HARDIN-DAVIS, INC.

Review of "Final Technical Report Lower Skagit River Instream Flow Studies" by Duke Engineering and Services, Inc., June 1999

March 2005

I. INTRODUCTION

Skagit County Public Works contracted with Hardin-Davis, Inc. (HDI) in November 2004 to review the 1999 instream flow study of the lower Skagit River. Specifically, HDI was directed to review the Duke Engineering and Services (DEAS) report, which deals with instream flow studies and estuary studies on the Skagit River from River Mile 24 (RM24) to the mouth.

In the DEAS study, the stated objective was to "provide instream flow technical data to the Parties for use in the discussion and establishment of Lower Skagit River instream flow recommendations downstream of River Mile 24.3" (DEAS 1999, p 2).

Skagit County asked HDI for an independent review in order to determine whether the DEAS report accomplished its stated objective. HDI was asked specifically to accomplish the following tasks:

- Review the DEAS report, appendices, and background information,
- Review the RHABSIM analyses that led to the weighted usable area (WUA) calculations,
- Carry out alternative calculations where appropriate,
- Assess the overall validity of the DEAS IFIM study,
- Determine whether the results of the DEAS report are sufficient for use by Washington Department of Fisheries and Wildlife (WDFW) and Washington Department of Ecology (WDOE) in setting flow recommendations.

An additional task given HDI was to assess the validity of the WDFW/WDOE flow recommendations. That assessment is in a separate summary report by HDI.

II. METHODS

The Instream Flow Incremental Methodology (IFIM) is a standard tool in assessing flows needed for fish and other aquatic species (Bovee 1996). Often, application of the IFIM focuses on the Physical Habitat Simulation (PHABSIM), which is a key component of IFIM.

The WDFW and WDOE have issued guidelines for carrying out instream flow studies (WDFW & WDOE 2004). The WDFW/WDOE publications include procedures for various steps in application of the models. HDI reviewed the following steps taken by DEAS:

A. Project Scoping
B. Site selection

C. Transect selection
D. Selection of flow range to measure and model
E. Hydraulic modeling
F. Habitat Suitability Index (HSI) curves
G. Habitat (WUA) modeling
H. Interpretation of results

Specific materials reviewed by HDI included the following:

- DEAS report (DEAS 1999) and appendices
- RHABSIM files calibrated by DEAS and used to produce the WUA results

HDI also visited the IFIM sites in December 2004 with Gary Stoyka (Skagit County).

III. Findings

A. Project Scoping
This part of the study appears to have been carried out in accordance with agency guidelines. Meetings with interested parties were held and documented, and there was consensus regarding the analytical tools to be used. One aspect of project scoping that might have been lacking was agreement or discussion at the outset as to how the study results would be interpreted, and how they would be used to make flow recommendations. According to the DEAS report, all parties agreed to apply IFIM to the task of determining flow recommendations. However, it is not known whether methods of data interpretation (i.e. how to get from WUA to recommended flows) were discussed or agreed to.

Another aspect of project scoping that needed more emphasis was the degree to which flows might be limiting to spawning and rearing life stages in the lower Skagit River. It may be that this stretch of the river is most important as a migration corridor between higher-quality upstream habitat and the ocean. An extensive report on limiting factors in the basin did not include low flows in the mainstem as one of the factors (Smith 2003).

B. Site Selection
The study area was divided into three riverine reaches, based on previous work of the Skagit System Cooperative (SSC). A fourth, estuarine reach, downstream of RM 8.1, was also assessed by DEAS but that work is not reviewed here. The river mile (RM) boundaries for this review are:

Reach 1: RM 8.1-18.6
Reach 2: RM 18.6-22.3
Reach 3: RM 22.3-24.3

Since the reach divisions had been made previously by the SSC, the use of the same divisions by DEAS does not seem controversial.

C. Transect Selection and Weighting

DEAS selected transects to represent a variety of habitat types. Each transect has a different description (DEAS Table 2.1-2), though some of the differences seem minor (e.g. "wider glide" vs. "very wide glide." In most IFIM habitat mapping studies, a table is included that lists the overall frequency of each mesohabitat type in the study area. This is useful for comparison to the final transect weighting. Without this information, it is difficult to evaluate, for example, whether or not "wide, steep-sided glide; rip-rap" actually represents 25.22% of the study area (DEAS 1999; Table 2.1-2). DEAS did not include such a table in the report. Their final transect weighting is evidently based on that type of breakdown (according to Appendix A-3.2), but the table summarizing the mesohabitat breakdown is not included.

A minor criticism of the final transect selection is that the ultimate results are based largely on very few transects. Transect 2 alone represents over 25% of the study area, and the first five transects account for over 75%.

In this study, certain specific transects were run separately for spawning analysis. These transects (T7 and T8) are in the section of the river that is cited (p.15) as the only section with any appreciable spawning habitat in the study area. It is appropriate to assess spawning transects separately from transects with no spawning potential. However, spawning ultimately accounts for flow recommendations for almost half the year (DEAS Table 5.4-1); thus it would strengthen the analysis if these flow recommendations were based on more than two transects.

A larger question is whether spawning is a significant issue in this study area. During the HSI field work in 1998, (Section F, below) DEAS was unable to observe spawning. Flow recommendations are therefore based on only two transects in what is apparently a marginal spawning area. The scoping process probably addressed the issue of whether it is justifiable to set spawning flows for this study area. A discussion in the DEAS report of the justification for their approach would have been useful.

D. Flow Range

Selecting a range of flows to measure is a key step in an instream flow study. The hydraulic models can lose accuracy when extrapolated flows are much lower or higher than measured flows. It is important for the model to be able to span a range of flows that coincides with the range of flows of interest.

DEAS measured a wide range of flows, from about 7000 to about 29,000 cfs, plus a measured WSL at 43,000 cfs. This allowed a simulation range of 2900 cfs to 72,000 cfs. The low extrapolated flow is well below the 80% exceedance flow for the driest month, and the high extrapolated flow is also well above the 20% exceedance flow for the wettest month (Figure 1). This is more than adequate for the purposes of the study.

E. Hydraulic Models

The RHABSIM files used for all mainstem transects were obtained by HDI from DEAS in late November of 2004. HDI reviewed these files to check general calibration procedures, including the following:

- Calculated discharges

- Predicted water surface elevations (WSL)
- Predicted velocities
- Modeling options selected by DEAS

The general order that should be followed in hydraulic modeling is as follows:

1. Collect the field data (cross-sectional profile, depths, velocities, water surface elevations)
2. Build a raw IFG-4 data file from the field data. In RHABSIM, this file is a *.RHB file
3. Calibrate the raw file. Correct errors in the data, and make minor adjustments to obtain realistic simulations of depth and velocity over an agreed-upon range of flows
4. Build an IFG-4 production file. This is basically a calibrated file with all the simulated discharges entered. The production file simulates depths and velocities for each discharge
5. Merge the output from (4) with habitat suitability (HSI) information to produce weighted usable area (WUA).

Rearing Results
DEAS followed this general order, but apparently made a major mistake at Step 4. The hydraulic files had been calibrated (files dated October 1998), and approved (unknown date) by WDFW. The calibrated files were provided to HDI in a folder called SKAGIT\FINAL; these files will be referred to as the "Final" files.

Subsequently, DEAS made files (dated January 1999) specifically for rearing analysis. These files, in the folder SKAGIT\FINAL\REARING will be referred to as the "Rearing" files. The Rearing files were much like the Final files, except the substrate codes were adapted specifically for rearing analysis. This was a legitimate alteration of the files for the purpose of determining rearing WUA.

