# Draft Instream Flow Guidelines Development

# Colorado River Flow Relationships to Aquatic Habitat and State Threatened Species: Blue Sucker

Prepared for

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**and San Antonio Water System**

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# 1.0 INTRODUCTION

The lower Colorado River basin supports a diverse ecological community that relies on the quality, quantity, and timing of water moving through the system. The LCRA-SAWS Water Project (LSWP) has the potential to alter characteristics of the flow regime for the lower Colorado River, including the possibility of using instream structures to facilitate the removal of water for off-channel storage facilities (OCSF). Because of these potential changes, the Colorado River Flow Relationships to Aquatic Habitat and State Threatened Species: Blue Sucker Study was developed to assess potential impacts or benefits on the aquatic resources of the lower Colorado River with and without implementation of the project. An additional study objective was to quantify the condition of the aquatic environment under different flow scenarios to satisfy federal and state permitting requirements and ensure compliance with the environmental principles set forth for this project.

Two of the environmental principles incorporated into the LSWP contract relate directly to this study and state that before project implementation, studies must show that the project (1) "protects and benefits the lower Colorado River watershed and the Lower Colorado River Authority (LCRA) Service Area, including municipal, industrial, agricultural, recreational, and environmental interests"; and (2) "provides for instream flows no less protective than those included in the LCRA Water Management Plan (LWMP) for the Lower Colorado River Basin, as approved by the Texas Commission on Environmental Quality."

Separate, yet consistent with the description of LSWP environmental principles has been the development of the Texas Instream Flow Program (TIFP) that has a legislative mandate (Senate Bill 2) to identify instream flow conditions that support a "sound ecological environment", which is described as "…a functioning ecosystem characterized by intact, natural processes, resilience, and a balanced, integrated, and adaptive community of organisms comparable to that of the natural habitat of a region." (TIFP Draft 2006).

The goal of this interim report is to take the results-to-date of the LSWP studies and develop draft instream flow guidelines for the lower Colorado River specific to the LSWP. This report has integrated critical components (background and framework) of the TIFP (TIFP DRAFT 2006) and National Research Council (NRC 2005) to ensure compliance with all anticipated state-mandated requirements. The document is organized to first provide an overview of the LSWP status relative to each of the four key instream flow technical components (hydrology and hydraulics, biology, geomorphology, and water quality), then to describe the integration of these study components, and finally, to provide preliminary recommendations for instream flow guidelines for the lower Colorado River specific to the LSWP.

It is important to convey that additional field validation data is scheduled for collection during spring 2007 and may provide insight resulting in refinement of the recommendations. Additionally, comments received from the LSWP project team, Science Review Panel, or Advisory group may result in further adjustments or refinements to the proposed instream flow recommendations. Final recommendations will be issued in summer 2007 accompanied by a detailed technical report describing all study components and their integration.

# 2.0 STUDY COMPONENTS

Rivers are complex, dynamic systems that support a myriad of important ecological functions. They transport water, sediment, organic matter, nutrients, and energy downstream, which support aquatic communities. Rivers and associated riparian habitats provide longitudinal movement corridors for terrestrial and avian wildlife. Natural riverine ecosystems also provide lateral transfer and cycling of water, sediment, nutrients, and energy between the stream channel and floodplain areas. Healthy floodplains act as "sponges" that store water during high flow events and release it back to the channel during low flow periods. This function serves to dampen downstream flood peaks (and associated flood damages) and helps ensure that adequate baseflows are available to aquatic communities during seasonal dry periods. Floodplains and associated riparian vegetation also help to filter contaminants and improve surface and ground water quality.

Streamflow acts as a "master" variable that directly and indirectly influences the full range of riverine resources and functions, including hydrology and hydraulics, biology (aquatic and riparian), geomorphology, and water quality. The individual riverine components also influence each other either directly or indirectly. Because of this interdependence among the various resource components and processes, the full range of flow regime components were evaluated in the LSWP aquatic habitat study.

## 2.1 Hydrology and Hydraulics

Natural streamflow regimes are characterized by seasonal and inter-annual variability, and native aquatic and riparian biota are adapted to this variability. For example, seed dispersal by native riparian vegetation often coincides with the typical springtime high flow. Seasonal flow patterns may also cue spawning for various native fish species including the blue sucker. Year-to-year hydrologic variability is also important. For example, wet periods that are characterized by large overbank floods are important for creating habitat complexity and promoting lateral and longitudinal nutrient cycling. However, if major flooding occurred every year, the frequent disturbance would prevent riparian communities from becoming established and would compromise the stability of aquatic communities. Because different ecological functions are served by climatic conditions, inter-annual hydrologic variability was also considered in developing instream flow guidelines for the lower Colorado River.

On a smaller scale, river hydraulics (the patterns of water movement inside the channel) can be as important as hydrologic cycling. Water depth and velocity are not only useful for characterizing aquatic habitat but also play a vital role in river processes like erosion, deposition and overall formation of bedforms.

## 2.2 Biology

Native aquatic species have evolved such that their life history stages have adjusted to the variability and seasonal pattern of natural flow regimes. Hydraulic habitat (flow, depth, velocity, and substrate) is one component of habitat for native aquatic species that is dependent upon the flow regime. Individual species may be adapted to spend all or a majority of their time in a particular hydraulic environment, such as backwaters or riffles. Other species may require a variety of hydraulic habitats for feeding, resting, and reproductive activities. Altered flow regimes can change the availability of important hydraulic habitats for certain species, resulting in shifts in aquatic community composition or diversity. Changes in channel morphology, such as reduced diversity in bed and bank topography, can also limit the availability and diversity of hydraulic habitat.

The streamflow regime, together with channel morphology, largely controls the composition, distribution, and extent of riparian vegetation on streambank and floodplain areas. Individual vegetation types have different inundation tolerances and water requirements. Grasses and other herbaceous species often occupy wet areas close to the channel, while species with lower inundation tolerances occupy higher-elevation surfaces. Because of these flow-specific requirements, changes in flood magnitude, timing, frequency, duration or recession rate all have the potential to compromise the native riparian community. Altered flow regimes may tend to favor nonnative riparian species. Low-flow characteristics are also important for riparian vegetation. The inundation width of the channel during the summer growing season will define the inward lateral extent of riparian vegetation. Vegetation will tend to encroach onto surfaces that remain dry during the growing season. In systems altered by artificially high summertime irrigation flow releases as observed in the lower Colorado River system, the inward extent of vegetation will be limited relative to rivers with naturally lower summertime flows. In systems where summertime base flows are reduced or eliminated by diversions, vegetation will tend to encroach inward into the active channel. If the encroaching vegetation is not scoured away by floods, channel capacity and aquatic habitat will be reduced over time. Therefore, the natural balance of edge vegetation growth and scouring is an important riverine component for many ecological processes.

## 2.3 Geomorphology

The morphology of river-floodplain systems is dynamic. Together with streamflow, the physical channel form provides important hydraulic habitat features such as pools, riffles, and backwaters. Geomorphic variables including channel width, depth, bed material characteristics, plan form, and slope are all potentially adjustable. They are controlled by the influx of water and sediment against the backdrop of a particular geologic/physiographic setting. Classic geomorphic theory suggests that streams tend toward a state of "dynamic equilibrium" in which channel size, shape, and slope adjust over a period of time to the dominant sediment and flow regime (Mackin 1948, Leopold et al. 1964). In a stream that is in equilibrium, features such as pools that are lost due to in-filling tend to be replaced by new pool features created by scour elsewhere in the system. Over time, the distribution of habitat features in an equilibrium channel is maintained.

When streamflow or sediment supply is changed by dams, diversions, or other alterations, channel equilibrium may be disturbed. A channel may begin to downcut, aggrade, or widen as it responds to changes in the flow and/or sediment regime (Williams and Wolman 1984, Schumm 1969). If an instream flow recommendation is developed based on an analysis of existing hydraulic habitat in a rapidly widening or incising river, habitat will not be effectively protected over the long term. Therefore, geomorphic trends in the lower Colorado River were considered when developing the instream flow guidelines.

Channel morphology and processes are a function of a wide spectrum of different flow regime parameters. Much attention is paid to the "bankfull channel", which empirical research has found to correspond to discharges with recurrence intervals between 1.2 and 4 years (Leopold et al. 1964). These moderate-magnitude bankfull floods are effective at flushing accumulated fine sediments from gravels, scouring pools, building riffles, removing vegetation from active channel areas, inundating bars, and maintaining channel capacity. Bankfull discharge has also been found to correspond to effective discharge, which is the flow that transports the largest amount of sediment when averaged over a long period of time (Wolman and Miller 1960, Andrews 1980, Leopold 1992, Andrews 1994).

Less frequent, higher magnitude floods that overtop the streambanks also perform important geomorphic functions. Overbank floods can create new side channels, form or erode islands, build log jams, cut off meander bends, and deposit fresh sediment and viable seeds on the floodplain. These processes maintain channel complexity and habitat diversity, as well as provide the disturbance needed for recruitment of certain riparian plants.

## 2.4 Water Quality

Streamflow directly influences water quality parameters including temperature, sediment and nutrient concentrations, dissolved oxygen, and pollutant concentrations. Dams and diversions that impound water and/or alter downstream flow release volumes can significantly alter water quality conditions, especially when point and non-point sources of pollution occur in downstream waters. Flow regime alterations that increase bank erosion rates can adversely affect water quality by increasing inputs of fine sediments and attached nutrients and contaminants. In general, water quality is a sensitive riverine component that responds to changes in land use, groundwater recharge, and channel morphology as well as instream flows.

# 3.0 STUDY PROGRESS AND RESULTS

Intensive data collection activities associated with the key study components were completed in 2004-2006 at the sites depicted in Figure 3.1. Detailed hydraulic and biological (aquatic and riparian) information was collected at each of the ten sites (BIO-WEST 2005). Geomorphologic data were collected at the La Grange and Columbus study sites as well as at the United States Geological Survey (USGS) gage locations at La Grange and Columbus. Water quality information from the entire lower Colorado River was provided by the LSWP Water Quality team and included in the analysis with segment designations corresponding to those used by that study team.

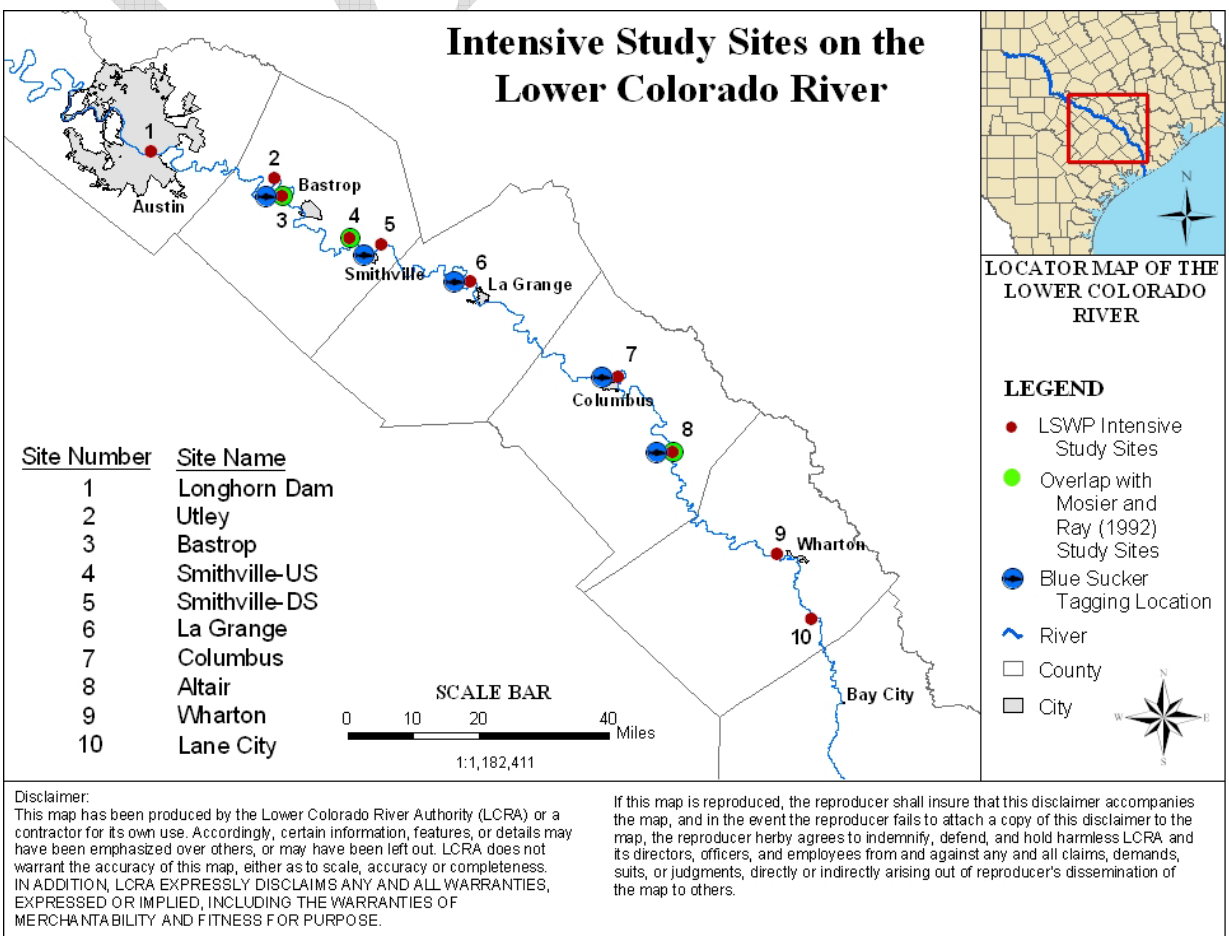


**Figure 3.1.** LSWP Intensive Study Sites

## 3.1 Hydrology and Hydraulics

### 3.1.1 Hydrology

Mosier and Ray (1992) provide a comprehensive overview of the major hydrological changes experienced on the lower Colorado River over the past century. For this study, additional detailed hydrologic evaluation of the historical flows in the Colorado River was conducted to

aid in the development of instream flow guidelines. Statistical time-series software was used to assess current and pre-1940 (pre-Highland Lakes) conditions, quantify alteration of the quantity and timing of flows, and characterize the physical behavior of water in the system at an ecologically relevant scale. Although flows in the Colorado River downstream of Austin have been impacted by human activity for more than 100 years and there are currently diversions, return flows and low water dams, the major alteration to the natural flow regime occurred with the completion of Buchanan and Mansfield Dams (1937 and 1940, respectively) (Figure 3.2).

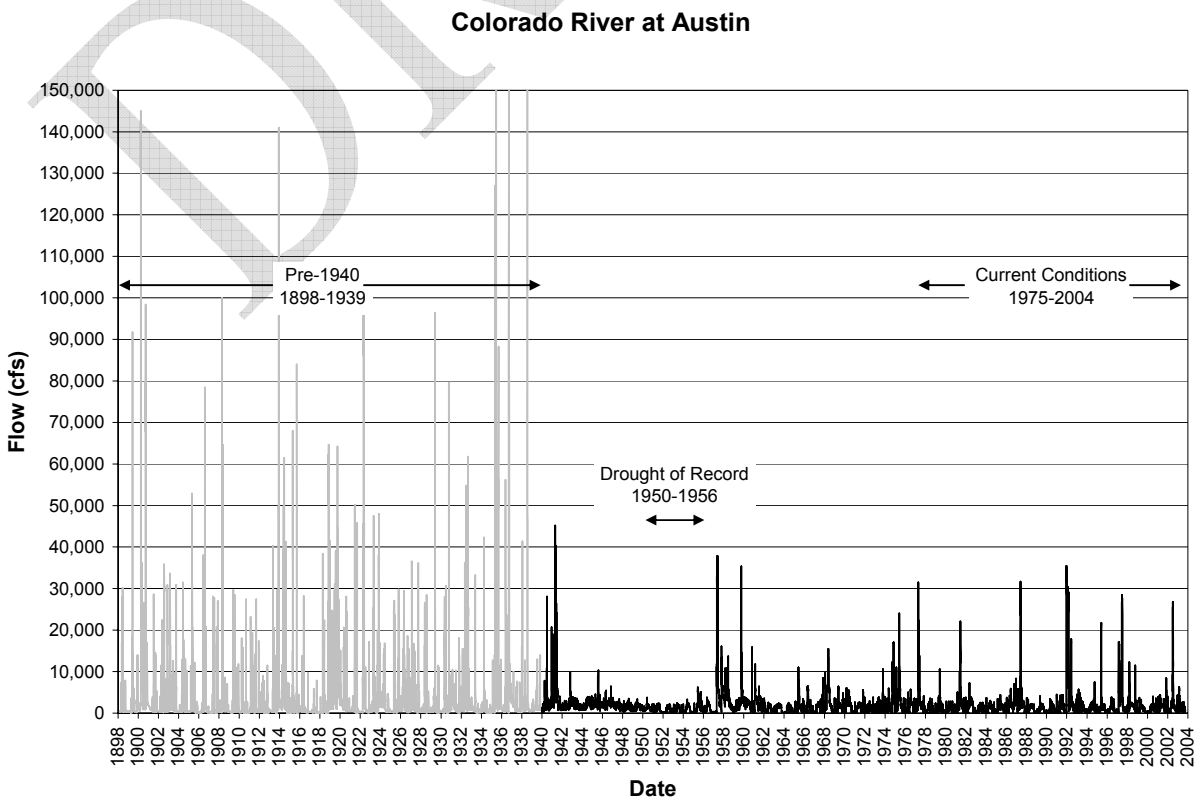


**Figure 3.2.** Lower Colorado River hydrograph (1898 to 2004).

For this analysis, the pre-1940 time period is used to represent "natural" conditions. Current (or "existing") conditions were evaluated using the 1975-2004 time period, since this time period is being used by the LSWP Surface Water Availability Team to determine interim instream flow requirements based on the Lyon's method.

Neither the pre-1940 nor the current period includes the 1950-1956 drought of record. Flow in the lower Colorado River during the drought of record was reflective of the flow management that occurred downstream of recent, major development projects (Buchanan and Mansfield Dams); therefore, the Austin and Columbus historical records of daily flow during that period were not useful for developing instream flow recommendations. Although winter flows in the lower reaches were lower during the drought than in the pre-1940 and current time periods, summer base flows during the drought were higher than pre-1940 conditions due to releases for downstream uses. Therefore, based on available data, the operations of the system during the drought, and the approach taken in this report to develop instream flow recommendations, the

drought of record was not included in flow guidelines development because it was not characterized by a daily flow regime that was either representative or extreme.

Figure 3.3 depicts a typical example of changes in the flow regime at Austin for pre-1940 and existing hydrographs using two years which had similar total annual flows. Differences in precipitation patterns aside, summer flows are elevated (irrigation releases) and winter flows somewhat depressed (recapturing storage) in the existing hydrograph relative to pre-1940 conditions.

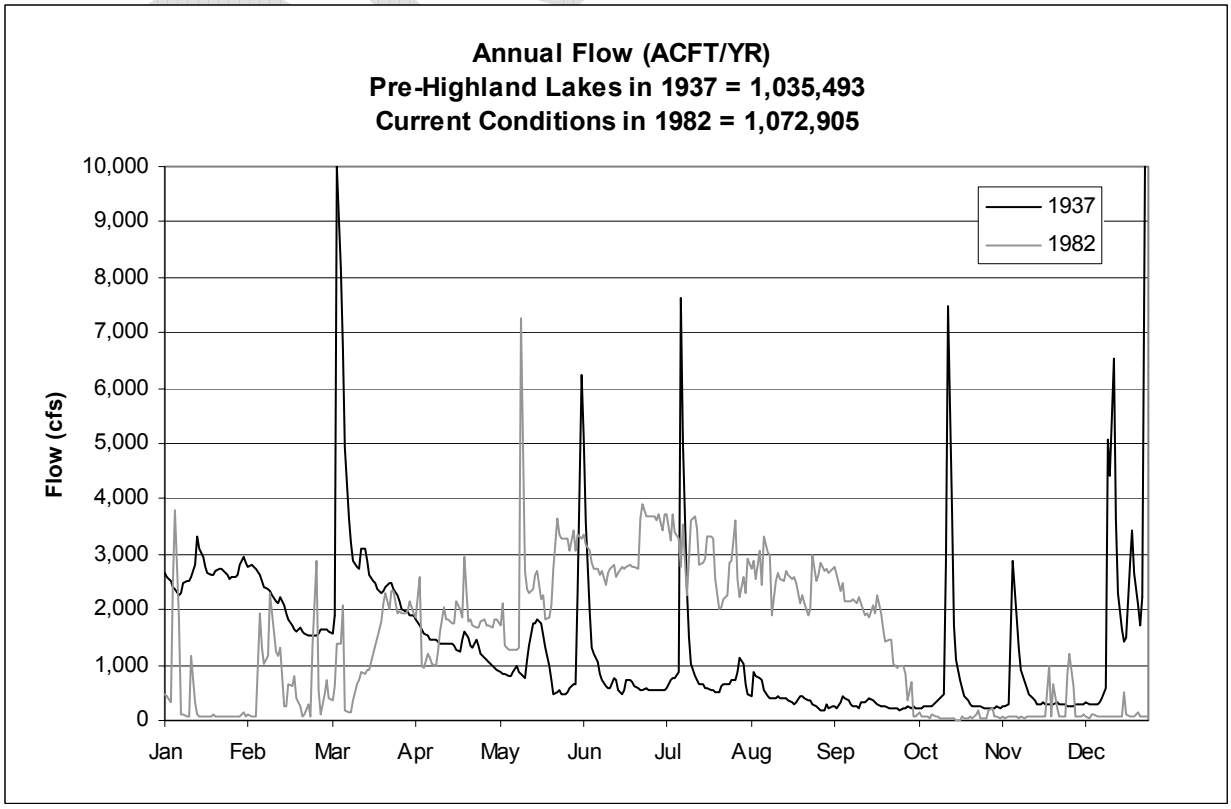


**Figure 3.3.** Pre-1940 and existing hydrographs for years which had similar total annual flows.

There are two USGS gages on the river with daily flow records that include data prior to 1940; 08158000 Colorado River at Austin (since 1898) and 08161000 Colorado River at Columbus (since 1916). The TIFP recommend using naturalized flows developed for the state's Water Availability Model (WAM) to characterize natural flow conditions. This analysis has not been performed as part of the present study for two reasons. First, because the long records of the Austin and Columbus gages can be used as an alternative to characterize the "natural" flow regime. Secondly, because a reference gage with records of an unmanaged period concurrent with the naturalized flow dataset (needed to confidently convert the monthly flows from the WAM to daily flows) is not available for this river segment downstream of Austin.

