Instream Flow and Fish Habitat Assessment

FERC Project No. 2545, Avista Corporation

Prepared by:

Northwest Hydraulic Consultants

North Vancouver, British Columbia

and

Hardin-Davis, Inc.

Corvallis, Oregon

June 2004

CONTENTS

LIST OF FIGURES

List of Figures

List of Tables

List of Appendices

ACKNOWLEDGMENTS

This study was carried out to provide information for the relicensing of the Spokane River Project (FERC #2545) at the Post Falls Hydroelectric Development, and for the planning process on the middle Spokane River undertaken by Water Resource Inventory Area (WRIA) 55/57. Avista Corporation and WRIA 55/57 both contributed to the study, the latter through a grant provided by the Washington Department of Ecology.

INTRODUCTION

Purpose

This study was carried out in 2003-04 by NHC and HDI to provide information for the relicensing of the Spokane River Project (FERC #2545) at the Post Falls Hydroelectric Development, and for the planning process on the middle Spokane River undertaken by Water Resource Inventory Area (WRIA) 55/57. In particular, the relationship between instream flows and rainbow trout spawning, fry emergence, and summer rearing habitat were examined. Avista Corporation and WRIA 55/57 both contributed to the study, the latter through a grant provided by the Washington Department of Ecology.

Objectives

- Assess the relationship between effective spawning (combined spawning and incubation) and streamflows in the free flowing reach below the Post Falls HED (Post Falls Reach).
- Assess the relationship between effective spawning habitat and streamflows in the free-flowing reach below the Monroe Street HED (Monroe Street Reach).
- Assess juvenile and adult weighted usable area (WUA) as related to stream flows during the summer rearing period in the Post Falls Reach.

METHODS

These streamflow studies were conducted in spawning and rearing areas throughout the free-flowing reach of the Spokane River downstream from Post Falls Dam in Idaho, and in spawning habitats in the reach downstream of the Monroe Street Dam in Spokane, Washington (Figure 1). Measurements were made at nine study sites or transects as indicated on the figure.

Post Falls Reach Spawning and Incubation

The number of rainbow trout fry that successfully emerge from the spawning gravels in the Post Falls Reach is thought to be limited by spawning and incubation flows (Bennett and Underwood 1988). Therefore, our studies linked topographic habitat measurements, the stage discharge relationship, and hydraulic simulation (PHABSIM) to provide a model of effective spawning at selected locations. Two methods were used, one based on transects, and one based on topographic mapping.

Transect assessment method

1. Based on ongoing spawning surveys conducted by Avista, and spawning surveys conducted by Parametrix in 2003 (Parametrix 2003), we selected two known spawning areas at Harvard Road and Starr Road Bar (Figure 1) as our sampling sites. A roughly rectangular area of major spawning activity was delineated at each site.

2. Site-specific spawning criteria (depth, velocity and substrate) were developed, based on the literature and ongoing studies on the Spokane River. The spawning criteria were circulated to the

Fisheries Working Group (FWG) and approved in December 2003 (Northwest Hydraulics and Hardin-Davis 2003).

3. Three transects were placed across each spawning area, near the upstream and downstream boundaries and the midpoint (Figures 2 and 3). Each transect crossed areas of suitable spawning substrate. At each transect, depth, velocity and substrate measurements were made at 20-25 points at three different flows (1340, 2520, and 4050 cfs, though at lower flows, many points were dry). One of the three transects was extended to cross the entire channel in order to develop a stage-discharge relationship.

4. One additional stage measurement was made at 10,300 cfs in March, 2004. A stage-discharge relationship was then determined using a power function fitted to the measured data points. The results were checked against predictions made using the MANSQ step-backwater model.

5. The hydraulic measurements were then used in the IFG4 program to allow for simulation of depth and velocity conditions for a range of flows from 2,000 to 15,000 cfs, encompassing the range of spawning and incubation flows identified in previous studies (Bennett and Underwood 1988, Johnson 1997). At the highest flow for which all transects were measured (4050 cfs at the Harvard gage), velocities were low over the spawning gravels at both sites. Therefore, the depth-calibration option (zero-velocity option) of IFG4 was used. In this option, cell velocities are based on known total discharge and depth at each cell, rather than actual measured velocities.

6. The results of the hydraulic simulation were combined with habitat suitability index (HSI) curves for spawning and incubation to generate weighted useable area (WUA) vs. discharge for these two spawning sites. Weighted useable area numbers from the model are in units of ft^2/1,000 ft of stream length. These values were converted to total available area by multiplying the WUA by the length of the site in feet divided by 1,000 feet.

Topographic assessment method

A detailed survey of the near-shore areas in the selected spawning sites was undertaken. Sokkia SET 300 and Leica TC 307 total stations with TDS Ranger and Sokkia SDR33 data loggers were used to survey the topography and describe the distribution of gravel in these areas. Areas of gravel were identified and classified according to dominant, sub-dominant and percent dominant substrate according to the classification attached in Appendix 1.

In order to assess the influence of flows on rainbow trout spawning and incubation habitat, we developed a modified wetted-area method. Topography generated from detailed surveys and the stage-discharge relationships determined for the PHABSIM analysis were combined to determine total submerged area for a range of flows at each site. In contrast to PHABSIM, this technique determines the total area at each site covered by various depths of water without extrapolating longitudinally from point measurements along a transect. Unlike PHABSIM, however, it does not include velocity measurements. Water surface elevations were simulated for flows from 2,000 to 15,000 cfs using the techniques described above.

Based on HSI information developed for the transect analyses, surveyed habitat was considered suitable for rainbow trout spawning if the substrate was gravel (0.1-3.0 inch) and the depth was equal to or greater than 1.0 feet. Habitat was considered suitable for incubation if substrate was gravel (0.1-3.0 inch) and depth was equal to or greater than 0.1 foot (i.e., the redd would remain

wetted). As noted above, for purposes of this measure of spawning and incubation habitat, it was assumed that water velocity was suitable in all areas meeting the above substrate and depth criteria. Based on these simplified suitability measures, estimates of the total and available spawning and incubation habitat were developed for a range of Post Falls HED discharge and Spokane River flows. Using this information, target incubation flow ranges to protect rainbow trout redds could be established based on the range of flows at which spawning occurred in a given year.

Monroe Street Reach Spawning and Incubation

Spawning habitat within this reach consists of small patches of suitable spawning substrates located primarily amidst vegetation along banks of the river. The habitat characteristics are heavily influenced by brush and larger vegetation, thus the interaction of varying depth, velocity, and substrate combinations cannot easily be assessed by standard PHABSIM-type methodologies.

Several areas of rainbow trout spawning activity were identified during earlier spawning surveys conducted in this reach by Parametrix (2003). Two of these sites, Peaceful Valley and Evergreen Road, were selected by the FWG for analysis as part of the present study (see Figures 1, 4, and 5). Several redds were located in these areas and flagged as part of the Parametrix surveys.

The techniques employed at the Evergreen and Peaceful Valley sites to evaluate the influence of flows on rainbow trout spawning and incubation were generally the same as the topographic analyses performed at the Harvard Road and Starr Road Bar sites, as described above. At each site, topography and substrate conditions were delineated for several small patches of suitable gravel. As was done at the upstream sites, water surface elevations and discharge were determined at four flows, and a stage-discharge relationship was determined based on these data and a step-backwater model. Water surface elevations affecting the gravel patches were simulated for flows up to 12,000 cfs.

Post Falls Reach Juvenile and Adult Rearing

The objective of this analysis was to determine the habitat-flow relationship through estimation of weighted usable area (WUA) for juvenile and adult rainbow trout in the Post Falls reach during the summer low-flow period. The Post Falls Reach was singled out for this study because summer flows in parts of the reach are significantly diminished by losses to groundwater, and because parts of the reach have abundant populations of rainbow trout.

1. Site-specific HSI curves were developed based on a snorkeling study carried out by NHC and HDI in July 2003. The observations were combined with literature data to generate HSI curves for three size classes of resident rainbow trout: Juvenile I (2.5-4 inches), Juvenile II (4-9.5 inches) and adult (>=10 inches). Proposed depth and velocity curves for these three life stages were circulated to Hal Beecher (WDFW) and the FWG in November 2003. Following some minor revisions, appropriate HSI curves for use in this study were agreed upon (Appendix 2).

2. We identified recommended transect locations in the Post Falls Reach to represent a variety of habitat types and hydrological conditions. We conducted a site visit with interested parties and confirmed five transect locations (Table 1).

3. We made PHABSIM measurements at each transect for the 3-velocity IFG4 methodology (Milhous et al. 1981). Measurements were made at Post Falls HED flow releases of approximately 500, 1500, and 2500 cfs, though the actual downstream flows at each of the five transects varied from site to site (Table 2).

4. The 3-velocity IFG-4 program was used to simulate hydraulic conditions at each transect at a range of flows corresponding to dam releases of approximately 300 to 2,500 cfs. The upper extrapolation range was 2500 cfs at each site; the lower extrapolation range at each site depended on the actual flows observed (affected by groundwater gains/losses) during the low-flow field measurements.

5. The hydraulic simulation data were combined with the HSI criteria to generate weighted useable area (WUA) as a function of flow at each transect location.

RESULTS

Post Falls Reach Spawning and Incubation

Transect assessment of spawning and incubation

Transect profiles at the Harvard Road and Starr Road Bar sites are shown with water surface elevations for the measured flows superimposed in Figures 6a-c and 7a-c. Simulated water surface elevations (WSEL) compared favorably with measured WSEL's.

The velocities predicted by the model are approximate, since they were based on cross-sectional shape only (i.e., using the depth-calibration option; see Methods), and not on measured velocities at 4050 cfs. Predicted velocities at each simulated flow are listed in Appendix 3.

Weighted useable area numbers were converted to total available area, in order to compare the results directly with those of the topographic method. Available area as a function of discharge at the Harvard Road and Starr Road Bar spawning sites is given for rainbow trout spawning and for incubation in Figures 8 and 9.

At Harvard Road, available spawning area peaks at 6,400 ft^2 over a range of about 7,000 to 8,500 cfs, and declines at higher and lower flows. The decline at lower flows is based on water surface elevations interpolated from known values. The decline at higher flows may be affected by uncertainties in the HSI values for deep water (difficulties of observing redds in deep, fast water).

Available incubation area at the Harvard Road site shows a plateau of about 8,200 ft^2 at 6,000 to 8,500 cfs, with a very slight decline at higher flows. This indicates that little or no incubation area is lost as flows drop from 15,000 down to 6,000 cfs. From 6,000 down to 4,500 cfs, available incubation area drops by about 15%. Below 4,500 cfs, incubation area drops sharply, indicating that substantial redd desiccation becomes more likely as flows drop below 4,500 cfs.

For the Starr Road Bar site, available spawning area is highest over a range of about 7,500 to 10,500 cfs; the maximum value is 9,600 ft^2 at a flow of 9,000 to 9,500 cfs. It declines with a moderately steep slope as flows drop below 7,000 cfs.

Available incubation area at the Starr Road Bar site reaches a plateau of about 15,000-16,000 ft^2 at flows from 8,500 to 13,500 cfs. As flows drop below 9,500, incubation area declines; the slope becomes steeper as flows drop below about 6,500 cfs.

Topographic assessment of spawning and incubation sites

The topographic maps of spawning habitat enable calculation of suitable spawning area based on water depth and substrate. Based on the HSI curves, areas with suitable gravel (0.1 – 3.0 in.) and depths greater than 1.0 ft were considered suitable for spawning, and depths greater than 0.1 ft suitable for incubation.

For the Harvard Road site, available spawning and incubation area curves parallel each other, with both declining at a roughly constant slope as flows decrease (Figure 10). The decline in spawning area becomes steeper below about 4,500-5,000 cfs. The decline in incubation area is steepest below about 4,000 cfs. Maximum values for spawning and incubation are about 9,000 ft^2 and 11,000 ft^2, respectively, reached at the upper limit of the modeled flows (15,000 cfs).

Figures 11a-d address the effectiveness of spawning habitat (i.e., ability to maintain suitable habitat conditions through the incubation period), showing the percent change in incubation habitat as flows drop below selected spawning flows. For example, if spawning occurs at 12,000 cfs, all of the area that had been suitable for spawning at 12,000 cfs remains suitable for incubation until flows drop below 8,500 cfs; if spawning occurs at 6,000 cfs, incubation area starts to decline below 4,500 cfs.

For the Starr Road Bar site, the area of suitable spawning habitat declines gradually, with a slightly increasing slope, as flows drop to about 6,500 cfs. The drop is steeper from about 6,500 to 4,500 cfs before again flattening out a bit below 4,500 cfs. As flows decrease below 8,500 cfs, incubation area decreases at a faster rate than it does at higher flows (Figure 12). Incubation area also drops sharply below 4,000 cfs. Maximum values for spawning and incubation area are about 16,000 ft^2 and 18,000 ft^2, respectively.

Similar to the effective spawning area analysis conducted for the Harvard Road site, Figures 13a-d show the percent change in incubation habitat at the Starr Road Bar site as flows drop based on selected spawning flows. If spawning occurs at 12,000 cfs, no incubation area is lost until flows drop to 7,000 cfs; if spawning occurs at 6,000 cfs, incubation area starts to decline steeply at flows below 4,000 cfs.

Comparison of transect and topographic assessments

Figures 14 and 15 compare spawning and incubation results for the two methods. For Harvard Road, correspondence is close up to about 8,500 cfs; at higher flows, the topographic estimate continues to increase, while the transect estimate declines. This pattern is similar for spawning and incubation. For the Starr Road Bar site, the two spawning curves diverge widely at higher flows, but the divergence for the two incubation curves is slight.

Monroe Street Reach Topographic Assessment of Spawning and Incubation

Peaceful Valley Site

A regression model was used to estimate water surface elevations up to 12,000 cfs; from 2,000 to 12,000 cfs, the estimated change in stage was about 3.5 feet. Measured and modeled stage-discharge

data for both sites are summarized in Appendix 4. The stage-discharge relationship is subject to some uncertainty at the highest flows simulated, since no measurements were made above 3,680 cfs at this site. The regressions for gravel area, water surface level and flow were combined to calculate the area of rainbow trout spawning habitat available for a range of flows (Figure 16).

At 12,000 cfs, suitable spawning area at the Peaceful Valley site is 1750 ft^2 and still increasing. It declines steeply, in a near-linear fashion, as flows decrease down to 5,500 cfs, at which point no suitable spawning habitat remains.

Suitable incubation area at the Peaceful Valley site is maximized at nearly 1,900 ft^2 once flows reach 8,000 cfs (Figure 16). Incubation area drops sharply below 7,000 cfs, losing about 70% of its value between 7,000 and 5,000 cfs, and all suitable habitat is lost at 3,500 cfs.

Evergreen Road Site

For this site, an additional stage measurement was made at 8,650 cfs. In a similar fashion to the Peaceful Valley site, regressions were performed on the data using a power function, and a stage-discharge relationship was developed for flows up to 12,000 cfs (Appendix 4).

At 12,000 cfs, suitable spawning area at the Evergreen Road site is just over 1,950 ft^2. Spawning area here declines steeply with declining flows; less than half the total remains at 8,500 cfs. Virtually no suitable spawning area remains when flows fall to 7,000 cfs. Suitable incubation area reaches a maximum of almost 1,960 ft^2 at flows of 10,500 cfs and above. Suitable incubation area here declines steeply as flows drop below 9,000 cfs. Less than half the incubation area remains at 7,000 cfs, and almost no incubation area remains below 5,500 cfs (Figure 17).

Spawning Habitat and Flow Ranges for Effective Spawning

The relationship between spawning flow and effective incubation conditions (i.e. at least 0.1 ft. water depth) was examined for the study sites at Monroe Street Reach in the same manner as for the upper reach sites, by plotting the percentage of suitable incubation area that remains as flow is reduced following four different spawning flows. At the Peaceful Valley site, effective incubation area drops sharply as flow decreases below all four spawning flows once a threshold flow is reached. If spawning occurs at 12,000 cfs, incubation area declines steeply below 7,500 cfs; if spawning occurs at 6,000 cfs, incubation area declines steeply below 4,000 cfs (Figure 18a-d).

At the Evergreen Road site, the decline in effective incubation is steeper than at the Peaceful Valley site. For a spawning flow of 12,000 cfs, incubation area begins to decline at 10,500 cfs, and is more than half gone at 7,000 cfs. If spawning at this site occurs at a flow of 6,000 cfs, all the incubation area remains suitable down to 4,500 cfs, but it is all gone at 4,000 cfs (Figure 19a-d).

Post Falls Rearing Habitat

Measured and simulated WSEL's and velocities were compared for the simulation range of interest (300 to 2,500 cfs at the two upstream sites, 50 to 2,500 cfs at the others); no anomalous values were noted. Complete calibration details for the five rearing transects are listed in Appendix 5.

Flow release from Post Falls HED is diminished by losses to groundwater downstream to about Sullivan Road, where groundwater begins to return to the channel. Therefore, weighted useable area

was calculated and is discussed below in terms of flow at the site for each transect ("Site Flow"), and in terms of discharge at the HED for combined transects ("Dam Release Flow").

Individual Transect Sites

McGuire Park Site: Adult and Juvenile II WUA show broad peaks at site flows of 500 to 800 cfs; over this same range, Juvenile I habitat is at its lowest point (Figure 20). Adult WUA declines steadily beyond about 850 cfs, but both juvenile curves show secondary peaks at higher flows.

Corbin Park Site: Juvenile I WUA is nearly constant at all flows (Figure 21). Juvenile II and Adult rearing curves show steady declines with increasing flows at this site.

Barker Road Site: Juvenile I habitat is highest at low site flows (50-150 cfs), then declines sharply (Figure 22). Juvenile II WUA rises steeply with increasing discharge, peaking at about 250-400 cfs. Adult WUA shows a broad peak beginning at about 500 cfs.

Sullivan Road Boulder-Glide Site: Adult WUA rises steeply from a low value at 50 cfs, peaking at about 200 cfs (Figure 23). Beyond 200 cfs, the WUA line shows a very gradual decline as flows increase. Juvenile I and II WUA curves show no clear pattern. They rise to maximum levels at 1,750 and 2,500 cfs, respectively; however, both these curves also show relatively high values at the lowest flows

Sullivan Road Cascade Site: Adult WUA is nearly constant above 150 cfs; below this value WUA declines sharply (Figure 24). Juvenile I and II WUA is highest at flows below 300 cfs, declining gradually as flows increase.

Combined Transect Sites

The relationship between dam release and flows at the rearing transects is displayed in Table 7. The numbers are based on regression analysis of flows from 1951 to 2002 (S. Miller, personal communication). Based on the regression, flow at the Barker Road transect is from 140 to 250 cfs less than dam release for the range of flows 250 to 3,500 cfs at the HED. It is important to note that these are average values; they will not always predict site flow accurately, depending on the water year and other factors.

Based on our transect measurements, flow at the Sullivan Road glide was about 25 cfs higher than Barker, and flow at the Sullivan Road cascade was about 50 cfs higher, for the range of flows measured in the field. Flows at the McGuire and Corbin Park transects were assumed to be equal to the measurements at McGuire Park gage.

Weighted useable area for combined transects was expressed in terms of Post Falls HED release. Results for three reaches (McGuire and Corbin Park, Barker Road, Sullivan Road glide and cascade) are plotted in Figures 25 to 27.

McGuire and Corbin Parks combined site: Low flows provide the highest WUA for adults and Juvenile II (Figure 25). For Juvenile I, the WUA curve is bimodal, with one peak at a flow of 300 cfs, and a second at about 1,600 cfs.

Barker Road site: The WUA curves for HED flows (Figure 26) has the same shape as Figure 22 (site-specific flows), but is offset because of the 140-250 cfs losses to groundwater that reduce flows at the transect location. Juvenile I WUA peaks at an HED discharge of 300 cfs. Juvenile II WUA rises steeply with increased flow, peaks at HED discharge of 400-500 cfs, then decreases. Adult WUA also rises steadily with increased HED discharge, with the largest values occurring at HED flows between about 750 and 1,300 cfs.

Sullivan Road glide and cascade combined site: Juvenile I WUA is high for HED discharges of 300 to 550 cfs, with a second, higher peak at a discharge of 2,000 cfs (Figure 27). Juvenile II WUA is high, and nearly flat, over an HED discharge range of about 300 to 700 cfs; it also has a second peak at 2,300-2,500 cfs. Adult WUA peaks at an HED discharge of 300-350 cfs; WUA is slightly less, but nearly constant, out to 900 cfs, then diminishes gradually with higher flows.

DISCUSSION

Post Falls Reach spawning and incubation

Differences between the two assessment methods

The transect method incorporates approximate velocity into the spawning WUA, while the topographic method is based on depth and substrate only. The HSI curves for the transect method have an upper depth limit (suitability declines above 2.5 ft, then is constant at 0.4 past depths of 4.0 ft.), while for the topographic method, any depth greater than 1 ft is considered optimal. The area estimate for the transect method is less precise than the topographic method; the former is based on rectangles derived from a relatively small number of points, while the latter is based on a complete areal survey incorporating many more points.

The transect method can give more accurate results for assessing spawning habitat, since point velocity measurements can be included. In this study, point velocity measurements were not made at any flow above 4,050 cfs; at this discharge, velocities over the spawning gravels were low compared to main-channel velocities. Extrapolating to higher discharges from these measurements would have been inaccurate. The depth-calibration method was employed in our upward simulations to give an approximation of the behavior of velocities at higher discharges, and is useful for detecting habitat trends. The two methods are similar for assessing incubation habitat; the topography method is probably slightly more precise, based on the larger number of measurements.

At the Harvard Road site, transect data and topographic data both indicate that the steepest declines in incubation and spawning area occur at flows below 5,000 cfs (Figure 14). The transect-based decline is steeper; this may be due to the smaller number of points making up the estimate, and to the influence (for spawning WUA) of velocity in the calculations.

At the Starr Road Bar site, available spawning habitat based on topography declines with decreasing flow over the whole flow range, with a fairly constant slope. The topography curve meets the transect curve at 7,500 cfs, and both curves then decline as flows decrease. The incubation curves

are nearly identical for the two methods; both show a steep decline as flow falls below 7,000 cfs (Figure 15).

For both sites, the flow at which incubation area begins to be lost depends strongly on the flow at which spawning occurs (see Figures 11 and 13).

Flow management for spawning and incubation

In order for rainbow trout fry to emerge successfully, flows must be sufficient during the incubation period (approximately April 1-May 31) so that the eggs and pre-emergent fry in the redds remain wetted. At present, Avista and the resource agencies have an open consultation each year to discuss how and when to make adjustments to Post Falls HED discharge during the incubation period, in an effort to minimize redd dewatering. These adjustments are based on direct observations of spawning and fry emergence, an approximate knowledge of the stage-discharge relationship at key spawning areas, and upstream lake levels and run-off conditions.

The information presented here could assist in future flow adjustments. Based on the transect and topographic data, the effects of flow alternatives can be assessed in terms of areal changes in spawning and incubation habitat. This type of quantitative assessment gives managers another tool for evaluating effects of the timing and magnitude of flow regulation during spawning and incubation periods. This could improve the management of Post Falls HED discharge during future spawning and incubation periods.

Monroe Street Reach spawning and incubation

The Peaceful Valley site appears sensitive to flow decreases. Almost no spawning habitat is available below 6,000 cfs, and effective incubation declines sharply as flows fall below any given spawning flow. The Evergreen Road site is more sensitive to flow decreases. Almost no potential spawning habitat is available below 7,500 cfs, and effective incubation declines steeply for any given spawning flow. Another consideration for spawning and incubation flows at the Evergreen Road site is the inflow from Hangman (Latah) Creek. The pattern of inflow from this creek (Appendix 6) could influence the stage-discharge relationship at the Evergreen site during both spawning and incubation.

Post Falls Reach juvenile and adult rearing

As flows decrease in the McGuire and Corbin (Idaho) sites, there is no major loss of rearing habitat. In fact, for these two sites combined, low flows appear to be better than high flows in terms of rearing habitat. Current minimum flow releases from Post Falls HED are probably adequate at these two sites in terms of physical habitat for trout.

At the Barker site, WUA for adults and larger juveniles drops steeply as site flows (at the transect) drop below about 500 cfs and 200 cfs, respectively. This wide, shallow riffle site is probably more suitable for juvenile habitat and invertebrate production than for adult habitat, thus site flows in the 200 cfs range are probably not detrimental in terms of physical habitat.

At the Sullivan sites, 150-200 cfs (site flow) appears to provide optimum levels of WUA for all three life stages of rainbow trout. These transects are probably the most important for assessing rearing habitat conditions and flow relationships in the Post Falls reach, since most of the trout observed in the July field studies were observed here.

Post Falls HED discharge

Based on the information we collected, the most important considerations for rainbow trout rearing and adult habitat in the Post Falls Reach are to maintain (if possible) sufficient flow in the Sullivan Road area, and to avoid dewatering the Barker Road area. Based on the combined site WUA expressed in terms of HED discharge, discharges of about 400 cfs at the Post Falls HED provide near-maximum WUA for all three trout rearing stages in the important Sullivan Road reach (see Figure 27). Flow releases of about this same range also provide good physical habitat potential for juvenile trout in the Barker Road reach (see Figure 26). Good physical habitat for adult trout in the Barker Road reach (if this life stage is a management objective here) would occur at a Post Falls HED release of about 700 cfs. While all life stages are essential, the fisheries management agencies have indicated they believe it is the mature age classes (those with spawning potential) that possibly limit the population over time in the Spokane River and are therefore a primary consideration for minimum flow needs.

This study provides information on the likely effects of various flows on physical habitat in the Spokane River. The effects of flow changes on physical habitat are an important consideration for the assessment of flow management alternatives in the Spokane River. Other factors, such as water temperature and groundwater gains and losses, may also need to be considered before recommended flows can be agreed upon.

REFERENCES

Bennett, J.H. and T.J. Underwood 1988. Population dynamics and factors affecting rainbow trout (Salmo gairdneri) in the Spokane River, Idaho. Department of Fish and Wildlife Resources, College of Forestry, Wildlife, and Range Sciences, Univ. of Idaho, Moscow, ID.

Johnson, E. 1997. Upper Spokane River rainbow trout spawning and emergence study for 1995 and 1996. Avista Utilities.

Milhous, R.T., D.L. Wegner, and T. Waddle. 1981. User's guide to the Physical Habitat Simulation System. Instream Flow Information Paper No. 11. U.S. Fish and Wildlife Service FWS/OBS-81/43.

Northwest Hydraulic Consultants and Hardin-Davis, Inc. 2003. Habitat suitability information for the Spokane River.

Parametrix 2003. Rainbow trout spawning survey, 2003. Final report. Prepared for Fisheries Work Group, Spokane River Project Relicensing. Parametrix. Kirkland, WA.

WDFW 2003. Draft. Instream Flow Study Guidelines: technical and habitat suitability issues. Olympia, WA.

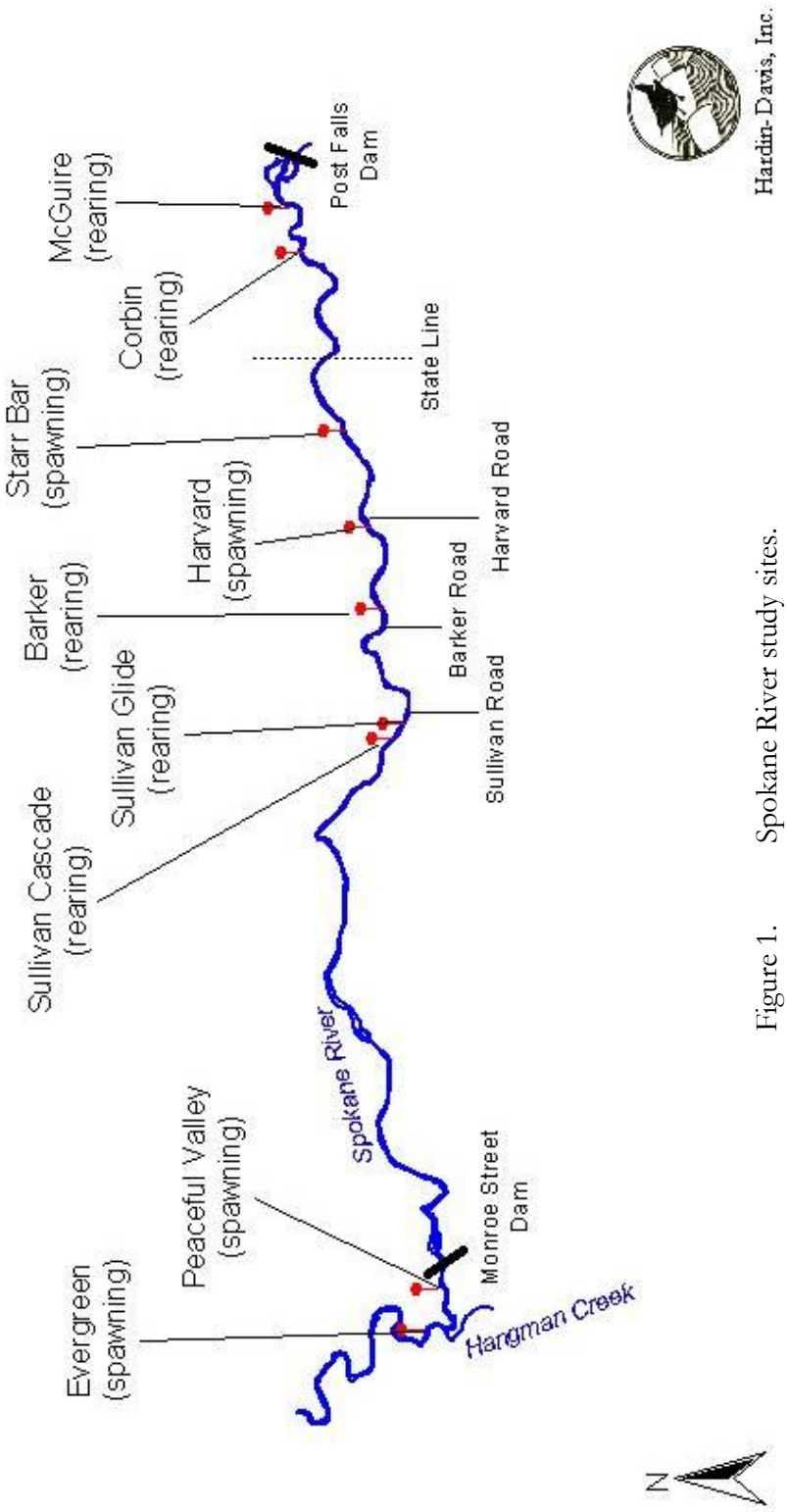


Figure 1. Spokane River study sites.

