Walter Hardman Project Water Use Plan

Lower Cranberry Creek: Rainbow Trout Rearing Habitat Monitoring

Implementation Year 1

Reference: WHNMON-2

Study Period: 2012

Triton Environmental Consultants Ltd.

October 2012

Project number: 4383
Version: 1
October 2012

WALTER HARDMAN PROJECT WATER USE PLAN

LOWER CRANBERRY CREEK: RAINBOW TROUT REARING HABITAT MONITORING

Reference: WHNMON#2

Walter Hardman Water Use Plan Monitoring Program: Rainbow Trout Rearing Habitat Monitoring

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October 2012

Executive Summary

Triton Environmental Consultants Ltd. (Triton) was retained by BC Hydro to complete a one year habitat monitoring program to determine how Rainbow Trout (*Oncorhynchus mykiss*) rearing habitat suitability in lower Cranberry Creek is affected by changes in discharge. The objective was to gather information to answer the management question of whether a minimum flow through the diversion dam upstream will increase the quality and quantity of rearing habitat for Rainbow Trout over historical operating practice.

The study focused on a section of lower Cranberry Creek between impassable falls located at approximately 2.7 km upstream from the confluence with the Upper Arrow Lake Reservoir, and the confluence of Cranberry Creek with an unnamed tributary 7.7 km upstream. Hydrometric and habitat data were collected at transects established in three habitat types (pools, riffles, and glides) considered to be important to the life history stages of Rainbow Trout. Field work was completed between August and October 2011 and data were collected over a range of flows.

Habitat Suitability Index (HSI) curves for Rainbow Trout life stages (fry and juvenile) were received from the BC Ministry of Environment and were used in conjunction with the hydrometric and habitat data to determine the weighted usable width (WUW) for each transect in the study area. In general, the trend was an increase in the available habitat for both life stages with increases in flow from base flow conditions. As depth increased, isolated pools were reconnected, allowing more even distribution of individuals throughout the creek. Velocity was also determined to increase with increasing flow in all three habitat units. The resulting WUW was shown to increase with increasing discharge in the creek although each habitat unit responded slightly differently.

Our results also showed an optimal discharge where mean velocities were within the preferred ranges for fry and juvenile fish as indicated by the WUW. WUW for fry reached a maximum value at 1.06 m^3s^{-1} while the WUW for juvenile peaked at 1.51 m^3s^{-1}. Beyond this stage, the calculated WUW in showed a decreasing trend as instream velocities exceeded the preferences for Rainbow Trout.

Additional flows from the diversion structure were shown to have a positive impact on the quality and quantity of effective rearing habitat for both Rainbow Trout life stages. This positive relationship continued until the habitat suitability exceeded preferred thresholds for each of the life history phases, after which time available habitats began to decline because of the increase in water velocity. Initiating a minimum flow in Cranberry Creek of 0.1 m^3s^{-1} will likely improve the quality and quantity of rearing habitat for Rainbow Trout over conditions of base flow; however any influence from the diversion flows will be negated at higher background flows.

WHNMON-2 STATUS OF OBJECTIVES, MANAGEMENT QUESTIONS AND HYPOTHESES

Objectives	Management Questions	Management Hypothesis	Status
To determine the effectiveness of the 0.1 m^3s^{-1} flow release for improving the quality and quantity of Rainbow Trout rearing habitat in Lower Cranberry Creek and provide information on potential fisheries benefits obtained by alternative minimum flow releases.	Does the implementation of the 0.1 m^3s^{-1} minimum flow release improve the quality and quantity of effective rearing habitat for Rainbow Trout over that predicted for historical operation of no minimum flow release provision?	Overarching hypotheses to be tested by monitoring program: H_0: Operation of the diversion dam to provide a minimum flow of 0.1 m^3s^{-1} does not improve the quality and quantity of rearing habitat for Rainbow Trout in Lower Cranberry Creek over condition of no minimum flow. H_A: Operation of the diversion dam to provide a minimum flow of 0.1 m^3s^{-1} does improve the quality and quantity of habitat for Rainbow Trout in Lower Cranberry Creek over conditions of no minimum flow.	The release of a 0.1 m^3s^{-1} minimum flow will result in a significant increase in the suitable (depth and velocity integrated) habitat area in key Rainbow Trout rearing locations but only within a range of flows above baseline levels. An optimal discharge was determined for both fry and juveniles after which habitats begin to decline because of increase in water velocity.
	Would the implementation of a 0.5 m^3s^{-1} minimum flow release provide increased protection and / or enhancement of Rainbow Trout rearing habitat over that delivered by the 0.1 m^3s^{-1} minimum flow release?	Overarching hypotheses cannot be tested directly because of the variation in the seasonal pattern and magnitude of inflows to Cranberry Creek therefore three sub-hypotheses were tested: H_1: The release of a 0.1 m^3s^{-1} minimum flow will result in a significant increase in the depth of flow in key Rainbow Trout rearing locations. H_2: The release of a 0.1 m^3s^{-1} minimum flow will not result in an unsuitable increase in the flow velocity in key Rainbow Trout rearing locations. H_3: The release of a 0.1 m^3s^{-1} minimum flow will result in a significant increase in the minimum wetted area of key Rainbow Trout rearing locations that conforms to the depth and velocity characteristics used by Rainbow Trout.	The release of a 0.5 m^3s^{-1} minimum flow will not result in a significant increase in the suitable (depth and velocity integrated) habitat area in key Rainbow Trout rearing locations.

Disclaimer

This report is rendered solely for the use of BC Hydro in connection with the Walter Hardman Project Water Use Plan Monitoring Program (WHNMON #2: Rainbow Trout Rearing Habitat Monitoring Program), and no person may rely on it for any other purpose without BC Hydro's prior written approval. Should a third party use this report without approval, they may not rely upon it. BC Hydro and Triton accept no responsibility for loss or damages suffered by any third party as a result of decisions made or actions taken based on this report.

This report is based on facts and opinions contained within the referenced documents provided by BC Hydro. We have attempted to identify and consider relevant facts and documents pertaining to the scope of work, as of the time period during which we conducted this analysis. However, our opinions may change if new information is available or if information we have relied on is altered.

We applied accepted professional practices and standards in developing and interpreting data obtained by our field measurement, sampling, and observations. While we used accepted professional practices in interpreting data provided by BC Hydro or third party sources we did not verify the accuracy of data provided by BC Hydro or third party sources.

This report should be considered as a whole and selecting only portions of the report for reliance may create a misleading view of our opinions.

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1.0 Introduction

Triton Environmental Consultants Ltd. (Triton) was retained by BC Hydro to complete a one year habitat monitoring program to determine how Rainbow Trout (*Oncorhynchus mykiss*) rearing habitat suitability in lower Cranberry Creek is affected by changes in discharge. The objective was to gather information to answer the management question of whether a 0.1 m^3s^{-1} minimum flow through the diversion dam upstream would increase quality and quantity of rearing habitat for Rainbow Trout over historical operating practice (no diversion flow).

This program is one of several described by the Walter Hardman Water Use Plan (BC Hydro, 2004) which are designed to monitor the outcomes of operational changes and changes to physical works, and provide information on which to base future operating decisions.

1.1 Project Background

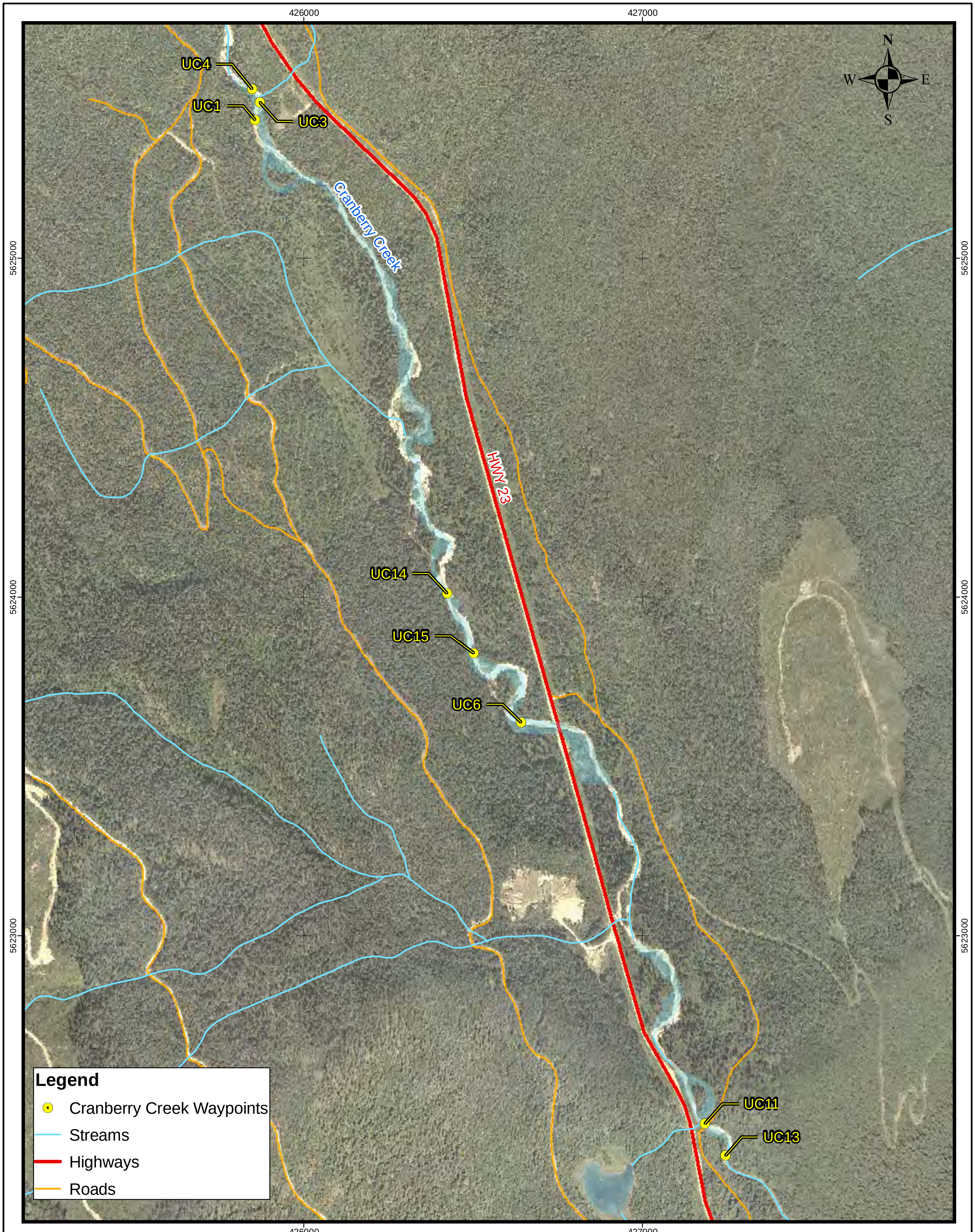
The Walter Hardman Hydroelectric project is located on Cranberry Creek, within the Columbia-Shuswap Regional District. The generating station is approximately 25 km south of Revelstoke, BC and uses water diverted from Cranberry Creek to generate power. When creek flows are greater than plant capacity (approximately 4.3 m^3s^{-1}) excess water is released to Lower Cranberry Creek; however when flows are less than plant capacity no water is released over the diversion dam into the creek.

The cessation of flows results in the dewatering of much of Cranberry Creek Rainbow Trout habitat within this stream section. The Water Use Planning Committee recognized the impacts associated with the dewatering during low flow periods and hypothesized that the construction of a diversion structure to deliver continuous flows during the year would have a positive effect on Rainbow Trout production. To address this problem a water diversion structure was installed at the diversion dam with the objective of delivering a minimum flow of 0.1 m^3s^{-1}.

Fish usage in Cranberry Creek is limited by an impassable barrier (falls) located approximately 2.3 km upstream from the confluence with Arrow Lakes Reservoir (Figure 1-1). Kokanee Salmon (*Oncorhynchus nerka*) are restricted to the lower stream section, while Rainbow Trout are the sole sport fish species inhabiting the stream section from the barrier to the diversion dam (sculpins are also present upstream). Rainbow Trout are also present above the diversion dam but the diversion dam precludes any upstream passage.

Rainbow Trout are resident in Cranberry Creek throughout the year (Summit, 2000). They rear in riffles and runs, and juveniles seek out slower waters and typically shallower depths than adults. The current low flow regime in the section below the diversion dam often causes parts of the stream to dewater and has the potential to reduce suitable habitat conditions throughout the channel for Rainbow Trout rearing. The relationship between the amount of available habitat and flow relies on the achievement of preferred depths and velocities for different life history phases of Rainbow Trout.

This report provides a description of Rainbow Trout rearing habitat in Cranberry Creek and assesses the impacts of diversion flows 0.1 m^3s^{-1} on Rainbow Trout rearing habitat values. A second study focussed on flow related impacts on Kokanee in lower Cranberry Creek (WHNMON-1).



Cranberry Creek

Figure 1.1.
Site Location Map

Basemap Source: British Columbia Imagery WMS	0 50 100 200 300 400 500 Meters **Scale:** 1:15,000		**Map Datum:** UTM NAD 83 Zone 11
Project No: 4383	**File No:** Map#: N:\ACTIVE\4383_Cranberry_Creek \MXD\CranberryCreekFigure1.mxd	**Date:** January 9, 2013	TRITON ENVIRONMENTAL CONSULTANTS LTD.

2.0 Methods

The methodology for the Lower Cranberry Creek Rainbow Trout Rearing Habitat Monitoring program follows the BC Hydro Terms of Reference (BC Hydro, 2010) and adheres to the Resources Information Standards Committee (RISC) Fish and Fish Habitat Inventory (RISC, 2000), and the Fish Collection Methods and Standards (RISC, 1997).