The Indicators of Hydrologic Alteration (IHA) software package was used to characterize changes in the flow regime at the Austin and Columbus gages. Range of Variability Analysis (RVA) (Richter et. al., 1997) indicates that flow conditions have been altered most in the summer (July and August), with existing conditions exhibiting higher flows than would have occurred

naturally. Alteration is exhibited to a lesser extent in the fall, with November flows somewhat lower than would have occurred naturally (Figure 3.4).

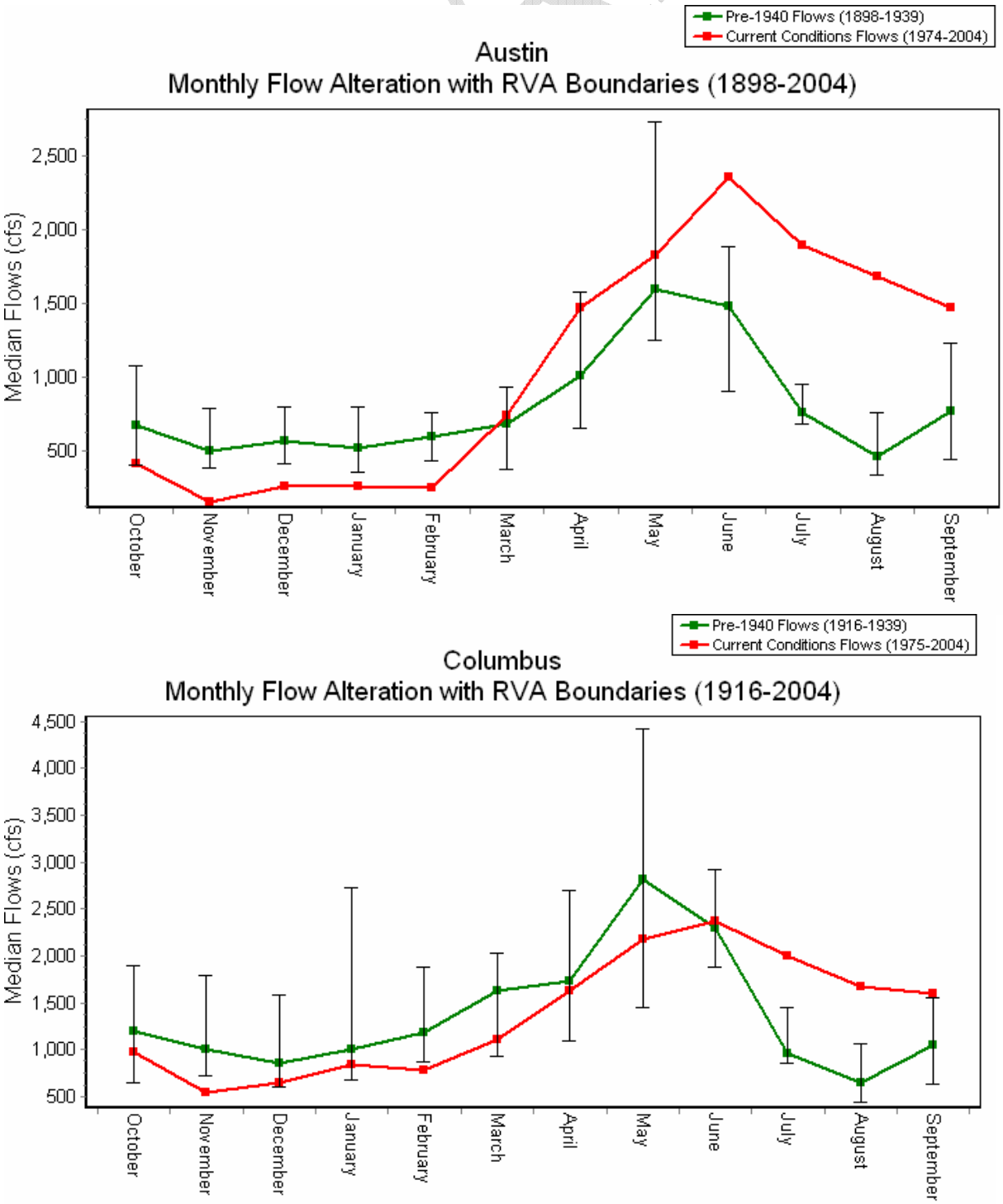


**Figure 3.4.** Pre-1940 versus existing comparison of median flows (range includes 25th and 75th percentiles).

The changes in the median durations and frequencies of extreme events have been most substantial at the higher flows. High flow magnitudes, at all durations evaluated by the IHA software, are now much lower than would have occurred naturally. This is to be expected since one of the purposes of the Highland Lakes is to provide flood control.

### 3.2.1 Hydraulics

As outlined in the 2005 activities report (BIO-WEST 2005), the hydraulic model utilized for this project is River2D, a two-dimensional, depth-averaged, finite element, hydrodynamic code developed at the University of Alberta (Steffler and Blackburn 2002). River 2D predicts water depth and velocity based upon observed inputs including flow rate, elevation and bathymetry data. Recent projects using River2D for aquatic habitat modeling include the Green and Yampa Rivers (Bowen et al. 2001), the Yellowstone River (Bowen et al. 2003), Canadian prairie rivers (Katapodis 2003) and the Columbia River (Hanrahan et al. 2004); River2D is also reported to work well for stream restoration design (Schwartz 2003).

Work completed for this project in 2006 consisted of mesh refinement, application of substrate roughness, and calibration and validation of model output at all ten sites. Hydraulic model output was used to determine area of available habitat (see Section 4.0) for a range of flows between 150 cubic feet per second (cfs) and 8,000 cfs (Table 3.1).

**Table 3.1** Modeled flow rates

| Modeled flow rates (cfs) | | | | |
|---|---|---|---|---|
| 150 | 750 | 1,500 | 2,500 | 5,000 |
| 300 | 1,000 | 1,750 | 3,000 | 7,000 |
| 500 | 1,250 | 2,000 | 4,000 | 8,000 |

Model calibration was completed for at least three flow rates at each site, where one model fell generally within the range of the left column of Table 3.1, one within the center column, and one within the right column. At some sites one additional model was calibrated where field data were available. To model additional intermediate flow rates, rating curves relating flow rate to water surface elevation were developed at each site to determine boundary conditions.

A uniform, triangular, finite element mesh with 3-meter spacing between nodes (vertices) was used at each site (Figure 3.5). This node spacing allowed identification of habitat patches with surface areas as small as eight square meters. The model mesh extended both upstream and downstream of site boundaries to ensure depth and velocity fields within the area of interest were not influenced by spurious numerical effects that have potential to occur near the model edges. At each site, the same geometric mesh was used for all modeled flow rates; adjustments made at a particular steady-state flow rate were carried through to each of the other flow rates at the same site.

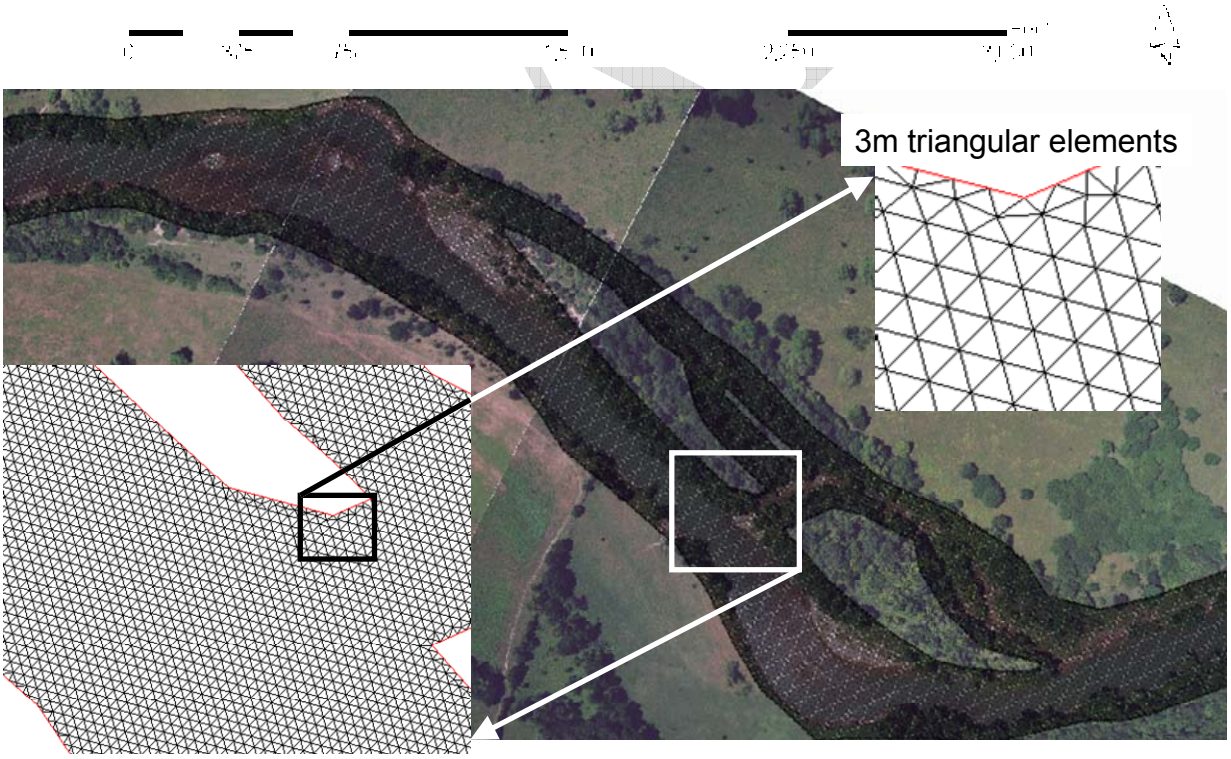


**Figure 3.5** River2D model mesh with 3-meter triangular elements, Utley site (Site 2)

Calibration proceeded by adjusting model inputs so model predictions tracked field observations. Roughness, bathymetry and the downstream water surface elevation boundary condition were the three primary model inputs used as mechanisms of calibration. Spatially-varying roughness, input at each model node, was based upon substrate mapping and pebble counts. A Chezy roughness height equivalent to the maximum diameter of each size class was applied; however, a multiplier was applied to each size class during calibration. While roughness differed at each site, roughness magnitude generally ranged from 0.004 meters (for silt), 0.06 meters for sand, and up to 1.0 meters for boulders and vegetated areas.

Water surface elevation was the primary indicator used for calibration; point measurements of depth and velocity were supplementary. Adjustments to model inputs were made until model predictions for water surface elevation matched field data near the downstream benchmark, near the upstream benchmark, and at intermediate locations where field data were available. Predicted depth and velocity were matched as nearly as possible at discrete points where observations were available. Areas with rock outcrops or ridges forming water surface steps were incorporated, predicted flow rate in secondary channels was matched to observations, and bathymetric complexities were incorporated to match observed water surface profiles.

For most models the predicted water surface elevation profile matched observations within 2" (5 cm) and many models matched observations within 3/4" (2 cm). No calibrated model predicted water surface elevation more than 4" (10 cm) higher or lower than field observations. Half of the depth and velocity field measurements were used for calibration as described above; the remaining half were compared to predictions made by calibrated models to assess accuracy.

Additional validation measures include water surface elevation measurements at upstream and mid-reach locations, as well as field maps of water edge. Comparison of calibrated model predictions to validation data for the Utley site at 407 cfs (11.52 cms) and 1,930 cfs (54.65 cms) is shown in Figures 3.6-3.9.

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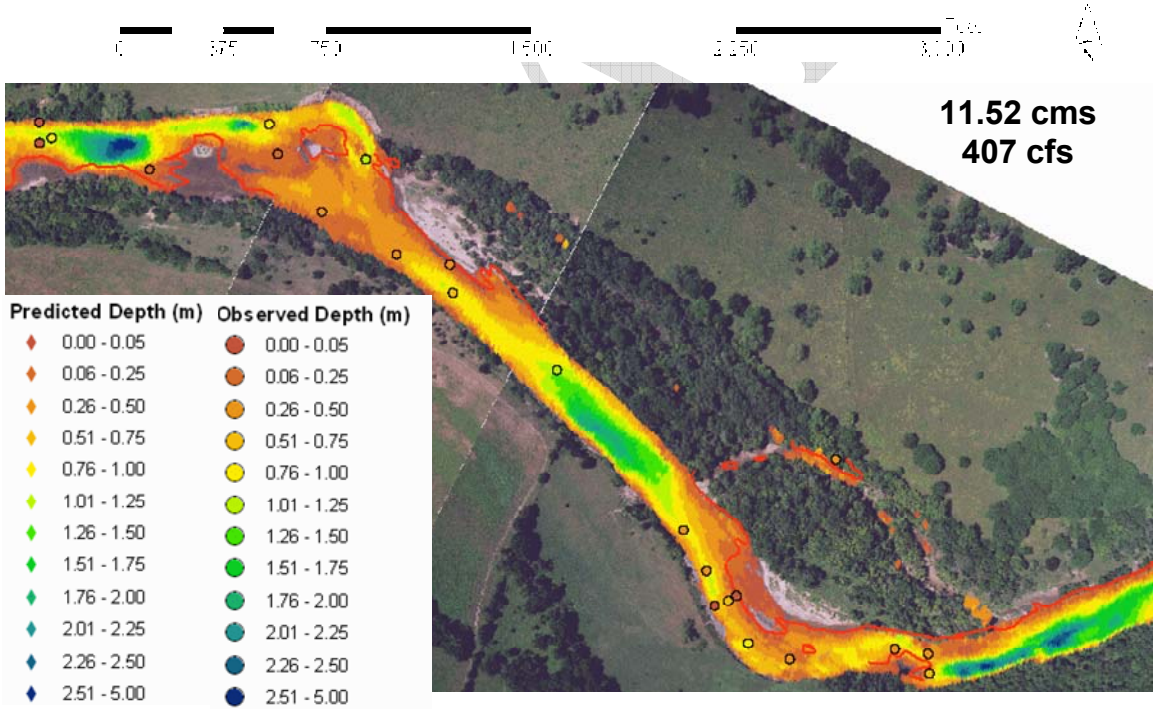


