DRAFT FLOW STUDY
ENTIAT WATERSHED WRIA 46

Prepared for:

ENTIAT WATERSHED PLANNING UNIT
Chelan County Conservation District
Wenatchee, WA

Prepared by:

ENTRIX, INC.
Seattle, WA

Project No. 339202

August 25, 2003

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1.1 THE ENTIAT WATERSHED

The Entiat River is located on the eastside of the Cascade Mountains in north central Washington. The river flows southeast about 53 miles from the Cascade Crest (7,000 ft elevation) to enter the Columbia River at the town of Entiat, which is about 20 miles north of Wenatchee (Figure 1-1). The Entiat watershed is about 42 miles long, varies in width from 5 to 14 miles, and has a drainage area of 267,734 acres, 418.3 square miles (CCCD, 1999 Draft).

Eighty-seven percent of the Entiat watershed is in public ownership, primarily National Forest System lands. However, along the lower 25 miles of the river, most of the valley bottom is in private ownership including about 1,300 acres of prime orchard land.

The Entiat River supports viable salmon and steelhead populations as well as several reproducing populations of native fish. Its principal tributary, the Mad River, supports reproducing populations of rainbow trout, bull trout, cutthroat trout, steelhead and spring chinook. Spring chinook and steelhead are currently listed as endangered and bull trout are listed as threatened under the Federal Endangered Species Act (ESA). The species of interest in this flow study are steelhead, spring chinook and summer chinook.

Due to the watershed's location, topography and aspect, weather patterns are highly variable. Precipitation and temperature extremes are rather common yet their occurrence is sporadic and often unpredictable. Cold temperatures during winter can cause anchor ice and high intensity thunderstorms are common during summer, especially in July. These thunderstorms often cause lightning strikes in rugged, inaccessible areas, some of which become major project fires. Approximately 60% of the watershed has been burned during the past 30 years (USFS, 1996). As a result, total annual runoff and sediment yield has been observed to vary considerably in response to both precipitation and the recurrence of large fires.

The demand for off stream water use is primarily tied to the irrigation season, which extends from mid-March or April through September. The primary irrigation use is for orchard crops and the highest demand for irrigation typically occurs from late June through August.

A comprehensive discussion of watershed topography, climate, hydrology, fire history and land ownership/use is provided in the Entiat Co-operative River Basin Study (USDA, 1979) the 1996 Watershed Assessment Entiat Analysis Area Version 2.0 (USFS 1996) and the Entiat Coordinated Resource Management Plan (CCCD, 1999 Draft).

Figure 1-1 Entiat Watershed Map

1.2 PLANNING UNIT HISTORY

Stakeholders in the Entiat River watershed have a vision of the future, a future that provides for the coexistence of people, fish and wildlife. The drive toward this vision began during a period of growing discontent, especially among area landowners, involving water rights and fisheries protection actions by some government agencies. Enforcement actions in 1991 and 1992 and forecasts of increased regulation with the coming of ESA listings had landowners and agency personnel on edge. A clear message delivered during this time was that the Entiat community could best prepare itself for the future by initiating its own planning effort rather than waiting for another entity to take the lead.

Seizing on this call for a pro-active approach, members of the Chelan County Conservation District met with the Entiat Chamber of Commerce in 1993 to gain support for the Entiat watershed planning effort. The Chamber initiated a search for local citizens interested in participating and a Landowner Steering Committee was formed to begin the process.

Work began in December of 1993 when a small planning group of local landowners, representatives of the Conservation District, Natural Resource Conservation Service and Entiat Ranger District met to outline a planning process, identify stakeholders and craft a preliminary mission statement with goals. Monthly meetings began in February 1994, culminating in mid-1994 with a decision to organize using the Coordinated Resource Management Planning model developed by the NRCS. This "CRMP" organization involved a Landowner Steering Committee, a Technical Advisory Committee and a Watershed Planning Coordinator.

The CRMP group made significant progress between 1994 and 1998. They compiled existing information and collected new information. The NRCS Stream Team gathered essential information during a stream survey of the lower Entiat, leading to recommendations for channel and riparian restoration.

Until 1998 the Entiat CRMP group accomplished its work on a shoestring budget, largely supported by donated time and effort. The Draft Entiat Coordinated Resource Management Plan (CCCD, 1999) documents this progress. Unresolved issues, such as instream flow, were beyond the financial means of the CRMP group.

The Washington State Watershed Planning and Salmon Recovery Acts relieved this funding dilemma in 1998. In response to this opportunity, the Conservation District and Forest Service led a successful effort to secure funding through the State Planning Act. The Entiat CRMP group reorganized, with support of the Initiating Governments (Chelan County, City of Entiat, Entiat Irrigation District), to become the Entiat Planning Unit, taking on the tasks of addressing water quality, water quantity, and instream flow and habitat. The existing organization consists of the Planning Unit, supported by four technical work groups, two watershed coordinators and several contractors focused on specific analysis tasks. Funding from other sources such as the Colville Tribes and the State Salmon Recovery Funding Board have supplemented State Watershed Planning support for the Entiat effort.

The already broad range of stakeholders widened when the Planning Unit was created. Landowners include residents who were born and raised in the Entiat valley, as well as recent settlers. Orchardists, logging, grazing, environmental interests, and the interests of retired citizens are all represented. Some Planning Unit members reside in the valley and earn their living outside of the watershed, while others are directly dependent on its resources for their income. The Technical Committees are composed of County, State, and Federal employees, representatives of the Yakama Nation and Colville Tribes, as well as other interest groups. This expanded stakeholder participation and the objectives of the 2514 watershed planning process led to the refinement of the mission and goal statement first developed in 1993.

Planning Unit members are confident that this science-based planning process fulfills their vision and goals and that with landowner cooperation, regulating agencies may not find it necessary to apply "One Size Fits All" regulations in this watershed. The concept of "Optimum Utilization of Flow", which was developed by the Entiat Planning Unit, was key to this outcome and provides the central theme for this Instream Flow Study.

"Optimum Utilization of Flow" is based on the premise that the existing water supply can be used in a manner that provides more habitat for aquatic life while maintaining existing human use and providing for growth. The Planning Unit recognizes that this balance can only be achieved through careful application of a collaborative problem-solving process.

Often, streamflow requirements for several instream water uses and, at times, downstream delivery requirements are so closely related in terms of their timing and magnitude that the composite water use requirement can be satisfied by a streamflow that is much less than the sum of the individual requirements. Such water uses are called "conjunctive uses" and the amount of streamflow necessary to satisfy these uses is called the conjunctive instream flow requirement. Great emphasis was placed on identifying seasonal conjunctive instream flow requirements for specific segments of the Entiat River because of the high degree of compatibility that exists between such flow requirements and the Planning Unit's goal of achieving "Optimum Utilization of Flow" through an interactive problem resolutions process.

2.0 INTRODUCTION

2.1 PURPOSE

The Entiat Water Resource Inventory Area (WRIA) Planning Unit (EWPU) is formally organized and recognized under the Washington State Watershed Planning Act (WPA, Chapter 90.82, Revised Code of Washington). In providing direction to the EWPU, the Initiating Governments elected to develop a watershed plan for water quantity, water quality, habitat, and instream flow in accordance with the WPA. Committing to planning for instream flows under the WPA includes the development of recommended instream flows, as well as strategies to meet those instream flows.

The EWPU was committed to recommending instream flows for the Entiat River through application of the Instream Flow Incremental Method (IFIM). At its April 19, 2000 meeting, the EWPU formally adopted a robust application of the IFIM as the methodology to be used to develop streamflow recommendations. As part of that decision, the EWPU contracted with ENTRIX to conduct a study to identify the passage and spawning needs in the lower 28 miles of the Entiat River and the lower two miles of the mad river. Results of the ENTRIX study are presented in this report to assist the EWPU in negotiating streamflow recommendations that will meet the specific needs of the Entiat watershed.