After calibration and WDFW review, no changes to any <u>hydraulic inputs</u> (elevations, velocities, etc.) should have been made. However, hydraulic changes were made to the Rearing files; the newly-entered data were erroneous. Flawed hydraulic data were mistakenly entered into at least 7 of the 10 transects. The most serious problem was that the stage-of-zero-flow (SZF) values in the Rearing files were changed significantly from those in the Final files (Table 1).

The SZF data found in these Rearing files caused major errors in the predicted water surface elevations at seven of the ten transects (Table 2). Even in a large river like the Skagit, errors of 1.0 ft or more are unacceptable; in the DEAS rearing file, seven of the transects had errors larger than this, and three transects had errors larger than 5.0 ft.

The WSL prediction errors mean that all of the predicted depths used in calculating WUA were incorrect at the majority of transects. These errors in turn caused velocity errors (since, for a fixed discharge, if the depths are incorrect, the velocities will also be incorrect). The Velocity Adjustment Factor (VAF) output is an indicator of the magnitude of this error. At the measured discharge, the VAF should be close to 1.0, indicating that little or no adjustment of the measured value was necessary. Table 3 shows that VAF values were far from 1.0 at seven of the transects. In general, a

VAF of 0.5 at the measured flow indicates that simulated velocities were half of the measured values.

As a result of these errors, the WUA rearing results reported in DEAS 1999 are incorrect. The amount of error is great enough that no conclusions on the flow-habitat relationship can be drawn from the DEAS analysis. In order to proceed with the study, WUA must be recalculated with corrected rearing files.

Note: The erroneous rearing files (SKAGLOW.RHB and SKAGMID.RHB) were used to produce all of the rearing WUA results in DEAS (1999). We confirmed this by running these rearing files with the given HSI curves (DEAS 1999 Appendix C), which reproduced the rearing WUA values found in the DEAS report and appendices. The SKAGHIGH.RHB file also had erroneous SZF data; these errors are not tabulated here because the high-flow analyses did not affect the recommended flows.

Other Issues in the Rearing Analysis

The substrate codes in the rearing files were altered in consultation with the Committee in order to confine rearing habitat to the margins of the river. This was done by inserting a dummy substrate code (99.9) for all cells beyond the shear zone (DEAS Section 2.2.5). The criteria for designating the boundary of the shear zone are not clearly defined in the report; however, the boundaries at each transect were apparently agreed upon by the Committee.

Cross-sectional plots of the transects indicate that the shear zone designations might be incorrect in some cases (Appendix 1). For example, the mid-channel on T6 is a bar, with moderate depths and velocities at mid-flow, yet it was not modeled for rearing habitat (99.9 substrate code). At transect 8, a mid-channel eddy with low velocities was also blanked out. These and other areas should be reviewed to make sure that suitable rearing habitats were not left out.

A different "given flow" was used at each transect. In general, this is not an accepted practice. The given flow should be the same for each group of transects, unless the gage flow was actually different for each transect (i.e. different dates of data collection), or unless there are known inflows between the transects. If flows were actually different at each transect, that should be explained in the report.

Spawning Results

The spawning WUA results are based on the data files from the Final folder. These files are free of the major SZF errors reported above for the rearing transects.

The spawning simulation includes T7, a divided channel. The hydraulics of divided channels are often complex, so it is not surprising that DEAS encountered problems with T7. The stage-discharge relationship on this transect did not follow a 3-point regression line, thus it was converted into two 2-point lines. The proportion of the flow in each side of the channel was measured at three discharges. The proportion in each side is known at the measured flows, but only approximated for all the simulated discharges. The DEAS method (regression) of approximating the proportions is acceptable. The problem is that this split channel makes up a significant part of the spawning results. The uncertainty in the proportion of flow in each side of T7 means that there is significant uncertainty regarding the ultimate spawning WUA.

The stage-discharge relationship in the left channel uses a very high SZF--just two feet lower than the WSL measured at 7000 cfs. As a general rule, measured stage minus SZF should be comparable for transects within a study area. The comparison in Table 4 indicates that stage-minus-SZF is far below average for the site on both sides of T7, thus, the stage-discharge relationships in both channels of T7 are questionable.

F. Habitat Suitability Indices

Habitat suitability indices (HSI) have the potential to affect WUA results strongly. It is important for HSI curves to be agreed upon by all parties early in the study. DEAS made a significant field effort in 1998 to incorporate local data into the HSI curves. DEAS also obtained agency approval of the final HSI curves.

As a check of the HSI curves used in the study, HDI plotted the DEAS curves vs. the WDFW/WDOE (2004) default curves. Small differences between the DEAS curves and WDFW curves are standard procedure, and would be expected to improve the reliability of the results, since local field data were incorporated. Large differences, or unusual shapes in the curves, might indicate errors in data analysis or transcription.

For the most part, DEAS curves were similar to the WDFW default curves. Spawning was extended to deeper water for some of the species, which is reasonable in a large river. Juvenile curves for steelhead and chinook were adjusted toward shallower water and lower velocities. This is a little surprising for a large river. It might be accurate, based on the sizes of fish that use this reach, or it might bias the results toward slightly lower flows.

The DEAS adjustments to the juvenile curves were based on 473 observations of juvenile salmonids (DEAS p. 16). HDI did not review any specific data (such as number of each species observed, size ranges of the juvenile fish, etc.), so it is difficult to comment on the curve adjustments. It is possible that juvenile adjustments were affected by the following:

- difficulty of snorkeling in deeper, faster water
- proportion of juveniles in different size classes
- observations of large groups of juveniles (it is not clear whether 473 individual observations were made, or a relatively small number of groups, totaling 473 fish).

In the DEAS analysis, juvenile habitat required a cell to have the following characteristics:

- appropriate depth and velocity
- position inside of the shear zone
- cover, or a favorable (boulder or cobble) substrate code

On most of the transects, relatively few cells had favorable substrate or cover values for rearing salmonids. Table 5 lists the percentages of cells with suitable rearing substrate or cover, within the river margins designated as potential rearing habitat. Even disregarding all the area outside the shear zone, there appears to be very little good rearing habitat in the study area. This indicates that areas upstream of this study reach might be more important for salmonid rearing, and that flows in this reach are not a significant driver of rearing success.

G. Habitat (WUA) results

REARING: The rearing results in the DEAS report and appendices are incorrect, because they are based on faulty input files (Section E, above). WUA needs to be re-calculated with corrected files.

HDI reconstructed rearing files using the calibrated files that existed in the DEAS Final directory, plus the DEAS information on shear-zone boundaries. These files should not be considered definitive, because they still include some minor problems (different given flows for each transect, possible stage-discharge problems), and because they have not been reviewed by DEAS or WDFW. Nevertheless, these reconstructed files should be very close to what DEAS intended as their final rearing files. Figures 2 to 4 give WUA as a function of flow for rearing salmonids in the Skagit River. The DEAS results are also shown for comparison.

Spawning Results

Figure 5 compares spawning WUA for each of the three locations: T7 left channel, T7 right channel, and T8. WUA for the left and right sides of T7 trend in opposite directions, which may be due to problems in the hydraulic simulation (Section E, above). The combined spawning results for the two transects are driven largely by T8. Thus, the flow recommendations in the DEAS report are largely based on a single transect.