**Figure 3.6** Utley, 407 cfs (11.52 cms) depth validation

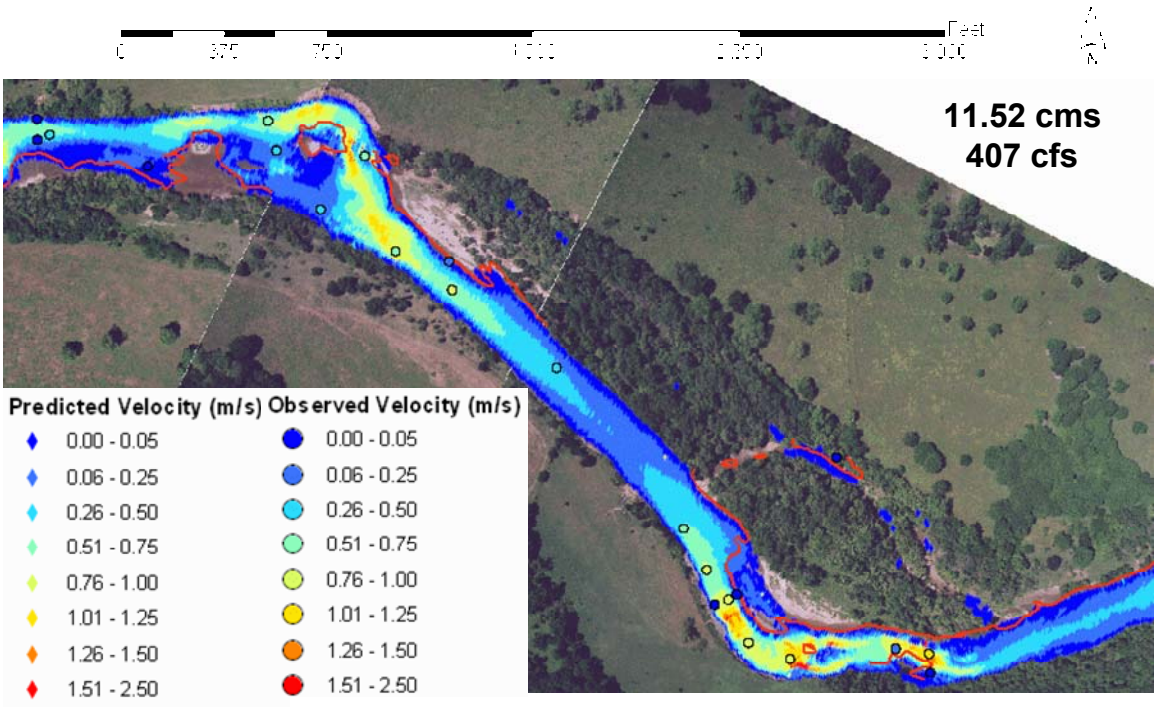


**Figure 3.7** Utley, 407 cfs (11.52 cms) velocity validation

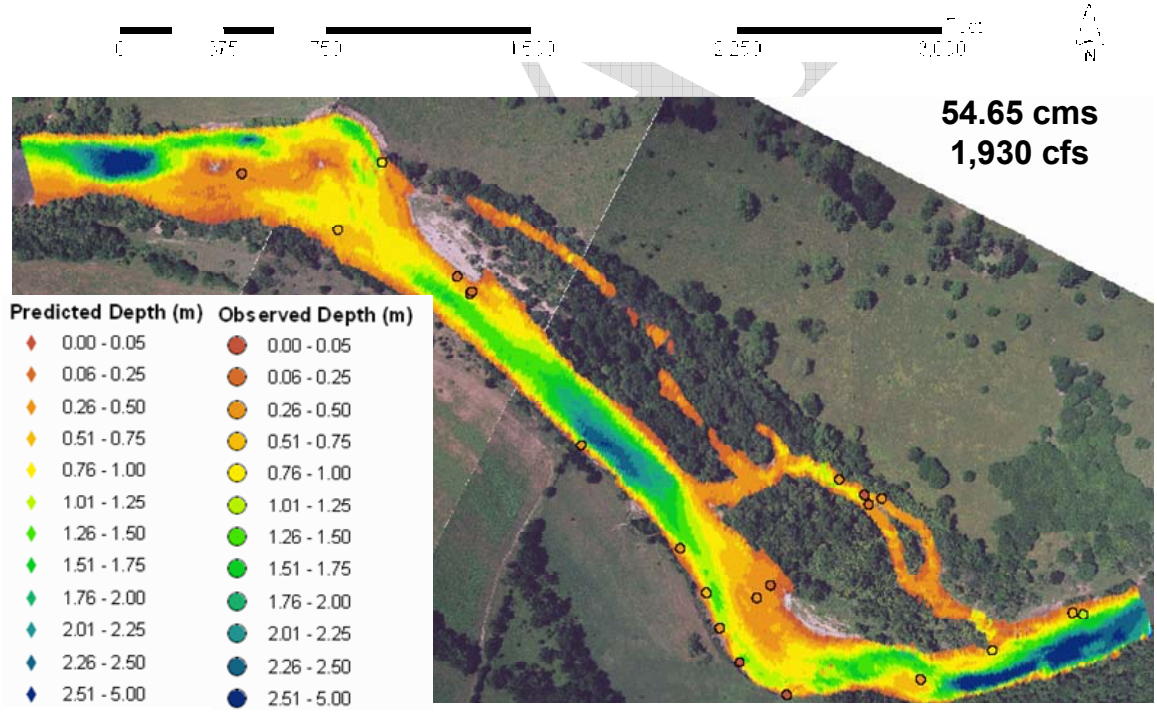


**Figure 3.8** Utley, 1,930 cfs (54.64 cms) depth validation

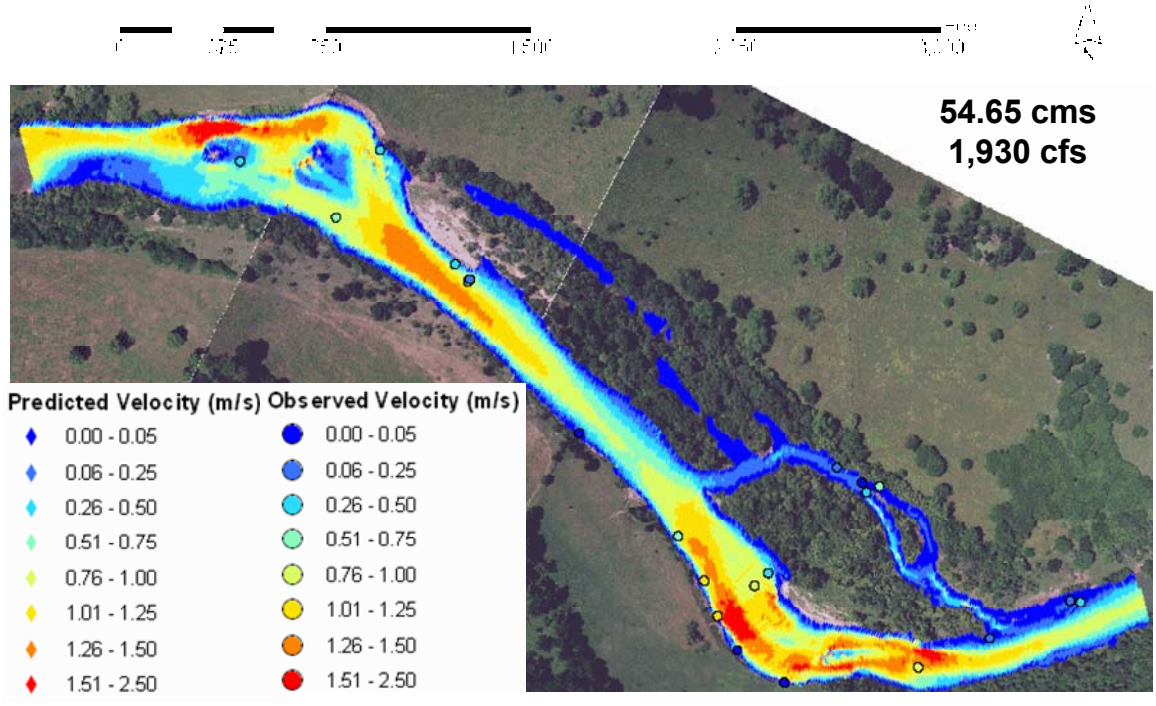


**Figure 3.9** Utley, 1,930 cfs (54.65 cms) velocity validation

## 3.2 Biology

### 3.2.1 Aquatic Habitat

Habitat use data were collected in 2004-2006 using various fish sampling techniques including seining, backpack electrofishing, barge electrofishing, and boat electrofishing to provide effective coverage of a wide range of habitats. Often, a barge-mounted electrofisher with a hand-held wand was used to stun fishes in the sample area into a seine set at the downstream boundary of the sample area. An attempt was made to sample fish from relatively small areas of approximately 3 meters x 3 meters with consistent depths, velocities, and substrates; however, exact size and dimensions were sometimes changed to facilitate sampling larger areas of relatively uniform habitat when fish densities were low. Once captured, fish were identified to species, counted, and released. Life stage (i.e., juvenile or adult) was determined based on size classifications used by Mosier and Ray (1992) for those species in which there was previous evidence of substantial ontogenetic changes in habitat use. Upon completion of fish sampling, velocity, depth, and substrate were characterized at five points representing each corner and the middle of the sampled area. Velocity and depth were measured using a Marsh-McBirney Flowmate Model 2000 portable flow meter and incremental wading rod. Dominant and subdominant substrates were classified as silt, sand, gravel, cobble, boulder, or bedrock following the standard Wentworth scale based on particle size.

During the study period, over 13,000 fish representing 15 families and 50 species were collected from various habitats of the lower Colorado River from Longhorn Dam to Wharton. Data was collected at discharges ranging from 188 to 2,030 cfs which includes much higher discharges than previously sampled by Mosier and Ray; however, these discharges are still within effective sampling conditions. Approximately 2/3 of the biological data was used for habitat guild and suitability criteria development, with the remaining 1/3 being used for biological validation. As noted above, warmwater rivers such as the lower Colorado River maintain high species richness, and therefore, limiting habitat information to only one or two species limits the usefulness of model output. In certain cases, flows thought to protect the integrity of the river based on few or individual species needs may actually be detrimental (Bain et al. 1988, Lobb and Orth 1991; Aadland 1993). Therefore, a habitat guild approach was taken in this study as a way to better represent the habitat needs of the lower Colorado River aquatic community. A habitat guild is defined as a group of species that use the same habitat types (Austen et al. 1994).

To create the habitat guilds, habitat conditions were characterized for each sample site (N=153) by averaging depth and velocity data at five individual points and converting substrate types into percent coverage within the sample site. Habitat data along with sample reach (i.e., Bastrop, Columbus, etc.) and abundance data from 29 ecological units (species or particular life stages of species) were then summarized in a Canonical Correspondence Analysis (CCA) (Figure 3.10). Ecological units with a sample size of less than 15 individuals were not included in the analysis. Since sample reach did not explain a significant portion of the variation in abundance of ecological units, it was excluded from further analysis. Based on the resulting CCA ordination plot, the 29 ecological units were grouped into five habitat guilds which were generally similar to those established by Mosier and Ray (1992). The project team did not lump the Mosier and Ray (1992) data into our analysis. Instead, the Mosier and Ray information was used as an independent check on our 2004-2006 sampling. The project team also met with Mr. Doyle Mosier (TPWD) to discuss sampling methods, flow ranges sampled, and results. Mr.

Mosier was pleased with the recent sampling in a wider range of flows and with the assignment of species into habitat guilds.

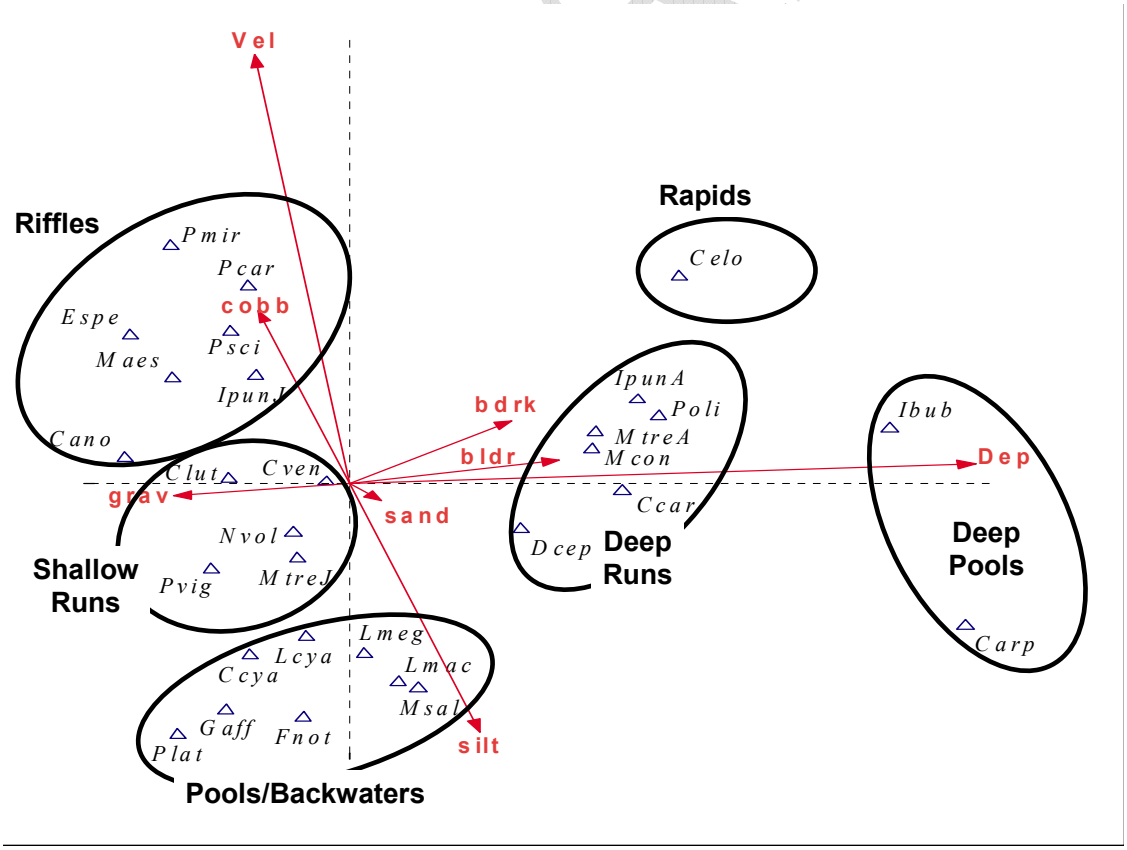


**Figure 3.10.** Multivariate ordination plot showing species associations among depth, velocity, and substrate gradients. Black circles designate habitat guilds.

As evident in Figure 3.10, occasionally species were located in close proximity to potential habitat guild boundaries. In these instances, life history information for those species was used to aid in final habitat guild assignment. Brief life history descriptions and observations specific to the lower Colorado River for each species used in the habitat modeling are provided in Appendix A. The species and number of fish collected in each of the defined habitat guilds are presented in Table 3.2.

**Table 3.2.** Habitat Guilds and blue sucker life stage categories derived from depth, velocity, and substrate use, as well as supplemental radio telemetry and spawning survey study results.

| Habitat Guild | Species/Life Stages | Number Collected |
|---|---|---|
| **Riffles** | *Percina sciera* | 121 |
| | *Percina carbonaria* | 95 |
| | *Ictalurus punctatus* (<180 mm) | 640 |
| | *Phenacobius mirabilis* | 65 |
| | *Etheostoma spectabile* | 27 |
| | *Campostoma anomalum* | 30 |
| | *Macrhybopsis spp.* | 280 |
| **Shallow Runs** | *Cyprinella lutrensis* | 1989 |
| | *Cyprinella venusta* | 1305 |
| | *Pimephales vigilax* | 698 |
| | *Notropis volucellus* | 516 |
| | *Micropterus treculii* (<170 mm) | 91 |
| **Deep Runs** | *Pylodictis olivaris* | 107 |
| | *Ictalurus punctatus* (>180 mm) | 71 |
| | *Moxostoma congestum* | 131 |
| | *Micropterus treculii* (>170 mm) | 23 |
| | *Carpiodes carpio* | 215 |
| | *Dorosoma cepedianum* | 451 |
| **Shallow Pools / Edge / Backwaters** | *Micropterus salmoides* | 19 |
| | *Lepomis megalotis* | 490 |
| | *Lepomis macrochirus* | 115 |
| | *Lepomis cyanellus* | 29 |
| | *Cichlasoma cyanoguttatum* | 45 |
| | *Gambusia affinis* | 92 |
| | *Poecilia latipinna* | 33 |
| | *Fundulus notatus* | 15 |
| **Deep Pools** | *Ictiobus bubalus* | 16 |
| | *Cyprinus carpio* | 18 |
| **Blue Sucker Life Stages** | | |
| **Adult blue suckers / Rapids** | *Cycleptus elongatus* | 82* |
| **Spawning blue suckers** | *Cycleptus elongatus* | ** |

*Data collected during fish sampling was supplemented with habitat data from the radio telemetry portion of the study.

**Habitat data collected at four confirmed spawning locations was used in constructing the spawning blue sucker habitat category.

For each habitat guild, suitability criteria for the continuous variables depth and velocity were created using nonparametric tolerance limits (NPTL) (Bovee 1986). The habitat criteria curves developed were based on the NPTL for the central 50%, 75%, 90% and 95% of the data. The NPTL were taken or interpolated from Somerville (1958) with a confidence level of 0.9. The tolerance limits for the central 50% were used as cutoffs for the most selected habitat and the range of data between these two points was given a suitability value of one. The tolerance limits for the central 75% were used to establish the range of data with a suitability value of 0.5. The tolerance limits for the central 90% were used establish a suitability value of 0.2, and the data between the 95% tolerance limits was given a suitability value of 0.1. The range of data beyond the central 95% tolerance limit was given a value of zero and considered unsuitable. Criteria for the categorical data substrate were fitted using normalized frequencies.

Suitability criteria for all habitat guilds are presented in Appendix B. For a specific example, all habitat suitability criteria developed for the Riffle habitat guild are presented in Figures 3.11-3.13. To supplement the habitat guild approach, life-history information gathered for blue suckers was also used to develop specific habitat suitability criteria for adult and spawning habitat. Adult habitat data from the radio telemetry study was combined with biological collection data to develop the adult blue sucker habitat suitability curve. Based on the habitat guild analysis, adult blue suckers fell into a monospecific group labeled 'Rapids". Therefore, this category will be referenced as adult blue sucker / rapids for this report. Finally, the habitat data collected in 2005 and 2006 at four locations with confirmed blue sucker spawning were used to create habitat suitability criteria specifically for spawning blue suckers. The habitat suitability criteria developed for the spawning blue sucker habitat category is presented in Figures 3.14-3.16 with adult blue sucker/rapids suitability criteria included in Appendix B.

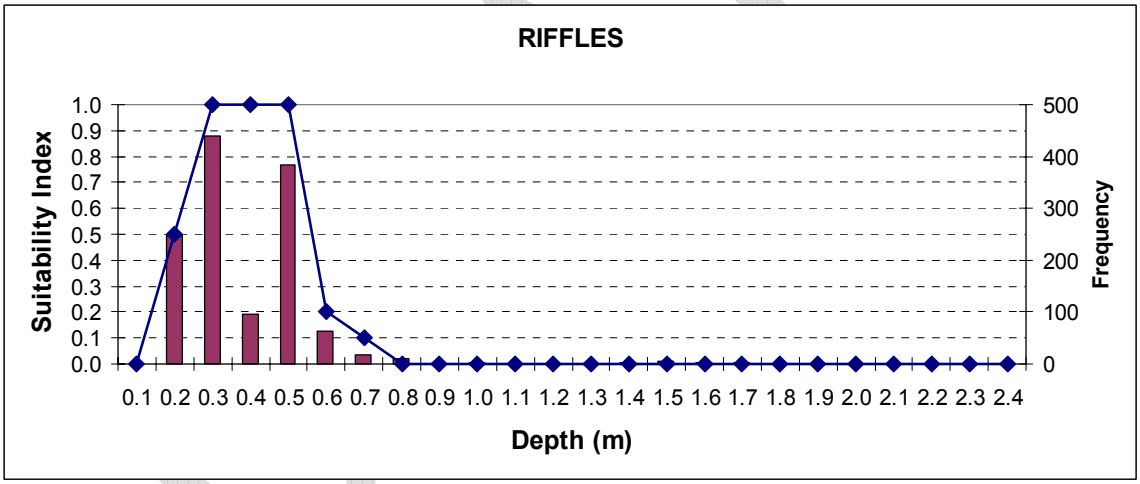


**Figure 3.11** Frequency distribution and HSC values for Riffles Habitat Guild for depth in the lower Colorado River.

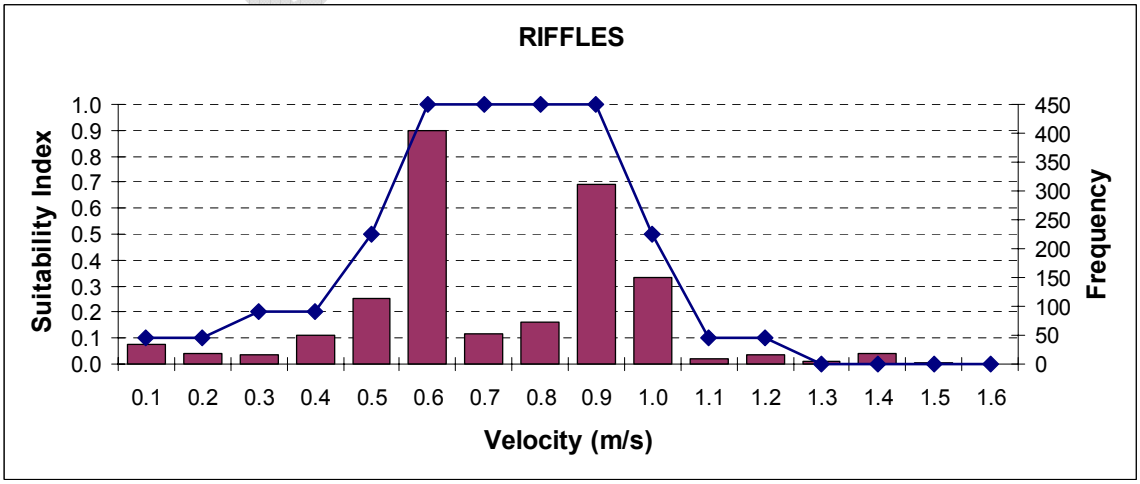


**Figure 3.12** Frequency distribution and HSC values for Riffles Habitat Guild for velocity in the lower Colorado River.

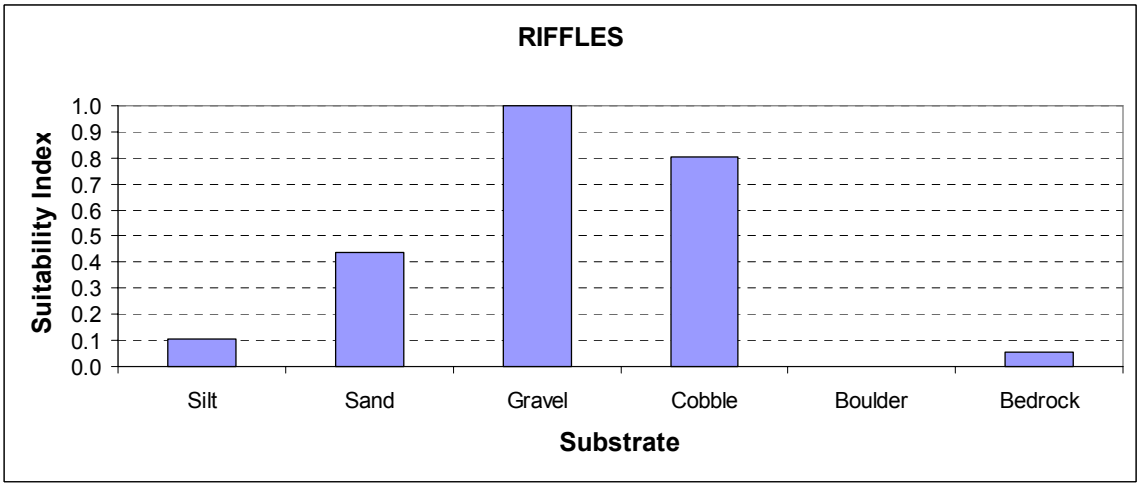


**Figure 3.13** Frequency distribution and HSC values for Riffles Habitat Guild for substrate in the lower Colorado River.

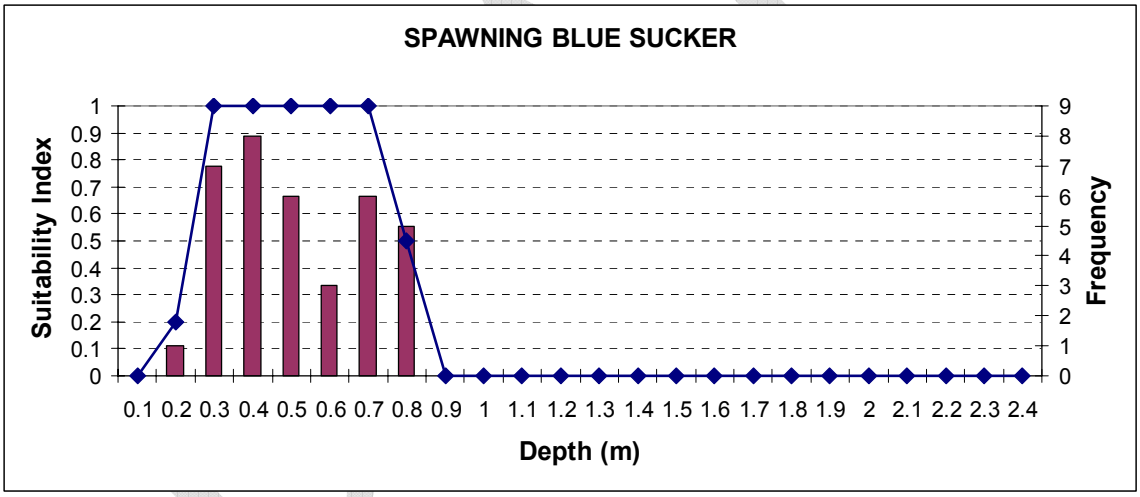


**Figure 3.14** Frequency distribution and HSC values for Spawning Blue Sucker for depth in the lower Colorado River.

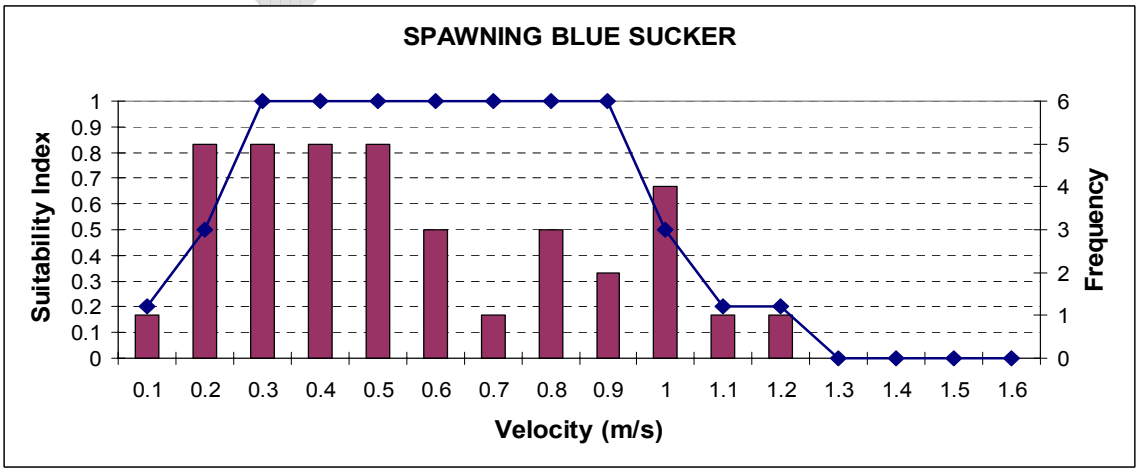


**Figure 3.15** Frequency distribution and HSC values for Spawning Blue Sucker for velocity in the lower Colorado River.

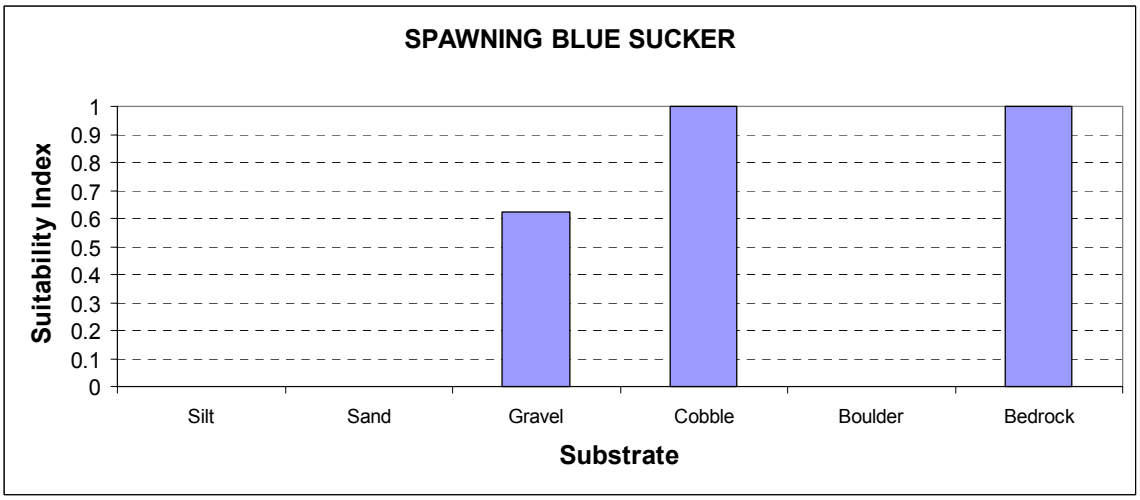


**Figure 3.16** Frequency distribution and HSC values for Spawning Blue Sucker for substrate in the lower Colorado River.