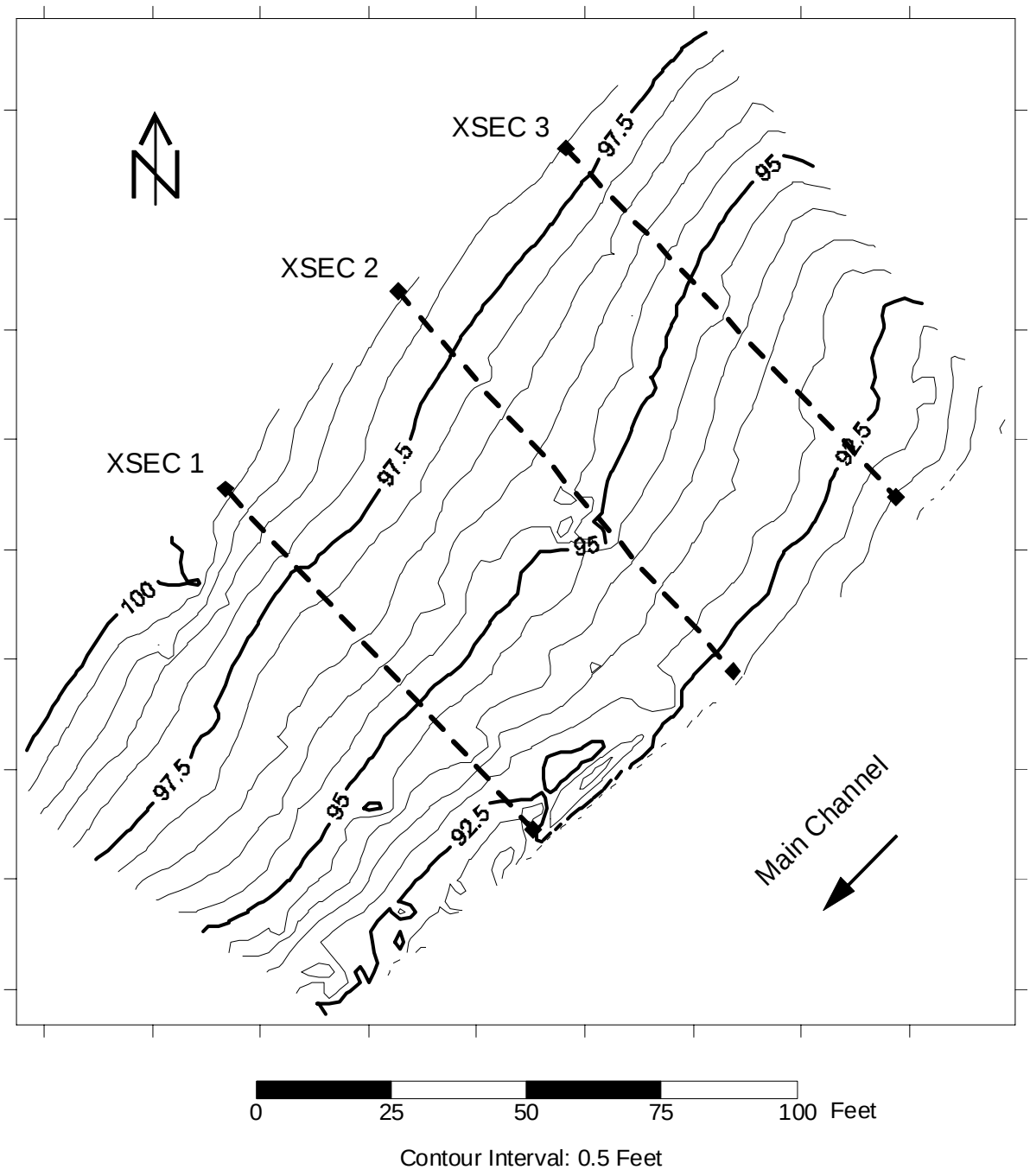


Figure 2. Map of Harvard Road spawning site showing location of PHABSIM transects (distances and elevations in feet).

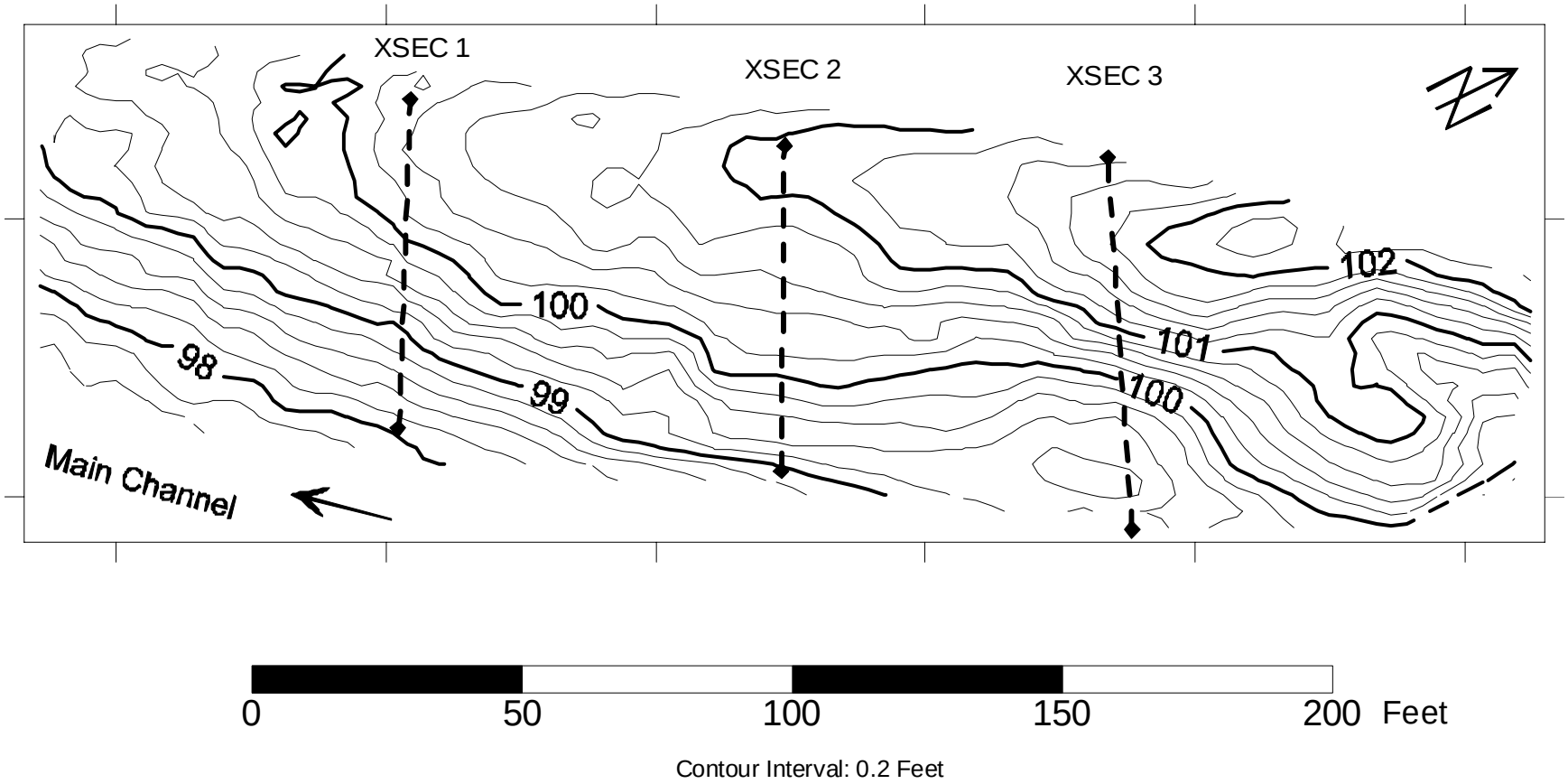


Figure 3. Map of Starr Road Bar spawning site showing location of PHABSIM transects (distances and elevations in feet).

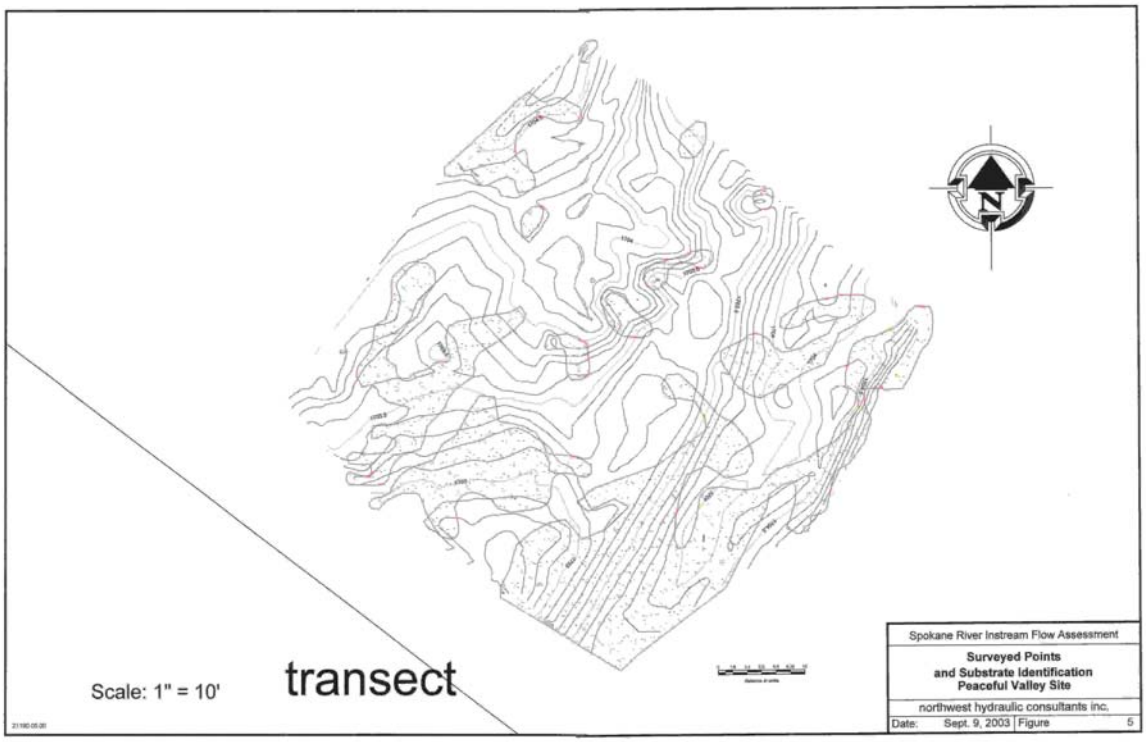


Figure 4. Map of Peaceful Valley spawning site.

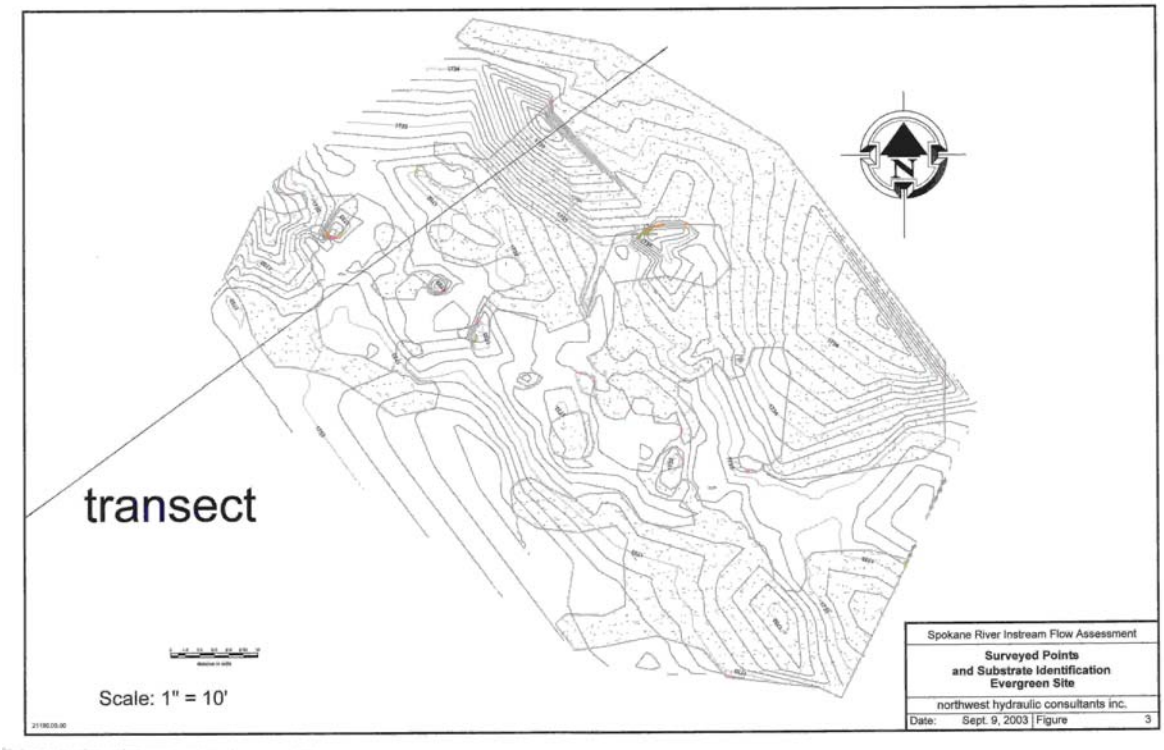


Figure 5. Map of Evergreen spawning site.

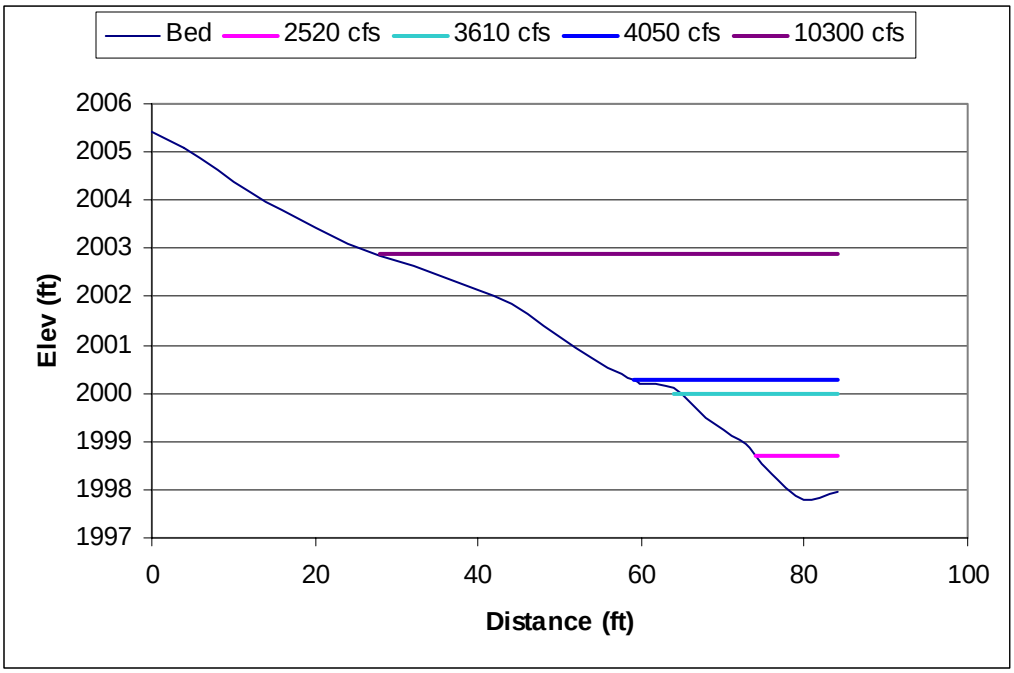


Figure 6a. Measured water surface elevations at Harvard Road transect 1 (vertical scale exaggerated).

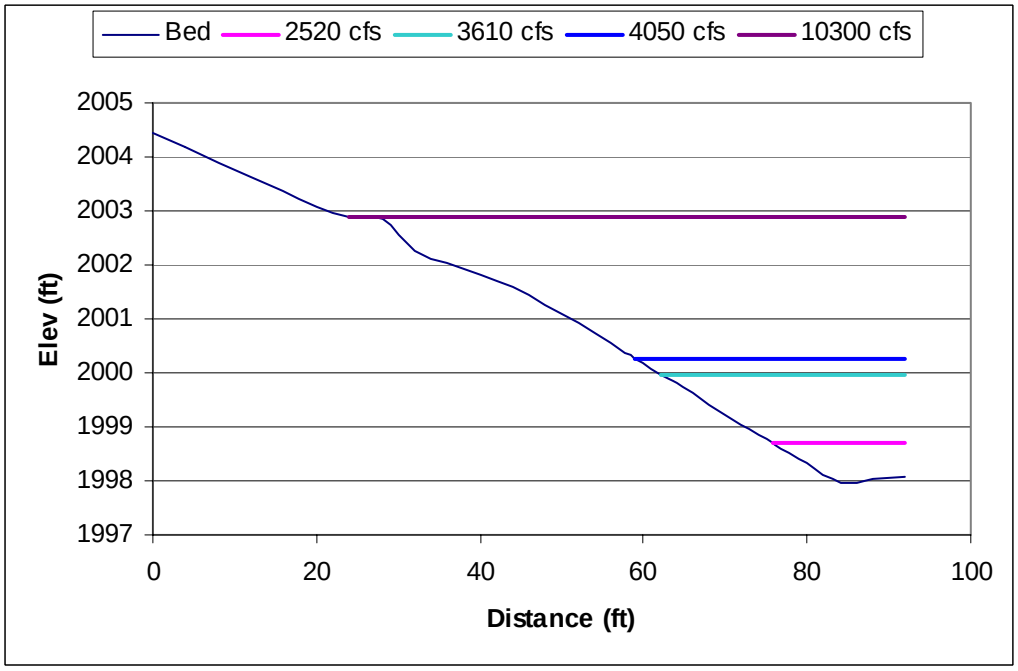


Figure 6b. Measured water surface elevations at Harvard Road transect 2 (vertical scale exaggerated).

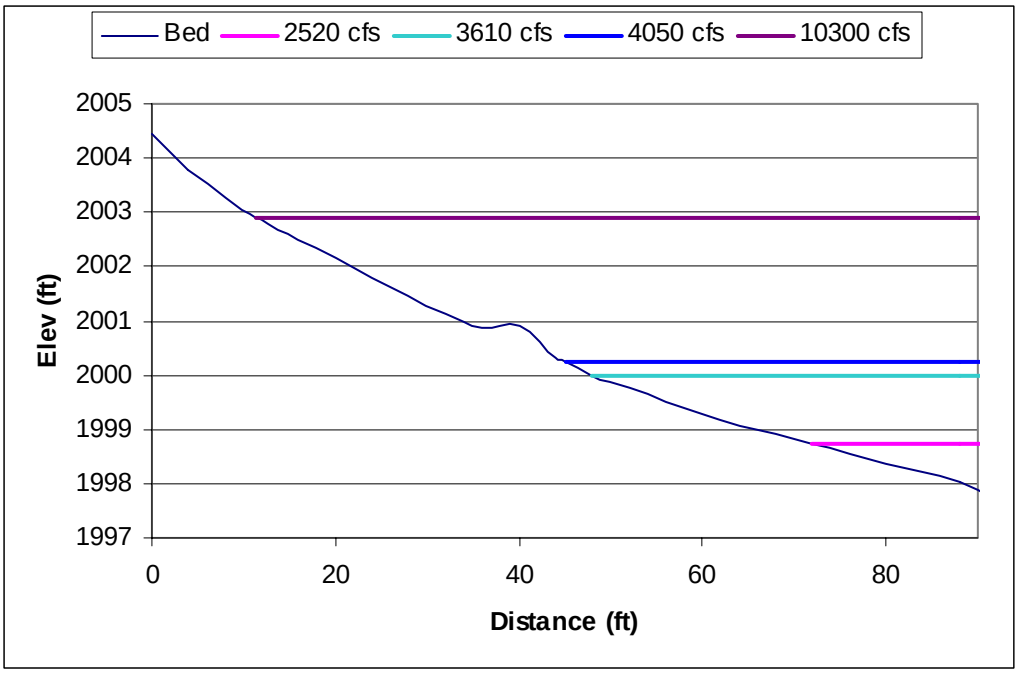


Figure 6c. Measured water surface elevations at Harvard Road transect 3 (vertical scale exaggerated).

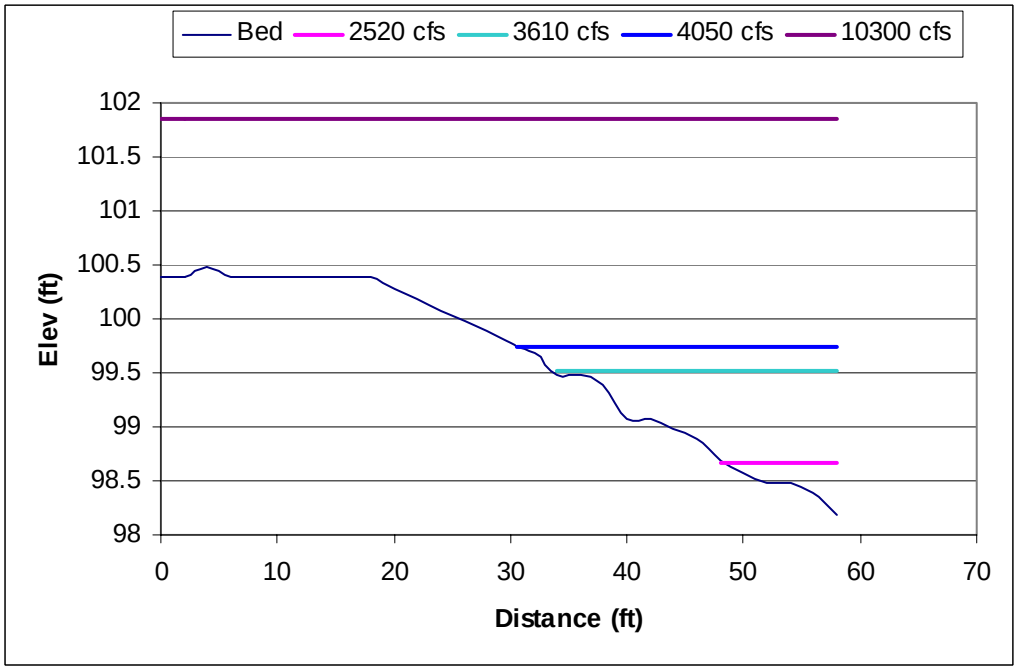


Figure 7a. Measured water surface elevations at Starr Road Bar transect 1 (vertical scale exaggerated).

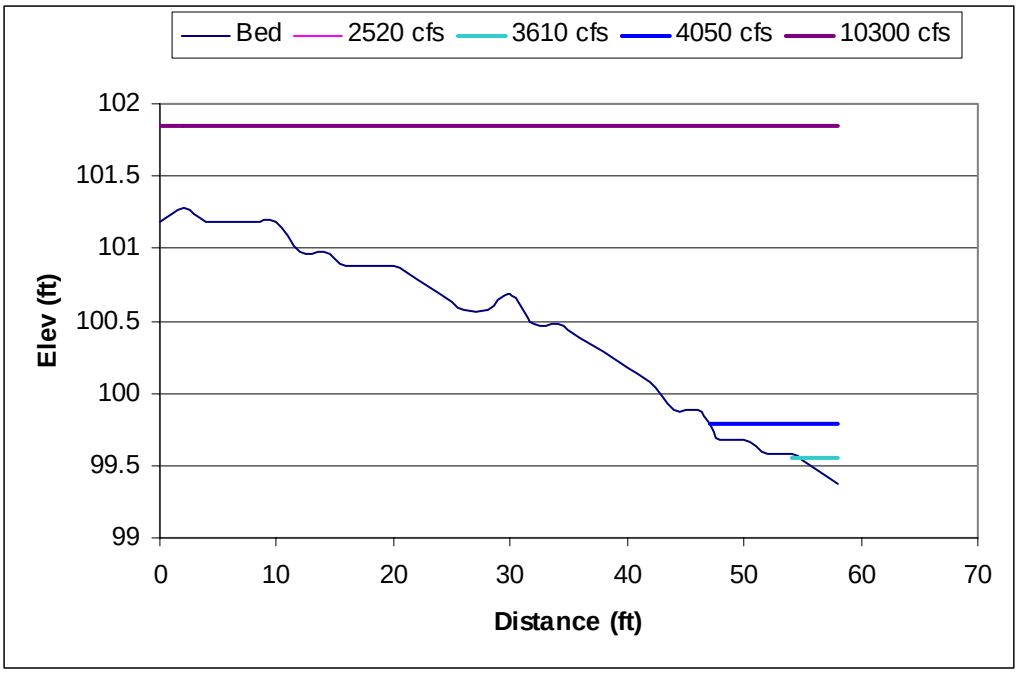


Figure 7b. Measured water surface elevations at Starr Road Bar transect 2 (vertical scale exaggerated).

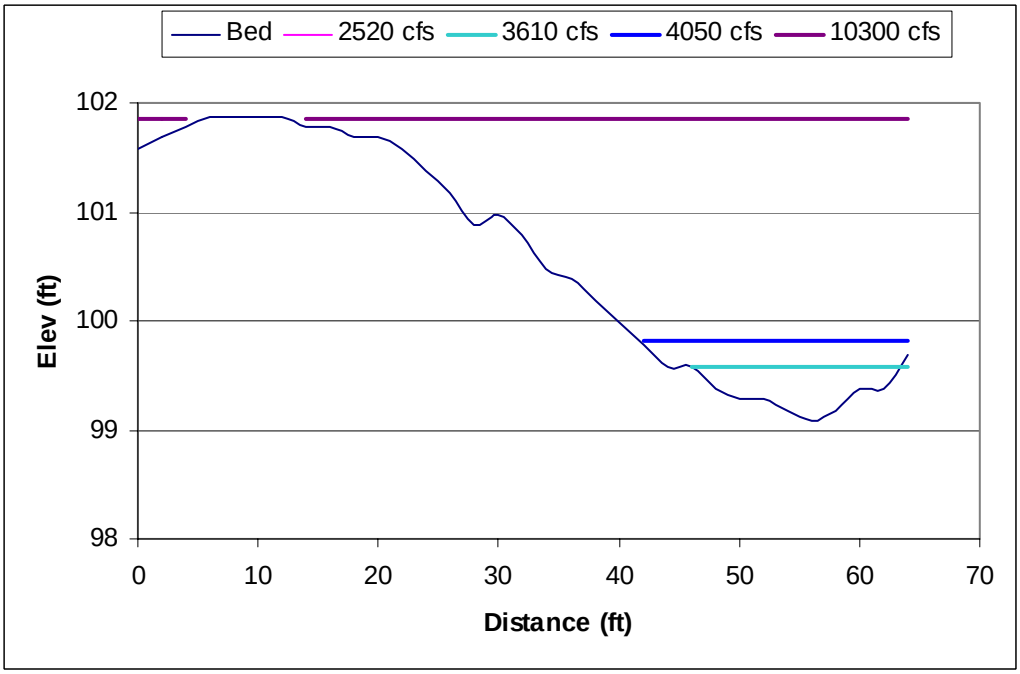


Figure 7c. Measured water surface elevations at Starr Road Bar transect 3 (vertical scale exaggerated).