H. Interpretation

The main objective of DEAS was to provide instream flow technical data for use in the establishment of flow recommendations (DEAS page 2). The technical data were interpreted by the Committee, and flow recommendations (DEAS Table 5.1-3) were produced. These recommendations were based on steelhead and chinook rearing for 6½ months of the year, and on chinook, chum, and steelhead spawning for the remaining 5½ months.

Obviously, the flow recommendations based on rearing need to be redone, since they are based on incorrect hydraulic models. DEAS did collect sufficient data for modeling the relationship between flow and habitat. The problems noted above can be corrected with the existing field and computer data. The DEAS study, with new, re-calibrated rearing files and with some changes to the spawning files, would provide a sufficient model of the relationship between flow and physical habitat.

The data interpretation done by DEAS and the committee was overly simplified. For rearing, they combined the WUA for chinook and steelhead (DEAS Table 5.1-1) and picked the flow that maximized this sum. The same approach was used for spawning, except that the key species varied according to the time period. For spawning (DEAS Table 5.1-2) the flow that maximized WUA for steelhead (April-June), chinook+chum (October-November 15) or chum alone (November 16-December 15) was recommended. If averaging WUA from two species is to be done, it would make more sense to first normalize the results for each, and then average them.

The interpretation of WUA should be improved by incorporating more of the *incremental* part of IFIM. The WUA vs. flow curves provide much more information on habitat than the single numbers picked from DEAS Tables 5.1-1 and 5.1-2. Once the correct WUA numbers are produced, they can be improved by the addition, for each life stage, of the flow range for which WUA is at least 90% of maximum. In most cases, 90% of the maximum WUA occurs at a flow much lower than the flow that produces maximum WUA (Table 6). It seems more realistic to examine ranges of WUA values as opposed to just the peaks, considering the precision levels in several components of PHABSIM, and the fact that input discharges were in increments of 500 cfs.

A quantitative analysis of the effects of different flow regimes on WUA in the mainstem Skagit would be much more useful than single-number monthly flow rules. The flow scenarios under consideration for build-out in the Skagit basin are approximately 100 to 200 cfs greater than current demand. In order to assess the effect of a flow alternative, WUA should be calculated at all the naturally occurring and scenario flows. This can be done by combining a flow-exceedance curve and the WUA curve into a habitat exceedance curve. One habitat exceedance curve can be constructed for each month and for each life stage. Habitat exceedance curves can then be compared for natural vs. existing vs. build-out conditions.

Habitat exceedance analysis will show the frequency and magnitude of habitat reductions during each month. The comparison is made for every flow level that occurs. For example, the natural 75%-exceedance flow for May is 14,800 cfs. Habitat values could be compared for this flow vs. a build-out flow of 14,700 or 14,600 cfs (subtracting the 100 or 200 cfs scenario). Similarly, habitat values would be computed for every other exceedance level from 5% to 95%, and plotted.

Differences in WUA between scenarios usually become detectable as flows decrease (i.e. as percentage exceedance increases). For most flows in this study area, the natural and scenario results will be virtually identical because WUA from two high flows is being compared. At the right side of the curve, the natural and scenario results could differ very slightly, because WUA from two lower flows is compared. The habitat exceedance analysis not only quantifies all the habitat conditions (instead of focusing on single, maximum values), it also identifies the points where the biggest differences exist.

This type of analysis will likely show that the WUA differences between natural and build-out conditions are indistinguishable for much of the year. For example, in April, flow is equal to or greater than 10,200 cfs 85% of the time. Thus, 85% of the time in April, the WUA difference is at most the difference between WUA at 10,200 and 10,100 cfs. Such a difference is well below the significance level for distinguishing a WUA difference, and is probably also near the precision level for distinguishing depth and velocity differences with standard field equipment.

A habitat exceedance analysis does not by itself provide definitive flow recommendations. But it does identify the periods during each month in which the potential impacts are distinguishable. Discussion of alternatives could then focus on certain times of the year.

IV. SUMMARY

The DEAS study was in many ways a standard application of IFIM. Considerable effort appears to have gone into the study plan, and establishing consensus at key points (e.g. transect selection, HSI curves). Field work was done on some life stages in order to adjust the default WDFW HSI curves. The study was done "by the book" for the most part, meaning that guidelines of WDFW/WDOE (2004) were followed. The overall importance of rearing and spawning WUA in the reach, as compared to its value as a migration corridor, probably deserves more explanation

The WUA values reported for rearing are incorrect because major data errors found their way into key DEAS input files. There are also other hydraulic issues that should be reviewed. Once corrections and reviews are complete, the results should give a sufficient picture of WUA in the study reach.

When the corrected results are obtained and agreed upon, flow recommendations can be revisited. New flow recommendations should take into account limiting factors, the precision levels of the models, and the incremental part of IFIM. Flow reservations should take into account the relatively small build-out scenarios of Skagit County. One way to do this is habitat exceedance analysis of different alternatives to determine the impact, if any. It is probable that the flow scenarios of the County produce no detectable difference in WUA.

V. References

Bovee, K.D. 1996. The compleat IFIM: a coursebook for IF 250. U.S. Dept. Interior, USGS. Biological Resources Division, Washington, D.C. Draft August 1996.

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Smith, C. J. 2003. Salmon and steelhead habitat limiting factors, Water Resource Inventory Areas 3 and 4, the Skagit and Samish basins. Washington State Conservation Commission.

Washington Department of Fisheries and Wildlife and Washington Department of Ecology 2004. Instream Flow Study Guidelines: Technical and Habitat suitability issues. Draft February 04, 2004.

Washington Department of Fisheries and Wildlife and Washington Department of Ecology 2000. Instream Flow Study Guidelines. May 2000.

VI. Figures

1. Range of flows measured by DEAS, normal over period of record (80% to 20% exceedance flows, 1941-2003), and simulated by DEAS.
2. Weighted useable area (WUA) simulated by HDI and from the DEAS (1999) report, chinook and coho salmon.
3. Weighted useable area (WUA) simulated by HDI and from the DEAS (1999) report, steelhead and bull trout.
4. Weighted useable area (WUA) simulated by HDI and from the DEAS (1999) report, cutthroat trout.
5. Spawning chinook salmon WUA compared for Transect 8, both channels of Transect 7, and the combined mean.

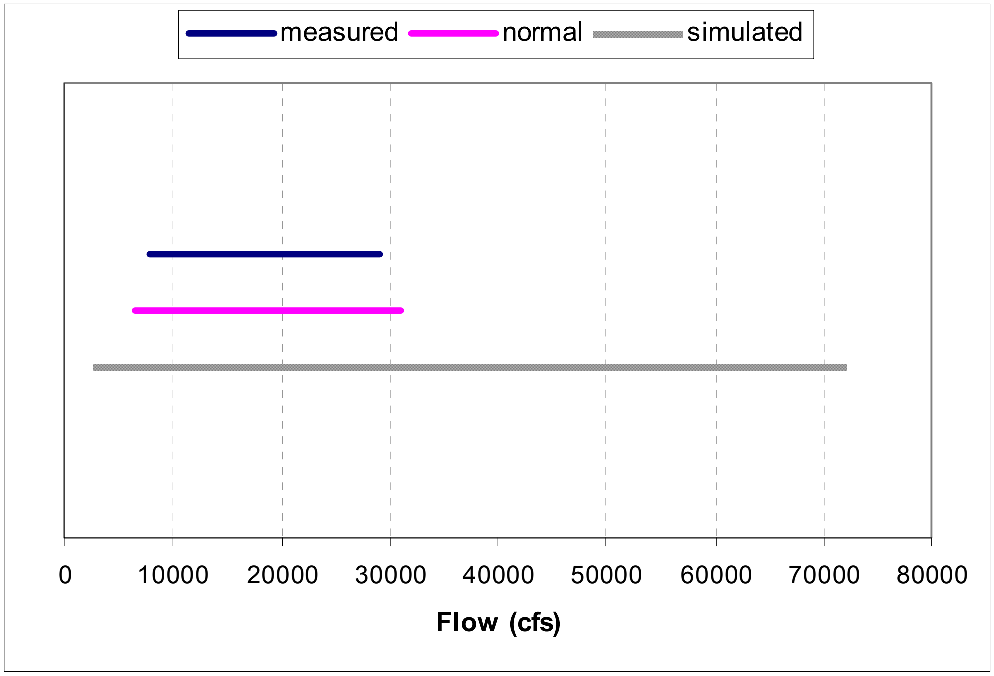

Figure 1. Range of flows measured by DEAS, normal over period of record (80% to 20% exceedance flows, 1941-2003), and simulated by DEAS.

