Program. Department of Natural Resources. Denver, CO. 80203.

Grant, G.E., J.E. Duval, G.J. Koerper and J.L. Fogg. 1992. XSPRO: A channel cross-section analyzer. Technical Note 387. Bureau of Land Management. Denver, CO. 80225-0047.

Kircher, J.E., A.F. Choquette and B.D. Richter. 1985. Estimation of natural streamflow characteristics in western Colorado. Water-Resources Investigations Report 85-4086. United States Geological Survey. Box 25425, Denver Federal Center. Lakewood, CO 80225.

Laursen, H.I. 1978. Structural analysis. Second edition. New York. McGraw-Hill Book Company.

Merriman, D.C., and A.M. Janicki. 2005. Colorado's Instream Flow Program – How it works and why its's good for Colorado. 1313 Sherman Street, Room 721, Denver, CO 80203.

Nehring, R.B. 1979. Evaluation of instream flow methods and determination of water quantity needs for streams in the State of Colorado. Colorado Division of Wildlife. Fort Collins, CO.

Ray, G.A. and W.F. Megahan. 1979. Measuring cross sections using a sag tape: a generalized procedure. USDA Forest Service General Technical Report INT-47. Intermountain Forest and Range Experiment Station. U.S. Department of Agriculture. Ogden, UT. 84401.

Silvey, L. 1976. R-2 Cross Program: A sag-tape method of channel cross section measurement for use with instream flow determinations. United States Department of Agriculture, Forest Service Region 2. 11177 W. 8th Avenue. Lakewood, CO 80225.

Stalnaker and Wick.

Weatherred, J.D., H.L. Silvey and D.J. Pfankuch. 1981. Program documentation for R2-CROSS-81. Watershed Systems Development Group. United States Department of Agriculture, Forest Service. 3825 East Mulberry Street. Fort Collins, CO 80524.

Appendix A - Program Calculations

Some R2CROSS users may be interested in the calculations performed by the Microsoft Excel for Windows macro. The four major computations performed within the R2CROSS macro are sag-tape corrections, estimation of Manning's "n", calculation of a water line comparison table, and calculation of a staging table.

Sag-Tape Calculations.

Channel geometry measurements that are taken using the sag-tape methodology must be corrected to a level reference. R2CROSS uses catenary curve formulas to compute these corrections from a sagging tape that has been leveled at each end. The use of the catenary curve solution is based on the assumption that the suspended steel tape is analogous to a suspended cable placed under a unidirectionally distributed load (Laursen 1978).

The derivation of the catenary curve solution is beyond the scope of this manuscript. Basically, R2CROSS uses the length of tape in suspension, the tension applied to the tape, and the standard weight of one foot of tape to apply the necessary vertical distance corrections to each cell vertical within the cross section.

When using a level and stadia rod to survey channel geometry, the tape weight and tension defaults, supplied in the original R2CROSS.WK4 worksheet, will simulate an extremely light tape stretched at very high tension. This results in a sag correction of approximately zero at each cell vertical.

Use of Manning's Equation.

Manning's equation is defined as:

$$Q = \frac{1.486 * A * R^{2/3} * S^{1/2}}{n}$$

where;
Q = discharge (cfs);
A = cross-sectional area (ft^2);
R = hydraulic radius (ft);
S = slope (ft/ft); and
n = Manning's "n", a dimensionless coefficient of roughness.

Manning's equation is used in two separate R2CROSS calculations. It is first used to provide an initial estimate of Manning's "n" using the rearranged equation:

$$n = \frac{1.486 * A * R^{2/3} * S^{1/2}}{Q}$$

The parameters Q, A, R, and S are calculated from the raw field data and used to solve directly for "n". Once estimated, Manning's "n" remains constant throughout the remainder of the stream flow modeling.

The empirically-derived estimate of Manning's n and estimates of A, R, and S, are then used repeatedly in Manning's equation to solve for Q at each simulated water surface elevation within the staging table (Table 3).

Calculation of the Water Line Comparison Table.

R2CROSS uses two techniques for estimating cross-sectional area. One estimate is obtained by summing the product of "measured" water depth and cell width for all cells in the cross section (A_m). This technique allows independent water surface elevations within each cell and provides the most accurate estimate of cross-sectional area at the time the field measurement was made. However, this technique cannot be used to simulate a single, flat water surface elevation at computer-modeled stream discharges.

The second technique used to estimate cross-sectional area involves projecting a single water surface elevation across the stream channel. Channel bottom elevations are subtracted from this projected water surface elevation to obtain a "computed" water depth at each cell vertical. Cross-sectional area is obtained by summing the product of the "computed" water depth and cell width at each cell vertical (A_c). This technique constrains the water surface to a flat plane and is useful for simulating discharges above and below the field-measured discharge.

The water line comparison table (Figure H) iteratively calculates 31 separate estimates of A_c, using projected waterlines ranging from 0.25 feet above to 0.25 feet below the mean waterline measured in the field. The single water surface elevation that results in A_c equal to A_m is interpolated from the water line comparison table and is used in the staging table as the best estimate of the waterline at the field-measured discharge.

Calculation of the Staging Table.

The final product of the R2CROSS macro is the staging table (Figure I). In addition to the three critical biologic criteria ($\bar{x}_d$, *%WP*, and $\bar{x}_v$), R2CROSS also calculates incremental estimates of top width (TW), maximum depth (D_{max}), cross-sectional area (A), wetted perimeter (WP), hydraulic radius (R), and flow (Q) at a number of waterline elevations. The upper limit of the model occurs at bankfull discharge which is defined as the lower of the two grassline elevations measured in the field. The lower limit is either 1.75 feet below the waterline calculated in the waterline comparison table or stage of zero flow (the lowest field-measured channel profile), whichever is higher in elevation. The formulae for each of the parameters estimated in the staging table are summarized in Table 3.