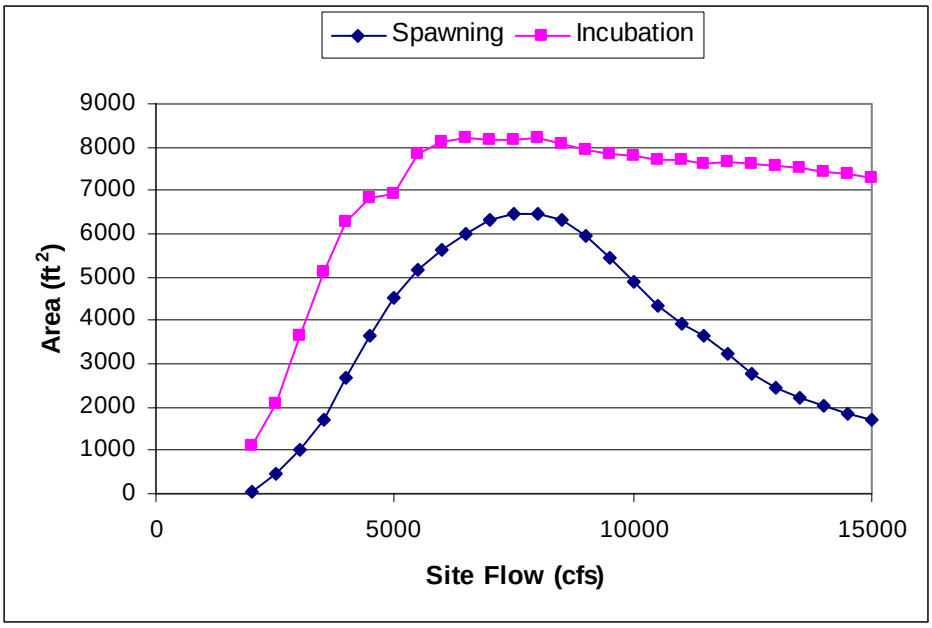


Figure 8. Available area vs. discharge for rainbow trout spawning and incubation at Harvard Road transects (PHABSIM).

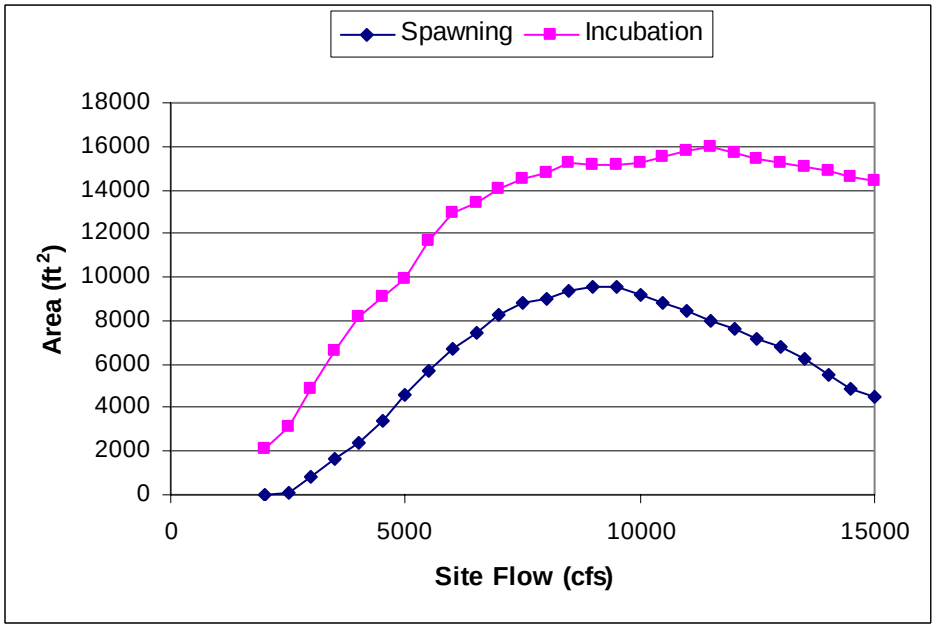


Figure 9. Available area vs. discharge for rainbow trout spawning and incubation at Starr Road Bar transects (PHABSIM).

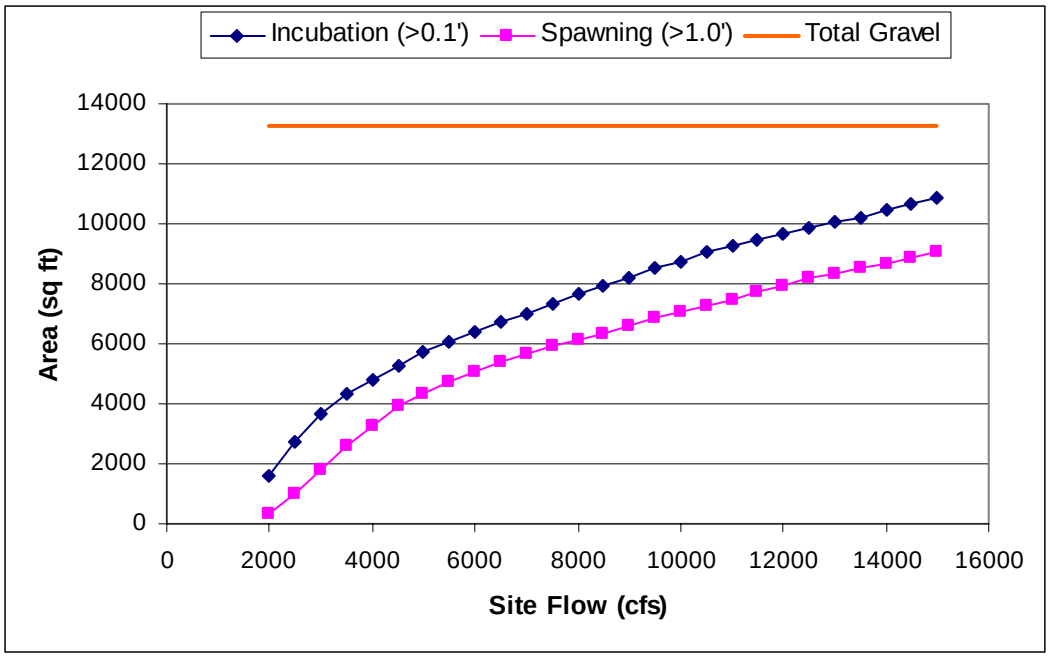


Figure 10. Spawning and incubation area at Harvard Road based on surveyed topography.

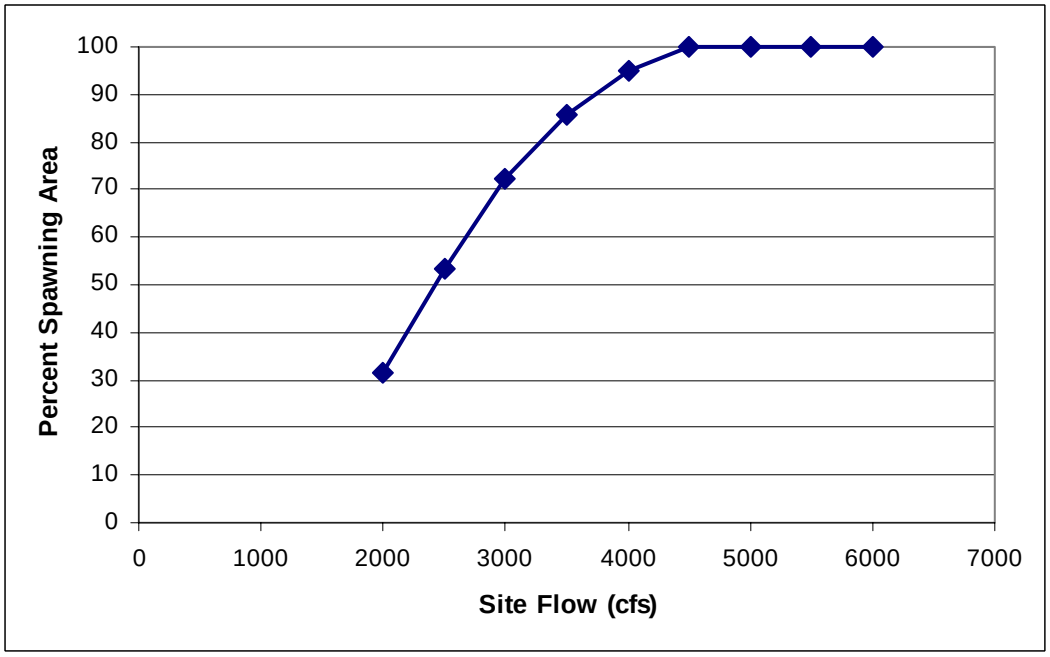


Figure 11a. Percent of 6000 cfs spawning area available for incubation at the Harvard Road site (based on surveyed topography).

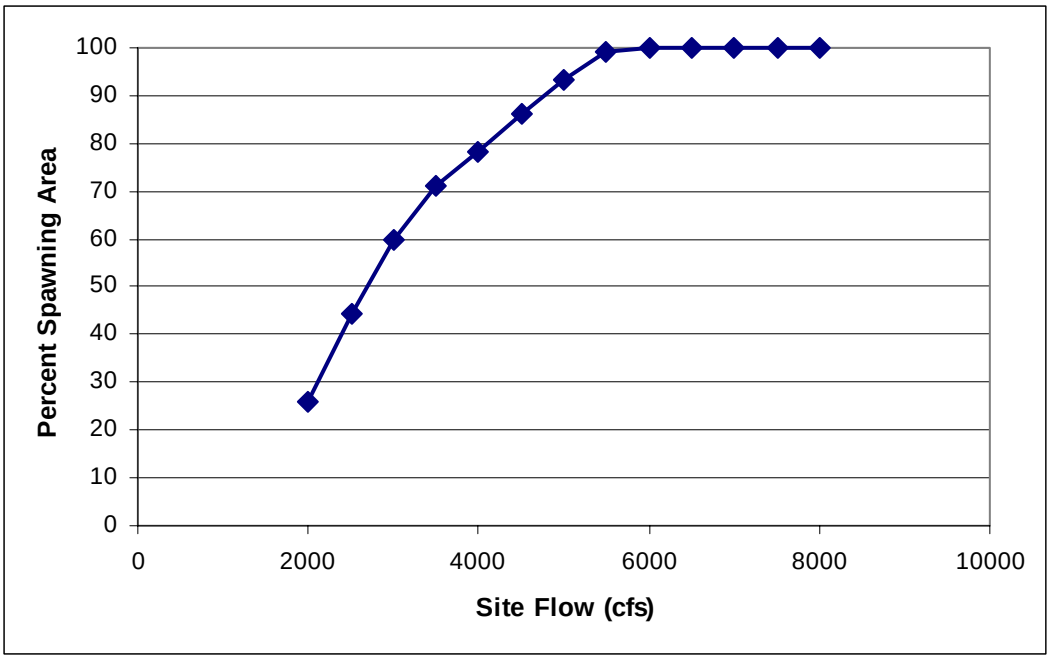


Figure 11b. Percent of 8000 cfs spawning area available for incubation at the Harvard Road site (based on surveyed topography).

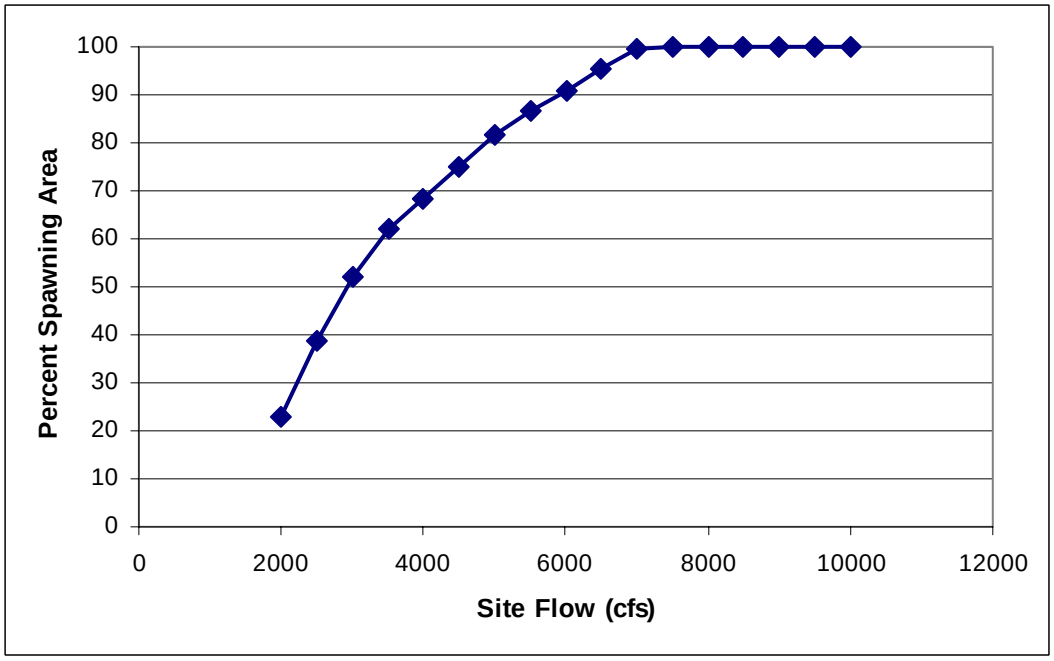


Figure 11c. Percent of 10,000 cfs spawning area available for incubation at the Harvard Road site (based on surveyed topography).

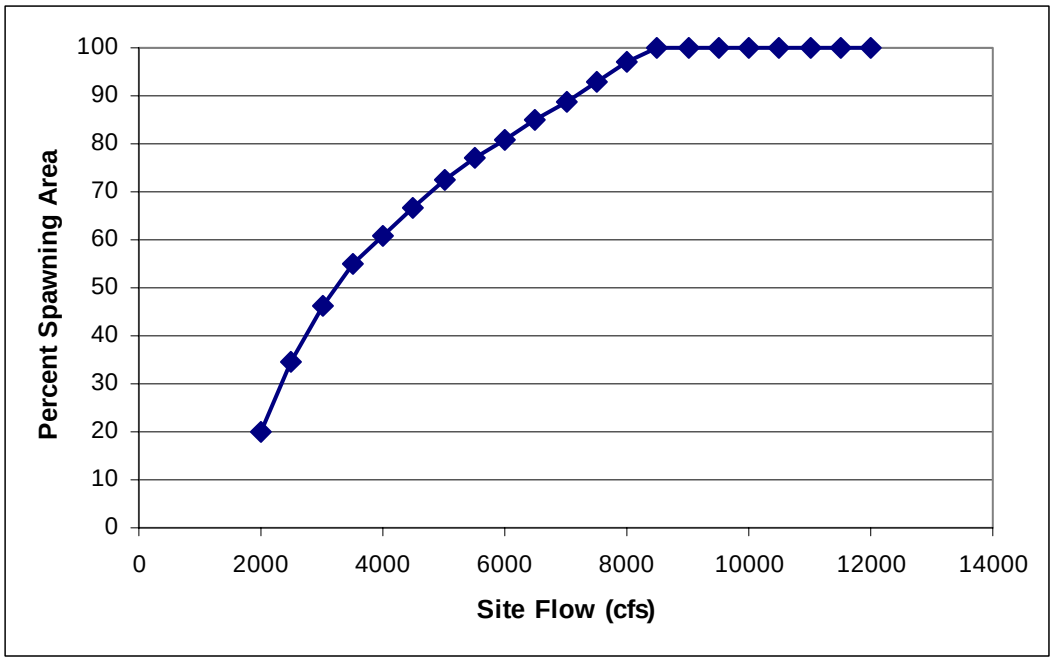


Figure 11d. Percent of 12,000 cfs spawning area available for incubation at the Harvard Road site (based on surveyed topography).

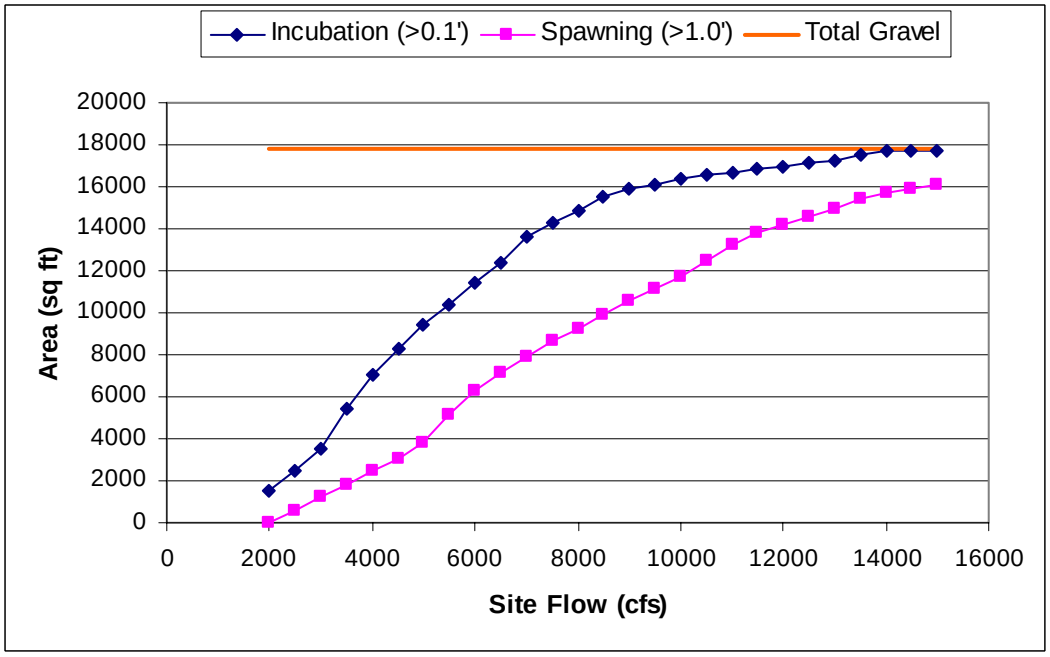


Figure 12. Spawning and incubation area at Starr Road Bar based on surveyed topography.

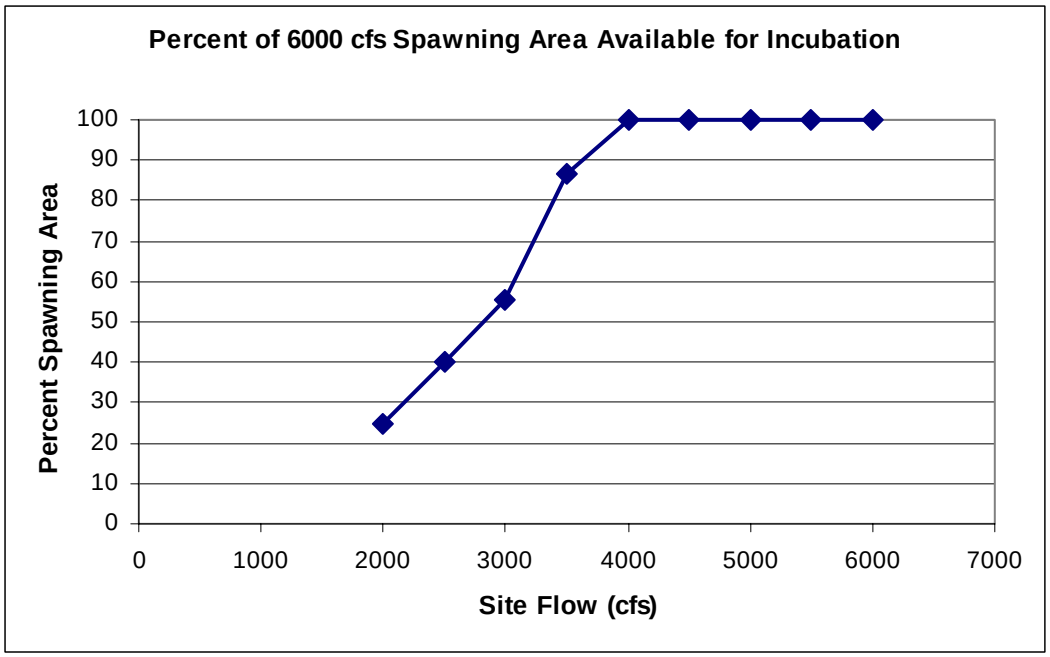


Figure 13a. Percent of 6000 cfs spawning area available for incubation at the Starr Road Bar site (based on surveyed topography).

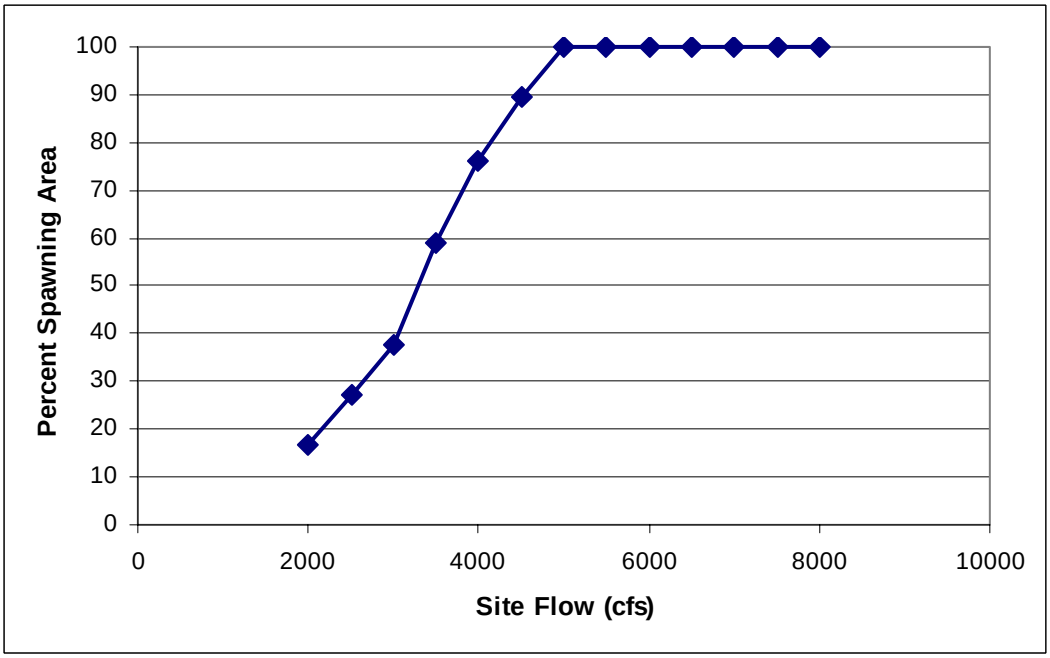


Figure 13b. Percent of 8000 cfs spawning area available for incubation at the Starr Road Bar site (based on surveyed topography).

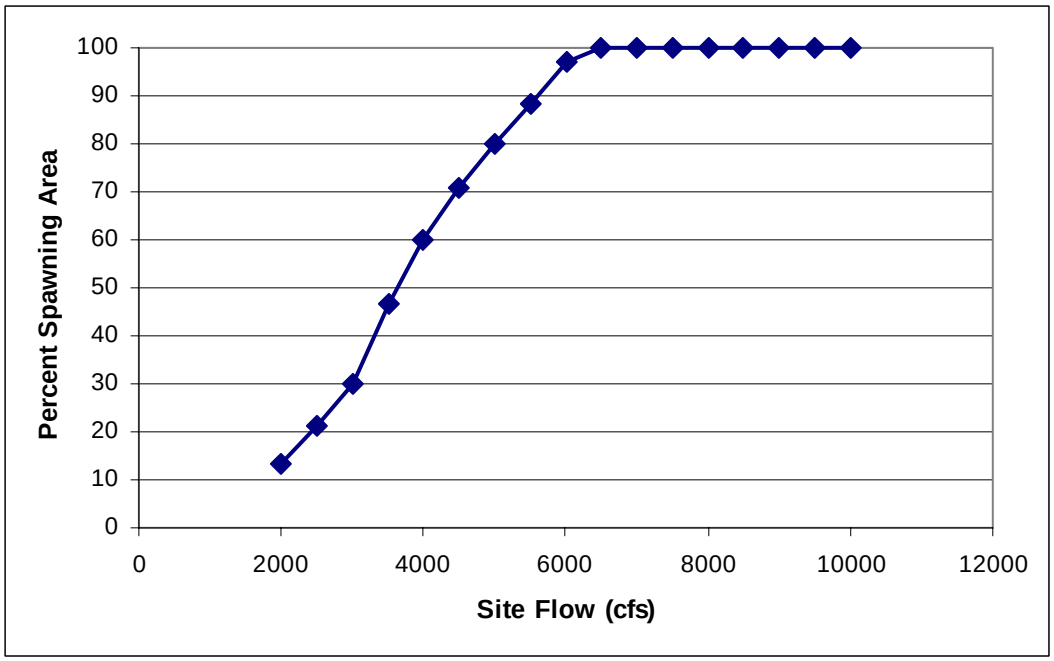


Figure 13c. Percent of 10,000 cfs spawning area available for incubation at the Starr Road Bar site (based on surveyed topography).

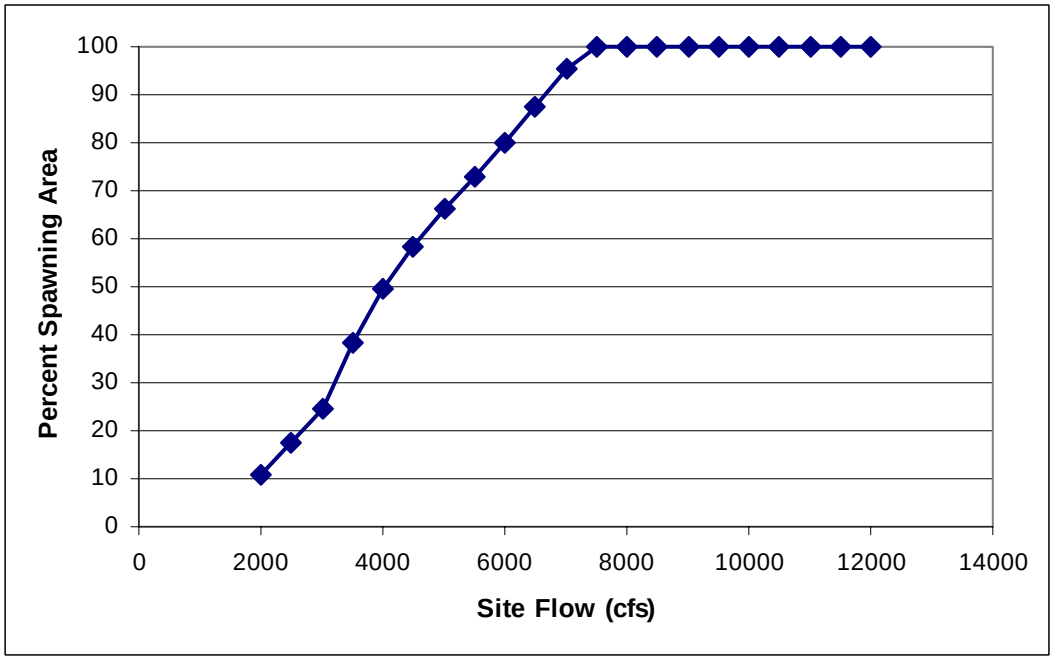


Figure 13d. Percent of 12,000 cfs spawning area available for incubation at the Starr Road Bar site (based on surveyed topography).

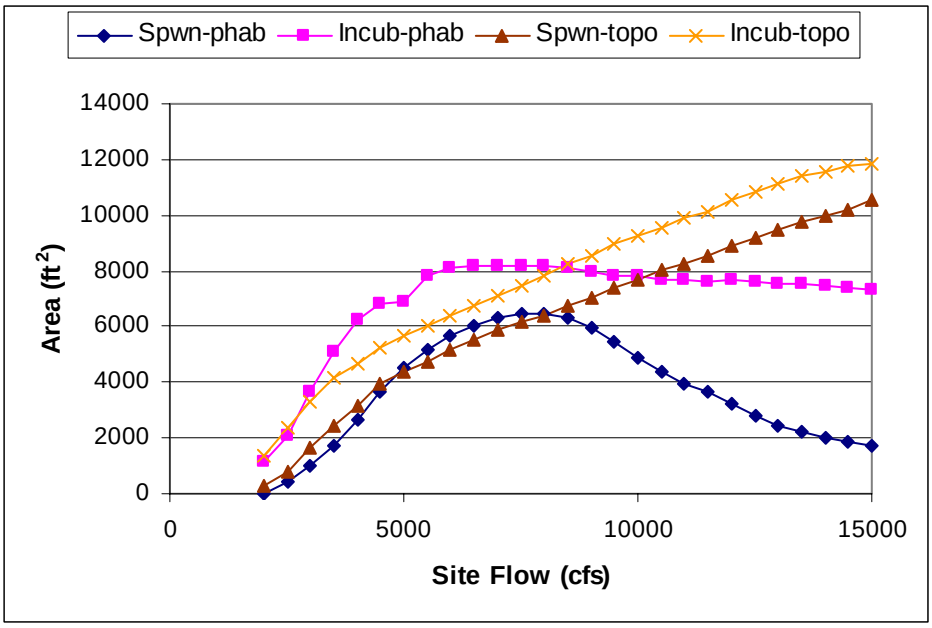


Figure 14. Comparison of available area vs. flow for rainbow trout spawning and incubation at the Harvard Road site using two different methods: PHABSIM and topographic analysis.