These flow recommendations will be associated with key life stages of the target fish species for the following stream segments:

Entiat River Segment 1	Columbia River confluence to Mad River
Entiat River Segment 2	Mad River confluence to Potato Creek Moraine
Entiat River Segment 3	Potato Creek Moraine to Fox Creek
Mad River	Entiat River confluence to R.M. 10

2.2 SCOPE

ENTRIX assisted the EWPU with developing a study plan to address the issues specific to the Entiat Watershed. Due to budgetary constraints, the Planning Unit recruited the assistance of other agencies to fulfill the remaining data gathering and analysis needs for a stream-specific modified IFIM study. The April 2002 Work Plan identified the tasks and the party responsible for completion. The following tasks remained the responsibility of ENTRIX.

2.2.1 FLOW DURATION CURVES

The Water Quantity Work Group compiled and reviewed all USGS and USFS streamflow records for the Entiat and Mad Rivers. Data gaps in these records were filled through the application of appropriate correlation techniques and the daily records were provided to ENTRIX for Entiat River Segments 1 through 3 and the Mad River.

ENTRIX used these daily data files to prepare representative hydrographs for the Entiat and mad Rivers and four sets of annual and monthly streamflow duration curves. The hydrographs illustrate the time of year streamflows are the highest and lowest. The streamflow duration analysis illustrates the likelihood of a particular magnitude streamflow occurring during particular month of interest. A discussion of the hydrographs and duration curves is provided in Section 4.1.

2.2.2 Analysis of Spawning and Passage Issues

The following tasks remained work items for ENTRIX.

- Reconnaissance of stream segments for study site selection. ENTRIX was assisted by John Monahan of WDOE and Phillip Archibald of United States Forest Service (USFS). Mr. Monahan's familiarity with the history of this project and Mr. Archibald's familiarity with the system and the fish activity, were invaluable toward locating transects that would provide the best representation of the spawning and passage issues and juvenile rearing flow in the system.

- Installed transects and staff gages in Segments 1 and 2 and Mad River. Record water surface elevations. Substrate composition cross-section profile. During the July reconnaissance, it was determined that three transects in Segment 3 would be beneficial to the study and were added to the work plan.

- Collected three data sets and site photos at each transect in Segments 1, 2 and 3 and in the Mad River.

- Prepare a report on spawning, passage and rearing requirements for the lower Mad River and Entiat Segments 1, 2 and 3, and river aesthetics for Segment 2.

2.2.3 Selection of a Streamflow Requirement

Following the EWPU acceptance of this report, ENTRIX will assist the EWPU with selection of an instream flow recommendation by providing explanations of study results, technical comment on EWPU proposals and a facilitator for the issue resolution process.

3.0 METHODS

3.1 IDENTIFICATION OF STUDY PURPOSE

Prior to implementation of this study, the ENTRIX team met with the EWPU Instream Flow work group to discuss implementation of the April 2002 Work Plan. It was determined in this meeting that the ENTRIX study would focus specifically on the identification of passage, spawning, and juvenile rearing flows for Segments 1 and 2 of the Entiat River, and on passage and spawning flows for the lower two miles of the Mad River. Segment 3 of the Entiat River was later included in the ENTRIX work plan following an EWPU/ENTRIX reconnaissance visit in July 2002. Because Segment 3 historically experiences the highest rate of spawning activity of the identified segments, the study focused on spawning and rearing.

3.2 IDENTIFICATION OF STUDY AREAS AND TRANSECTS

Stream segments are defined and characterized in the April 2002 Work Plan. Study sites were selected within each stream reach during a reconnaissance visit in late July 2002. During this visit, with the assistance of Phillip Archibald of the United States Forest Service (USFS) and John Monahan of the Washington Department of Ecology (WDOE), the ENTRIX team was directed to known spawning areas and sites of passage concern. Transects were selected to represent typical hydraulic and substrate conditions for these areas. Areas selected for study as spawning habitat were limited in size by the location of suitable substrate. Areas selected for study as “passage reaches” possessed shallow depths for over a length of three or more channel widths.

Study site and transect locations were based also on the following criteria:

- Landowner permission for access;
- Representation of typical spawning areas or passage reaches within the segment;
- Availability of credible streamflow data; and
- Ability to obtain an accurate flow measurement for comparison to the gage record.

The transects and photo points selected for the aesthetic evaluation in Segment 2, were chosen for their visibility from the roadway.

The following text summarizes the specific focus and data collection activity intended for each river segment. River segments, study sites and transects are sequentially numbered in the upstream direction. Table 3-1 lists study sites and transects by river segment and defines the intended use of the field data collected at the transect.

Table 3-1 Summary Table of Segment, Site and Transects

Segment	Site/R.M.	Transect	Purpose	Description	In-Field Observations 8/02, 9/02. 10/02
Entiat Segment 1	R.M. 0.8 Site 1	1	Spawning	1 chosen for Chinook Spawning. 2 & 3 Chosen for steelhead spawning, "no Chinook". Transects are located on right bank channels.	Active spawning 10/02
		2	Spawning/ Passage		No passage into the side channel at lower flows.
		3	Spawning		
		4	Flow	In combination with the average of 2 and 3, provides total flow measurement.	Spawning activity observed downstream 10/02
	R.M. 1.3 Keystone		Spawning/ Passage	Chosen because of spawning in previous years and potential passage issues at low flow.	Spawning 9/02 and 10/02
	R.M. 4.5 Dinkleman		Passage	Potential passage issue.	Adults holding in scour pool downstream of "V" weir, all 3 visits.
Mad River	R.M. 0.2	1	Passage	The transect is a potential passage issue -- however, a more likely passage issue is located just upstream of the transect on private property. We did not have	
	R.M. 1.2	2	Spawning	Spawning in previous years.	Chinook redd in 9/02
	R.M. 1.3	3	Spawning	Spawning in previous years.	Steelhead redds in 7/02. Chinook redd on transect 9/02
Entiat Segment 2	R.M. 10.6	Lower	Passage/ Aesthetic	Chosen for potential passage issues and aesthetics viewpoint.	
	R.M. 14.9	Upper	Passage/ Aesthetic	Chosen for potential passage issues and aesthetics viewpoint.	
Entiat Segment 3	R.M. 25.8	1	Spawning	Chosen because of spawning in previous years. Segment 3 typically has the most spawning of the studied segments.	
		2	Spawning		Good cover along right bank.
		3	Spawning		Redd on right bank.

3.2.1 ENTIAT SEGMENT 1 COLUMBIA RIVER TO MAD RIVER

The April 2002 Work Plan indicates that ENTRIX would establish four or five transects at which streamflow requirements for salmon/steelhead passage, spawning, and winter habitat conditions would be assessed. At least one transect was to be established at each site to define channel shape and streambed/streambank composition.

Three sites were selected in Segment 1 (Figure 3-1) with a total of six transects. Site 1 is located at River Mile (R.M.) 0.8 and was chosen for its recent history of spawning activity. Transects 1, 2 and 3 are all located in areas of observed spawning. Transect 1 is on the main channel, while Transects 2 and 3 are in a side channel. Transect 4 was established for the purpose of measuring the entire streamflow at the site. Spawning was observed downstream of Transect 4 in the run tail out. Transect 2 was at the downstream entrance to the side channel and is being evaluated for both passage and spawning.

Figure 3-1. Topographic Map of the Entiat River -- Segment 1.

Site 2 is located near the Keystone gage at R.M. 1.3. This site was selected for its historical spawning activity as well as passage concerns due to the wide, shallow channel and mid-channel gravel bar. A single transect is located between the bridge and the gage, across the upstream end of the gravel bar.

The third site is located near approximately 300 feet upstream of the Dinkelman Canyon Bridge at R.M. 4.5. A single transect was placed across the river in a shallow riffle just upstream of the recently constructed boulder "V“ weir. This transect was located to evaluate passage.