Table 3. Hydraulic Formulae used in R2CROSS Staging Table

Parameter	Formula
Top Width (TW)	$\sum_{i=1}^{n} TW_i$
Average Depth ($\bar{x}_d$)	$\frac{A}{TW}$
Maximum Depth (D_{max})	$\underset{i=1}{\overset{n}{MAX}}(D_i)$
Area (A)	$\sum_{i=1}^{n} A_i$
Wetted Perimeter (WP)	$\sum_{i=1}^{n} WP_i$
Percent Wetted Perimeter (%WP)	$\frac{WP}{Bankfull\ WP} * 100$
Hydraulic Radius (R)	$\frac{A}{WP}$
Flow (Q)	$\frac{1.486 * A * R^{\frac{2}{3}} * S^{\frac{1}{2}}}{n}$
Average Velocity ($\bar{x}_v$)	$\frac{Q}{A}$

Colorado Water Conservation Board
Department of Natural Resources
1313 Sherman Street, Room 721, Denver, Colorado 80203
Phone: (303) 866-3441 * Fax: (303) 866-4474
www.cwcb.state.co.us

Pursuant to ISF Rule 5c of the Rules Concerning the Colorado Instream Flow and Natural Lake Level Program, this notice identifies the streams to be considered for instream flow appropriations in 2015. At the January 2015 meeting of the Colorado Water Conservation Board (CWCB), staff may request that the Board form its intent to appropriate instream flow water rights for the streams listed on the attached Instream Flow Appropriation List. The attached list contains a description of the Instream Flow (ISF) Recommendations including stream name, watershed, county, upper terminus, lower terminus, length, and USGS quad sheet name(s).

Please note that the attached list includes 23 new recommendations (indentified with an*) that were received in January 2014 and 20 recommendations that were received in previous years. The older recommendations did not move forward in previous years due to the need for additional scientific data and/or ongoing attempts to address stakeholder issues.

Copies of the Instream Flow Recommendations and Appendices of data submitted into the Official CWCB Record are available for review by the public during regular business hours (8:00 a.m. - 5:00 p.m.) at the Colorado Water Conservation Board's Office, located at 1313 Sherman Street, Room 723, Denver, Colorado, 80203. In addition to the CWCB office, copies of the Instream Flow and Natural Lake Level Recommendations are available online at:

http://cwcb.state.co.us/environment/instream-flow-program/Pages/2015ProposedISFAppropriations.aspx

In addition to the above Instream Flow Recommendations and Appendices, staff may rely on any additional data, exhibits, testimony, or other information submitted by any party as part of the Official CWCB Record to support its Instream Flow Recommendations.

It should also be noted that, pursuant to the ISF Rules:

5d. (3)
(a) The Board may change flow amounts of contested ISF appropriations based on information received during the public notice and comment period.

(b) Staff will maintain, pursuant to Rule 5e.(3), an ISF Subscription Mailing List for each water division composed of the names of all persons who have sent notice to the Board Office that they wish to be included on such list for a particular water division. Any person desiring to be on the ISF Subscription Mailing List(s) must send notice to the Board Office.

(c) Any meetings held between Staff and members of the public will be open to the public. Staff may provide Proper Notice prior to any such meetings and may provide notice to persons on the ISF Subscription Mailing List(s).

(d) Any Notice to Contest must be received at the Board office no later than March 31, 2015, or the first business day thereafter. All Notices of Party status and Contested Hearing Participant status must be received at the Board office no later than April 30, 2015 or the first business day thereafter.

(e) Staff will announce its Final Staff ISF Recommendation concerning contested appropriations at the September 2015 Board meeting and will send notice of the Final Staff Recommendation to all persons on the Contested Hearing Mailing List.

(f) The Board may take final action on any uncontested ISF appropriations at the May 2015 Board meeting.

Should you wish to comment on the proposed Instream Flow Recommendations, you may do so by writing Jeff Baessler of the Board's staff at the address given above or by sending your comments by email to jeffrey.baessler@state.co.us, or rob.viehl@state.co.us. It should be noted that while your appearance at any meeting is welcome, such an appearance is not necessary for your concerns to be recognized. Staff will take your comments into account and, if you so request, will present them to the Board in your absence. If you are not currently on the Board's Instream Flow Subscription Mailing List and you would like to be, please contact the Board's Office at the address given above.

Div	Stream	Watershed	County	Length (miles)	Upper Terminus	Lower Terminus	Quad Sheet(s)
1	Coal Creek	St. Vrain	Boulder	6.10	Boulder County Open Space Boundary	Louisville Wastewater Treatment Outfall	Louisville, Lafayette
1	Coal Creek	St. Vrain	Boulder	1.70	Louisville Wastewater Treatment Outfall	Pumping station #2	Louisville, Lafayette
1	North Clear Creek	Clear	Gilpin	5.95	confl. Chase Gulch	Wastewater Treatment Plant	Black Hawk
1	North Clear Creek	Clear	Gilpin	1.73	Wastewater Treatment Plant	confl. Clear Creek	Black Hawk, Squaw Pass
1	*Boxelder Creek	Cache la Poudre	Larimer	11.0	confl. South & North Boxelder Creeks	confl. Slab Canyon Wash	Livermore, Table Mountain
1	Graves Creek	Lone Tree - Owl	Larimer	2.68	Colorado-Wyoming border	South Line S27 T12N R68W	Carr West, Round Butte
1	*Sand Creek	Cache la Poudre	Larimer	10.25	Colorado-Wyoming border	confl. Boxelder Creek	Table Mountain
1	*Sand Creek	Cache la Poudre	Larimer	9.43	Headwaters	Inlet Mountain Supply	Round Butte