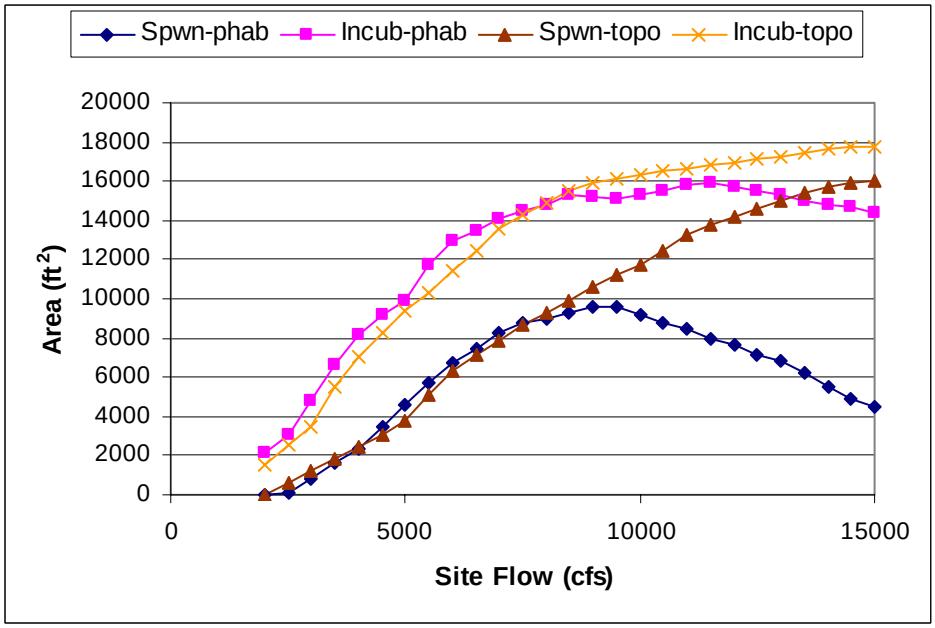


Figure 15. Comparison of available area vs. flow for rainbow trout spawning and incubation at the Starr Road Bar site using two different methods: PHABSIM and topographic analysis.

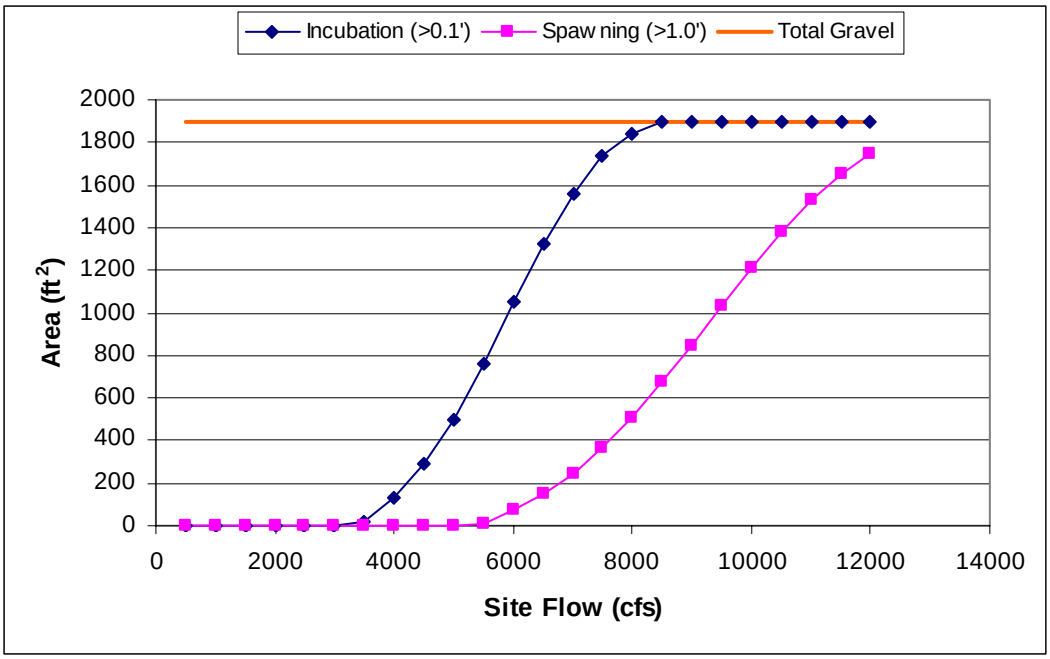


Figure 16. Spawning and incubation area at Peaceful Valley site based on surveyed topography.

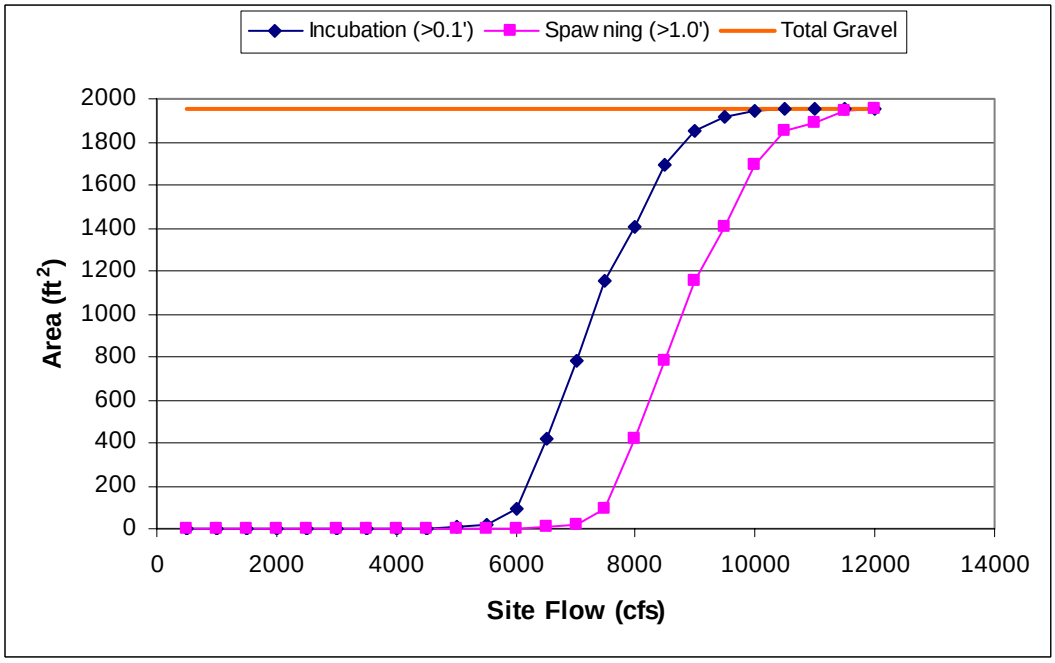


Figure 17. Spawning and incubation area at Evergreen site based on surveyed topography.

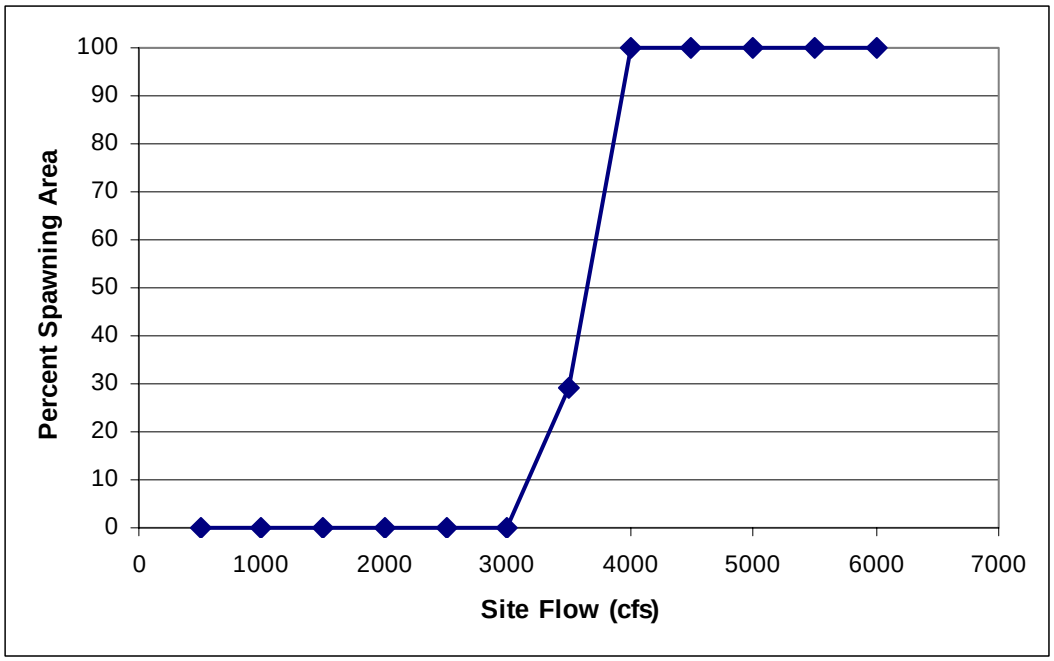


Figure 18a. Percent of 6000 cfs spawning area available for incubation at the Peaceful Valley site.

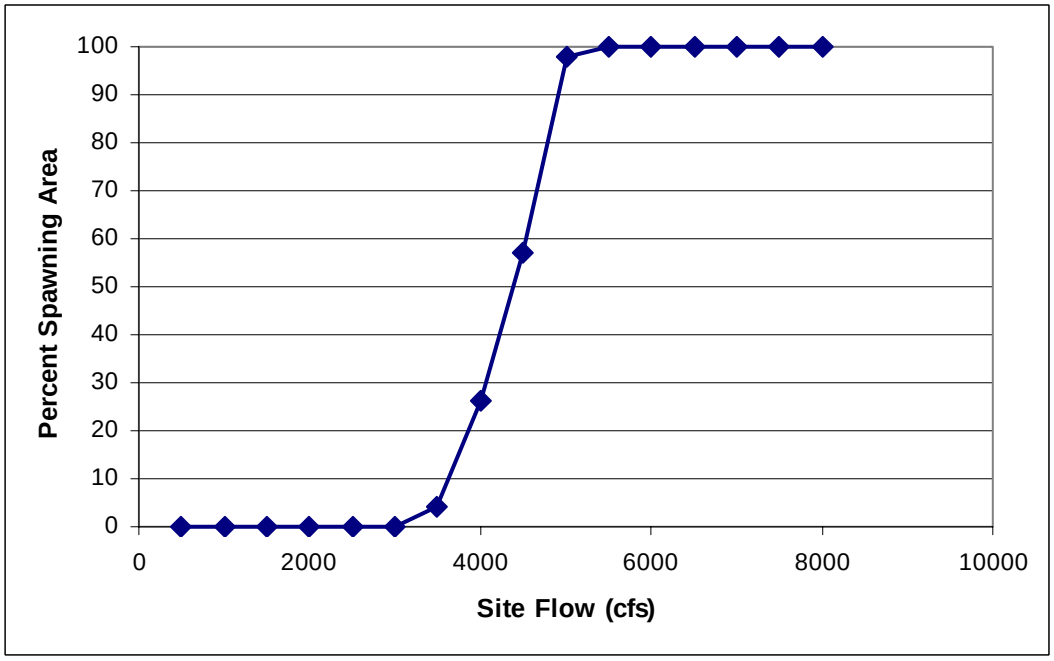


Figure 18b. Percent of 8000 cfs spawning area available for incubation at the Peaceful Valley site.

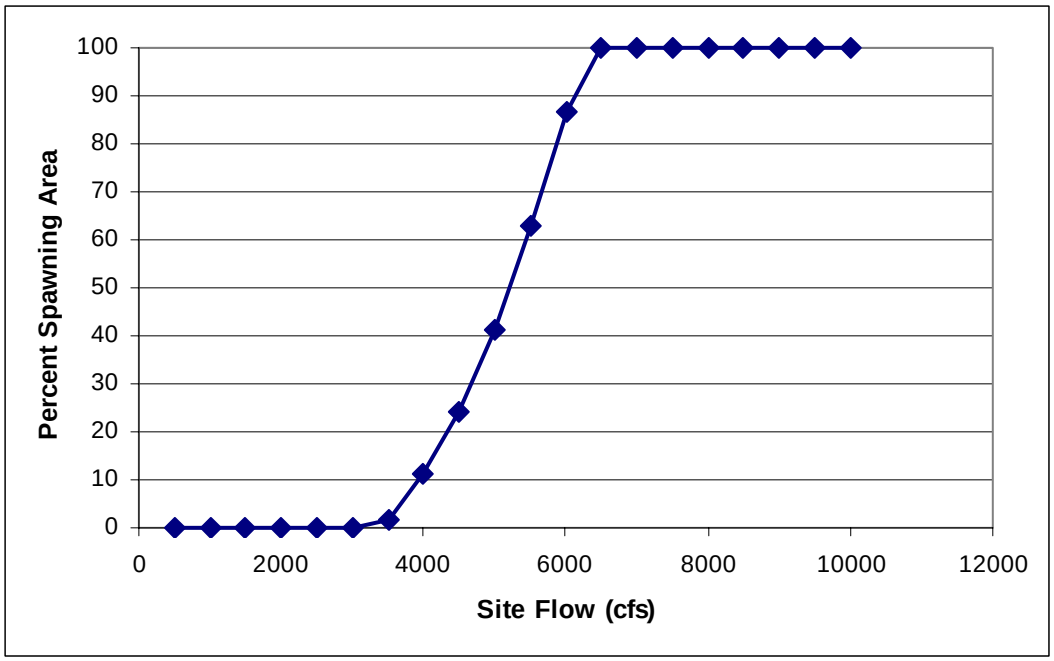


Figure 18c. Percent of 10,000 cfs spawning area available for incubation at the Peaceful Valley site.

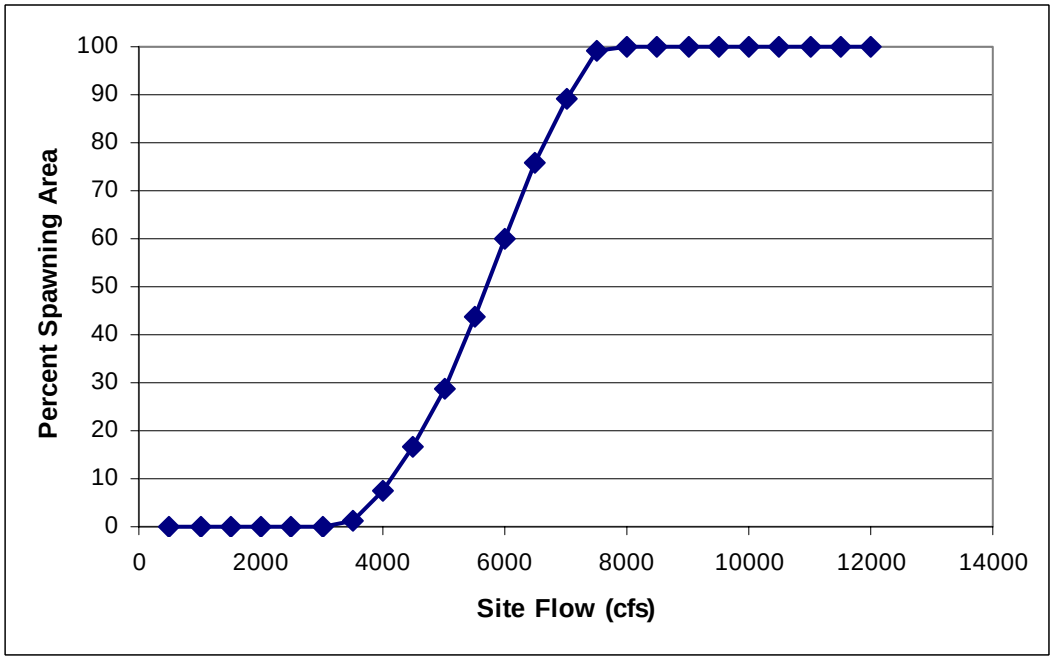


Figure 18d. Percent of 12,000 cfs spawning area available for incubation at the Peaceful Valley site.

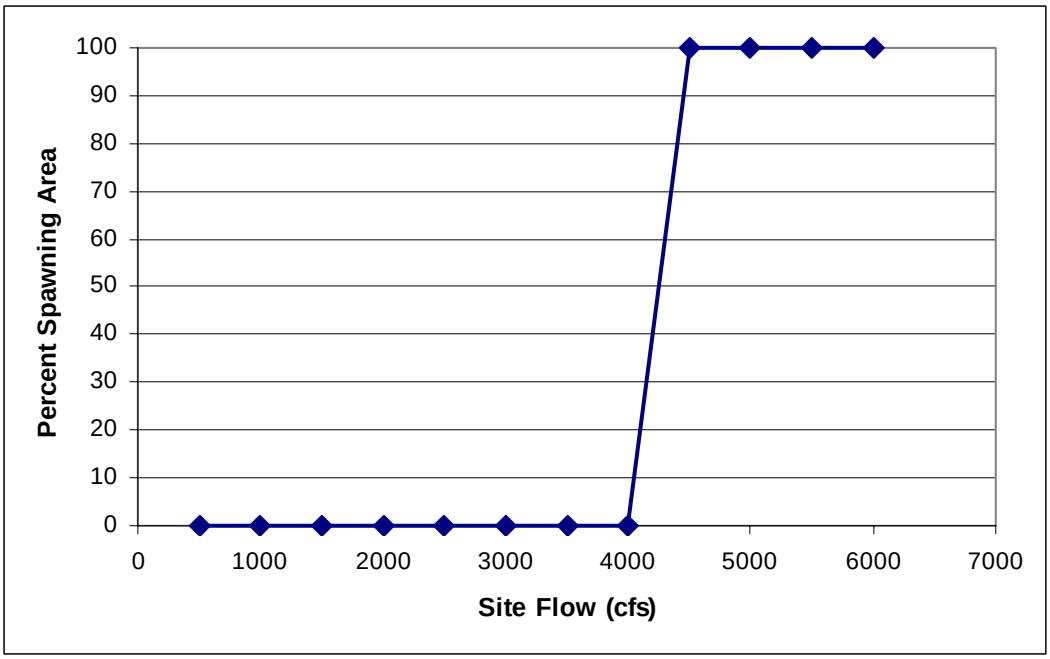


Figure 19a. Percent of 6000 cfs spawning area available for incubation at the Evergreen site.

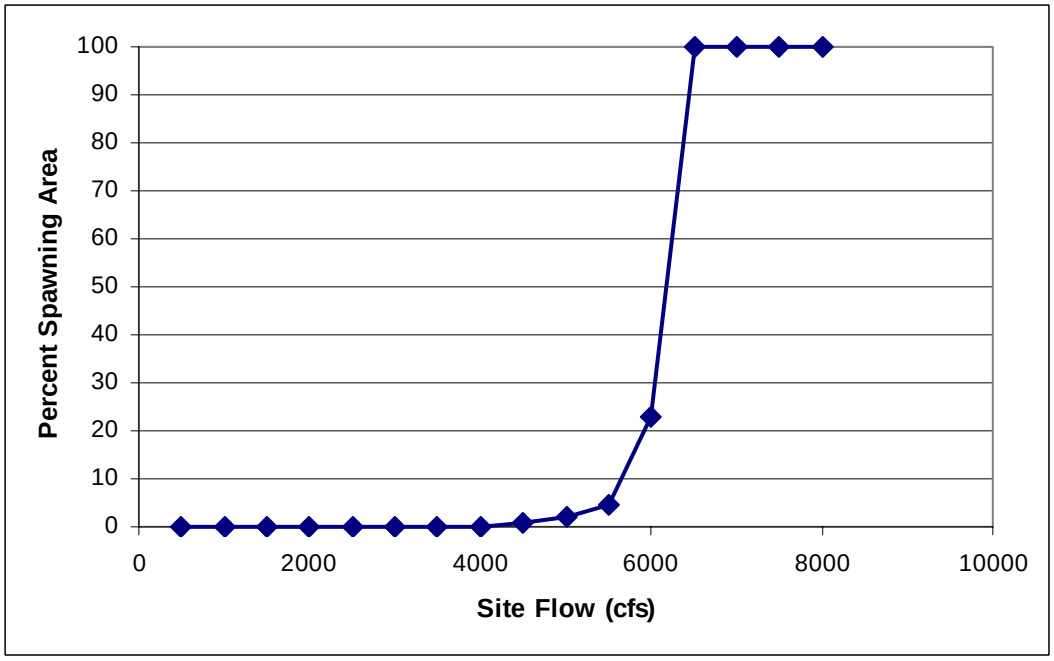


Figure 19b. Percent of 8000 cfs spawning area available for incubation at the Evergreen site.

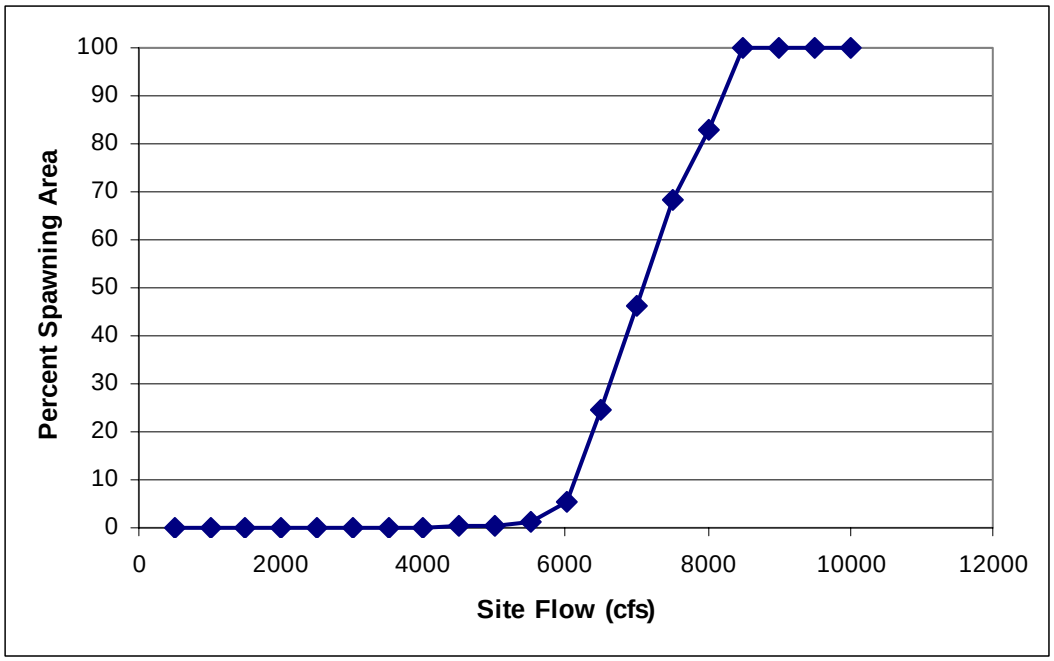


Figure 19c. Percent of 10000 cfs spawning area available for incubation at the Evergreen site.

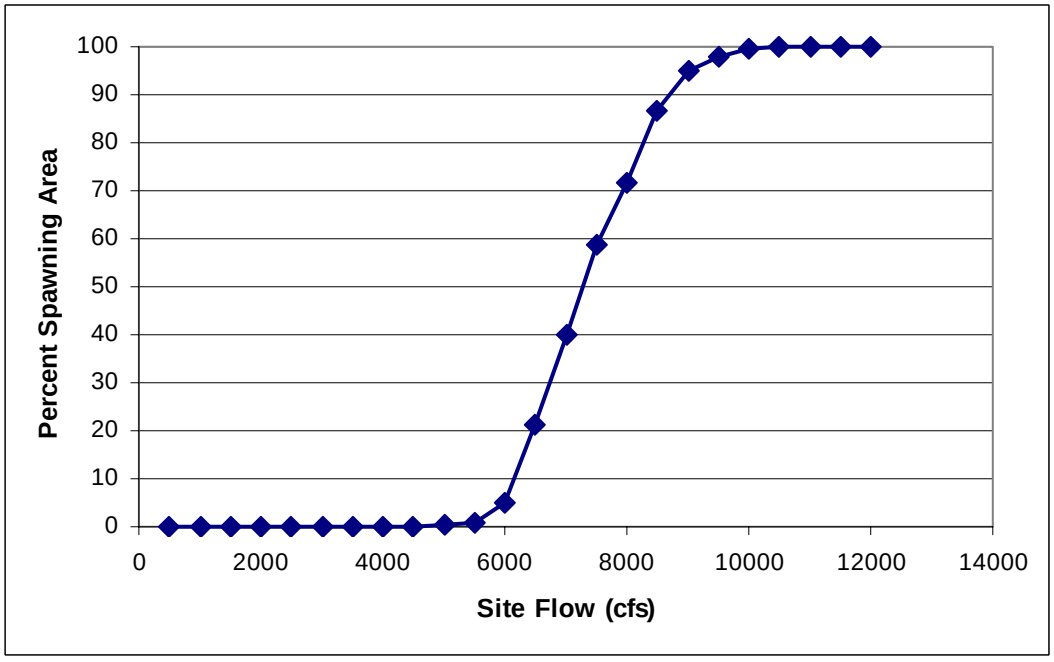


Figure 19d. Percent of 12000 cfs spawning area available for incubation at the Evergreen site.

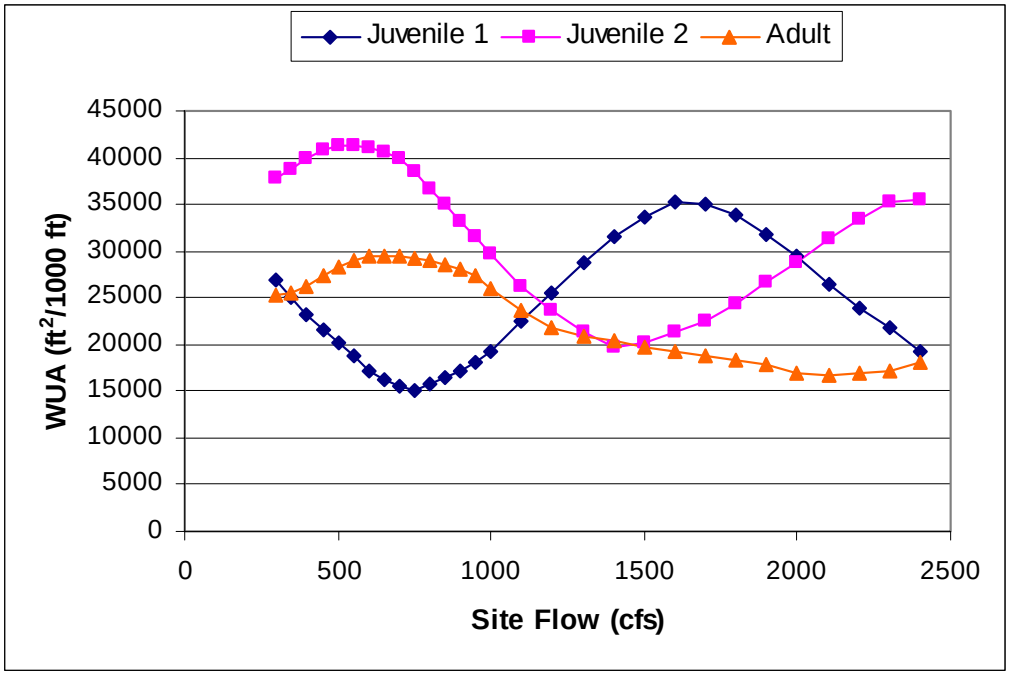


Figure 20. Weighted useable area (WUA) vs. discharge for rearing at McGuire Park transect.