3.2.2 ENTIAT SEGMENT 2 MAD RIVER TO POTATO CREEK MORAINE

During several years of observation, spawning has not been seen in Segment 2. However, many salmon pass through this segment to spawn in Segment 3. The focus of our study in Segment 2 was on confirming fish passage and determining adequate flows to maintain natural appearing views of the river. The Work Plan anticipated that four transects would be sufficient to evaluate fish passage and river aesthetics for Segment 2. Criteria to maintain river aesthetics are based on wetted perimeter during fall months and 60 to 70 % exceedance flow during snowmelt. Due to limited access and highly consistent channel morphology only two transects were selected for study. Both offered aesthetic views from the roadway and typical passage conditions for the segment.

The lower site is located at R.M. 10.6 just upstream of the Mad River Road Bridge (Figure 3-2). One transect is located at this site to assess adult passage and flow requirements for aesthetics. Two photograph points were also located on the bridge and marked for identical views at each flow.

The second site is located at R.M. 14.9, near Roundy Creek. One transect was selected at this site to evaluate passage and river aesthetics. One photograph point is located alongside a curve in the road, just off the road in a curve. The photograph point proved a good upstream view of the river.

The photographic comparison of the observed flows is provided in the Aesthetics Assessment in Section 4 of this report.

3.2.3 ENTIAT SEGMENT 3 POTATO CREEK MORAINE TO FOX CREEK

This segment experiences the highest rate of spawning activity of the identified segments. During the July reconnaissance visit, this segment was added to the ENTRIX work plan to ensure that instream flows were recommended for spawning salmon. Three transects are located in Segment 3 at R.M. 25.8, each located in historic spawning areas (Figure 3-3). Two of the transects span the entire width of the river, the third crosses a side channel.

3.2.4 MAD RIVER

The lower ten miles of the Mad River were assessed as a single stream segment with the primary focus of the assessment being the lower 2 miles. Two transects were anticipated for the Mad River in the April 2002 Work Plan. The field studies were to focus on fish passage and spawning flows using methods similar to those in Segment 1 of the Entiat River. A total of three transects are located in two different sites (Figure 3-2).

Figure 3-2. Topographic Map of Entiat River -- Segment 2 and the Mad River.

Figure 3-3. Topographic Map of the Entiat River -- Segment 3.

The Mill Town site has one transect. It is located at R.M. 0.2 upstream of the bridge. The site was selected to assess fish passage concerns. Approximately 300 feet upstream of this site is a location with a stronger potential for passage concerns, however it is on private property and access was not available.

Two additional transects are located at R.M. 1.2 and 1.3. These transects were placed in areas of known spawning activity, based on annual observations.

3.3 IDENTIFICATION OF THE PERIOD OF YEAR FOR THE STUDY

Discussions with members of the Instream Flow Work Group produced a phenology chart for salmon and steelhead known to utilize the Entiat and Mad Rivers. The chart resulting from this work is discussed and presented in Section 4 of this report and presented as Figure 4-1. The chart identifies the months of the year when life history activity of salmon and steelhead is highest. Thus, it identifies those months of the year when streamflow is needed for fish passage and spawning.

3.4 IDENTIFICATION OF STREAMFLOW CONDITIONS FOR STUDY PERIODS

The U.S. Geological Survey, in cooperation with other agencies, has periodically operated both continuous and miscellaneous measurement sites in the Entiat watershed. In addition, as part of the Barometer Watershed Program, the USDA Forest Service operated two continuous recording stations in the watershed.

Since January 2001, the Water Quantity Work Group has compiled and reviewed all USGS and USFS streamflow records for the Entiat and Mad Rivers. Data gaps in these records were filled through application of appropriate correlation techniques. The Instream Flow Work Plan required only reasonable estimates of daily streamflow data be generated when filling data gaps. Thus, considerable latitude existed in the Work Group’s choice of methods to extend, or synthesize, streamflow records for each of the study segments.

The resulting streamflow record was used by ENTRIX to illustrate seasonal and annual variation in streamflow and support our assessment of fish passage and habitat conditions (flow duration and time series analyses). The streamflow hydrographs indicate the time of year (months) when streamflows are highest and lowest. The streamflow duration analysis performed by ENTRIX identifies the likelihood of a particular magnitude stream flow occurring during any month. The results of this analysis are provided in Section 4.1.

3.5 FIELD DATA COLLECTION

The April 2002 Work Plan indicates that, ENTRIX would obtain three sets of hydraulic data at each of the transects, beginning in mid-August 2002. Because it is important to assess passage and spawning at low streamflow levels, one set of field data would be collected in January or February 2003 to ensure that a data set exists for very low streamflow conditions. This winter measurement would represent hydraulic conditions during drought in August or September.

A fourth set of data might be collected in mid-June or July 2003 if it becomes necessary to have a high flow data set. However, it is not cost-effective to assess passage or spawning conditions at streamflow higher than the natural range of streamflows anticipated during the migration or spawning seasons.

Three data sets and flow measurements have been obtained thus far. Because of the unusually low stream flows during October 2002 the collection of data in January or February 2003 is not necessary. But because, streamflows were also unusually low during August and September collection of a fourth data set may be desirable (see Results and Conclusion Section 5).

Transects and staff gages were installed August 13 through August 15. At this time, the staff gages were surveyed and the initial data set and flow measurements and water surface elevations were obtained. The data set included left and right bank water surface elevation, depth of flow and stream velocity at numerous points across the stream. The flow was measured using a Swoffer meter and topset wading rod.

In order to measure streamflow at a transect, the width of the stream was divided into a number of cells; generally, these were two-foot increments, unless smaller cells were required to accurately describe the bed profile. The intention was to divide the width of channel into 20 increments with approximately equal flow in each increment (cell). For each cell, the stream depth and average velocity of flow were measured. The meter was placed at a depth of 0.6 of the distance from the water surface to the streambed, where average velocity is expected to occur in shallow streams such as the Entiat and Mad Rivers. The product of the cell width, depth, and velocity is the discharge through that increment of the cross section. The total of the incremental section discharges equals the discharge of the river.

The second set of data and flow measurements was obtained September 25 and 26. During this field effort, the streambed composition (substrate data) was assessed. The lower flow in September provided better visibility of the streambed and more consistent coding than that, which would have occurred in August. A sample of the substrate coding form is provided in Appendix C, with the Substrate/Water Surface Elevation graphs. The coding categories used by ENTRIX approximate the categories used in the Washington Departments of Ecology (WDOE) and Fish and Wildlife (WDFW) 1995 PHABSIM study and emphasize classification of spawning gravels for salmon and steelhead. These spawning gravels are associated with the substrate codes 6 (Large Gravel 26-75 mm) and 7 (Cobble 75-150 mm) on the data form.

The third set of data and flow measurements was collected October 24th and 25th. This data set was collected with the intention of representing very low streamflow. The flow observed in October is similar to those expected in January or February, without the complications of cold temperatures and river ice.

ENTRIX staff and members of the Instream Flow Work Group visually assessed mid-winter aquatic habitat conditions within each river segment in January 2003, giving particular attention to the relative amount of influence low seasonal streamflows, streambed topography and air temperature appear to have on winter habitat conditions. Conclusions drawn from this site visit are provided in Section 5.5 of this report.

3.6 DATA PRESENTATION

The data collected during this study is presented by plotting; (1) cross sections to show the streambed profile and composition (substrate), (2) the water surface elevations associated with each measured streamflow, and (3) scattergrams to show the relationship of observed depths and velocities to commonly applied spawning criteria for salmon and steelhead. These plots are provided in Appendices C, D and E, respectively, with a discussion of their significance in Section 4 of this report.

4.0 RESULTS

4.1 BACKGROUND

Prior work by the EWPU and others has resulted in the acquisition of considerable knowledge regarding land ownership, water use, streamflow characteristics, stream channel type, stream corridor condition, aquatic habitat composition, and fish utilization for the Entiat and Mad Rivers (USDA 1979, USFS 1996, CCCD 1999, Ag Fish Water Tour may 2000, April 2002 Work Plan).