To address the primary management question regarding the effectiveness of implementing a minimum flow release in improving Rainbow Trout rearing habitat, an overarching hypothesis was developed: Operation of the diversion dam to provide minimum flow releases of 0.1 m^3s^{-1} does improve the quality and quantity of rearing habitat for Rainbow Trout in Lower Cranberry Creek over conditions of no minimum flow. This hypothesis cannot be tested directly because of the variation in the seasonal pattern and magnitude of inflows to Cranberry Creek, therefore three sub-hypotheses were tested:

H_1: The release of a 0.1 m^3s^{-1} minimum flow will result in a significant increase in the depth of flow in key Rainbow Trout rearing locations.

H_2: The release of a 0.1 m^3s^{-1} minimum flow will not result in an unsuitable increase in the flow velocity in key Rainbow Trout rearing locations.

H_3: The release of a 0.1 m^3s^{-1} minimum flow will result in a significant increase in the minimum wetted area of key Rainbow Trout rearing locations that conforms to the depth and velocity characteristics used by Rainbow Trout.

2.1 Study Design

The hypotheses were tested by analyzing habitat suitability at various flow rates and determining the effectiveness of a minimum flow of 0.1 m^3s^{-1}. Triton targeted collection of habitat measurements at three levels of discharge in Lower Cranberry Creek:

- Low – approximately equivalent to minimum base flow of 0.01 m^3s^{-1}
- Moderate – approximately equivalent to discharge of 0.70 m^3s^{-1}
- High – during a spill event at the diversion structure 2.06 m^3s^{-1}

Low flow ranged from negligible to 0.01 m^3s^{-1} when no spills were taking place and is representative of pre-diversion flow. Suitable rearing locations for Rainbow Trout were therefore identified at this flow level. Moderate flow ranged from 0.12 m^3s^{-1} to 1.36 m^3s^{-1} and was aimed to be representative of 0.1 m^3s^{-1} above base flow. High flow ranged from 1.44 m^3s^{-1} to 2.68 m^3s^{-1} and was necessary to determine the effect on habitat availability when background flow is high (e.g., storm run-off). Sampling at three levels allowed us to directly observe changes in the habitat suitability and availability in Cranberry Creek. Additionally, data taken over a range of flows was used to create relationships and therefore predict the changes in habitat suitability and availability with varying increases of minimum flow.

2.2 Field Study

The study area was located along the lower section of Cranberry Creek between the impassable falls located approximately 2.7 km upstream from Upper Arrow Lake and the confluence of Cranberry Creek with an unnamed tributary at km 7.7. The falls prevent Kokanee from migrating further upstream; however Rainbow Trout are present throughout lower and upper Cranberry Creek.

The inability of the structure at the overflow weir to function as designed predicated the need to target natural flow events that would approximate study objective flows. However, the lack of monitoring data at the diversion structure made prediction of discharge conditions difficult and therefore associated field surveys did not always capture ideal flow conditions. In the absence of a discharge monitoring system, data on timing of spills and on release discharges were not available. Therefore the field crew relied on communication with BC Hydro personnel (Karen Bray) in Revelstoke to obtain information on flows in Cranberry Creek. Additionally, local weather reports were accessed to attempt site visits during dry periods and webcam images at the diversion dam provided feedback on spill conditions. This information was used to time field trips. The program involved multiple field visits to collect data; Table 3-1 outlines the schedule of field visits where data was collected.

An initial reconnaissance trip was completed September 7, 2010 to identify general habitat conditions and provide guidance for the transect selection. A subsequent trip was undertaken September 14, 2010 to establish transects as well as install a staff gauge and continuous recording stage monitoring device to provide information on stream flow variability. Stream flows were elevated during this time and exceeded base flow conditions. High flow conditions continued through September 2010 which precluded collection of habitat suitability data. It was decided based on dialogue with BC Hydro personnel (Karen Bray) that the Rainbow Trout habitat suitability would be deferred until 2011. Low flows were present in late August 2011 which provided the opportunity to collect habitat data at base flow conditions.

2.2.1 Transect Site Selection

Hydraulic and habitat information obtained from the field reconnaissance conducted in 2010 was used to select transect sites which were based on the on presence of preferred Rainbow Trout rearing habitat (e.g., low velocities with available cover). The rationale for placement of transects was primarily based on a selection process that attempted to include the full range of hydraulic units encountered in Cranberry Creek. Fifteen (15) transects were established perpendicular to the channel and located in habitat types considered to be important to the life history stage of Rainbow Trout over a range of discharges. Additionally access and safety were considered in the selection process. Transects were located in areas where crews could safely work under a range of flows.

Table 2-1. Transect distribution per habitat unit

Habitat Unit	***Transect***
Pool	UC**1**, 5, 10, **14**
Riffle	UC2, **4**, 7, 9, 12, **13, 15**
Glide	UC**3**, **6**, 8, **11**

Numbers in bold indicate transects where data was collected at all three flows levels

2.2.2 Habitat Types

Three habitat types: pool, riffle, and glide, were chosen for analysis based on their importance to the Rainbow Trout population in Cranberry Creek. **Pools** are hydraulic units where the water surface slope is zero degrees. They are normally deeper and wider than the aquatic habitat immediately above and below. Pools were found sporadically throughout the study area in Cranberry Creek. **Riffles** were found throughout the Rainbow Trout section of Cranberry Creek and are characterized by shallow (less than 0.30 m depth) broken surface water over mixed cobble or gravel substrates with channel gradient within the 1% to 3% range. **Glides** were found in the lower gradient sections (less than 1%) of Cranberry Creek and were characterized by shallow (i.e., depth less than or equal to 5% of the average stream width), uniform flow, and unbroken surface water over primarily homogenous gravel substrates (Armantrout, 1998).

2.2.3 Field Data Collection

BC Hydro personnel (Karen Bray) in Revelstoke provided information on flows in Cranberry Creek. The low flow assessment was directed at collecting Rainbow Trout rearing habitat data when no spills were taking place over the diversion dam. Local weather reports were accessed to plan site visits during dry periods and webcam images at the diversion dam provided feedback on spill conditions.

Field crews completed three visits to Lower Cranberry Creek: one in November 2010, and two in September 2011 to collect data over a range of flows. Transects were marked and geo-referenced to allow re-identification in the field. Geo-coordinates (Universal Transverse Mercator – UTM) were collected with a handheld GPS unit using the NAD83 map datum. Each transect was identified with a simple numerical system and benchmarks (stakes) were installed at each transect on both stream banks so that water level measurements could be referenced to the same fixed point for each site visit.

Hydrometric data was collected at a minimum of 20 sampling stations along each transect. The distributions of the sampling stations across each transect were uniform and measured from the established benchmarks. At each sampling station measurements of habitat characteristics (i.e., depth, velocity, and substrate) were collected. A horizontal axis Swoffer model 2100 single propeller current meter was used to collect depth and velocity data. When measuring depth and velocity, the propeller always faced directly upstream into the flow. The cross-sectional profile was tied in with the exact position of each depth and velocity vertical. Channel bed elevation data and water level were collected using standard surveying techniques and the channel and wetted widths were also noted. Discharge (Q) in the creek was then calculated at each transect.

The equation is: $Q = \sum_i^n (W_i * D_i * V_i)$

where '$\mathbf{W_i}$' is the width of cell '***i***' on the transect, '$\mathbf{D_i}$' is water depth at cell '***i***', '$\mathbf{V_i}$' is the water velocity at cell '***i***', and '**n**' is the number of cells across the transect.

Substrate was visually quantified as the percentage of each size class (listed in Table 2-2) to the nearest 25% at each station along the transect. Digital photographs in each of four directions (upstream, downstream, left bank, and right bank) were obtained at each transect and archived. Triton targeted habitat measurements at three levels of discharge in Lower Cranberry Creek.

Table 2-2. Substrate Size Class (RIC, 1999)

Substrate	*Size* (mm)*
Fines	<2
Small Gravels	2 to 16
Large Gravels	16 to 64
Small Cobble	64 to 128
Large Cobble	128 to 256
Boulders	256 to 4,000
Bedrock	>4,000

2.3 Data Compilation and Analysis

Project-specific data forms were developed to ensure consistent data collection at each sampling site. All data collected was entered into a Microsoft Excel spreadsheet for analysis. Data was collected at minimum flows at eight transects and at moderate and high flows at all 15 transects. To address the effects of minimum flow, transects with data collected at all of the three stages (i.e., discharge was 0.01 m^3s^{-1}, 0.70 m^3s^{-1} and 2.06 m^3s^{-1} respectively) were used in the analysis. Discharge however was calculated using data from all 15 transects.

In order to determine how the usable rearing habitat in the system changes over a range of flows, transects were completed within representative habitat units. Data collected from each habitat unit (e.g., pool, riffle, glide) were compared separately to isolate the effects of discharge in each of the three hydrologically unique habitats.

2.3.1 Habitat Suitability Indices

The Habitat Suitability Index (HSI) curves for Rainbow Trout life stages were received from the BC Ministry of Environment (now Forests, Lands and Natural Resource Operations) and are provided in Appendix 1. Although not specific to Cranberry Creek, these curves are considered the most appropriate curves for application to that system that are available (Ptolemy pers. comm.). Curves for both fry and juveniles were included to cover the rearing life stages.

2.3.2 Weighted Usable Width

Weighted usable width (WUW) is a measure of how much of the wetted channel is suitable for a life history stage based on the habitat suitability index (HSI) criteria for that particular species. It incorporates a specified set of parameters and for our analysis we considered water depth, water velocity, and channel bed substrate. The methods used follow instream flow guidelines designed to describe changes in suitable fish habitat for the species and life history stage of management concern (Hatfield et. al., 2007; Reid, 2005). The approach uses empirical data (from field measurements) to the extent possible in order to avoid errors inherent in hydraulic modelling of streams with complex channels.

The WUW was calculated at the micro-scale for each of the 15 transects by comparing the measured parameters (e.g., depth, water velocity, and substrate) with HSI curves for the species and life stage of interest (i.e., Rainbow Trout fry and juvenile).

The equation is: $WUW_{dvs} = \sum_i^n (W_i * D_i * V_i * S_i)$;

where '$\mathbf{W_i}$' is the width of cell '$\boldsymbol{i}$' on the transect, '$\mathbf{D_i}$' is the habitat suitability of depth at cell '$\boldsymbol{i}$', '$\mathbf{V_i}$' is the habitat suitability of velocity at cell '$\boldsymbol{i}$', '$\mathbf{S_i}$' is the habitat suitability of substrate at cell '$\boldsymbol{i}$' (Hatfield et al., 2007; Ptolemy, 2001).

Based on the calculated WUW and the measured discharge, a polynomial regression equation was used to estimate WUW at different discharge rates. The results are summarized and graphed to show the relationship between flow and habitat suitability over range of potential flows (WUW versus discharge [Q]). The optimal value for WUW was calculated using the derivation of the polynomial equation.

3.0 Results and Discussion

Field crews completed three visits to lower Cranberry Creek to collect data over a range of flows. The dates for each visit are listed in Table 3-1. Tabular summaries of general habitat characteristics as well as plots of transect profiles are included in Appendix 2.

Table 3-1. Schedule of field visits

Date	Discharge (m^3s^{-1})	Stage	Comments
September 7, 2010	-	High	Initial Reconnaissance.
September 14, 2010	-	High	Install staff gauge and continuous monitoring device.
November 2 – 4, 2010	0.7*	Moderate	Hydrometric data collection at transects.
September 1 – 8, 2011	0.01*	Low	Hydrometric data collection at transects.
September 21 – 22, 2011	2.06*	High	Hydrometric data collection at transects.

*mean value derived from data collected at all transects during that sample period.

3.1 Hydraulic Changes with Change in Discharge

In general, the trend among the low, moderate, and high flow stages that were assessed was an increase in available habitat with increase in flow. As the wetted width expanded more habitat became accessible to juvenile fish, and as depth increased, isolated pools were reconnected, allowing a more even distribution of individuals throughout the creek. Table 3-2 shows the mean values for the measured hydraulic parameters in each habitat unit.

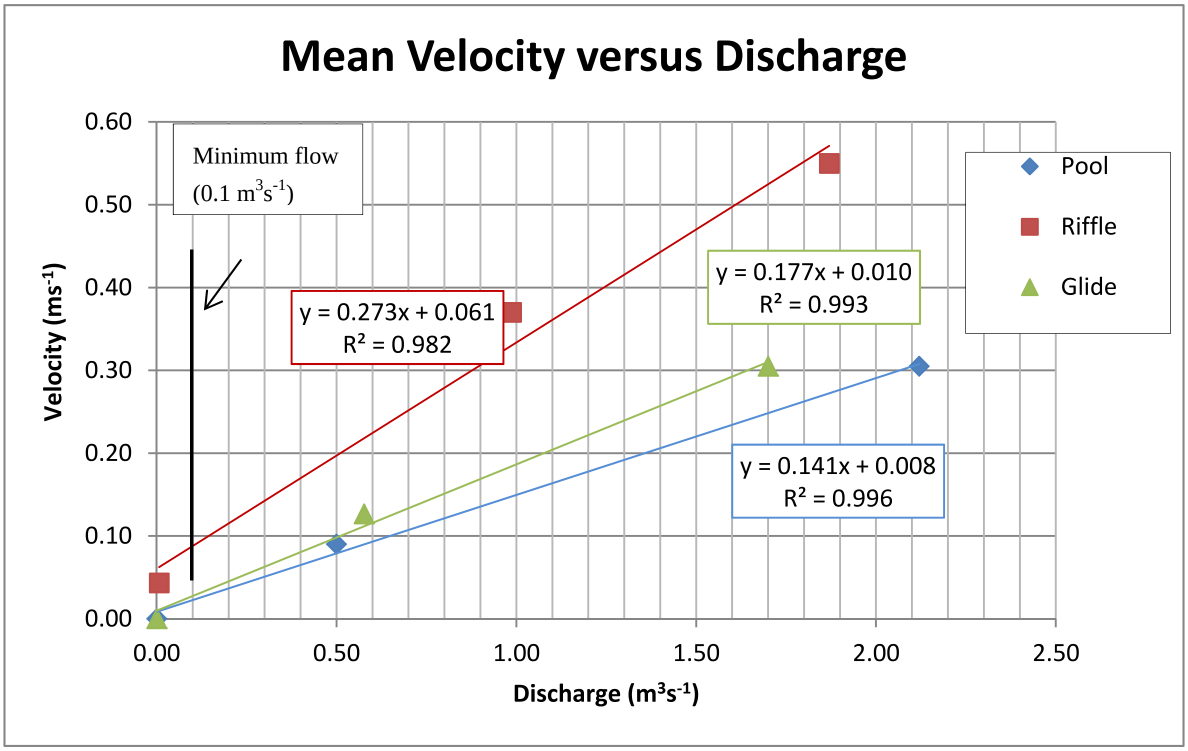
Table 3-2. Mean hydraulic measurements per habitat unit (Appendix 3)

Habitat Unit	Stage	Mean Discharge (m^3s^{-1})	Mean Depth (m)	Mean Velocity (ms^{-1})	Mean Wetted Width (m)
Pool	**Low**	0.00	0.47	0.00	7.20
	Moderate	0.50	0.64	0.09	7.60
	High	2.12	0.81	0.31	7.95
Riffle	**Low**	0.01	0.06	0.04	6.27
	Moderate	0.99	0.18	0.37	11.83
	High	1.87	0.27	0.55	12.33
Glide	**Low**	0.00	0.23	0.00	6.90
	Moderate	0.58	0.36	0.13	9.37
	High	1.70	0.35	0.31	11.85

Depths increased with increasing discharge (Table 3-2). The greatest change occurred in pools while the smallest change occurred in glides. The inequality in change of depth among the habitat units indicates each unit is hydrologically unique and will therefore respond differently to an increase in discharge.