Using the seven habitat categories (5 habitat guilds and 2 blue sucker life stages), the majority of the habitat types found in the lower Colorado River are represented. The one habitat type that is not represented is deep, extremely fast water. As shown in the habitat suitability curves in Appendix B, no depth is too deep for the deep run or deep pool habitat guilds (Appendix B, Figures B7 and B13) but there is a limit on velocity (Appendix B, Figures B8 and B14). No aquatic species were collected in this deep, extremely fast habitat type and therefore it was not deemed relevant for the aquatic habitat modeling portion of the study. The substrate criteria documents that the river is gravel dominated but the secondary substrates differ per habitat guild (i.e. higher silt and sand in shallow pools/edge/backwaters habitat guild [Appendix B, Figure B12].

### 3.2.2 Riparian Habitat

Detailed riparian baseline conditions were described within each of the ten intensive sites in the 2005 Activities Report (BIO-WEST 2005). Land use changes have had a strong influence on changes that have occurred in the riparian zone, with many areas being plowed for agriculture up to the river shoreline and other areas impacted by activities such as gravel mining. In addition, streamflow conditions within the lower Colorado River have been altered over the period of record, which has influenced characteristics of the riparian vegetation. The Highland Lakes have dampened the high magnitude, overbank floods that were prevalent during pre-1940 conditions, thus potentially limiting the outward lateral extent of riparian vegetation along the river corridor. However, the lateral extent of riparian vegetation is likely less influenced by water availability from the river in this region than the impacts associated with land use changes. Although the frequency of high magnitude flood events has been reduced, short-term hydrologic variability in areas near Austin has increased within the range of managed flow conditions because of hydropower peaking releases. Irrigation releases have resulted in higher-than-natural flows during the summer season and may have prevented normal inward migration of vegetation into the channel, and the associated stabilizing influence of such conditions.

As a result of land use practices and the altered hydraulic conditions since the completion of the Highland Lakes, the current riparian zone along the lower Colorado River consists of multiple terraces with varying degrees of connectivity to the river channel. The highest terrace (a part of the floodplain) has been highly altered, and the frequency of connectivity from the river channel has been greatly reduced by the man-made influences described above. Connectivity to the floodplain requires overbank flows that are controlled by climatic variability and are outside the influence of lower Colorado River operations. The lower terraces that support an active riparian zone are influenced by the hydrologic regime and geomorphic processes described in section 3.3. Summertime base flows, high flow pulses, and bankfull discharge are controlling the riparian community recruitment and establishment along the active floodplain (lower terraces) of the lower Colorado River.

Because of the importance of the hydrologic and geomorphologic conditions on riparian characteristics and the resources required to develop a suitable riparian zone model, the evaluation of hydrology and geomorphology was used to indirectly evaluate riparian conditions. The detailed riparian assessment documented in BIO-WEST (2005) will serve as a

baseline starting point for long-term monitoring evaluations necessary to evaluate the effectiveness of instream flow guidelines.

## 3.3 Geomorphology

On the lower Colorado River, streamflow and sediment transport dynamics shape and maintain sand and gravel bars, side channels and backwaters, riffle and pool habitats, river banks, and floodplain and terrace features. These geomorphic features provide important habitat for macroinvertebrates, fish, riparian plants, and other associated wildlife species. The flow regime associated with the proposed LSWP project has the potential to change the current timing, magnitude, and particle size distribution of sediment transport in the lower Colorado River. The changes in sediment transport, in turn, would have the potential to alter the geomorphic condition of the river and associated aquatic and riparian habitat.

A geomorphic field reconnaissance (by boat) of the lower Colorado River was conducted in February 2005 (BIO-WEST 2005). From that reconnaissance and subsequent interaction with reviewers, a sediment transport evaluation effort was implemented. The effort focused on completing a thorough geomorphic assessment to appropriately divide the study area into distinct geomorphic reaches and then analyze sediment transport rates and yields at select modeling transects within the intensive study sites and at nearby USGS gages.

Because no bedload data are available for the lower Colorado River and because field collection of bedload samples was beyond the scope of this project, our analysis approach relies on sediment transport modeling. Although reach-scale HEC-RAS hydraulics models have been developed for the lower Colorado River by LCRA, no sediment transport module is currently available for use in conjunction with HEC-RAS. Therefore, we opted to model transport at the four individual transects using the SAMwin Hydraulic Design Package (Thomas et al. 2002). The focus of the analysis was on the La Grange and Columbus river reaches because these reaches provide a diversity of aquatic and riparian habitat and are located immediately upstream from a potential additional instream structure that may be required should Off-Channel Storage Facilities (OCSF) be sited in Colorado County. In addition, both the La Grange and Columbus reaches have active USGS gages with good, consistent flow and discharge measurement records, and few/no changes in location or datum.

Four transects were selected for sediment transport modeling/analysis. The farthest-upstream transect is located at a bedrock riffle in the middle of the La Grange intensive study site (site 6). This transect is located approximately at River Mile 180.9, and will be referred to as "LA Site". The next transect is located at the La Grange USGS gage (gage #08160400) at River Mile 177.9 and the new State Highway 71 bridge crossing. This transect is located in a sand-bedded "run" type habitat, and will be referred to as "LA Gage". Continuing downstream, the third transect is located in a gravel riffle at the downstream end of the Columbus intensive study site (site 7). This transect is located approximately at River Mile 135, and will be referred to as "CO Site". The final transect is located at the Columbus USGS gage (gage #08161000) at River Mile 134 and the U.S. Highway 90 bridge crossing. This transect is located in a sand-bedded "run" type habitat, and will be referred to as "CO Gage".

LA Site

The project team surveyed the LA Site sediment transport modeling transect in Spring 2006 using a total station. A hand-held GPS was used to determine the real-world horizontal coordinates of the transect endpoints. A nearby benchmark established by the project team as part of the intensive study site modeling efforts (MDPIN06) was surveyed to determine the real-world elevation of the modeling transect. Flow at the nearby La Grange USGS gage at the time of the survey was approximately 500 cfs. Water surface elevations at the right and left edges of water as well as an approximate water surface slope were also surveyed.

The LA Site transect is located within a bedrock riffle. Because this bedrock is not mobile and does not characterize the size of sediment moved as bedload, we instead evaluated the size distribution of the material within a gravel bar spanned by the river-right portion of the transect (Figure 3.17). Surface material size distribution was determined by completing a pebble count (Wolman 1954) of 300 rocks on the bar. In addition, bulk sediment samples were collected at two locations on the bar. Separate surface and subsurface samples were collected at each site, for a total of four bulk samples (Figure 3.18). Samples were sieved and weighed at the Utah State University Soils Lab. The composite size distribution of the two subsurface bulk samples was used for sediment transport analysis.

**Figure 3.17** Upstream view from LA Site gravel bar.

**Figure 3.18** View of surface and subsurface material at one of the bulk sample sites on the LA Site gravel bar.

Cross section coordinates were input into the SAMwin hydraulic design package along with slope and roughness information to generate transect hydraulics (width, depth, velocity, shear stress, etc.) at ten flows of interest. Hydraulics were determined for flows between 170 cfs and 80,000 cfs using the "Normal Depth" and "Composite by Conveyance" options within SAMwin. Slope and roughness information were determined based on information from the River 2D model for the La Grange intensive study site and from the LCRA's HEC-RAS model.

Once the LA Site hydraulics were modeled, the SAM.aid tool was used to select sediment transport equations appropriate for use at the site. The Ackers-White and Laursen (Madden) 1985 equations were used to generate transport rating curves in SAMwin. The default values in SAM were used for sediment density and water temperature (60 degrees F). A flow duration curve representing existing hydrologic conditions was developed using daily flows at the Bastrop USGS gage for the time period 1/1/75-9/30/04. This flow duration curve was input into the SAM package to generate sediment yield and effective discharge information under "existing conditions" (Figure 3.19). Data from the La Grange USGS gage were not used because of the short period of record with continuous data (1988-present).

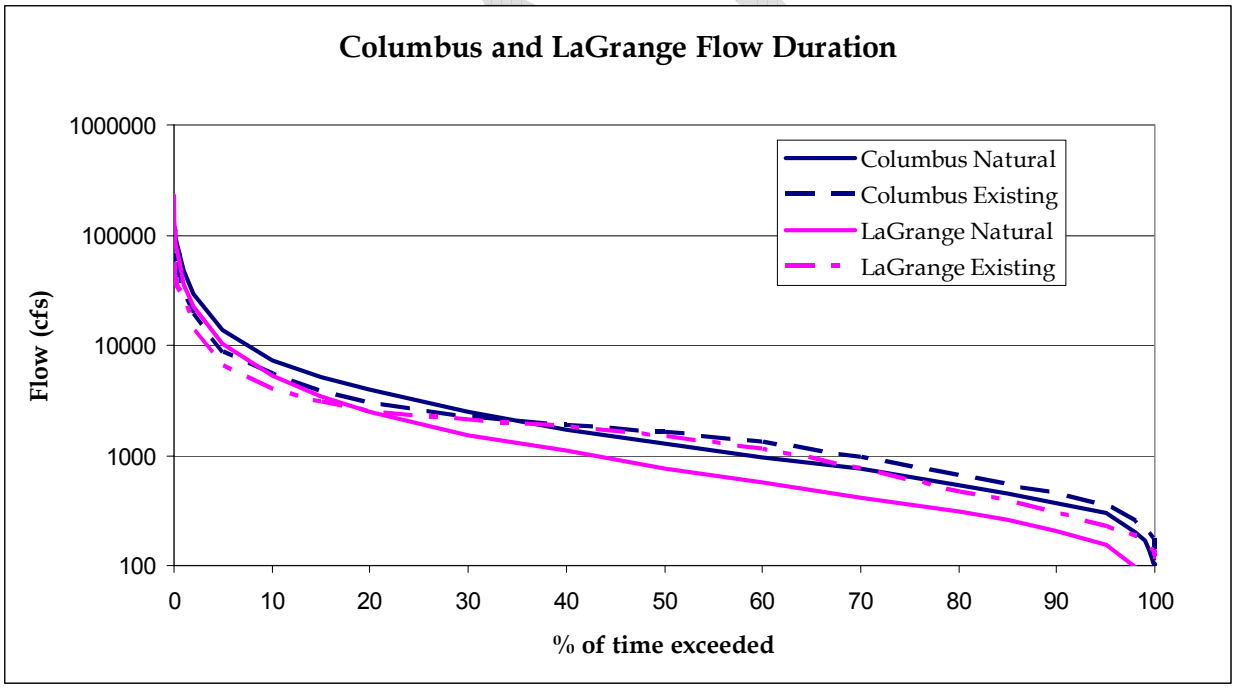


**Figure 3.19.** Flow duration curves used for sediment transport analysis. Data from the Austin and Bastrop USGS gages were used to develop the La Grange curves.

LA Gage

At the LA Gage sediment transport modeling transect, USGS discharge measurement data were used to develop hydraulic information (width, mean depth, velocity) at ten different flows. Slope data were obtained from the LCRA's Columbus Reach HEC-RAS model (which extends upstream to the La Grange USGS gage). The LA Gage transect is located in a sand-bedded, deep run habitat. Therefore, in order to characterize the substrate size distribution, bulk samples were collected from a boat using a pole-mounted sediment dredge sampler. Three evenly spaced samples were collected across the wetted portion of the channel. Samples were sieved and weighed at the Utah State University Soils Lab.

The LA Gage hydraulic data were used as inputs for the SAM.aid tool to select an appropriate set of sediment transport equations for the site. The Ackers-White, Laursen (Copeland), and Engelund-Hansen equations were used to generate transport rating curves in SAMwin. The same flow duration curve used to model sediment yield at the LA Site transect was also used to generate sediment yield and effective discharge information at the LA Gage transect.

CO Site

The project team surveyed the CO Site sediment transport modeling transect in Spring 2006 using a total station. One of the benchmarks established by the project team as part of the intensive study site modeling efforts (DSPIN07) was used as the left transect endpoint, and another established benchmark (MDPIN07) was used as a backsight to determine real-world horizontal and vertical coordinates. Flow at the nearby Columbus USGS gage at the time of the survey was approximately 416 cfs. Water surface elevations at the right and left edges of water were noted during the transect survey.

As with the LA Site, a combination of pebble counts and bulk samples were used to characterize the surface and subsurface particle sizes at the CO Site. A 300-rock pebble count was completed in the gravel riffle located in the central portion of the transect. In this same location, a bulk-sample of the subsurface material was also collected. Bulk samples of surface and sub-surface material were also collected from the sand/gravel bar spanned by the transect (Figure 3.20). Samples were sieved and weighed at the Utah State University Soils Lab. The composite size distribution of the two subsurface samples was used for sediment transport analysis.

**Figure 3.20** View of surface and subsurface material at the bulk sample site on the CO Site bar.

Cross section coordinates were input into the SAMwin hydraulic design package along with slope and roughness information to generate transect hydraulics (width, depth, velocity, shear stress, etc.) at ten flows of interest. Hydraulics were determined for flows between 250 cfs and 69,000 cfs. Slope and roughness information were determined based on information from the River 2D model for the Columbus intensive study site and from the LCRA's HEC-RAS model.

Once the CO Site hydraulics were modeled, the SAM.aid tool was used to select sediment transport equations appropriate for use at the site. The Ackers-White, Laursen (Madden) 1985, Laursen (Copeland), and Engelund-Hansen equations were used to generate transport rating curves in SAMwin. A flow duration curve developed using daily flows at the Columbus USGS gage for the time period 1/1/1975-9/30/2004 was input into the SAM package to generate sediment yield and effective discharge information under existing conditions (Figure 3.19).

CO Gage

At the CO Gage sediment transport modeling transect, USGS discharge measurement data were used to develop hydraulic information (width, mean depth, velocity) at ten different flows. Slope data were obtained from the LCRA's Garwood Reach HEC-RAS model (which extends upstream to the Columbus USGS gage). The CO Gage transect is located in a deep, sand-bedded run/pool habitat. Bulk substrate samples were collected at three points distributed across the wetted portion of the channel along the transect. Samples were sieved and weighed at the Utah State University Soils Lab. The composite size distribution of the three samples was used for preliminary sediment transport analysis.

The CO Gage hydraulic data were used as inputs for the SAM.aid tool to select an appropriate set of sediment transport equations for the site. The Ackers-White, Laursen (Copeland), and Engelund-Hansen equations were used to generate transport rating curves in SAMwin. The same flow duration curve used to model sediment yield at the CO Site transect was also used to generate sediment yield and effective discharge information at the CO Gage transect (Figure 3.19).

### 3.3.1 Hydraulics and Sediment Size

Hydraulic and sediment size characteristics are summarized in Table 3.3 for the 30,000 cfs discharge level. The LA Site is the steepest, shallowest and coarsest transect analyzed. The LA Gage and CO Gage transects are fairly similar hydraulically, and are much flatter and finer-grained than the LA Site. The CO Site is intermediate between the LA Site and the Gage sites.

**Table 3.3.** Comparison of particle size and hydraulic characteristics at the four sediment modeling transects.

| Transect | Median (D50) particle size (mm) | Hydraulic Characteristics at 30,000 cfs | | | |
|---|---|---|---|---|---|
| | | Velocity (ft/s) | Mean Depth (ft) | Top Width (ft) | Slope (ft/ft) |
| LA Site | 38 (surface)<br>20 (subsurface) | 5.20 | 13.36 | 432 | 0.0008 |
| LA Gage | 0.5 | 4.37 | 17.8 | 386 | 0.00024 |
| CO Site | 3 (surface at bar)<br>23 (surface in channel)<br>0.8 (subsurface) | 3.74 | 15.6 | 513 | 0.0004 |
| CO Gage | 0.35 | 4.00 | 17.2 | 432 | 0.00017 |

### 3.3.2 Sediment Rating Curves

Rating curves for total sediment load at the four analysis transects are shown in Figures 3.21-3.24. Although the curves vary depending on the transport equation used, several trends are apparent when the results from a single equation (Ackers-White) are compared among the transects. The LA Site and CO Site have relatively flat curves, and transport sediment even at

flows below 1,000 cfs. The LA Gage and CO Gage have steeper curves, and do not begin transporting "substantial amounts" (arbitrarily defined as 100 tons/day for the purposes of this discussion) of sediment until flows exceed 2,000 and 4,000 cfs, respectively. The steepness of these curves is partly due to the fact that these transects are located in areas where the water surface slope steepens as flow increases, thus leading to increased transport rates. In addition, more fine-grained sediments are available for transport at the gage transects.

These same trends in steepness are apparent when the gravel (particles 2mm and greater) and sand (particles less than 2mm) fractions are plotted separately (Figures 3.25 and 3.26). At both the LA Site and CO Site, which are located in riffles, substantial sand transport occurs even at low flows of 500 cfs. At the LA and CO gage sites, sand transport does not become substantial until flows exceed about 2,000 and 4,000 cfs, respectively. However, at high flows, greater sand transport rates occur at the deeper gage transects than at the LA Site and CO Site riffle transects (Figure 3.25 and 3.26). Gravel transport rates are always significantly lower than sand transport rates at the modeled transects. For the purposes of this discussion, a "substantial amount" of gravel is arbitrarily defined as 1 ton/day. Substantial gravel transport occurs earliest at the steep LA Site transect (at about 1,300 cfs), followed by the CO Site and LA Gage transects (at about 6,000-8,000 cfs), and finally the CO Gage transect (at about 28,000 cfs).

As discussed in Section 3.1, the pre-1940 flow regime exhibited lower summertime monthly flows than the existing (1975-2004) period. Although the rating curves provided in Figures 3.21-3.26 are not calibrated to field-measured values and there is substantial scatter in the data depending on the transport equation selected, it can be concluded that sand transport rates were lower under the pre-1940 flow regime than under existing hydrologic conditions. The difference between pre- and post-1940 summertime transport rates would be greatest at the LA Gage and CO Gage transects, which have steeper rating curves. At these gage sites, transport rates likely dropped to near zero during pre-1940 summertime flow conditions. Pre-1940 sand transport rates would also have been lower in riffle areas like the LA Site and CO Site transects.