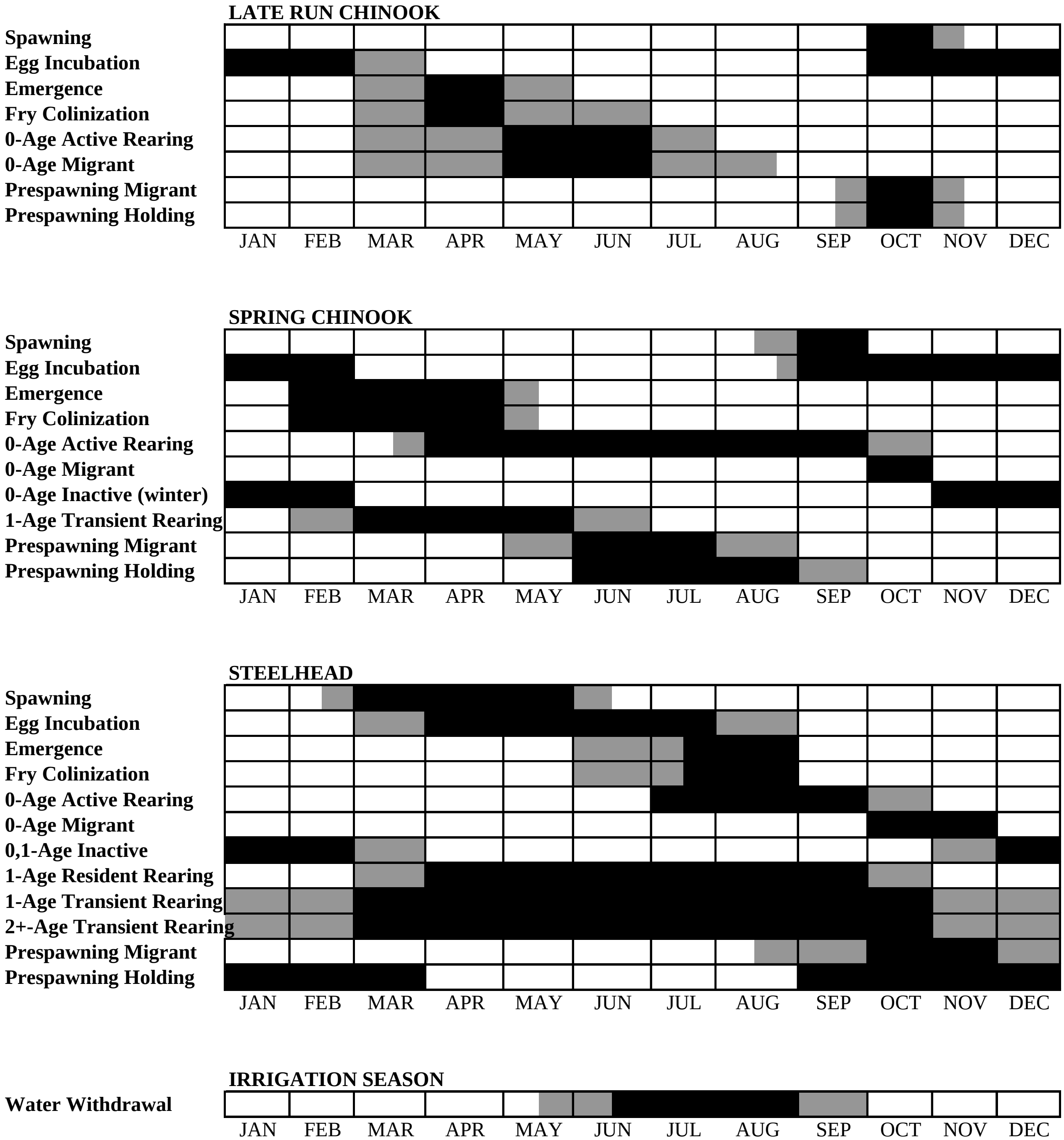
This information has been thoroughly discussed with the EWPU instream flow and water quantity work groups. Based upon these discussions, the IFIM stream segments appearing in Table 4-1 were delineated and coordinated with an ongoing EDT study. A detailed description of stream segment characteristics is provided in the April 2002 Final Work Plan (ENTRIX 2002).

Table 4-1 Summary of IFIM Segments

IFIM Study Segment	River Miles	EDT Study Reach	Landmarks
Entiat - 1	0.6 to 10.6	1 through 5	Mouth to Mad River
Entiat - 2	10.6 to 16.1	6 through 9	Mad River to Potato Moraine
Entiat - 3	16.1 to 28.5	10 through 12	Potato Moraine to Fox Creek
Mad River	0 to 10	Not defined	Mouth to Camp Nine

Although steelhead, spring chinook and summer chinook utilize different segments of the Entiat and the Mad Rivers to different degrees, no difference has been observed in the timing of a particular species' life history activity across stream segments. Thus, the timing of life history activities presented in Figure 4-1 is applicable to all stream segments being addressed in this report.

Figure 4-1. Phenology Chart for Chinook and Steelhead in the Entiat and Mad Rivers



Stream Use Key:
Black Areas = Periods of Heaviest Use
Grey Areas = Periods of Moderate Use
Blank Areas = Periods of Little or No Use

The USGS has maintained a gaging station on the Entiat River near Ardenvoir since 1957. This long-term record is supplemented by daily records from four shorter-term stations maintained by the USGS or the USFS and numerous miscellaneous measurements obtained by these entities. Tables 4-2 and 4-3 summarize the locations and period of record for the streamflow records on the Entiat and Mad Rivers.

Table 4-2. Stream Gaging History of Record for the Entiat River

Agency	R.M.	Gage Number	Location/Notes	Type of Record	Period of Record
USGS	0.5	12453000	Entiat River at Entiat	Continuous	11/1/10-9/30/25
	0.0		(inundated by R.Reach dam)	Continuous	6/1/51-9/30/58
USGS	1.5	12452990	Entiat River near Entiat	Miscellaneous	10/12/71-3/15/96
			(Entiat at Keystone)	Continuous	3/15/96-present
USGS	18	12452800	Entiat River near Ardenvoir	Continuous	9/1/57-present
			(Gage at Stormy Creek)		
USFS	33.6		Entiat River at Entiat Falls	Continuous	10/1/66-9/30/78
USFS	34		Entiat River at North Fork	Continuous	10/1/66-9/30/78

Table 4-3. Stream Gaging History of Record for the Mad River

Agency	R.M.	Gage Number	Location/Notes	Type of Record	Period of Record
USGS			Mad River near Ardenvoir	Grab	9/13/67-8/24/77
USFS			("Mad at Mill Camp")	Grab	8/29/90-present
USGS			Mad near Entiat confluence-R.M. 10.6 on Entiat	Miscellaneous	04/14/99-present

These streamflow records have been compiled and reviewed by the EWPU Water Quantity Work Group. Missing data were synthesized such that long-term records were available for Segments 1 through 3 of the Entiat River. In addition, the Water Quantity Work Group synthesized a long-term record for the lower Mad River.

ENTRIX received the compiled long-term streamflow data from the Water Quantity Work Group and prepared the hydrographs and the streamflow statistics appearing in Section 4.2 and Appendix B of this report.

4.2 STREAMFLOW PATTERNS AND MAGNITUDES

The Entiat and Mad Rivers derive nearly all of their total annual streamflow from snowmelt, and thus, experience much higher streamflows during May and June than during the remainder of the year (Figure 4-2). A comparison between the "average" monthly streamflow and the "median" monthly streamflow indicates that the most common streamflows are typically 10% to 30 % less than the calculated "average monthly streamflow" would indicate (Table 4-4). This disparity between the "average" and "median" streamflow results from the arithmetic average and the median being calculated from a data set containing a relatively small number of very large streamflows and a very large number of low streamflows. On both the Entiat and Mad Rivers, the calculated average annual streamflows are more than twice as large as the median annual streamflow. This disparity is critically important to recognize when discussing water allocation between off stream uses and instream flows. For either the Entiat or Mad Rivers, use of average annual or average monthly streamflow statistics would lead to the allocation of a much larger amount of water than typically exists. Such a decision would likely lead to endless future conflict.