						Reservoir No. 1	
1	Spottlewood Creek #1	Cache La Poudre	Larimer	2.03	NW S29 T12N R68W	NW S33 T12N R68W	Round Butte
1	Spottlewood Creek #2	Cache La Poudre	Larimer	1.61	NW S34 T11N R68W	SW S34 T11N R68W	Carr SW, Carr West
1	Lone Tree Creek	Lone Tree - Owl	Weld	2.88	NW S29 T12N R67W	SE S31 T12N R67W	Carr West
2	Beaver Creek	Upper Arkansas	Freemont	8.90	confl. East Beaver Creek	confl. unnamed tributary	Phantom Canyon, Mount Pittsburg
2	West Beaver Creek	Upper Arkansas	Freemont, Teller	7.50	confl. Douglas Gulch	confl. East Beaver Creek	Big Bull Mtn, Phantom Canyon
2	Baker Creek	Huerfano	Huerfano	2.14	Headwaters	USFS Boundary	Trinchera, Trinchera Peak
2	Bonnett Creek	Huerfano	Huerfano	3.30	Headwaters	USFS Boundary	Big Bull Mountain, Phantom Canyon
2	Arkansas River	Upper Arkansas	Pueblo	9.13	outlet of Fish Hatchery	confl. Fountain Creek	North West Pueblo
2	Apishapa River	Apishapa	Las Animas	4.50	Headwaters	confl. Herick Canyon Creek	Cucharas Pass, Herlick Canyon
4	*Alkali Creek	Lower Gunnison	Delta	7.83	Headwaters	Lone Star Ditch Headgate	Indian Point, Point Creek
4	*Hubbard Creek	North Fork Gunnison	Delta	1.88	USFS Boundary	Deer Trail Ditch Headgate	Bowie
4	*Terror Creek	North Fork Gunnison	Delta	3.26	confl. East & West Terror Creeks	Fawcett Ditch Headgate	Bowie
4	*Little Cimarron River (Increase)	Upper Gunnison	Gunnison, Hinsdale	17.9	Headwaters	Butte Ditch Headgate	Lost Lake, Sheep Mountain, Uncompahgre Peak
4	*Little Cimarron River	Upper Gunnison	Gunnison, Montrose	6.56	Butte Ditch Headgate	confl. Cimarron River	Cimarron, Curecanti Needle, Lost Lake
4	*Schaefer Creek	North Fork Gunnison	Gunnison	5.92	Headwaters	confl. Grouse Spring Creek	Anthracite Range, Marcellina Mtn., Paonia Reservoir, West Beckwith Mtn.
4	*Kelso Creek	Lower Gunnison	Mesa	15.43	Headwaters	confl. Escalante Creek	Kelso Point, Snipe Mountain
5	*Timber Springs Gulch	Eagle	Eagle	1.90	Springs Complex	Groff Ditch Headgate	Edwards, Wolcott
5	Dry Fork Roan Creek	Parachute-Roan	Garfield	7.61	confl. South Dry Fork and North Fork Dry Fork Creeks	confl. Roan Creek	Long Point, Wagon Track Ridge
6	*Brush Creek	Lower White	Garfield, Rio Blanco	5.31	Headwaters	confl. East Douglas Creek	Calf Canyon, Douglas Pass
6	*East Douglas Creek (Increase)	Lower White	Garfield, Rio Blanco	1.56	confl. Bear Park Creek	confl. Brush Creek	Brushy Point
6	*East Douglas Creek (Increase)	Lower White	Rio Blanco	14.22	confl. Brush Creek	confl. Cathedral Creek	Brushy Point, White Coyote Draw
6	Piceance Creek	Piceance-Yellow	Rio Blanco	7.70	confl. Dry Fork Creek	confl. White River	Barcus Creek SE, White River City
6	*Soldier Creek	Lower White	Rio Blanco	3.67	confl. Right Fork & Middle Fork Soldier Creeks	confl. Cathedral Creek	Black Cabin Gulch, Razorback Ridge
6	Yellow Creek	Piceance-Yellow	Rio Blanco	4.74	Springs in NWNE S12, T1N R98W, 6PM	confl. Barcus Creek	Barcus Creek SE

6	Yellow Creek	Piceance-Yellow	Rio Blanco	7.11	confl. Barcus Creek	confl. White River	Barcus Creek, Barcus Creek SE, Rough Gulch
6	*Armstrong Creek	Upper Yampa	Routt	0.10	Lower Terminus of ISF case # 06CW035	confl. Elkhead Creek	Quaker Mountain
6	*Big Canyon Creek	Upper Yampa	Routt	4.36	Headwaters	confl. Elkhead Creek	Quaker Mountain
6	*Elkhead Creek	Upper Yampa	Routt	3.68	Lower Terminus of ISF Case # 06CW034	confl. First Creek	Bears Ears Peak, Quaker Mountain
6	*Hole-in-the-Wall Creek	Upper Yampa	Routt	4.01	Headwaters	confl. Elkhead Creek	Bears Ears Peak, Quaker Mountain
6	*North Fork Elkhead Creek	Upper Yampa	Routt	3.22	Headwaters	confl. Sawmill Creek	Bears Ears Peaks, Buck Point, Slide Mountain
6	*North Fork Elkhead Creek	Upper Yampa	Routt	6.17	confl. Sawmill Creek	confl. Elkhead Creek	Slide Mountain
6	*Sawmill Creek	Upper Yampa	Routt	3.44	Headwaters	confl. North Fork Elkhead Creek	Buck Point, Slide Mountain
6	*Stuckey Creek	Upper Yampa	Routt	4.10	Headwaters	confl. Elkhead Creek	Bears Ears Peaks, Quaker Mountain
6	Willow Creek (Increase)	Upper Yampa	Routt	4.65	outlet of Steamboat Lake	confl. Beaver Creek	Hahns Peak
6	Willow Creek (Increase)	Upper Yampa	Routt	1.32	confl. Beaver Creek	confl. Lester Creek	Hahns Peak