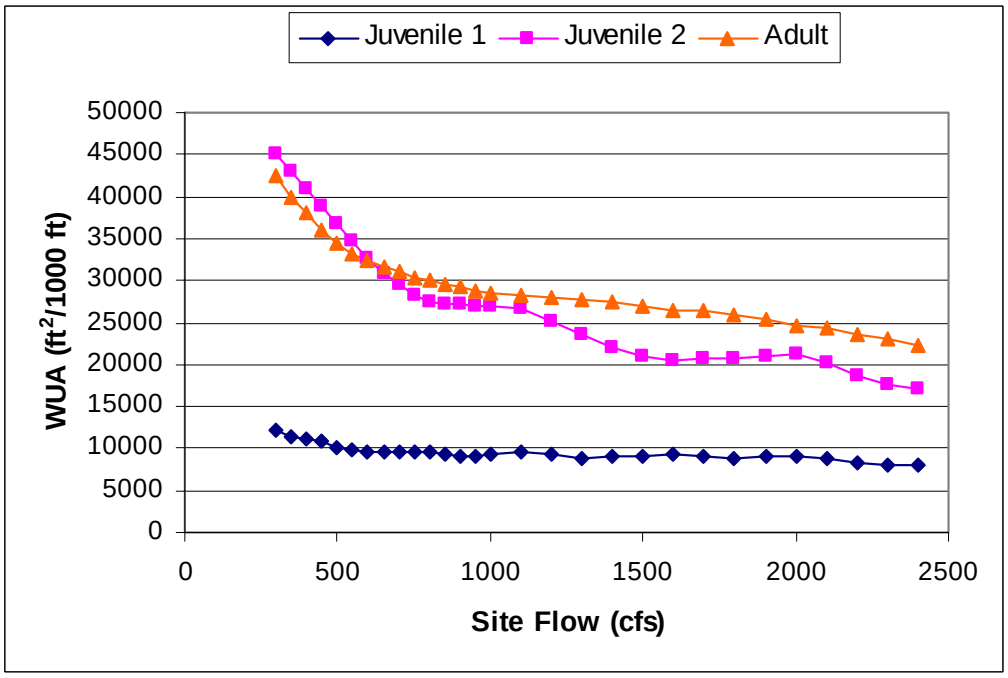


Figure 21. Weighted useable area (WUA) vs. discharge for rearing at Corbin Park transect.

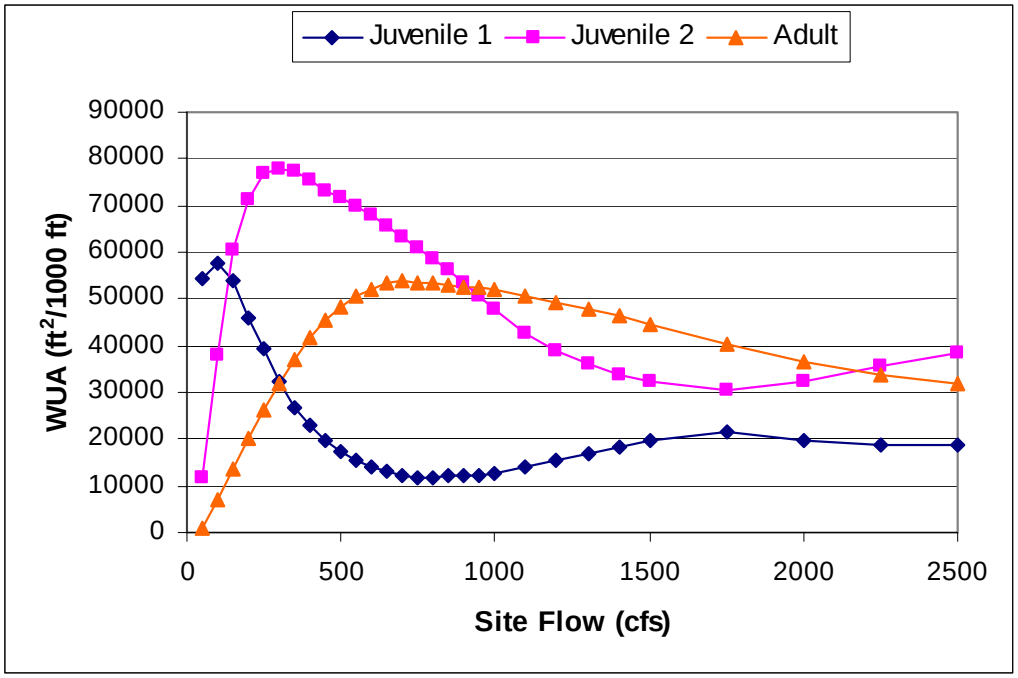


Figure 22. Weighted useable area (WUA) vs. discharge for rearing at Barker Road transect.

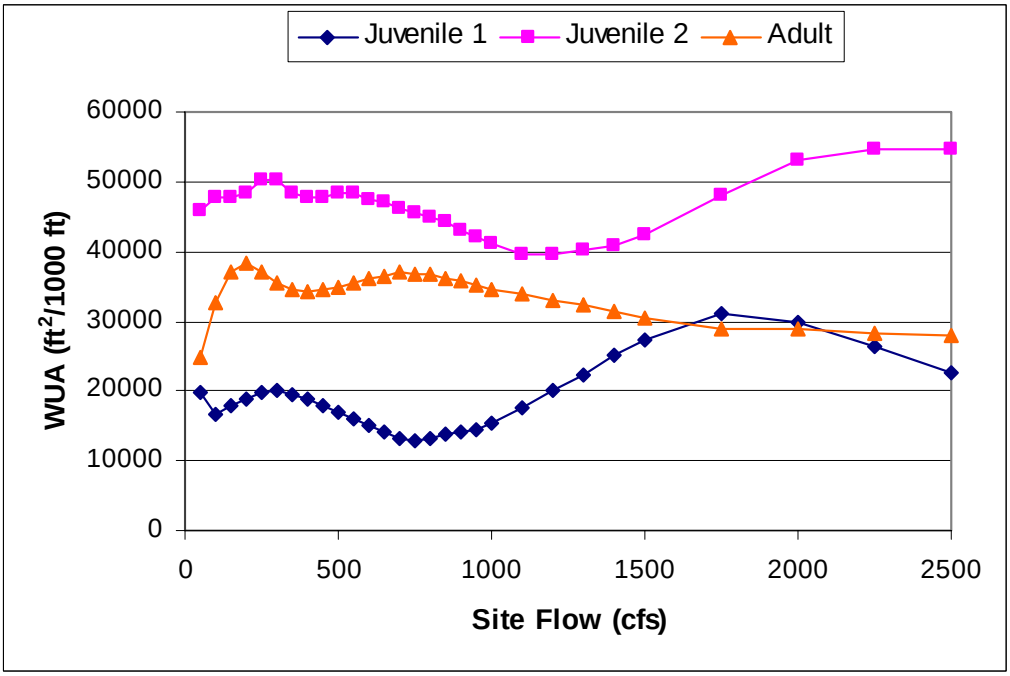


Figure 23. Weighted useable area (WUA) vs. discharge for rearing at Sullivan boulder-glide transect.

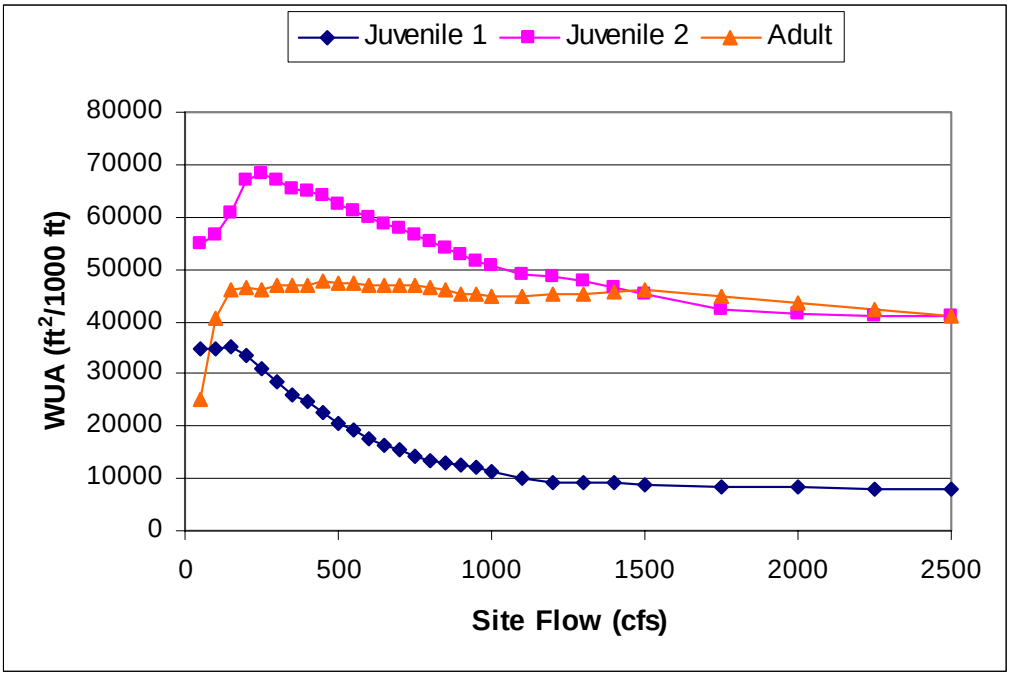


Figure 24. Weighted useable area (WUA) vs. discharge for rearing at Sullivan cascade transect.

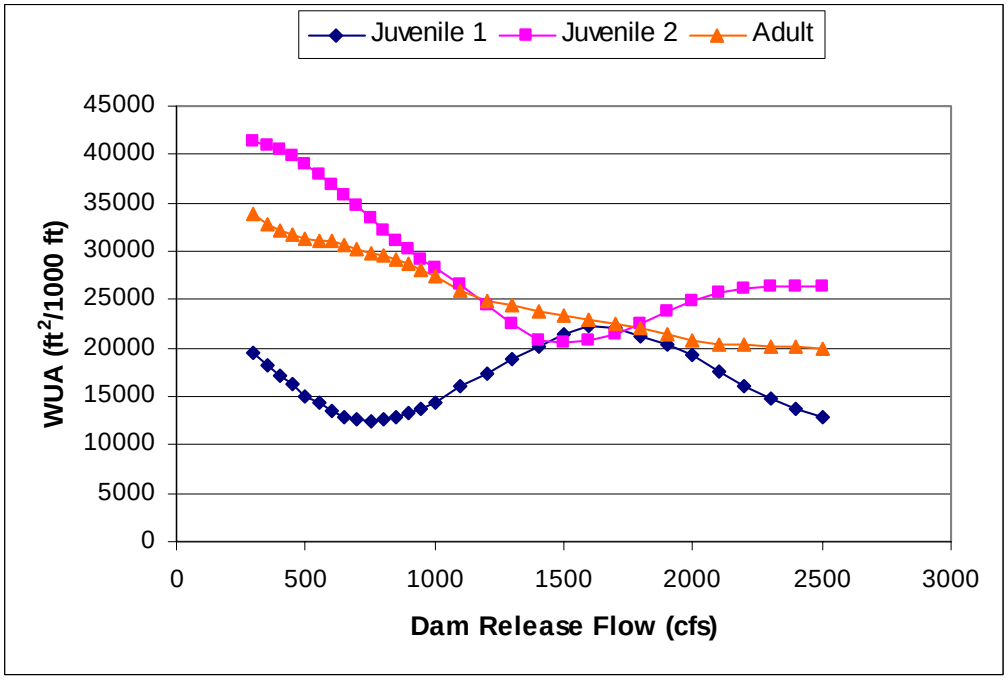


Figure 25. Combined weighted useable area (WUA) vs. dam release for rearing at McGuire Park and Corbin Park sites.

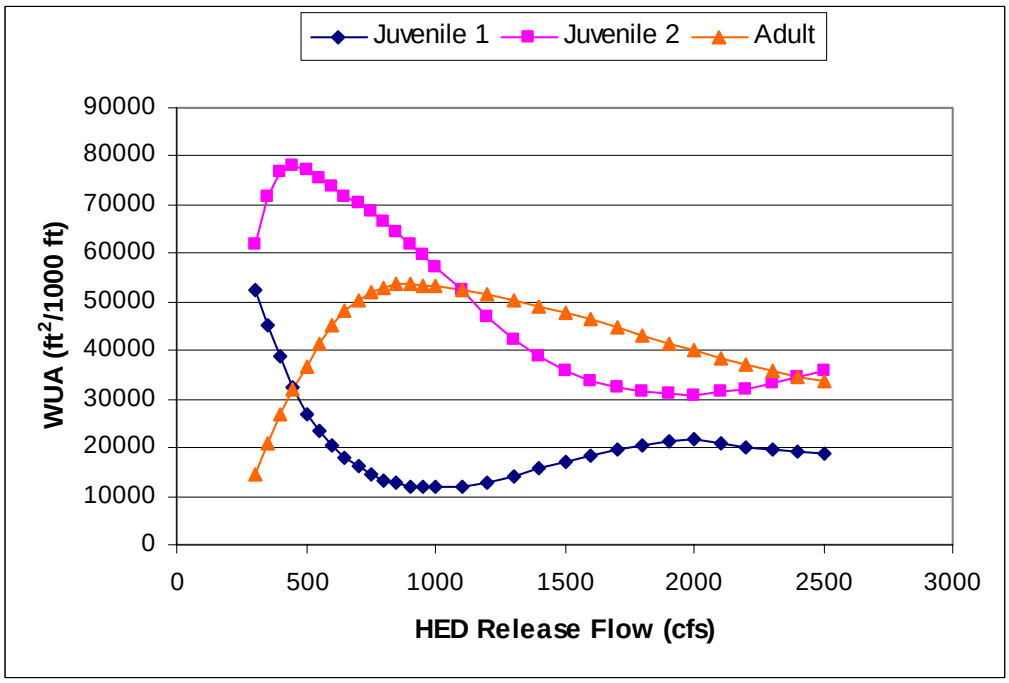


Figure 26. Weighted useable area (WUA) vs. dam release for rearing at the Barker Road site.

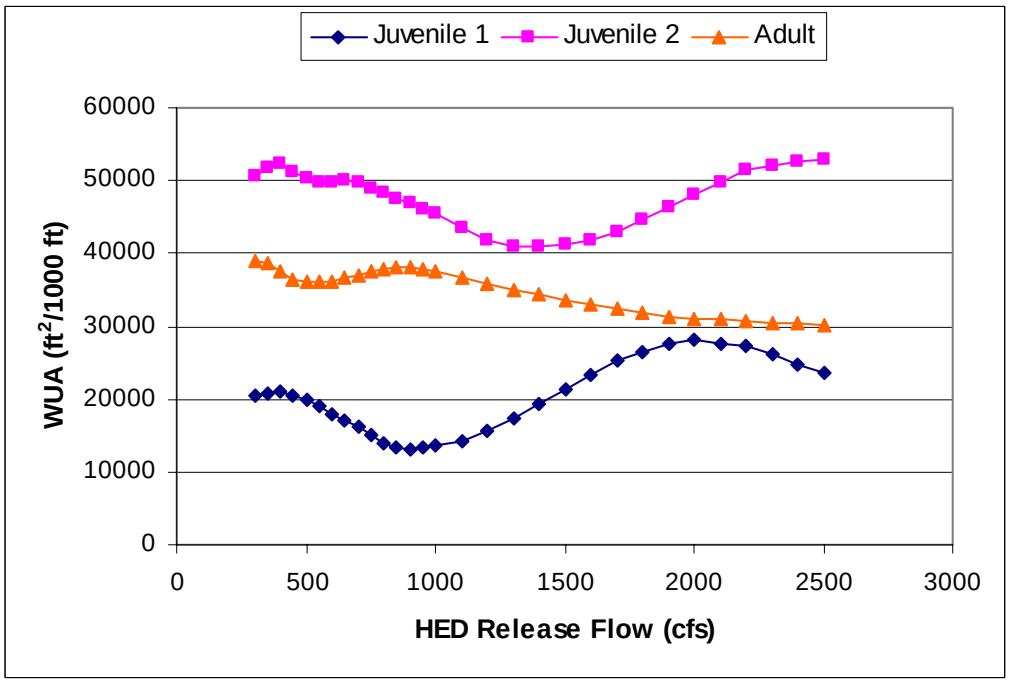


Figure 27. Combined weighted useable area (WUA) vs. dam release for rearing at the Sullivan Road sites.

Transect	River Mile	Habitat Type	Hydrology
McGuire Park	101.0	riffle	approximately equal to dam release
Corbin Park	99.6	run	approximately equal to dam release
Barker Road	90.8	wide riffle	300-500 cfs loss
Sullivan Glide	88.5	boulder-glide	Barker plus 25 cfs groundwater
Sullivan Cascade	88.0	cascade	Barker plus 50 cfs groundwater

Table 1. Characteristics of Post Falls rearing transects during September 2003 field studies.

Transect	Low Flow (cfs)	Mid Flow (cfs)	High Flow (cfs)
McGuire Park	365	1350	2394
Corbin Park	365	1352	2577
Barker Road	98	871	2000
Sullivan Glide	125	896	2025
Sullivan Cascade	150	921	2050

Table 2. Calibration flows at Post Falls rearing transects.

Flow (cfs)	Depth >= 0.1' Area (sq ft)	Depth > 1.0' Area (sq ft)	Water Surface Elevation (ft)
2000	1599	354	92.34
2500	2724	1020	92.95
3000	3672	1832	93.45
3500	4363	2571	93.87
4000	4821	3254	94.24
4500	5287	3905	94.57
5000	5745	4363	94.86
5500	6090	4716	95.12
6000	6395	5086	95.37
6500	6725	5367	95.59
7000	7014	5672	95.80
7500	7352	5913	95.99
8000	7697	6146	96.17
8500	7938	6355	96.34
9000	8227	6580	96.51
9500	8533	6853	96.66
10000	8734	7038	96.80
10500	9055	7263	96.94
11000	9264	7464	97.07
11500	9489	7745	97.20
12000	9682	7914	97.32
12500	9866	8171	97.44
13000	10043	8308	97.55
13500	10212	8549	97.66
14000	10493	8685	97.76
14500	10662	8870	97.86
15000	10879	9079	97.96

Table 3. Wetted gravel area versus flow using simulated water surface elevations at Harvard Road site (elevations are local).

Flow (cfs)	Depth >= 0.1' Area (sq ft)	Depth > 1.0' Area (sq ft)	Water Surface Elevation (ft)
2000	1567	0	98.41
2500	2516	603	98.86
3000	3504	1205	99.23
3500	5465	1848	99.54
4000	7064	2443	99.81
4500	8293	3014	100.06
5000	9402	3801	100.27
5500	10351	5135	100.47
6000	11387	6308	100.65
6500	12424	7112	100.81
7000	13597	7908	100.97
7500	14288	8631	101.11
8000	14883	9282	101.24
8500	15534	9941	101.37
9000	15936	10568	101.49
9500	16113	11178	101.60
10000	16346	11733	101.71
10500	16538	12488	101.81
11000	16675	13252	101.91
11500	16828	13766	102.00
12000	16964	14224	102.09
12500	17109	14618	102.17
13000	17246	14955	102.25
13500	17479	15405	102.33
14000	17696	15727	102.41
14500	17728	15936	102.48
15000	17728	16056	102.56

Table 4. Wetted gravel area versus flow using simulated water surface elevations at Starr Road Bar site (elevations are local).

Flow (cfs)	Depth >= 0.1' Area (sq ft)	Depth > 1.0' Area (sq ft)	Water Surface Elevation (ft)
500	0	0	95.26
1000	0	0	96.55
1500	0	0	97.31
2000	0	0	97.85
2500	0	0	98.27
3000	0	0	98.62
3500	22	0	98.91
4000	134	0	99.16
4500	291	0	99.39
5000	500	0	99.59
5500	763	14	99.78
6000	1050	74	99.94
6500	1326	153	100.10
7000	1562	249	100.24
7500	1735	368	100.37
8000	1844	510	100.50
8500	1893	673	100.62
9000	1894	849	100.73
9500	1894	1032	100.83
10000	1894	1212	100.93
10500	1894	1379	101.03
11000	1894	1528	101.12
11500	1894	1653	101.21
12000	1894	1751	101.29

Table 5. Wetted gravel area versus flow using simulated water surface elevations at Peaceful Valley site (elevations are local).

Flow (cfs)	Depth >= 0.1' Area (sq ft)	Depth > 1.0' Area (sq ft)	Water Surface Elevation (ft)
500	0	0	76.85
1000	0	0	77.14
1500	0	0	77.44
2000	0	0	77.73
2500	0	0	78.02
3000	0	0	78.31
3500	0	0	78.61
4000	0	0	78.90
4500	4	0	79.19
5000	8	0	79.48
5500	19	0	79.78
6000	95	4	80.07
6500	415	8	80.36
7000	785	19	80.65
7500	1152	95	80.95
8000	1401	415	81.24
8500	1690	785	81.53
9000	1854	1152	81.82
9500	1912	1401	82.12
10000	1948	1690	82.41
10500	1956	1854	82.70
11000	1958	1891	82.99
11500	1958	1940	83.29
12000	1958	1954	83.58

Table 6. Wetted gravel area versus flow using simulated water surface elevations at Evergreen site (elevations are local).

Dam Release	McGuire-Corbin	Barker	Sullivan Glide	Sullivan Cascade
300	300	158	183	208
350	350	205	230	255
400	400	253	278	303
450	450	301	326	351
500	500	348	373	398
550	550	396	421	446
600	600	443	468	493
650	650	491	516	541
700	700	538	563	588
750	750	586	611	636
800	800	634	659	684
850	850	681	706	731
900	900	729	754	779
950	950	776	801	826
1000	1000	824	849	874
1100	1100	919	944	969
1200	1200	1014	1039	1064
1300	1300	1110	1135	1160
1400	1400	1205	1230	1255
1500	1500	1300	1325	1350
1600	1600	1395	1420	1445
1700	1700	1490	1515	1540
1800	1800	1585	1610	1635
1900	1900	1681	1706	1731
2000	2000	1776	1801	1826
2100	2100	1871	1896	1921
2200	2200	1966	1991	2016
2300	2300	2061	2086	2111
2400	2400	2157	2182	2207
2500	2500	2252	2277	2302

Table 7. Post Falls Dam release flow and equivalent study site flows used in modeling (all values in cfs).

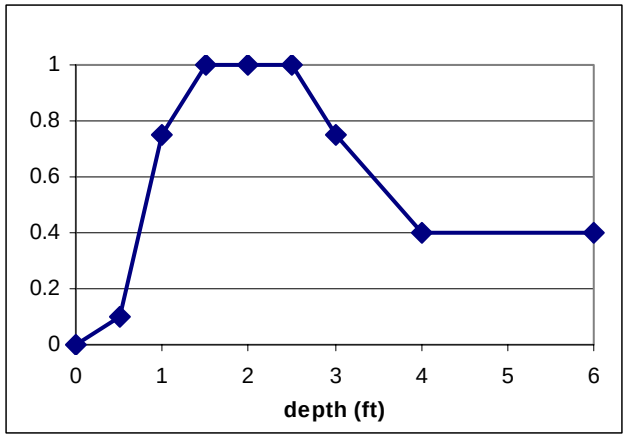
APPENDICES

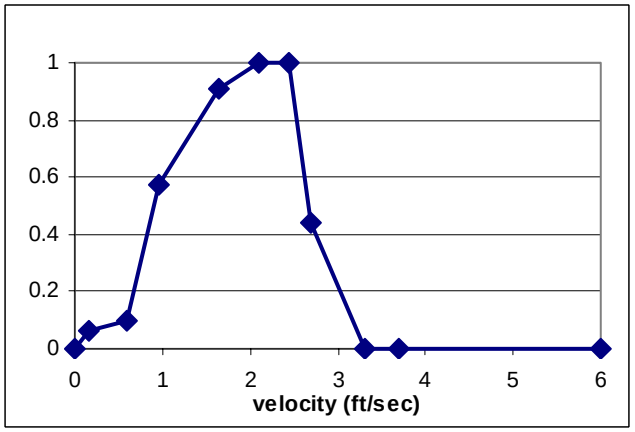
1. Substrate classification categories used in the study.
2. Habitat suitability (HSI) information used.
3. Hydraulic details for transect-based spawning analysis.
4. Measured and modeled stage-discharge data for Monroe Reach sites.
5. Hydraulic details for rearing analysis.
6. Latah Creek flow exceedance curves.
7. Site photographs at different flows.
8. Incubation habitat vs. spawning flow.
9. Stage discharge and wetted perimeter.
10. WUA and percent WUA vs. flow at each site.

APPENDIX 1

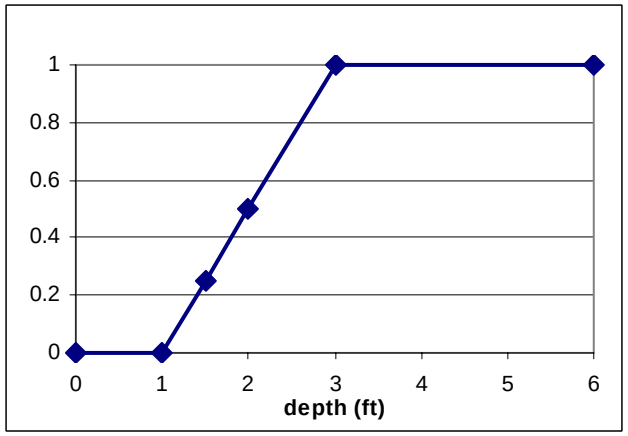
Substrate Description	**Substrate Survey Code**	**Size Range (inches)**	**Mean Size (inches)**
detritus	0		
silt/clay	1	< 0.1	-
sand	2	< 0.1	-
small gravel	3	0.1 - 0.5	0.3
medium gravel	4	0.5 - 1.5	1.0
large gravel	5	1.5 - 3	2.25
small cobble	6	3 - 6	4.5
large cobble	7	6 - 12	9
boulder	8	> 12	
bedrock	9		

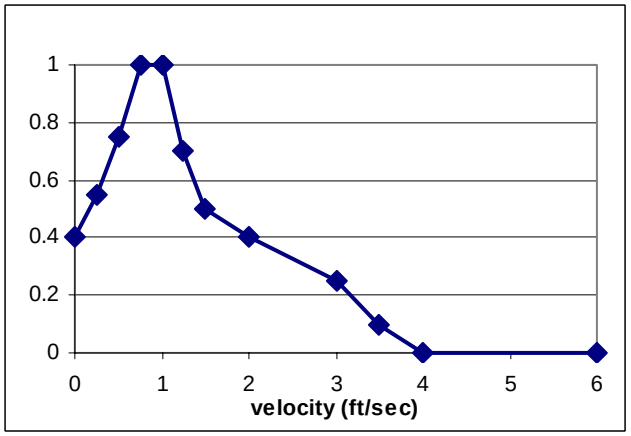
A-1. Substrate classification categories used in the study.



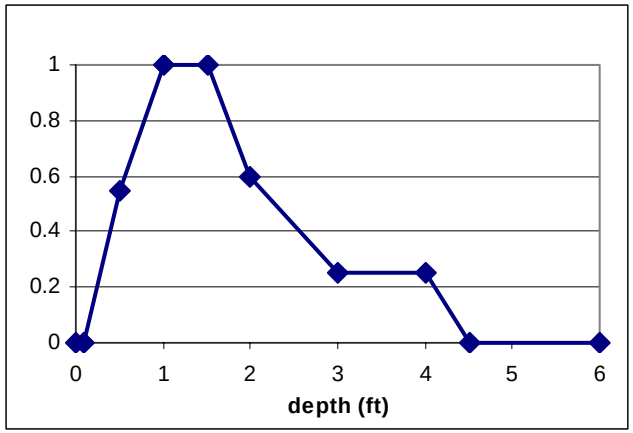


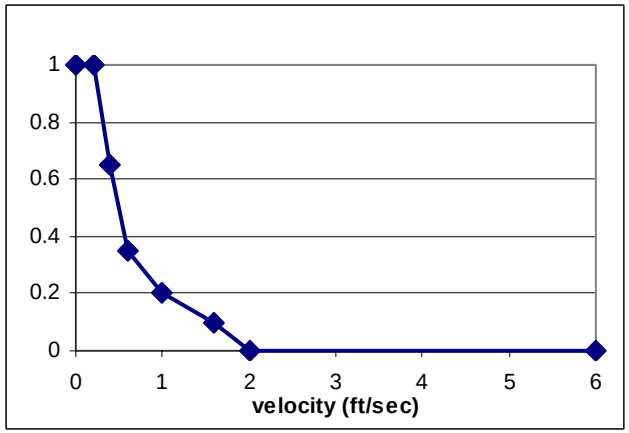
A2-1. Spawning rainbow trout depth and velocity suitability curves used in the study.



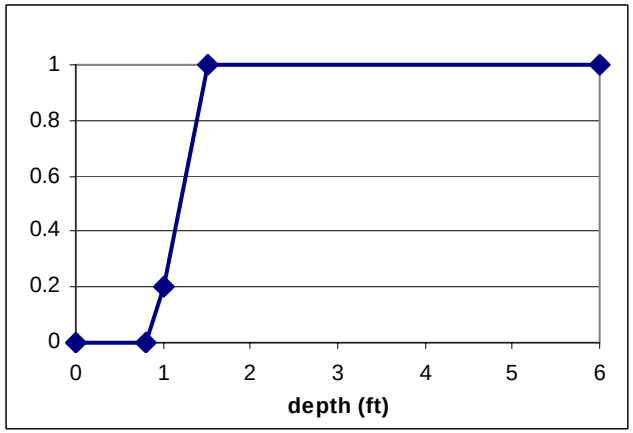


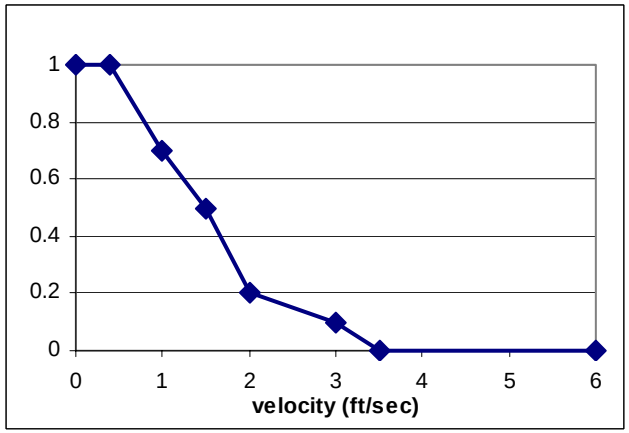
A2-2. Rearing Adult rainbow trout depth and velocity suitability curves used in the study.





