FINAL TECHNICAL REPORT
SPOKANE RIVER INSTREAM FLOW STUDIES

Prepared for

Spokane County Public Works Department
and
WRIA 54 & 57 Watershed Planning Units

Prepared by

EES Consulting

1155 N. State St., Suite 700
Bellingham, WA 98225

May 2007

ACKNOWLEDGMENTS

Funding for this project has been provided by the WRIA 54 and WRIA 57 Planning Units through the Spokane County Public Works Department using the following grants: Washington Department of Ecology (Ecology) 2514 Watershed Planning Program, Ecology Instream Flow Supplemental, Ecology Water Resources Grant. Members of the WRIA 54 & WRIA 57 Instream Flow Technical Team have provided valuable time, input, and decisions throughout the duration of this study.

Thanks to Tim Vore and Avista Utilities who supplied valuable aerial photographs of the river as well as much local knowledge and flow adjustment of the river when possible.

Special thanks are due to the people who assisted in various ways on this study. Local landowners, particularly the Spokane Rifle Club, were very cooperative in allowing field teams to access their property for study purposes. Thanks to the Spokane Sheriff's Department for access to restricted river launches. The staff at Spokane County Public Works Department has been extremely helpful in many ways, particularly with field and technical support and coordinating communication with committees and involved parties.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The Spokane River Physical Habitat Simulation (PHABSIM) Instream Flow study focuses on the fish habitat and instream flow needs of resident salmonids. Fisheries resources of primary concern in the Spokane River are game fish, including rainbow trout and mountain whitefish.

The study area was subdivided into two main Spokane River Instream Flow Study Areas (WRIA 57 and 54) and four tributaries: Spring, Little Chamokane, Coulee, and Deep creeks. The main Spokane River Study Areas encompass the mainstem from River Mile (RM) 63.8 at the upstream end of Nine Mile Reservoir to RM 73.8 at the Monroe Street Bridge near downtown Spokane. The river was further segmented into the WRIA 54 section, which extended from RM 63.8 to RM 72.3 at the mouth of Latah Creek, and the WRIA 57 section, which extended from RM 72.3 to RM 73.8. Five transects were selected for the study in WRIA 54 and two transects were selected in WRIA 57.

The mainstem Spokane River Instream Flow Study was conducted using the Physical Habitat Simulation (PHABSIM) modeling approach, which is commonly referred to as the U.S. Fish and Wildlife Service Instream Flow Incremental Method (IFIM). The tributary instream flow studies were conducted using the Toe-Width method developed by the US Geological Survey. Results of the PHABSIM study are contained in the main report. Results from the tributary Toe-Width study are contained in Appendix C.

A principal product of PHABSIM is the Weighted Usable Area (WUA) chart, which is a quantifiable index of habitat value, relative to flow. The modeled flow range in the mainstem Spokane River is from 350 cfs to 16,000 cfs. This report documents WUA results for rearing salmonids, including both rainbow trout and mountain whitefish. WUA results for spawning are reported for both species in WRIA 54 and only mountain whitefish in WRIA 57.

This report is organized into six main sections, 1.0 Introduction, 2.0 Methodology, 3.0 Results, 4.0 Hydrology, 5.0 Draft Recommendations and 6.0 References. The methodology, results, and hydrology are contained in the main body of the text and supporting technical data is located in the appendices.

PHABSIM ASSESSMENT
GLOSSARY OF TERMS

Calibration Flow	Measured flow used to evaluate model (RHABSIM, PHABSIM) performance.
EESC	EES Consulting, Inc. Primary consultant for Spokane River PHABSIM study
Freshet	A sudden rise in the level of a stream, or a flood due to heavy rains or the rapid melting of snow and ice.
HABSIM	The Weighted Usable Area Habitat Simulation in RHABSIM.
HSC	Habitat Suitability Criteria- Values for depth, velocity, substrate and cover that reflect the likelihood that fish will use a particular range for each factor. HSC unique for each species and life stage of concern.
HYDSIM	The hydraulic model in RHABSIM.
IFIM	Instream Flow Incremental Methodology
PHABSIM	Analysis and integration of physical stream measurements and habitat preference criteria require the use of a group of computer programs developed by the US Fish and Wildlife Service. This set of programs is called Physical Habitat Simulation System (PHABSIM).
RCW	Revised Code of Washington
Redd	Most salmonids deposit their eggs in nests called redds. Redds are dug in the streambed substrate by the female. Most redds occur in predictable areas and are easily identified by an experienced observer by their shape, size, and color (lighter than surrounding areas because rocks have been overturned and biofilm and silt have been cleaned away). Mountain White Fish, also a salmonid, do not dig redds, but broadcast eggs into the river.
RHABSIM	PHABSIM is a suite of computer programs developed by the US Fish and Wildlife Service. EESC uses RHABSIM, a PC version of the original PHABSIM program, developed by Tom Payne and Associates of Arcata, CA.
Stream Reach	A subset of the study area that is distinguished from other reaches for stated reasons.
Study Area	The portion of a river or stream that will be addressed in the study.
Study Site	A particular area within a Reach where transects are grouped.
VAF	Velocity Adjustment Factors (VAF) are a measure of how well the model simulates velocities using a three velocity set regression data set. A VAF between 0.90 and 1.10 is considered good. A VAF between 0.85 and 0.90 or between 1.10 and 1.15 is considered to be fair. A VAF between .80 and .85 or 1.15 and 1.20 is marginal, while a VAF below 0.80 or above 1.20 is considered poor.
WDFW	Washington Department of Fish and Wildlife
Ecology	Washington Department of Ecology
WSE	Water surface elevation
WUA	Habitat quantification is expressed as an index called Weighted Useable Area (WUA), and is given in habitat per 1,000 linear ft of stream. WUA is the habitat rating (0.00-1.00) of the velocity multiplied by the habitat rating of the depth multiplied by the habitat rating of the substrate multiplied by the area of the cell, summed for all cells in the reach.

1.0 INTRODUCTION

1.1 Authority

EES Consulting, Inc. (EESC) conducted this study under contract to Spokane County and Tetra Tech, for the WRIA 54 and WRIA 55/57 Planning Units. This study was undertaken as part of the WRIA 54 & 55/57 Watershed planning processes administered by the Washington Department of Ecology (RCW 90.82).

This report is organized into five main sections; 1.0 Introduction, 2.0 Methodology and Approach, 3.0 Results, 4.0 Hydrology and 5.0 References. The methodology, results and hydrology are contained in the main body of the text and supporting technical data are located in the appendices.

1.2 Background

Two previous instream flow studies, focusing on different study areas and fish life stages, have been completed within the Spokane River watershed. One of these, "Instream Flow and Fish Habitat Assessment (Northwest Hydraulic Consultants and Hardin-Davis, Inc, 2004) overlaps slightly with the current study by employing a PHABSIM modeling approach to assess the relationship between streamflow and habitat potential on the mainstem Spokane River from the Post Falls Dam in Idaho, downstream to the confluence with Latah Creek. For most of the study area, spawning and rearing life stages were evaluated, however only spawning was assessed in the one-mile reach of WRIA 57 below the Monroe Street Bridge in Spokane.

A second study, conducted by Golder Associates (2003) utilized a wetted perimeter approach to evaluate the adequacy of established minimum instream flows in the Little Spokane River. Additional IFIM studies conducted in the basin include the Blue Creek IFIM and IFIM studies for fish and benthic invertebrates on Chamokane Creek.

This study focuses on the free-flowing portion of the Spokane River above Nine Mile Reservoir and below the Monroe Street Bridge in Spokane, spanning lower WRIA 57 and upper WRIA 54. The intent of doing additional work in WRIA 57 was to assess rainbow trout rearing habitat flow requirements (spawning needs were assessed in the aforementioned study). A PHABSIM modeling approach was employed to develop this assessment.

Additionally, photographs of several riffles in WRIA 57 and 54 were taken at different flows. The purpose of this photo documentation was to show the effect of different flow levels on the inundation of the riffle habitat. Sites included upstream and downstream of the Centennial Trail (Sandifur) bridge, upstream of the TJ Meenach Bridge, and downstream of the Gun Club. Selected photo documentation of the riffle habitat is presented in Appendix D.

An instream flow analysis was also conducted on four WRIA 54 tributary streams: Coulee, Deep, Little Chamokane, and Spring creeks. Toe-width methodology was used to develop estimates for preferred flows for rainbow trout rearing and spawning (Spring Creek only).

1.3 Study Objectives

Study objectives for the Spokane Instream Flow Studies were:

- Quantify the relationship between stream flow and available aquatic habitat for appropriate salmonid species and life stages for the free-flowing reach of the Spokane River above Nine Mile Reservoir.

- Quantify the preferred stream flow for trout rearing and spawning habitat, as appropriate, for Spring, Little Chamokane, Coulee and Deep creeks.

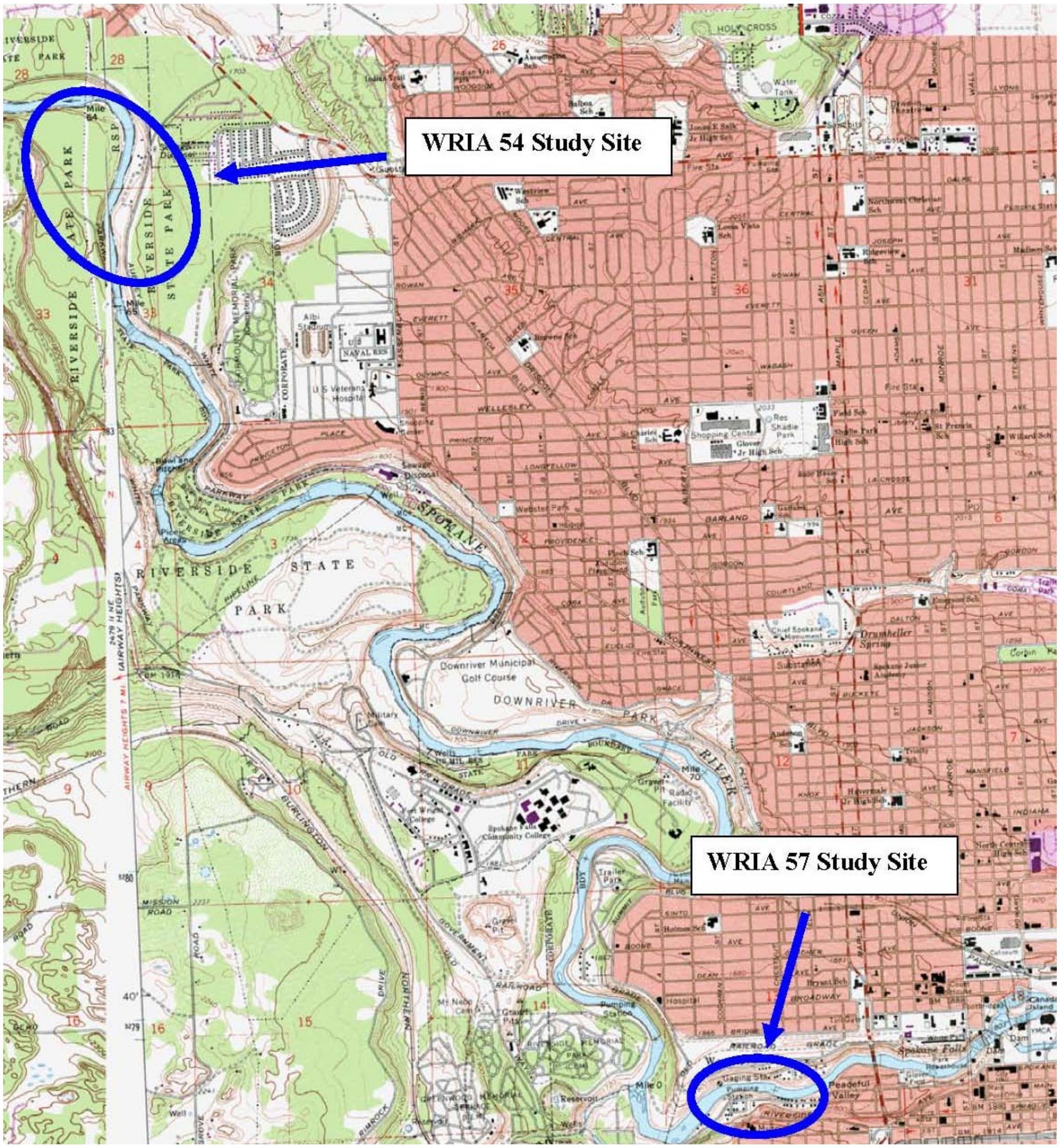
- Provide a well-documented, scientific basis to serve as a decision making tool for considering instream flow recommendations. Specifically, the areas of interest are the mainstem Spokane River from the backwater of Nine Mile Reservoir (RM 63.8), upstream to the Monroe Street Bridge at RM 73.8 and the four tributaries (Figure 1.3-1).

1.4 Spokane River Watershed

Originating as rainfall and snowmelt on the western flank of the Rocky Mountains, the headwaters of the Spokane River flow into Lake Coeur d'Alene in Idaho. The outlet to Lake Coeur d'Alene is partially controlled by a dam operated by Avista Utilities and water is stored in the lake on a seasonal basis. The drainage area of the Spokane River is approximately 4,290 square miles at the Spokane USGS gage site. Latah Creek, which enters the river approximately ½ mile downstream of the Spokane gage, provides a mean annual flow of 200 cfs from an additional 704 square mile watershed. The Spokane River Basin study area extends from RM 73.8, in Spokane (the Monroe Street bridge), downstream to the backwater of Nine Mile Reservoir. The gradient of the Spokane River within the study area is generally low and averages about 0.27% from Monroe Street downstream to Nine Mile Reservoir. Several higher gradient rapids can be found within this river segment.

The topography, hydrology and land use in the Spokane watershed are diverse. In the mountainous headwaters, much of the area is managed forest land with snow fields on the higher peaks and dense coniferous forests covering the mid-elevation slopes. The headwater streams are generally steep, while the upper and mid river segments generally wind along wider valley floors. The study area of this instream flow study is in a constricted valley with a mixed land use that is predominantly recreational park land along its banks. The banks of the river are mainly covered with boulders and cobble with some bedrock and minor areas of rip rap.