 Exhibit 8

STATE OF COLORADO

Viehl - DNR, Rob <rob.viehl@state.co.us>

CWCB Proposed 2015 ISF Recommendations

1 message

Rob Viehl <Rob.Viehl@state.co.us> Thu, Nov 6, 2014 at 1:33 PM
To: rob.viehl@state.co.us

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

1313 Sherman Street, Room 718, Denver, Colorado 80203

Phone: (303) 866-3441 * Fax: (303) 866-4474

www.cwcb.state.co.us

Pursuant to ISF Rule 5c. of the Rules Concerning the Colorado Instream Flow and Natural Lake Level Program, this notice identifies the streams and lakes to be considered for instream flow (ISF) and natural lake level appropriations in 2015. At the January 2015 meeting of the Colorado Water Conservation Board (CWCB), staff may request that the Board form its intent to appropriate instream flow and natural lake level water rights for the streams and lakes listed on the attached Instream Flow and Natural Lake Level Appropriation List. The attached list contains a description of the Instream Flow and Natural Lake Level Recommendations including stream name, watershed, county, upper terminus, lower terminus, length, and USGS quad sheet name(s).

Copies of the Instream Flow and Natural Lake Level Recommendations and Appendices of data submitted into the Official CWCB Record are available for review by the public during regular business hours (8:00 a.m. - 5:00 p.m.) at the Colorado Water Conservation Board's Office, located at 1313 Sherman Street, Room 718, Denver, Colorado, 80203. In addition to the CWCB office, copies of the Instream Flow and Natural Lake Level Recommendations are available online at:

http://cwcb.state.co.us/environment/instream-flow-program/Pages/2015ProposedISFAppropriations.aspx

In addition to the above Instream Flow and Natural Lake Level Recommendations and Appendices, staff may rely on any additional data, exhibits, testimony, or other information submitted by any party as part of the Official CWCB Record to support its Instream Flow and Natural Lake Level Recommendations.

It should also be noted that, pursuant to the ISF Rules:

5d. (3)

(a) The Board may change flow amounts of contested ISF appropriations based on information received during the public notice and comment period.

(b) Staff will maintain, pursuant to Rule 5e.(3), an ISF Subscription Mailing List for each water division composed of the names of all persons who have sent notice to the Board Office that they wish to be included on such list for a particular water division. Any person desiring to be on the ISF Subscription Mailing List(s) must send notice to the Board Office.

(c) Any meetings held between Staff and members of the public will be open to the public. Staff may provide Proper Notice prior to any such meetings and may provide notice to persons on the ISF Subscription Mailing List(s).

(d) Any Notice to Contest must be received at the Board office no later than March 31, 2015, or the first business day thereafter. All Notices of Party status and Contested Hearing Participant status must be received at the Board office no later than April 30, 2015 or the first business day thereafter.

(e) Staff will announce its Final Staff ISF Recommendation concerning contested appropriations at the September 2015 Board meeting and will send notice of the Final Staff Recommendation to all persons on the Contested Hearing Mailing List.

(f) The Board may take final action on any uncontested ISF appropriations at the May 2015 Board meeting.

Should you wish to comment on the proposed Instream Flow and Natural Lake Level Recommendations, you may do so by writing Jeff Baessler of the Board's staff at the address given above or by sending your comments by email to jeffrey.baessler@state.co.us, or rob.viehl@state.co.us. It should be noted that while your appearance at any meeting is welcome, such an appearance is not necessary for your concerns to be recognized. Staff will take your comments into account and, if you so request, will present them to the Board in your absence. If you are not currently on the Board's Instream Flow Subscription Mailing List and you would like to be, please contact the Board's Office at the address given above.

Instream Flow Recommendations

Div	Stream	Watershed	County	Length (miles)	Upper Terminus	Lower Terminus	Quad Sheet(s)
1	Graves Creek	Lone Tree - Owl	Larimer	2.68	Colorado-Wyoming border	South Line S27 T12N R68W 6th PM	Carr West, Round Butte
1	Spottlewood Creek #1	Cache La Poudre	Larimer	2.03	NW S29 T12N R68W 6th PM	NW S33 T12N R68W 6th PM	Round Butte
1	Lone Tree Creek	Lone Tree - Owl	Weld	2.88	NW S29 T12N R67W 6th PM	SE S31 T12N R67W 6th PM	Carr West
4	Alkali Creek	Lower Gunnison	Delta	7.83	Headwaters	Lone Star Ditch Headgate	Indian Point, Point Creek