A2-3. Rearing Juvenile-1 (2.0-3.5") rainbow trout depth and velocity suitability curves used in the study.





A2-4. Rearing Juvenile-2 (4.0-9.0") rainbow trout depth and velocity suitability curves used in the study.

Substrate Description	Survey Code	Size Range (inches)	Rearing Suitability	Spawning Suitability
detritus	0		0	0
silt/clay	1	< 0.1	0.1	0
sand	2	< 0.1	0.1	0
small gravel	3	0.1 - 0.5	0.1	0.8
medium gravel	4	0.5 - 1.5	0.3	1.0
large gravel	5	1.5 - 3	0.3	0.8
small cobble	6	3 - 6	0.5	0.5
large cobble	7	6 - 12	0.7	0
boulder	8	> 12	1.0	0
bedrock	9		0.3	0

A2-5. Substrate suitability data for rearing and spawning rainbow trout.

Flow (cfs)	XS 1 Measured WSL	XS 1 Simulated WSL	XS 2 Measured WSL	XS 2 Simulated WSL	XS 3 Measured WSL	XS 3 Simulated WSL
1340	91.39	91.26	91.40	91.27	91.41	91.28
2520	92.76	92.96	92.77	92.97	92.78	92.98
4050	94.30	94.26	94.31	94.27	94.34	94.28
10,300	96.95	96.88	96.96	96.89	96.98	96.90

A3-1. Measured vs. modeled water surface elevations at Harvard Road spawning site (WSL measured in feet and relative to local datum).

Flow (cfs)	XS 1 Measured WSL	XS 1 Simulated WSL	XS 2 Measured WSL	XS 2 Simulated WSL	XS 3 Measured WSL	XS 3 Simulated WSL
1340	97.74	97.59	97.76	97.60	97.78	97.61
2520	98.63	98.86	98.65	98.87	98.67	98.88
4050	99.77	99.83	99.79	99.84	99.81	99.85
10,300	101.83	101.76	101.85	101.77	101.87	101.78

A3-2. Measured vs. modeled water surface elevations at Starr Road Bar spawning site (WSL measured in feet and relative to local datum).

Station (ft)	2500 cfs	5000 cfs	7500 cfs	10000 cfs
0				
4				
8				
10				
12				
14				0.6
16				0.81
18				1.09
20				1.3
22				1.47
24			0.5	1.55
26			0.83	1.69
28			1.05	1.81
30			1.13	1.87
32			1.28	1.98
34			1.35	2.03
36			1.47	2.13
38			1.41	2.08
40			1.41	2.08
42		0.68	1.64	2.27
44		0.94	1.78	2.4
46		1.01	1.83	2.44
48		1.13	1.91	2.52
50		1.19	1.95	2.56
52		1.29	2.03	2.63
54		1.34	2.07	2.67
56		1.38	2.1	2.71
58		1.46	2.17	2.77
60		1.46	2.17	2.77
62		0.94	1.78	2.4
64		1.01	1.83	2.44
66		1.13	1.91	2.52
68		1.38	2.1	2.71
70		1.5	2.21	2.81
72		1.54	2.24	2.84
74	0.44	1.65	2.34	2.94
76	0.77	1.78	2.46	3.06
78	0.98	1.9	2.58	3.18
80	1.02	1.93	2.6	3.21
82	1.06	1.96	2.63	3.23
84	1.02	1.93	2.6	3.21
86	1.1	1.98	2.66	3.26
88	1.17	2.04	2.71	3.32
92	1.06	1.96	2.63	3.23
96	1.21	2.06	2.74	3.34

Station (ft)	2500 cfs	5000 cfs	7500 cfs	10000 cfs
100	1.3	2.14	2.81	3.42
104	1.39	2.21	2.89	3.5
112	1.57	2.37	3.05	3.67
120	1.68	2.47	3.15	3.78
128	1.77	2.55	3.24	3.87
136	1.7	2.49	3.18	3.81
144	1.68	2.47	3.15	3.78
152	1.77	2.55	3.24	3.87
160	1.84	2.63	3.32	3.96
168	1.9	2.68	3.38	4.02
176	1.97	2.75	3.45	4.1
184	2.14	2.92	3.64	4.3
192	2.26	3.05	3.77	4.45
200	2.32	3.11	3.84	4.52
208	2.34	3.14	3.87	4.56
216	2.26	3.05	3.77	4.45
224	2.15	2.94	3.65	4.32
232	2.04	2.82	3.53	4.18
240	2.04	2.82	3.53	4.18
248	2.04	2.82	3.53	4.18
256	1.94	2.72	3.42	4.06
264	2.17	2.95	3.67	4.34
272	2.17	2.95	3.67	4.34
280	2.15	2.94	3.65	4.32
288	2.14	2.92	3.64	4.3
296	2.02	2.8	3.51	4.17
304	1.9	2.68	3.38	4.02
312	1.9	2.68	3.38	4.02
320	1.97	2.75	3.45	4.1
328	1.9	2.68	3.38	4.02
336	1.84	2.63	3.32	3.96
344	1.81	2.59	3.28	3.92
352	1.5	2.3	2.98	3.6
356	1.21	2.06	2.74	3.34
360	0.64	1.72	2.4	3
364		1.29	2.03	2.63
368			1.47	2.13
372				0.81
376				
380				
384				
Average	1.67	2.15	2.63	3.1

A3-3. Simulated velocities for Harvard Road spawning site Transect 1 (values in bold represent the spawning area).

Station (ft)	2500 cfs	5000 cfs	7500 cfs	10000 cfs
0				
4				
8				
10				
12				
14				0.63
16				0.83
18				1.11
20				1.32
22				1.49
24			0.53	1.56
26			0.85	1.7
28			1.06	1.83
30			1.15	1.89
32			1.3	2
34			1.37	2.05
36			1.49	2.15
38			1.43	2.1
40			1.43	2.1
42		0.69	1.65	2.29
44		0.96	1.8	2.42
46		1.02	1.84	2.46
48		1.15	1.93	2.54
50		1.2	1.97	2.58
52		1.3	2.04	2.65
54		1.35	2.08	2.69
56		1.39	2.12	2.72
58		1.48	2.19	2.79
60		0.96	1.8	2.42
62		1.09	1.88	2.5
64		1.2	1.97	2.58
66		1.25	2.01	2.61
68		1.35	2.08	2.69
70		1.39	2.12	2.72
72		1.44	2.15	2.76
74		1.48	2.19	2.79
76		1.48	2.19	2.79
78		1.56	2.26	2.86
80	0.3	1.63	2.32	2.93
82	0.46	1.66	2.36	2.96
84	0.72	1.76	2.45	3.05
86	0.78	1.8	2.48	3.08
88	0.89	1.86	2.54	3.14
90	1.03	1.94	2.62	3.23

Station (ft)	2500 cfs	5000 cfs	7500 cfs	10000 cfs
92	**0.99**	**1.91**	**2.59**	**3.2**
96	1.21	2.08	2.75	3.36
100	1.31	2.15	2.83	3.44
104	1.4	2.23	2.9	3.52
112	1.58	2.38	3.07	3.69
120	1.69	2.49	3.17	3.81
128	1.77	2.57	3.26	3.9
136	1.71	2.51	3.2	3.83
144	1.69	2.49	3.17	3.81
152	1.77	2.57	3.26	3.9
160	1.85	2.64	3.34	3.98
168	1.91	2.7	3.4	4.05
176	1.98	2.77	3.48	4.13
184	2.15	2.94	3.66	4.33
192	2.27	3.07	3.8	4.48
200	2.32	3.13	3.86	4.55
208	2.35	3.16	3.9	4.58
216	2.27	3.07	3.8	4.48
224	2.16	2.95	3.68	4.34
232	2.05	2.84	3.55	4.21
240	2.05	2.84	3.55	4.21
248	2.05	2.84	3.55	4.21
256	1.94	2.73	3.44	4.09
264	2.18	2.97	3.69	4.36
272	2.18	2.97	3.69	4.36
280	2.16	2.95	3.68	4.34
288	2.15	2.94	3.66	4.33
296	2.03	2.82	3.53	4.19
304	1.91	2.7	3.4	4.05
312	1.91	2.7	3.4	4.05
320	1.98	2.77	3.48	4.13
328	1.91	2.7	3.4	4.05
336	1.85	2.64	3.34	3.98
344	1.81	2.6	3.3	3.94
352	1.5	2.32	3	3.62
356	1.21	2.08	2.75	3.36
360	0.65	1.73	2.42	3.02
364		1.3	2.04	2.65
368			1.49	2.15
372				0.83
376				
380				
Average	1.68	2.12	2.62	3.09

A3-4. Simulated velocities for Harvard Road spawning site Transect 2 (values in bold represent the spawning area).

Station (ft)	2500 cfs	5000 cfs	7500 cfs	10000 cfs
0				
4				
8				
10				
12				
14				0.65
16				0.84
18				1.11
20				1.31
22			0.19	1.48
24			0.55	1.55
26			0.85	1.69
28			1.06	1.81
30			1.14	1.87
32			1.29	1.98
34			1.36	2.03
36			1.48	2.13
38			1.42	2.08
40			1.42	2.08
42		0.7	1.64	2.27
44		0.95	1.78	2.4
46		1.02	1.82	2.44
48		1.14	1.91	2.51
50		1.19	1.95	2.55
52		1.29	2.02	2.63
54		1.34	2.06	2.66
56		1.38	2.1	2.7
58		1.46	2.17	2.77
60		1.46	2.17	2.77
62		1.5	2.2	2.8
64		1.54	2.24	2.83
66		1.54	2.24	2.83
68		1.58	2.27	2.86
70	0.32	1.61	2.3	2.9
72	0.32	1.61	2.3	2.9
74	0.46	1.65	2.33	2.93
76	0.57	1.68	2.36	2.96
78	0.78	1.78	2.45	3.05
80	0.89	1.84	2.51	3.11
82	0.94	1.87	2.54	3.14
84	1.02	1.92	2.59	3.19
86	1.1	1.98	2.65	3.25
88	1.17	2.03	2.7	3.3
92	1.06	1.95	2.62	3.22

Station (ft)	2500 cfs	5000 cfs	7500 cfs	10000 cfs
96	1.21	2.06	2.73	3.33
100	1.3	2.13	2.8	3.41
104	1.39	2.2	2.87	3.48
112	1.57	2.36	3.03	3.65
120	1.68	2.46	3.14	3.77
128	1.76	2.54	3.22	3.86
136	1.7	2.48	3.16	3.79
144	1.68	2.46	3.14	3.77
152	1.76	2.54	3.22	3.86
160	1.84	2.61	3.3	3.94
168	1.9	2.67	3.36	4
176	1.97	2.74	3.44	4.09
184	2.13	2.9	3.62	4.28
192	2.25	3.03	3.75	4.43
200	2.31	3.09	3.82	4.5
208	2.34	3.12	3.85	4.54
216	2.25	3.03	3.75	4.43
224	2.15	2.92	3.64	4.3
232	2.03	2.81	3.51	4.16
240	2.03	2.81	3.51	4.16
248	2.03	2.81	3.51	4.16
256	1.93	2.7	3.4	4.04
264	2.16	2.94	3.65	4.32
272	2.16	2.94	3.65	4.32
280	2.15	2.92	3.64	4.3
288	2.13	2.9	3.62	4.28
296	2.02	2.79	3.49	4.15
304	1.9	2.67	3.36	4
312	1.9	2.67	3.36	4
320	1.97	2.74	3.44	4.09
328	1.9	2.67	3.36	4
336	1.84	2.61	3.3	3.94
344	1.8	2.57	3.26	3.9
352	1.49	2.29	2.97	3.58
356	1.21	2.06	2.73	3.33
360	0.65	1.71	2.39	2.99
364		1.29	2.02	2.63
368			1.48	2.13
372				0.84
376				
380				
384				
Average	1.6	2.16	2.61	3.11

A3-5. Simulated velocities for Harvard Road spawning site Transect 3 (values in bold represent the spawning area).

Station (ft)	2500 cfs	5000 cfs	7500 cfs	10000 cfs
0			**0.96**	**1.66**
2			**0.96**	**1.66**
4			**0.87**	**1.57**
6			**0.96**	**1.66**
8			**0.96**	**1.66**
10			**0.96**	**1.66**
12			**0.96**	**1.66**
14			**0.96**	**1.66**
16			**0.96**	**1.66**
18			**0.96**	**1.66**
20			**1.05**	**1.74**
22		**0.17**	**1.13**	**1.83**
24		**0.31**	**1.22**	**1.91**
26		**0.42**	**1.29**	**1.98**
28		**0.52**	**1.37**	**2.06**
30		**0.61**	**1.45**	**2.14**
32		**0.69**	**1.52**	**2.21**
34		**0.85**	**1.66**	**2.36**
36		**0.85**	**1.66**	**2.36**
38		**0.92**	**1.73**	**2.43**
40		**1.12**	**1.93**	**2.64**
42		**1.12**	**1.93**	**2.64**
44		**1.19**	**1.99**	**2.7**
46		**1.25**	**2.05**	**2.77**
48	**0.23**	**1.37**	**2.18**	**2.9**
50	**0.32**	**1.42**	**2.24**	**2.96**
52	**0.39**	**1.48**	**2.3**	**3.03**
54	**0.39**	**1.48**	**2.3**	**3.03**
56	**0.47**	**1.54**	**2.35**	**3.09**
58	**0.59**	**1.64**	**2.47**	**3.21**
59.5	0.65	1.7	2.53	3.27
78	0.65	1.7	2.53	3.27
84	0.81	1.85	2.69	3.45
90	0.96	2	2.85	3.63
98	1.05	2.09	2.96	3.74
108	1.31	2.37	3.26	4.08
116	1.39	2.46	3.36	4.19
128	1.55	2.63	3.55	4.4
138	1.73	2.84	3.79	4.66
148	1.9	3.04	4.01	4.91
158	2.1	3.27	4.28	5.21
168	2.16	3.34	4.36	5.3
178	2.32	3.53	4.58	5.54
188	2.53	3.78	4.87	5.86

Station (ft)	2500 cfs	5000 cfs	7500 cfs	10000 cfs
198	2.56	3.82	4.91	5.91
208	2.79	4.09	5.23	6.27
218	2.76	4.06	5.19	6.22
228	2.65	3.92	5.03	6.04
238	2.82	4.13	5.27	6.31
248	2.76	4.06	5.19	6.22
258	2.65	3.92	5.03	6.04
268	2.62	3.89	4.99	6.00
278	2.62	3.89	4.99	6.00
288	2.47	3.71	4.78	5.77
298	2.03	3.19	4.19	5.11
308	1.39	2.46	3.36	4.19
308	1.47	2.54	3.46	4.29
309	1.19	2.23	3.11	3.91
314	0.65	1.70	2.53	3.27
323				0.32
Average	1.63	2.23	2.75	3.5

A3-6. Simulated velocities for Starr Road Bar spawning site Transect 1 (values in bold represent the spawning area).

Station (ft)	2500 cfs	5000 cfs	7500 cfs	10000 cfs
0				**0.91**
2				**0.79**
4				**0.91**
6				**0.91**
8				**0.91**
10				**0.91**
12			**0.3**	**1.14**
14			**0.3**	**1.14**
16			**0.45**	**1.24**
18			**0.45**	**1.24**
20			**0.45**	**1.24**
22			**0.57**	**1.34**
24			**0.69**	**1.44**
26			**0.79**	**1.53**
28			**0.79**	**1.53**
30			**0.69**	**1.44**
32			**0.89**	**1.62**
34			**0.89**	**1.62**
36			**0.99**	**1.71**
38			**1.08**	**1.79**
40		**0.19**	**1.16**	**1.88**
42		**0.32**	**1.25**	**1.96**

Station (ft)	2500 cfs	5000 cfs	7500 cfs	10000 cfs
44		**0.54**	**1.41**	**2.12**
46		**0.63**	**1.48**	**2.19**
48		**0.71**	**1.56**	**2.27**
50		**0.87**	**1.7**	**2.42**
52		**0.79**	**1.63**	**2.34**
54		**0.79**	**1.63**	**2.34**
56		**0.87**	**1.7**	**2.42**
58		**1.01**	**1.84**	**2.56**
62		1.01	1.84	2.56
68		1.14	1.97	2.7
71		1.14	1.97	2.7
74	0.47	1.56	2.41	3.16
78	0.66	1.73	2.58	3.35
84	0.82	1.88	2.75	3.54
90	0.97	2.03	2.91	3.72
98	1.06	2.13	3.02	3.83
108	1.32	2.41	3.33	4.18
116	1.4	2.49	3.43	4.29
128	1.55	2.67	3.63	4.5
138	1.73	2.88	3.87	4.77
148	1.91	3.08	4.1	5.03
158	2.1	3.32	4.37	5.33
168	2.17	3.39	4.45	5.42
178	2.32	3.58	4.67	5.67
188	2.53	3.83	4.97	6
198	2.56	3.87	5.01	6.04
208	2.79	4.15	5.33	6.41
218	2.77	4.12	5.29	6.37
228	2.65	3.98	5.13	6.18
238	2.82	4.18	5.37	6.46
248	2.77	4.12	5.29	6.37
258	2.65	3.98	5.13	6.18
268	2.62	3.94	5.09	6.14
278	2.62	3.94	5.09	6.14
288	2.48	3.76	4.88	5.9
298	2.04	3.24	4.28	5.23
308	1.4	2.49	3.43	4.29
308	1.47	2.58	3.53	4.4
309	1.19	2.27	3.18	4.01
314	0.66	1.73	2.58	3.35
323				0.34
Average	1.88	2.36	2.67	3.21

A3-7. Simulated velocities for Starr Road Bar spawning site Transect 2 (values in bold represent the spawning area).

Station (ft)	2500 cfs	5000 cfs	7500 cfs	10000 cfs
0				**0.36**
2				**0.13**
4				
6				
8				
10				
12				
14				
16				
18				**0.13**
20				**0.13**
22				**0.36**
24				**0.67**
26				**0.92**
28			**0.46**	**1.25**
30			**0.31**	**1.14**
32			**0.58**	**1.35**
34			**0.9**	**1.62**
36			**0.99**	**1.71**
38		**0.2**	**1.17**	**1.88**
40		**0.44**	**1.33**	**2.04**
42		**0.63**	**1.48**	**2.2**
44		**0.79**	**1.63**	**2.35**
46		**0.87**	**1.7**	**2.42**
48		**0.87**	**1.7**	**2.42**
50		**1.08**	**1.9**	**2.63**
52		**1.08**	**1.9**	**2.63**
54		**1.08**	**1.9**	**2.63**
56		**1.15**	**1.97**	**2.7**
58		**1.21**	**2.03**	**2.77**
60		**1.21**	**2.03**	**2.77**
62		**1.01**	**1.84**	**2.56**
64		**1.01**	**1.84**	**2.56**
66.5		0.79	1.63	2.35
68		1.15	1.97	2.7
71		1.15	1.97	2.7
74	0.48	1.56	2.4	3.16
78	0.66	1.72	2.58	3.35
84	0.82	1.88	2.74	3.54
90	0.97	2.03	2.91	3.71
98	1.06	2.12	3.01	3.83
108	1.32	2.4	3.32	4.17

Station (ft)	2500 cfs	5000 cfs	7500 cfs	10000 cfs
116	1.4	2.49	3.42	4.28
128	1.55	2.66	3.62	4.5
138	1.73	2.87	3.86	4.76
148	1.9	3.07	4.09	5.02
158	2.1	3.31	4.35	5.32
168	2.16	3.38	4.44	5.42
178	2.32	3.57	4.66	5.66
188	2.53	3.82	4.95	5.99
198	2.56	3.86	4.99	6.04
208	2.79	4.14	5.31	6.4
218	2.76	4.1	5.27	6.36
228	2.65	3.96	5.11	6.17
238	2.81	4.17	5.35	6.45
248	2.76	4.1	5.27	6.36
258	2.65	3.96	5.11	6.17
268	2.62	3.93	5.07	6.13
278	2.62	3.93	5.07	6.13
288	2.47	3.75	4.87	5.9
298	2.04	3.23	4.26	5.22
308	1.4	2.49	3.42	4.28
308	1.47	2.58	3.52	4.39
309	1.19	2.26	3.17	4
314	0.66	1.72	2.58	3.35
323				0.36
Average	1.88	2.28	2.98	3.37

A3-8. Simulated velocities for Starr Road Bar spawning site Transect 3 (values in bold represent the spawning area).

Site/Flow (cfs)	Measured WSL	Simulated WSL
Peaceful Valley		
494	95.58	95.24
1240	96.56	96.95
2080	97.45	97.92
3680	99.53	99.00
Evergreen		
494	76.58	76.85
1240	77.36	77.28
2080	77.95	77.78
3680	78.81	78.71
8650	81.54	81.63

4-1. Measured vs. modeled water surface elevations at Monroe Reach spawning sites (WSL measured in feet and relative to local datum).

Site/Flow (cfs)	Measured WSL	Simulated WSL
McGuire		
365	93.71	93.71
1352	94.89	94.89
2577	95.73	95.73
Corbin		
365	91.57	91.57
1352	93.18	93.18
2577	94.57	94.57
Barker		
125	94.26	94.26
940	95.83	95.82
2000	96.68	96.69
Sullivan Boulder-Glide		
125	91.84	91.84
896	94.95	94.95
2025	96.91	96.91
Sullivan Cascade		
175	91.94	91.95
946	94.15	94.12
2075	95.50	95.53

A5-1. Measured vs. modeled water surface elevations at all rearing transects (WSL measured in feet and relative to local datum).

Station (ft)	Measured (ft/s)	Simulated (ft/s)
15	0.00	0.28
20	1.48	1.34
25	0.68	0.61
30	0.61	0.55
35	0.59	0.53
40	0.00	0.15
45	0.41	0.37
50	1.28	1.16
55	0.77	0.7
60	2.26	1.09
65	3.74	2.8
70	4.25	3.84
75	4.50	4.16
80	5.02	4.85
85	4.88	4.66
90	5.25	4.68
95	4.66	4.61
100	4.81	4.79
105	4.90	4.5
110	4.35	4.12
115	4.13	4.08
120	3.98	4.17
125	3.66	3.7
130	3.69	4.49
135	4.14	4.81
140	3.87	2.96
145	3.75	3.32
150	4.00	3.18
155	4.28	4.57
160	4.50	4.19
165	3.90	3.83
170	4.26	3.79
175	4.23	3.99
180	4.15	3.95
185	3.98	4.29
190	3.60	3.25
195	2.36	2.13
200	2.48	2.24
205	1.76	1.59
210	0.88	0.8
215	0.82	0.74
220	0.50	0.45

A5-2. Measured and simulated cell velocities for McGuire Park rearing transect, 2577 cfs.

Station (ft)	Measured (ft/s)	Simulated (ft/s)
23		
28		0.22
34	0.00	0.33
40	0.30	0.31
46	1.05	1.37
52	1.90	1.96
58	2.78	3.46
64	3.04	3.05
70	2.71	2.95
76	2.85	2.78
82	3.25	3.59
88	3.20	3.31
94	3.13	3.19
100	3.23	3.50
106	3.40	3.63
112	3.04	3.30
118	3.59	3.78
124	3.44	3.62
130	3.26	3.43
136	3.21	3.32
142	3.16	3.42
148	3.67	3.96
154	3.63	3.72
160	3.77	3.73
166	3.50	3.74
172	3.23	3.58
178	3.63	3.74
184	2.86	2.95
190	2.62	2.70
196	3.09	3.19
202	1.76	1.81
208	0.99	1.02
214	0.10	
215		

A5-3. Measured and simulated cell velocities for Corbin Park rearing transect, 2577 cfs.

Station (ft)	Measured (ft/s)	Simulated (ft/s)
24		
27	0.17	0.17
34	0.4	0.4
40	0.68	0.67
47	2.07	2.06
54	2.07	2.07
61	1.12	1.12
64	2.22	2.22
71	1.25	1.25
78	1.42	1.42
85	1.66	1.67
92	0.84	0.84
99	1.62	1.63
106	1.79	1.8
113	1.78	1.79
120	1.58	1.58
127	0.92	0.92
134	1.75	1.76
141	2.37	2.38
148	1.40	1.4
152	3.09	3.1
155	2.91	2.92
159	2.72	2.73
162	3.55	3.56
165	3.15	3.16
169	3.18	3.19
173	2.65	2.66
176	2.47	2.48
183	3.85	3.86
186	2.17	2.18
190	2.53	2.54
193	2.47	2.48
197	2.57	2.58
204	2.15	2.16
211	2.23	2.24
216	2.38	2.39
224	1.41	1.41
231	2.40	2.4
238	1.62	1.61
245		
252	0.1	0.1
259	0.1	0.1

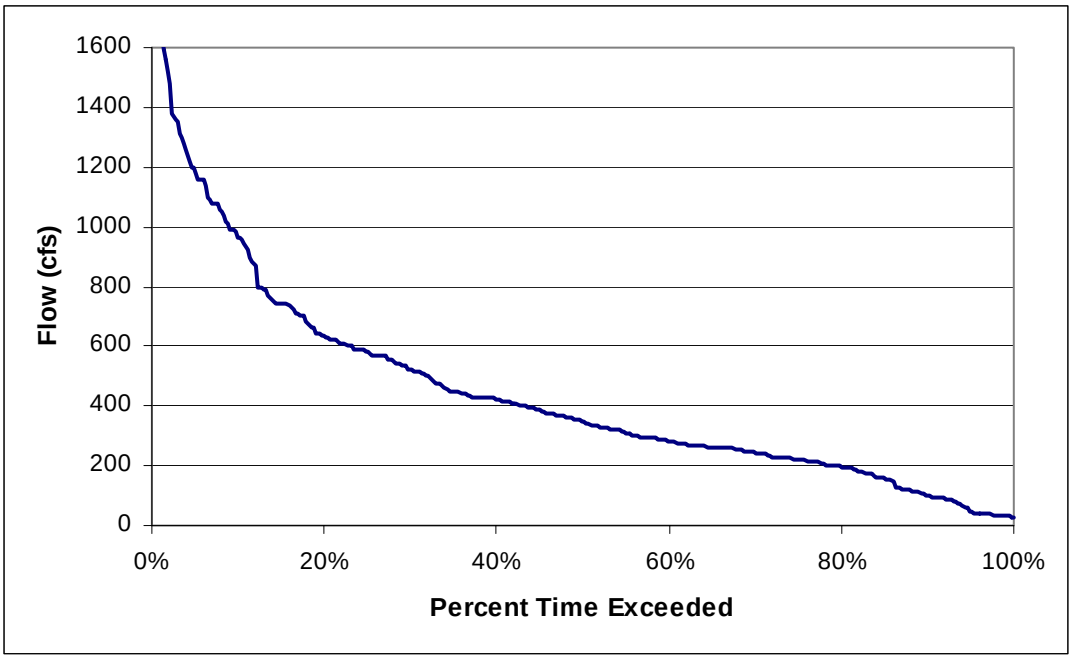
A5-4. Measured and simulated cell velocities for Barker Road rearing transect, 940 cfs.