1.3-1 Spokane River IFIM Reach Map



2.0 METHODOLOGY AND APPROACH

The instream flow studies described in this report employed the following methodologies:

- PHABSIM – mainstem Spokane River study areas
- Photo documentation of various flow over riffles (see section 1.2)
- Toe-Width – WRIA 54 tributaries: Deep, Coulee, Little Chamokane, and Spring Creeks

The toe width portion of the study is described in Appendix C. The photo documentation of riffle habitat is presented in Appendix D. The remainder of this report focuses on the PHABSIM portion of the instream flow study.

2.1 Overview of PHABSIM Methodology

Unless otherwise noted, PHABSIM study procedures follow the WDFW/Ecology Instream Flow Guidelines (April, 2004). The PHABSIM methodology is based on the premise that stream-dwelling fish are more often found in a certain range of depths, velocities, substrates, and cover types, depending upon the species and life stage, and that the availability of these preferred habitat conditions varies with stream flow. PHABSIM is designed to quantify potential physical habitat available for each life stage of interest, for a target fish species, at various levels of stream discharge, using a series of modeling programs initially developed by the US Fish and Wildlife Service. Major components of the methodology include:

- Study site and transect selection
- Transect weighting
- Field collection of hydraulic data
- Hydraulic simulation to determine the spatial distribution of combinations of depths and velocities with respect to substrate and cover under a variety of discharges
- Habitat simulation, using habitat suitability criteria, to generate an index of change in habitat relative to change in discharge

The product of the habitat simulation is expressed as Weighted Usable Area (WUA) for a range of stream discharges. It is important to recognize that the product of a PHABSIM analysis is not a set value but a range of values to be used as a tool for discussing and determining a range of stream flows that will meet the needs of all affected resources.

2.2 Stream Description

The Spokane River Study Area extends from the upper end of the Nine Mile Reservoir (RM 63.8), upstream to the Monroe Street Bridge (RM 73.8). Rainbow trout and mountain whitefish utilize this area as a corridor for upstream and downstream movement, spawning and for both juvenile and adult rearing.

Within the mainstem Spokane River Study Area, the river is primarily contained in a single, confined channel. For short distances, the channel may split around islands or gravel bars and form distinct geomorphic features that exhibit habitat variations dissimilar from the main channel.

Differences in morphology and hydrology in the Spokane River were addressed by segmenting the river into two distinct reaches. Study reaches within the ten mile study area of the Spokane River were differentiated by changes in hydrology, slope and habitat type.

2.3 Stream Reach Description

WRIA 54 Reach (RM 63.8-72.3): The majority of the WRIA 54 Reach is characterized by moderate-gradient, long, wide glides with short sections of riffles, rapids and pools. Side and split channel areas comprise less than 8 % of the river length. The upper end of this reach, just downstream of Latah Creek and again near the T.J. Meenach Bridge, is less confined, with a few mid-channel bars and islands. Near the lower end of this reach, large bedrock features create several rapids that are interspersed with long glides.

WRIA 57 Reach (RM 72.3-73.8): The WRIA 57 Reach is low gradient, with well-defined banks. Long glides are the dominant habitat feature, with pools and wide riffles interspersed throughout the reach. Latah Creek marks the lower boundary of the WRIA 57 reach.

2.4 Physical Habitat Surveys

Physical habitat surveys were conducted with low elevation, high resolution aerial photographs and an on site field survey of the Spokane River from Nine Mile reservoir to the Monroe Street Bridge. The purpose of the survey was to obtain an overview of the river and determine the frequency of various types of fisheries habitat found within the study area.

The aerial photos, supplied by Avista Utilities, were used to characterize the habitat types throughout the Spokane River. Areas with a variety of habitat types located in a relatively short distance were noted as possible locations for transect placement. With the initial habitat characterization complete, the entire length of the Spokane River from Nine Mile reservoir to the Monroe Street Bridge was surveyed on foot in order to ground truth the initial habitat typing from the aerial photos. When necessary, habitat types were changed to match what was observed on the ground. A frequency distribution of habitat types formed the basis for transect weighting. Details of the habitat frequency analysis are described in Section 2.6.

2.5 Transect Selection

Study sites and transects were selected to represent the variety of habitat types within the Spokane River (Table 2.6-2). EESC selected 7 transects within the 2 study reaches between the Monroe Street Bridge and Nine Mile Reservoir. The study sites and transects were approved by representatives of the Department of Ecology and WDFW during a site visit on March 29, 2006. Figures 2.5-1 and 2.5-2 show locations of study sites and transect locations throughout the Spokane River Study Area.

During the site visit, WDFW representatives requested photo documentation of riffle habitat at several locations in the study area. The reason for the photographs was to visually compare the effect of streamflow on the riffle habitat. Photo sites were selected at 3 different locations:

- Upstream and downstream of the Centennial Foot Bridge
- Up stream of the T.J. Meenach Bridge
- Downstream of the Gun Club

Staff from the Spokane County Public Works Department took photographs at various river flows. See section 1.2 for additional details and Appendix D for presentation of the photographs.

2.6 Transect Weighting

Habitat mapping transects were drawn on aerial photographs (1:1,200), every 300 feet. All mapped transects were viewed in the field at a flow of 2,500 – 3,000 cfs. Each transect was compared to the PHABSIM modeling transects and was tallied under the PHABSIM transect that was most similar. Criteria used for discriminating between transects were width, depth, velocity, slope and substrate. The number of transects tallied under each PHABSIM transect was divided by the total number of mapping transects for each WRIA. WRIA 57 and WRIA 54 transect weighting was done separately and based on the total number of mapping transects in each WRIA. In WRIA 54, a few mapping transects that occurred in white water habitat near the Bowl and Pitcher and the Devils Toenail were not tallied since no PHABSIM transects had conditions that were similar.

Thirty three mapping transects were located in WRIA 57 (Monroe Street Bridge to Latah Creek). Forty one percent of the transects were similar to Transect 1 and 59% were comparable to Transect 2.

One hundred and thirty six (136) habitat mapping transects were located on aerial photographs, viewed and categorized on the Spokane River in WRIA 54 (Latah Creek to Nine mile reservoir backwater, located just downstream of the Gun Club). The transect weighting was based on the proportion of mapping transects similar to each of the calibration transects.

Figure 2.5-1 WRIA 54 IFIM Transects

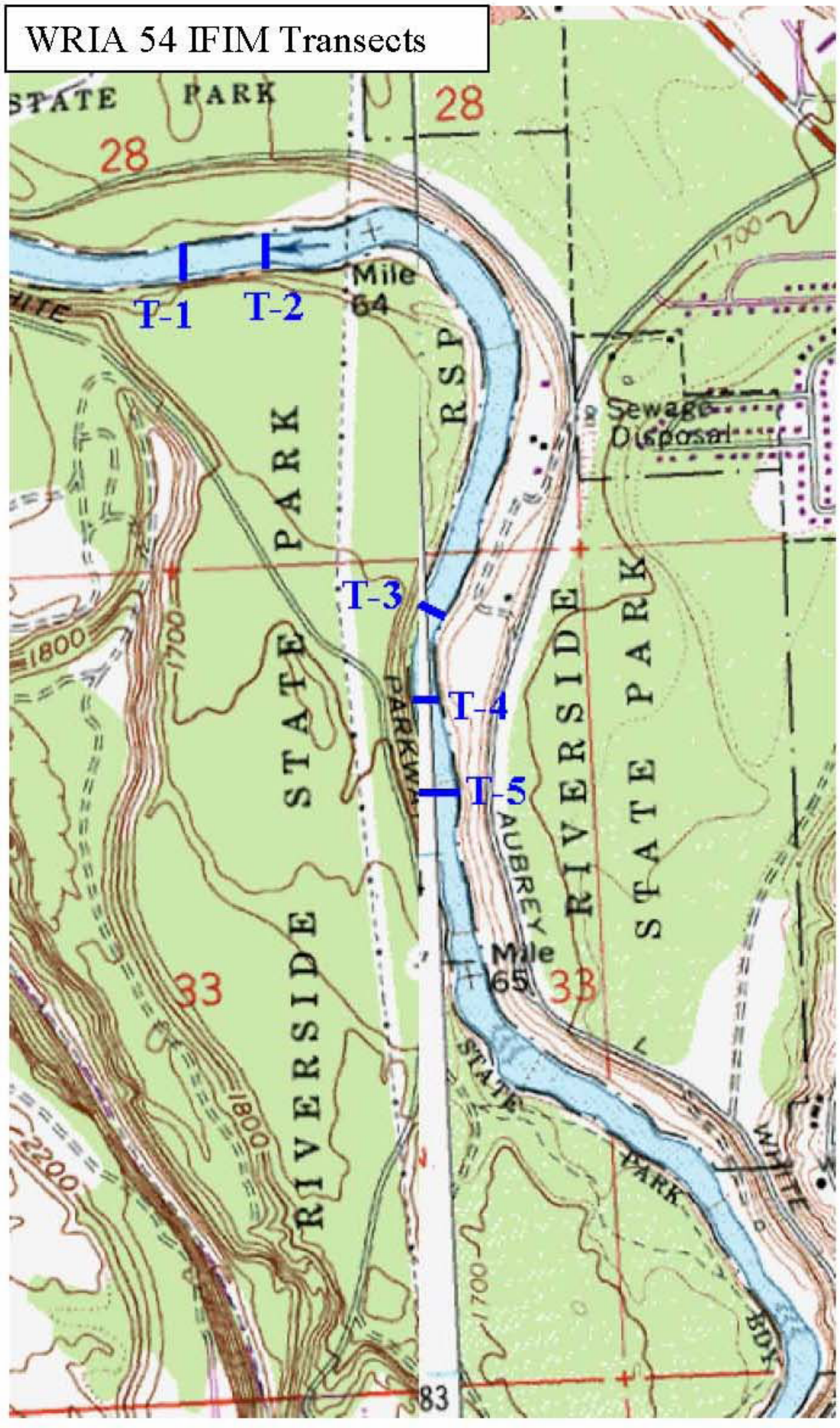


Figure 2.5-2 WRIA 57 IFIM Transects

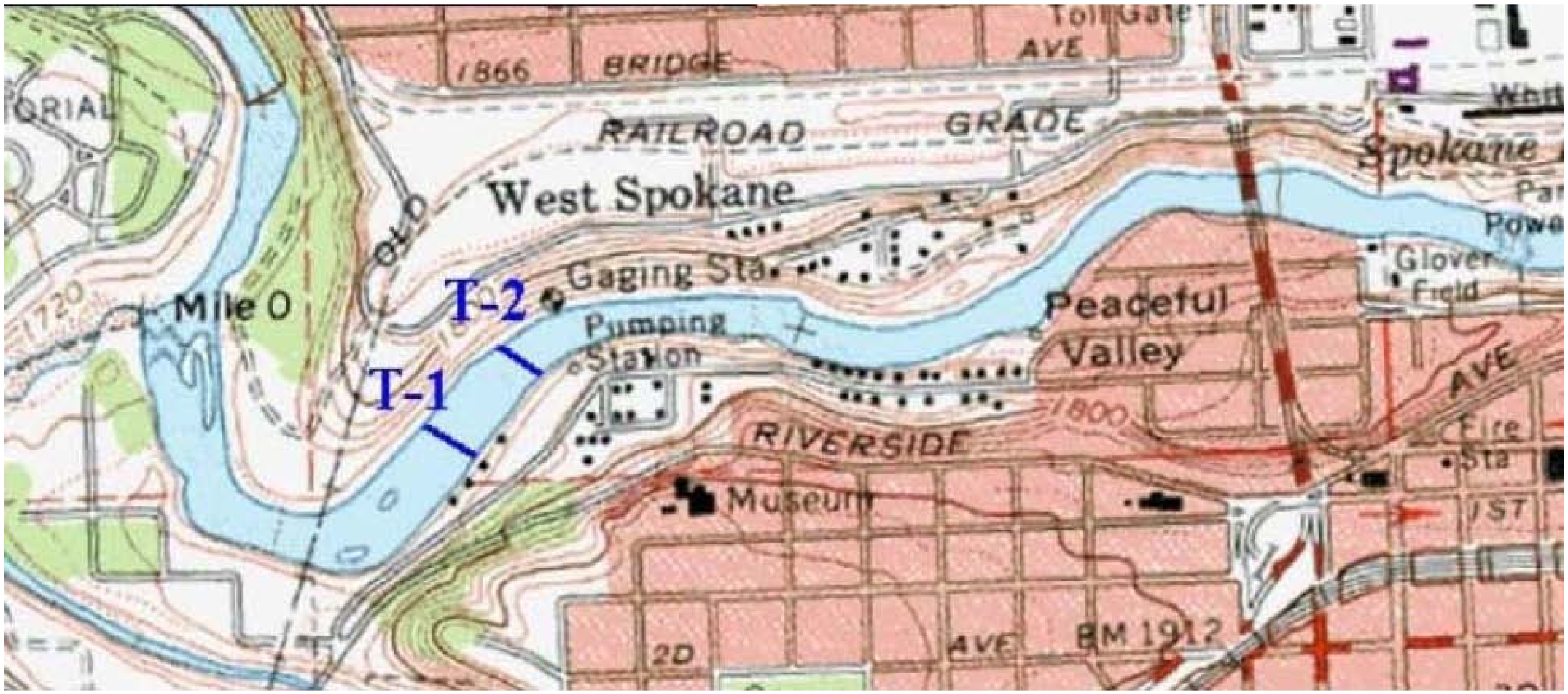


Table 2.6-1 Macrohabitat Type and Descriptions	
Habitat Name	**Habitat Description**
Backwater/Eddy Pool	Upstream of flow obstruction or on channel margins where flow decelerates. Slower velocity and deeper, non-turbulent flow with a strong hydraulic control. Often fine particles due to reduced shear stress. Water surface slope <1%.
Lateral pool	Pool formed on the margin of the stream as a result of a structural element, substrate composition, or thalweg location. (Generally at least ½ of the pool perimeter interfaces with adjacent habitat units.)
Glide	Smooth generally unbroken surface, generally laminar flow, moderate to shallow depth, often smaller substrates. Often doubles as a pool tailout.
Run	Deeper with fast to moderate velocities (more than a glide), lateral bottom profile normally uneven, surface is broken and often turbulent. Poorly sorted substrate upstream of obstructions.
Riffle	Topographic crossover between pool and bar in pool-riffle morphology; spans the channel; particles are usually fairly well-sorted; water surface slope 1-4%
Side channel	Small channel relative to main channel; may or may not have flow at time of survey; includes remnant flood terrace side channels that can often be vegetated.
	Note: Habitat types may change as flow changes and comparisons for transect weighting were all made at nearly the same flow of 2,500 – 3,000 cfs.