Throughout the remainder of this report, "exceedance flows" will be used to describe water availability (streamflow magnitude) on a monthly, seasonal or annual basis because these statistics provide a more reliable indication of the amount of water that typically exists during a particular time period. Exceedance streamflow can be graphically represented as a streamflow that is equaled or exceeded a specified percentage of time based on recorded or synthesized daily streamflow data (Figure 4-3).

Monthly exceedance curves for the Entiat River near Ardenvoir (Ardenvoir gage), the Entiat River at Keystone and the lower Mad River are used extensively in Chapter 5 when discussing the applicability and strategy for implementing the results of our passage, spawning and rearing assessments.

4.3 FISH PASSAGE ASSESSMENT

Streamflow requirements for the upstream migration of adult salmon and steelhead were evaluated in the lower Mad River and Segments 1 and 2 of the Entiat River. The evaluation consisted of identifying areas where upstream fish movement might be impeded by shallow depths (shallow runs, riffles, bars) then obtaining measurements at these locations to determine the relationship between streamflow and the percentage of the channel width satisfying depth of flow criteria for salmon and steelhead passage (Thompson 1972).

In order for passage conditions to be deemed "adequate" for adult fish at least 25 % of the wetted channel width must meet or exceed Thompson's (1972) minimum depth criteria (0.8 feet for chinook or 0.6 feet for steelhead). Of this 25 % at least 10% of the width must be contiguous. For example, a wetted channel 40 feet wide must have at least ten feet of width flowing 0.8 feet (9.5 inches) deep to pass salmon <u>and</u> of that ten feet, four feet must be contiguous at the cross section and through the length of the reach.

Figure 4-2. Median Monthly Streamflow Hydrographs for the Entiat and Mad Rivers

Table 4-4. Monthly Average Streamflows Compared to Monthly Median Streamflows

Station: Entiat River Washington near Ardenvoir (gage 12452800) also known as Entiat River at Stormy Creek
(9/01/1957 to 9/30/2001)

Flow (cfs)

	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Median	84	91	117	267	955	1300	496	177	101	90	94	83	144
Average	106	114	149	326	1068	1431	641	219	114	100	129	126	377
Avg/Med	1.26	1.25	1.28	1.22	1.12	1.10	1.29	1.24	1.12	1.11	1.37	1.52	2.62

Station: Entiat River near Entiat, Washington (gage 12452990) also known as Entiat River at Keystone
(10/01/1957 to 9/30/2001)

Flow (cfs)

	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Median	138	146	195	361	1144	1527	608	242	157	145	149	137	210
Average	164	176	224	439	1293	1685	765	288	170	156	189	187	478
Avg/Med	1.19	1.20	1.15	1.21	1.13	1.10	1.26	1.19	1.08	1.07	1.27	1.37	2.28

Station: Mad River at Ardenvoir, Washington (gage 12452890) Synthesized Stream Flows
(10/01/1992 to 12/3/2002)

Flow (cfs)

	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Median	25.6	26.1	30.8	116.2	246	211.8	68	37.3	25.4	22.8	24.2	23.4	31.3
Average	27	37	53	135	321	250	93	43	27	25	29	30	89
Avg/Med	1.05	1.42	1.72	1.16	1.30	1.18	1.37	1.15	1.06	1.10	1.20	1.28	2.85

Figure 4-3. Annual Exceedance Curves for the Entiat River at the Ardenvoir and Keystone Gages, and the Lower Mad River with Calculated Average Annual Streamflow Highlighted.

The relationship between streamflow and passage depth is summarized in Figures 4-4 and 4-5 for Segments 1 and 2 of the Entiat River and Figure 4-6 and 4-7 for an Entiat River side channel and the lower Mad River. The cross section and depth of flow measurements that support Figures 4-4 through 4-7 are provided in Appendix C. No locations are known (or expected to exist) in Segments 1 and 2 of the Entiat River or in the lower Mad River where high stream velocity would impede upstream migration of salmon or steelhead. Hence, stream velocity was not assessed as a potential impediment to fish passage.

Inspection of Figures 4-4 and 4-5 indicates that adequate fish passage conditions exist in the mainstem Entiat River at very low streamflows. This observation is corroborated by the historic use of River Segment 3 by summer chinook during years of below normal streamflow.

Passage for spring and summer chinook into the side channel habitat of Segment 1 and the lower Mad River is of concern however. This concern is evident from inspection of Figures 4-6 and 4-7 and is corroborated by observing very limited use of these habitats by summer chinook. Passage flow requirements for steelhead in these habitats are typically exceeded by natural runoff conditions and observations of steelhead spawning in these habitats are common.

4.4 SPAWNING FLOW ASSESSMENT

Streamflow requirements to retain access to and use of existing salmon and steelhead spawning areas were assessed by placing transects across main channel and side channel sites known to be used by spawning fish. At each of these transects a cross sectional streambed profile was obtained, the composition of streambed materials was determined and the water surface elevation was measured at multiple streamflows. These site-specific data are presented in Appendix C. The graphs found in Appendix C also identify the areas with spawnable substrate. The spawning analysis is limited to these areas.

In addition, streamflow depth and velocity was measured at numerous locations along the transect. These measurements were uniformly spaced (at one or two-foot intervals) such that each measurement represents hydraulic conditions for about the same amount of wetted surface area at a particular transect. Scattergram plots compare sets of depths and velocities at multiple streamflows to commonly used spawning habitat criteria. Only those sets of depths and velocities associated with suitably sized spawning materials for salmon or steelhead appear in the scattergrams (Appendix D).

Counting the number of scattergram points meeting the criteria indicates the degree to which observed streamflows provide suitable spawning conditions. Table 4-5 provides the results of this analysis for Chinook and Table 4-6 provides the results for steelhead. The salient information from Tables 4-5 and 4-6 is plotted as habitat versus streamflow relationships in Figures 4-8 through 4-11.

4.5 REARING FLOW ASSESSMENT

Streamflow for rearing habitat is addressed in Section 5.5 associated with the winter habitat analysis.

Figure 4-4. Percent of Main Channel Width Meeting or Exceeding Thompson's (1972) Passage Criteria in Segment 1 of the Entiat River

Figure 4-4 continued. Percent of Main Channel Width Meeting or Exceeding Thompson's (1972) Passage Criteria for Depth in Segment 1 – Keystone and Dinkelman Sites.

Figure 4-5. Percent of Main Channel Width Meeting or Exceeding Thompson's (1972) Passage Criteria for Depth in Segment 2 of the Entiat River.

Figure 4-6. Percent of Side Channel Width Meeting or Exceeding Thompson's (1972) Passage Criteria for Depth in Segment 1, Site 1 of the Entiat River.

Figure 4-7. Percent of Channel Width Meeting or Exceeding Thompson's (1972) Passage Criteria for Depth in the Lower Mad River.

Table 4-5. Percent of Scattergram Points Compatible with Chinook Spawning Criteria at the Observed Flows.

(Limited to the Points Associated with Spawning Gravels)

Table 4-6. Percent of Scattergram Points Compatible with Steelhead Spawning Criteria at the Observed Streamflows

(Limited to the Points Associated with Spawning Gravels)

Figure 4-8. Percent of Measurements Meeting or Exceeding Chinook Spawning Criteria in the Entiat River.

Figure 4-9. Percent of Measurements Meeting or Exceeding Chinook Spawning Criteria in the Mad River.

Figure 4-10. Percent of Measurements Meeting or Exceeding Steelhead Spawning Criteria in the Entiat River.

Figure 4-11. Percent of Measurements Meeting or Exceeding Steelhead Spawning Criteria in the Mad River.