Station (ft)	Measured (ft/s)	Simulated (ft/s)
-12		
-9		0.05
-7		0.07
-6	0.00	0.02
-2	0.00	0.05
1	0.05	0.05
4	0.78	0.84
7	0.10	0.11
10	0.10	0.11
13	0.27	0.29
16	1.23	1.32
19	2.70	2.9
22	2.54	2.73
25	2.27	2.44
28	3.32	3.56
31	3.50	3.76
34	4.02	3.82
37	4.42	5.07
40	3.91	4.63
43	4.96	5.4
46	5.66	6.83
49	5.13	5.52
52	5.26	5.7
55	5.26	5.81
58	2.55	3.01
61	3.46	3.34
64	3.03	3.4
67	1.54	1.68
70	1.83	1.96
73	1.55	1.66
76	0.75	0.76
79	0.33	0.38
82	0.16	0.17
85	0.17	0.18
88	0.26	0.28
91	0.00	0.17
94	0.05	0.05
97	0.00	0.02
103		0.07
106		0.03
109		

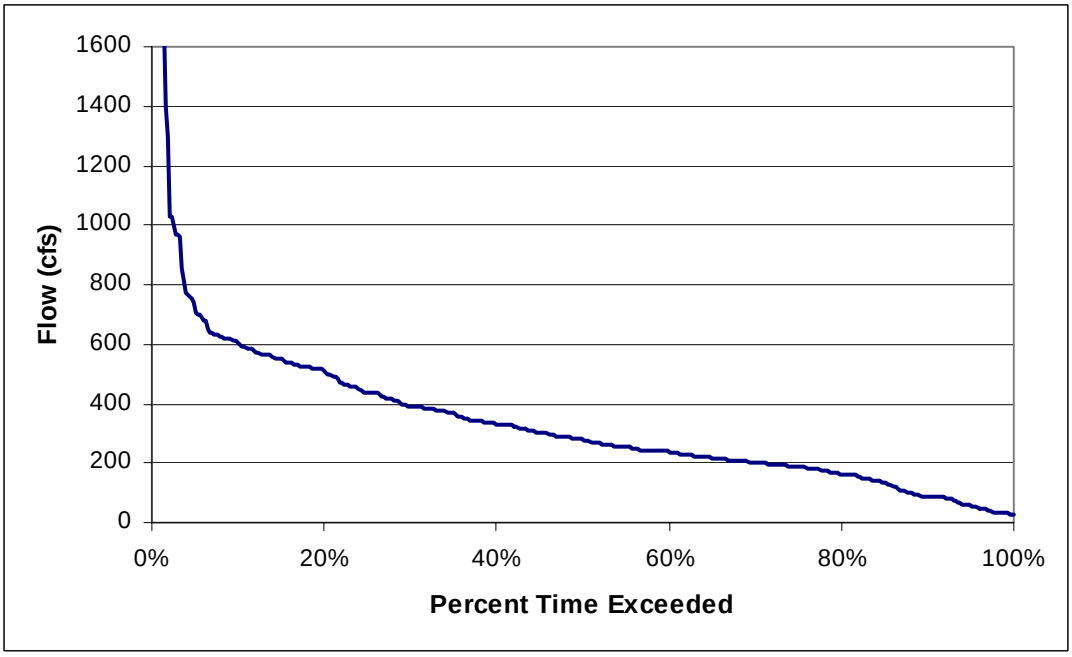
A5-5. Measured and simulated cell velocities for Sullivan Boulder-Glide rearing transect, 2025 cfs.

Station (ft)	Measured (ft/s)	Simulated (ft/s)
0		
6		
12		
18	0	1.01
26	1.80	1.74
30	1.53	1.45
32	1.58	1.55
36	2.04	2.01
40	2.26	2.23
44	-0.04	0.2
48	0.81	0.79
52	2.97	2.93
56	1.76	1.74
59	1.54	1.52
62	3.60	3.56
65	3.81	3.76
68	3.29	3.25
71	3.99	3.95
74	2.91	2.88
77	2.78	2.75
80	2.57	2.54
84	4.56	4.51
88	3.10	3.07
92	2.26	2.24
96	2.31	2.28
100	0.80	0.79
104	0.19	0.18
108	0.15	0.14
112	0.30	0.3
116	0.68	0.67
120	0.83	0.81
124	0.42	0.39
128	0.46	0.49
132	0.46	0.49
136	0.21	0.2
140	0	0.1
142	0	0.01
145		

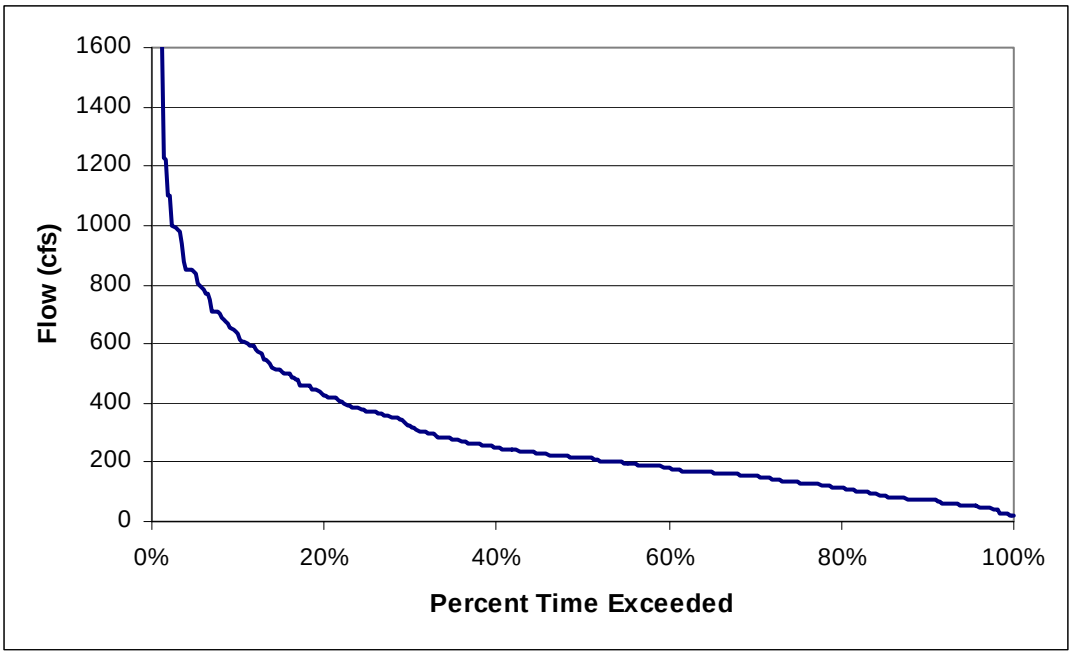
A5-6. Measured and simulated cell velocities for Sullivan Cascade rearing transect, 946 cfs.



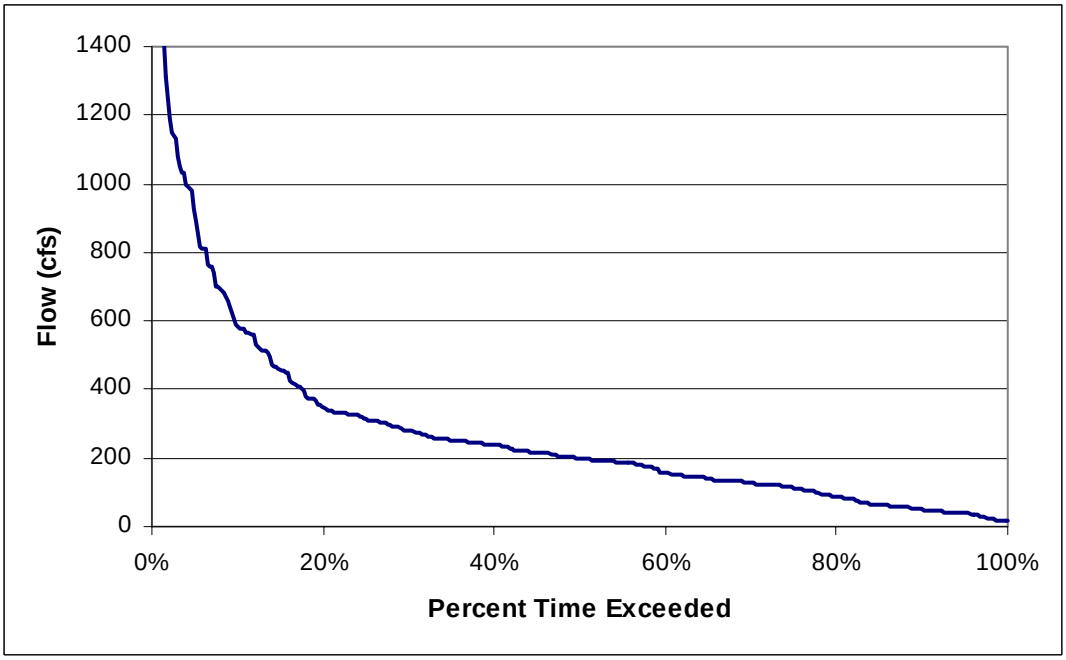
A6-1. Julian Week 14 (Apr 2-8) Flow Exceedance, Latah (Hangman) Creek at mouth.



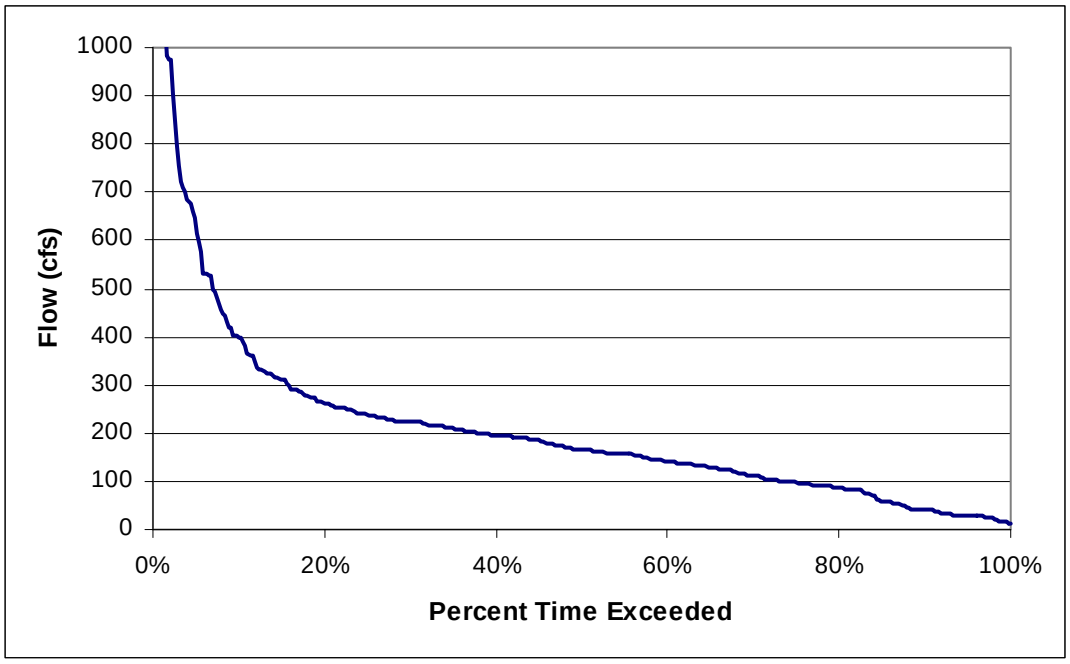
A6-2. Julian Week 15 (Apr 9-15) Flow Exceedance, Latah (Hangman) Creek at mouth.



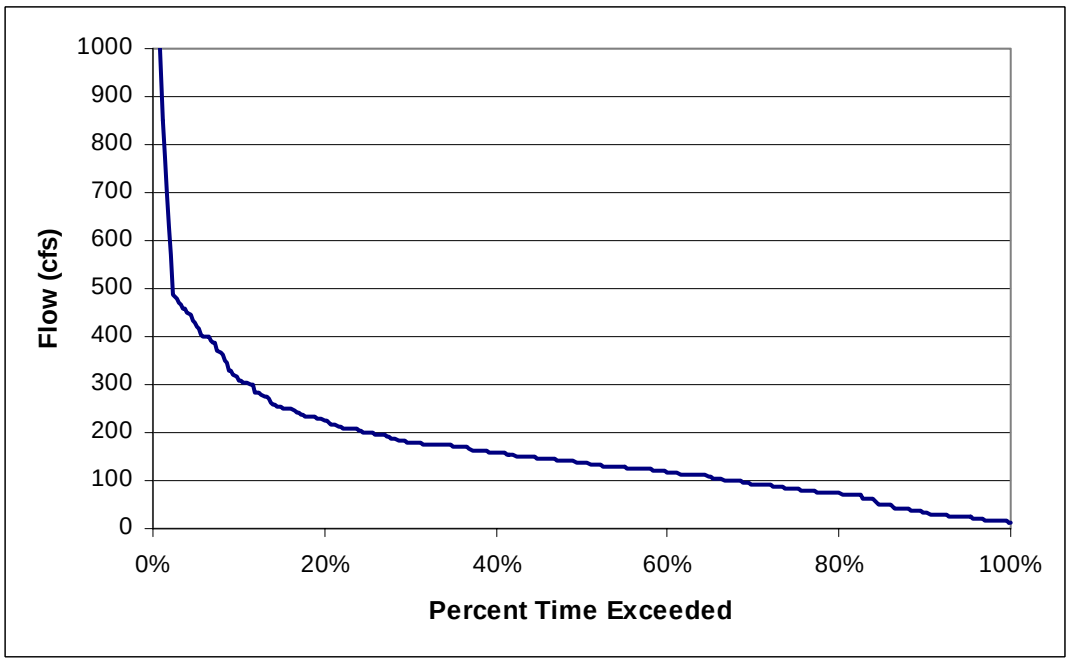
A6-3. Julian Week 16 (Apr 16-22) Flow Exceedance, Latah (Hangman) Creek at mouth.



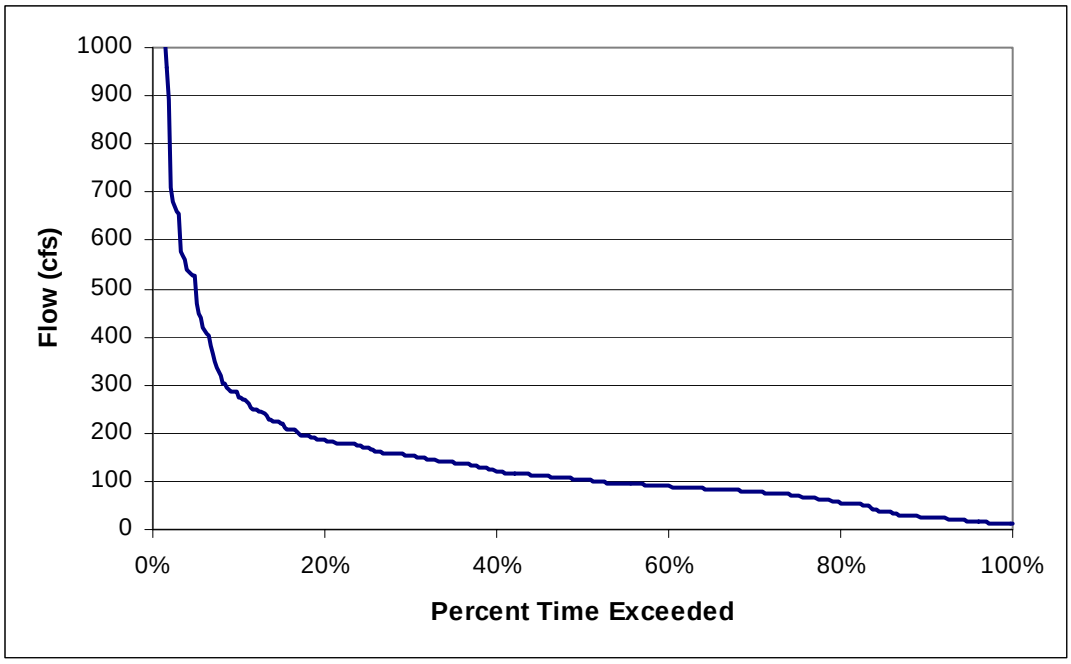
A6-4. Julian Week 17 (Apr 23-29) Flow Exceedance, Latah (Hangman) Creek at mouth.



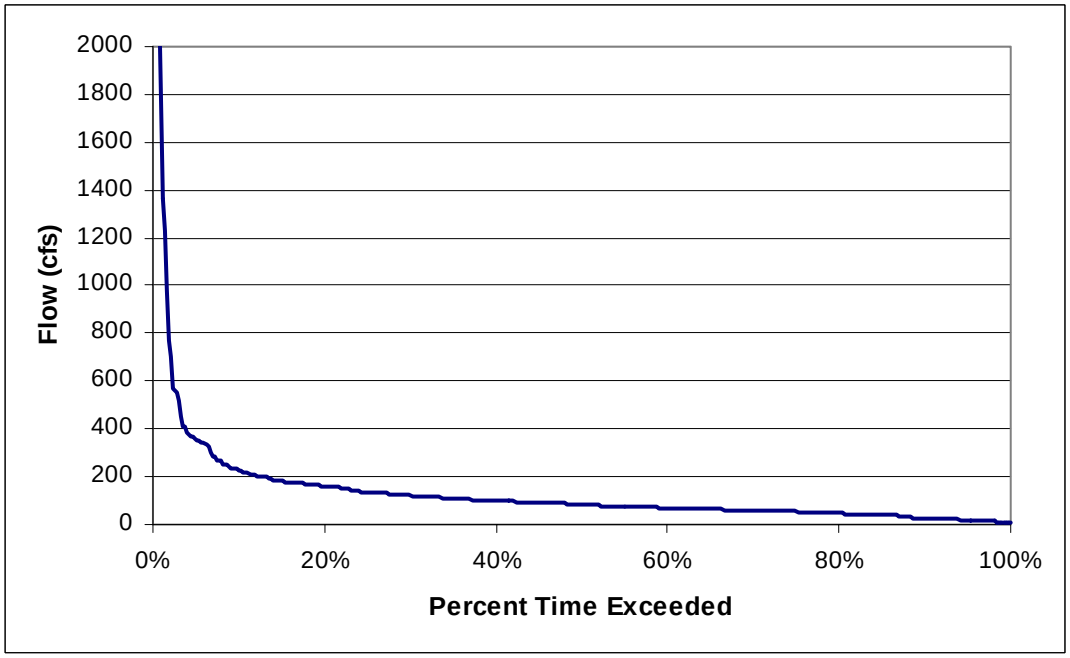
A6-5. Julian Week 18 (Apr 30-May 6) Flow Exceedance, Latah (Hangman) Creek at mouth.



A6-6. Julian Week 19 (May 7-13) Flow Exceedance, Latah (Hangman) Creek at mouth.



A6-7. Julian Week 20 (May 14-20) Flow Exceedance, Latah (Hangman) Creek at mouth.



A6-8. Julian Week 21 (May 21-17) Flow Exceedance, Latah (Hangman) Creek at mouth.

APPENDIX 7: SITE PHOTOS

A7-1. McGuire Park rearing transect at a. 365 cfs (9/3/03), b. 1350 cfs (9/15/03), c. 2394 cfs (9/16/03).

A7-2. Corbin Park rearing transect at a. 365 cfs (9/3/03), b. 1352 cfs (9/15/03), c. 2577 cfs (9/16/03).

A7-3. Starr Road Bar spawning site at a. 1900 cfs (9/16/03), 3600 cfs (10/30/03).

A7-4. Harvard Road spawning site at a. 1900 cfs (9/16/03), b. 3600 cfs (10/30/03).

A7-5. Barker Road rearing transect at a. 98 cfs (9/3/03), b. 871 cfs (9/15/03), c. 2000 cfs (9/16/03).

A7-6. Sullivan Boulder-Glide rearing transect at a. 125 cfs (9/3/03), 896 cfs (9/15/03), c. 2025 cfs (9/16/03).

A7-7. Sullivan Cascade rearing transect at a. 150 cfs (9/3/03), b. 921 cfs (9/15/03), c. 2050 cfs (9/16/03).

A7-8. Peaceful Valley spawning site at a. 1230 cfs (9/15/03), b. 3360 cfs (10/30/03).

A7-9. Evergreen spawning site at a. 1230 cfs (9/15/03), b. 3450 cfs (10/30/03).

A7-1. McGuire Park rearing transect at a. 365 cfs (9/3/03), b. 1350 cfs (9/15/03), c. 2394 cfs (9/16/03).

a. 

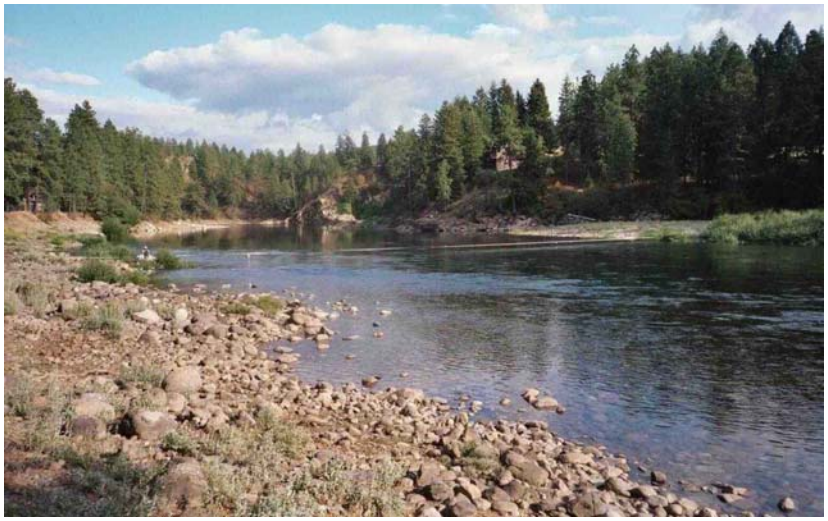
b. 

c. 

A7-2. Corbin Park rearing transect at a. 365 cfs (9/3/03), b. 1352 cfs (9/15/03), c. 2577 cfs (9/16/03).

a. 

b. 

c. 

A7-3. Starr Road Bar spawning site at a. 1900 cfs (9/16/03), 3600 cfs (10/30/03).

a. 

b. 

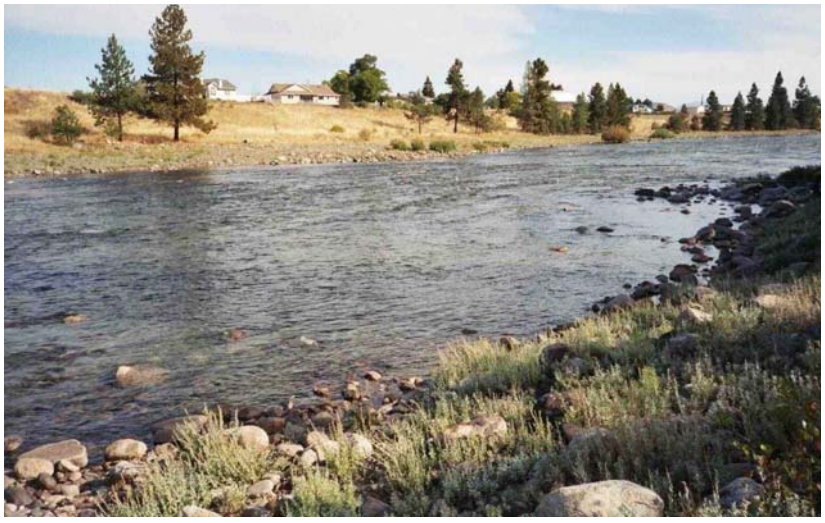
A7-4. Harvard Road spawning site at a. 1900 cfs (9/16/03), b. 3600 cfs (10/30/03).

a.

b.

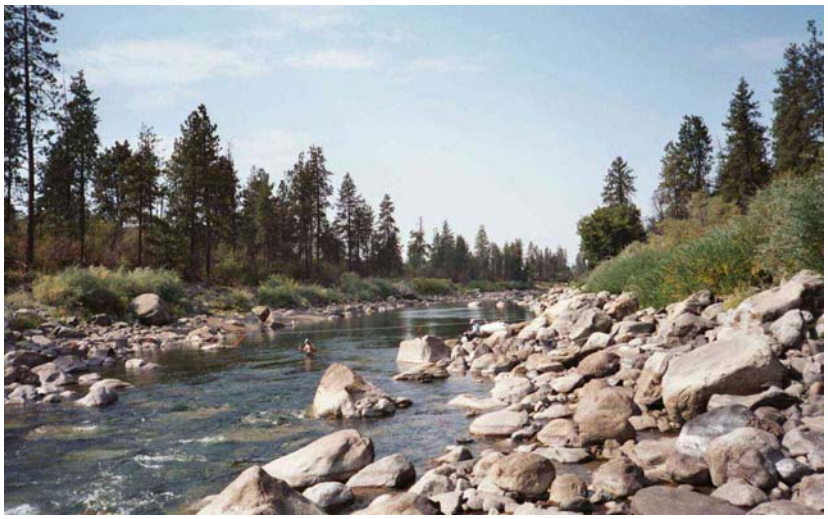
A7-5. Barker Road rearing transect at a. 98 cfs (9/3/03), b. 871 cfs (9/15/03), c. 2000 cfs (9/16/03).

a. 

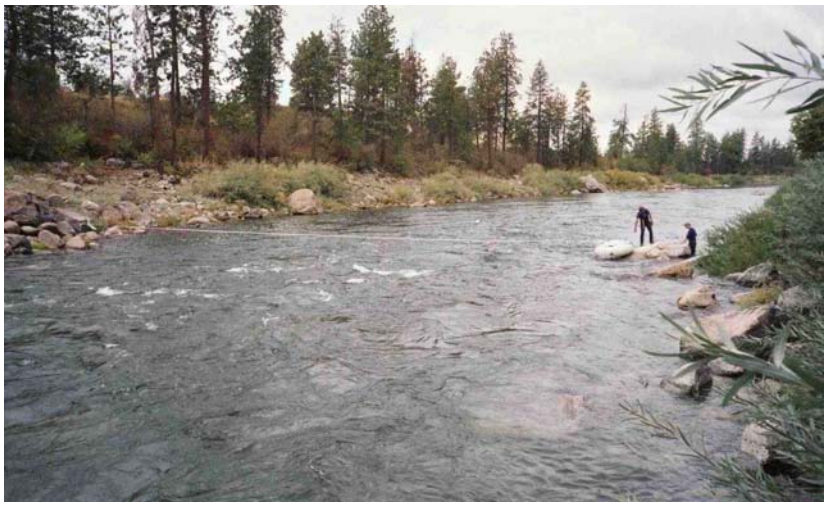
b. 

c. 

A7-6. Sullivan Boulder-Glide rearing transect at a. 125 cfs (9/3/03), 896 cfs (9/15/03), c. 2025 cfs (9/16/03).

a. 

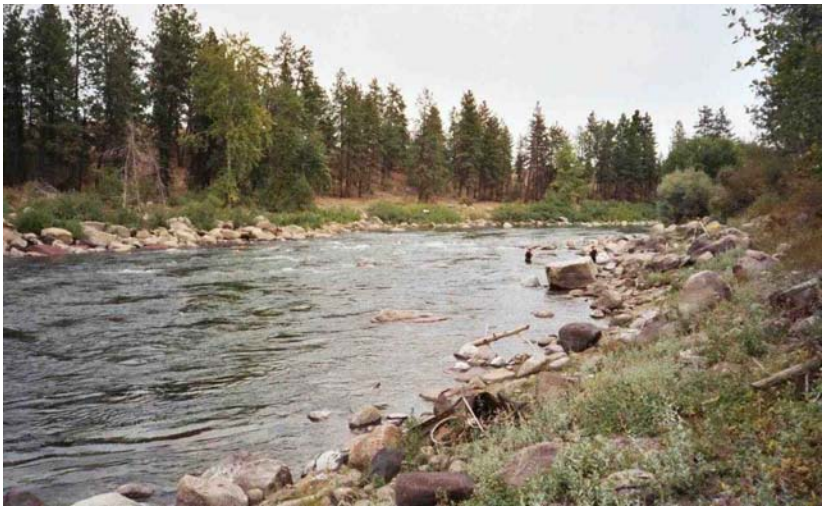
b. 

c. 

A7-7. Sullivan Cascade rearing transect at a. 150 cfs (9/3/03), b. 921 cfs (9/15/03), c. 2050 cfs (9/16/03).

a.

b.



c.

A7-8. Peaceful Valley spawning site at a. 1230 cfs (9/15/03), b. 3360 cfs (10/30/03).

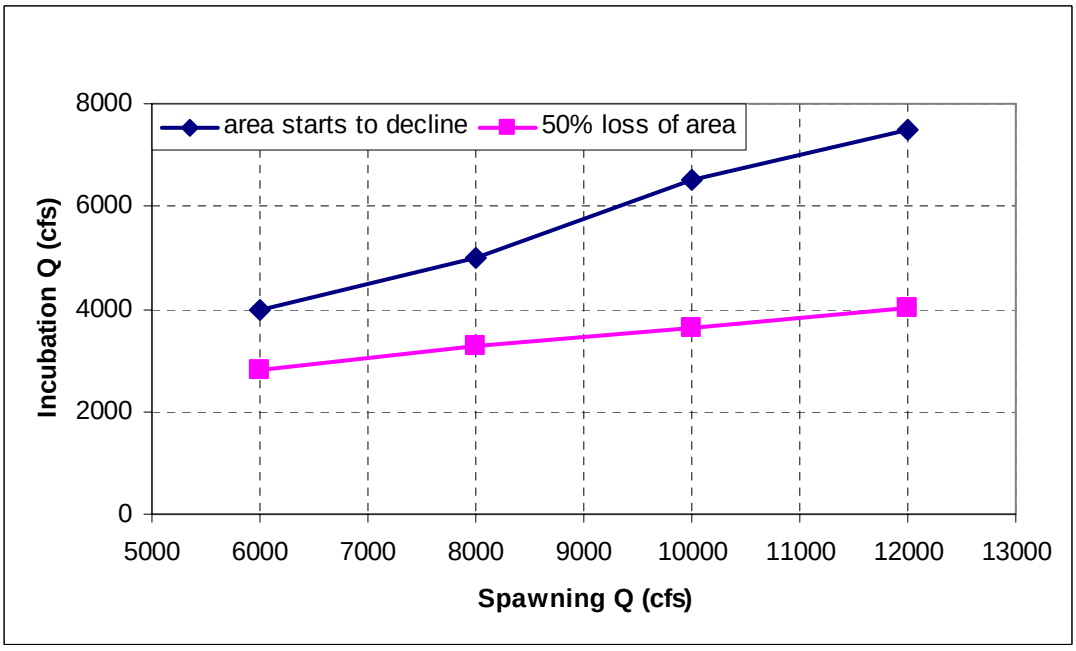
a. 

b. 