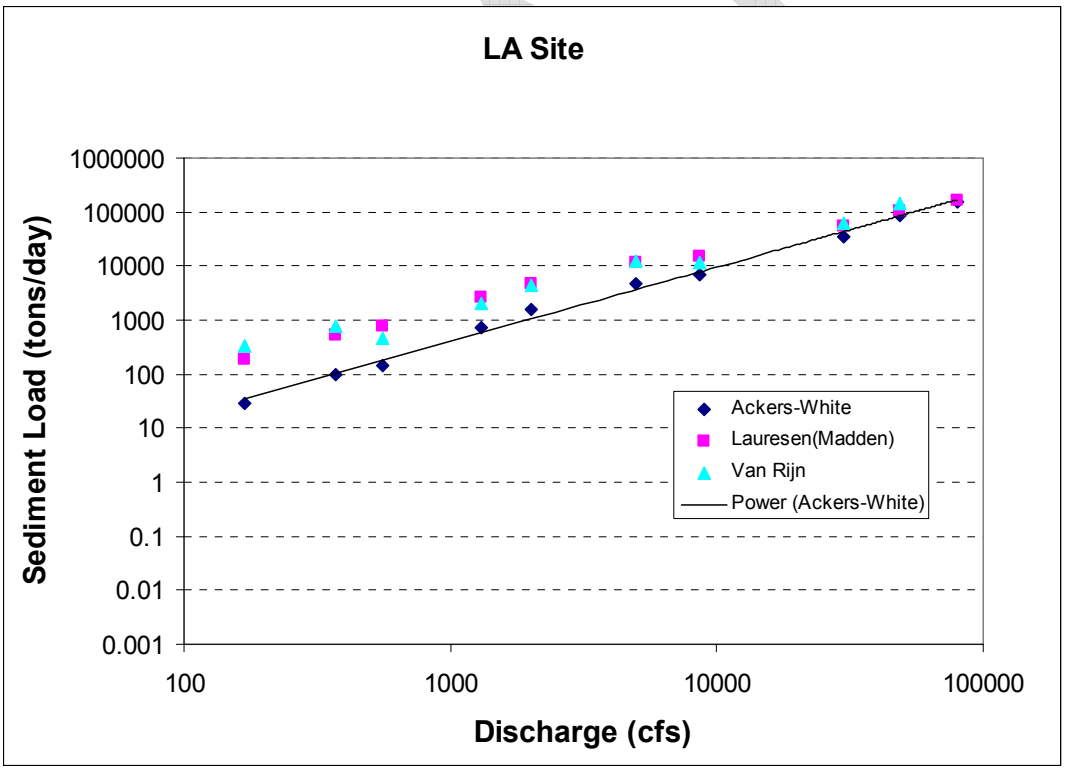


**Figure 3.21.** Sediment rating curves for LA Site.

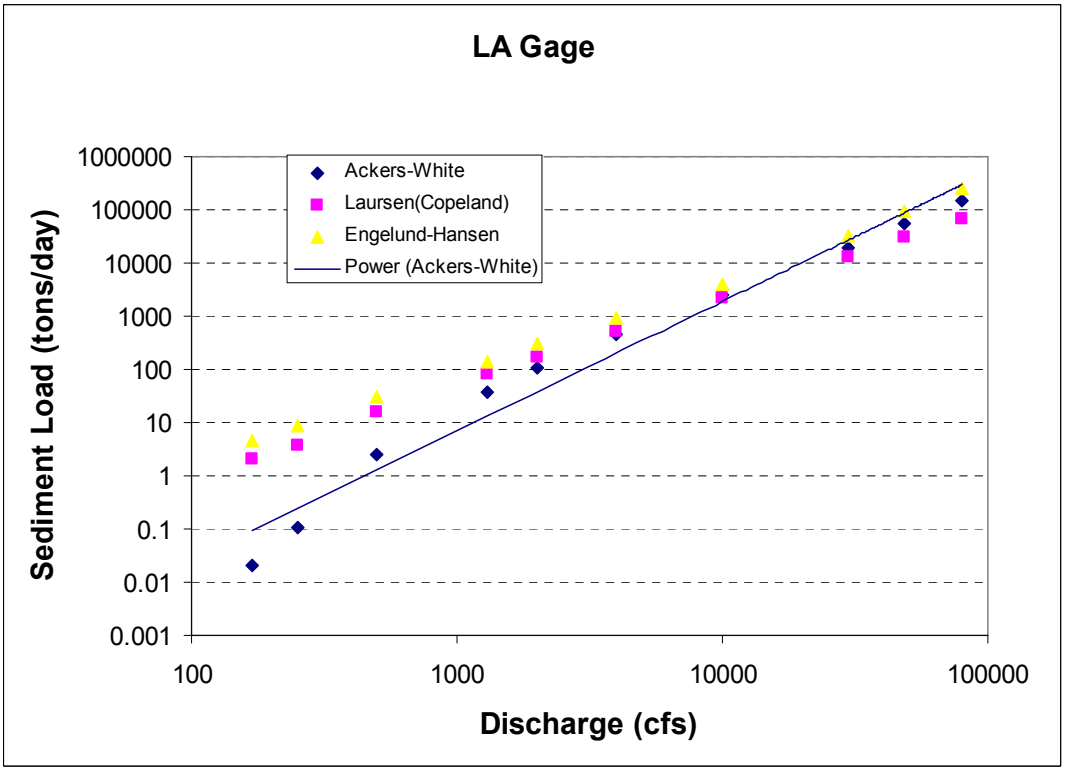


**Figure 3.22.** Sediment rating curves for LA Gage.

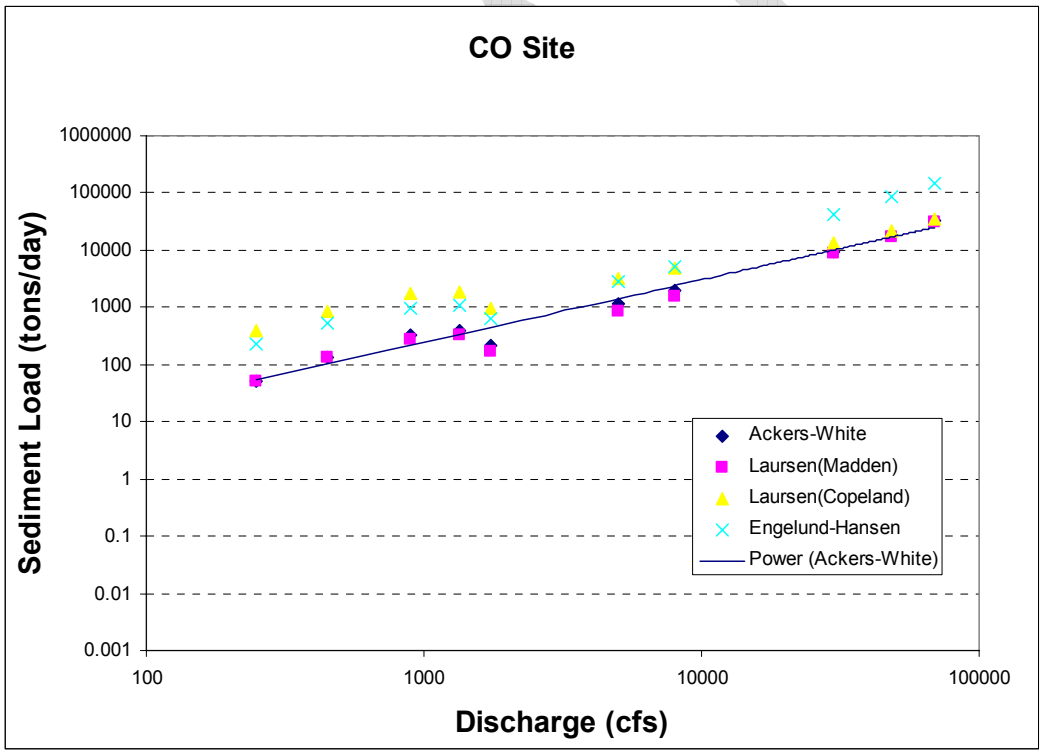


**Figure 3.23.** Sediment rating curves for CO site.

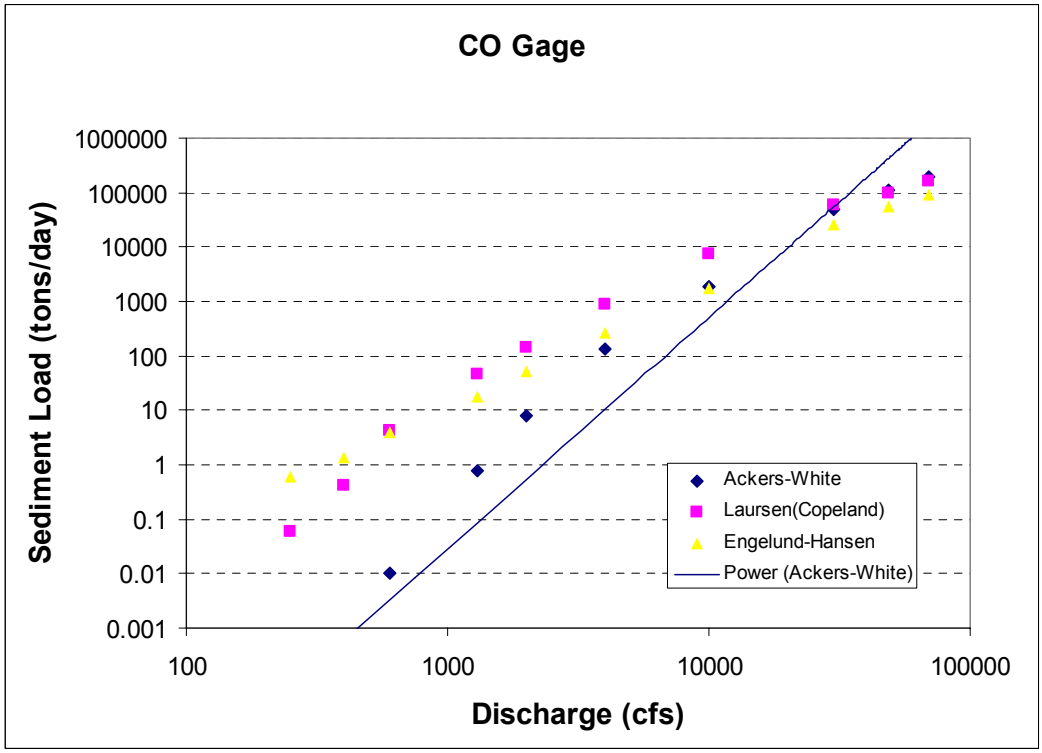


**Figure 3.24.** Sediment rating curves for CO Gage.

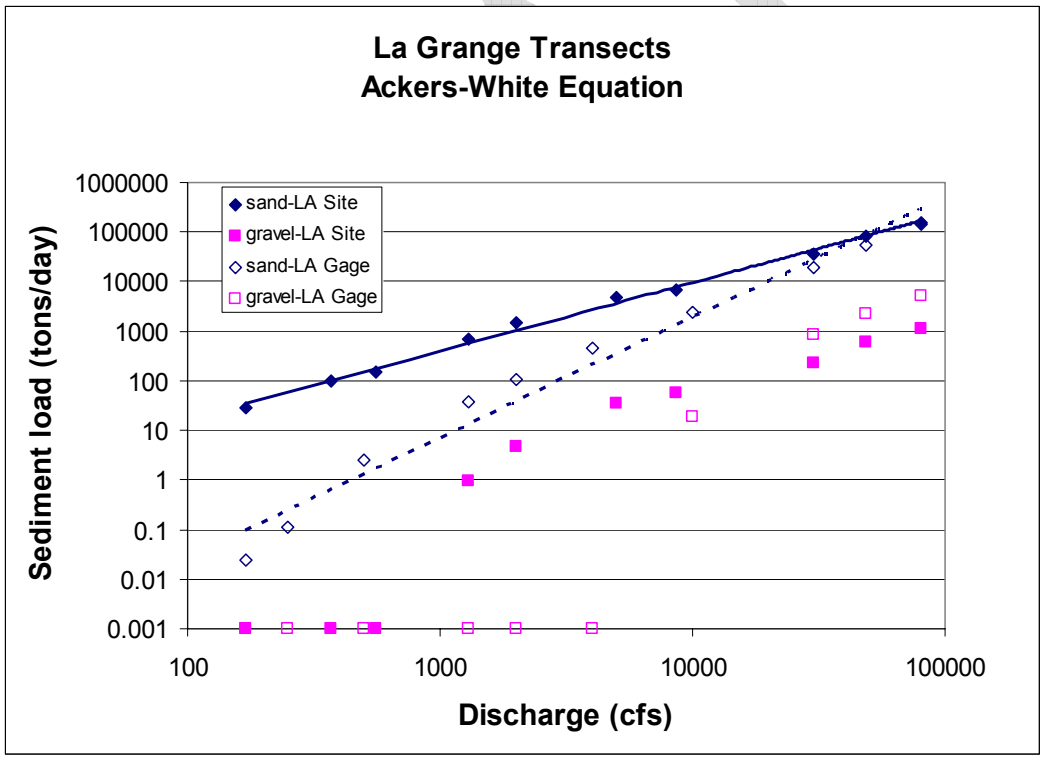


**Figure 3.25.** Sand and Gravel transport rating curves at La Grange sites.

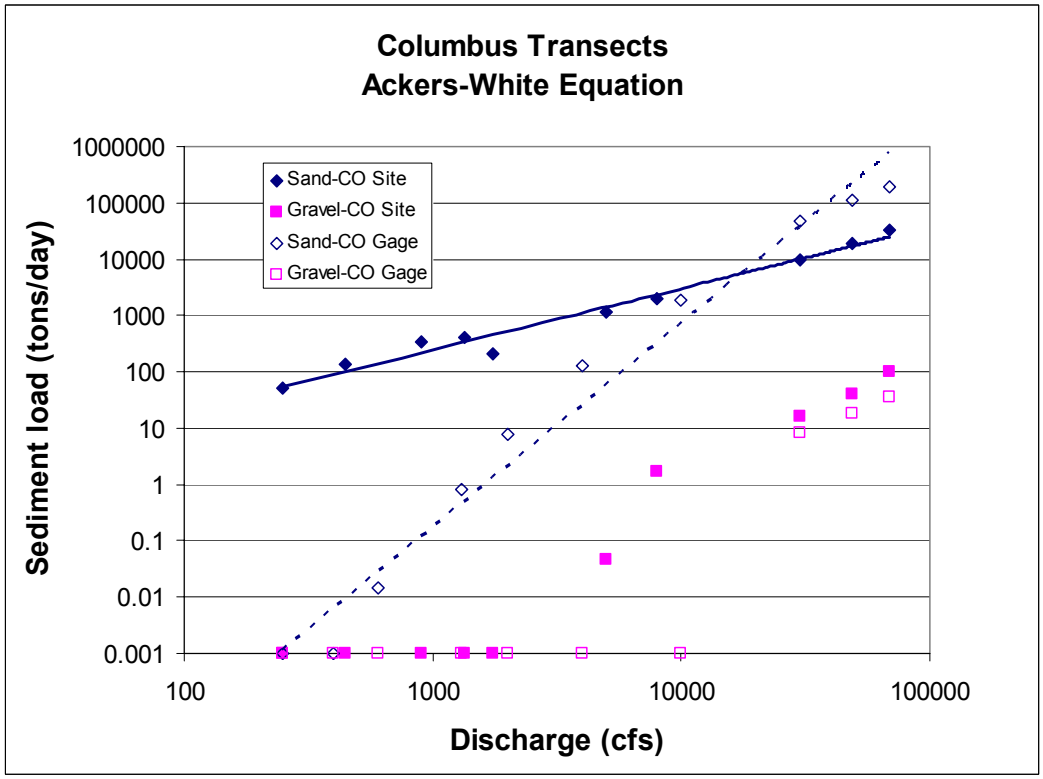


**Figure 3.26.** Sand and Gravel transport rating curves at Columbus sites.

Under existing summertime conditions where flows are typically held at approximately 1,000 - 2,000 cfs, a large portion of the streambed in the river is constantly in motion. Under these existing conditions, the sand moving through riffle and run areas most likely accumulates in the flattest-gradient, lowest-velocity pool and backwater areas of the river. In a more natural flow regime with reduced transport rates, sediment would accumulate less rapidly in these low velocity habitats during summertime low flows, and they would be retained as deeper, more diverse habitat features. In addition, less winnowing/transport of sand would occur along the channel margins. New shoreline sand deposits would likely develop in areas that are not already dominated by sand, providing more gradually-sloping banks and bar features with greater near-bank topographic complexity. These shoreline sand deposits could also provide establishment sites for emergent and herbaceous riparian vegetation. This type of vegetation provides cover and shade for shallow, slackwater-type habitats, and serves as a source of nutrients and organic matter. This type of non-woody vegetation provides ecosystem benefits as long as it is periodically scoured by high flows so that stands do not reach densities that would have negative impacts in terms of reducing channel capacity. Reduced baseflows could also lead to new deposits of fine gravel in steep riffle areas. A return to more natural summertime baseflow conditions would likely lead to more stable (i.e., less mobile) substrate conditions, which could have positive implications for macroinvertebrate productivity and species richness.

### 3.3.3 Effective Discharge

Plots of the percentage of annual sediment load transported by different discharge increments are provided in Figure 3.27. These plots are the product of the sediment transport rating curve and the flow duration curve (discharge frequency curve). Although the highest-magnitude flood flows have the greatest sediment transport capacity, they occur very infrequently. Therefore, they are not typically the flows that transport the greatest amount of sediment over a long period of time. Typically, moderate-magnitude flood flows which occur more regularly (e.g., 1 or 2-yr recurrence interval floods) transport the greatest amount of sediment. This flow (the peak discharge increment on plots such as Figure 3.27) is known as the "effective discharge", and has been found to approximately equal the bankfull discharge (Andrews 1980, Leopold 1992, Andrews and Nankervis 1995).

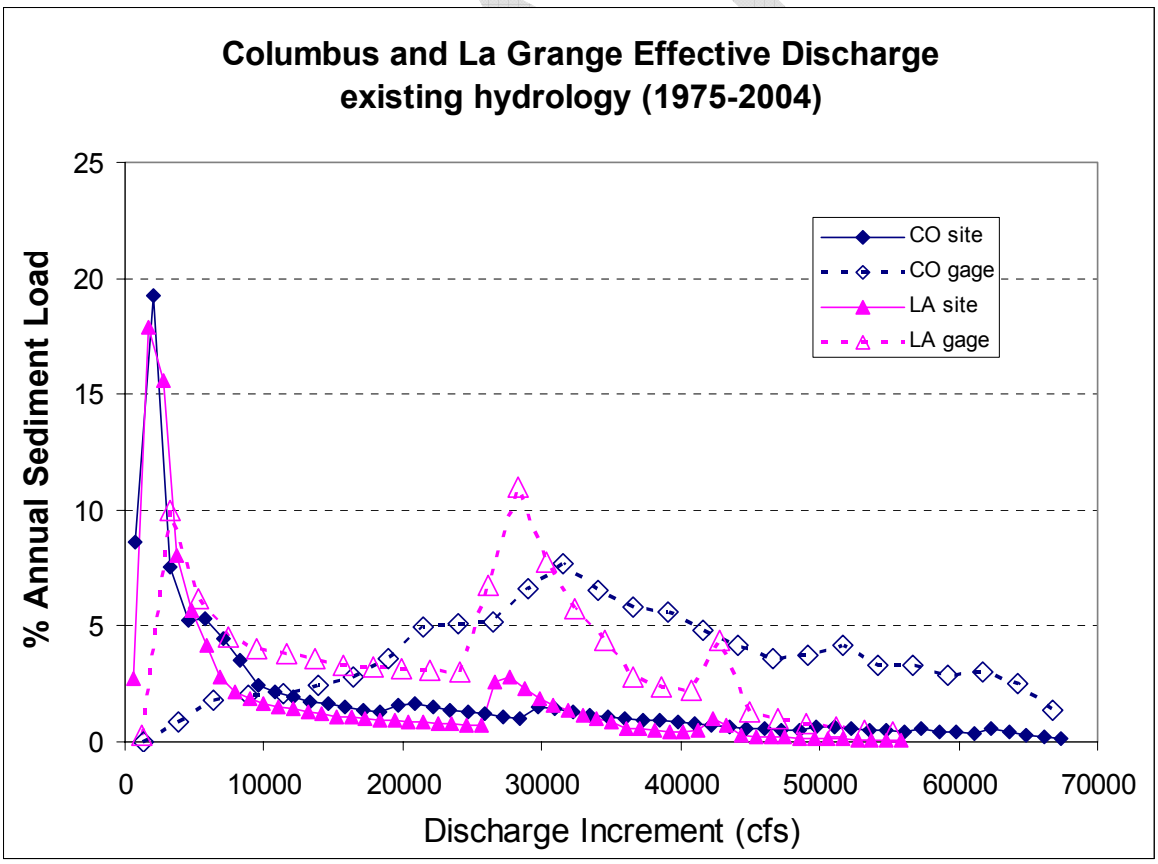


**Figure 3.27.** Effective discharge plots for Columbus and La Grange transects.

Several trends are apparent in the plots for the different analysis transects. At both the LA Site and CO Site, the greatest proportion of total sediment is transported by low flows. At the LA Site, the peak occurs at the discharge increment of about 1,700 cfs; at the CO Site, the peak occurs at the discharge increment of about 2,000 cfs. At these relatively low flow ranges, sand-sized particles are being transported while little to no gravel is mobile (Figures 3.25 and 3.26).