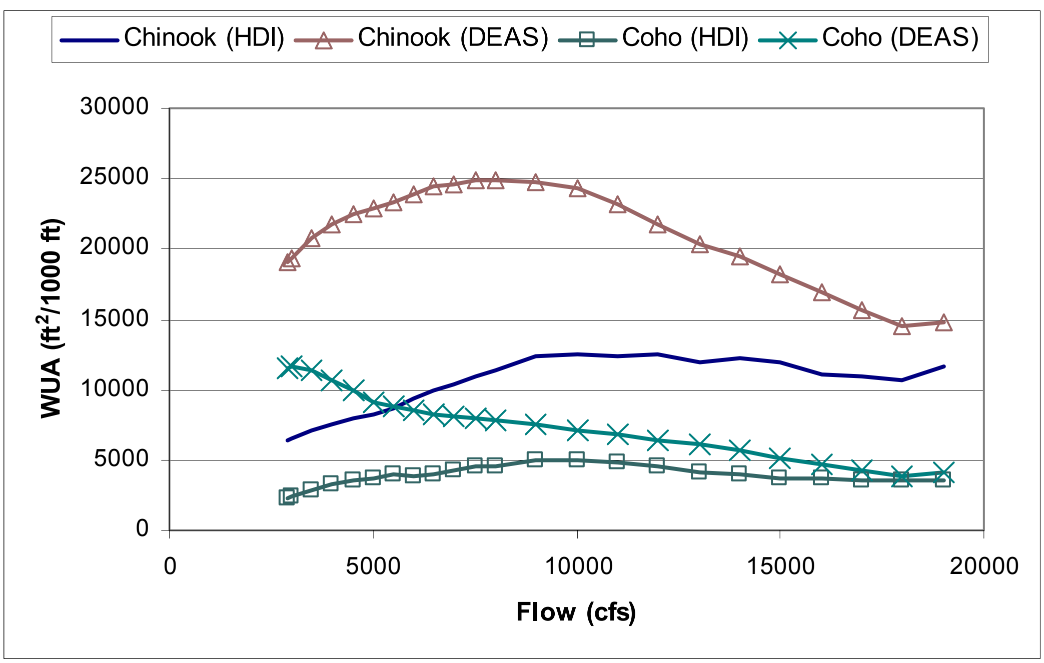

Figure 2. Weighted useable area (WUA) simulated by HDI and from the DEAS (1999) report, chinook and coho salmon, juvenile rearing.

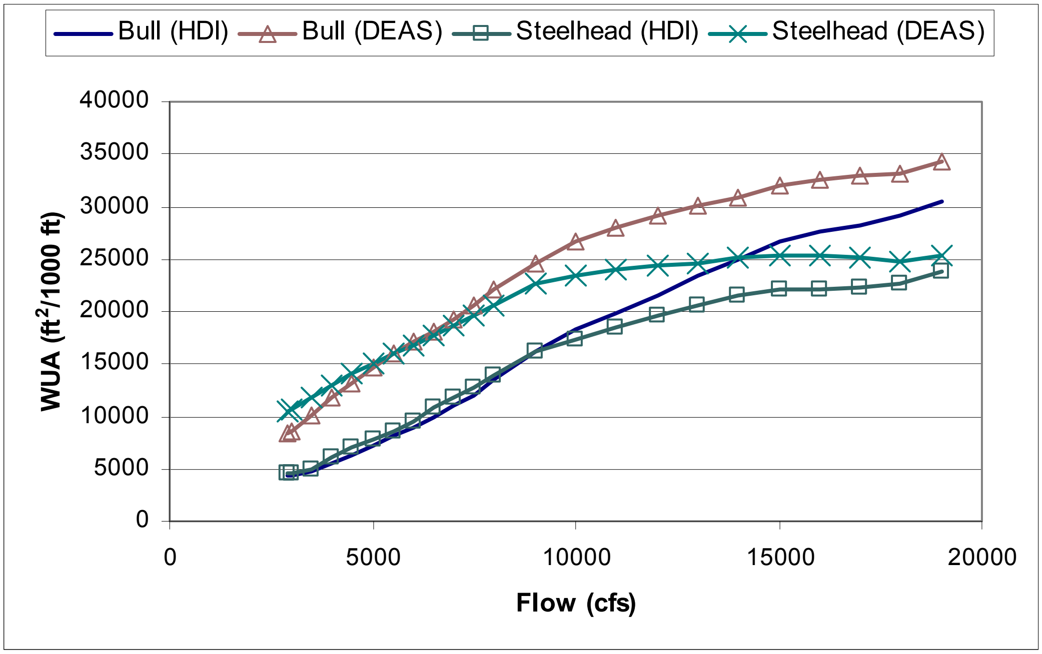

Figure 3. Weighted useable area (WUA) simulated by HDI and from the DEAS (1999) report, steelhead and bull trout, juvenile rearing.

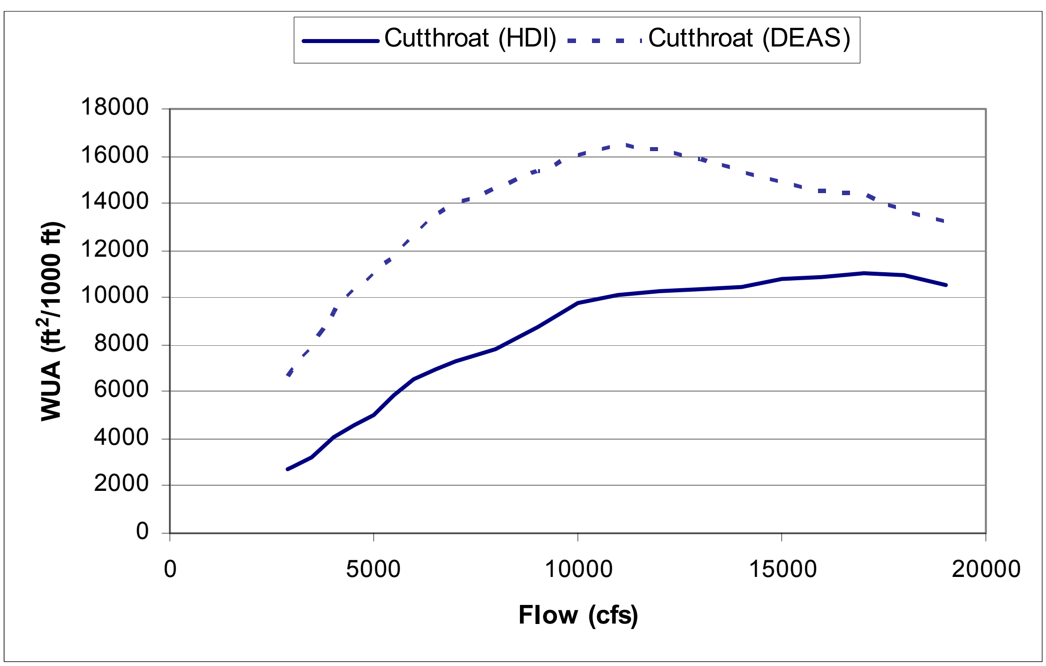

Figure 4. Weighted useable area (WUA) simulated by HDI and from the DEAS (1999) report, cutthroat trout, juvenile rearing.