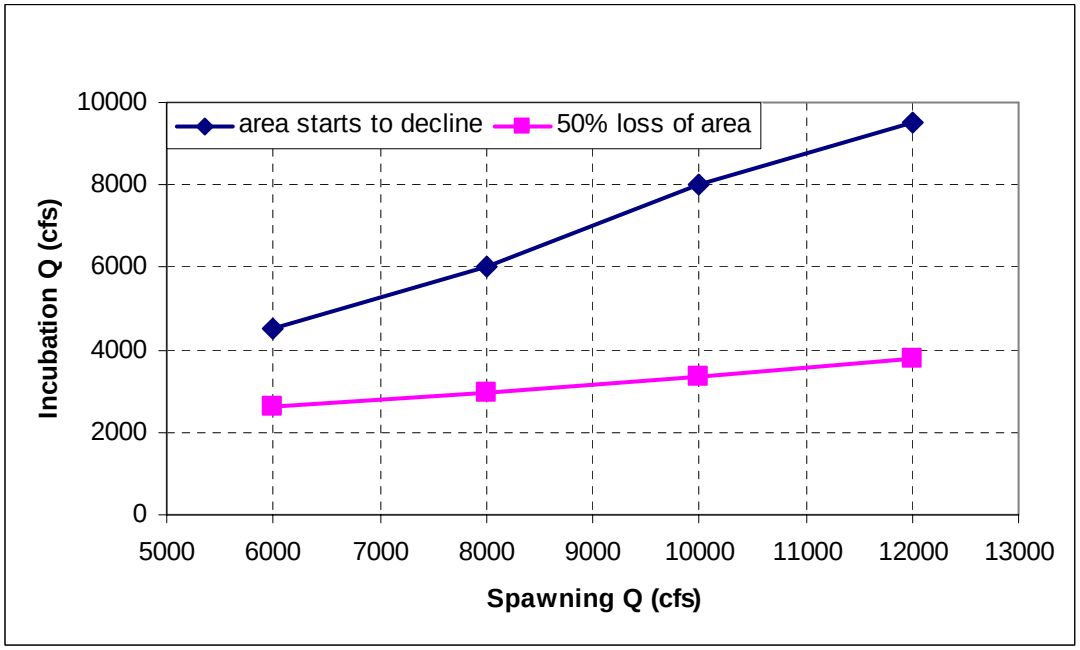
A7-9. Evergreen spawning site at a. 1230 cfs (9/15/03), b. 3450 cfs (10/30/03).

a.

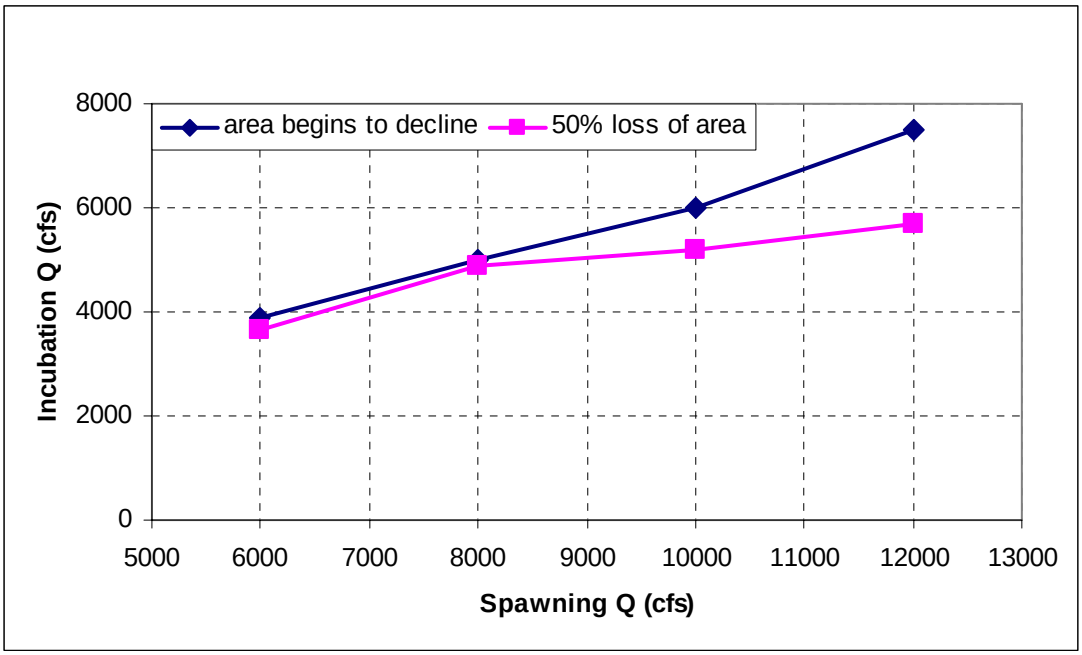
b.



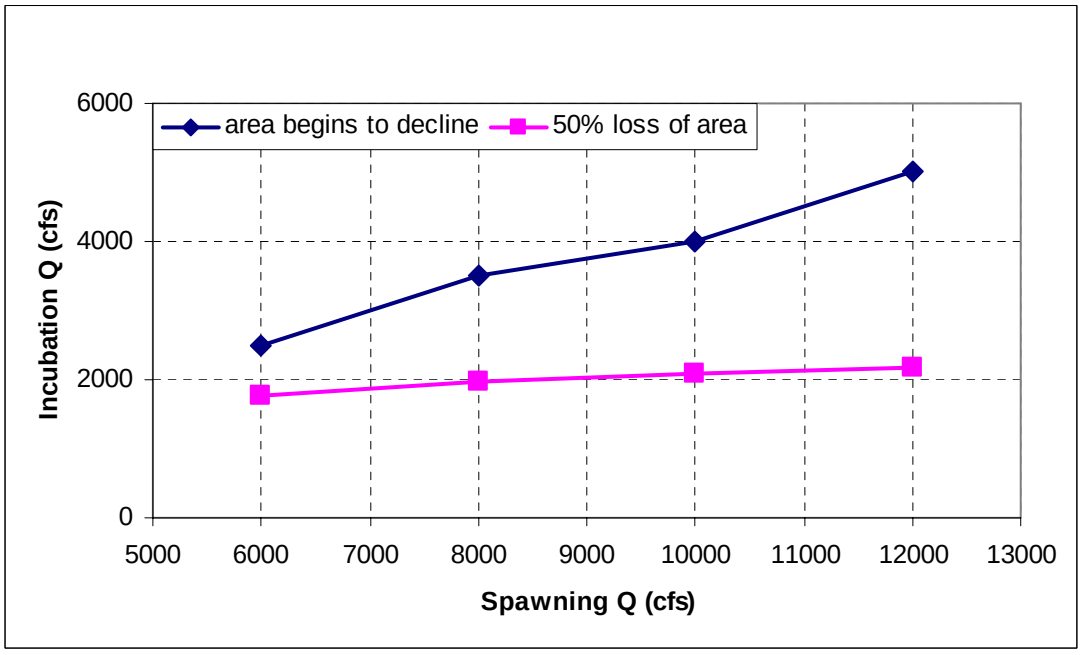
A8-1. Flow at which area suitable for incubation starts to decline, and declines by 50%, given a specific spawning flow—Starr Road spawning site.



A8-2. Flow at which area suitable for incubation starts to decline, and declines by 50%, given a specific spawning flow—Harvard Road spawning site.



A8-3. Flow at which area suitable for incubation starts to decline, and declines by 50%, given a specific spawning flow—Evergreen Road spawning site.



A8-4. Flow at which area suitable for incubation starts to decline, and declines by 50%, given a specific spawning flow—Peaceful Valley spawning site.

Site Flow (cfs)	Local WSE (ft)	Wetted Perimeter (ft)
300	93.59	137.2
350	93.68	139.7
400	93.77	142.1
450	93.85	144.3
500	93.92	147.0
550	94.00	151.0
600	94.07	154.1
650	94.13	161.1
700	94.20	171.8
750	94.26	174.0
800	94.32	176.3
850	94.38	180.1
900	94.43	184.8
950	94.49	190.2
1000	94.54	192.3
1100	94.65	194.7
1200	94.75	201.5
1300	94.84	202.9
1400	94.94	204.2
1500	95.03	205.5
1600	95.11	206.8
1700	95.2	208.0
1800	95.28	209.0
1900	95.36	210.1
2000	95.44	211.0
2100	95.51	212.0
2200	95.59	213.0
2300	95.66	213.9
2400	95.73	214.8

A9-1. Modeled discharge, water surface elevation, and wetted perimeter at McGuire Park rearing site.

Site Flow (cfs)	Local WSE (ft)	Wetted Perimeter (ft)
300	91.42	134.2
350	91.54	136.2
400	91.65	139.0
450	91.75	142.8
500	91.85	145.1
550	91.95	145.9
600	92.04	146.8
650	92.13	147.6
700	92.22	148.4
750	92.30	149.2
800	92.38	149.9
850	92.46	150.6
900	92.54	151.4
950	92.62	152.0
1000	92.69	152.7
1100	92.84	155.0
1200	92.98	159.8
1300	93.11	164.2
1400	93.24	165.8
1500	93.37	167.8
1600	93.49	169.7
1700	93.61	171.6
1800	93.73	173.4
1900	93.85	175.0
2000	93.96	176.6
2100	94.07	178.5
2200	94.18	180.2
2300	94.28	182.0
2400	94.39	183.7

Table A9-2. Modeled discharge, water surface elevation, and wetted perimeter at Corbin Park rearing site.

Site Flow (cfs)	Local WSE (ft)	Wetted Perimeter (ft)
50	93.81	142.8
100	94.14	160.6
150	94.37	165.7
200	94.54	177.2
250	94.69	180.8
300	94.82	183.6
350	94.94	186.1
400	95.04	188.4
450	95.14	190.9
500	95.23	195.1
550	95.31	201.8
600	95.39	207.7
650	95.46	212.6
700	95.53	217.1
750	95.59	221.3
800	95.66	224.0
850	95.72	226.4
900	95.77	228.7
950	95.83	231.0
1000	95.88	233.1
1100	95.98	238.6
1200	96.08	241.6
1300	96.17	243.8
1400	96.25	245.8
1500	96.33	247.7
1750	96.52	251.9
2000	96.69	253.7
2250	96.85	256.9
2500	96.99	258.2

A9-3. Modeled discharge, water surface elevation, and wetted perimeter at Barker Road rearing site.

Site Flow (cfs)	Local WSE (ft)	Wetted Perimeter (ft)
50	90.93	58.7
100	91.59	69.5
150	92.05	72.4
200	92.42	76.4
250	92.73	81.6
300	92.99	83.2
350	93.23	84.1
400	93.44	84.9
450	93.64	85.6
500	93.82	86.3
550	93.99	87.6
600	94.15	88.9
650	94.30	90.8
700	94.45	93.0
750	94.58	95.0
800	94.71	96.4
850	94.84	98.3
900	94.96	100.2
950	95.07	102.4
1000	95.19	104.8
1100	95.40	109.4
1200	95.60	114.1
1300	95.78	118.8
1400	95.96	122.2
1500	96.13	124.7
1750	96.52	130.2
2000	96.88	131.4
2250	97.20	132.5
2500	97.50	133.6

A9-4. Modeled discharge, water surface elevation, and wetted perimeter at Sullivan Road Boulder-Glide rearing site.

Site Flow (cfs)	Local WSE (ft)	Wetted Perimeter (ft)
50	90.87	80.8
100	91.42	93.6
150	91.79	99.7
200	92.08	102.0
250	92.33	103.9
300	92.54	105.6
350	92.72	107.1
400	92.89	108.3
450	93.04	109.2
500	93.18	110.1
550	93.31	110.9
600	93.43	112.8
650	93.55	117.4
700	93.66	121.6
750	93.76	124.7
800	93.86	126.2
850	93.95	126.9
900	94.04	127.6
950	94.13	128.3
1000	94.21	129.0
1100	94.37	130.3
1200	94.51	131.6
1300	94.65	132.8
1400	94.78	134.0
1500	94.91	135.2
1750	95.19	137.9
2000	95.45	139.4
2250	95.69	145.8
2500	95.91	153.4

A9-5. Modeled discharge, water surface elevation, and wetted perimeter at Sullivan Road Cascade rearing site.

Site Flow (cfs)	Local WSE (ft)	Wetted Perimeter (ft)
2000	98.41	260.1
2500	98.86	270.7
3000	99.23	279.0
3500	99.54	285.4
4000	99.81	290.0
4500	100.06	295.7
5000	100.27	300.5
5500	100.47	320.4
6000	100.65	322.1
6500	100.81	322.6
7000	100.97	323.0
7500	101.11	323.4
8000	101.24	323.8
8500	101.37	324.1
9000	101.49	324.5
9500	101.6	324.8
10000	101.71	324.8
10500	101.81	324.8
11000	101.91	324.8
11500	102.00	324.8
12000	102.09	324.8
12500	102.17	324.8
13000	102.25	324.8
13500	102.33	324.8
14000	102.41	324.8
14500	102.48	324.8
15000	102.56	324.8

A9-6. Modeled discharge, water surface elevation, and wetted perimeter at Starr Road Bar spawning site.

Site Flow (cfs)	Local WSE (ft)	Wetted Perimeter (ft)
2000	92.36	281.8
2500	92.97	293.9
3000	93.47	308.1
3500	93.89	315.8
4000	94.26	322.4
4500	94.59	326.3
5000	94.88	328.8
5500	95.14	336.9
6000	95.39	340.7
6500	95.61	344.5
7000	95.82	347.1
7500	96.01	350.5
8000	96.19	352.8
8500	96.36	354.9
9000	96.53	357.1
9500	96.68	359.7
10000	96.82	361.7
10500	96.96	363.5
11000	97.09	365.1
11500	97.22	366.8
12000	97.34	368.1
12500	97.46	369.3
13000	97.57	370.3
13500	97.66	371.1
14000	97.78	372.2
14500	97.88	373.2
15000	97.98	374.1

A9-7. Modeled discharge, water surface elevation, and wetted perimeter at Harvard Road spawning site.

Site Flow (cfs)	Total Area	Juvenile-I		Juvenile-II		Adult	
		WUA	% Total Area	WUA	% Total Area	WUA	% Total Area
300	136495	26810	19.6	37827	27.7	25226	18.5
350	139003	25126	18.1	38752	27.9	25631	18.4
400	141348	23268	16.5	39936	28.3	26267	18.6
450	143560	21664	15.1	40739	28.4	27304	19.0
500	146187	20145	13.8	41290	28.2	28360	19.4
550	149794	18846	12.6	41228	27.5	28888	19.3
600	153251	17213	11.2	41001	26.8	29500	19.2
650	160254	16184	10.1	40546	25.3	29525	18.4
700	170947	15549	9.1	39786	23.3	29495	17.3
750	173206	15096	8.7	38475	22.2	29263	16.9
800	175480	15731	9.0	36750	20.9	29088	16.6
850	179229	16443	9.2	34951	19.5	28622	16.0
900	183980	17244	9.4	33137	18.0	28020	15.2
950	189379	18195	9.6	31513	16.6	27261	14.4
1000	191457	19328	10.1	29653	15.5	26042	13.6
1100	193807	22607	11.7	26248	13.5	23622	12.2
1200	200666	25625	12.8	23724	11.8	21837	10.9
1300	202030	28683	14.2	21391	10.6	20991	10.4
1400	203345	31528	15.5	19800	9.7	20368	10.0
1500	204618	33743	16.5	20083	9.8	19790	9.7
1600	205851	35262	17.1	21246	10.3	19349	9.4
1700	207049	35100	17.0	22390	10.8	18841	9.1
1800	208081	33755	16.2	24401	11.7	18386	8.8
1900	209083	31755	15.2	26696	12.8	17782	8.5
2000	210061	29410	14.0	28746	13.7	16953	8.1
2100	211016	26547	12.6	31329	14.8	16623	7.9
2200	211950	23882	11.3	33513	15.8	16867	8.0
2300	212864	21747	10.2	35148	16.5	17260	8.1
2400	213760	19314	9.0	35605	16.7	18024	8.4
2500	219602	17421	7.9	35800	16.3	18674	8.5

A10-1. Weighted useable area (WUA) at the McGuire Park rearing site (area units are ft^2/1000 ft of linear stream distance).

Site Flow (cfs)	Total Area	Juvenile-I		Juvenile-II		Adult	
		WUA	% Total Area	WUA	% Total Area	WUA	% Total Area
300	133658	12261	9.2	45012	33.7	42369	31.7
350	135605	11417	8.4	42897	31.6	39927	29.4
400	138372	11023	8.0	40905	29.6	37976	27.4
450	142211	10761	7.6	38866	27.3	36050	25.3
500	144457	9999	6.9	36825	25.5	34425	23.8
550	145312	9897	6.8	34715	23.9	33226	22.9
600	146136	9703	6.6	32637	22.3	32478	22.2
650	146933	9689	6.6	30956	21.1	31687	21.6
700	147705	9692	6.6	29658	20.1	31016	21.0
750	148455	9629	6.5	28338	19.1	30303	20.4
800	149185	9489	6.4	27584	18.5	30015	20.1
850	149897	9294	6.2	27302	18.2	29654	19.8
900	150592	9120	6.1	27084	18.0	29271	19.4
950	151271	9176	6.1	26968	17.8	28877	19.1
1000	151936	9342	6.1	26860	17.7	28607	18.8
1100	154159	9498	6.2	26773	17.4	28249	18.3
1200	158959	9250	5.8	25087	15.8	27933	17.6
1300	163319	8840	5.4	23564	14.4	27694	17.0
1400	164836	8945	5.4	21919	13.3	27368	16.6
1500	166801	8956	5.4	20887	12.5	26951	16.2
1600	168714	9287	5.5	20521	12.2	26524	15.7
1700	170579	9025	5.3	20623	12.1	26301	15.4
1800	172399	8866	5.1	20662	12.0	25831	15.0
1900	174003	9014	5.2	20899	12.0	25286	14.5
2000	175594	9044	5.2	21151	12.0	24711	14.1
2100	177389	8722	4.9	20183	11.4	24252	13.7
2200	179150	8239	4.6	18756	10.5	23665	13.2
2300	180878	7923	4.4	17684	9.8	23070	12.8
2400	182576	7943	4.4	17151	9.4	22327	12.2
2500	184246	8259	4.5	16728	9.1	21389	11.6

A10-2. Rainbow Trout weighted useable area (WUA) at the Corbin Park rearing site (area units are ft^2/1000 ft of linear stream distance).

Site Flow (cfs)	Total Area	Juvenile-I		Juvenile-II		Adult	
		WUA	% Total Area	WUA	% Total Area	WUA	% Total Area
50	142303	54373	38.2	11680	8.2	1152	0.8
100	160054	57822	36.1	37911	23.7	7044	4.4
150	165120	53705	32.5	60285	36.5	13600	8.2
200	176556	45884	26.0	71177	40.3	20105	11.4
250	180201	39252	21.8	76730	42.6	26337	14.6
300	183006	32295	17.6	77968	42.6	32033	17.5
350	185501	26770	14.4	77324	41.7	37045	20.0
400	187758	23040	12.3	75482	40.2	41596	22.2
450	190270	19877	10.4	73352	38.6	45625	24.0
500	194465	17513	9.0	71489	36.8	48511	24.9
550	201031	15567	7.7	69818	34.7	50825	25.3
600	207002	13949	6.7	68068	32.9	52253	25.2
650	211884	13108	6.2	65741	31.0	53246	25.1
700	216351	12401	5.7	63449	29.3	53910	24.9
750	220599	11777	5.3	60992	27.6	53646	24.3
800	223266	11902	5.3	58531	26.2	53366	23.9
850	225665	12022	5.3	56071	24.8	53095	23.5
900	227966	12014	5.3	53388	23.4	52687	23.1
950	230180	12130	5.3	50542	22.0	52306	22.7
1000	232259	12512	5.4	47682	20.5	51897	22.3
1100	237819	14071	5.9	42738	18.0	50536	21.2
1200	240711	15559	6.5	38902	16.2	49097	20.4
1300	242917	17043	7.0	35909	14.8	47873	19.7
1400	244896	18452	7.5	33691	13.8	46377	18.9
1500	246776	19612	7.9	32305	13.1	44644	18.1
1750	250857	21762	8.7	30659	12.2	40390	16.1
2000	252726	19738	7.8	32324	12.8	36550	14.5
2250	255857	18693	7.3	35638	13.9	33695	13.2
2500	257099	18791	7.3	38419	14.9	31793	12.4

A10-3. Rainbow Trout weighted useable area (WUA) at the Barker Road rearing site (area units are ft^2/1000 ft of linear stream distance).

Site Flow (cfs)	Total Area	Juvenile-I		Juvenile-II		Adult	
		WUA	% Total Area	WUA	% Total Area	WUA	% Total Area
50	53577	19819	37.0	45941	85.7	24669	46.0
100	63258	16675	26.4	47852	75.6	32680	51.7
150	65416	17957	27.5	47803	73.1	36955	56.5
200	68777	18995	27.6	48382	70.3	38191	55.5
250	73530	19695	26.8	50176	68.2	37071	50.4
300	74660	20166	27.0	50189	67.2	35652	47.8
350	75362	19371	25.7	48481	64.3	34439	45.7
400	75987	18832	24.8	47739	62.8	34348	45.2
450	76561	17944	23.4	47878	62.5	34476	45.0
500	77175	17084	22.1	48383	62.7	34870	45.2
550	78272	16138	20.6	48309	61.7	35409	45.2
600	79362	15029	18.9	47570	59.9	35979	45.3
650	81183	13991	17.2	46978	57.9	36489	44.9
700	83193	13070	15.7	46318	55.7	36928	44.4
750	85106	13031	15.3	45673	53.7	36802	43.2
800	86346	13292	15.4	45010	52.1	36604	42.4
850	88137	13682	15.5	44286	50.2	36217	41.1
900	89857	14010	15.6	43163	48.0	35754	39.8
950	91861	14537	15.8	42147	45.9	35337	38.5
1000	94040	15323	16.3	41157	43.8	34670	36.9
1100	98220	17648	18.0	39692	40.4	33990	34.6
1200	102476	20032	19.5	39656	38.7	32907	32.1
1300	106828	22289	20.9	40099	37.5	32216	30.2
1400	109884	25021	22.8	40958	37.3	31270	28.5
1500	112039	27443	24.5	42277	37.7	30472	27.2
1750	116892	31101	26.6	48014	41.1	29042	24.8
2000	117877	29851	25.3	52955	44.9	29020	24.6
2250	118781	26325	22.2	54567	45.9	28366	23.9
2500	119618	22754	19.0	54593	45.6	27916	23.3

A10-4. Rainbow Trout weighted useable area (WUA) at the Sullivan Road Boulder-Glide rearing site (area units are ft^2/1000 ft of linear stream distance).

Site Flow (cfs)	Total Area	Juvenile-I		Juvenile-II		Adult	
		WUA	% Total Area	WUA	% Total Area	WUA	% Total Area
50	79788	34838	43.7	54693	68.5	25022	31.4
100	92015	34922	38.0	56726	61.6	40705	44.2
150	97920	35305	36.1	60571	61.9	46145	47.1
200	100072	33381	33.4	66858	66.8	46473	46.4
250	101861	31026	30.5	68462	67.2	46093	45.3
300	103405	28492	27.6	67139	64.9	47029	45.5
350	104771	26002	24.8	65420	62.4	47052	44.9
400	105856	24749	23.4	64826	61.2	47059	44.5
450	106726	22644	21.2	63896	59.9	47650	44.6
500	107527	20634	19.2	62525	58.1	47381	44.1
550	108272	19105	17.6	61087	56.4	47189	43.6
600	110044	17644	16.0	60035	54.6	46898	42.6
650	114528	16256	14.2	58794	51.3	46918	41.0
700	118712	15293	12.9	57801	48.7	46901	39.5
750	121808	14386	11.8	56492	46.4	46839	38.5
800	123217	13542	11.0	55131	44.7	46468	37.7
850	123905	12985	10.5	53847	43.5	45929	37.1
900	124564	12527	10.1	52620	42.2	45381	36.4
950	125223	11963	9.6	51507	41.1	45044	36.0
1000	125915	11410	9.1	50522	40.1	44859	35.6
1100	127227	9949	7.8	49156	38.6	44935	35.3
1200	128454	9295	7.2	48447	37.7	45082	35.1
1300	129609	9285	7.2	47716	36.8	45387	35.0
1400	130785	9195	7.0	46666	35.7	45798	35.0
1500	131946	8945	6.8	45246	34.3	45898	34.8
1750	134619	8321	6.2	42512	31.6	44759	33.2
2000	136049	8484	6.2	41669	30.6	43451	31.9
2250	142342	7971	5.6	41148	28.9	42386	29.8
2500	149856	7984	5.3	40932	27.3	41250	27.5

A10-5. Rainbow Trout weighted useable area (WUA) at the Sullivan Road Cascade rearing site (area units are ft^2/1000 ft of linear stream distance).

Site Flow (cfs)	Total Area	Spawning		Incubation	
		WUA	% Total Area	WUA	% Total Area
2000	67928	9	0.0	2137	3.1
2500	69466	134	0.2	3080	4.4
3000	72645	859	1.2	4834	6.7
3500	75256	1617	2.1	6627	8.8
4000	76824	2368	3.1	8160	10.6
4500	78011	3432	4.4	9137	11.7
5000	79095	4573	5.8	9939	12.6
5500	81659	5681	7.0	11701	14.3
6000	82785	6687	8.1	12991	15.7
6500	83406	7462	8.9	13448	16.1
7000	84541	8225	9.7	14034	16.6
7500	85081	8771	10.3	14479	17.0
8000	86073	8981	10.4	14777	17.2
8500	86466	9324	10.8	15281	17.7
9000	86660	9584	11.1	15189	17.5
9500	86887	9585	11.0	15153	17.4
10000	87472	9196	10.5	15263	17.4
10500	88020	8811	10.0	15521	17.6
11000	88825	8421	9.5	15816	17.8
11500	88825	7999	9.0	15954	18.0
12000	88825	7608	8.6	15685	17.7
12500	88825	7167	8.1	15465	17.4
13000	88825	6788	7.6	15256	17.2
13500	88825	6206	7.0	15049	16.9
14000	88825	5497	6.2	14836	16.7
14500	88825	4889	5.5	14646	16.5
15000	88825	4524	5.1	14432	16.2

A10-6. Rainbow Trout weighted useable area (WUA) generated by PHABSIM at the Starr Road Bar spawning site (area units are ft^2/1000 ft of linear stream distance, and total area includes the entire channel cross section).

Site Flow (cfs)	Total Area	Spawning		Incubation	
		WUA	% Total Area	WUA	% Total Area
2000	48786	35	0.1	1115	2.3
2500	50342	464	0.9	2054	4.1
3000	52486	1019	1.9	3635	6.9
3500	54404	1730	3.2	5110	9.4
4000	56035	2673	4.8	6261	11.2
4500	56840	3652	6.4	6822	12.0
5000	57269	4502	7.9	6921	12.1
5500	58650	5169	8.8	7832	13.4
6000	59313	5647	9.5	8105	13.7
6500	59963	6016	10.0	8200	13.7
7000	60417	6331	10.5	8185	13.5
7500	60997	6465	10.6	8187	13.4
8000	61392	6448	10.5	8205	13.4
8500	61760	6313	10.2	8088	13.1
9000	62127	5972	9.6	7952	12.8
9500	62574	5456	8.7	7857	12.6
10000	62929	4886	7.8	7804	12.4
10500	63232	4352	6.9	7706	12.2
11000	63513	3933	6.2	7691	12.1
11500	63794	3640	5.7	7624	12.0
12000	64036	3223	5.0	7656	12.0
12500	64225	2786	4.3	7594	11.8
13000	64399	2445	3.8	7567	11.8
13500	64562	2203	3.4	7505	11.6
14000	64730	2021	3.1	7442	11.5
14500	64888	1852	2.9	7396	11.4
15000	65046	1709	2.6	7313	11.2

A10-7. Rainbow Trout weighted useable area (WUA) generated by PHABSIM at the Harvard Road spawning site (area units are ft^2/1000 ft of linear stream distance, and total area includes the entire channel cross section).