The curve for the LA Site has a strong secondary peak at the discharge increment between about 26,000- 29,000 cfs (Figure 3.27). This flow range is the effective discharge for gravel transport at the site. Minor secondary peaks can be seen in the CO Site curve at about 21,500 cfs and 31,500 cfs, when gravel would be in transport at the site. This gravel-based effective discharge is important for channel (and riffle) maintenance, and flows of this size reach the top of the banks at the CO Site and LA Site transects. Flows of this size are equaled or exceeded between 0.5-2% of the time (Figure 3.19). The computed 2-year recurrence interval flood at the Columbus USGS gage is 48,500 cfs (Espey Consultants 2002), suggesting that the gravel-based effective discharge at the LA Site and CO Site transects has a recurrence interval of less than 2 years. However, the flow resulting from a 2-year recurrence interval storm event was calculated at 26,500 cfs at the La Grange USGS gage and at 26,611 at the Columbus USGS gage (Halff Associates 2002). Regardless, the majority of gravel-sized sediment at these sites is transported by moderate-magnitude, commonly occurring flood flows.

The sediment yield plot for the LA Gage has its primary peak at a discharge of about 28,000 cfs, with a secondary peak at about 2,700 cfs. Although flows of 2,700 cfs do not transport sediment at a rapid rate (Figure 3.22), flows in this range occur frequently and over time transport a substantial volume of material (primarily sand in this case). The CO Gage site does not exhibit the lower-flow peak seen in the plots for the other sites (Figure 3.27). This is because the CO gage is located in an area with a very flat water surface slope at low flow that is not able to transport significant quantities of sediment of any size until higher discharges. The CO gage peak occurs at a flow of about 31,500 cfs. Effective discharge for the gage transects (28,000-31,500 cfs) is essentially equivalent to the gravel-based effective discharge at the CO Site and LA Site transects.

### 3.3.4 Pulse Flow Hydrologic Evaluation

In addition to modeling sediment transport, hydrologic analyses were also completed to identify the characteristics of pulse flows on the lower Colorado under pre-1940 ("natural") and existing flow conditions. Specifically, the Indicators of Hydrologic Alteration (IHA) software program (TNC 2006) was used to generate a variety of hydrologic parameters using daily flow data at the Columbus USGS gage as input into the program. The Columbus gage was selected for IHA analysis because of its proximity to the sediment transport analysis transects and its long, continuous period of record. Water years 1917-1939 were analyzed as the "pre-impact" (i.e. natural/pre-1940) time period; water years 1975-2004 were analyzed as the "post-impact" (existing) time period. Pre- and post-impact are simply terms used in the IHA program.

Within IHA, a non-parametric analysis was completed using IHA default values to define hydrologic parameters and instream flow components. Version 7 of IHA defines high pulse flows in two different ways. The IHA parameter "high pulse" is defined as any flow that exceeds the pre-impact 75$^{th}$ percentile flow (using the default non-parametric threshold). The Environmental Flow Component (EFC) parameter "high flow pulse" has a more complex definition. Rising flows between the pre-impact 50$^{th}$-75$^{th}$ percentile flows as well as any flows above the pre-impact 75$^{th}$ percentile flow are considered high flows (using the default non-parametric thresholds/definitions). However, the EFC algorithms classify "high flows" into three categories: high flow pulses, small floods (high flows with return intervals between 2 and 10 years), and large floods (high flows with return intervals of 10 years and greater). Therefore, the EFC "high flow pulses" exclude the larger-magnitude floods and more specifically define flow events that exceed average/ baseflow conditions but are not great enough to be considered actual "floods" (see TNC 2006 for more details regarding these parameter definitions). For the purposes of our analysis, we examined the magnitude, frequency, and duration of both the IHA "high pulse" and EFC "high flow pulse" outputs to help define recommendations for pulse flows on the lower Colorado River.

Results of the IHA high flow pulse analyses are summarized in Table 3.4. Flows classified as "IHA High Pulses" are flows above the pre-impact 75$^{th}$ percentile flow of 3,178 cfs. Flows classified as "EFC High Flow Pulses" include flows within the overall range of 1,300 cfs (the pre-impact 50$^{th}$ percentile flow) up to 43,600 cfs (the EFC small flood threshold); however, not all flows within the range are necessarily classified as EFC high flow pulses depending on their rising or falling trends (see TNC 2006 for details).

**Table 3.4.** Results of IHA analysis of lower Colorado River flows at the Columbus USGS gage.

| | Pre-1940 (1917-1939) | | | Existing (1975-2004) | | |
|---|---|---|---|---|---|---|
| Parameter | 25% Value | Median Value | 75% Value | 25% Value | Median Value | 75% Value |
| IHA High Pulse Count (events/yr) | 6 | 10 | 13 | 4.75 | 8 | 13 |
| IHA High Pulse Duration (days) | 3 | 4 | 5.5 | 2 | 3 | 4.125 |
| EFC High Flow Pulse Frequency (events/yr) | 9 | 11 | 15 | 8 | 11.5 | 15 |
| EFC High Flow Pulse Duration (days) | 5 | 5 | 7 | 3.4 | 4.75 | 5 |
| Annual 1-day Maximum Flow (cfs) | 26,300 | 43,600 | 99,200 | 11,530 | 23,900 | 50,680 |
| Annual 3-day Maximum Flow (cfs) | 18,670 | 37,970 | 90,000 | 8,235 | 19,690 | 40,540 |

As seen in Table 3.4, existing high pulse characteristics remain quite similar to pre-1940 values for both the IHA and EFC parameters. This is because many of the lower-magnitude high flow events on the lower Colorado River are caused by rain storms that occur below the Lake Travis Watershed. These events are not affected by the Highland Lakes system. In contrast, the larger-magnitude high flow events (floods with frequencies of once per year or less) on the lower Colorado River have been substantially altered by the Highland Lakes. This is evident in the IHA results for annual 1-day and 3-day maximum flows (Table 3.4).

## 3.4 Water Quality

A steady state QUAL-TX model was developed and calibrated by the LSWP Water Quality team from Longhorn Dam to the Bay City Dam. For the instream flow guidelines development, six flow scenarios were originally run in this model to estimate the dissolved oxygen (DO) concentration in each model segment of the main stem of the Colorado River below Longhorn Dam. For these model runs, headwater flow (i.e., the flow at the Austin USGS gauge, which was used to represent the flow passing Longhorn Dam) was reduced to the lowest possible amount. Each run used a flow balance based on results from the Water Availability Model (WAM) for future conditions in 2060 with Project (i.e., the 2006 PVA WAM run) and all diversions were set to flow demands in 2060 with Project (maximum demands predicted for 2060, as they are incorporated into the WAM). The following three scenarios were run for 2060 conditions in August and again for September (six total runs); these two months are those in which DO is predicted to be critical (because of diversions, high temperatures, and low flows):

- City of Austin (CoA) fully permitted discharge and concentration and all other dischargers at 100% permit limits
- CoA at current conditions (based on Discharge Monitoring Reports (DMRs) from 1999 – 2005) and all other dischargers at 75% permit limits

- CoA at potential future conditions (based on proposed return flow amounts and possible changes in their permits) and all other dischargers at 75% permit limits

The first is the worst case scenario, with CoA discharge and concentrations at maximum permitted. The second is based on recent CoA DMRs. The third is based on estimated CoA return flows (as provided from the WAM run) and potential concentrations (mainly from permit) in 2060. The results from QUAL-TX include the flow passing through each segment and each segment's predicted DO concentration.

Of the six scenarios, only the worst case scenario (CoA discharge and concentrations at maximum permitted during August) results in predicted DO concentrations below 4.0 mg/L. Under this worst case scenario, the minimum DO concentration recorded is 3.87 mg/L with concentrations under 4.0 mg/L occurring in less than 1% of the segments, concentrations under 5.0 mg/L occurring within 12% of the segments, and DO concentrations greater than 5.0 mg/L occurring within 87% of the segments. The predicted DO concentrations from this worst-case scenario are acceptable to meet the lower Colorado River aquatic community needs during low-flow periods. Therefore, a detailed evaluation of the other five scenarios (in which predicted DO concentrations were higher) was not conducted.

Although the predicted DO concentrations from the above analysis are acceptable to meet the aquatic community needs during low-flow periods, the river discharge used in all model runs described above are considerably greater than the current LCRA Water Management Plan critical flow requirements (120 cfs Bastrop) for the lower Colorado River and the projected subsistence flow recommendations from this study. Therefore, the LSWP water quality team conducted an additional model run evaluating predicted DO concentrations in the river at discharges less than or equal to 120 cfs. To make this discharge scenario possible, the following assumptions were placed on the model:

- Headwaters were set to 50cfs,
- 50cfs was added as return flows from the two major CoA Waste-Water Treatment Plants (WWTP) at fully permitted concentrations,
- Incremental flows were set to zero,
- Tributary flows were set to zero (including tributaries with WWTP dischargers),
- 13 main stem dischargers were set to fully permitted flows and concentrations.

The discharge passing through the lower Colorado River with these assumptions in place amounts to approximately 105cfs near Bastrop, 115cfs near Columbus, and 120cfs near Wharton. The lowest predicted DO concentration in the lower Colorado River under this simulated low-flow condition is 4.98 mg/L. For this run, less than 2% of the segments show a DO concentration between 4.98 and 5.0 mg/L with all other segments maintaining DO concentrations of greater than 5.0 mg/L. The higher predicted DO concentrations under this simulated low-flow condition relative to the fully permitted 2060 with project run (at two to three times the discharge) is explained by the percentage of dilution flows from Longhorn dam. Under the simulated low-flow run, the dilution flows from Longhorn dam make up 40-50% of

the flow in the river. Under the worst-case scenario 2060 with project condition modeled above, nearly 100% of the flow in the river is from downstream dischargers.

There is a level of conservatism built into both described conditions as flow will always be required to be passed through Longhorn Dam, projected COA discharge concentrations are much less than the fully permitted concentrations run, and projected CoA return flows would not allow discharge in the river to get as low as the last simulated model run. However, even under these extreme conditions, LSWP water quality modeling predicts average and diel DO concentrations in the river will be acceptable to meet the needs of the lower Colorado River aquatic community.

# 4.0 INTEGRATION

In order to meet the environmental principles set forth for the LSWP and remain consistent with the TIFP objectives to conserve biodiversity and maintain biological integrity, the project team is following the recommendations of the NRC (2005) which has subsequently been endorsed by the TIFP (TIFP DRAFT 2006). The integration process involves four components of the hydrologic regime: subsistence flows, base flows, high flow pulses, and overbank flows. A brief overview of the definitions and objectives of the instream flow components as presented in TIFP (2006) is presented in Table 4.1.

**Table 4.1**. Definitions and objectives of instream flow components (TIFP DRAFT 2006).

| | |
|---|---|
| ***Subsistence Flows*** | |
| Definition: | Infrequent, seasonal periods of low flow. |
| Objectives: | Primary objective is to maintain water quality criteria. Secondary objectives to provide important low flow life cycle cues or refugia habitat. |
| ***Base Flows*** | |
| Definition: | Normal flow conditions between storm events. |
| Objectives: | Ensure adequate habitat conditions, including variability, to support the natural biological community. |
| ***High Pulse Flows*** | |
| Definition: | Short-duration, within-channel, high flow events following storm events. |
| Objectives: | Maintain important physical habitat features. Provide longitudinal connectivity along the river channel. |
| ***Overbank Flows*** | |
| Definition: | Infrequent, high flow events that exceed the normal channel. |
| Objectives: | Maintain riparian areas. Provide lateral connectivity between the river channel and active floodplain. |

## 4.1 Flow Components Development and Integration

The development of instream flow recommendations requires the integration of multiple disciplines at several key stages in the process. During the analysis phase, integration of the analytical results is necessary to develop specific flow recommendations (i.e. subsistence flow, base flow, etc.). Once the specific flow recommendations are developed, an integration of those flow recommendations into a proposed flow regime is required. Table 4.2 provides an

overview of the integration of analysis tools in the development of specific flow recommendations. Flow regime integration and preliminary recommendations are discussed in Sections 4.2 and 4.3.

**Table 4.2.** Analytical Component Integration Overview

| | Hydrology and Hydraulics | Biology | Geomorpholgy | Water Quality |
|---|---|---|---|---|
| **Subsistence Flows** | Hydrologic analysis<br>Hydraulic modeling | Habitat Modeling<br>$X^{th}$ percent exceedance level<br>Base flows | | Dissolved oxygen modeling |
| **Base Flows** | Hydrologic analysis<br>Hydraulic modeling | Habitat Modeling<br>$X^{th}$ percent Habitat exceedance level(s)<br>Base flows | Sediment transport modeling<br>Base flow<br>Particle movement | Dissolved oxygen modeling |
| **High Flow Pulses** | Hydrologic analysis<br>Pulse Flows | Riparian assessment | Sediment transport modeling<br>Particle movement<br>Effective discharge | |
| **Overbank Flows** | Hydrologic analysis<br>Flood events | Riparian assessment<br>Active floodplain connectivity | Sediment transport modeling<br>Effective discharge | |

## 4.2 Subsistence and Base Flow Development

Hydraulic and habitat modeling, sediment transport analysis, and water quality modeling were used to support the development of subsistence and base flow guidelines. Figure 4.1 is a flowchart that, in simple terms, describes the process for subsistence and base flow recommendations development. The numbers in the upper right hand corner of each task do not necessarily reflect the order of steps as several tasks are conducted simultaneously, but are included to serve as reference numbers for the discussion. Several of the tasks (Reference #s 1-5) in the top portion of the flowchart (Figure 4.1) have already been described in the results section (Section 3.0) or in the 2005 Activities Report (BIO-WEST 2005). This discussion will start with the habitat modeling activities (flow chart reference # 8).

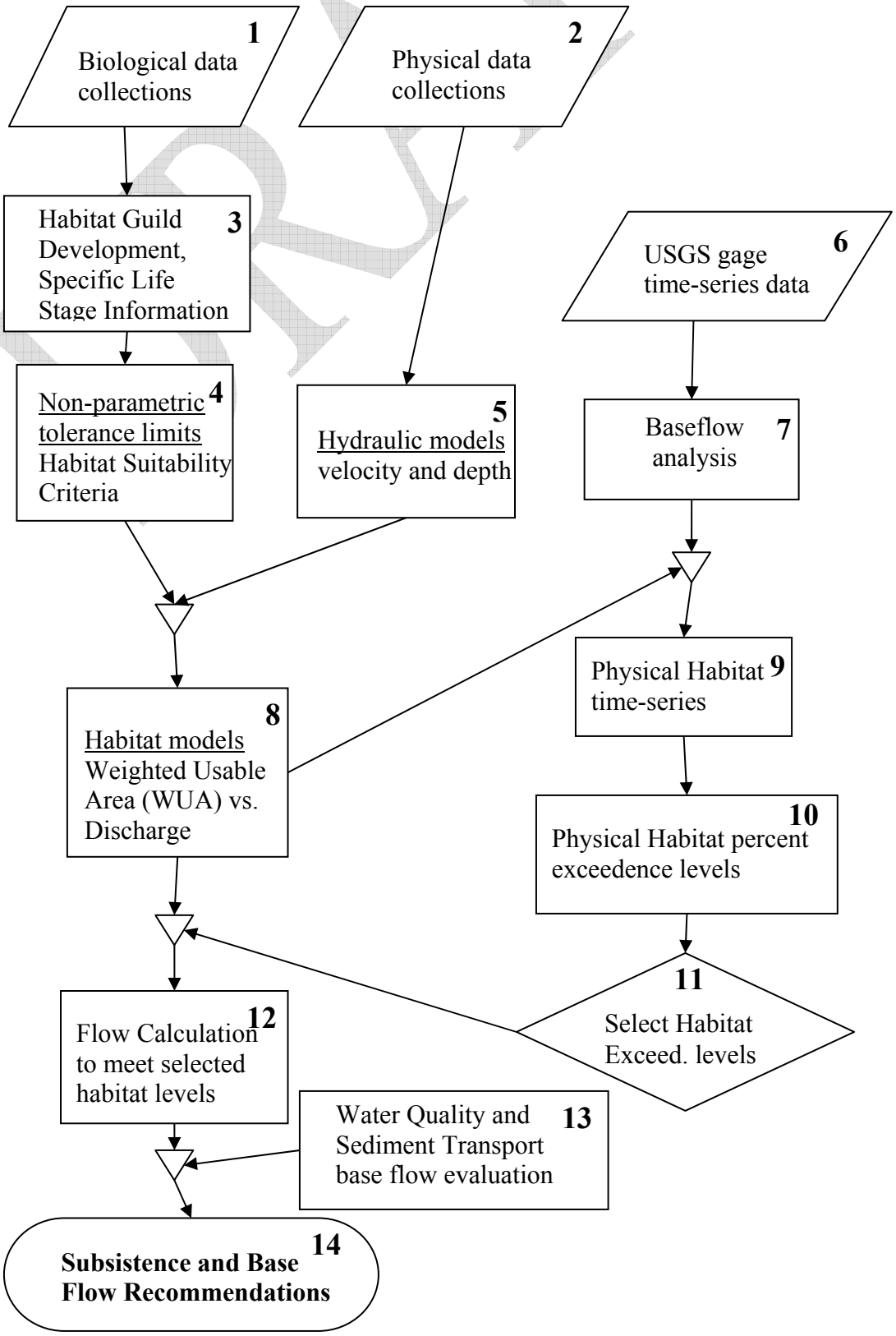


**Figure 4.1.** Subsistence and Base Flow Development Flowchart

### 4.2.1 Habitat Modeling

Habitat for the seven categories was computed on a node-by-node basis from the HSC values for depth, velocity, and substrate (flowchart reference #8 [Figure 4.1]). The composite suitability index (CSI) for a given node was computed as the geometric mean of the individual velocity ($Velocity_{SI}$), depth ($Depth_{SI}$) and substrate ($Substrate_{SI}$) suitabilities (Hardy 2000):

$$CSI = (Velocity_{SI} * Depth_{SI} * Substrate_{SI})^{1/3}$$

Habitat simulations were computed for each of the seven habitat categories under each modeled flow rate at each intensive study site. Figure 4.2 shows a sample output of riffle habitat guild suitability at four flow rates at the Utley site. The simulated combined suitability at these flow rates were used to generate contours of suitable riffle habitat between 0 and 1.0 to visualize the spatial distribution of predicted habitat at the Utley site. The color of the predicted habitat reflects the level of suitability for the riffle habitat guild with 1.0 being most selected and 0 being unsuitable.

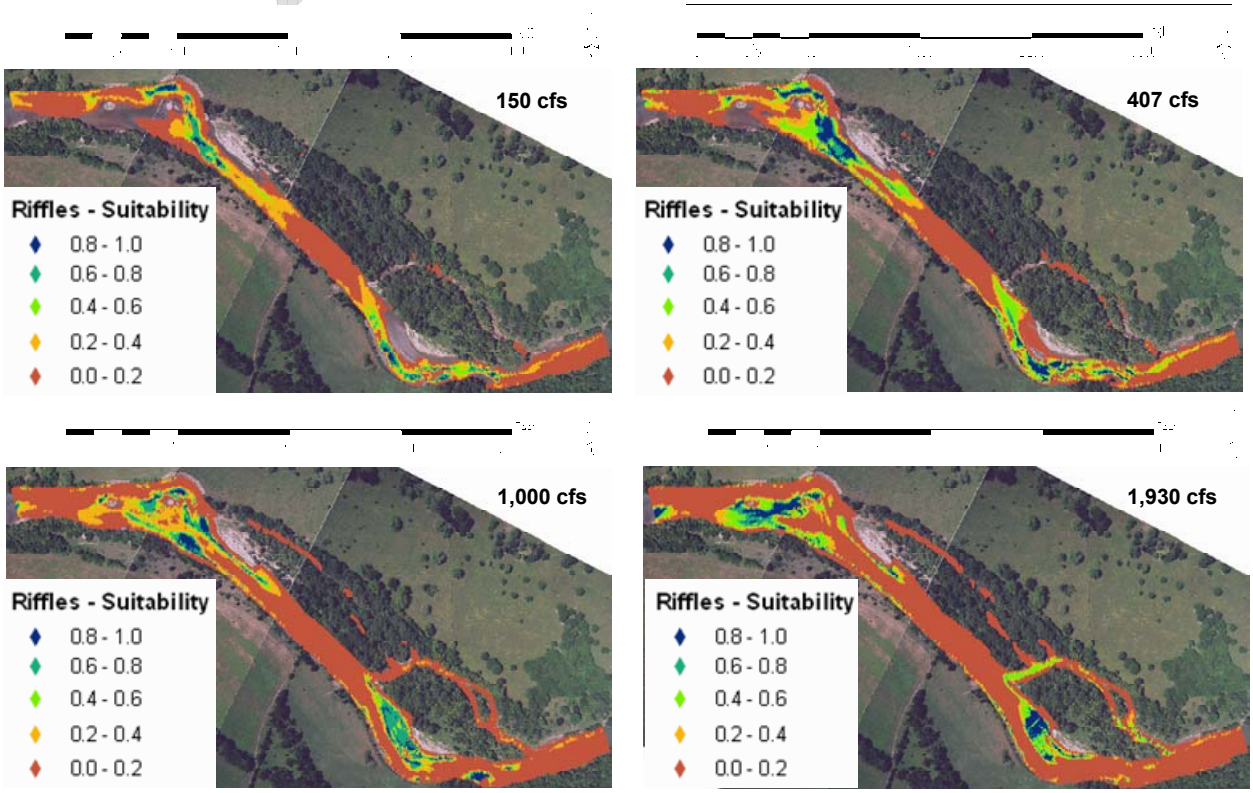


**Figure 4.2.** Simulated riffle habitat at Utley intensive study site (Site 2) at four modeled discharge rates.

Additionally, the habitat model output was compared back to habitat mapping at several sites at two different discharges. Figure 4.3 shows the simulated riffle habitat guild output at 300 cfs with an overlay of the field habitat mapping of riffles conducted at approximately 275 cfs. The simulated riffle habitat guild suitability extends out from the field mapped riffles area which is to be expected because of the slightly higher flows. Also, it is important to note the distinction

between riffle habitat guild suitability and visual observations of "riffles" in the field. As they are not the exact same measure, they are not expected to be exact. Overall, the mapped "riffles" cover the majority of the higher suitability simulated riffle habitat guild. Additional field habitat mapping versus predicted habitat will be presented in an Appendix in the final technical report.