Table 2.6-2 Spokane River Transect Weighting		
Transect No.	**Transect Description**	**Transect Weight**
Reach 57		
1	Run, shallower, wider and faster than Transect 2.	41%
2	Smooth glide, laminar flow. Higher velocities on right bank	59%
Reach 54		
1	Mid Width Glide. Downstream of Rifle Club	29.4%
2	Pool/Glide Complex. Downstream of Rifle Club	27.2%
3	Med Fast Run, faster water all across transect	16.2%
4	Medium Run. Slightly faster on left bank	11.8%
5	Glide/ Run transition. 50/50 each habitat type	15.4%

2.7 Field Methods

Mainstem Spokane River

The field methods and hydraulic analysis for the mainstem Spokane River followed the 1-velocity method as described in Payne (2003). This method uses one set of velocity measurements and a water surface elevation (WSE), usually at the high flow, and two additional stage discharge points (WSE) as input to the PHABSIM model to generate hydraulic simulations for the desired range of flows at each transect. The EESC field team obtained a high flow set of hydraulic calibration measurements at each transect. Measurements included depths and velocities at close intervals across the transect and water surface elevations at each transect at each of the three flows. See section 2.11 for additional details of the PHABSIM modeling.

Mid-channel depth and velocity distributions at the calibration flow were measured using an acoustic doppler current profiler (ADCP) mounted on a small trimaran boat and side-tied to a jet boat. The ADCP records real time water temperature and uses temperature calibrated acoustic pulses to measure water velocities and depths across the channel. According to an extensive evaluation conducted by the U.S. Geological Survey (USGS), "ADCP's can be used successfully for data collection under a variety of field conditions" (USGS 1996). ADCP hydraulic measurements are made from a boat by moving the ADCP across the channel while it collects vertical-velocity profile and channel-depth data. The ADCP tracks the distance traveled from the point of origin so each depth and velocity measurement is coordinated with a horizontal distance on the transect. Measurements are taken at close intervals across the transect and at multiple levels in the water column. The ADCP is connected by cable to a power source and a radio modem that is linked to a laptop computer on shore. The computer is used to program the instrument, monitor its operation, and collect and store the data.

Because the ADCP will not measure in depths less than approximately 1.5 feet, shallow depth measurements near shore and other locations were taken manually using a Swoffer brand, propeller-type velocity meter mounted on a standard top-set USGS wading rod. Manually measured velocities were taken at sixth tenths of the depth when depths were less than 2.5 feet and at two tenths and eight tenths of the depth when depths equaled or exceeded 2.5 feet or when the expected velocity profile was altered by an obstruction immediately upstream.

An auto level was used to measure headpin elevations (the end point of each transect), water surface elevations (WSE), hydraulic controls and above water bed elevations along each transect. All measurements were referenced relative to a temporary benchmark. Bed elevations below the water surface were obtained by subtracting measured depths taken during velocity calibration from the water surface elevations for that particular transect. Except when surveying the bed profile, the surveyor attempted to measure elevations to the nearest .01 feet.

Substrate and cover were measured visually during a low flow period in September. In the deeper portions of pool transects substrate was measured with the aid of a mask and snorkel. Substrate was classified using a three-digit code representing the most abundant particle size, the second-most abundant particle size, and the percentage of the most abundant particle size. For example, a code of 73.7 would mean that the most abundant substrate was large cobble (6 to 12-inch diameter), that small gravel (0.5 to 1.5-inch diameter) was the second-most abundant substrate, and that large cobble represented 70 percent of the cell area. Cover and substrate codes are shown in Appendix A and are referenced from the revised Washington State Resource Agency Instream Flow Guidelines (WDFW/Ecology, 2004).

Spokane River Tributaries

Upon agreement with the Spokane River Instream Flow Technical Team (IFTT), instream flow assessments on four Spokane river tributaries were conducted using the Toe-Width method

(Swift 1976). The four streams selected for assessment were Coulee, Deep, Spring, and Little Chamokane creeks. The Spokane Tributaries Toe-Width assessment is presented in Appendix C of this report.

2.8 Affected Species and Life Stages

Fisheries resources of primary concern in the Spokane River are rainbow trout and mountain whitefish. These species were identified as the principal species of concern for WRIA 54 and 57 by WDFW and this decision was supported by the IFTT and the Planning Unit. Both species utilize the study area during a significant portion of their life cycle. In a letter dated February 8, 2007 WDFW recommended that rainbow trout and mountain whitefish receive equal weighting when considering Spokane River instream flow needs. Figure 2.8-1 presents the life stage timing of target species in the Spokane River.

2.9 Habitat Suitability Criteria

Fish are not found randomly in streams and rivers, but rather have preferences for particular ranges of depth, velocity, cover and substrate. These preferences vary depending on species and life stage. In PHABSIM studies, the ranges of each of these parameters are commonly referred to as fish preference criteria or a Habitat Suitability Criteria (HSC).

Habitat Suitability Criteria for the Spokane River PHABSIM study for rainbow trout were recommended by the Washington Department of Ecology and Washington Department of Fish and Wildlife (WDFW/Ecology, 2004). Washington State data from many studies, over several years have been combined to form a comprehensive data set. In the absence of site specific data for each PHABSIM study, this Washington "standard" HSC is used. The HSC tables used for the Spokane PHABSIM study are contained in Appendix A to this report. Rainbow Trout life stages to be modeled are;

- Spawning
- Juvenile/Adult Rearing
- Winter Rearing

No HSC data for Mountain Whitefish are published in the Washington State Instream Flow Guidelines. After consultation with Hal Beecher, WDFW Instream Flow Biologist, habitat suitability criteria for Mountain Whitefish will be the same as used for the Little Spokane River Instream Flow Study for WRIA 55. Mountain Whitefish life stages to be modeled are;

- Spawning
- Fry
- Juvenile Rearing
- Adult Rearing

Figure 2.8-1
Spokane River Fish Periodicity

Species	Lifestage	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
Mountain Whitefish	Spawning		■	■									
	Incubation		■	■	■	■	■	■					
	Adult Rearing	■	■	■	■	■	■	■	■	■	■	■	■
	Juvenile Rearing	■	■	■	■	■	■	■	■	■	■	■	■
Rainbow Trout	Spawning						■	■					
	Incubation						■	■	■	■			
	Adult Rearing	■	■	■	■	■	■	■	■	■	■	■	■
	Juvenile Rearing	■	■	■	■	■	■	■	■	■	■	■	■

Based on: WDFW IFTT Recomendations 3/30/2006

Key:

Grey indicates periods of use ■

Blank areas indicate periods of little or no use

2.10 Data Compilation Methods

The ADCP interfaces directly with a laptop computer when collecting data. Software provided by RD Instruments, manufacturer of the ADCP, is used to record and display the data in real time as it is collected. This output of this program is a text file which contains transect details, including depth (ft), velocity (ft/sec), distance (ft), and error checking values for each vertical and bin along the transect. Verticals are columns looking straight down from the water surface to the river bottom at measured distances from the starting point. Velocity data taken at incremental depths at each vertical are called bins.

EESC used Riverine Habitat Simulation (RHABSIM) by Thomas R. Payne and Associates, Arcata, CA to model the Spokane River flows. RHABSIM is a PC conversion and enhancement of the original PHABSIM suite of hydraulic and habitat modeling software developed by the U.S. Fish and Wildlife Service. A conversion utility from RHABSIM allows the ADCP data to be imported into a spreadsheet. This utility screens out errors and converts bins of velocities into mean column velocities (average velocity in ft/sec for each vertical). Three summary columns are created:

- Distance from the beginning of the transect
- Depth
- Mean column velocity of each vertical

The ADCP cannot take measurements in shallow water (under 1.5 feet). As a result, field staff from EESC took manual depth and velocity measurements along each bank where the depths were too shallow. The manual measurements taken along each river bank, the ADCP data, and substrate and cover values were entered into a spreadsheet. Depths were converted into elevations (ft) by subtracting the measured depth from a surveyed water surface elevation. A total discharge for each transect was then calculated. At this point the data for each transect was subjected to a final check for errors and corrected. The corrected data files were then converted into a format readable by RHABSIM. RHABSIM read the file, and the completed data deck was ready for model calibration.

2.11 Data Analysis

2.11.1 Hydraulic Modeling

Analysis and integration of physical stream measurements and habitat preference criteria require the use of a group of the RHABSIM computer programs. There are two main programs in the RHABSIM library: the hydraulic model (called HYDSIM) and the habitat model (called HABSIM).

Hydraulic modeling involves two sequential steps. The first step, a short version of what the USGS does to rate a stream gauge, is to develop a stage-discharge relationship, and the second stage is velocity calibration. The stage is the height of the water surface at a location (in this case at each transect). At several (at least 3) widely separated (lowest flow should be half or less of the next highest flow) calibration flows, stages and flows should be measured and recorded.

These can be graphed on logarithmic scale and will yield a (relatively) straight line and a regression equation can be fit to the line. The regression equation then predicts the water surface height (and, by subtraction, the depth, when bed elevation at different locations are known) at different flows from what were measured at the calibration flows. At each point along a transect, velocity calibration is needed to estimate velocity. An average velocity for the river can be calculated at a transect if flow and the cross-sectional area of the river is known at the transect.

Flow (Q, in cubic feet per second) = cross-sectional area (A) x average velocity (V), and A=depth x width; thus V = Q/A.

Velocity calibration allows fine-tuning of velocity distribution across a transect; it is not uniform, but faster in some places and slower in others. Over a range of flows it is possible to modify (either increase or decrease) the "cell" velocity relative to the average velocity by using measured velocity to indicate relative resistance to flow or roughness. Successful velocity calibration generates reasonable approximations of the local velocities. Other velocity calibration methods are also available. Overall, the Washington Department of Fish and Wildlife approves the calibration approach used in this technical report.

The HABTAT program integrates the simulated hydraulic information from HYDSIM with habitat suitability criteria (i.e., preference or HSI curves) and quantifies habitat availability over a range of flows for the specified target species and life stages. Habitat quantification is expressed as an index called Weighted Useable Area (WUA), and is given in units of habitat per 1,000 linear ft of stream.

2.11.2 Hydraulic Modeling Procedures

EESC calibrated the Spokane River hydraulic model using methods described in Payne (2003). All of the input decks were initially processed using the Problem Report subroutine of the Field Data Entry Module of RHABSIM. This program looks for errors in data placement and produces a hard copy of the pertinent information needed to run the model, including transect weighting factors, slopes, stage of zero flow and WSE. EESC collected one set of velocity calibration measurements at each transect at the high calibration flow. In addition to the high flow calibration flow, a WSE at each transect and a discharge measurement at each study site at the two lower flows were used to generate the stage-discharge relationship.

In Washington State, a standard "three velocity set" regression model is often used on all transects. The three-velocity set models require that verticals be placed in exactly the same locations along the stream bed and that <u>velocity measurements be taken at these verticals at all three calibration flows</u>. The data collection for a three velocity set model is time consuming and very expensive in any stream or river that is not wadeable at all calibration flows.

A less expensive, yet good approach is the use of a "one velocity set" model. "One velocity set" models use the velocities from one of the calibration flow measurements for velocity modeling and employ the WSE's from the other calibration flows to develop the stage/discharge relationship. After discussions on PHABSIM analysis with representatives from WDFW and

Ecology, all parties agreed that a "one velocity set" modeling approach would be appropriate for use at the Spokane River transects.

One of the goals of the hydraulic simulation is to have the model accurately reflect measured velocities and depths at calibration flows, while minimizing changes to the data. In this regard, only minor changes were made to the IFIM decks in order for the model to more accurately predict cell velocities at the simulated flow. When calibrating one velocity set data decks, normally, two types of corrections can be made directly or indirectly to velocity data: 1) changes in the measured velocity; and, 2) changes in the Manning's N (roughness coefficient) for given cells. Changes were kept to a minimum and the decks were revised only when specific changes improved model performance.

One type of data change was a minor velocity adjustment (0.01 - 0.10 ft/sec) in some cells where there was a measured depth but no measured velocity. The model interprets a measured zero velocity as a blank and will attempt to fill that cell with a velocity based on a mass balance equation for the transect, taking into consideration slope, adjacent velocities, and calculated Manning's N values. Replacing a measured 0.00 with a velocity of 0.01 or 0.1 often corrects this problem. In addition, edge cells are often assigned high Manning's N values (i.e., the roughness coefficient) by the model. The high N values slow the velocity through these cells, giving an unrealistic simulation of velocities. In these instances the N values were manually reduced.

The range of extrapolation for simulated depths and velocities depends on the hydraulics of the channel and the spread between calibration flows. When using one velocity set models, the accuracy of the velocity simulation, slope and Manning's N values are considered. In the case of one velocity set models, the Velocity Adjustment Factors (VAFs) are adjustment factors of discharge, not velocities, and a wider range of values (between 0.10 and 10.0) is acceptable. A summary of VAFs and calibration details are presented in Tables 2 and 4 of Appendix B. Flows of interest were within the limits of acceptable extrapolation.

2.11.3 Measured Flows for the Spokane River

A single set of calibration flow data was developed from the field measurements. Actual measured flows for the Spokane River are shown in Table 2.11-1.