4.6 AESTHETIC FLOW ASSESSMENT

The aesthetic flow assessment involved the evaluation of a series of photographs taken at two viewpoints established in Segment 2 of the Entiat River during the July reconnaissance trip and revisited during August, September and October. Additional photos will be taken in January to represent the aesthetics during winter. The aspects of each aesthetic consideration are:

> **Wetted Channel Area:** The extent to which the channel is inundated by flow. In general, a fully wetted channel bottom has a higher aesthetic significance than a channel bottom that is only partially inundated. This is particularly apparent if there are no natural channel features such as lateral, mid-channel, or point bars, which one would expect to see, exposed at lower water levels.
>
> **Water Surface Pattern and Expression:** The extent of the diversity of water surface features and their compatibility with channel gradient and streambed materials. Evidence of diversity and intensity of surface water expression such as turbulence, eddies, pool or pocket water patterns were assessed when evaluating this consideration. In general, a channel with diverse hydraulic features and a pronounced sense of flow velocity has a higher aesthetic value than a channel with few hydraulic features, or with little appearance of flow velocity.

The photo presentation in Appendix A provides photographs at each transect, in all three Entiat River segments and the Mad River. The aesthetic flow assessment evaluates only the sites in Segment 2.

There is a distinct change in the visual attributes at both transects in Segment 2 between the August streamflow and the September and October flows. The decrease in the wetted channel area was the most significant factor in the overall observed change. Of the three observed flows, the stream flow in August provides river views that are most appealing. The August flow also exhibited more intense and diverse hydraulics, with a much stronger appearance of flowing water. The August flow of approximately 200 cfs was very near the monthly median flow levels for August and appeared appropriate for the channel. The flows observed in September (approximately 80 cfs) and October (approximately 50 cfs) were in the 90th percentile of flow exceedance. A strong sense of flow was not obvious and no unusual features were exposed to improve the aesthetic value.

Based on these findings, the highest recommended flows for mainstem aesthetics should be near the median monthly flow with the lowest recommended aesthetic flows being near the 70th percentile of flow exceedance.

5.0 DISCUSSION AND APPLICATION OF STUDY RESULTS

5.1 BACKGROUND

The field measurements used in this study were collected during the time of year that coincided with spring chinook spawning and with the migration and spawning of summer chinook. Several redds were observed at or near our transects. Hence, we have a very high-degree of confidence in the choice of study sites for evaluating chinook spawning. Steelhead redds constructed during April and May 2002 were observed during a July 2002 site visit and used as criterion for study site selection and transect location in Segment 1 and the lower Mad River. Thus, a high degree of confidence also exists in our choice of study sites to represent steelhead-spawning in these stream reaches.

Streamflow measurements were made at each study site during each data collection visit. These measurements are compared to same day records from the USGS stream gages in Table 5.1. A high degree of compatibility exists between the measured and recorded streamflows. This should instill confidence in the accuracy and reliability of the depth and velocity measurements used to evaluate passage and spawning conditions because the streamflow measurements and the depth and velocity data used in this study were obtained by the same staff using the same equipment and following very similar data collection protocols.

Table 5-1. Comparison between ENTRIX streamflow measurements and USGS gage record.

Location	August	September	October
Segment 1			
Site 1	231	90	73
Site 2	223	100	81
Site 3	227	100	77
Keystone Gage	**232**	**101**	**88**
Segment 2			
Lower	233	85	58
Upper	196	73	52
Ardenvoir Gage	**203**	**71**	**54**
Segment 3			
Site 1	190	71	46
Mad River			
Site 1	33.61	23.16	22.69
Site 2	39.79	22.95	21.28
Site 3	39.50	27.21	23.85

The analytical methods and criteria used in this study to evaluate passage and spawning conditions were introduced by Ken Thompson (Thompson, 1972) and discussed during the 1972

Joint ASCE-AFS Instream Flow Requirement Workshop. Since its introduction, the Thompson Method has been rigorously critiqued and widely applied. It remains the most widely applied method for assessing fish passage in small streams and wadeable rivers.

The method is applied much less frequently to determine spawning flow requirements because it lacks the sophistication of habitat simulation methods. However, the Thompson method for assessing spawning flow requirements is strongly based upon site-specific field measurements, observed or recorded seasonal streamflows, and knowledge of spawning behavior. As applied in this study, the Thompson Method yields a relationship between spawnable area and streamflow, which is similar to the output of more sophisticated habitat simulation models.

The depth and velocity criteria associated with the Thompson Method have also been widely discussed and applied. They are not as refined or as sophisticated as criteria commonly associated with habitat simulation methods, but they are very representative of the acceptable range of spawning conditions for salmon and steelhead in streams and wadeable rivers. The particular substrate, depth and velocity criteria used in this study to evaluate chinook and steelhead spawning were discussed with and approved by the WRIA #46 Instream Flow Work Group, prior to initiating our filed studies. Thus, the EWPU can have confidence in the analytical procedures, which were applied in this study.

5.2 FALL 2002 STREAMFLOWS

Field measurements were obtained in the Entiat River near median streamflow conditions for August but at abnormally low streamflow conditions for September and October (Figure 5-1a). Field measurements collected in the Mad River at streamflows near normal for August, September and October (Figure 5-1b). The occurrence of abnormally low streamflow conditions in the Entiat River during September and October was highly beneficial for the fish passage assessment, but a little detrimental to the evaluation of streamflow requirements for spawning.

September and October streamflows provided the opportunity to visually assess adult passage conditions throughout the river segments being studied and to collect field measurements at our fish passage study sites when natural streamflow conditions had about their highest potential to impede fish movement. Thus, we have very high confidence in the results of the fish passage assessment.

The September and October streamflows at which observation was made and field measurements were collected to evaluate passage and spawning are of a similar magnitude. Thus, the September and the October hydraulic measurements (particularly depth of flow) vary little from one another. Therefore, the three data sets available for assessment of flow requirements for chinook spawning are not as robust as one might desire. Nevertheless, the similarity of the September and October hydraulic measurements are useful because they provide corroborating data sets regarding access to, and the quality of, spawning habitats when stream flow is abnormally low.

Figure 5-1a. Entiat River Exceedance Flows at which Flow Measurements and depth-velocity data were obtained.

Figure 5-1b. Mad River Exceedance Flows at which Flow Measurements and depth-velocity data were obtained.

5.3 DISCUSSION OF FISH PASSAGE FLOW

Application of Thompson's (1972) passage width criteria in Figures 4-4 and 4-5 indicates that the most critical fish passage reaches in the lower 10 miles of the Entiat River are the Keystone and Dinkelman sites. The minimum streamflow required for adult chinook passage at these sites is in the range of 50 cfs. Similarly, the minimum streamflow required for steelhead passage at these locations appears to be in the range of 35 cfs. However, neither the chinook nor steelhead passage flow requirement is being proposed for consideration by the EWPU because they are superceded by larger instream flow requirements for spring and summer chinook spawning which are needed during the same time period as passage flow (see Section 5.4).

Fish passage into a side channel at Site 1 Segment 1 can be assessed using Figure 4-6. During the time period in which spring and summer chinook spawn (late August through October), streamflows are insufficient for chinook to enter this side channel. Steelhead passage into this side channel is satisfied when streamflow at the Keystone gage is about 165 cfs or larger.

Although steelhead migrate into the Entiat River from September through November (Figure 4-1) they generally hold (winter-over) in mainstem habitats until they seek out spawning habitats in April and May. During April and May when steelhead spawning occurs, streamflow at the Keystone gage is almost always equal to or greater than 165 cfs (Figure 5-2) and steelhead passage into the side channel at Segment 1 is unimpaired. Recurrent observations of steelhead spawning in this side channel by the Instream Flow Work Group corroborate this assessment.

Application of Thompson's passage width criteria to Figure 4-7 indicates the minimum streamflow for adult chinook passage in the lower Mad River is about 35 cfs at Transect 1 and 45 cfs at Transect 3. Because access was not granted by a landowner, we were unable to place the downstream passage transect (Transect 1) in the most critical passage reach. Thus, greater emphasis should be placed on the results of applying Thompson's passage width criteria to Transect 3 and concluding that 40 to 45 cfs would be the recommended streamflow for chinook passage in the lower Mad River. Steelhead passage is met when streamflows are 25 cfs or more.