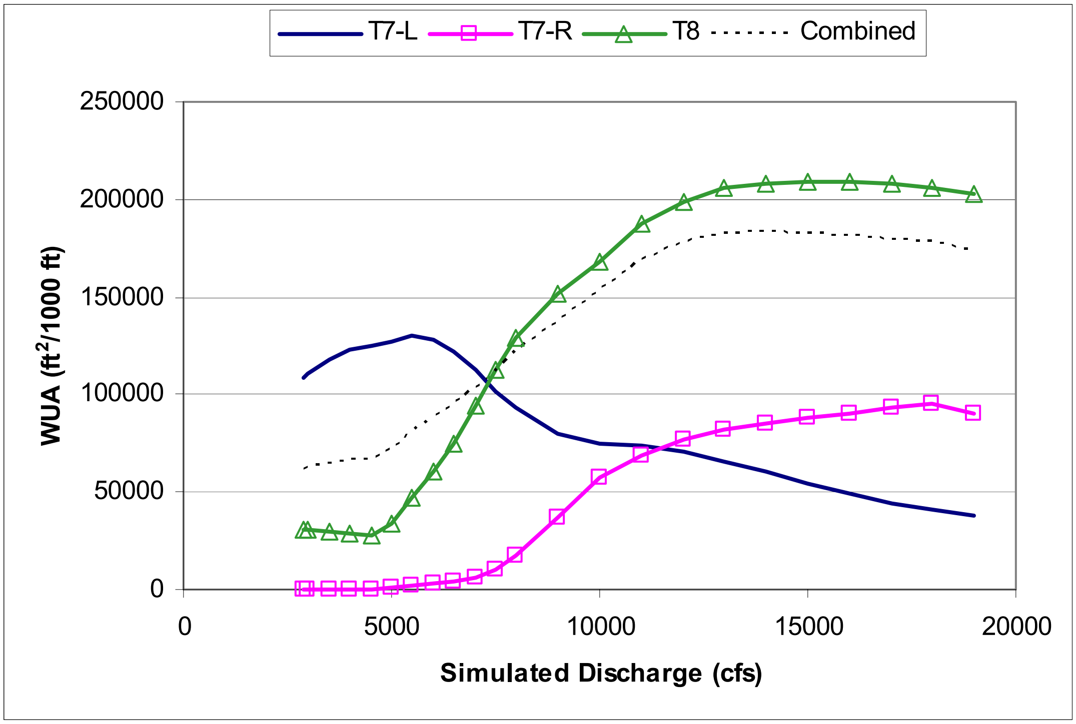

Figure 5. Spawning chinook salmon WUA compared for Transect 8, both channels of Transect 7, and the combined mean.

VII. TABLES

1. Stage-of-zero-flow (SZF) errors at each transect in the file ("Rearing") used to generate WUA for rearing salmonids. Data from "Final" file are as calibrated by DEAS, and used here as the baseline for comparison.

2. Water-surface prediction errors at each transect in the file ("Rearing") used to generate WUA for rearing salmonids. Data from "Final" file are as calibrated by DEAS, and used here as the baseline for comparison.

3. Velocity prediction errors at each transect in the file ("Rearing") used to generate WUA for rearing salmonids, expressed as the Velocity Adjustment Factor (VAF) used by the model to match calibration depths and velocities. Data from "Final" file are as calibrated by DEAS, and used here as the baseline for comparison.

4. Difference between lowest measured stage and stage of zero flow (SZF) used by DEAS in final calibration, showing wide variability among transects.

5. Percentage of cells in transect segments analyzed in report that have suitable substrate or cover characteristics for rearing salmonids.

6. HDI-corrected weighted useable area (WUA) for rearing chinook and steelhead, and the average of both (units: ft^2/1000 ft channel length). Values within 90% of the maximum are shaded; maximum value for each species is in boldface.

Transect	SZF "Rearing"	SZF "Final"	Input error
1	75.50	74.27	1.23
2	75.50	61.18	14.32
3	75.50	67.02	8.48
4	75.50	65.84	9.66
5	75.50	73.73	1.77
6	76.88	76.88	0.00
7L	84.67	84.67	0.00
7R	81.40	84.44	-3.04
8	81.00	81.00	0.00
9	75.50	71.38	4.12
10	76.39	76.39	0.00

Table 1. Stage-of-zero-flow (SZF) errors at each transect in the file ("Rearing") used by DEAS to generate WUA for rearing salmonids. Data from "Final" file are as calibrated by DEAS, and used here as the baseline for comparison.

Transect	WSL "Rearing"	WSL "Final"	Simulation error
1	86.80	85.57	1.23
2	84.27	69.95	14.32
3	82.59	74.11	8.48
4	86.78	77.12	9.66
5	83.61	81.44	2.17
6	80.84	80.84	0
7L	86.78	86.78	0
7R	85.01	88.05	-3.04
8	86.08	86.08	0
9	83.46	79.34	4.12
10	82.02	82.02	0

Table 2. Water-surface prediction errors at each transect in the file ("Rearing") used to generate WUA for rearing salmonids. Data from "Final" file are as calibrated by DEAS, and used here as the baseline for comparison.

Transect	VAF “Rearing”	VAF “Final”
1	0.87	1.023
2	0.15	1.013
3	0.28	0.998
4	0.35	0.982
5	0.69	0.988
6	0.93	0.933
7L	1.03	1.033
7R	4.84	1.132
8	1.09	1.089
9	0.30	1.056
10	1.049	1.049

Table 3. Velocity prediction errors at each transect in the file (“Rearing”) used to generate WUA for rearing salmonids, expressed as the Velocity Adjustment Factor (VAF) used by the model to match calibration depths and velocities. Data from “Final” file are as calibrated by DEAS, and used here as the baseline for comparison. A VAF of 0.5 indicates that predicted velocities are 50% of measured values; a VAF of 2.0 indicates that predicted velocities are twice the measured values.

Transect	Stage - SZF
1	11.4
2	8.9
3	7.2
4	11.5
5	8.1
6	4.2
7L	2.1
7R	3.5
8	5.4
9	8.3
10	6.0

Table 4. Difference between lowest measured stage and stage of zero flow (SZF) used by DEAS in final calibration, showing wide variability among transects.

Transect	Cover (%)	Substrate (%)	Total suitable (%)
1	3.1	5.5	8.6
2	6.4	0.0	6.4
3	3.6	0.0	3.6
4	28.8	1.4	30.1
5	13.4	11.9	25.4
6	16.5	0.0	16.5
8	5.8	0.0	5.8
9	38.5	2.6	41.0
10	53.6	0.0	53.6

Table 5. Percentage of cells in transect segments analyzed in report that have suitable substrate or cover characteristics for rearing salmonids.