4	Hubbard Creek	North Fork Gunnison	Delta	1.88	USFS Boundary	Deer Trail Ditch Headgate	Bowie
4	Terror Creek	North Fork Gunnison	Delta	1.55	confl. East & West Terror Creeks	Terror Ditch Headgate	Bowie
4	Terror Creek	North Fork Gunnison	Delta	1.71	Terror Ditch Headgate	Fire Mountain Canal	Bowie
4	Schaefer Creek	North Fork Gunnison	Gunnison	5.92	Headwaters	confl. Grouse Spring Creek	Anthracite Range, Marcellina Mtn., Paonia Reservoir, West Beckwith Mtn.
4	Kelso Creek	Lower Gunnison	Mesa	11.90	Headwaters	Red Squirrel Ditch Headgate	Kelso Point, Snipe Mountain
5	Timber Springs Gulch	Eagle	Eagle	1.90	Springs Complex	Groff Ditch Cottonwood Enlargement Headgate	Edwards, Wolcott
6	Brush Creek	Lower White	Garfield, Rio Blanco	5.31	Headwaters	confl. East Douglas Creek	Calf Canyon, Douglas Pass
6	East Douglas Creek (Increase)	Lower White	Garfield, Rio Blanco	1.56	confl. Bear Park Creek	confl. Brush Creek	Brushy Point
6	East Douglas Creek (Increase)	Lower White	Rio Blanco	14.22	confl. Brush Creek	confl. Cathedral Creek	Brushy Point, White Coyote Draw
6	Soldier Creek (Increase)	Lower White	Rio Blanco	3.67	confl. Right Fork & Middle Fork Soldier Creeks	confl. Cathedral Creek	Black Cabin Gulch, Razorback Ridge
6	Yellow Creek	Piceance-Yellow	Rio Blanco	3.55	confl. Barcus Creek	confl. Lambert Springs	Barcus Creek, Barcus Creek SE, Rough Gulch
6	Yellow Creek	Piceance-Yellow	Rio Blanco	3.58	confl. Lambert Springs	confl. White River	Rough Gulch
6	Armstrong Creek	Upper Yampa	Routt	0.10	Lower Terminus of ISF case # 06CW035	confl. Elkhead Creek	Quaker Mountain
6	Elkhead Creek	Upper Yampa	Routt	0.56	Lower Terminus of ISF Case # 06CW034	confl. Armstrong Creek	Bears Ears Peak, Quaker Mountain
6	Elkhead Creek	Upper Yampa	Routt	3.12	confl. Armstrong Creek	confl. First Creek	Quaker Mountain
6	Willow Creek (Increase)	Upper Yampa	Routt	4.65	outlet of Steamboat Lake	confl. Beaver Creek	Hahns Peak

6	Willow Creek (Increase)	Upper Yampa	Routt	1.32	confl. Beaver Creek	confl. Lester Creek	Hahns Peak

Natural Lake Level Recommendations

Div	Lake	Watershed	County	Location (NAD 1983 Zone 13 North)	Quad Sheet(s)
1	Spottlewood Lake # 1	Cache La Poudre	Larimer	UTM North:4524450.31 UTM East: 500088.64	Carr SW
1	Spottlewood Lake # 2	Cache La Poudre	Larimer	UTM North:4524566.61 UTM East: 500021.07	Carr SW
1	Spottlewood Lake # 3	Cache La Poudre	Larimer	UTM North:4524806.62 UTM East: 500159.81	Carr SW
1	Spottlewood Lake # 4	Cache La Poudre	Larimer	UTM North:4524786.50 UTM East: 500226.24	Carr SW
1	Spottlewood Lake # 5	Cache La Poudre	Larimer	UTM North:4524912.38 UTM East: 500530.95	Carr West

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

1313 Sherman Street, Room 721
Denver, CO 80203

NOTICE

To: Instream Flow Subscription Mailing Lists

Subject: Proposed 2015 Instream Flow and Natural Lake Level Appropriations in Water Divisions 1, 4, 5 and 6

Date: January 30, 2015

At its January 26-27, 2015 regular meeting, the Colorado Water Conservation Board (CWCB) declared its intent to appropriate instream flow (ISF) water rights on 16 streams segments and natural lake level (NLL) water rights on 4 lakes. The attached ISF table provides the name, watershed, county, upper terminus, lower terminus, length and flow amounts for all sixteen stream segments. The attached NLL table provides the name, watershed, county, location, surface elevation and volume for the 4 lakes.

Copies of the Instream Flow and Natural Lake Level Recommendations and Appendices of data submitted into the Official CWCB Record are available for review by the public during regular business hours (8:00 a.m. - 5:00 p.m.) at the Colorado Water Conservation Board's Office, located at 1313 Sherman Street, Room 718, Denver, Colorado, 80203. In addition to the CWCB office, copies of the Instream Flow and Natural Lake Level Recommendations are available online at:

http://cwcb.state.co.us/environment/instream-flow-program/Pages/2015ProposedISFAppropriations.aspx

In addition to the above Instream Flow and Natural Lake Level Recommendation Summary Reports and Appendices, staff may rely on any additional data, exhibits, testimony, or other information submitted by any party as part of the Official CWCB Record to support its Instream Flow Recommendations. Pursuant to Rule 5d.(3) of the Rules Concerning the Colorado Instream Flow and Natural Lake Level Program adopted by the Colorado Water Conservation Board, it should also be noted that:

(a) The Board may change flow amounts of contested ISF appropriations based on information received during the public notice and comment period.

(b) Staff will maintain, pursuant to Rule 5e.(3), an ISF Subscription Mailing List for each water division composed of the names of all persons who have sent notice to the Board Office that they wish to be included on such list for a particular water division. Any person desiring to be on the ISF Subscription Mailing List(s) must send notice to the Board Office.

(c) Any meetings held between Staff and members of the public will be open to the public. Staff may provide Proper Notice prior to any such meetings and may provide notice to persons on the ISF Subscription Mailing List(s).

(d) Any Notice to Contest must be received at the Board office no later than March 31, 2015. All Notices of Party status and Contested Hearing Participant status must be received at the Board office no later than April 30, 2015.

(e) Staff will announce its Final Staff Instream Flow Recommendation concerning contested appropriations at the September 2015 Board meeting and, prior to that meeting, will send notice of the Final Staff Recommendation to all persons on the Contested Hearing Mailing List.

(f) The Board may take final action on any uncontested ISF appropriations at the May 2015 Board meeting.

A notice to contest an ISF or NLL appropriation must be made in writing and contain the following information: (a) identification of the Person(s) requesting the hearing; (b) identification of the ISF or NLL appropriation(s) at issue; and (c) the contested facts and a general description of the data upon which the Person will rely to the extent known at that time.