Inspection of Figure 5-3 indicates that natural streamflow seldom equals or exceeds 40 cfs in the Mad River during chinook migration and spawning, where as Figure 5-4 indicates that 25 cfs is almost always equaled or exceeded during the steelhead migration and spawning season. This natural streamflow pattern probably explains why little chinook spawning is observed in the lower Mad River but steelhead spawning is common.

Figure 5-2. Entiat River Historical March, April and May Daily Exceedance Flows at Keystone and Ardenvoir Gages.

Figure 5-3. Mad River Streamflow Exceedances during September and October.

Figure 5-4. March, April and May Streamflow Exceedances Derived From Synthesized daily Data for the Lower Mad River.

5.4 DISCUSSION OF SPAWNING FLOW

5.4.1 CHINOOK SPAWNING

Depth and velocity data were collected over substrate suitable for chinook spawning when streamflow was approximately 230, 100 and 77 cfs in River Segment 1 and 190, 70 and 46 cfs in River Segment 3. These data sets bracket the range of streamflows during the chinook spawning season from about the 90% or 95% exceedance flow to the 5% or 10% exceedance flow (Figure 5-5). We could not collect data near the median September or October streamflows because of the low water year type.

Figure 4-8 indicates that the availability of chinook spawning area in River Segment 1 is quite limited at streamflows less than 100 cfs. This figure also indicates that the largest amount of chinook spawning area was observed at streamflows near 200 cfs. It can be inferred that streamflows near 300 cfs would probably provide more spawning area than what was observed near 200 cfs.

By considering Figures 4-8a and 5-5b in unison, one can conclude that streamflow of 200 cfs or larger seldom occurs in River Segment 1during the chinook spawning season. Thus, the chinook spawning area associated with streamflows of this magnitude or larger is generally not available to spawners. Because streamflows are seldom large enough during the spawning season to provide the amount of habitat associated with streamflows of 200 cfs or larger it is not necessary to define a spawning habitat versus streamflow relationship for streamflows any larger than 200 cfs. Additionally, Figure 5-4 indicates that an instream flow requirement of 200 cfs or more for chinook spawning would be both highly restrictive on water use and unlikely of being attained 80 to 90 % of the time.

The recommended spawning flow for Chinook salmon in River Segment 1 clearly exists between 100 and 200 cfs. However, Figure 4-8a is not well enough defined between our field observations of 232 cfs and 101 cfs to choose the recommended flow with much confidence.

Figure 5-6 is a scattergram of historic summer Chinook redd counts in River Segment 1 versus the median October streamflow for the year in which the redd count was made. Figure 5-7 is a plot of the redd count and median October streamflow four years prior to the redd count, i.e. the year in which the returning adults were spawned.

One should not expect to see a relationship between these redd counts and median monthly streamflow, because the number of adult salmon returning to the Entiat River is strongly influenced by factors outside the watershed (i.e. Columbia River passage and ocean survival). However, the scattergrams are very useful for identifying the range of October streamflows during which the majority of the redd counts fall. Visual assessment of Figures 5-6 and 5-7 indicates that the vast majority of summer Chinook redd counts in River Segment 1 occurred at streamflows between 100 and 165 cfs. Selecting a streamflow near this value 165 cfs as the instream flow requirement for chinook spawning during October would ensure that much of the natural streamflow variability (below 165 cfs) under which this run is accustomed to spawning, is not impaired by future water diversions. One or more additional sets of field data collected between 140 and 170 cfs is recommended to refine Figure 4-8b.

Figure 5-5. Entiat River Exceedance Flows during the Chinook Spawning Season, Highlighting the Streamflows at Which Depth and Velocity Data Sets Were Collected During 2002.

Figure 5-6. Segment 3 Spring Chinook Redd Count vs. Median September Flow at Keystone During Year of the Redd Count.

Figure 5-7. Spring Chinook Redd Count vs. Median September Flow at Keystone 4 Years Prior to Redd Count.

Very similar conclusions can be drawn from Figures 4-8b and 5-5a regarding streamflow requirements for the protection of existing spring chinook spawning in River Segment 3. Figure 4-8b is not well defined between 71 and 190 cfs because of the type of water year that coincided with our filed program. The greatest amount of spawnable area is available at streamflows of 200 cfs (and larger). However, natural streamflows in River Segment 3 during the spring chinook spawning season (September) equal or exceed 200 cfs less than 10 % of the time. Thus, one can conclude that existing spring chinook salmon production in River Segment 3 (and therefore the Entiat River) is dependant on a range of streamflows notably less than 200 cfs. One might examine Figures 4-8b and 5-5a concurrently and conclude that an instream flow for spring Chinook spawning is between about 90 and 150 cfs.

Figure 5-8 plots historic spring chinook redd counts in River Segment 3 against the median September streamflow for the year in which the redd count was made. Figure 5-9 presents the redd counts and median September streamflows for the year in which the returning adults were spawned (i.e. four years earlier). Inspection of these figures indicates that an instream flow of 120 to 125 cfs would maintain most of the natural variation in September streamflow under which the existing spring chinook run has developed. This estimate should be corroborated by collecting an additional data set at the study site when the streamflow is approximately 110 to 140 cfs then revising Figure 4-8b.

Figure 4.7 indicates that a very small percentage of our depth of flow measurements at chinook spawning sites in the lower Mad River meet minimum depth criteria for passage until streamflow is about 35 cfs or more. Figure 5-3 indicates that natural streamflows in the Mad River seldom equal or exceed 35 cfs during the spring run or summer chinook spawning seasons. Thus, it can be concluded that natural streamflow seldom provides Chinook with good access into the Mad River. A very similar conclusion was reached when evaluating the streamflow necessary for chinook spawning in the lower Mad River e.g. natural streamflow is too low to support good chinook spawning conditions in the Mad River (Figures 4-9 and 5-3). Therefore, the efficacy of establishing an instream flow for chinook spawning in the Mad River is questionable unless it is being considered in association with upstream water storage for fall release or stream channel modification. We are not recommending an instream flow for chinook spawning in the Mad River because natural streamflows are too low to support chinook spawning.

Figure 5-8. Segment 3 Spring Chinook Redd Count vs. Median September Flow at Ardenvoir During Year of the Redd Count.

Figure 5-9. Spring Chinook Redd Count vs. Median September Flow at Ardenvoir 4 Years Prior to Redd Count.

5.4.2 Steelhead Spawning – Entiat River and Transects 2 and 3 in the Lower Mad River.

Figure 4-10a (Transects 1 and 3) indicates that more than 60 % of the available spawning gravel in the side channel at Site 1, Segment 1, has suitable depth and velocity for steelhead spawning when the streamflow at Keystone is 250 cfs. Figure 5-2 indicates that Entiat River streamflow almost always exceeds 250 cfs during the steelhead spawning season. One can infer from Figure 4-10 that 80 % or more of the available spawning gravel in the side channel at Site 1 is suitable for spawning when streamflow at the Keystone gage is approximately 350 cfs. Figure 5-2 indicates that 350 cfs is equaled or exceeded approximately 55 % of the time during April and over 95 % of the time during May. We have insufficient data to be any more specific about an instream flow recommendation for maintaining existing steelhead spawning conditions in side channel or channel margin habitat of River Segment 1.

Figure 4-10a also implies that a streamflow of 300 to 350 cfs will about maximize available steelhead spawning area at the Keystone site. Thus, the information presented in Figures 4-10a and 5-2 indicates an instream flow of 350 cfs for steelhead spawning would about maximize available spawning area throughout River Segment 1 and have a very high probability of occurring during April and May.

Similarly observations of Figures 4-10b and 5-2 indicate an instream flow of 300 to 350 cfs would also be applicable in Segment 3 for protecting existing steelhead spawning. Observations of steelhead spawning conditions at our study sites in River Segments 1 and 3 should be conducted around 300 cfs to refine Figure 4-10 and substantiate or modify this opinion.