Table 2.11-1
Calibration Flows (cfs), Spokane River, WRIA 57 & 54

	Low Flow 8/14&15/2006	**Medium Flow 7/5&6/2006**	**High Flow And Velocity Calibration 6/23/2006**
WRIA 57 Discharge (cfs)	867	2,681	6,225
WRIA 57 Water Temp (degrees F)	62	69	62-63
WRIA 54 Discharge (cfs) T1 & T2 870 cfs on 9/12/06	1,069	3,157	6,328-6,970
WRIA 54 Water Temp (degrees F)	59-60	65	62

2.11.4 Model Performance

Only minor changes were made to the original input decks. Most revisions fell into three categories:

- Replacing a measured velocity of 0.0 ft/second with a velocity of 0.1 ft/second
- Changing the Manning's N value to either reduce or increase the velocities in the given cell
- Adjusting the bed elevations at the stream margin cells slightly

Appendix B summarizes calibration details for each transect. Mean error of the stage/discharge relationship, ratio of measured vs. predicted discharges, and *B* coefficients were all within the acceptable limits for PHABSIM calibration.

Output from the calibrated hydraulic models was then used to simulate water depths and velocities in the Spokane River throughout a range of flows from 350 cfs to 16,000 cfs.

After the hydraulic models were calibrated, transect weighting and lengths to simulate a 1,000 foot reach were added as shown in Table 2.6-1 and 2.6-2. Final hydraulic model runs were made to produce input for the HABTAT habitat model. These hydraulic runs were then combined with habitat suitability criteria for both spawning and rearing life stages of the target species to calculate WUA.

3.0 RESULTS

Within the HABTAT program, output from the hydraulic modeling is combined with habitat suitability criteria (HSC) for depth, velocity, and substrate/cover for the target species life stages. The output from this model is expressed as Flow (Q) in cubic feet per second (cfs) vs. Weighted Usable Area (WUA), which is an index of available habitat per 1,000 lineal ft of stream, for each species and life stage of concern.

WUA incorporates the hydraulic variables of width, depth, velocity, slope, substrate and cover measured in the Spokane River with the habitat needs of each species and illustrates how the habitat for each species varies with changes in flow. The hydraulics are largely influenced by the shape of the river channel with narrower channels exhibiting increased velocity that may limit available habitat for the target fish species.

3.1 Weighted Usable Area Results

Figures 3.1-1 and 3.1-2 show Spokane River Flow vs. WUA graphs for WRIA 57 rainbow trout and mountain whitefish rearing and spawning life stages. Figures 3.1-3 and 3.1-4 show Spokane River Flow v WUA graphs for WRIA 54 rainbow trout and mountain whitefish rearing and spawning life stages. Tables 3.1-1 to 3.1-4 give tabular results of the Spokane River WUA data.

3.2 Measured Water Temperature

Water temperature was measured and recorded by the ADCP at each measured discharge at each Study Site. Table 2.11-1 shows water temperature measurements at each location.