Should you wish to comment on the proposed ISF or NLL Recommendations, you may do so by writing Jeff Baessler of the Board's staff at the address given above or by sending your comments by email to jeffrey.baessler@state.co.us. It should be noted that while your appearance at any meeting is welcome, such an appearance is not necessary for your concerns to be recognized. Staff will take your comments into account and, if you so request, will present them to the Board in your absence. If you are not currently on the Board's Instream Flow Subscription Mailing List and you would like to be, please contact the Board's Office at the address given above.

Instream Flow Recommendations

Div	Stream	Watershed	County	Length (miles)	Upper Terminus*	Lower Terminus*	Flow (CFS)
1	Graves Creek	Lone Tree Creek – Owl Creek	Larimer	2.76	Colorado-Wyoming border	confl. unnamed tributary	0.17 (1/1-12/31)

1	Spottlewood Creek	Cache La Poudre	Larimer	3.53	A point at UTM North: 4537937.85 East 495521.89	A point at UTM North: 4534887.62 East: 498663.70	0.1 (1/1-12/31)
4	Alkali Creek	Lower Gunnison	Delta	5.10	Headwaters	Lone Star Ditch Headgate	0.3 (11/1-5/15) 2 (5/16-7/31) 1.5 (8/1-8/31) 0.8 (9/1-10/31)
4	Hubbard Creek	North Fork Gunnison	Delta	1.88	U. S. Forest Service Boundary	Deertrail Ditch Headgate	8.3 (4/1-6/10) 2.6 (6/11-8/15) 1.8 (8/16-3/31)
4	Terror Creek	North Fork Gunnison	Delta	1.55	confl. East & West Terror Creeks	Terror Ditch Headgate	1.5 (10/1-3/31) 4.8 (4/1-9/30)
4	Terror Creek	North Fork Gunnison	Delta	1.52	Terror Ditch Headgate	Fire Mountain Canal	4.2 (4/1-5/31)
4	Schaefer Creek	North Fork Gunnison	Gunnison	5.92	Headwaters	confl. Grouse Spring Creek	1.7 (12/1-4/15) 4.6 (4/16-7/31) 2.9 (8/1-11/30)
5	Timber Springs Gulch	Eagle	Eagle	0.47	Springs Complex	BLM Property Boundary	1 (11/1-3/31) 1.3 (4/1-10/31)
6	Brush Creek	Lower White	Garfield, Rio Blanco	5.31	Headwaters	confl. East Douglas Creek	0.5 (11/1-3/31) 0.65 (4/1-10/31)
6	East Douglas Creek (Increase)	Lower White	Garfield, Rio Blanco	1.56	confl. Bear Park Creek	confl. Brush Creek	2.1 (5/1-7/15) 0.5 (7/16-10/15)
6	East Douglas Creek (Increase)	Lower White	Rio Blanco	14.22	confl. Brush Creek	confl. Cathedral Creek	0.5 (5/15-10/15)
6	Soldier Creek (Increase)	Lower White	Rio Blanco	3.67	confl. Right Fork & Middle Fork Soldier Creeks	confl. Cathedral Creek	0.4 (4/1-9/30)
6	Yellow Creek	Piceance-Yellow	Rio Blanco	3.66	confl. Barcus Creek	confl. Lambert Springs	1.5 (3/1-6/15) 0.6 (6/16-2/29)
6	Yellow Creek	Piceance-Yellow	Rio Blanco	3.45	confl. Lambert Springs	confl. White River	2.3 (3/1-6/15) 1.1 (6/16-2/29)
6	Armstrong Creek	Upper Yampa	Routt	0.10	Lower Terminus of ISF case # 06CW035	confl. Elkhead Creek	1 (4/1-6/30) 0.5 (7/1-7/31) 0.22 (8/1-3/31)
6	Elkhead Creek	Upper Yampa	Routt	3.68	Lower Terminus of ISF Case # 06CW034	confl. First Creek	7.6 (4/1-6/30) 4.1 (7/1-7/31) 1.7 (8/1-3/31)

*All UTM's NAD 1983 Zone 13 North

Natural Lake Level Recommendations

Div	Lake	Watershed	County	Location*	Elevation (ft)	Volume (Acre Feet)
1	Spottlewood Lake # 1	Cache La Poudre	Larimer	UTM North:4524450.31 UTM East: 500088.64	5,635	0.19
1	Spottlewood Lake # 2	Cache La Poudre	Larimer	UTM North:4524806.62 UTM East: 500159.81	5,646	0.12
1	Spottlewood Lake # 3	Cache La Poudre	Larimer	UTM North:4524786.50 UTM East: 500226.24	5,648	0.17
1	Spottlewood Lake # 4	Cache La Poudre	Larimer	UTM North:4524912.38 UTM East: 500530.95	5,659	0.16

*All UTM's NAD 1983 Zone 13 North

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

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John Hickenlooper, Governor

Mike King, DNR Executive Director

James Eklund, CWCB Director

TO: Colorado Water Conservation Board Members

FROM: Jeff Baessler, Deputy Section Chief
Stream and Lake Protection Section

DATE: November 20, 2014

AGENDA ITEM: #19. Notice of 2015 Instream Flow Recommendation Appropriations in Water Divisions 1, 4, 5, and 6

Background

Pursuant to Instream Flow ("ISF") Rule 5c., the Colorado Water Conservation Board is providing notice that the following 21 stream segments and 5 natural lake level recommendations are being considered for ISF and natural lake level appropriations in 2015. At the January 2015 CWCB meeting, Staff may request that the Board form its intent to appropriate ISF and natural lake level water rights on some or all these streams and lakes. These streams were previously noticed at the Board's March 2014 meeting.