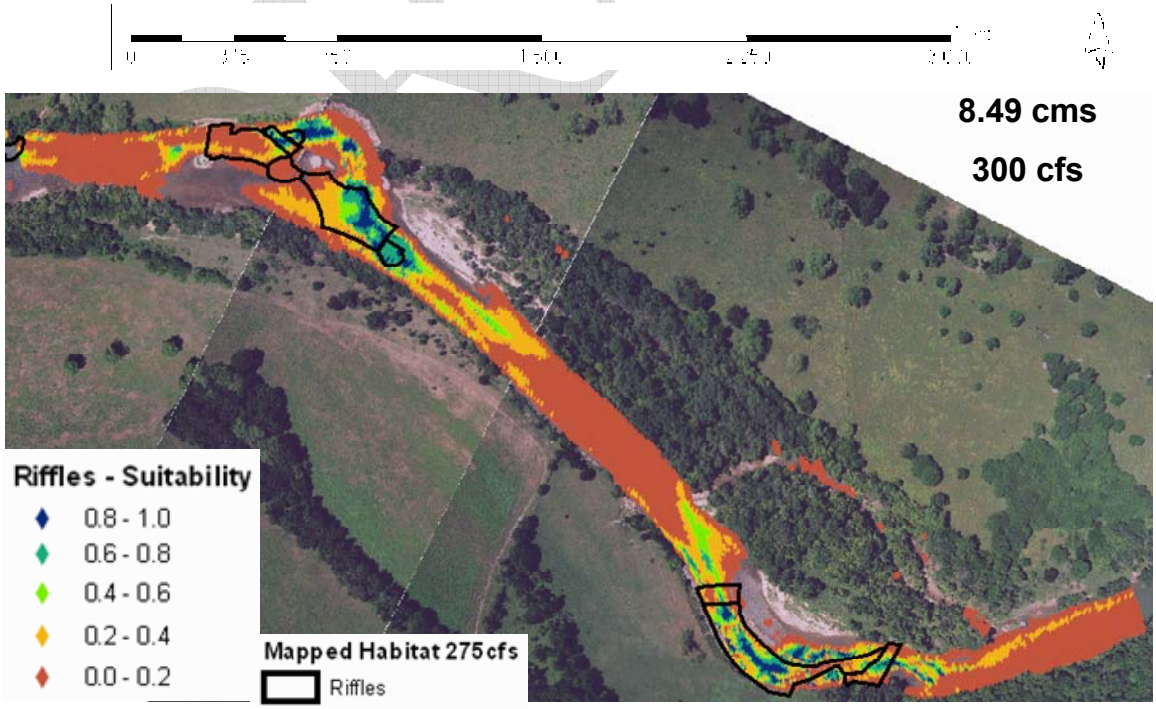


**Figure 4.3**. Utley, 300 cfs (8.495 cms) biological mapping validation; field mapping 11/28/2006 approx. 275cfs

Biological validation data was collected at five sites (Utley, Smithville [downstream], La Grange, Altair, and Wharton) during intermediate flows (~ 1,300 to 2,000cfs) and at all ten sites under lower flow (~ 300 to 700cfs) conditions. Figure 4.4 shows the simulated combined suitability for the riffle habitat guild at Utley at 1,930cfs along with the biological validation data collected at that flow. Fish data collected at this flow rate are plotted relative to the abundance of riffle habitat guild species collected (Figure 4.4). A black dot is placed on a sample site where no riffle habitat guild species were collected and a circle with an X through it represents a sample site where the appropriate species were collected. The size of the circle represents the level of abundance as described in the legend. Additional biological validation maps versus predicted habitat will be presented in an Appendix in the final technical report.

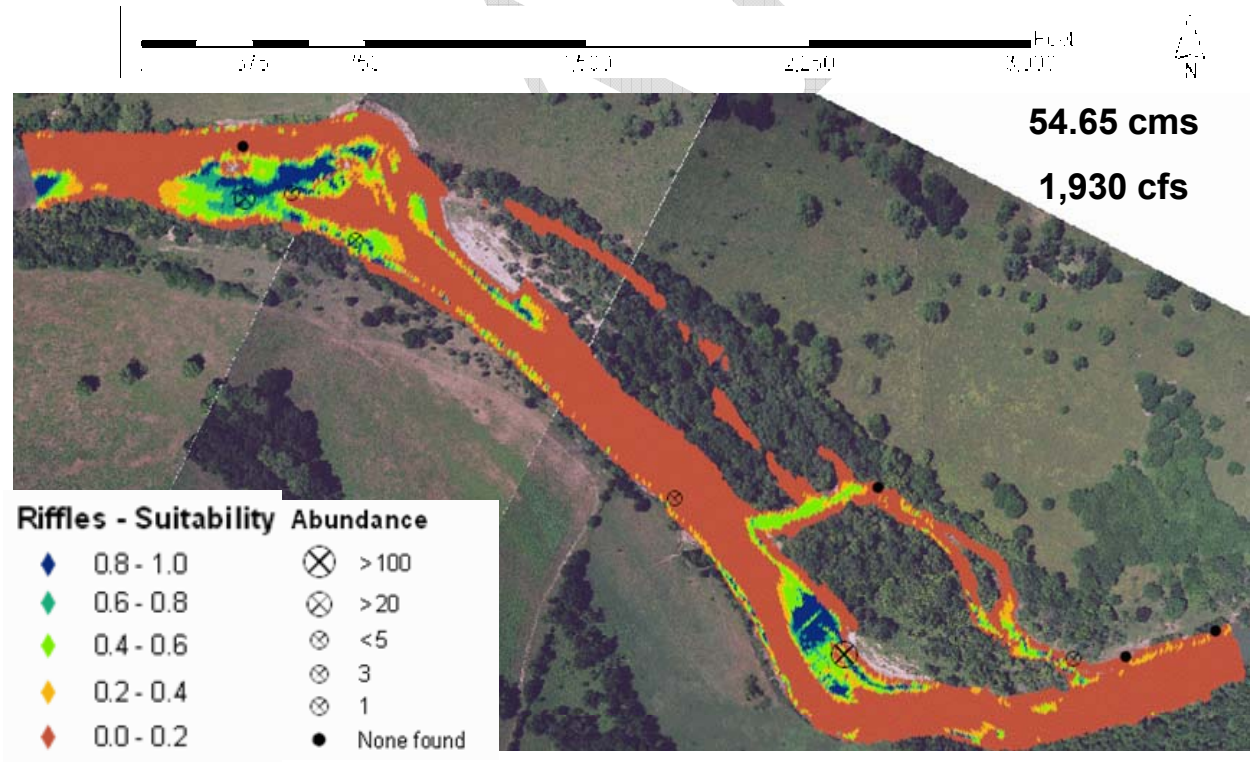


**Figure 4.4.** Utley, 1,930 cfs (54.65 cms) biological validation

The biological validation data is included as a general, qualitative description of what is going on in the river. Several possible inclusions of error in this validation approach exist including the mesh being +/- 2 m, the fish being collected +/- 2 m, etc. Therefore, the biological validation data is not expected to match exactly to predicted habitat suitability. Overall, biological validation data corresponds well with predicted habitat suitability and provides further support of habitat modeling results.

Habitat simulation results were used to compute weighted usable area versus discharge relationships for each of the seven habitat categories at each of the ten sites. Area is reported as square feet per 1,000 linear feet along river centerline. Figures 4.5 and 4.6 show this relationship and the corresponding percent of maximum habitat for the Utley (Site2) intensive study site. The relationships and corresponding percent of maximum habitat for all sites are included in Appendix C. The intensive study site results were grouped into five reaches as depicted in Figure 4.7.

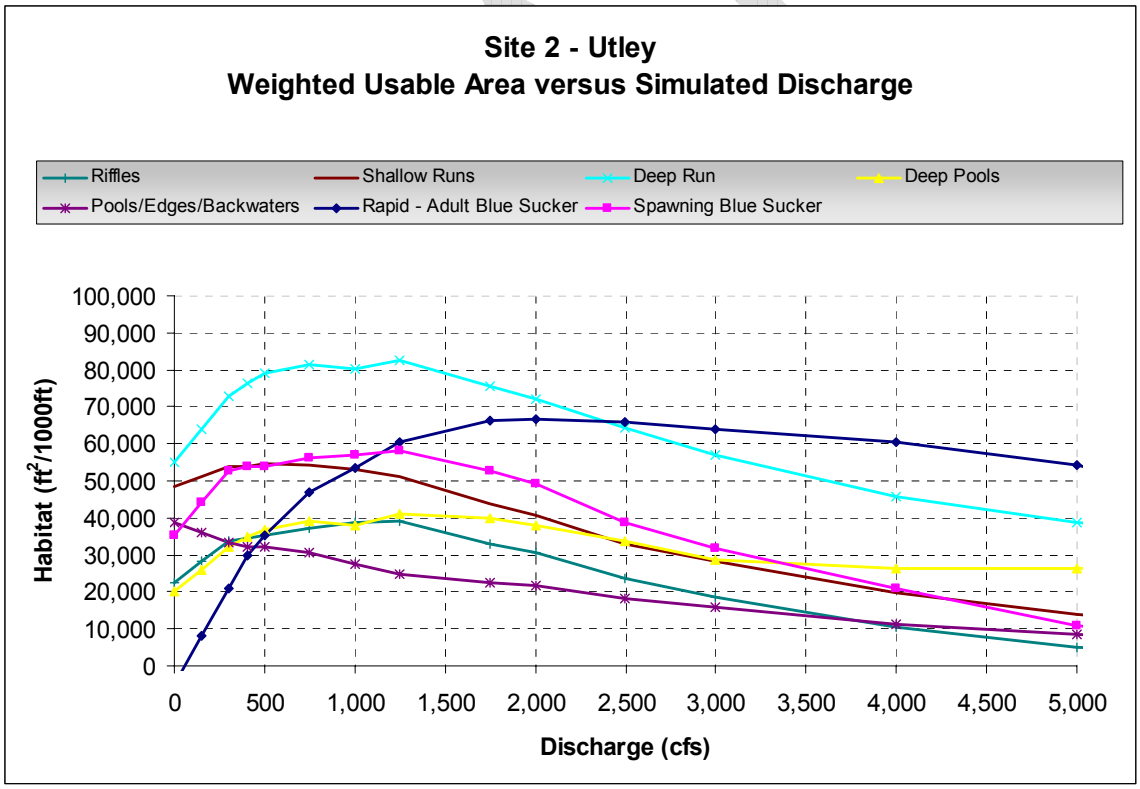


**Figure 4.5.** Weighted usable area versus simulated discharge at Utley (Site 2)

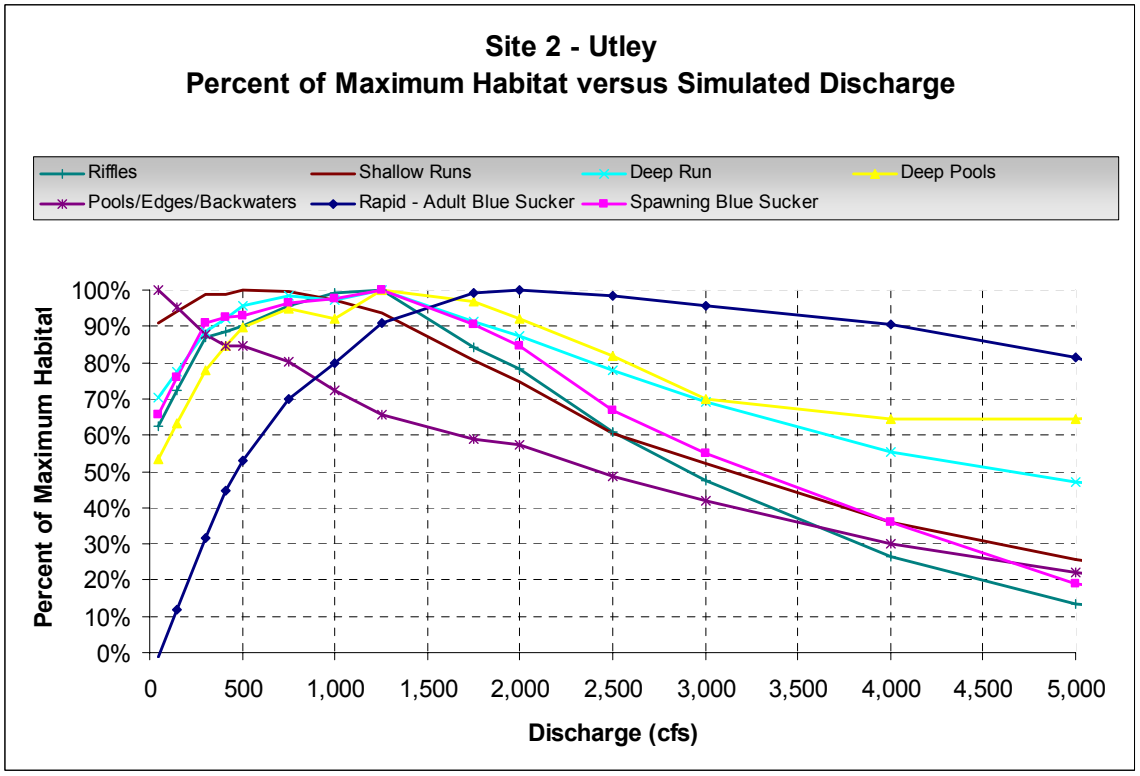


**Figure 4.6.** Percent of Maximum Habitat versus simulated discharge at Utley (Site 2)

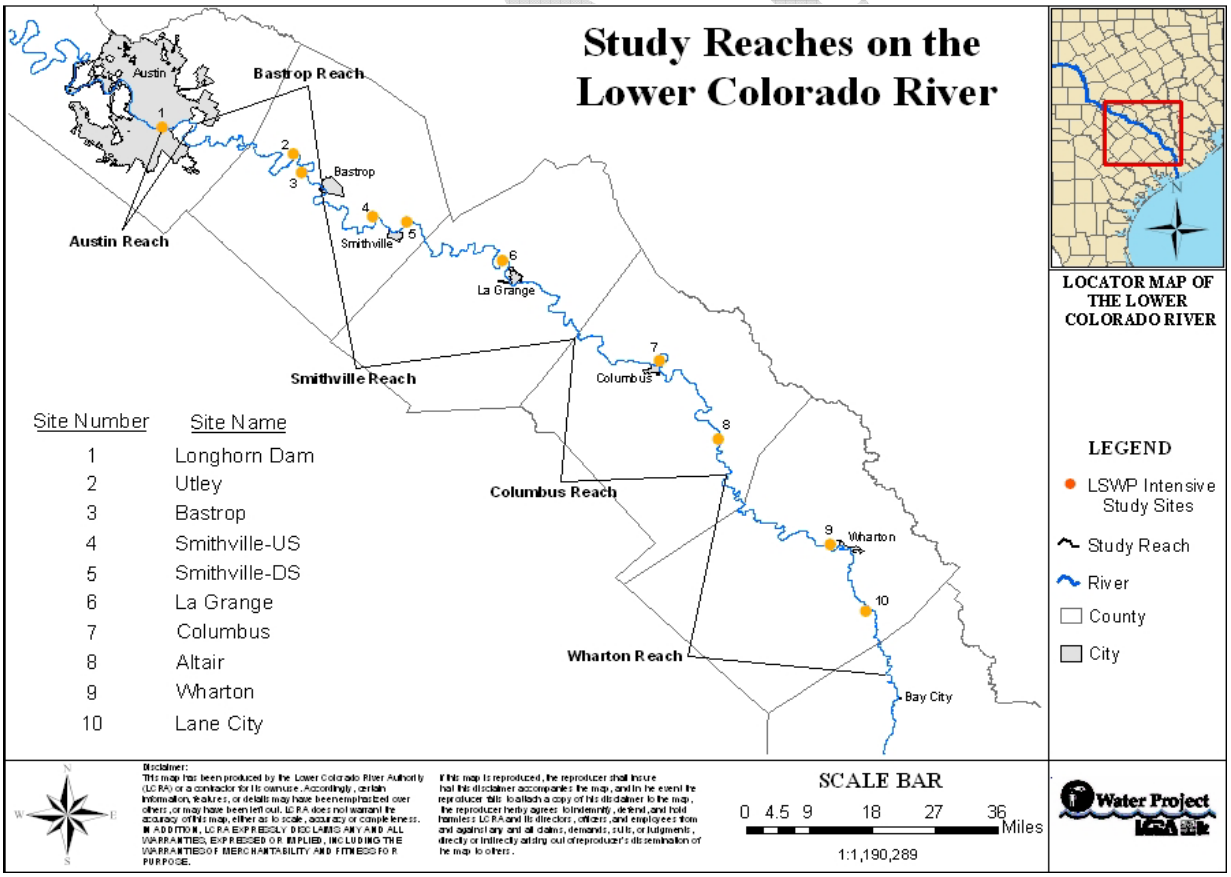


**Figure 4.7.** LSWP Reaches

## 4.2.2 Habitat Time Series Modeling

Physical habitat times series were computed based on two flow scenarios. These included the existing condition (1975 to 2004) and pre-1940 (1898/1916 – 1940). The existing flow scenario was included in the habitat time series analysis because 1) the field data (physical and biological) used for the hydraulic and habitat models, sediment transport analysis, and baseline riparian conditions were all collected under the existing flow regime, and 2) the present day geomorphic conditions, riparian zone, water chemistry, aquatic habitat, and biological resources have all been imprinted by the existing flow regime. Additionally, the water quality and biological data collected by LCRA over the past decade reflect high levels of quality and diverse biological communities. Therefore, an examination of the existing flow regime was deemed necessary to evaluate the potential for maintaining similar conditions.

The pre-1940 "natural" flow scenario was included to be consistent with the guidance of the TIFP and Natural Flow paradigm theory. Even though the data collected for this study was done under the existing flow regime, using natural flow conditions as a reference for comparison often provides insight into the ecological variability of large river systems.

In order to compute the physical habitat time series (flowchart reference #9 [Figure 4.1]), a daily flow record is needed. For the existing conditions flow scenario, daily flow records from the

USGS gages (flowchart reference #6 [Figure 4.1]) nearest to the study sites were used. For the pre-1940 scenario, the daily flow record for the upper reaches (Austin, Bastrop [Utley and Bastrop sites], and Smithville [Smithville upstream and downstream, and La Grange sites]) were derived from the Austin gage and the lower reaches (Columbus [Columbus and Altair sites], and Wharton [Wharton and Lane City sites]) were derived from the Columbus gage.

Since the ultimate purpose of habitat time series analysis is development of subsistence and base flow recommendations, it was necessary to limit the range of flows over which the analysis would be performed. This is necessary because relatively poorer habitat conditions can result from flows that are either too high or too low. We found that including the entire range of flows resulted in percentile targets (the amount of time above which a certain amount of habitat is available) that were driven by high flow rather than low flow conditions. Because it does not make ecological sense to set low base and subsistence flow recommendations that are driven by poor habitat conditions resulting from extremely high flows, we decided to set a maximum flow at which the weighted usable area versus discharge relationships would be applied. To set this maximum we used the U.S. Bureau of Reclamations BFI program for base flow separation (flowchart reference #7 [Figure 4.1]). The BFI program implements a deterministic procedure developed in 1980 by the British Institute of Hydrology to separate base flows from pulse flows.

From the BFI output, we chose the 95$^{th}$ percentile flow from the Columbus pre-1940 base flow time series as the maximum flow for which the weighted usable area to discharge curve would be applied. The Columbus value was 5,838 cfs. While we considered applying a different maximum for the upper sites based on the Austin gage base flow time series, we decided that the value derived for Austin, 2,470 cfs, was unnecessarily restrictive of the range of flows to include in the analysis and, since the application of the Columbus value did not result in cases of flow targets being driven by high flow conditions, we elected to apply the Columbus value to all sites. For days on which flow exceeded 5,838 cfs "NO DATA" was entered into the habitat time series. By removing the high flows, base and subsistence flow habitat calculations would not be skewed by reduced habitat conditions during these high flow times.

Physical habitat time series were computed by applying the weighted usable area to discharge curves (flowchart reference #8 [Figure 4.1]) developed for each habitat category and reach to the daily flow record for each base flow adjusted scenario (flowchart reference #7 [Figure 4.1]). Comparative results in the form of Habitat Duration Curves (Austin and Wentzel 2001) for the shallow pools/edge/backwater habitat guild, riffle habitat guild, and adult blue sucker/rapids habitat category for all months at the Bastrop reach is presented in Figures 4.8-4.13, respectively. Habitat duration curves display the amount of time over the entire daily flow record that habitat is available. For example, Figure 4.13 shows that 80% of the time (existing time period [1975-2004]), adult blue sucker/rapids habitat for the Bastrop Reach in March was at least ~35,000 ft$^2$/1000ft or greater.