Figure 3.1-1 WRIA 57 Reach Rainbow Trout WUA

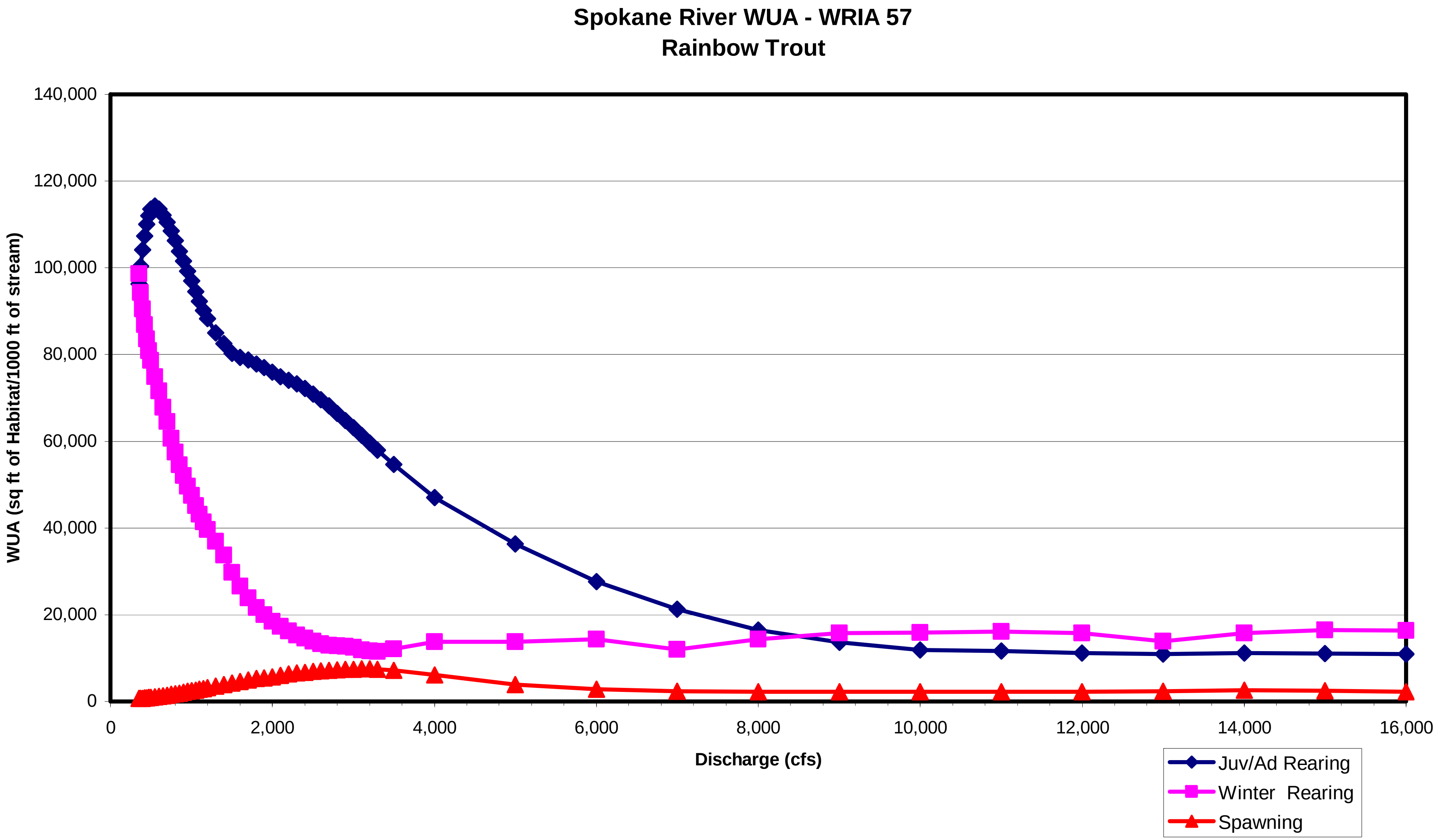


Figure 3.1-2 WRIA 57 Reach Mountain Whitefish WUA

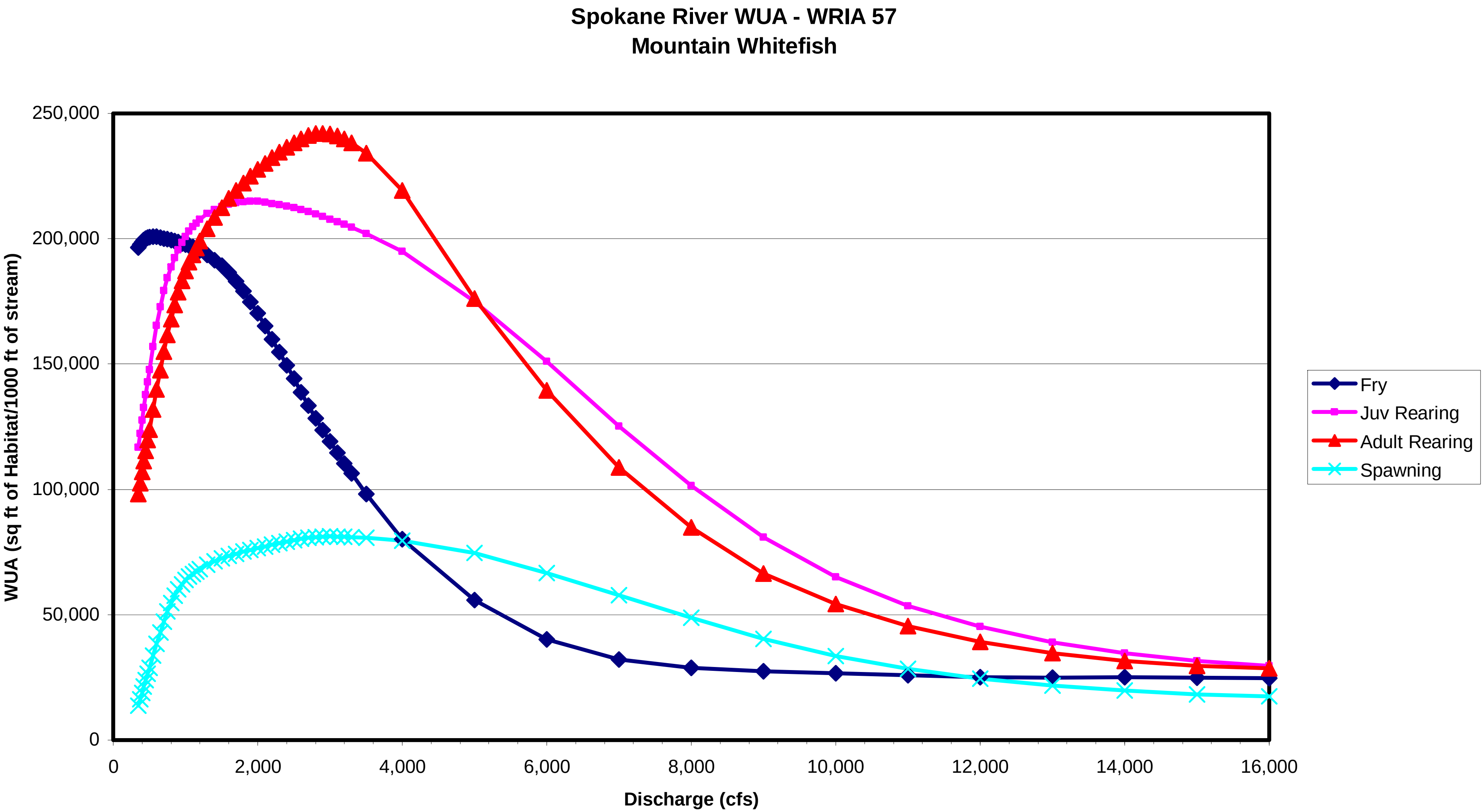


Figure 3.1-3 WRIA 54 Reach Rainbow Trout WUA

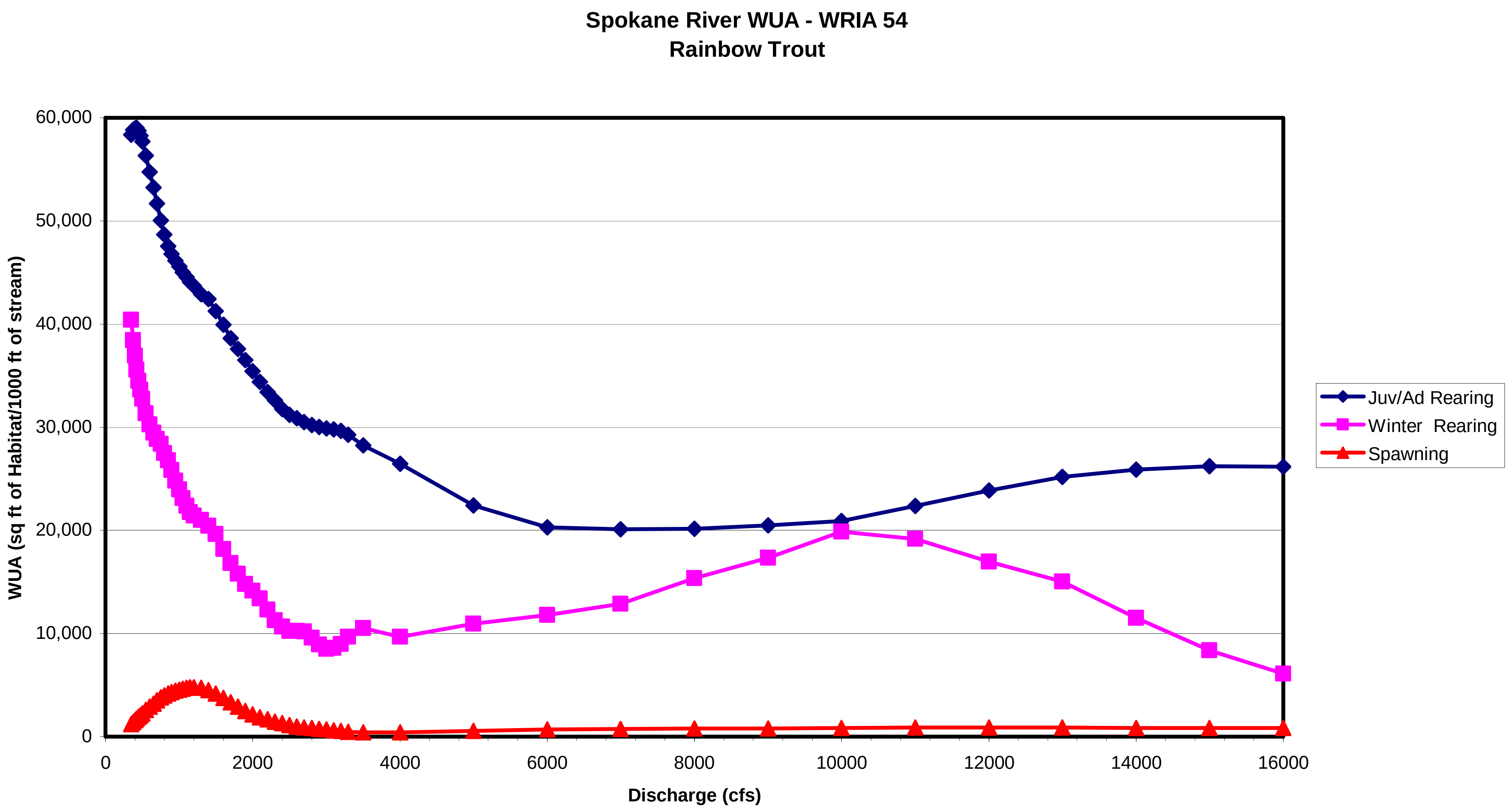


Figure 3.1-4 WRIA 54 Reach Mountain Whitefish WUA

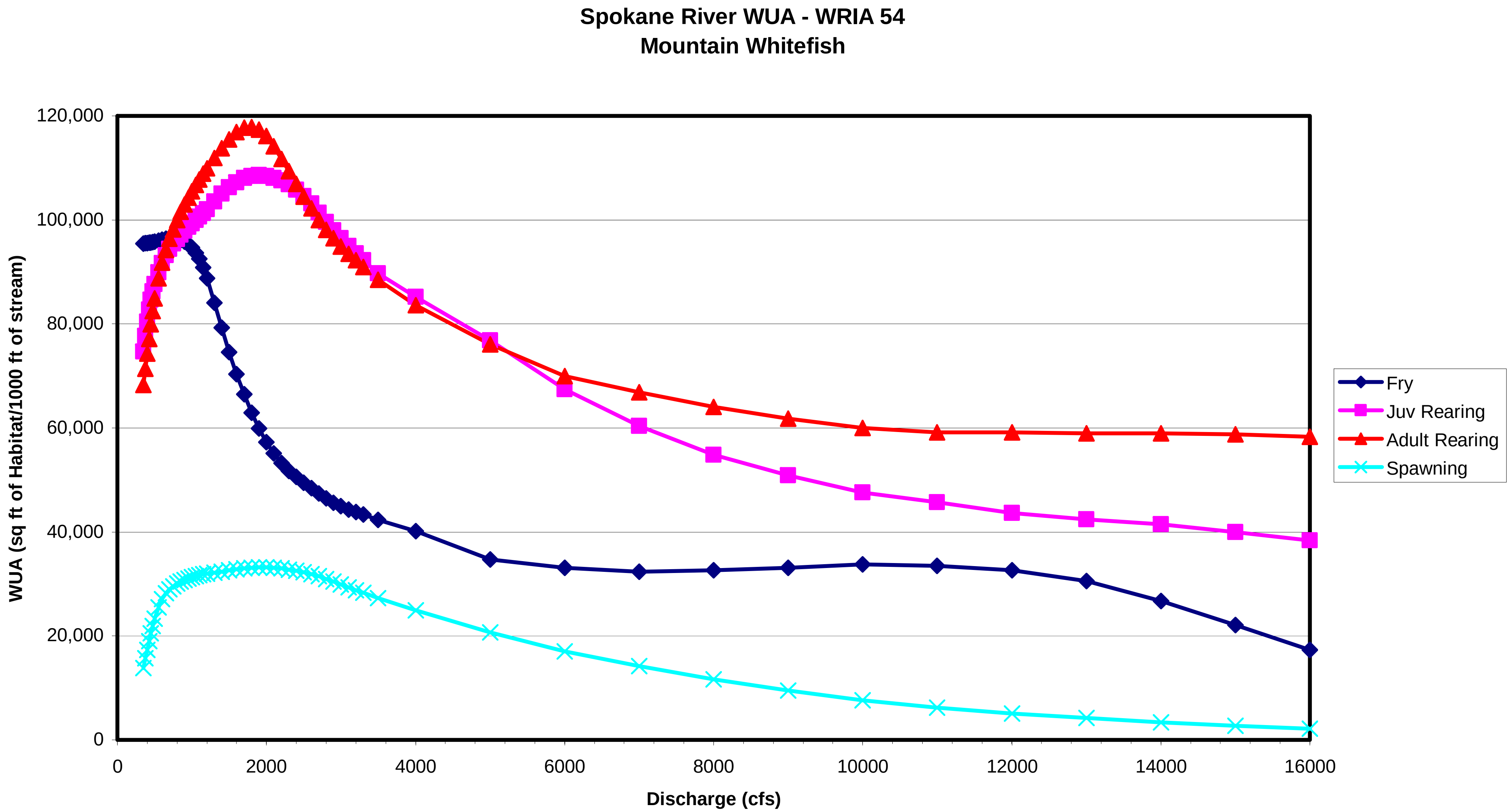


Table 3.1-1 Spokane River WRIA 57 Weighted Usable Area (WUA) Rainbow

Spokane River WUA, WRIA 57			Rainbow Trout			
Flow	Juv/Ad Rearing	% of Peak	Winter Rearing	% of Peak	Spawning	% of Peak
350	96,294	84.2%	98,642	100.0%	690	9.2%
375	100,367	87.8%	94,312	95.6%	714	9.5%
400	104,149	91.1%	90,541	91.8%	741	9.9%
425	107,353	93.9%	86,899	88.1%	785	10.4%
450	109,970	96.2%	83,604	84.8%	832	11.1%
475	112,063	98.0%	80,849	82.0%	885	11.8%
500	113,579	99.4%	78,675	79.8%	941	12.5%
550	114,307	100.0%	74,905	75.9%	1,057	14.1%
600	113,528	99.3%	71,596	72.6%	1,177	15.7%
650	112,118	98.1%	67,809	68.7%	1,305	17.4%
700	110,478	96.6%	64,491	65.4%	1,451	19.3%
750	108,525	94.9%	60,596	61.4%	1,600	21.3%
800	106,277	93.0%	57,447	58.2%	1,754	23.3%
850	103,846	90.8%	54,539	55.3%	1,936	25.7%
900	101,529	88.8%	52,030	52.7%	2,113	28.1%
950	99,207	86.8%	49,590	50.3%	2,292	30.5%
1,000	96,921	84.8%	47,432	48.1%	2,462	32.7%
1,050	94,473	82.6%	45,101	45.7%	2,628	35.0%
1,100	92,276	80.7%	43,100	43.7%	2,800	37.2%
1,150	90,210	78.9%	41,398	42.0%	2,979	39.6%
1,200	88,264	77.2%	39,667	40.2%	3,160	42.0%
1,300	85,045	74.4%	36,959	37.5%	3,530	47.0%
1,400	82,463	72.1%	33,700	34.2%	3,904	51.9%
1,500	80,327	70.3%	29,757	30.2%	4,254	56.6%
1,600	79,317	69.4%	26,520	26.9%	4,608	61.3%
1,700	78,749	68.9%	23,834	24.2%	4,956	65.9%
1,800	77,810	68.1%	21,685	22.0%	5,245	69.8%
1,900	77,051	67.4%	19,949	20.2%	5,444	72.4%
2,000	75,987	66.5%	18,490	18.7%	5,676	75.5%
2,100	74,905	65.5%	17,249	17.5%	5,995	79.7%
2,200	74,104	64.8%	16,229	16.5%	6,307	83.9%
2,300	73,288	64.1%	15,332	15.5%	6,559	87.2%
2,400	72,195	63.2%	14,617	14.8%	6,739	89.6%
2,500	70,927	62.0%	13,915	14.1%	6,900	91.8%
2,600	69,603	60.9%	13,308	13.5%	7,095	94.4%
2,700	68,152	59.6%	12,952	13.1%	7,206	95.8%
2,800	66,429	58.1%	12,785	13.0%	7,294	97.0%
2,900	64,782	56.7%	12,712	12.9%	7,370	98.0%
3,000	63,069	55.2%	12,445	12.6%	7,458	99.2%
3,100	61,377	53.7%	11,889	12.1%	7,518	100.0%
3,200	59,656	52.2%	11,628	11.8%	7,519	100.0%
3,300	58,005	50.7%	11,561	11.7%	7,414	98.6%
3,500	54,704	47.9%	12,103	12.3%	7,196	95.7%
4,000	46,971	41.1%	13,711	13.9%	6,055	80.5%
5,000	36,277	31.7%	13,707	13.9%	3,873	51.5%
6,000	27,634	24.2%	14,314	14.5%	2,861	38.0%
7,000	21,301	18.6%	12,048	12.2%	2,327	30.9%
8,000	16,406	14.4%	14,360	14.6%	2,239	29.8%
9,000	13,599	11.9%	15,779	16.0%	2,281	30.3%
10,000	11,889	10.4%	15,851	16.1%	2,183	29.0%
11,000	11,679	10.2%	16,093	16.3%	2,183	29.0%
12,000	11,175	9.8%	15,792	16.0%	2,222	29.6%
13,000	10,935	9.6%	13,828	14.0%	2,355	31.3%
14,000	11,137	9.7%	15,750	16.0%	2,540	33.8%
15,000	11,060	9.7%	16,438	16.7%	2,518	33.5%
16,000	10,884	9.5%	16,326	16.6%	2,184	29.0%

Table 3.1-2 Spokane River WRIA 57 Weighted Usable Area (WUA) Whitefish

Spokane River WUA, WRIA 57				Mountain Whitefish				
Flow	Fry	% of Peak	Juv Rearing	% of Peak	Adult Rearing	% of Peak	Spawning	% of Peak
350	196,547	97.9%	116,824	54.3%	98,074	40.5%	13,717	16.9%
375	197,768	98.5%	122,171	56.8%	102,515	42.4%	16,290	20.1%
400	198,693	98.9%	127,476	59.3%	106,896	44.2%	18,837	23.2%
425	199,475	99.3%	132,710	61.7%	111,207	45.9%	21,363	26.3%
450	200,063	99.6%	137,779	64.1%	115,437	47.7%	23,927	29.5%
475	200,403	99.8%	142,750	66.4%	119,624	49.4%	26,437	32.6%
500	200,559	99.9%	147,667	68.7%	123,775	51.1%	28,886	35.6%
550	200,801	100.0%	156,989	73.0%	131,949	54.5%	33,697	41.5%
600	200,824	100.0%	165,387	76.9%	139,816	57.8%	38,423	47.3%
650	200,476	99.8%	172,817	80.4%	147,593	61.0%	42,975	52.9%
700	200,026	99.6%	179,197	83.4%	155,021	64.0%	47,308	58.2%
750	199,836	99.5%	184,327	85.7%	161,703	66.8%	51,244	63.1%
800	199,537	99.4%	188,689	87.8%	167,867	69.4%	54,726	67.4%
850	199,119	99.2%	192,431	89.5%	173,639	71.7%	57,636	71.0%
900	198,609	98.9%	195,618	91.0%	178,780	73.9%	60,097	74.0%
950	198,120	98.7%	198,385	92.3%	183,203	75.7%	62,188	76.6%
1,000	197,704	98.4%	200,799	93.4%	187,099	77.3%	63,853	78.6%
1,050	197,205	98.2%	202,923	94.4%	190,550	78.7%	65,175	80.2%
1,100	196,787	98.0%	204,748	95.2%	193,574	80.0%	66,262	81.6%
1,150	196,131	97.7%	206,202	95.9%	196,375	81.1%	67,240	82.8%
1,200	195,363	97.3%	207,592	96.6%	199,054	82.2%	68,143	83.9%
1,300	193,604	96.4%	209,957	97.7%	203,998	84.3%	69,906	86.1%
1,400	191,469	95.3%	211,660	98.5%	208,400	86.1%	71,241	87.7%
1,500	189,319	94.3%	212,870	99.0%	212,440	87.8%	72,416	89.2%
1,600	186,516	92.9%	213,785	99.4%	216,110	89.3%	73,488	90.5%
1,700	182,921	91.1%	214,374	99.7%	219,162	90.5%	74,346	91.5%
1,800	179,033	89.1%	214,796	99.9%	222,145	91.8%	75,154	92.5%
1,900	174,820	87.1%	214,976	100.0%	224,939	92.9%	75,872	93.4%
2,000	170,179	84.7%	214,929	100.0%	227,590	94.0%	76,541	94.2%
2,100	165,085	82.2%	214,597	99.8%	230,061	95.0%	77,216	95.1%
2,200	159,890	79.6%	214,033	99.6%	232,402	96.0%	77,942	96.0%
2,300	154,793	77.1%	213,548	99.3%	234,598	96.9%	78,599	96.8%
2,400	149,497	74.4%	213,063	99.1%	236,552	97.7%	79,234	97.6%
2,500	144,161	71.8%	212,415	98.8%	238,317	98.5%	79,826	98.3%
2,600	138,778	69.1%	211,586	98.4%	239,876	99.1%	80,307	98.9%
2,700	133,388	66.4%	210,788	98.1%	241,164	99.6%	80,677	99.3%
2,800	128,333	63.9%	209,856	97.6%	241,975	100.0%	80,991	99.7%
2,900	123,679	61.6%	208,779	97.1%	242,046	100.0%	81,201	100.0%
3,000	119,063	59.3%	207,725	96.6%	241,732	99.9%	81,216	100.0%
3,100	114,569	57.0%	206,718	96.2%	240,975	99.6%	81,138	99.9%
3,200	110,372	55.0%	205,676	95.7%	239,812	99.1%	81,061	99.8%
3,300	106,295	52.9%	204,453	95.1%	238,292	98.4%	80,974	99.7%
3,500	98,092	48.8%	201,988	94.0%	234,217	96.8%	80,733	99.4%
4,000	80,223	39.9%	194,860	90.6%	219,148	90.5%	79,629	98.0%
5,000	55,765	27.8%	174,867	81.3%	176,156	72.8%	74,632	91.9%
6,000	40,210	20.0%	151,053	70.3%	139,561	57.7%	66,633	82.0%
7,000	32,217	16.0%	125,188	58.2%	108,720	44.9%	57,760	71.1%
8,000	28,830	14.4%	101,557	47.2%	84,879	35.1%	48,743	60.0%
9,000	27,333	13.6%	80,934	37.6%	66,410	27.4%	40,305	49.6%
10,000	26,549	13.2%	64,976	30.2%	54,301	22.4%	33,580	41.3%
11,000	25,939	12.9%	53,436	24.9%	45,529	18.8%	28,475	35.1%
12,000	24,986	12.4%	45,264	21.1%	39,243	16.2%	24,550	30.2%
13,000	24,850	12.4%	38,950	18.1%	34,706	14.3%	21,796	26.8%
14,000	24,985	12.4%	34,588	16.1%	31,590	13.1%	19,766	24.3%
15,000	24,861	12.4%	31,447	14.6%	29,673	12.3%	18,284	22.5%
16,000	24,677	12.3%	29,637	13.8%	28,612	11.8%	17,450	21.5%