Flow (cfs)	Chinook	Steelhead	Chinook + Steelhead
2900	6418	4490	5454
3000	6481	4557	5519
3500	7059	5043	6051
4000	7581	6100	6840
4500	7936	7023	7480
5000	8299	7799	8049
5500	8704	8569	8636
6000	9362	9496	9429
6500	9951	10859	10405
7000	10346	11820	11083
7500	11000	12848	11924
8000	11437	13983	12710
9000	12341	16174	14257
10000	**12576**	17349	14962
11000	12408	18405	15407
12000	12470	19695	16082
13000	12010	20508	16259
14000	12208	21572	16890
15000	11890	22110	17000
16000	11059	22017	16538
17000	10904	22228	16566
18000	10677	22681	16679
19000	11681	**23794**	**17738**

Table 6. HDI-corrected weighted useable area (WUA) for rearing chinook and steelhead, and the average of both (units: ft^2/1000 ft channel length). Values within 90% of the maximum are shaded; maximum value for each species is in boldface.

APPENDIX 1

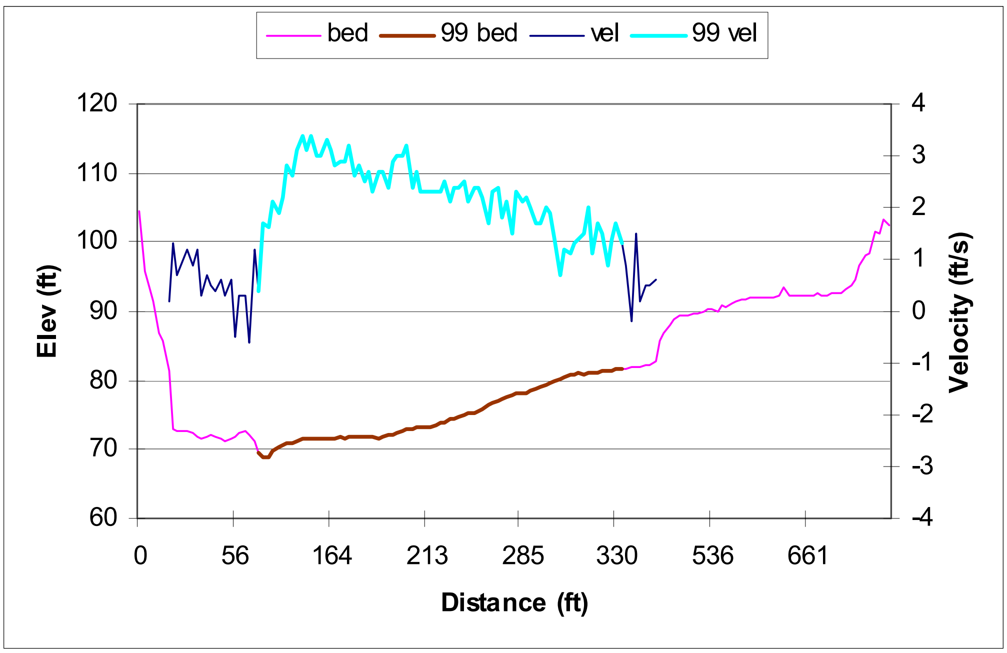

Figure A1-1. Transect 1 bed and measured low-flow velocity profiles. Sections of each profile labeled “99” are the sections of the transect blanked out by DEAS in the RHABSIM rearing analysis.

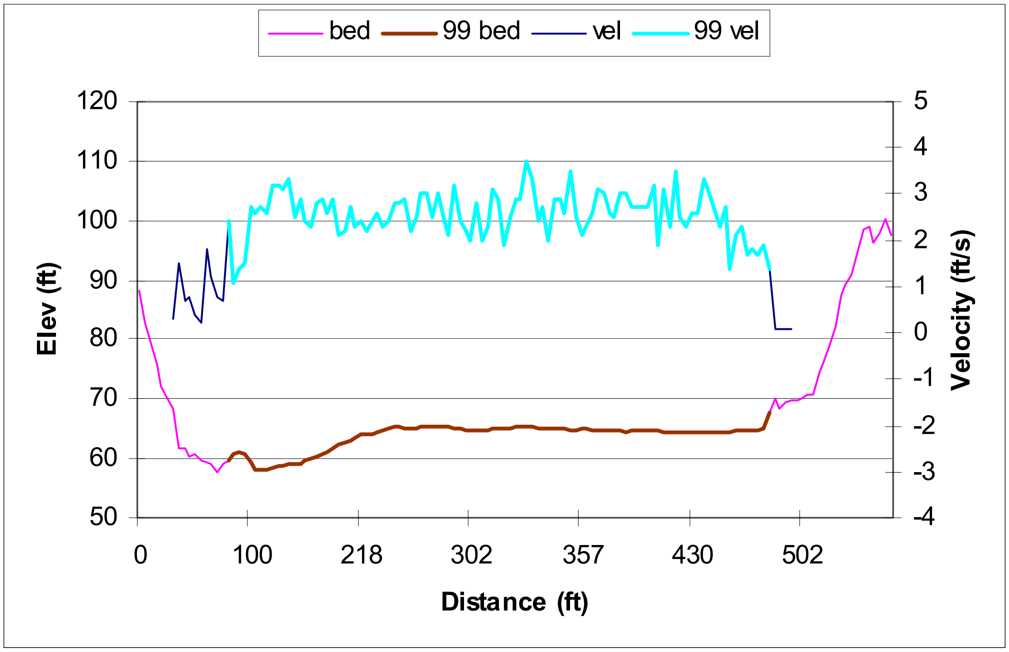

Figure A1-2. Transect 2 bed and measured low-flow velocity profiles. Sections of each profile labeled "99" are the sections of the transect blanked out by DEAS in the RHABSIM rearing analysis.

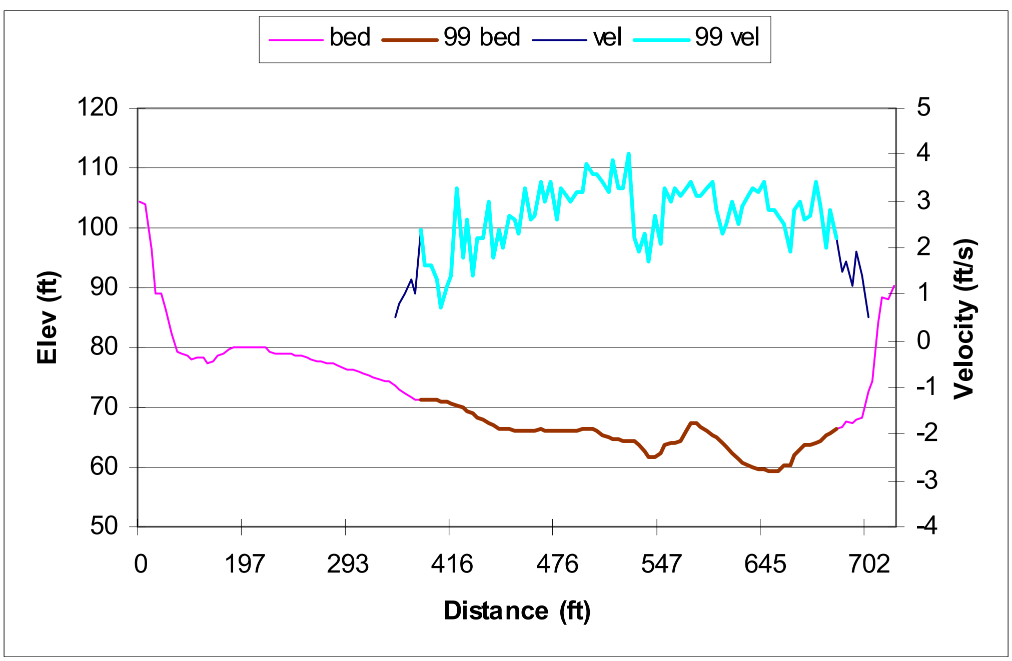

Figure A1-3. Transect 3 bed and measured low-flow velocity profiles. Sections of each profile labeled "99" are the sections of the transect blanked out by DEAS in the RHABSIM rearing analysis.