Velocities measured at each transect increased linearly with discharge (Table 3-2). In general, with every 0.1 m^3s^{-1} increase in discharge, the velocity increased approximately 0.02 ms^{-1} (Figure 3-1).

Figure 3-1. Relationship between velocity and discharge in Cranberry Creek



The wetted widths at the pool transects were the most consistent of the three habitat units and only varied by 0.75 m (7.2 m to 7.95 m) for an increase of 4.8% over the range of discharges measured, compared to increases in wetted width of 27.3% in riffles and 25.4% in glides. Table 3-3 shows the mean wetted width as a percentage of mean channel width at the three levels of discharge.

Table 3-3. Mean wetted width as a percentage of mean channel width at the three levels of discharge measured

Stage	Habitat Unit		
	Pool	Riffle	Glide
Low	40.1%	29.4%	34.1%
Moderate	41.7%	55.0%	46.6%
High	44.9%	56.7%	59.5%

3.2 Weighted Usable Width

The HSI curve data (Figure 3-2 and Figure 3-3; Appendices 1A and 1B) was applied to the hydrometric data for each transect to calculate the weighted usable width (WUW) for both fry and juvenile life stages. A summary of the calculated WUW per transect at three stages of flow provided in Appendix 4.

Figure 3-2. Habitat suitability index curves for Rainbow Trout fry (summer rearing)

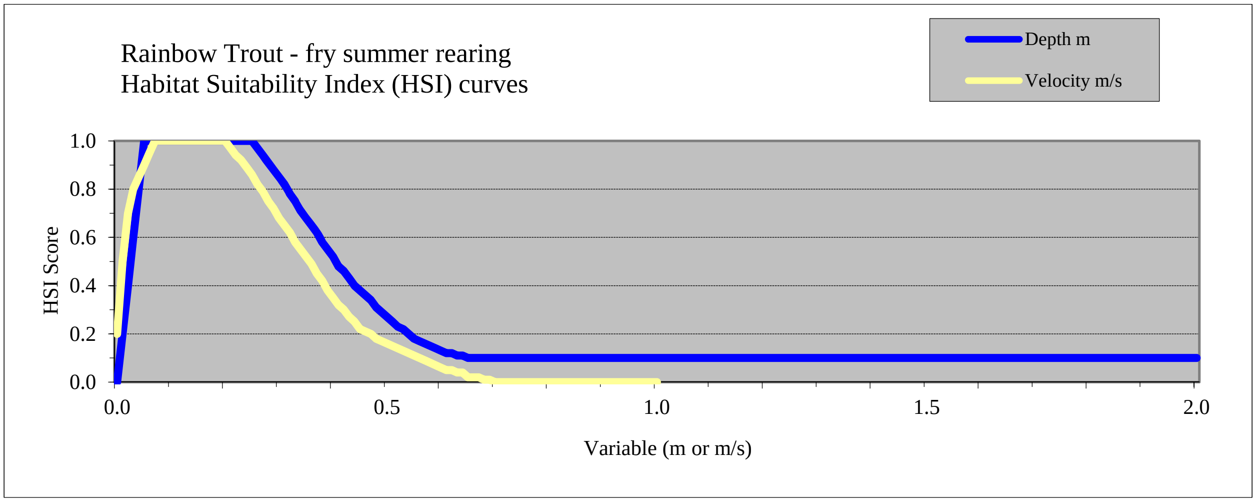
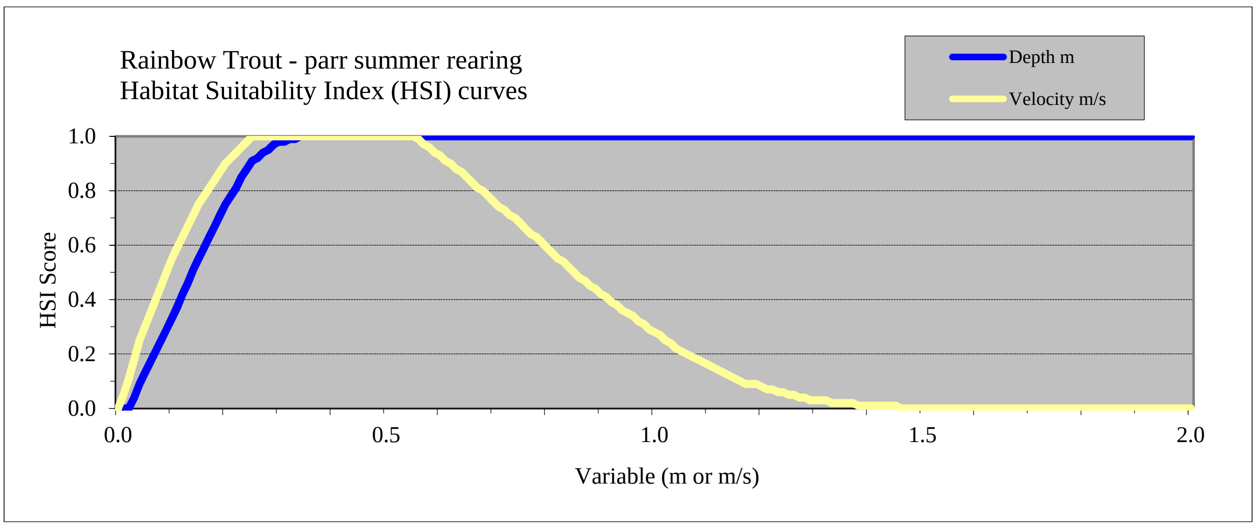


Figure 3-3. Habitat suitability index curves for Rainbow Trout juveniles (summer rearing)



Each habitat unit responded slightly differently to the increase in discharge which affected the available suitable habitat. Figure 3-4 to Figure 3-6 show the WUW values against the measured discharge for each habitat unit. The points represent the WUW calculated from empirical data and the fitted line shows the relationship between discharge and WUW. A polynomial regression was used because the relationship between discharge and usable habitat was not linear.

The graphs show maximum values for WUW indicating an optimal discharge for Rainbow Trout fry and juveniles within each habitat unit. As discharge increased beyond background flows (i.e., 0.01 m^3s^{-1}), the WUW for fry reached a maximum value in riffles when discharge was 1.06 m^3s^{-1} (Figure 3-5) and in glides at 1.33 m^3s^{-1} (Figure 3-6), beyond these rates of discharge the WUW decreased. The WUW for fry did not change significantly in pools (Figure 3-4). The WUW for juveniles was greatest at 1.51 m^3s^{-1} in riffles and 1.64 m^3s^{-1} in glides while pools showed the greatest WUW at 2.74 m^3s^{-1}.

For each of the three habitat units, the fit of the regression line was higher for juveniles than for fry suggesting a stronger relationship between discharge, specifically velocity and WUW for the former. This is likely associated with the narrower range of both depths and velocities that are suitable (HSI > 0) for fry as compared to juveniles (Figure 3-2 and 3-3). Factors such as channel roughness will result in variability in depth and velocity at a particular discharge that can result in a particular site being less suitable for fry then the same habitat unit at a different location. Juveniles are more robust to such micro-variations and therefore show a more consistent relationship between discharge and WUW.