Table 3.1-3 Spokane River WRIA 54 Weighted Usable Area (WUA) Rainbow

Spokane River WUA, WRIA 54			Rainbow Trout			
Flow	Juv/Ad Rearing	% of Peak	Winter Rearing	% of Peak	Spawning	% of Peak
350	58,373	98.9%	40,431	100.0%	1,233	25.7%
375	58,825	99.7%	38,419	95.0%	1,407	29.3%
400	58,985	100.0%	36,919	91.3%	1,578	32.9%
425	58,996	100.0%	35,563	88.0%	1,746	36.4%
450	58,719	99.5%	34,487	85.3%	1,910	39.8%
475	58,268	98.8%	33,643	83.2%	2,071	43.2%
500	57,721	97.8%	32,757	81.0%	2,235	46.6%
550	56,319	95.5%	31,317	77.5%	2,568	53.6%
600	54,752	92.8%	30,264	74.9%	2,896	60.4%
650	53,226	90.2%	29,438	72.8%	3,210	66.9%
700	51,660	87.6%	28,860	71.4%	3,507	73.1%
750	50,038	84.8%	28,364	70.2%	3,786	79.0%
800	48,658	82.5%	27,495	68.0%	4,000	83.4%
850	47,571	80.6%	26,776	66.2%	4,183	87.2%
900	46,774	79.3%	25,859	64.0%	4,335	90.4%
950	46,122	78.2%	24,831	61.4%	4,451	92.8%
1,000	45,558	77.2%	23,970	59.3%	4,565	95.2%
1,050	45,033	76.3%	23,111	57.2%	4,663	97.2%
1,100	44,559	75.5%	22,342	55.3%	4,726	98.5%
1,150	44,072	74.7%	21,747	53.8%	4,770	99.5%
1,200	43,674	74.0%	21,426	53.0%	4,795	100.0%
1,300	42,915	72.7%	20,994	51.9%	4,749	99.0%
1,400	42,443	71.9%	20,428	50.5%	4,508	94.0%
1,500	41,248	69.9%	19,656	48.6%	4,178	87.1%
1,600	39,917	67.7%	18,168	44.9%	3,780	78.8%
1,700	38,644	65.5%	16,831	41.6%	3,345	69.8%
1,800	37,586	63.7%	15,772	39.0%	2,927	61.0%
1,900	36,489	61.8%	14,786	36.6%	2,508	52.3%
2,000	35,431	60.1%	14,138	35.0%	2,163	45.1%
2,100	34,411	58.3%	13,370	33.1%	1,902	39.7%
2,200	33,385	56.6%	12,295	30.4%	1,682	35.1%
2,300	32,629	55.3%	11,288	27.9%	1,469	30.6%
2,400	31,775	53.9%	10,643	26.3%	1,304	27.2%
2,500	31,191	52.9%	10,252	25.4%	1,125	23.5%
2,600	30,854	52.3%	10,239	25.3%	1,004	20.9%
2,700	30,476	51.7%	10,177	25.2%	911	19.0%
2,800	30,195	51.2%	9,603	23.8%	828	17.3%
2,900	30,031	50.9%	8,916	22.1%	756	15.8%
3,000	29,876	50.6%	8,508	21.0%	687	14.3%
3,100	29,795	50.5%	8,610	21.3%	619	12.9%
3,200	29,634	50.2%	8,989	22.2%	553	11.5%
3,300	29,285	49.6%	9,668	23.9%	491	10.2%
3,500	28,243	47.9%	10,544	26.1%	424	8.8%
4,000	26,460	44.8%	9,691	24.0%	440	9.2%
5,000	22,407	38.0%	10,927	27.0%	568	11.8%
6,000	20,302	34.4%	11,794	29.2%	684	14.3%
7,000	20,126	34.1%	12,861	31.8%	745	15.5%
8,000	20,172	34.2%	15,362	38.0%	788	16.4%
9,000	20,509	34.8%	17,351	42.9%	821	17.1%
10,000	20,896	35.4%	19,872	49.1%	849	17.7%
11,000	22,381	37.9%	19,156	47.4%	870	18.1%
12,000	23,848	40.4%	16,942	41.9%	873	18.2%
13,000	25,174	42.7%	15,024	37.2%	870	18.1%
14,000	25,879	43.9%	11,518	28.5%	858	17.9%
15,000	26,232	44.5%	8,349	20.6%	841	17.5%
16,000	26,189	44.4%	6,104	15.1%	825	17.2%

Table 3.1-4 Spokane River WRIA 54 Weighted Usable Area (WUA) Whitefish

Spokane River WUA, WRIA 54				Mountain Whitefish				
Flow	Fry	% of Peak	Juv Rearing	% of Peak	Adult Rearing	% of Peak	Spawning	% of Peak
350	95,489	98.9%	74,701	68.8%	68,269	57.9%	13,841	41.7%
375	95,514	98.9%	77,715	71.6%	71,352	60.6%	15,665	47.2%
400	95,564	99.0%	80,442	74.1%	74,296	63.1%	17,341	52.2%
425	95,618	99.0%	82,753	76.2%	77,153	65.5%	18,966	57.1%
450	95,689	99.1%	84,612	77.9%	79,896	67.8%	20,536	61.8%
475	95,774	99.2%	86,228	79.4%	82,484	70.0%	21,955	66.1%
500	95,832	99.2%	87,628	80.7%	84,886	72.1%	23,305	70.2%
550	96,016	99.4%	89,885	82.8%	88,747	75.3%	25,518	76.8%
600	96,215	99.6%	91,647	84.4%	91,795	77.9%	27,046	81.4%
650	96,414	99.8%	93,164	85.8%	94,261	80.0%	28,218	85.0%
700	96,531	100.0%	94,449	87.0%	96,370	81.8%	28,975	87.2%
750	96,565	100.0%	95,450	87.9%	98,214	83.4%	29,559	89.0%
800	96,462	99.9%	96,341	88.7%	99,950	84.8%	30,086	90.6%
850	96,158	99.6%	97,149	89.5%	101,533	86.2%	30,491	91.8%
900	95,784	99.2%	97,929	90.2%	102,960	87.4%	30,796	92.7%
950	95,240	98.6%	98,613	90.8%	104,293	88.5%	31,059	93.5%
1,000	94,660	98.0%	99,308	91.5%	105,520	89.6%	31,302	94.2%
1,050	93,684	97.0%	99,944	92.0%	106,697	90.6%	31,525	94.9%
1,100	92,547	95.8%	100,601	92.7%	107,819	91.5%	31,721	95.5%
1,150	90,803	94.0%	101,294	93.3%	108,902	92.4%	31,859	95.9%
1,200	88,758	91.9%	102,002	93.9%	109,939	93.3%	31,986	96.3%
1,300	84,096	87.1%	103,563	95.4%	111,920	95.0%	32,165	96.8%
1,400	79,264	82.1%	105,044	96.7%	113,816	96.6%	32,390	97.5%
1,500	74,607	77.3%	106,243	97.9%	115,474	98.0%	32,608	98.2%
1,600	70,365	72.9%	107,223	98.8%	116,869	99.2%	32,838	98.9%
1,700	66,458	68.8%	108,010	99.5%	117,742	99.9%	33,016	99.4%
1,800	62,962	65.2%	108,470	99.9%	117,815	100.0%	33,144	99.8%
1,900	59,917	62.0%	108,577	100.0%	117,328	99.6%	33,217	100.0%
2,000	57,230	59.3%	108,419	99.9%	116,151	98.6%	33,183	99.9%
2,100	55,069	57.0%	108,068	99.5%	114,176	96.9%	33,103	99.7%
2,200	53,224	55.1%	107,550	99.1%	111,769	94.9%	32,981	99.3%
2,300	51,722	53.6%	106,863	98.4%	109,374	92.8%	32,769	98.7%
2,400	50,599	52.4%	105,841	97.5%	106,889	90.7%	32,503	97.9%
2,500	49,504	51.3%	104,597	96.3%	104,516	88.7%	32,213	97.0%
2,600	48,416	50.1%	103,161	95.0%	102,270	86.8%	31,906	96.1%
2,700	47,395	49.1%	101,408	93.4%	100,012	84.9%	31,480	94.8%
2,800	46,440	48.1%	99,625	91.8%	98,091	83.3%	30,969	93.2%
2,900	45,619	47.2%	98,013	90.3%	96,445	81.9%	30,474	91.7%
3,000	44,952	46.6%	96,483	88.9%	94,920	80.6%	29,925	90.1%
3,100	44,301	45.9%	94,983	87.5%	93,474	79.3%	29,365	88.4%
3,200	43,812	45.4%	93,590	86.2%	92,236	78.3%	28,819	86.8%
3,300	43,362	44.9%	92,211	84.9%	90,961	77.2%	28,290	85.2%
3,500	42,354	43.9%	89,677	82.6%	88,486	75.1%	27,297	82.2%
4,000	40,193	41.6%	85,198	78.5%	83,628	71.0%	24,894	74.9%
5,000	34,711	35.9%	76,850	70.8%	76,091	64.6%	20,696	62.3%
6,000	33,093	34.3%	67,441	62.1%	69,951	59.4%	17,058	51.4%
7,000	32,393	33.5%	60,364	55.6%	66,881	56.8%	14,212	42.8%
8,000	32,605	33.8%	54,837	50.5%	64,063	54.4%	11,652	35.1%
9,000	33,138	34.3%	50,848	46.8%	61,753	52.4%	9,484	28.6%
10,000	33,779	35.0%	47,612	43.9%	60,026	50.9%	7,641	23.0%
11,000	33,439	34.6%	45,728	42.1%	59,177	50.2%	6,204	18.7%
12,000	32,601	33.8%	43,594	40.2%	59,137	50.2%	5,094	15.3%
13,000	30,542	31.6%	42,429	39.1%	58,956	50.0%	4,190	12.6%
14,000	26,709	27.7%	41,443	38.2%	59,011	50.1%	3,431	10.3%
15,000	22,143	22.9%	39,976	36.8%	58,780	49.9%	2,764	8.3%
16,000	17,296	17.9%	38,386	35.4%	58,340	49.5%	2,180	6.6%

4.0 HYDROLOGY

The Spokane River gage at Spokane has a long-term record that provides a solid hydrological display of the runoff pattern. Although the Spokane gage gives a very good record of flow for WRIA 57, the inflow from Latah Creek and ground water accretion to the river throughout WRIA 54, contributes a substantial quantity of water which is not measured at the gage. During the summer low flow months, Latah Creek flows are generally low while ground water can add 30% to the flow between the Spokane gauge and the Gun Club. This accretion was documented by the Washington Department of Ecology and USGS on August 30, 2005 when 613 cfs was measured at the Spokane gage and 797 cfs was measured at the Gun Club. Spokane River flows from the August 30, 2005 accretion measurements are shown in Table 4-1. Low flow discharge comparisons based on EES measurements at the Spokane River at Spokane gauge on August 14th and Spokane River at Gun Club on August 15th , 2006 are not exactly comparable, but reinforce the case for significant inflow between the two sites. Discharges at the Spokane gauge were 867 cfs while 1 day later discharges at the Gun Club were 1,069 cfs.

Table 4-1
2005 Accretion Flows

Location	Date	Discharge (cfs)
Spokane R at Spokane	8/30/2005	613
Hangman Cr at Spokane	8/30/2005	1.5
Spokane R blw TJ Meenach B	8/30/2005	703
Spokane R at Gun Club	8/30/2005	797
Deep Creek nr Confluence	8/29/2005	0.0
Spokane R blw Nine Mile Dam	8/30/2005	938

Streamflow from the mountainous regions of the Spokane basin is highest from April through June, averaging 160%-265% of the 6,685 cfs mean annual flow (MAF) as snowmelt fills the streams for an extended period. August and September are generally the lowest flow months of the year with an average discharge of just 26% of MAF. The timing and duration of the spring runoff is strongly influenced by snowpack, day length, air temperature and wind. During the fall and winter months streamflow is influenced by fluctuating freezing levels and rainfall. Fall and winter flows are generally moderate, averaging approximately 50%-100% of MAF.

Avista Utilities operates the Spokane Hydroelectric Project (FERC No. 2545), which has project components both upstream and downstream of the WRIA 54 and 57 study reaches, but not within this the study area. Although Avista generally operates the hydroelectric project on a near run-of-river basis, water is seasonally stored and released from Lake Coeur d'Alene by a dam located upstream of Spokane in Post Falls, Idaho.

The annual hydrograph for the Spokane River at Spokane (1891- 2004) is presented in Figure 4-1. In comments on the Draft report, several Planning Unit members noted that since 1968 water operations in the Spokane River have changed. Figure 4-2 illustrates the annual hydrograph utilizing only records from Water Year1968 – 2005.