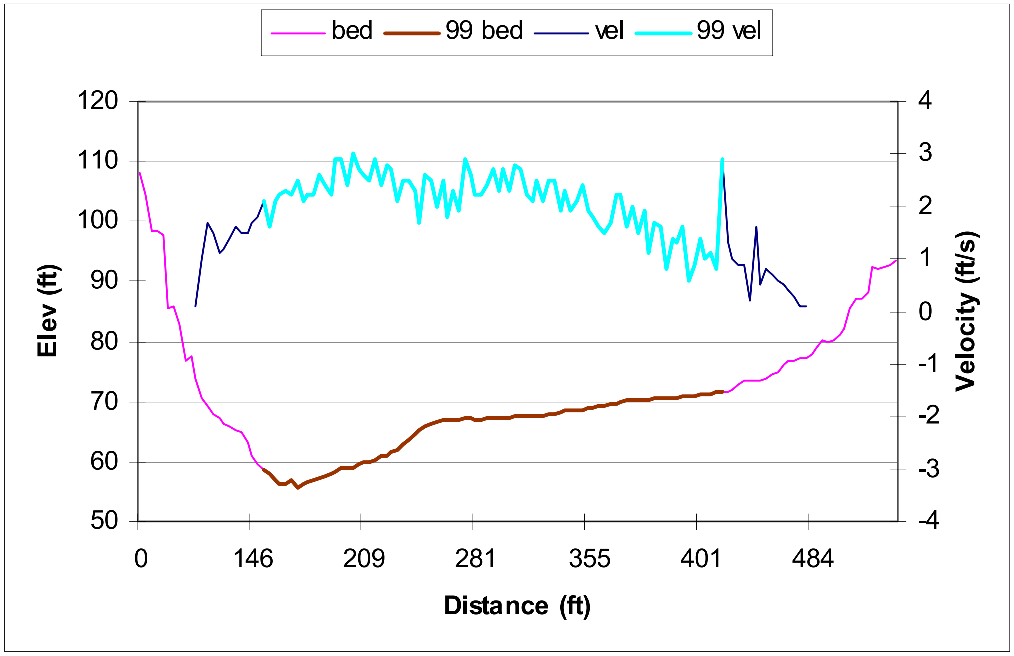

Figure A1-4. Transect 4 bed and measured low-flow velocity profiles. Sections of each profile labeled “99” are the sections of the transect blanked out by DEAS in the RHABSIM rearing analysis.

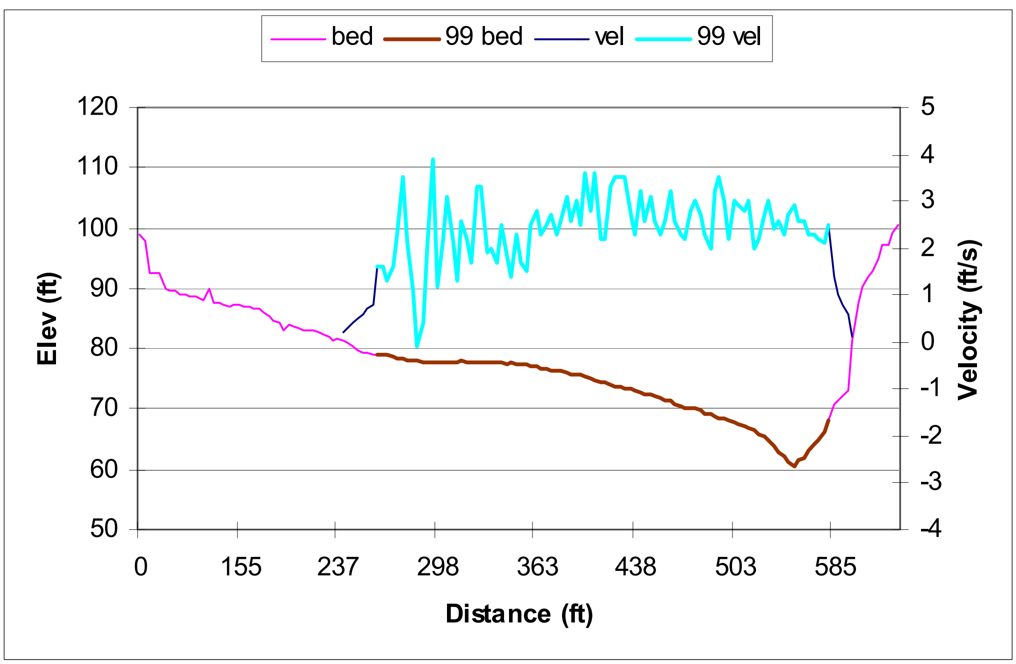

Figure A1-5. Transect 5 bed and measured low-flow velocity profiles. Sections of each profile labeled “99” are the sections of the transect blanked out by DEAS in the RHABSIM rearing analysis.

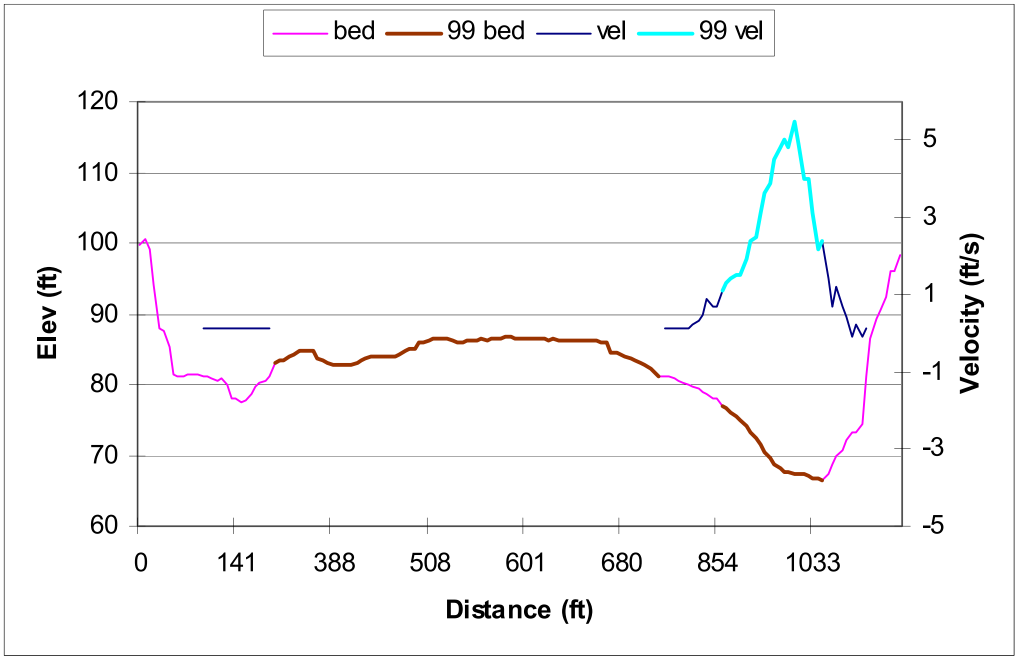

Figure A1-6. Transect 6 bed and measured low-flow velocity profiles. Sections of each profile labeled "99" are the sections of the transect blanked out by DEAS in the RHABSIM rearing analysis.