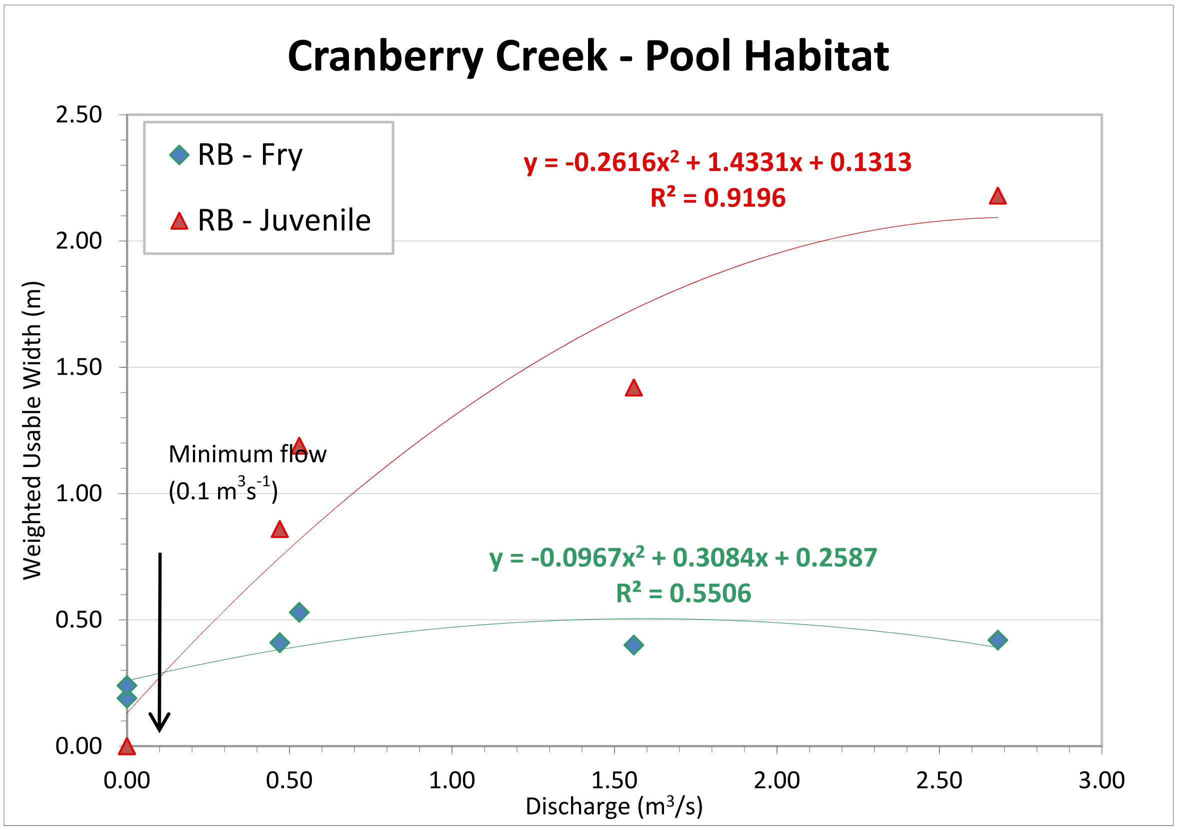


Figure 3-4. WUW versus discharge in pools

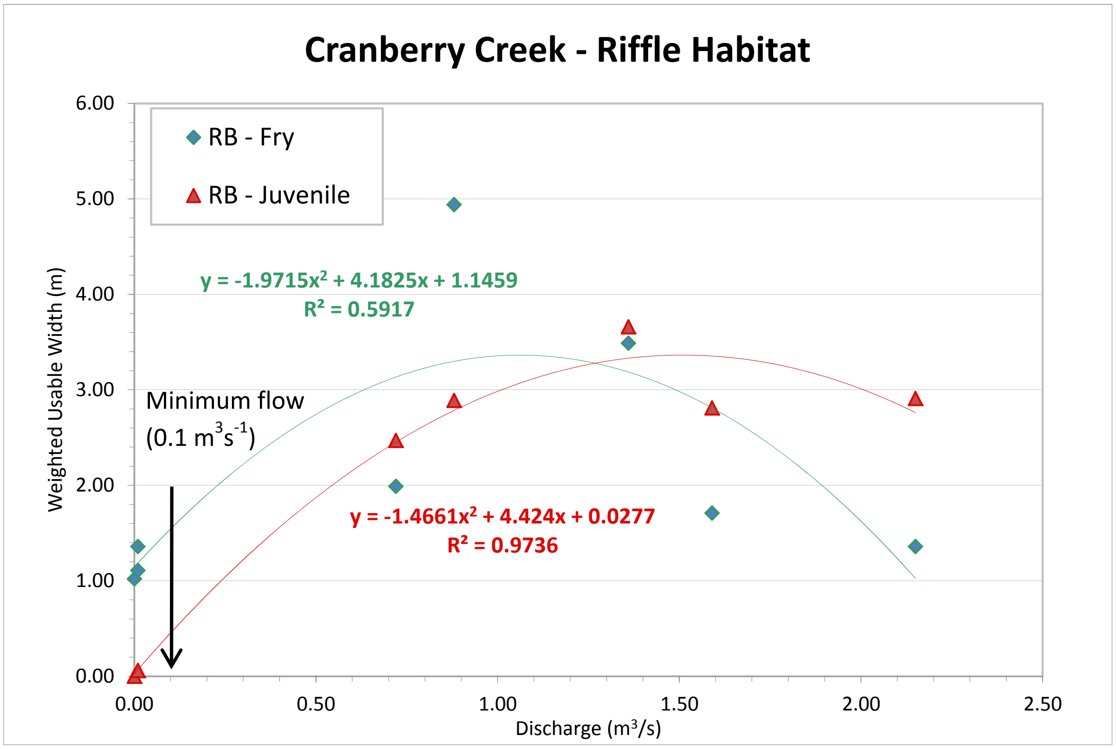


Figure 3-5. WUW versus discharge in riffles

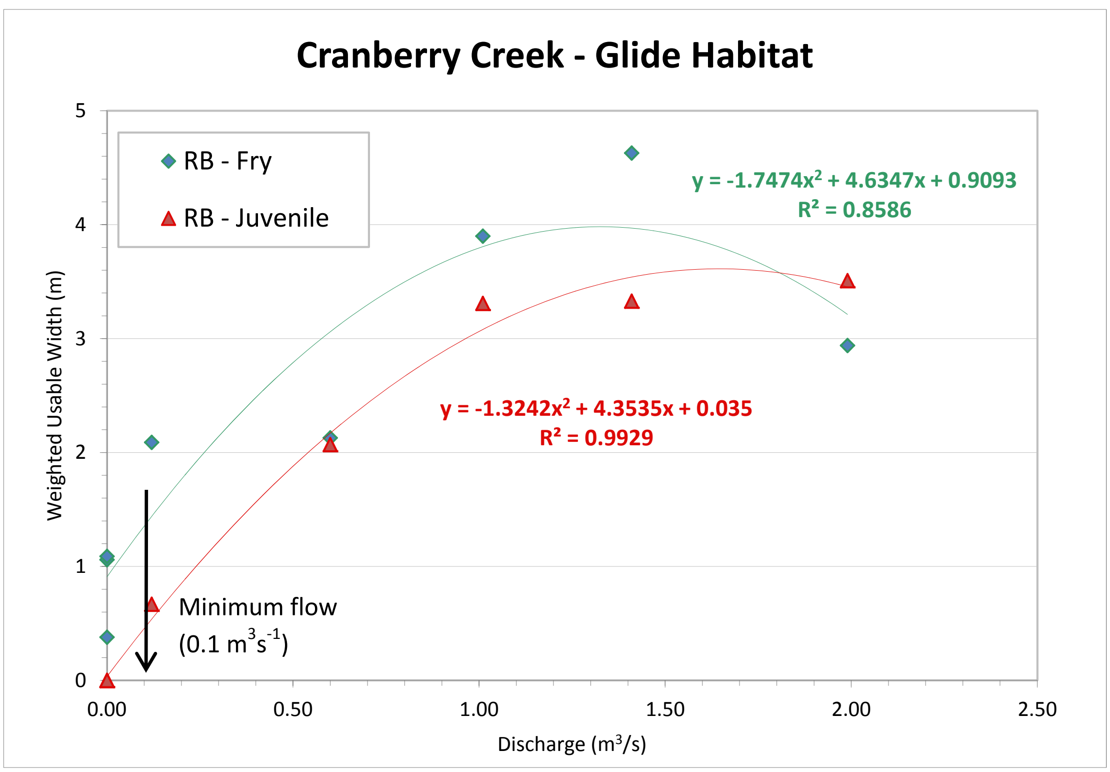


Figure 3-6. WUW versus discharge in glides

3.3 Effects of a Set Minimum Flow on Rainbow Trout Rearing Habitat

The relationships between the WUW and discharge were fitted with a polynomial curve. Each habitat unit (pool, riffle, glide) was analyzed separately to identify changes in habitat suitability and availability with the change in flow levels (Figure 3-4 to Figure 3-6).

3.3.1 Rainbow Trout Fry

With an increase of 0.1 m^3s^{-1} above historic flows (i.e., 0.01 m^3s^{-1}) the WUW for fry increased by 0.04 m in pools, 0.38 m in riffles, and 0.52 m in glides. An additional 0.1 m^3s^{-1} increase (i.e., Q = 0.2 m^3s^{-1}) raised the WUW 0.07 m in pools, 0.74 m in riffles, and 0.93 m in glides, above historic flows (Table 3-4).

Table 3-4. Estimated WUW for Rainbow Trout fry at increasing discharge

Rainbow Trout Fry	Hydraulic Habitat Unit	Discharge (m^3/s)								
		0.01	0.1	0.2	0.5	1	1.5	2	2.5	3
Estimated WUW (m)	Pool	0.25*	0.29	0.32	0.47*	0.47	0.50	0.41*	0.42	0.31
	Riffle	1.16*	1.54	1.90	2.74	3.36	2.98	2.00*	0.00	0.00
	Glide	0.84*	1.36	1.77	2.71*	3.80	3.93	3.19	1.58	0.00

* values calculated from field measurements

3.3.2 Rainbow Trout Juveniles

With an increase of 0.1 m^3s^{-1} above historic flows, the WUW for juveniles increased from 0.00 to 0.27 m in pools, 0.04 to 0.45 m in riffles, and from 0.00 to 0.46 m in glides. An additional 0.1 m^3s^{-1} increase in discharge (i.e., Q = 0.2 m^3s^{-1}) increased the WUW by 0.41 m in pools, 0.81 m in riffles, and 0.85 m in glides (Table 3-5); based on the derived relationship between WUW and discharge.

Table 3-5. Estimated WUW for Rainbow Trout juveniles at increasing discharge

Rainbow Trout Juvenile	Hydraulic Habitat Unit	Discharge (m^3/s)								
		0.01	0.1	0.2	0.5	1	1.5	2	2.5	3
Estimated WUW (m)	Pool	0.00*	0.27	0.41	1.03*	1.30	1.69	1.80*	2.08	2.08
	Riffle	0.04*	0.45	0.85	1.87	2.99	3.37	3.08*	1.93	1.01
	Glide	0.00*	0.46	0.85	2.02*	3.06	3.59	3.45	2.64	1.18

* values calculated from field measurements

4.0 Discussion

Cranberry Creek displayed highly variable flows throughout the project timelines, which made it difficult to collect data at targeted flows. Additionally, flow often changed during data collection trips. Diversion bypass flows during the study were estimated to be less than 0.01 m^3s^{-1}, or an order of magnitude below design flows, and approximated pre-diversion low flows. Overtopping of the diversion dam occurred during high flows in upper Cranberry Creek and as a result of gate adjustments at the Walter Hardman Reservoir. As there is no flow gauge in lower Cranberry Creek, the timing of field visits was best-guess, relying on weather forecasts and previous day images of the diversion dam. Several trips were cancelled on arrival at site due to elevated river flows. Future studies may be able to avoid this by installing real-time monitoring devices to monitor spills into the diversion channel and stream flows below the dam in Cranberry Creek.

4.1 Effects of 0.1 m^3s^{-1} Minimum Flow on Depth in Key Rearing Locations

Depth increased with increased flow. At baseline flows connectivity among habitats was poor, with flow becoming sub-surface in some sections and habitat restricted to isolated pockets. Rainbow Trout fry prefer depths from 0.04 m to 0.27 m (HSI greater than 95%; Appendix 1A). They are typically found in shallow water where they are less likely to be preyed upon by larger fish that may be holding in deeper pools. Juveniles (one- to three-year- old fish) prefer a minimum depth of 0.28 m (HSI greater than 95%; Appendix 1B). They are larger than fry and seek shelter in deeper areas of the creek. As discharge increased above baseline flow, connectivity was re-established with increasing depth. Mean depth increased in all habitat units at each increment of discharge considered. These results therefore support the first hypothesis that the release of a 0.1 m^3s^{-1} minimum flow will result in a significant increase in the depth of flow in key Rainbow Trout rearing locations.

4.2 Effects of 0.1 m^3s^{-1} Minimum Flow on Velocity in Key Spawning Locations

As discharge increased above baseline flows, the resultant increase in velocity improved the habitat values (measured as WUW) for both life history stages of Rainbow Trout. There was a threshold beyond which the mean velocities were above the upper limit of the preferred ranges for fry and juvenile fish. Rainbow Trout fry prefer velocities in the range of 0.06 ms^{-1} to 0.22 ms^{-1} (HSI at 95%; Appendix 1A). Literature (compiled by Ford et. al. 1995) confirms recently emerged fry prefer velocities less than 0.08 ms^{-1}. Velocity values greater than 0.22 ms^{-1} are too fast for fry to hold and in these conditions they will seek refuge in pools and sheltered areas along the margins. When fry emerge they migrate to riffle areas where they remain until fall or winter (Ford et. al. 1995). The optimal discharge where mean velocities are within the preferred range for fry in Cranberry Creek is 1.06 m^3s^{-1}, as indicated by the WUW.

Juveniles Rainbow Trout show a preference for velocities between 0.22 ms^{-1} and 0.53 ms^{-1} (HSI greater than 95%; Appendix 1B) as they are much stronger swimmers than fry and therefore are able to hold in faster current. They also prefer cobble and boulder substrate usually found in riffles (Ford et. at., 1995). As discharge exceeded 1.1 m^3s^{-1} mean velocities surpassed the preferred range for fry, however mean velocity increases up to a discharge of approximately 1.6 m^3s^{-1} fell within the preferred ranges for juveniles. Beyond this stage the resultant velocities exceeded the preferences for juvenile Rainbow Trout thereby reducing the habitat values in the system.

The addition of 0.1 m^3s^{-1} above base flow did not raise the mean velocity beyond the suitable range for juvenile Rainbow Trout. However when background flows were higher (greater than 1.0 m^3s^{-1} and 1.5 m^3s^{-1} for fry and juveniles respectively) the mean velocity was found to exceed the preferred ranges for both life stages. The second hypothesis that the release of a 0.1 m^3s^{-1} minimum flow will not result in an unsuitable increase in the flow velocity in key Rainbow Trout rearing locations is therefore accepted when background flow is less than 1.0 m^3s^{-1}.

4.3 Effects of 0.1 m^3s^{-1} Minimum Flow on Suitable Habitat Area in Rearing Locations

Additional flows from the diversion structure had a positive impact on the quality and quantity of effective rearing habitat for Rainbow Trout. As the depth and wetted width increased, isolated pools were reconnected and fish were able to move within more areas in the channel. This positive relationship continued until the habitat suitability exceeded preferred thresholds for each of the life history phases of Rainbow Trout, after which time available habitats began to decline because of the increase in water velocity.

In general, the WUW increased with discharge in all habitat units to a maximum, beyond which the resulting trend is a decline in habitat value based on instream velocity. There were increases in WUW for fry at all habitat units between base flows (0.01 m^3s^{-1}) and the design diversion flow (0.1 m^3s^{-1}). The WUW reached a maximum value when discharge approached 1.06 m^3s^{-1}. Beyond this level of discharge the mean velocities exceeded the preferred ranges for fry. The observed increase in WUW for juvenile Rainbow Trout was greater than that for fry at the initial flow increment above base flow (0.01 m^3s^{-1}). WUW values for juveniles increased with discharge beyond the diversion design of 0.1 m^3s^{-1} up to a maximum of approximately 1.5 m^3s^{-1}. The calculated WUW values for both riffle and glide habitats suggested an optimal discharge where habitat values are greatest for both fry and juveniles (i.e. 1.06 m^3s^{-1} for fry and 1.51 m^3s^{-1} for juveniles).

Wetted width approximated channel width at the maximum flows metered. At that point velocities increased without adding additional wetted habitat and resulted in the loss of suitable rearing habitats as demonstrated in the WUW versus discharge relationships. In general the relationship between WUW and discharge was stronger for juveniles then for fry at each of the three habitat units. This was assumed to be due to increased sensitivity of fry to variations in depth and velocity due to site-specific factors such as channel roughness. While these variations can be enough to result in lower HSI values for fry, the juveniles are more robust to these micro-variations.

The third hypothesis, that the release of a 0.1 m^3s^{-1} minimum flow will result in a significant increase in the minimum wetted area of key Rainbow Trout rearing location that conforms to the depth and velocity characteristics used by Rainbow Trout, is therefore accepted at base flows.

Positive impacts associated with the restoration of habitat connectivity will continue until background flows are within 1.0 m^3s^{-1} to 1.5 m^3s^{-1}. At this point velocities increase without adding additional wetted habitat, and result in the loss of suitable rearing habitats as demonstrated in the WUW versus discharge relationships. In addition to the current low flow impacts to Rainbow Trout production, high flows during fall rain events and spring runoff create hostile rearing conditions for Rainbow Trout by increasing velocities beyond the preferred ranges for rearing fish.

5.0 Conclusions

Additional flows from the diversion structure were shown to have a positive impact on the quality and quantity of effective rearing habitat for Rainbow Trout. At low flows (0.01 m^3s^{-1} to 0.1 m^3s^{-1}), connectivity was poor with flow becoming sub-surface in some sections and habitat restricted to isolated pockets. As flows rose above baseline (low flow) to up to 0.1 m^3s^{-1}, connectivity was re-established with increasing depth, and the wetted area widened which increased both fry and juvenile habitat values in Cranberry Creek. All three hypotheses were accepted but only within a range of flows above baseline levels. The positive relationship between flows and discharge continued until the habitat suitability exceeded preferred thresholds for each of the life history phases of Rainbow Trout (1.06 m^3s^{-1} for fry and 1.51 m^3s^{-1} for juveniles), after which time available habitats begin to decline because of the increase in water velocity.

Initiating a minimum flow in Cranberry Creek of 0.1 m^3s^{-1} will likely improve the quality and quantity of rearing habitat for Rainbow Trout over conditions of base flow, however at higher background flows any influence of diversion flows will be overwhelmed. Elevated flows in Cranberry Creek resulting from fall rains and spring runoff create hostile rearing conditions. In addition, free spill at the diversion dam and cessation of spills result in short-term streamflow variability and associated stranding risk. The inability of the diversion structure to function further elevates these risks.