Staff Recommendation

This is an informational item that provides notice of recommended stream segments and natural lakes that staff may bring to the Board in January 2015 with a recommendation that the Board form its intent to appropriate ISF and natural lake level water rights. No Board action is required.

Div	Stream	County	Recommender(s)
1	**Graves Creek** Colorado-Wyoming border to South Line S27 T12N R68W 6th PM	Larimer	CPW & City of Fort Collins
1	**Upper Spottlewood Creek** NW S29 T12N R68W 6th PM to NW S33 T12N R68W 6th PM	Larimer	CPW & City of Fort Collins
1	**Spottlewood Lake 1** UTM North: 4524450.31 East: 500088.64 (NAD 1983 Zone 13 North)	Larimer	CPW & City of Fort Collins
1	**Spottlewood Lake 2** UTM North: 4524566.61 East: 500021.07 (NAD 1983 Zone 13 North)	Larimer	CPW & City of Fort Collins
1	**Spottlewood Lake 3** UTM North: 4524806.62 East: 500159.81 (NAD 1983 Zone 13 North)	Larimer	CPW & City of Fort Collins
1	**Spottlewood Lake 4** UTM North: 4524786.50 East: 500226.24 (NAD 1983 Zone 13 North)	Larimer	CPW & City of Fort Collins

1	**Spottlewood Lake 5** UTM North: 4524912.38 East: 500530.95 (NAD 1983 Zone 13 North)	Larimer	CPW & City of Fort Collins
1	**Lone Tree Creek** NW S29 T12N R67W 6th PM to SE S31 T12N R67W 6th PM	Weld	CPW & City of Fort Collins
4	**Alkali Creek** Headwaters to Lone Star Ditch Headgate	Delta	BLM
4	**Hubbard Creek** USFS Boundary to Deer Trail Ditch Headgate	Delta	BLM
4	**Terror Creek** Confl. East & West Terror Creeks to Terror Ditch Headgate	Delta	BLM
4	**Terror Creek** Terror Ditch Headgate to Fire Mountain Canal	Delta	BLM
4	**Schaefer Creek** Headwaters to confl. Grouse Spring Creek	Gunnison	USFS
4	**Kelso Creek** Headwaters to Red Squirrel Ditch Headgate	Mesa	USFS
5	**Timber Springs Gulch** Springs Complex to Groff Ditch Cottonwood Enlargement Headgate	Eagle	BLM
6	**Brush Creek** Headwaters to confl. East Douglas Creek	Garfield, Rio Blanco	BLM
6	**East Douglas Creek** (Increase) Confl. Bear Park Creek to confl. Brush Creek	Garfield, Rio Blanco	BLM
6	**East Douglas Creek** (Increase) Confl. Brush Creek to confl. Cathedral Creek	Rio Blanco	BLM
6	**Soldier Creek (Increase)** Confl. Right Fork & Middle Fork Soldier Creeks to confl. Cathedral Creek	Rio Blanco	BLM
6	**Yellow Creek** *Confl. Barcus Creek to confl. Lambert Springs*	Rio Blanco	BLM
6	**Yellow Creek** *Confl. Lambert Springs to confl. White River*	Rio Blanco	BLM
6	**Armstrong Creek** Lower Terminus of ISF case # 06CW035 to confl Elkhead Creek	Routt	CPW
6	**Elkhead Creek** Lower Terminus of ISF Case # 06CW034 to confl. Armstrong Creek	Routt	CPW
6	**Elkhead Creek** Confl. Armstrong Creek to confl. First Creek.	Routt	CPW
6	**Willow Creek** (Increase) Outlet of Steamboat Lake to confl. Beaver Creek	Routt	BLM
6	**Willow Creek** (Increase) Confl. Beaver Creek to confl. Lester Creek	Routt	BLM

* CPW (Colorado Parks and Wildlife), BLM (Bureau of Land Management)

The detailed recommendations and appendices for these streams can be found on the CWCB website at http://cwcb.state.co.us/environment/instream-flow-program/Pages/2015ProposedISFAppropriations.aspx

STATE OF COLORADO

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TO: Colorado Water Conservation Board Members

FROM: Jeff Baessler
Stream and Lake Protection Section

DATE: March 1, 2014

SUBJECT: **Agenda Item 21, March 18-19, 2014, Board Meeting**
Stream and Lake Protection Section – Instream Flow Appropriation Recommendations for January 2015

Introduction and Staff Recommendation

Pursuant to Rule 5c. of the Rules Concerning the Colorado Instream Flow and Natural Lake Level Program ("ISF Rules"), Staff is providing notice that the following 43 stream segments have been recommended for instream flow ("ISF") appropriations in 2015. At the January 2015 CWCB meeting, Staff may request that the Board form its intent to appropriate ISF water rights on these streams.

Please note that the list below includes 23 new recommendations (identified with an *) and 20 recommendations that were received in previous years. Staff has not yet moved the older recommendations forward due to the need for additional scientific data and/or ongoing attempts to address stakeholder issues. In 2015, Staff will recommend that the Board move forward on the recommendations for which Staff is able to reasonably address all outstanding issues. Staff is currently working with the recommending entities to prioritize this list of recommendations.

This is an informational item with no Board action required.