Figure 4-11 indicates that the greatest percentage of our 2002 depth measurements over suitable substrate in the lower Mad River meet or exceed minimum criteria when streamflow is 40 cfs. It was inferred from the 2002 data that a streamflow near 60 or 70 cfs would result in a large percentage of the field measurements meeting or exceeding minimum criteria for spawning steelhead. In April 2003, an additional set of filed data was obtained in the Mad River at 73 cfs. These measurements indicate nearly all available spawning gravel is associated with suitable depths and velocities for steelhead spawning.

Figure 5-4 indicates that Mad River streamflow during the steelhead spawning season (April and May) is typically greater than 70 cfs. We are recommending 70 cfs for steelhead spawning in the Mad River.

5.5 Winter Habitat Assessment

5.5.1 Site Visit

In prior years, anchor ice had been observed in the lower Mad River and in Segments 1 and 2 of the Entiat River. Snow covered ice bridging with open velocity leads was commonly observed in Segment 3 of the Entiat River. It is well documented in professional literature that the occurrence of river ice or the persistence of near zero water temperatures often causes high mortality for juvenile fish and incubating eggs. Thus, the general quality of aquatic habitat conditions in the Entiat River during winter likely has a significant influence on salmon and steelhead production in the Entiat River. Photographs obtained during the Winter Habitat Assessment are provided in the Photo Presentation (Appendix A).

Establishing instream flows for the Mad and Entiat Rivers during winter will not alleviate or mitigate cold water temperatures, river ice conditions or associated fish mortalities. However, an adequate instream flow requirement during winter should prevent future streamflow withdrawals from substantially reducing current winter streamflow levels thereby increasing the frequency, duration and severity of cold stream temperatures, river icing and fish mortalities above current levels.

Winter habitat conditions were visually assessed during a January 14, 2003 site visit. This habitat assessment focused on observing river ice conditions and discussing their probable affects on juvenile salmonids and incubating eggs and alevins. The winter of 2002-2003 was warmer and drier than usual. Snow covered ice bridging was observed in the vicinity of the Segment 3 study site near Grandma Creek (R.M. 25.8) but the ice cover was not sufficiently developed to cause auefice or redirection of flow. The water temperature at this site was measured as being 0ºC with a pocket thermometer. No icing was observed near Stormy Creek at R.M. 17 or downstream. The lower mile of the Mad River was ice-free except for discontinuous snow covered shoreline ice. The temperature of the Mad River was measured at R.M. 1.3 as being 0ºC with a pocket thermometer.

During the January 14 site visit, the water surface elevation of Lake Entiat was observed as having the primary influence on winter habitat conditions near the confluence of the Columbia and Entiat Rivers. Cold air temperature and low Entiat River flow rates are of much less importance downstream of R.M. 0.8 than they are upstream because the backwater effect from Wells Dam is so pronounced.

At the Keystone Gage (R.M. 1.1), stream temperature was measured at 3.5 and 4.0 C° with a pocket thermometer. This location is upstream from the influence of Lake Entiat backwater thus; the flow rate of the Entiat River has the primary influence on water surface elevation and the potential dewatering of incubating eggs/alevins. In regard to incubation and overwinter mortalities, cold air temperatures are thought to be of lesser importance in River Segment 1 than streamflow levels because streamflow is more likely to be affected by man and it influences both the dewatering and oxygenation of juvenile fish and incubating eggs in the streambed.

5.5.2 WINTER INSTREAM FLOW RECOMMENDATIONS

River Segment 1 is primarily used by summer chinook that spawn during October. Juvenile spring chinook and steelhead overwinter in River Segment 1. Winter instream flows in the lower one or two miles of River Segment 1 would be expected to protect juvenile fish and incubating eggs/alevins from dewatering and freezing in a cold but generally ice-free environment. It is commonly accepted that maintaining the submergence and oxygenation of redds and of interstitial spaces inhabited by juvenile fish during periods of freezing weather will be adequate for their survival in cold, ice-free streams. Therefore, winter or incubation flows are commonly selected as being less than 100 percent of the spawning flow in streams where fall spawning occurs and river icing is not of major concern. Although winter incubation flows have been set as low as 65% of the spawning flow in other Washington streams, we advise against using less than 80 percent of the spawning flow in the lower Entiat River because spawning near the Keystone Gage occurs in shallow pool tail outs and riffle areas and river ice has been observed when very cold temperatures occur. Eighty percent of the October spawning flow in Segment 1 is 132 cfs (165 x 0.8 = 132 cfs).

The winter base flow at the Keystone Gage was calculated as being 142.5 cfs (the arithmetic mean of the median streamflows for the months of November through February). This value, 142.5 cfs, serves as a check on the reasonableness of the 132 cfs incubation flow calculated above. The rating curve for the Keystone Gage indicates about a ½ inch difference in water surface elevation for streamflows of 132 and 142.5 cfs. It is assumed that a difference of ½ inch in depth would have little effect on the overall survival of juvenile fish or incubating eggs/alevins in this river segment. Therefore, either of these streamflows or another streamflow between 130 and 145 cfs, would be an appropriate instream flow to adopt for protecting existing winter habitat conditions in River Segment 1. Little can be recommended as an instream flow to protect juvenile fish overwintering in the upper eight miles of River Segment 1 or in River Segment 2 because this topic was not specifically studied. It is also known that the formation of anchor ice is influenced more by channel conditions and air temperature than by flow rate. Thus, the value of an instream flow to deter anchor ice formation is questionable.

A winter instream flow (November through February) for River Segment 3 would be expected to protect incubating eggs/alevins and juvenile fish from dewatering or freezing in a cold environment highly prone to the formation of a river ice cover. River Segment 3 is the most important area for the spawning and incubation of spring chinook in the Entiat drainage. Spring chinook throughout the mid-Columbia and its tributaries are listed as "threatened" under the Federal Endangered Species Act (ESA). Thus, this species is afforded special consideration when establishing instream flows. A few summer chinook also spawn in River Segment 3 during October, but the majority of these fish spawn in River Segment 1. Summer chinook are not afforded special consideration under ESA.

As a result of the importance of River Segment 3 to spring chinook, the special status of these fish, and the importance of maintaining as high a winter streamflow as is practical to guard against the dewatering and freezing of redds, we recommend that a streamflow in the range of the 25 to 30 percent winter exceedance flow at the Ardenvoir Gage be used for the winter instream flow for River Segment 3. The 25 and 30 percent exceedance flows at the Ardenvoir Gage during winter typically from 110 to 132 cfs (Table 5-2). Their arithmetic average (mean) is 119.5. Examination of the rating curve for the Ardenvoir Gage indicates a difference of 0.15 feet (approximately 1-¾ inches) in water surface elevation for streamflows of 130 and 110 cfs.

Table 5-2. Exceedance Flows at Ardenvoir Gage November through March

Winter Months	25% Exceedance Flow (cfs)	30% Exceedance Flow (cfs)
November	127	113
December	123	110
January	121	112
February	132	118

Another streamflow to consider for comparison with the 25% to 30% winter exceedance flow is the incubation flow derived from using 100% of the spring chinook spawning flow. Spring chinook spawn during September in River Segment 3 and the recommended spawning flow for River Segment 3 is 120 to 125 cfs (See the discussion in Section 5.4.1 and Figures 5-8 and 5-9). Thus the instream flow for River Segment 3 during winter should be 120 to 125 cfs.

Very little salmon spawning occurs in the Mad River. Therefore incubation during winter months is not as important in the Mad River as it is in the Entiat River. However, recommending a winter instream flow for the lower Mad River has merit because juvenile steelhead and spring run chinook as well as resident fish overwinter in the lower Mad River.

We recommend using the present-day winter base flow for protection of overwintering resident fish and juvenile salmon/steelhead. The calculated winter base flow for the Mad River is 24 cfs. This flow, or another flow between 20 and 30 cfs, is recommended as the winter instream flow for the lower Mad River (November through March).

6.0 REFERENCES

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APPENDIX A

PHOTO PRESENTATION

APPENDIX B

FLOW DURATION CURVES

APPENDIX C

SUBSTRATE GRAPHS

APPENDIX D

PASSAGE TRANSECT GRAPHS

APPENDIX E

SPAWNING TRANSECT GRAPHS