6.0 References

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APPENDIX 1A

HSI VALUES FOR DEPTH AND VELOCITY FOR RAINBOW TROUT FRY

HSI values for depth and velocity for Rainbow Trout fry rearing habitat (Ptolemy, 2001)

Depth or Velocity (cm)	Depth or Velocity(m)	Depth (m)	Velocity (m/s)	Depth or Velocity (cm)	Depth or Velocity(m)	Depth (m)	Velocity (m/s)
0	0.00	0.00	0.20	46	0.46	0.36	0.21
1	0.01	0.20	0.50	47	0.47	0.34	0.20
2	0.02	0.40	0.70	48	0.48	0.31	0.18
3	0.03	0.60	0.80	49	0.49	0.29	0.17
4	0.04	0.80	0.85	50	0.50	0.27	0.16
5	0.05	1.00	0.90	51	0.51	0.25	0.15
6	0.06	1.00	0.95	52	0.52	0.23	0.14
7	0.07	1.00	1.00	53	0.53	0.22	0.13
8	0.08	1.00	1.00	54	0.54	0.20	0.12
9	0.09	1.00	1.00	55	0.55	0.18	0.11
10	0.10	1.00	1.00	56	0.56	0.17	0.10
11	0.11	1.00	1.00	57	0.57	0.16	0.09
12	0.12	1.00	1.00	58	0.58	0.15	0.08
13	0.13	1.00	1.00	59	0.59	0.14	0.07
14	0.14	1.00	1.00	60	0.60	0.13	0.06
15	0.15	1.00	1.00	61	0.61	0.12	0.05
16	0.16	1.00	1.00	62	0.62	0.12	0.05
17	0.17	1.00	1.00	63	0.63	0.11	0.04
18	0.18	1.00	1.00	64	0.64	0.11	0.04
19	0.19	1.00	1.00	65	0.65	0.10	0.02
20	0.20	1.00	1.00	66	0.66	0.10	0.02
21	0.21	1.00	0.97	67	0.67	0.10	0.02
22	0.22	1.00	0.94	68	0.68	0.10	0.01
23	0.23	1.00	0.92	69	0.69	0.10	0.01
24	0.24	1.00	0.89	70	0.70	0.10	0.00
25	0.25	1.00	0.86	71	0.71	0.10	0.00
26	0.26	0.97	0.82	72	0.72	0.10	0.00
27	0.27	0.94	0.79	73	0.73	0.10	0.00
28	0.28	0.91	0.75	74	0.74	0.10	0.00
29	0.29	0.88	0.72	75	0.75	0.10	0.00
30	0.30	0.85	0.68	76	0.76	0.10	0.00
31	0.31	0.82	0.65	77	0.77	0.10	0.00
32	0.32	0.78	0.62	78	0.78	0.10	0.00
33	0.33	0.75	0.58	79	0.79	0.10	0.00
34	0.34	0.71	0.55	80	0.80	0.10	0.00
35	0.35	0.68	0.52	81	0.81	0.10	0.00
36	0.36	0.65	0.49	82	0.82	0.10	0.00
37	0.37	0.62	0.45	83	0.83	0.10	0.00
38	0.38	0.58	0.42	84	0.84	0.10	0.00
39	0.39	0.55	0.38	85	0.85	0.10	0.00
40	0.40	0.52	0.35	86	0.86	0.10	0.00
41	0.41	0.48	0.32	87	0.87	0.10	0.00
42	0.42	0.46	0.30	88	0.88	0.10	0.00
43	0.43	0.43	0.27	89	0.89	0.10	0.00
44	0.44	0.40	0.25	90	0.90	0.10	0.00
45	0.45	0.38	0.22	91	0.91	0.10	0.00

Depth or Velocity (cm)	Depth or Velocity(m)	Depth (m)	Velocity (m/s)
92	0.92	0.10	0.00
93	0.93	0.10	0.00
94	0.94	0.10	0.00
95	0.95	0.10	0.00
96	0.96	0.10	0.00
97	0.97	0.10	0.00
98	0.98	0.10	0.00
99	0.99	0.10	0.00
100	1.00	0.10	0.00
101	1.01	0.10	0.00
102	1.02	0.10	0.00
103	1.03	0.10	0.00
104	1.04	0.10	0.00
105	1.05	0.10	0.00
106	1.06	0.10	0.00
107	1.07	0.10	0.00
108	1.08	0.10	0.00
109	1.09	0.10	0.00
110	1.10	0.10	0.00
111	1.11	0.10	0.00
112	1.12	0.10	0.00
113	1.13	0.10	0.00
114	1.14	0.10	0.00
115	1.15	0.10	0.00
116	1.16	0.10	0.00
117	1.17	0.10	0.00
118	1.18	0.10	0.00
119	1.19	0.10	0.00
120	1.20	0.10	0.00
121	1.21	0.10	0.00
122	1.22	0.10	0.00
123	1.23	0.10	0.00
124	1.24	0.10	0.00
125	1.25	0.10	0.00
126	1.26	0.10	0.00
127	1.27	0.10	0.00
128	1.28	0.10	0.00
129	1.29	0.10	0.00
130	1.30	0.10	0.00
131	1.31	0.10	0.00
132	1.32	0.10	0.00
133	1.33	0.10	0.00
134	1.34	0.10	0.00
135	1.35	0.10	0.00
136	1.36	0.10	0.00
137	1.37	0.10	0.00
138	1.38	0.10	0.00
139	1.39	0.10	0.00

Depth or Velocity (cm)	Depth or Velocity(m)	Depth (m)	Velocity (m/s)
140	1.40	0.10	0.00
141	1.41	0.10	0.00
142	1.42	0.10	0.00
143	1.43	0.10	0.00
144	1.44	0.10	0.00
145	1.45	0.10	0.00
146	1.46	0.10	0.00
147	1.47	0.10	0.00
148	1.48	0.10	0.00
149	1.49	0.10	0.00
150	1.50	0.10	0.00
151	1.51	0.10	0.00
152	1.52	0.10	0.00
153	1.53	0.10	0.00
154	1.54	0.10	0.00
155	1.55	0.10	0.00
156	1.56	0.10	0.00
157	1.57	0.10	0.00
158	1.58	0.10	0.00
159	1.59	0.10	0.00
160	1.60	0.10	0.00
161	1.61	0.10	0.00
162	1.62	0.10	0.00
163	1.63	0.10	0.00
164	1.64	0.10	0.00
165	1.65	0.10	0.00
166	1.66	0.10	0.00
167	1.67	0.10	0.00
168	1.68	0.10	0.00
169	1.69	0.10	0.00
170	1.70	0.10	0.00
171	1.71	0.10	0.00
172	1.72	0.10	0.00
173	1.73	0.10	0.00
174	1.74	0.10	0.00
175	1.75	0.10	0.00
176	1.76	0.10	0.00
177	1.77	0.10	0.00
178	1.78	0.10	0.00
179	1.79	0.10	0.00
180	1.80	0.10	0.00
181	1.81	0.10	0.00
182	1.82	0.10	0.00
183	1.83	0.10	0.00
184	1.84	0.10	0.00
185	1.85	0.10	0.00
186	1.86	0.10	0.00
187	1.87	0.10	0.00

Depth or Velocity (cm)	Depth or Velocity(m)	Depth (m)	Velocity (m/s)
188	1.88	0.10	0.00
189	1.89	0.10	0.00
190	1.90	0.10	0.00
191	1.91	0.10	0.00
192	1.92	0.10	0.00
193	1.93	0.10	0.00
194	1.94	0.10	0.00
195	1.95	0.10	0.00
196	1.96	0.10	0.00
197	1.97	0.10	0.00
198	1.98	0.10	0.00
199	1.99	0.10	0.00
200	2.00	0.10	0.00
201	2.01	0.10	0.00
202	2.02	0.10	0.00
203	2.03	0.10	0.00
204	2.04	0.10	0.00
205	2.05	0.10	0.00
206	2.06	0.10	0.00
207	2.07	0.10	0.00
208	2.08	0.10	0.00
209	2.09	0.10	0.00
210	2.10	0.10	0.00
211	2.11	0.10	0.00
212	2.12	0.10	0.00
213	2.13	0.10	0.00
214	2.14	0.10	0.00
215	2.15	0.10	0.00
216	2.16	0.10	0.00
217	2.17	0.10	0.00
218	2.18	0.10	0.00
219	2.19	0.10	0.00
220	2.20	0.10	0.00
221	2.21	0.10	0.00
222	2.22	0.10	0.00
223	2.23	0.10	0.00
224	2.24	0.10	0.00
225	2.25	0.10	0.00
226	2.26	0.10	0.00
227	2.27	0.10	0.00
228	2.28	0.10	0.00
229	2.29	0.10	0.00
230	2.30	0.10	0.00
231	2.31	0.10	0.00
232	2.32	0.10	0.00
233	2.33	0.10	0.00
234	2.34	0.10	0.00
235	2.35	0.10	0.00

Depth or Velocity (cm)	Depth or Velocity(m)	Depth (m)	Velocity (m/s)
236	2.36	0.10	0.00
237	2.37	0.10	0.00
238	2.38	0.10	0.00
239	2.39	0.10	0.00
240	2.40	0.10	0.00
241	2.41	0.10	0.00
242	2.42	0.10	0.00
243	2.43	0.10	0.00
244	2.44	0.10	0.00
245	2.45	0.10	0.00
246	2.46	0.10	0.00
247	2.47	0.10	0.00
248	2.48	0.10	0.00
249	2.49	0.10	0.00
250	2.50	0.10	0.00
251	2.51	0.10	0.00
252	2.52	0.10	0.00
253	2.53	0.10	0.00
254	2.54	0.10	0.00
255	2.55	0.10	0.00
256	2.56	0.10	0.00
257	2.57	0.10	0.00
258	2.58	0.10	0.00
259	2.59	0.10	0.00
260	2.60	0.10	0.00
261	2.61	0.10	0.00
262	2.62	0.10	0.00
263	2.63	0.10	0.00
264	2.64	0.10	0.00
265	2.65	0.10	0.00
266	2.66	0.10	0.00
267	2.67	0.10	0.00
268	2.68	0.10	0.00
269	2.69	0.10	0.00
270	2.70	0.10	0.00
271	2.71	0.10	0.00
272	2.72	0.10	0.00
273	2.73	0.10	0.00
274	2.74	0.10	0.00
275	2.75	0.10	0.00
276	2.76	0.10	0.00
277	2.77	0.10	0.00
278	2.78	0.10	0.00
279	2.79	0.10	0.00
280	2.80	0.10	0.00
281	2.81	0.10	0.00
282	2.82	0.10	0.00
283	2.83	0.10	0.00

Depth or Velocity (cm)	Depth or Velocity(m)	Depth (m)	Velocity (m/s)
284	2.84	0.10	0.00
285	2.85	0.10	0.00
286	2.86	0.10	0.00
287	2.87	0.10	0.00
288	2.88	0.10	0.00
289	2.89	0.10	0.00
290	2.90	0.10	0.00
291	2.91	0.10	0.00
292	2.92	0.10	0.00
293	2.93	0.10	0.00
294	2.94	0.10	0.00
295	2.95	0.10	0.00
296	2.96	0.10	0.00
297	2.97	0.10	0.00
298	2.98	0.10	0.00
299	2.99	0.10	0.00
300	3.00	0.10	0.00
301	3.01	0.10	0.00
302	3.02	0.10	0.00
303	3.03	0.10	0.00
304	3.04	0.10	0.00
305	3.05	0.10	0.00
306	3.06	0.10	0.00
307	3.07	0.10	0.00
308	3.08	0.10	0.00
309	3.09	0.10	0.00
310	3.10	0.10	0.00
311	3.11	0.10	0.00
312	3.12	0.10	0.00
313	3.13	0.10	0.00
314	3.14	0.10	0.00
315	3.15	0.10	0.00
316	3.16	0.10	0.00
317	3.17	0.10	0.00
318	3.18	0.10	0.00
319	3.19	0.10	0.00
320	3.20	0.10	0.00
321	3.21	0.10	0.00
322	3.22	0.10	0.00
323	3.23	0.10	0.00
324	3.24	0.10	0.00
325	3.25	0.10	0.00
326	3.26	0.10	0.00
327	3.27	0.10	0.00
328	3.28	0.10	0.00
329	3.29	0.10	0.00
330	3.30	0.10	0.00
331	3.31	0.10	0.00
332	3.32	0.10	0.00
333	3.33	0.10	0.00
334	3.34	0.10	0.00
335	3.35	0.10	0.00
336	3.36	0.10	0.00
337	3.37	0.10	0.00
338	3.38	0.10	0.00
339	3.39	0.10	0.00
340	3.40	0.10	0.00
341	3.41	0.10	0.00
342	3.42	0.10	0.00
343	3.43	0.10	0.00
344	3.44	0.10	0.00
345	3.45	0.10	0.00
346	3.46	0.10	0.00
347	3.47	0.10	0.00
348	3.48	0.10	0.00
349	3.49	0.10	0.00
350	3.50	0.10	0.00
351	3.51	0.10	0.00
352	3.52	0.10	0.00
353	3.53	0.10	0.00
354	3.54	0.10	0.00
355	3.55	0.10	0.00
356	3.56	0.10	0.00
357	3.57	0.10	0.00
358	3.58	0.10	0.00
359	3.59	0.10	0.00
360	3.60	0.10	0.00
361	3.61	0.10	0.00
362	3.62	0.10	0.00
363	3.63	0.10	0.00
364	3.64	0.10	0.00
365	3.65	0.10	0.00
366	3.66	0.10	0.00
367	3.67	0.10	0.00
368	3.68	0.10	0.00
369	3.69	0.10	0.00
370	3.70	0.10	0.00
371	3.71	0.10	0.00
372	3.72	0.10	0.00
373	3.73	0.10	0.00
374	3.74	0.10	0.00
375	3.75	0.10	0.00
376	3.76	0.10	0.00
377	3.77	0.10	0.00
378	3.78	0.10	0.00
379	3.79	0.10	0.00