Division	Stream Name	County(ies)	Recommender(s)
1	**Coal Creek** *(Boulder County Open Space Boundary to Louisville Wastewater Treatment outfall)*	Boulder	City of Louisville & CPW
1	**Coal Creek** *(Louisville Wastewater Treatment outfall to Lafayette pumping station #2)*	Boulder	City of Louisville & CPW
1	**North Clear Creek** *(Confl. Chase Gulch to Confl. Wastewater Treatment Plant)*	Gilpin	CPW & CDPHE
1	**North Clear Creek** *(Confl. Wastewater Treatment Plant to Confl. Clear Creek)*	Gilpin	CPW & CDPHE
1	*** Boxelder Creek**	Larimer	CPW & Larimer

	(Confl. South & North Boxelder Creeks to Confl. Slab Canyon Wash)		County Open Lands
1	**Graves Creek** *(Colorado – Wyoming Border to South Line S27 T12N R68W)*	Larimer	City of Fort Collins & CPW
1	*** Sand Creek** *(Colorado – Wyoming Border to Confl. Boxelder Creek)*	Larimer	CPW & Larimer County Open Lands
1	*** Sand Creek** *(Headwaters to Inlet Mountain Supply Reservoir # 1)*	Larimer	CPW & Larimer County Open Lands
1	**Spottlewood Creek #1** *(NW S29 T12N R68W to Road at NW S33 T12N R68W)*	Larimer	City of Fort Collins & CPW
1	**Spottlewood Creek #2** *(NW S34 T11N R68W to SW S34 T11N R68W)*	Larimer	City of Fort Collins & CPW
1	**Lone Tree Creek** *(NW S29 T12N R67W to SE S31 T12N R67W)*	Weld	City of Fort Collins & CPW
2	**Beaver Creek** *(Confl. East & West Beaver Creeks to Confl. Patton Canyon)*	Fremont	CPW
2	**West Beaver Creek** *(Confl. Douglas Gulch to Confl. East Beaver Creek)*	Fremont, Teller	CPW
2	**Baker Creek** *(headwaters to USFS Boundary)*	Huerfano	CPW
2	**Bonnett Creek** *(headwaters to USFS Boundary)*	Huerfano	CPW
2	**Apishapa River** *(Headwaters to Confl. Herlick Canyon Creek)*	Las Animas	CPW
2	**Arkansas River** *(Outlet of Fish Hatchery to Confl. Fountain Creek)*	Pueblo	CPW & City of Pueblo
4	*** Alkali Creek** *(Headwaters to Lone Starr Ditch Headgate)*	Delta	BLM
4	*** Hubbard Creek** *(USFS Boundary to Deer Trail Ditch Headgate)*	Delta	BLM
4	*** Terror Creek** *(Confl. East & West Terror Creeks to Fawcett Ditch Headgate)*	Delta	BLM
4	*** Little Cimarron River** (ISF Increase) *(Headwaters to Butte Ditch Headgate)*	Gunnison, Hinsdale	CPW
4	*** Little Cimarron River** *(Butte Ditch Headgate to Confl. Cimarron River)*	Gunnison, Montrose	CPW
4	*** Schaefer Creek** *(Headwaters to Confl. Grouse Spring Creek)*	Gunnison	USFS
4	*** Kelso Creek** *(Headwaters to Confl. Escalante Creek)*	Mesa	USFS
5	*** Timber Springs Gulch** *(Springs Complex to Groff Ditch Headgate)*	Eagle	BLM
5	**Dry Fork Roan Creek** *(Confl. North Dry Fork Creek & South Dry Fork Creek to Confl. Roan Creek)*	Garfield	BLM
6	*** Brush Creek** *(Headwaters to Confl. East Douglas Creek)*	Garfield, Rio Blanco	BLM
6	*** East Douglas Creek** (ISF Increase) *(Confl. Bear Park Creek to Confl. Brush Creek)*	Garfield, Rio Blanco	BLM
6	*** East Douglas Creek** (ISF Increase) *(Confl. Brush Creek to Confl. Cathedral Creek)*	Rio Blanco	BLM
6	**Piceance Creek**	Rio Blanco	BLM & CPW

	(Confl. Dry Fork to Confl. White River)		
6	*** Soldier Creek** (ISF Increase) (*Confl. Right Fork & Middle Fork Soldier Creeks to Confl. Cathedral Creek)*	Rio Blanco	BLM
6	**Yellow Creek** *(Confl. Barcus Creek to Lambert Springs)*	Rio Blanco	BLM
6	**Yellow Creek** *(Confl. Lambert Springs to Confl. White River)*	Rio Blanco	BLM
6	*** Armstrong Creek** *(Lower Terminus of ISF Case # 06CW035 to Confl. Elkhead Creek)*	Routt	CPW
6	*** Big Canyon Creek** *(Headwaters to Confl. Elkhead Creek)*	Routt	CPW
6	*** Elkhead Creek** *(Lower terminus of ISF Case # 06CW034 to the Confl. First Creek)*	Routt	CPW
6	*** Hole-in-the-Wall Creek** *(Headwaters to Confl. Elkhead Creek)*	Routt	CPW
6	*** North Fork Elkhead Creek** *(Headwaters to Confl. Sawmill Creek)*	Routt	CPW
6	*** North Fork Elkhead Creek** *(Confl. Sawmill Creek to Confl. Elkhead Creek)*	Routt	CPW
6	*** Sawmill Creek** *(Headwaters to Confl. North Fork Elkhead Creek)*	Routt	CPW
6	*** Stukey Creek** *(Headwaters to Confl. Elkhead Creek)*	Routt	CPW
6	**Willow Creek** (ISF Increase) *(Outlet of Steamboat Lake to Confl. Beaver Creek)*	Routt	BLM
6	**Willow Creek** (ISF Increase) *(Confl. Beaver Creek to Confl. Lester Creek)*	Routt	BLM

CPW (Colorado Parks and Wildlife), BLM (Bureau of Land Management), CDPHE (Colorado Department of Public Health and Environment), USFS (United States Forest Service)

The detailed recommendations and appendices for these streams will be posted on the CWCB website at:
http://cwcb.state.co.us/environment/instream-flow-program/Pages/2015ProposedISFAppropriations.aspx