Figure 4-1 Spokane River at Spokane
Exceedance Hydrograph (1891 to 2004)

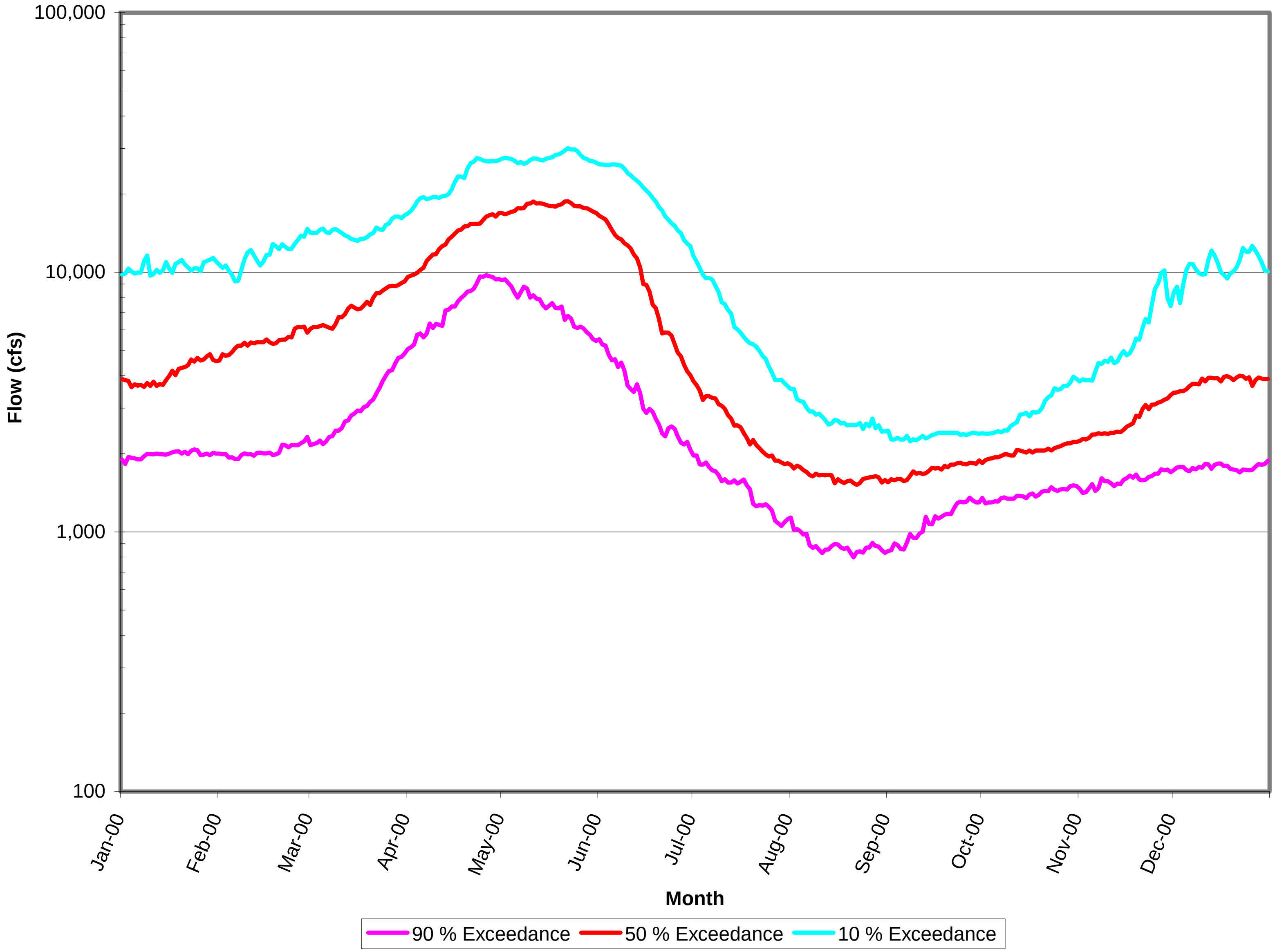
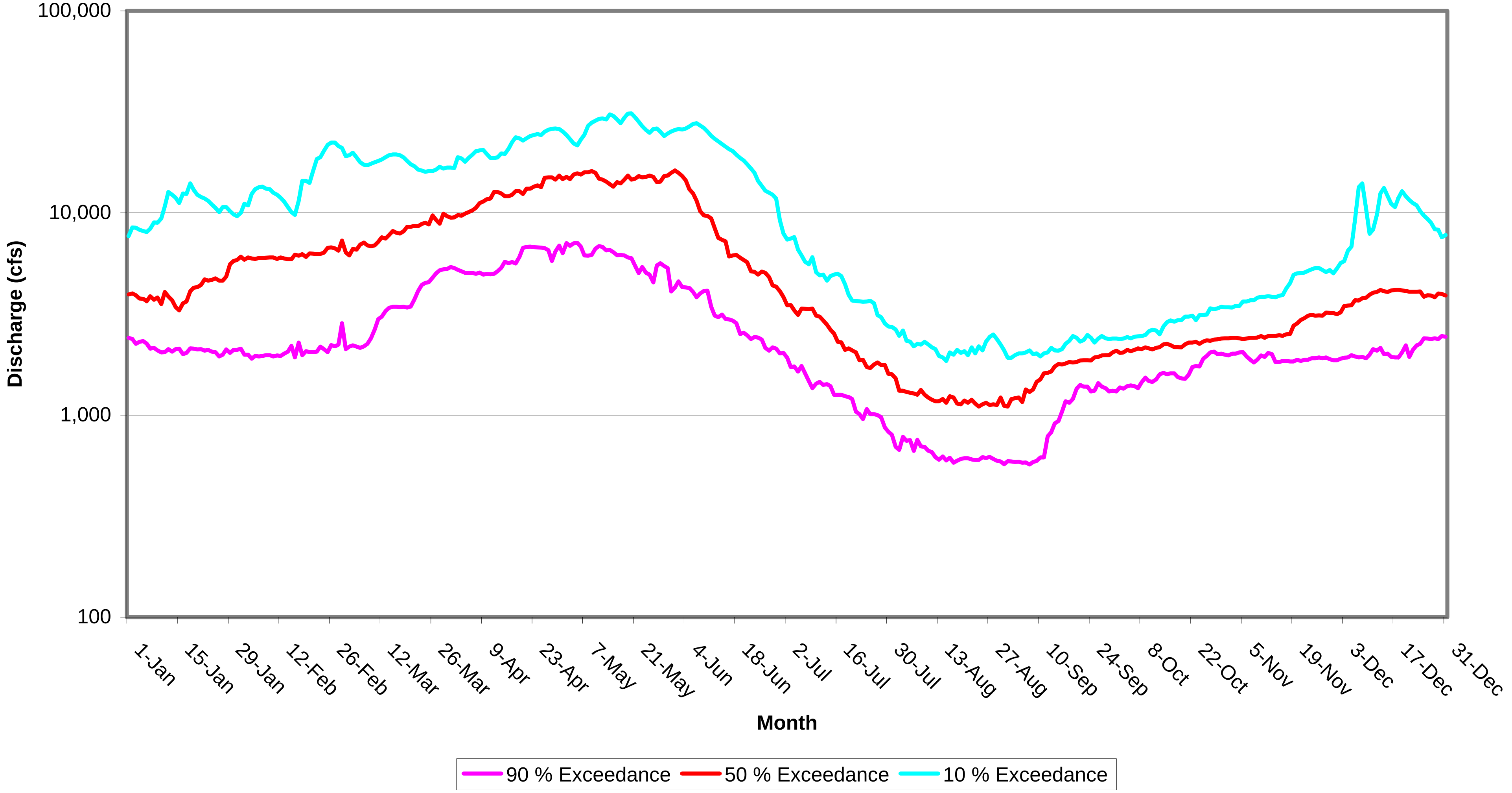


Figure 4-2. Spokane River at Spokane
Flow Exceedance Hydrograph, Water Years 1968-2005



5.0 DRAFT RECOMMENDATIONS

Instream flow recommendations best serve the community when they are based on shared objectives and are part of a carefully planned and considered water resource strategy. Essential elements of a water strategy would likely include instream flows, a water reservation exempt from instream flow, a maximum allocation that would set limits on the total amount of new water withdrawal at any given time, as well as other issues critical to Planning Unit members. Since neither objectives to guide instream flow setting, nor essential elements of a water resource strategy have been articulated, these instream flow recommendations, based on fish habitat preferences, should serve as the guidelines for discussion on this topic.

5.1 Balancing Needs Of Target Species

Initial information provided by fisheries biologists from WDFW and the Spokane Tribe indicated that habitat for both Rainbow Trout and Mountain Whitefish is important in the Spokane River and should be assessed in the current instream flow study (WDFW IFTT Recommendations, 2006). Further consultation has refined these recommendations and led to the suggestion that habitat needs of the two species be balanced on an equal basis (WDFW letter February 7, 2007).

Figures 5-1 and 5-2 show all of the life stages, for both species, on a single graph each for WRIA 57 and 54 respectively. Although somewhat busy, these graphs illustrate the gains and losses for each species and life stage as flows change.

It should be noted that peak WUA for each species generally occurs at a higher flow in the upstream Spokane River in WRIA 57 rather than downstream in WRIA 54. Although somewhat counterintuitive, wetted river channel in WRIA 57 is generally wider than in WRIA 54. The wider channel provides a greater area for the flow to spread out and habitat to be created as discharge in the river increases.

To facilitate evaluating the combined habitat results for both rainbow trout and mountain whitefish, two different comparisons of the data were made. For the first comparison the following computations were completed.

- The percent of peak WUA for the adult lifestage of whitefish and the juvenile/adult lifestage of rainbow were summed.
- A new "peak" WUA of this combined total was identified and all results were recomputed as a percent of this new peak.
- Results of this comparison are shown in Tables 5.1 and 5.2 for WRIA's 57 and 54 respectively. Peak percent for this comparison is shaded in gray.

Although the above comparison numerically balanced habitat for both species, the highest combined numbers resulted in a much higher percent habitat loss for whitefish than for rainbow trout. The second analysis attempts to more equally balance the habitat loss for each species. Tables 5.1-1 and 5.1-2 highlight in green the flows where the percent of peak habitat for each species is between 80% and 90%.

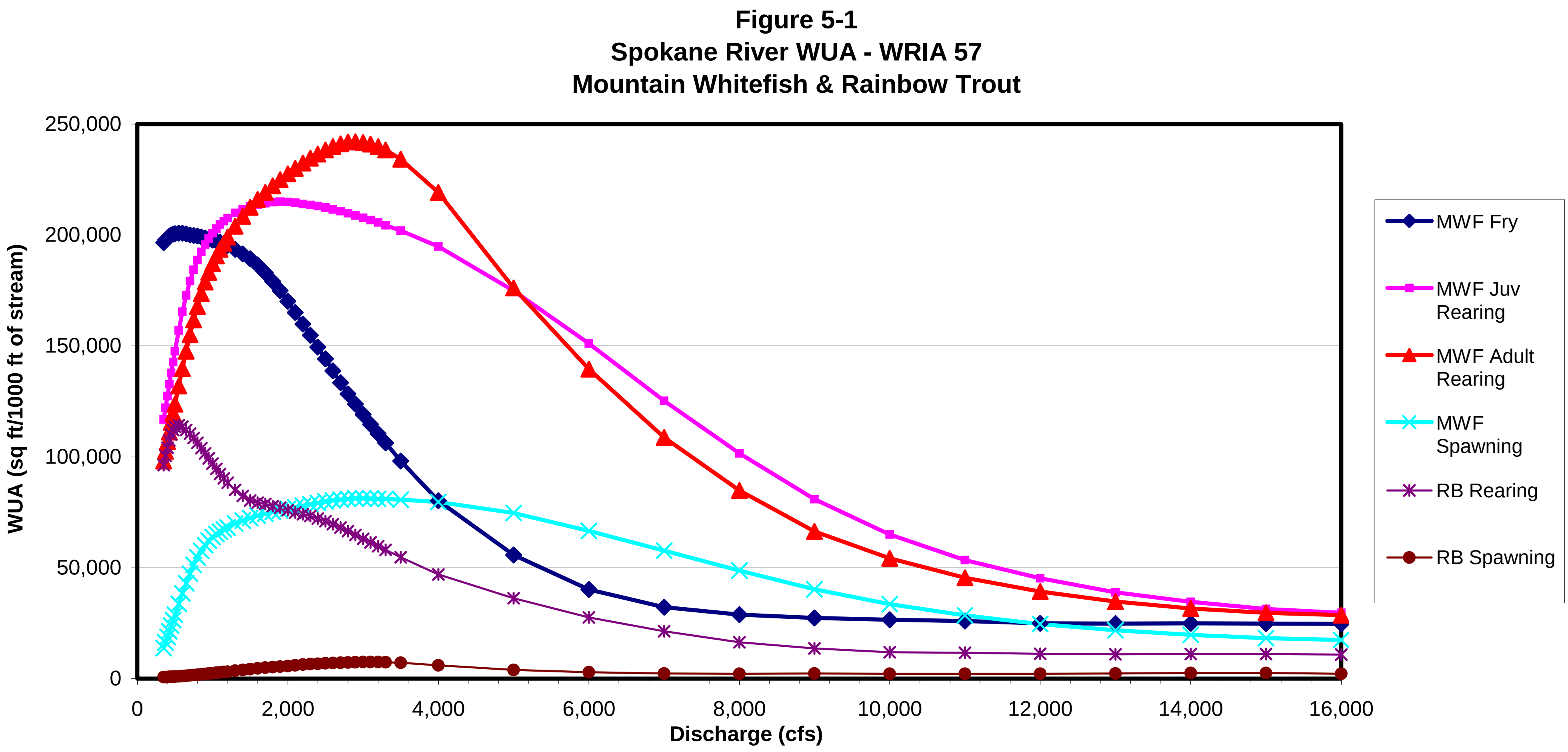


Figure 5-1
Spokane River WUA - WRIA 57
Mountain Whitefish & Rainbow Trout
WUA (sq ft/1000 ft of stream)
250,000
200,000
150,000
100,000
50,000
0
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
Discharge (cfs)
MWF Fry
MWF Juv Rearing
MWF Adult Rearing
MWF Spawning
RB Rearing
RB Spawning