Depth or Velocity (cm)	Depth or Velocity(m)	Depth (m)	Velocity (m/s)
380	3.80	0.10	0.00
381	3.81	0.10	0.00
382	3.82	0.10	0.00
383	3.83	0.10	0.00
384	3.84	0.10	0.00
385	3.85	0.10	0.00
386	3.86	0.10	0.00
387	3.87	0.10	0.00
388	3.88	0.10	0.00
389	3.89	0.10	0.00
390	3.90	0.10	0.00
391	3.91	0.10	0.00
392	3.92	0.10	0.00
393	3.93	0.10	0.00
394	3.94	0.10	0.00
395	3.95	0.10	0.00
396	3.96	0.10	0.00
397	3.97	0.10	0.00
398	3.98	0.10	0.00
399	3.99	0.10	0.00
400	4.00	0.10	0.00
401	4.01	0.00	0.00
402	4.02	0.00	0.00
403	4.03	0.00	0.00
404	4.04	0.00	0.00
405	4.05	0.00	0.00
406	4.06	0.00	0.00
407	4.07	0.00	0.00
408	4.08	0.00	0.00
409	4.09	0.00	0.00
410	4.10	0.00	0.00
411	4.11	0.00	0.00
412	4.12	0.00	0.00
413	4.13	0.00	0.00
414	4.14	0.00	0.00
415	4.15	0.00	0.00
416	4.16	0.00	0.00
417	4.17	0.00	0.00
418	4.18	0.00	0.00
419	4.19	0.00	0.00
420	4.20	0.00	0.00
421	4.21	0.00	0.00
422	4.22	0.00	0.00
423	4.23	0.00	0.00
424	4.24	0.00	0.00
425	4.25	0.00	0.00
426	4.26	0.00	0.00
427	4.27	0.00	0.00

Depth or Velocity (cm)	Depth or Velocity(m)	Depth (m)	Velocity (m/s)
428	4.28	0.00	0.00
429	4.29	0.00	0.00
430	4.30	0.00	0.00
431	4.31	0.00	0.00
432	4.32	0.00	0.00
433	4.33	0.00	0.00
434	4.34	0.00	0.00
435	4.35	0.00	0.00
436	4.36	0.00	0.00
437	4.37	0.00	0.00
438	4.38	0.00	0.00
439	4.39	0.00	0.00
440	4.40	0.00	0.00
441	4.41	0.00	0.00
442	4.42	0.00	0.00
443	4.43	0.00	0.00
444	4.44	0.00	0.00
445	4.45	0.00	0.00
446	4.46	0.00	0.00
447	4.47	0.00	0.00
448	4.48	0.00	0.00
449	4.49	0.00	0.00
450	4.50	0.00	0.00
451	4.51	0.00	0.00
452	4.52	0.00	0.00
453	4.53	0.00	0.00
454	4.54	0.00	0.00
455	4.55	0.00	0.00
456	4.56	0.00	0.00
457	4.57	0.00	0.00
458	4.58	0.00	0.00
459	4.59	0.00	0.00
460	4.60	0.00	0.00
461	4.61	0.00	0.00
462	4.62	0.00	0.00
463	4.63	0.00	0.00
464	4.64	0.00	0.00
465	4.65	0.00	0.00
466	4.66	0.00	0.00
467	4.67	0.00	0.00
468	4.68	0.00	0.00
469	4.69	0.00	0.00
470	4.70	0.00	0.00
471	4.71	0.00	0.00
472	4.72	0.00	0.00
473	4.73	0.00	0.00
474	4.74	0.00	0.00
475	4.75	0.00	0.00

Depth or Velocity (cm)	Depth or Velocity(m)	Depth (m)	Velocity (m/s)
476	4.76	0.00	0.00
477	4.77	0.00	0.00
478	4.78	0.00	0.00
479	4.79	0.00	0.00
480	4.80	0.00	0.00
481	4.81	0.00	0.00
482	4.82	0.00	0.00
483	4.83	0.00	0.00
484	4.84	0.00	0.00
485	4.85	0.00	0.00
486	4.86	0.00	0.00
487	4.87	0.00	0.00
488	4.88	0.00	0.00
489	4.89	0.00	0.00
490	4.90	0.00	0.00
491	4.91	0.00	0.00
492	4.92	0.00	0.00
493	4.93	0.00	0.00
494	4.94	0.00	0.00
495	4.95	0.00	0.00
496	4.96	0.00	0.00
497	4.97	0.00	0.00
498	4.98	0.00	0.00
499	4.99	0.00	0.00
500	5.00	0.00	0.00
501	5.01	0.00	0.00
502	5.02	0.00	0.00
503	5.03	0.00	0.00
504	5.04	0.00	0.00
505	5.05	0.00	0.00
506	5.06	0.00	0.00
507	5.07	0.00	0.00
508	5.08	0.00	0.00
509	5.09	0.00	0.00
510	5.10	0.00	0.00
511	5.11	0.00	0.00
512	5.12	0.00	0.00
513	5.13	0.00	0.00
514	5.14	0.00	0.00
515	5.15	0.00	0.00
516	5.16	0.00	0.00
517	5.17	0.00	0.00
518	5.18	0.00	0.00
519	5.19	0.00	0.00
520	5.20	0.00	0.00
521	5.21	0.00	0.00
522	5.22	0.00	0.00
523	5.23	0.00	0.00

Depth or Velocity (cm)	Depth or Velocity(m)	Depth (m)	Velocity (m/s)
524	5.24	0.00	0.00
525	5.25	0.00	0.00
526	5.26	0.00	0.00
527	5.27	0.00	0.00
528	5.28	0.00	0.00
529	5.29	0.00	0.00
530	5.30	0.00	0.00
531	5.31	0.00	0.00
532	5.32	0.00	0.00
533	5.33	0.00	0.00
534	5.34	0.00	0.00
535	5.35	0.00	0.00
536	5.36	0.00	0.00
537	5.37	0.00	0.00
538	5.38	0.00	0.00
539	5.39	0.00	0.00
540	5.40	0.00	0.00
541	5.41	0.00	0.00
542	5.42	0.00	0.00
543	5.43	0.00	0.00
544	5.44	0.00	0.00
545	5.45	0.00	0.00
546	5.46	0.00	0.00
547	5.47	0.00	0.00
548	5.48	0.00	0.00
549	5.49	0.00	0.00
550	5.50	0.00	0.00
551	5.51	0.00	0.00
552	5.52	0.00	0.00
553	5.53	0.00	0.00
554	5.54	0.00	0.00
555	5.55	0.00	0.00
556	5.56	0.00	0.00
557	5.57	0.00	0.00
558	5.58	0.00	0.00
559	5.59	0.00	0.00
560	5.60	0.00	0.00
561	5.61	0.00	0.00
562	5.62	0.00	0.00
563	5.63	0.00	0.00
564	5.64	0.00	0.00
565	5.65	0.00	0.00
566	5.66	0.00	0.00
567	5.67	0.00	0.00
568	5.68	0.00	0.00
569	5.69	0.00	0.00
570	5.70	0.00	0.00
571	5.71	0.00	0.00

Depth or Velocity (cm)	Depth or Velocity(m)	Depth (m)	Velocity (m/s)
572	5.72	0.00	0.00
573	5.73	0.00	0.00
574	5.74	0.00	0.00
575	5.75	0.00	0.00
576	5.76	0.00	0.00
577	5.77	0.00	0.00
578	5.78	0.00	0.00
579	5.79	0.00	0.00
580	5.80	0.00	0.00
581	5.81	0.00	0.00
582	5.82	0.00	0.00
583	5.83	0.00	0.00
584	5.84	0.00	0.00
585	5.85	0.00	0.00
586	5.86	0.00	0.00
587	5.87	0.00	0.00
588	5.88	0.00	0.00
589	5.89	0.00	0.00
590	5.90	0.00	0.00
591	5.91	0.00	0.00
592	5.92	0.00	0.00
593	5.93	0.00	0.00
594	5.94	0.00	0.00
595	5.95	0.00	0.00
596	5.96	0.00	0.00
597	5.97	0.00	0.00
598	5.98	0.00	0.00
599	5.99	0.00	0.00
600	6.00	0.00	0.00
601	6.01	0.00	0.00
602	6.02	0.00	0.00
603	6.03	0.00	0.00
604	6.04	0.00	0.00
605	6.05	0.00	0.00
606	6.06	0.00	0.00
607	6.07	0.00	0.00
608	6.08	0.00	0.00
609	6.09	0.00	0.00
610	6.10	0.00	0.00
611	6.11	0.00	0.00
612	6.12	0.00	0.00
613	6.13	0.00	0.00
614	6.14	0.00	0.00
615	6.15	0.00	0.00
616	6.16	0.00	0.00
617	6.17	0.00	0.00
618	6.18	0.00	0.00
619	6.19	0.00	0.00

Depth or Velocity (cm)	Depth or Velocity(m)	Depth (m)	Velocity (m/s)
620	6.20	0.00	0.00
621	6.21	0.00	0.00
622	6.22	0.00	0.00
623	6.23	0.00	0.00
624	6.24	0.00	0.00
625	6.25	0.00	0.00
626	6.26	0.00	0.00
627	6.27	0.00	0.00
628	6.28	0.00	0.00
629	6.29	0.00	0.00
630	6.30	0.00	0.00
631	6.31	0.00	0.00
632	6.32	0.00	0.00
633	6.33	0.00	0.00
634	6.34	0.00	0.00
635	6.35	0.00	0.00
636	6.36	0.00	0.00
637	6.37	0.00	0.00
638	6.38	0.00	0.00
639	6.39	0.00	0.00
640	6.40	0.00	0.00
641	6.41	0.00	0.00
642	6.42	0.00	0.00
643	6.43	0.00	0.00
644	6.44	0.00	0.00
645	6.45	0.00	0.00
646	6.46	0.00	0.00
647	6.47	0.00	0.00
648	6.48	0.00	0.00
649	6.49	0.00	0.00
650	6.50	0.00	0.00
651	6.51	0.00	0.00
652	6.52	0.00	0.00
653	6.53	0.00	0.00
654	6.54	0.00	0.00
655	6.55	0.00	0.00
656	6.56	0.00	0.00
657	6.57	0.00	0.00
658	6.58	0.00	0.00
659	6.59	0.00	0.00
660	6.60	0.00	0.00
661	6.61	0.00	0.00
662	6.62	0.00	0.00
663	6.63	0.00	0.00
664	6.64	0.00	0.00
665	6.65	0.00	0.00
666	6.66	0.00	0.00
667	6.67	0.00	0.00

Depth or Velocity (cm)	Depth or Velocity(m)	Depth (m)	Velocity (m/s)
668	6.68	0.00	0.00
669	6.69	0.00	0.00
670	6.70	0.00	0.00
671	6.71	0.00	0.00
672	6.72	0.00	0.00
673	6.73	0.00	0.00
674	6.74	0.00	0.00
675	6.75	0.00	0.00
676	6.76	0.00	0.00
677	6.77	0.00	0.00
678	6.78	0.00	0.00
679	6.79	0.00	0.00
680	6.80	0.00	0.00
681	6.81	0.00	0.00
682	6.82	0.00	0.00
683	6.83	0.00	0.00
684	6.84	0.00	0.00
685	6.85	0.00	0.00
686	6.86	0.00	0.00
687	6.87	0.00	0.00
688	6.88	0.00	0.00
689	6.89	0.00	0.00
690	6.90	0.00	0.00
691	6.91	0.00	0.00
692	6.92	0.00	0.00
693	6.93	0.00	0.00
694	6.94	0.00	0.00
695	6.95	0.00	0.00
696	6.96	0.00	0.00
697	6.97	0.00	0.00
698	6.98	0.00	0.00
699	6.99	0.00	0.00
700	7.00	0.00	0.00
701	7.01	0.00	0.00
702	7.02	0.00	0.00
703	7.03	0.00	0.00
704	7.04	0.00	0.00
705	7.05	0.00	0.00
706	7.06	0.00	0.00
707	7.07	0.00	0.00
708	7.08	0.00	0.00
709	7.09	0.00	0.00
710	7.10	0.00	0.00
711	7.11	0.00	0.00
712	7.12	0.00	0.00
713	7.13	0.00	0.00
714	7.14	0.00	0.00
715	7.15	0.00	0.00

Depth or Velocity (cm)	Depth or Velocity(m)	Depth (m)	Velocity (m/s)
716	7.16	0.00	0.00
717	7.17	0.00	0.00
718	7.18	0.00	0.00
719	7.19	0.00	0.00
720	7.20	0.00	0.00
721	7.21	0.00	0.00
722	7.22	0.00	0.00
723	7.23	0.00	0.00
724	7.24	0.00	0.00
725	7.25	0.00	0.00
726	7.26	0.00	0.00
727	7.27	0.00	0.00
728	7.28	0.00	0.00
729	7.29	0.00	0.00
730	7.30	0.00	0.00
731	7.31	0.00	0.00
732	7.32	0.00	0.00
733	7.33	0.00	0.00
734	7.34	0.00	0.00
735	7.35	0.00	0.00
736	7.36	0.00	0.00
737	7.37	0.00	0.00
738	7.38	0.00	0.00
739	7.39	0.00	0.00
740	7.40	0.00	0.00
741	7.41	0.00	0.00
742	7.42	0.00	0.00
743	7.43	0.00	0.00
744	7.44	0.00	0.00
745	7.45	0.00	0.00
746	7.46	0.00	0.00
747	7.47	0.00	0.00
748	7.48	0.00	0.00
749	7.49	0.00	0.00
750	7.50	0.00	0.00
751	7.51	0.00	0.00
752	7.52	0.00	0.00
753	7.53	0.00	0.00
754	7.54	0.00	0.00
755	7.55	0.00	0.00
756	7.56	0.00	0.00
757	7.57	0.00	0.00
758	7.58	0.00	0.00
759	7.59	0.00	0.00
760	7.60	0.00	0.00
761	7.61	0.00	0.00
762	7.62	0.00	0.00
763	7.63	0.00	0.00