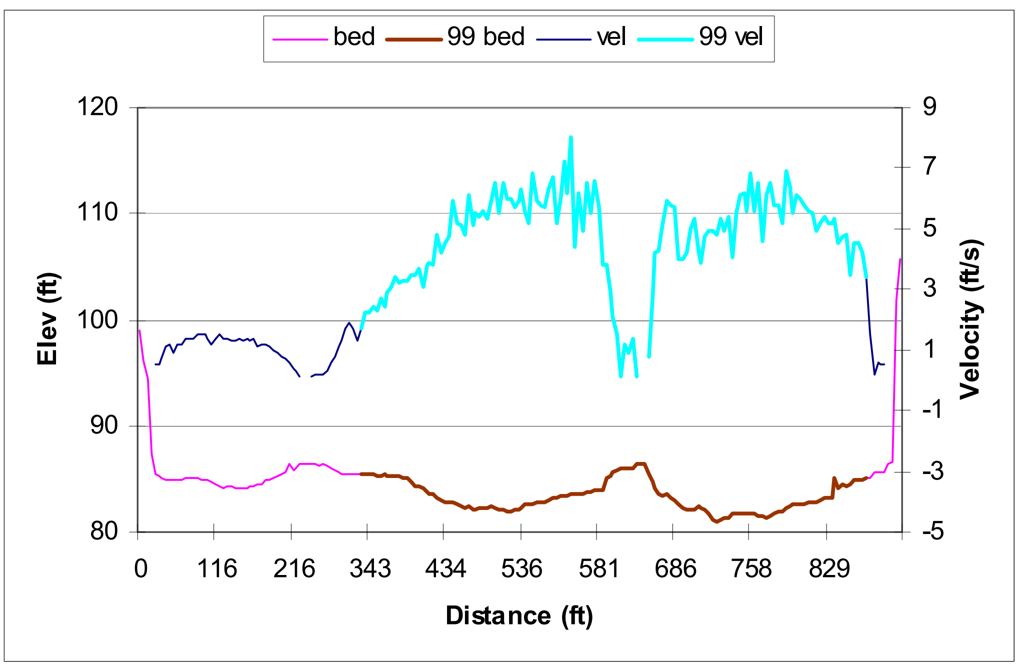

Figure A1-7. Transect 8 bed and measured low-flow velocity profiles. Sections of each profile labeled "99" are the sections of the transect blanked out by DEAS in the RHABSIM rearing analysis.

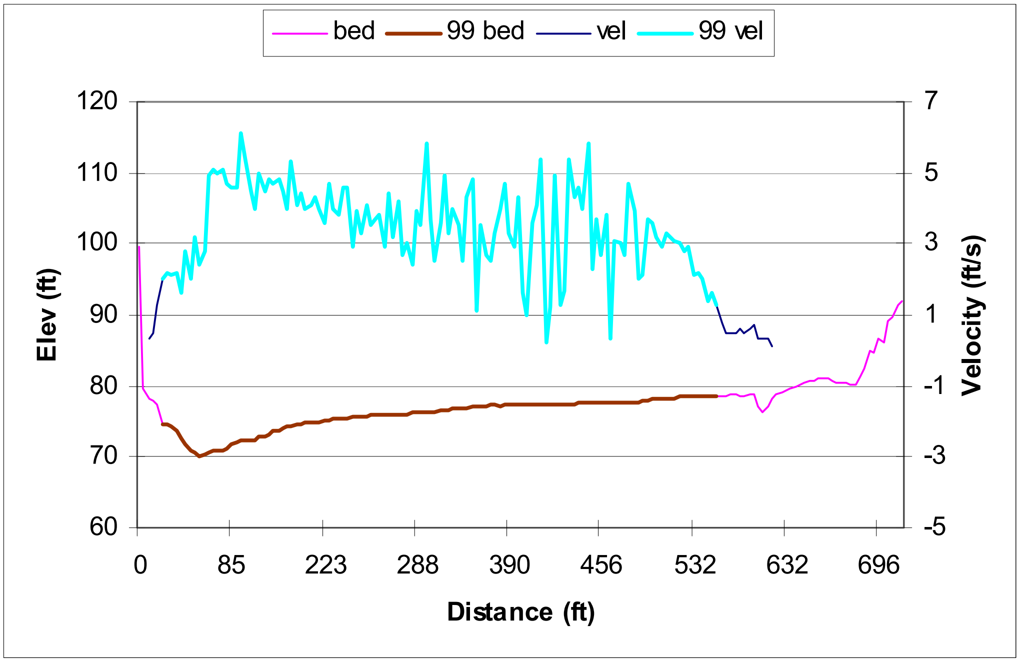

Figure A1-8. Transect 9 bed and measured low-flow velocity profiles. Sections of each profile labeled "99" are the sections of the transect blanked out by DEAS in the RHABSIM rearing analysis.

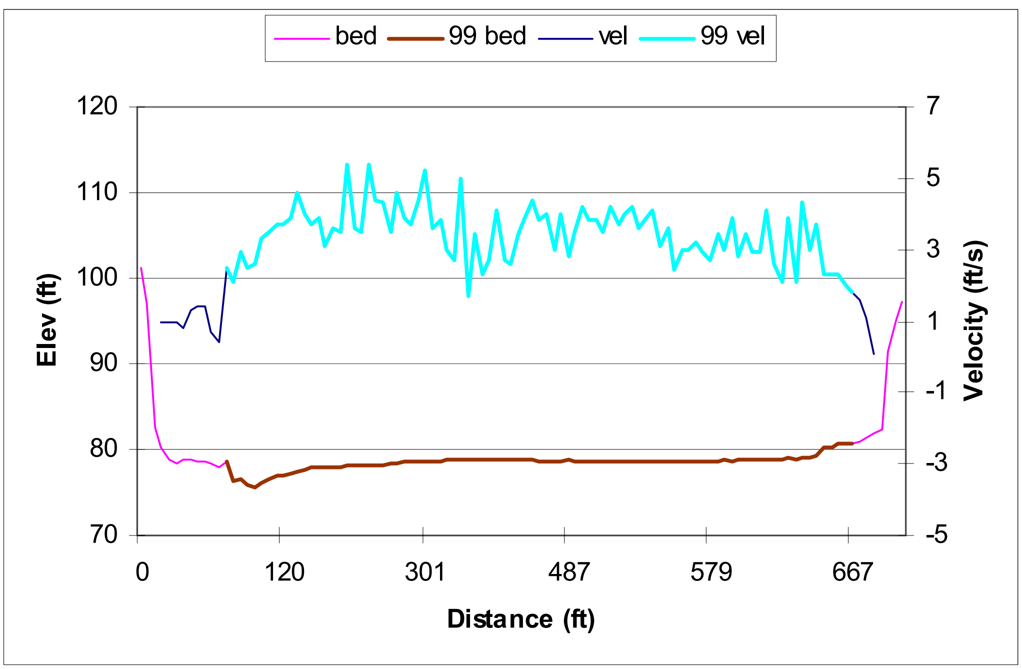

Figure A1-9. Transect 10 bed and measured low-flow velocity profiles. Sections of each profile labeled "99" are the sections of the transect blanked out by DEAS in the RHABSIM rearing analysis.