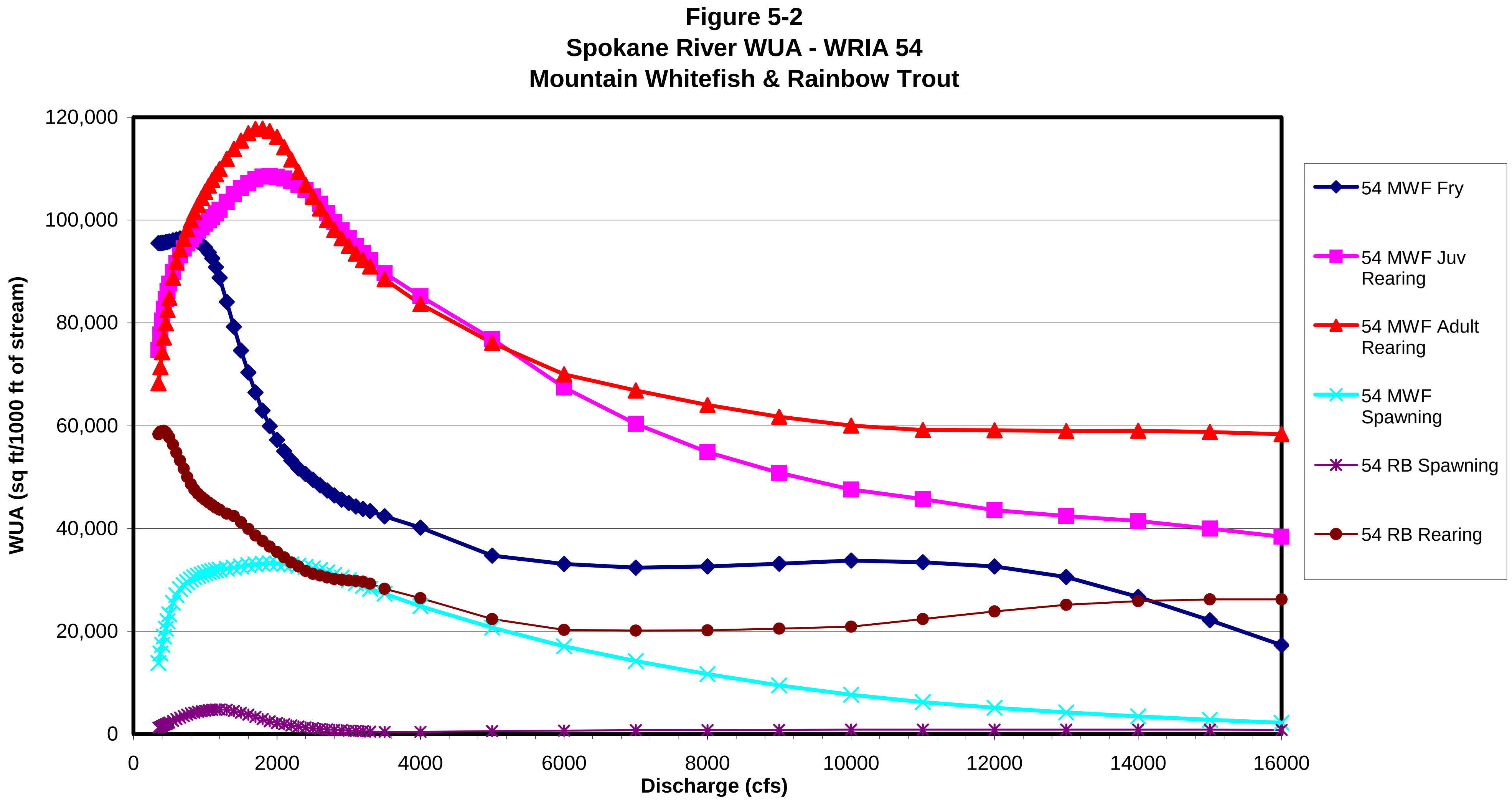


Figure 5-2
Spokane River WUA - WRIA 54
Mountain Whitefish & Rainbow Trout
WUA (sq ft/1000 ft of stream)
120,000
100,000
80,000
60,000
40,000
20,000
0
0
2000
4000
6000
8000
10000
12000
14000
16000
Discharge (cfs)
54 MWF Fry
54 MWF Juv Rearing
54 MWF Adult Rearing
54 MWF Spawning
54 RB Spawning
54 RB Rearing

Table 5.1-1 Spokane River Adult Rearing WUA, WRIA 57

Spokane River Adult Rearing WUA, WRIA 57			
Flow	WF % of Peak	RB % of Peak	Combined % of Peak
350	40.5%	84.2%	76.7%
375	42.4%	87.8%	80.0%
400	44.2%	91.1%	83.2%
425	45.9%	93.9%	86.0%
450	47.7%	96.2%	88.5%
475	49.4%	98.0%	90.6%
500	51.1%	99.4%	92.5%
550	54.5%	100.0%	95.0%
600	57.8%	99.3%	96.6%
650	61.0%	98.1%	97.8%
700	64.0%	96.6%	98.8%
750	66.8%	94.9%	99.4%
800	69.4%	93.0%	99.8%
850	71.7%	90.8%	99.9%
900	73.9%	88.8%	100.0%
950	75.7%	86.8%	99.9%
1,000	77.3%	84.8%	99.6%
1,050	78.7%	82.6%	99.2%
1,100	80.0%	80.7%	98.8%
1,150	81.1%	78.9%	98.4%
1,200	82.2%	77.2%	98.0%
1,300	84.3%	74.4%	97.5%
1,400	86.1%	72.1%	97.3%
1,500	87.8%	70.3%	97.1%
1,600	89.3%	69.4%	97.5%
1,700	90.5%	68.9%	98.0%
1,800	91.8%	68.1%	98.3%
1,900	92.9%	67.4%	98.6%
2,000	94.0%	66.5%	98.7%
2,100	95.0%	65.5%	98.7%
2,200	96.0%	64.8%	98.9%
2,300	96.9%	64.1%	99.0%
2,400	97.7%	63.2%	98.9%
2,500	98.5%	62.0%	98.7%
2,600	99.1%	60.9%	98.3%
2,700	99.6%	59.6%	97.9%
2,800	100.0%	58.1%	97.2%
2,900	100.0%	56.7%	96.3%
3,000	99.9%	55.2%	95.3%
3,100	99.6%	53.7%	94.2%
3,200	99.1%	52.2%	93.0%
3,300	98.4%	50.7%	91.7%
3,500	96.8%	47.9%	88.9%
4,000	90.5%	41.1%	80.9%
5,000	72.8%	31.7%	64.2%
6,000	57.7%	24.2%	50.3%
7,000	44.9%	18.6%	39.1%
8,000	35.1%	14.4%	30.4%
9,000	27.4%	11.9%	24.2%
10,000	22.4%	10.4%	20.2%
11,000	18.8%	10.2%	17.8%
12,000	16.2%	9.8%	16.0%
13,000	14.3%	9.6%	14.7%
14,000	13.1%	9.7%	14.0%
15,000	12.3%	9.7%	13.5%
16,000	11.8%	9.5%	13.1%

Table 5.1-2 Spokane River Adult Rearing WUA, WRIA 54

Spokane River WUA, WRIA 54			
Flow	**WF % of Peak**	**RB % of Peak**	**Combined % of Peak**
350	57.9%	98.9%	91.9%
375	60.6%	99.7%	93.8%
400	63.1%	100.0%	95.5%
425	65.5%	100.0%	96.9%
450	67.8%	99.5%	98.0%
475	70.0%	98.8%	98.8%
500	72.1%	97.8%	99.5%
550	75.3%	95.5%	100.0%
600	77.9%	92.8%	100.0%
650	80.0%	90.2%	99.7%
700	81.8%	87.6%	99.2%
750	83.4%	84.8%	98.5%
800	84.8%	82.5%	98.0%
850	86.2%	80.6%	97.7%
900	87.4%	79.3%	97.6%
950	88.5%	78.2%	97.6%
1,000	89.6%	77.2%	97.7%
1,050	90.6%	76.3%	97.7%
1,100	91.5%	75.5%	97.8%
1,150	92.4%	74.7%	97.9%
1,200	93.3%	74.0%	98.0%
1,300	95.0%	72.7%	98.2%
1,400	96.6%	71.9%	98.7%
1,500	98.0%	69.9%	98.3%
1,600	99.2%	67.7%	97.7%
1,700	99.9%	65.5%	96.9%
1,800	100.0%	63.7%	95.9%
1,900	99.6%	61.8%	94.5%
2,000	98.6%	60.1%	92.9%
2,100	96.9%	58.3%	90.9%
2,200	94.9%	56.6%	88.7%
2,300	92.8%	55.3%	86.7%
2,400	90.7%	53.9%	84.7%
2,500	88.7%	52.9%	82.9%
2,600	86.8%	52.3%	81.4%
2,700	84.9%	51.7%	79.9%
2,800	83.3%	51.2%	78.7%
2,900	81.9%	50.9%	77.7%
3,000	80.6%	50.6%	76.8%
3,100	79.3%	50.5%	76.0%
3,200	78.3%	50.2%	75.2%
3,300	77.2%	49.6%	74.3%
3,500	75.1%	47.9%	72.0%
4,000	71.0%	44.8%	67.8%
5,000	64.6%	38.0%	60.1%
6,000	59.4%	34.4%	54.9%
7,000	56.8%	34.1%	53.2%
8,000	54.4%	34.2%	51.9%
9,000	52.4%	34.8%	51.0%
10,000	50.9%	35.4%	50.6%
11,000	50.2%	37.9%	51.6%
12,000	50.2%	40.4%	53.1%
13,000	50.0%	42.7%	54.3%
14,000	50.1%	43.9%	55.0%
15,000	49.9%	44.5%	55.2%
16,000	49.5%	44.4%	55.0%

5.2 Example Draft Instream Flow Recommendations

Recommendations in this draft report are general in nature and cover a range of possible objectives. The WRIA 54 and 57 Planning Units are best suited to formulate clear objectives and develop details of a comprehensive water resources plan which, for each watershed, will address the full range of water issues including instream flow. Table 5.2-1 illustrates how instream flow recommendations could vary given the range of objectives the planning units could adopt related to different priorities for protecting fish habitat. The purpose of this instream flow study was to show how the habitat for the selected species changes with changes in flow. None of the recommendations shown are likely to be “right”. Rather they are based on the following subjective criteria that planning unit members may choose to consider in their instream flow deliberations.

- Criteria 1 - The priority objective is protection of habitat for combined species.
- Criteria 2 - The priority is maximum ability and flexibility to withdraw water while limiting effects on fish habitat.
- Criteria 3 - Both future water use and protecting fish habitat are important and reflected in instream flow setting.

The instream flows that follow these objectives are primarily based on the results of the Spokane River PHABSIM Study discussed in this document and the rainbow trout spawning analysis conducted below Monroe Street by Northwest Hydraulics and Hardin-Davis (2004). Additional data, including hydrologic records, results of ground water inflow studies and additional analysis may produce different results.

Below is a key listing the basic rationale for the individual recommendations. Timing for each species and lifestage reflects the individual fish periodicity from Figure 2.8-1. Spawning was given priority over rearing. Rearing for adults was given priority over fry and juveniles.

A	Covers 80% - 90% of peak rearing habitat for each species
B	Maximum spawning habitat for affected species
C	Maximum rainbow& white fish combined rearing habitat
D	2/3 of maximum spawning habitat for affected species
E	Incubation at 2/3 of spawning flow
F	90% of peak spawning habitat for affected species

Table 5.2-1 Spokane River Example Draft Instream Flow Recommendations

Month	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**
WRIA 57												
Criteria 1	1,100	3,000	3,000	2,000	2,000	WRIA 57 Spawning Requirements				1,100	1,100	1,100
Rationale	A	B	B	E	E	Evaluated by NW Hydraulics, 2004.				A	A	A
Criteria 2	900	800	800	533	533					900	900	900
Rationale	C	D	D	E	E	WRIA 57 Spawning Requirements				C	C	C
Criteria 3	850-1100	1,600	1,600	1,050	1,050	Evaluated by NW Hydraulics, 2004.				850-1100	850-1100	850-1100
Rationale	A	F	F	E	E					A	A	A
Month	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**
WRIA 54												
Criteria 1	850	1,900	1,900	1,900	1,900	1,200	1,200	850	850	850	850	850
Rationale	A	B	B	E	E	B	B	A	A	A	A	A
Criteria 2	550	475	475	316	316	650	650	550	550	550	550	550
Rationale	C	D	D	E	E	D	D	C	C	C	C	C
Criteria 3	650-850	800	800	533	533	900	900	650-850	650-850	650-850	650-850	650-850
Rationale	A	F	F	E	E	F	F	A	A	A	A	A
Spokane River at Spokane, USGS No. 12422500				**Mean Monthly Exceedance Flows (cfs)**								
10 % Exceedance	2968	5679	10505	10459	11705	14539	22400	27664	20440	6590	2768	2350
50 % Exceedance	2043	2675	3802	4100	5397	7433	13466	17865	9649	2593	1634	1727
90 % Exceedance	1394	1582	1774	1984	2046	3114	7475	7402	3372	1486	893	1097

6.0 REFERENCES

Golder Associates, 2003. Little Spokane River Basin (WRIA 55) Instream Flow Needs Assessment. Prepared for the WRIA 55/57 Watershed Planning Unit. 43 pp.

Morlock, S.E. 1996. Evaluation of Acoustic Doppler Current Profiler Measurement of River Discharge. U.S. Geological Survey, Water Resources Investigations Report 95-4218, Indianapolis Indiana.

Northwest Hydraulic Consultants and Hardin-Davis, Inc. 2004. Instream Flow and Fish Habitat Assessment, FERC Project No. 2545, Avista Corporation. Prepared for the Avista Corporation and WRIA 55/57 Watershed Planning Units. 93 pp.

Payne, T.R., 2003. The Influence of Multiple Calibration Velocity Sets on the PHABSIM Habitat Index. IFIM Users Workshop, Ft. Collins, CO., June 2003.

Swift, C.H. 1976. Estimation of Stream Discharges Preferred by Steelhead Trout for Spawning and Rearing in Western Washington. United States Geological Survey Open File Report 75-155. USGS, Tacoma, Washington. 50 pp.

Washington Department of Fish and Wildlife (WDFW) and Washington Department of Ecology (Ecology), 2004. Instream Flow Guidelines Update. Olympia WA., April 2004