Depth or Velocity (cm)	Depth or Velocity(m)	Depth (m)	Velocity (m/s)
764	7.64	0.00	0.00
765	7.65	0.00	0.00
766	7.66	0.00	0.00
767	7.67	0.00	0.00
768	7.68	0.00	0.00
769	7.69	0.00	0.00
770	7.70	0.00	0.00
771	7.71	0.00	0.00
772	7.72	0.00	0.00
773	7.73	0.00	0.00
774	7.74	0.00	0.00
775	7.75	0.00	0.00
776	7.76	0.00	0.00
777	7.77	0.00	0.00
778	7.78	0.00	0.00
779	7.79	0.00	0.00
780	7.80	0.00	0.00
781	7.81	0.00	0.00
782	7.82	0.00	0.00
783	7.83	0.00	0.00
784	7.84	0.00	0.00
785	7.85	0.00	0.00
786	7.86	0.00	0.00
787	7.87	0.00	0.00
788	7.88	0.00	0.00
789	7.89	0.00	0.00
790	7.90	0.00	0.00
791	7.91	0.00	0.00
792	7.92	0.00	0.00
793	7.93	0.00	0.00
794	7.94	0.00	0.00
795	7.95	0.00	0.00
796	7.96	0.00	0.00
797	7.97	0.00	0.00
798	7.98	0.00	0.00
799	7.99	0.00	0.00
800	8.00	0.00	0.00
801	8.01	0.00	0.00
802	8.02	0.00	0.00
803	8.03	0.00	0.00
804	8.04	0.00	0.00
805	8.05	0.00	0.00
806	8.06	0.00	0.00
807	8.07	0.00	0.00
808	8.08	0.00	0.00
809	8.09	0.00	0.00
810	8.10	0.00	0.00
811	8.11	0.00	0.00

Depth or Velocity (cm)	Depth or Velocity(m)	Depth (m)	Velocity (m/s)
812	8.12	0.00	0.00
813	8.13	0.00	0.00
814	8.14	0.00	0.00
815	8.15	0.00	0.00
816	8.16	0.00	0.00
817	8.17	0.00	0.00
818	8.18	0.00	0.00
819	8.19	0.00	0.00
820	8.20	0.00	0.00
821	8.21	0.00	0.00
822	8.22	0.00	0.00
823	8.23	0.00	0.00
824	8.24	0.00	0.00
825	8.25	0.00	0.00
826	8.26	0.00	0.00
827	8.27	0.00	0.00
828	8.28	0.00	0.00
829	8.29	0.00	0.00
830	8.30	0.00	0.00
831	8.31	0.00	0.00
832	8.32	0.00	0.00
833	8.33	0.00	0.00
834	8.34	0.00	0.00
835	8.35	0.00	0.00
836	8.36	0.00	0.00
837	8.37	0.00	0.00
838	8.38	0.00	0.00
839	8.39	0.00	0.00
840	8.40	0.00	0.00
841	8.41	0.00	0.00
842	8.42	0.00	0.00
843	8.43	0.00	0.00
844	8.44	0.00	0.00
845	8.45	0.00	0.00
846	8.46	0.00	0.00
847	8.47	0.00	0.00
848	8.48	0.00	0.00
849	8.49	0.00	0.00
850	8.50	0.00	0.00
851	8.51	0.00	0.00
852	8.52	0.00	0.00
853	8.53	0.00	0.00
854	8.54	0.00	0.00
855	8.55	0.00	0.00
856	8.56	0.00	0.00
857	8.57	0.00	0.00
858	8.58	0.00	0.00
859	8.59	0.00	0.00

Depth or Velocity (cm)	Depth or Velocity(m)	Depth (m)	Velocity (m/s)
860	8.60	0.00	0.00
861	8.61	0.00	0.00
862	8.62	0.00	0.00
863	8.63	0.00	0.00
864	8.64	0.00	0.00
865	8.65	0.00	0.00
866	8.66	0.00	0.00
867	8.67	0.00	0.00
868	8.68	0.00	0.00
869	8.69	0.00	0.00
870	8.70	0.00	0.00
871	8.71	0.00	0.00
872	8.72	0.00	0.00
873	8.73	0.00	0.00
874	8.74	0.00	0.00
875	8.75	0.00	0.00
876	8.76	0.00	0.00
877	8.77	0.00	0.00
878	8.78	0.00	0.00
879	8.79	0.00	0.00
880	8.80	0.00	0.00
881	8.81	0.00	0.00
882	8.82	0.00	0.00
883	8.83	0.00	0.00
884	8.84	0.00	0.00
885	8.85	0.00	0.00
886	8.86	0.00	0.00
887	8.87	0.00	0.00
888	8.88	0.00	0.00
889	8.89	0.00	0.00
890	8.90	0.00	0.00
891	8.91	0.00	0.00
892	8.92	0.00	0.00
893	8.93	0.00	0.00
894	8.94	0.00	0.00
895	8.95	0.00	0.00
896	8.96	0.00	0.00
897	8.97	0.00	0.00
898	8.98	0.00	0.00
899	8.99	0.00	0.00
900	9.00	0.00	0.00
901	9.01	0.00	0.00
902	9.02	0.00	0.00
903	9.03	0.00	0.00
904	9.04	0.00	0.00
905	9.05	0.00	0.00
906	9.06	0.00	0.00
907	9.07	0.00	0.00

Depth or Velocity (cm)	Depth or Velocity(m)	Depth (m)	Velocity (m/s)
908	9.08	0.00	0.00
909	9.09	0.00	0.00
910	9.10	0.00	0.00
911	9.11	0.00	0.00
912	9.12	0.00	0.00
913	9.13	0.00	0.00
914	9.14	0.00	0.00
915	9.15	0.00	0.00
916	9.16	0.00	0.00
917	9.17	0.00	0.00
918	9.18	0.00	0.00
919	9.19	0.00	0.00
920	9.20	0.00	0.00
921	9.21	0.00	0.00
922	9.22	0.00	0.00
923	9.23	0.00	0.00
924	9.24	0.00	0.00
925	9.25	0.00	0.00
926	9.26	0.00	0.00
927	9.27	0.00	0.00
928	9.28	0.00	0.00
929	9.29	0.00	0.00
930	9.30	0.00	0.00
931	9.31	0.00	0.00
932	9.32	0.00	0.00
933	9.33	0.00	0.00
934	9.34	0.00	0.00
935	9.35	0.00	0.00
936	9.36	0.00	0.00
937	9.37	0.00	0.00
938	9.38	0.00	0.00
939	9.39	0.00	0.00
940	9.40	0.00	0.00
941	9.41	0.00	0.00
942	9.42	0.00	0.00
943	9.43	0.00	0.00
944	9.44	0.00	0.00
945	9.45	0.00	0.00
946	9.46	0.00	0.00
947	9.47	0.00	0.00
948	9.48	0.00	0.00
949	9.49	0.00	0.00
950	9.50	0.00	0.00
951	9.51	0.00	0.00
952	9.52	0.00	0.00
953	9.53	0.00	0.00
954	9.54	0.00	0.00
955	9.55	0.00	0.00

Depth or Velocity (cm)	Depth or Velocity(m)	Depth (m)	Velocity (m/s)
956	9.56	0.00	0.00
957	9.57	0.00	0.00
958	9.58	0.00	0.00
959	9.59	0.00	0.00
960	9.60	0.00	0.00
961	9.61	0.00	0.00
962	9.62	0.00	0.00
963	9.63	0.00	0.00
964	9.64	0.00	0.00
965	9.65	0.00	0.00
966	9.66	0.00	0.00
967	9.67	0.00	0.00
968	9.68	0.00	0.00
969	9.69	0.00	0.00
970	9.70	0.00	0.00
971	9.71	0.00	0.00
972	9.72	0.00	0.00
973	9.73	0.00	0.00
974	9.74	0.00	0.00
975	9.75	0.00	0.00
976	9.76	0.00	0.00
977	9.77	0.00	0.00
978	9.78	0.00	0.00
979	9.79	0.00	0.00
980	9.80	0.00	0.00
981	9.81	0.00	0.00
982	9.82	0.00	0.00
983	9.83	0.00	0.00
984	9.84	0.00	0.00
985	9.85	0.00	0.00
986	9.86	0.00	0.00
987	9.87	0.00	0.00
988	9.88	0.00	0.00
989	9.89	0.00	0.00
990	9.90	0.00	0.00
991	9.91	0.00	0.00
992	9.92	0.00	0.00
993	9.93	0.00	0.00
994	9.94	0.00	0.00
995	9.95	0.00	0.00
996	9.96	0.00	0.00
997	9.97	0.00	0.00
998	9.98	0.00	0.00
999	9.99	0.00	0.00
1000	10.00	0.00	0.00

APPENDIX 1B

HSI VALUES FOR DEPTH AND VELOCITY FOR JUVENILE RAINBOW TROUT

HSI values for depth and velocity for juvenile Rainbow Trout rearing habitat (Ptolemy, 2001)

Depth or Velocity (cm)	Depth or Velocity (m)	Depth (m)	Velocity (m/s)
0	0.00	0.00	0.00
1	0.01	0.00	0.05
2	0.02	0.00	0.11
3	0.03	0.04	0.18
4	0.04	0.09	0.25
5	0.05	0.13	0.30
6	0.06	0.17	0.35
7	0.07	0.21	0.40
8	0.08	0.25	0.45
9	0.09	0.29	0.50
10	0.10	0.33	0.55
11	0.11	0.37	0.59
12	0.12	0.42	0.63
13	0.13	0.46	0.67
14	0.14	0.51	0.71
15	0.15	0.55	0.75
16	0.16	0.59	0.78
17	0.17	0.63	0.81
18	0.18	0.67	0.84
19	0.19	0.71	0.87
20	0.20	0.75	0.90
21	0.21	0.78	0.92
22	0.22	0.81	0.94
23	0.23	0.85	0.96
24	0.24	0.88	0.98
25	0.25	0.91	1.00
26	0.26	0.92	1.00
27	0.27	0.94	1.00
28	0.28	0.95	1.00
29	0.29	0.97	1.00
30	0.30	0.98	1.00
31	0.31	0.98	1.00
32	0.32	0.99	1.00
33	0.33	0.99	1.00
34	0.34	1.00	1.00
35	0.35	1.00	1.00
36	0.36	1.00	1.00
37	0.37	1.00	1.00
38	0.38	1.00	1.00
39	0.39	1.00	1.00
40	0.40	1.00	1.00
41	0.41	1.00	1.00
42	0.42	1.00	1.00
43	0.43	1.00	1.00
44	0.44	1.00	1.00
45	0.45	1.00	1.00

Depth or Velocity (cm)	Depth or Velocity (m)	Depth (m)	Velocity (m/s)
46	0.46	1.00	1.00
47	0.47	1.00	1.00
48	0.48	1.00	1.00
49	0.49	1.00	1.00
50	0.50	1.00	1.00
51	0.51	1.00	1.00
52	0.52	1.00	1.00
53	0.53	1.00	1.00
54	0.54	1.00	1.00
55	0.55	1.00	1.00
56	0.56	1.00	0.99
57	0.57	1.00	0.97
58	0.58	1.00	0.96
59	0.59	1.00	0.94
60	0.60	1.00	0.93
61	0.61	1.00	0.91
62	0.62	1.00	0.90
63	0.63	1.00	0.88
64	0.64	1.00	0.87
65	0.65	1.00	0.85
66	0.66	1.00	0.83
67	0.67	1.00	0.81
68	0.68	1.00	0.80
69	0.69	1.00	0.78
70	0.70	1.00	0.76
71	0.71	1.00	0.74
72	0.72	1.00	0.73
73	0.73	1.00	0.71
74	0.74	1.00	0.70
75	0.75	1.00	0.68
76	0.76	1.00	0.66
77	0.77	1.00	0.64
78	0.78	1.00	0.63
79	0.79	1.00	0.61
80	0.80	1.00	0.59
81	0.81	1.00	0.57
82	0.82	1.00	0.55
83	0.83	1.00	0.54
84	0.84	1.00	0.52
85	0.85	1.00	0.50
86	0.86	1.00	0.48
87	0.87	1.00	0.47
88	0.88	1.00	0.45
89	0.89	1.00	0.44
90	0.90	1.00	0.42
91	0.91	1.00	0.41

Depth or Velocity (cm)	Depth or Velocity (m)	Depth (m)	Velocity (m/s)
92	0.92	1.00	0.39
93	0.93	1.00	0.38
94	0.94	1.00	0.36
95	0.95	1.00	0.35
96	0.96	1.00	0.34
97	0.97	1.00	0.32
98	0.98	1.00	0.31
99	0.99	1.00	0.29
100	1.00	1.00	0.28
101	1.01	1.00	0.27
102	1.02	1.00	0.25
103	1.03	1.00	0.24
104	1.04	1.00	0.22
105	1.05	1.00	0.21
106	1.06	1.00	0.20
107	1.07	1.00	0.19
108	1.08	1.00	0.18
109	1.09	1.00	0.17
110	1.10	1.00	0.16
111	1.11	1.00	0.15
112	1.12	1.00	0.14
113	1.13	1.00	0.13
114	1.14	1.00	0.12
115	1.15	1.00	0.11
116	1.16	1.00	0.10
117	1.17	1.00	0.09
118	1.18	1.00	0.09
119	1.19	1.00	0.09
120	1.20	1.00	0.08
121	1.21	1.00	0.07
122	1.22	1.00	0.07
123	1.23	1.00	0.06
124	1.24	1.00	0.06
125	1.25	1.00	0.05
126	1.26	1.00	0.05
127	1.27	1.00	0.04
128	1.28	1.00	0.04
129	1.29	1.00	0.03
130	1.30	1.00	0.03
131	1.31	1.00	0.03
132	1.32	1.00	0.03
133	1.33	1.00	0.02
134	1.34	1.00	0.02
135	1.35	1.00	0.02
136	1.36	1.00	0.02
137	1.37	1.00	0.02
138	1.38	1.00	0.01
139	1.39	1.00	0.01

Depth or Velocity (cm)	Depth or Velocity (m)	Depth (m)	Velocity (m/s)
140	1.40	1.00	0.01
141	1.41	1.00	0.01
142	1.42	1.00	0.01
143	1.43	1.00	0.01
144	1.44	1.00	0.01
145	1.45	1.00	0.01
146	1.46	1.00	0.00
147	1.47	1.00	0.00
148	1.48	1.00	0.00
149	1.49	1.00	0.00
150	1.50	1.00	0.00
151	1.51	1.00	0.00
152	1.52	1.00	0.00
153	1.53	1.00	0.00
154	1.54	1.00	0.00
155	1.55	1.00	0.00
156	1.56	1.00	0.00
157	1.57	1.00	0.00
158	1.58	1.00	0.00
159	1.59	1.00	0.00
160	1.60	1.00	0.00
161	1.61	1.00	0.00
162	1.62	1.00	0.00
163	1.63	1.00	0.00
164	1.64	1.00	0.00
165	1.65	1.00	0.00
166	1.66	1.00	0.00
167	1.67	1.00	0.00
168	1.68	1.00	0.00
169	1.69	1.00	0.00
170	1.70	1.00	0.00
171	1.71	1.00	0.00
172	1.72	1.00	0.00
173	1.73	1.00	0.00
174	1.74	1.00	0.00
175	1.75	1.00	0.00
176	1.76	1.00	0.00
177	1.77	1.00	0.00
178	1.78	1.00	0.00
179	1.79	1.00	0.00
180	1.80	1.00	0.00
181	1.81	1.00	0.00
182	1.82	1.00	0.00
183	1.83	1.00	0.00
184	1.84	1.00	0.00
185	1.85	1.00	0.00
186	1.86	1.00	0.00
187	1.87	1.00	0.00

Depth or Velocity (cm)	Depth or Velocity (m)	Depth (m)	Velocity (m/s)
188	1.88	1.00	0.00
189	1.89	1.00	0.00
190	1.90	1.00	0.00
191	1.91	1.00	0.00
192	1.92	1.00	0.00
193	1.93	1.00	0.00
194	1.94	1.00	0.00
195	1.95	1.00	0.00
196	1.96	1.00	0.00
197	1.97	1.00	0.00
198	1.98	1.00	0.00
199	1.99	1.00	0.00
200	2.00	1.00	0.00
201	2.01	1.00	0.00
202	2.02	1.00	0.00
203	2.03	1.00	0.00
204	2.04	1.00	0.00
205	2.05	1.00	0.00
206	2.06	1.00	0.00
207	2.07	1.00	0.00
208	2.08	1.00	0.00
209	2.09	1.00	0.00
210	2.10	1.00	0.00
211	2.11	1.00	0.00
212	2.12	1.00	0.00
213	2.13	1.00	0.00
214	2.14	1.00	0.00
215	2.15	1.00	0.00
216	2.16	1.00	0.00
217	2.17	1.00	0.00
218	2.18	1.00	0.00
219	2.19	1.00	0.00
220	2.20	1.00	0.00
221	2.21	1.00	0.00
222	2.22	1.00	0.00
223	2.23	1.00	0.00
224	2.24	1.00	0.00
225	2.25	1.00	0.00
226	2.26	1.00	0.00
227	2.27	1.00	0.00
228	2.28	1.00	0.00
229	2.29	1.00	0.00
230	2.30	1.00	0.00
231	2.31	1.00	0.00
232	2.32	1.00	0.00
233	2.33	1.00	0.00
234	2.34	1.00	0.00
235	2.35	1.00	0.00

Depth or Velocity (cm)	Depth or Velocity (m)	Depth (m)	Velocity (m/s)
236	2.36	1.00	0.00
237	2.37	1.00	0.00
238	2.38	1.00	0.00
239	2.39	1.00	0.00
240	2.40	1.00	0.00
241	2.41	1.00	0.00
242	2.42	1.00	0.00
243	2.43	1.00	0.00
244	2.44	1.00	0.00
245	2.45	1.00	0.00
246	2.46	1.00	0.00
247	2.47	1.00	0.00
248	2.48	1.00	0.00
249	2.49	1.00	0.00
250	2.50	1.00	0.00
251	2.51	1.00	0.00
252	2.52	1.00	0.00
253	2.53	1.00	0.00
254	2.54	1.00	0.00
255	2.55	1.00	0.00
256	2.56	1.00	0.00
257	2.57	1.00	0.00
258	2.58	1.00	0.00
259	2.59	1.00	0.00
260	2.60	1.00	0.00
261	2.61	1.00	0.00
262	2.62	1.00	0.00
263	2.63	1.00	0.00
264	2.64	1.00	0.00
265	2.65	1.00	0.00
266	2.66	1.00	0.00
267	2.67	1.00	0.00
268	2.68	1.00	0.00
269	2.69	1.00	0.00
270	2.70	1.00	0.00
271	2.71	1.00	0.00
272	2.72	1.00	0.00
273	2.73	1.00	0.00
274	2.74	1.00	0.00
275	2.75	1.00	0.00
276	2.76	1.00	0.00
277	2.77	1.00	0.00
278	2.78	1.00	0.00
279	2.79	1.00	0.00
280	2.80	1.00	0.00
281	2.81	1.00	0.00
282	2.82	1.00	0.00
283	2.83	1.00	0.00

Depth or Velocity (cm)	Depth or Velocity (m)	Depth (m)	Velocity (m/s)
284	2.84	1.00	0.00
285	2.85	1.00	0.00
286	2.86	1.00	0.00
287	2.87	1.00	0.00
288	2.88	1.00	0.00
289	2.89	1.00	0.00
290	2.90	1.00	0.00
291	2.91	1.00	0.00
292	2.92	1.00	0.00
293	2.93	1.00	0.00
294	2.94	1.00	0.00
295	2.95	1.00	0.00
296	2.96	1.00	0.00
297	2.97	1.00	0.00
298	2.98	1.00	0.00
299	2.99	1.00	0.00
300	3.00	1.00	0.00
301	3.01	1.00	0.00
302	3.02	1.00	0.00
303	3.03	1.00	0.00
304	3.04	1.00	0.00
305	3.05	1.00	0.00
306	3.06	1.00	0.00
307	3.07	1.00	0.00
308	3.08	1.00	0.00
309	3.09	1.00	0.00
310	3.10	1.00	0.00
311	3.11	1.00	0.00
312	3.12	1.00	0.00
313	3.13	1.00	0.00
314	3.14	1.00	0.00
315	3.15	1.00	0.00
316	3.16	1.00	0.00
317	3.17	1.00	0.00
318	3.18	1.00	0.00
319	3.19	1.00	0.00
320	3.20	1.00	0.00
321	3.21	1.00	0.00
322	3.22	1.00	0.00
323	3.23	1.00	0.00
324	3.24	1.00	0.00
325	3.25	1.00	0.00
326	3.26	1.00	0.00
327	3.27	1.00	0.00
328	3.28	1.00	0.00
329	3.29	1.00	0.00
330	3.30	1.00	0.00
331	3.31	1.00	0.00

Depth or Velocity (cm)	Depth or Velocity (m)	Depth (m)	Velocity (m/s)
332	3.32	1.00	0.00
333	3.33	1.00	0.00
334	3.34	1.00	0.00
335	3.35	1.00	0.00
336	3.36	1.00	0.00
337	3.37	1.00	0.00
338	3.38	1.00	0.00
339	3.39	1.00	0.00
340	3.40	1.00	0.00
341	3.41	1.00	0.00
342	3.42	1.00	0.00
343	3.43	1.00	0.00
344	3.44	1.00	0.00
345	3.45	1.00	0.00
346	3.46	1.00	0.00
347	3.47	1.00	0.00
348	3.48	1.00	0.00
349	3.49	1.00	0.00
350	3.50	1.00	0.00
351	3.51	1.00	0.00
352	3.52	1.00	0.00
353	3.53	1.00	0.00
354	3.54	1.00	0.00
355	3.55	1.00	0.00
356	3.56	1.00	0.00
357	3.57	1.00	0.00
358	3.58	1.00	0.00
359	3.59	1.00	0.00
360	3.60	1.00	0.00
361	3.61	1.00	0.00
362	3.62	1.00	0.00
363	3.63	1.00	0.00
364	3.64	1.00	0.00
365	3.65	1.00	0.00
366	3.66	1.00	0.00
367	3.67	1.00	0.00
368	3.68	1.00	0.00
369	3.69	1.00	0.00
370	3.70	1.00	0.00
371	3.71	1.00	0.00
372	3.72	1.00	0.00
373	3.73	1.00	0.00
374	3.74	1.00	0.00
375	3.75	1.00	0.00
376	3.76	1.00	0.00
377	3.77	1.00	0.00
378	3.78	1.00	0.00
379	3.79	1.00	0.00

Depth or Velocity (cm)	Depth or Velocity (m)	Depth (m)	Velocity (m/s)
380	3.80	1.00	0.00
381	3.81	1.00	0.00
382	3.82	1.00	0.00
383	3.83	1.00	0.00
384	3.84	1.00	0.00
385	3.85	1.00	0.00
386	3.86	1.00	0.00
387	3.87	1.00	0.00
388	3.88	1.00	0.00
389	3.89	1.00	0.00
390	3.90	1.00	0.00
391	3.91	1.00	0.00
392	3.92	1.00	0.00
393	3.93	1.00	0.00
394	3.94	1.00	0.00
395	3.95	1.00	0.00
396	3.96	1.00	0.00
397	3.97	1.00	0.00
398	3.98	1.00	0.00
399	3.99	1.00	0.00
400	4.00	1.00	0.00

APPENDIX 1C

HSI VALUES FOR SUBSTRATE FOR RAINBOW TROUT FRY AND JUVENILE REARING STAGES

Substrate habitat suitability values for Rainbow Trout (Triton, 2012)

Substrate	Substrate Size (mm)*	Rainbow Trout	
		Fry Rearing	Juvenile Rearing
Rock	Greater than 4000	0.20	0.40
Boulder	256 – 4000	1.00	1.00
Large Cobble	128 – 256	1.00	0.80
Small Cobble	64 – 128	1.00	0.60
Large Gravel	16 – 64	1.00	0.50
Small Gravel	2 – 16	0.80	0.40
Sand/Silt	Less than 2	0.25	0.05

*Adapted from RIC – Site Card Field Guide, 1999 (taken from Triton 2009 Kookipi Creek Report p. 56)

APPENDIX 2

COMPILATION OF FIELD DATA PER TRANSECT

APPENDIX 3

MEAN HYDRAULIC MEASUREMENTS PER HABITAT UNIT

Mean Hydraulic Measurements per Habitat Unit

Habitat Unit	Stage	n	Mean Discharge (m^3s^{-1}) (Standard Deviation)	Mean Depth (m) (Standard Deviation)	Mean Velocity (ms^{-1}) (Standard Deviation)	Mean Wetted Width (m) (Standard Deviation)
Pool	**Low**	2	**0.00** (0.0)	**0.47** (0.01)	**0.00** (0.0)	**7.20** (1.70)
	Moderate	2	**0.50** (0.04)	**0.64** (0.05)	**0.09** (0.04)	**7.60** (2.12)
	High	2	**2.12** (0.79	**0.81** (0.14)	**0.31** (0.13)	**7.95** (1.48)
Riffle	**Low**	3	**0.01** (0.01)	**0.06** (0.04)	**0.04** (0.05)	**6.27** (2.57)
	Moderate	3	**0.99** (0.33)	**0.18** (0.03)	**0.37** (0.05)	**11.83** (2.84)
	High	2	**1.87** (0.40)	**0.27** (0.0)	**0.55** (0.08)	**12.33** (3.57)
Glide	**Low**	3	**0.00** (0.0)	**0.23** (0.03)	**0.00** (0.0)	**6.90** (1.23)
	Moderate	3	**0.58** (0.45)	**0.36** (0.07)	**0.13** (0.08)	**9.37** (2.32)
	High	2	**1.70** (0.41)	**0.35** (0.03)	**0.31** (0.05)	**11.85** (1.06)

APPENDIX 4

SUMMARY OF CALCULATED WEIGHTED USABLE WIDTH VALUES FOR EACH TRANSECT AT THREE STAGES

Calculated weighted usable width values for Rainbow Trout rearing at three stages in Cranberry Creek (Triton, 2012)

	Low Flow $Q_{AVG} = 0.01\ m^3s^{-1}$ (Sept 1 – 8, 2011)					Moderate Flow $Q_{AVG} = 0.70\ m^3s^{-1}$ (Nov 2 – 4, 2010)					High Flow $Q_{AVG} = 2.06\ m^3s^{-1}$ (Sept 19 – 21, 2011)				
		Fry		Juvenile			Fry		Juvenile			Fry		Juvenile	
Transect	Wetted Width (m)	WUW (m)	WUW % of wetted width	WUW (m)	WUW % of wetted width	Wetted Width (m)	WUW (m)	WUW % of wetted width	WUW (m)	WUW % of wetted width	Wetted Width (m)	WUW (m)	WUW % of wetted width	WUW (m)	WUW % of wetted width
UC1	6.00	0.19	3.16%	0.00	0.00	6.10	0.53	8.69	1.19	19.51	6.90	0.42	6.09	2.18	31.59
UC3	5.50	0.38	6.91%	0.00	0.00	6.80	2.09	30.74	0.67	9.85	11.10	2.94	26.49	3.51	31.62
UC4	7.60	1.36	17.89%	0.06	0.79	13.90	3.49	25.11	3.66	26.33	14.85	1.36	9.15	2.91	19.60
UC6	7.40	1.06	14.32%	0.00	0.00	11.30	3.90	34.51	3.31	29.29	12.60	4.63	36.75	3.33	26.43
UC11	7.80	1.09	13.97%	0.00	0.00	10.00	2.13	21.30	2.07	20.70	-	-	-	-	-
UC13	7.90	1.02	12.91%	0.00	0.00	13.00	4.94	38.00	2.89	22.23	-	-	-	-	-
UC14	8.40	0.24	2.86%	0.00	0.00	9.10	0.41	4.51	0.86	9.45	9.00	0.40	4.44	1.42	15.78
UC15	3.30	1.20	36.36%	0.06	1.82	8.60	1.99	23.14	2.47	28.72	9.80	1.71	17.45	2.81	28.67
Means	**6.74**	**0.81**	**13.30%**	**0.02**	**0.33%**	**9.85**	**2.42**	**23.15%**	**2.14**	**20.76%**	**10.71**	**1.91**	**16.72%**	**2.69**	**25.62%**