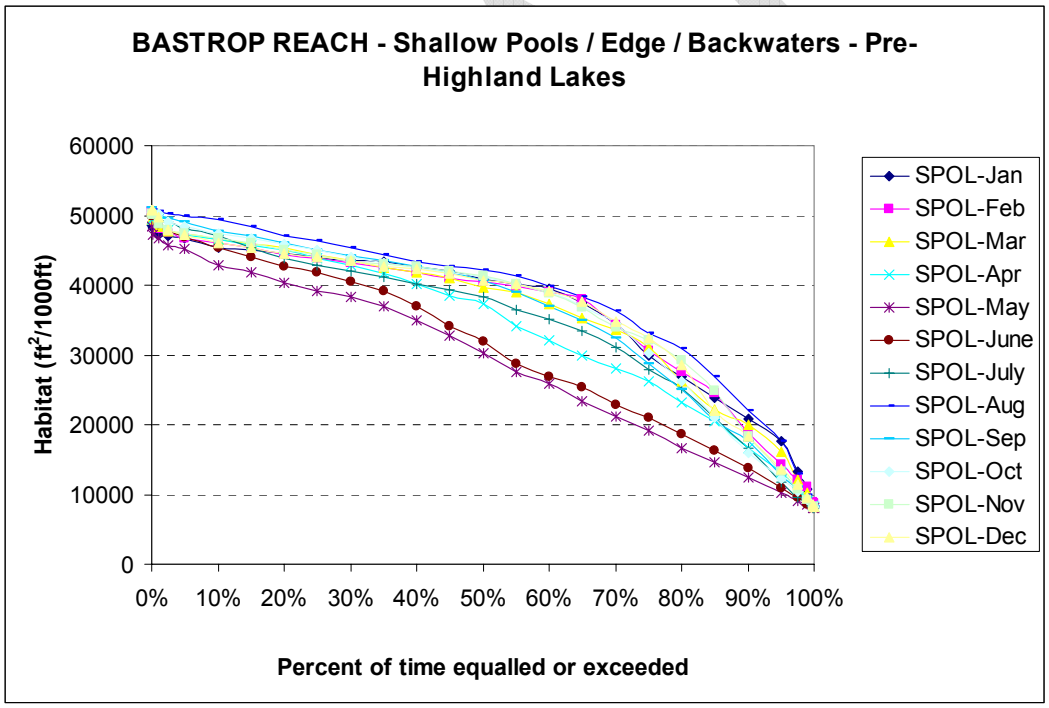


**Figure 4.8.** Habitat durations for shallow pools/edge/backwater for all months at the Bastrop Reach based on the pre-1940 flow regime.

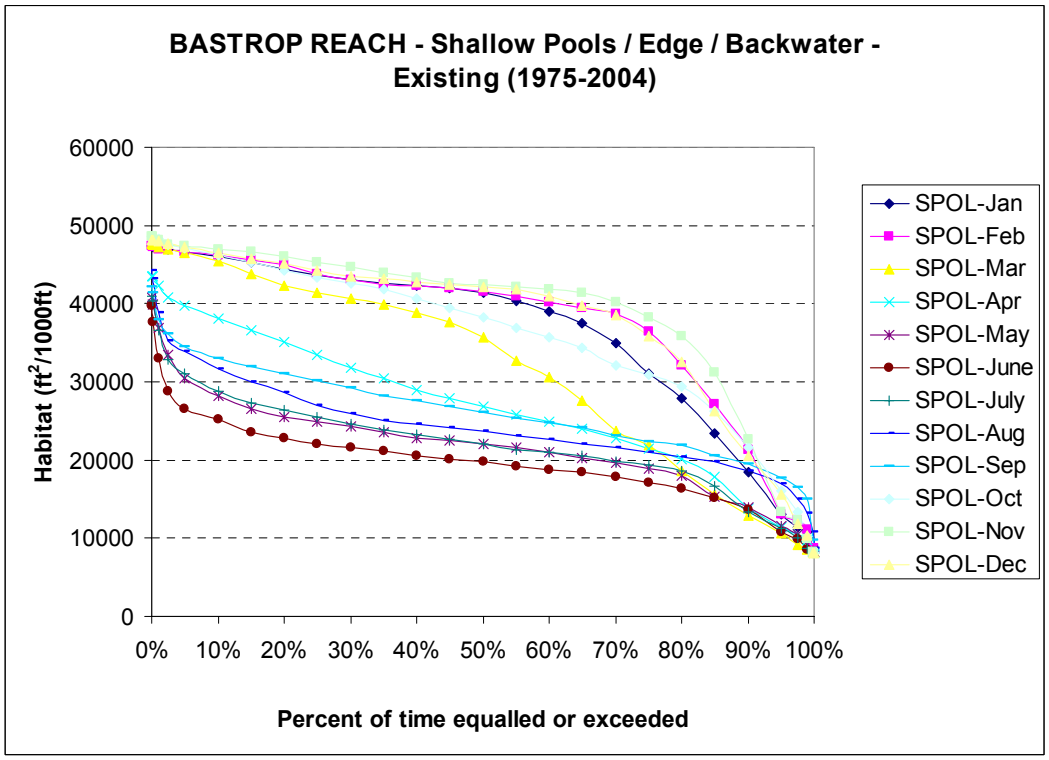


**Figure 4.9.** Habitat durations for shallow pools/edge/backwater for all months at the Bastrop Reach based on the existing flow regime.

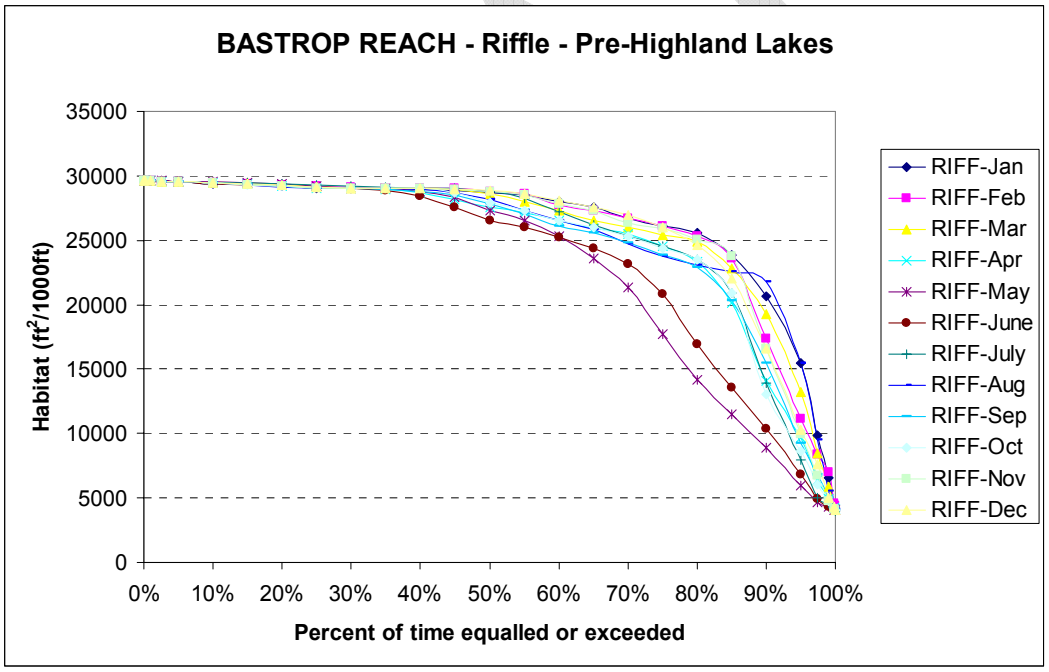


**Figure 4.10.** Habitat durations for riffles for all months at the Bastrop Reach based on the pre-1940 flow regime.

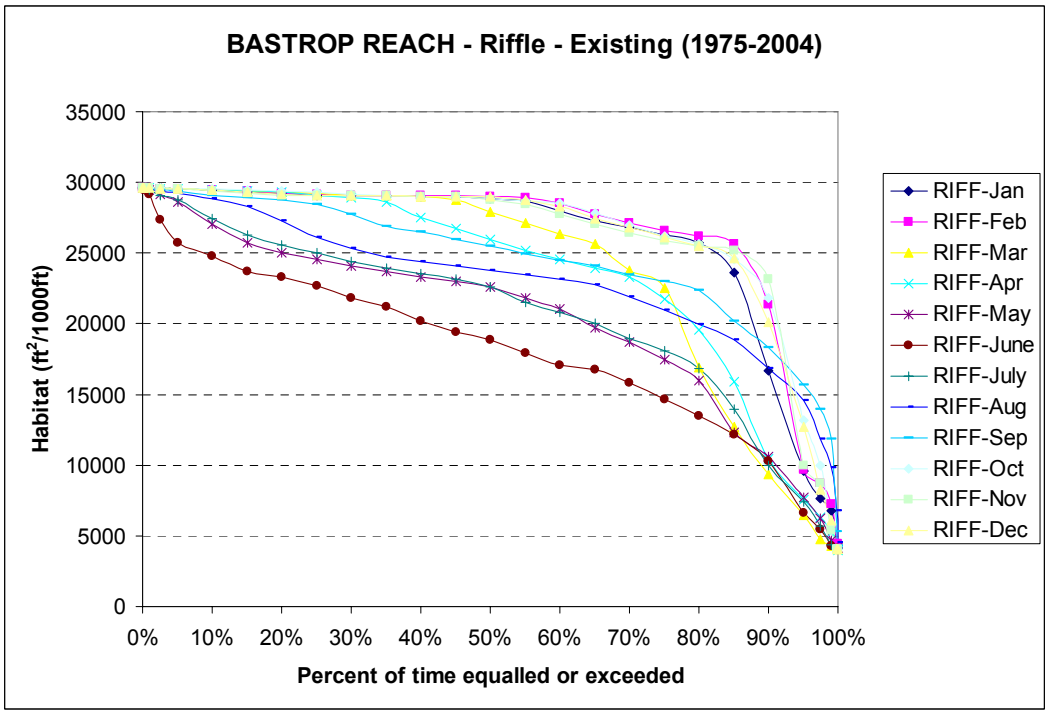


**Figure 4.11.** Habitat durations for riffles for all months at the Bastrop Reach based on the existing flow regime.

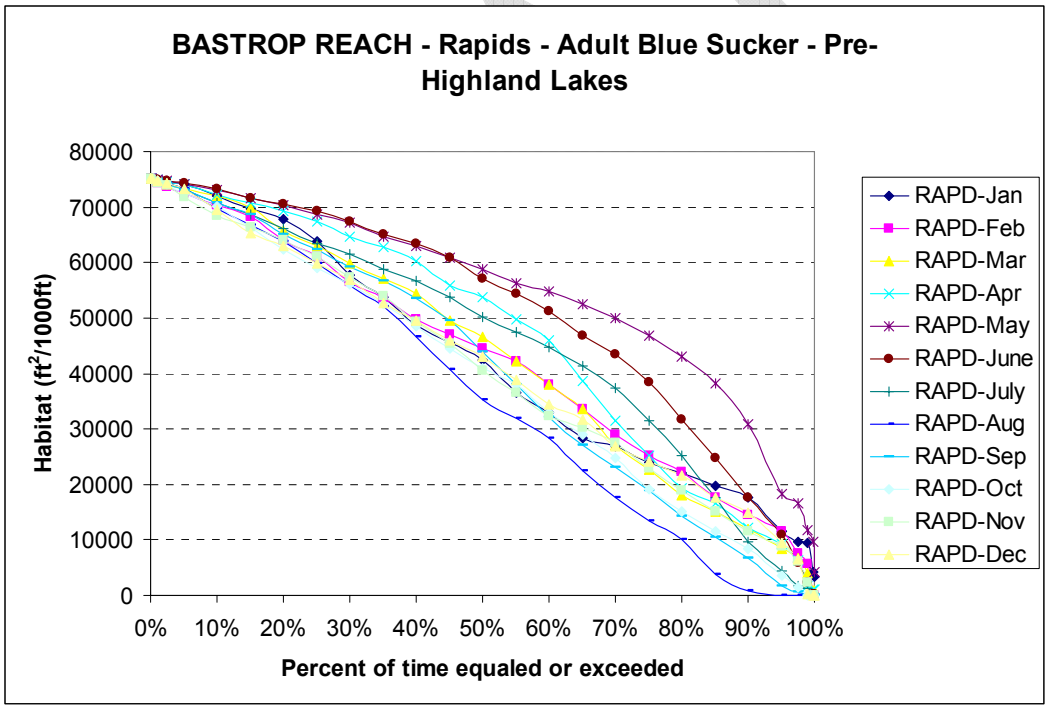


**Figure 4.12.** Habitat durations for rapids/adult blue sucker for all months at the Bastrop Reach based on the pre-1940 flow regime.

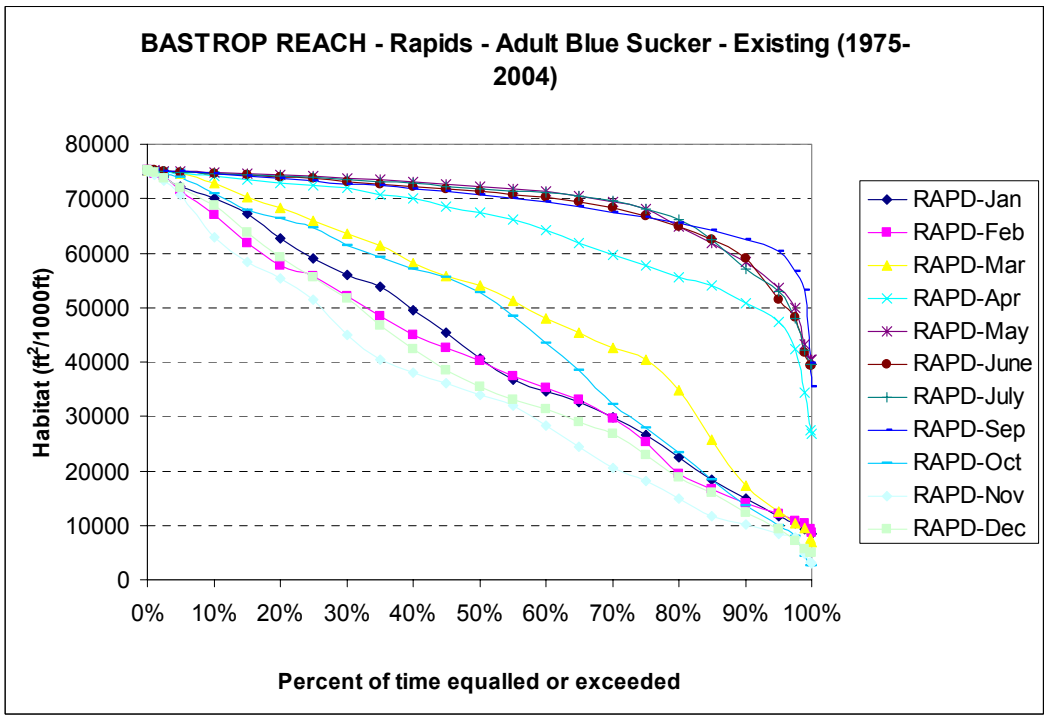


**Figure 4.13.** Habitat durations for rapids/adult blue sucker for all months at the Bastrop Reach based on the existing flow regime.

Habitat duration curves for each reach for each applicable habitat category per flow regime are included in Appendix D. Figures 4.8-4.13 and Appendix D figures for the Austin, Bastrop, Smithville, and Columbus reaches illustrate the differences in simulated habitat for both the existing and pre-Highlands lakes base flow conditions. The habitat time series modeling illustrates that both the existing and pre-1940 flow regimes provide all types of simulated habitat year round. The tighter fit lines for the Pre-Highland lakes condition relates to a higher level of habitat diversity year round. The spread in the lines for the existing condition reflects greater amounts of habitat are available during certain times of the year and less year round habitat diversity is achieved.

Figures 4.14-4.15 were included to highlight the major differences in simulated habitat per flow regime during a winter (January) and summer (July) month at the Bastrop reach.

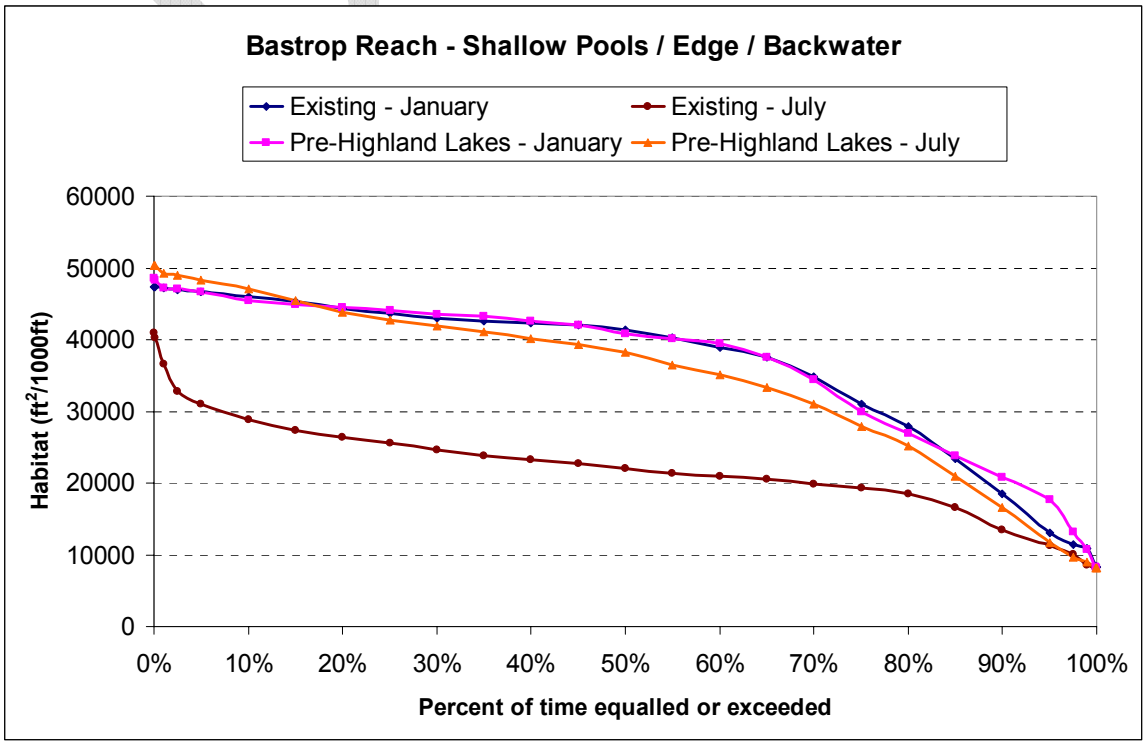


**Figure 4.14.** Habitat durations for shallow pools/edge/backwater for January and July at the Bastrop Reach for both flow regimes.

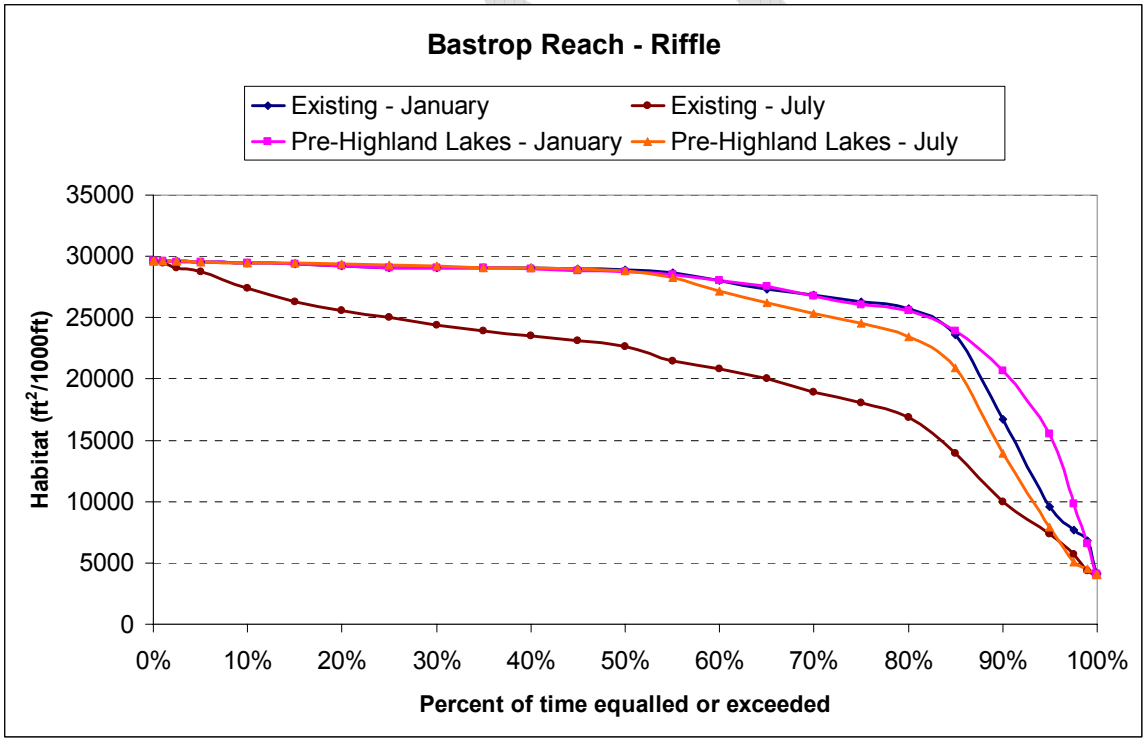


**Figure 4.15.** Habitat durations for riffles for January and July at the Bastrop Reach for both flow regimes.

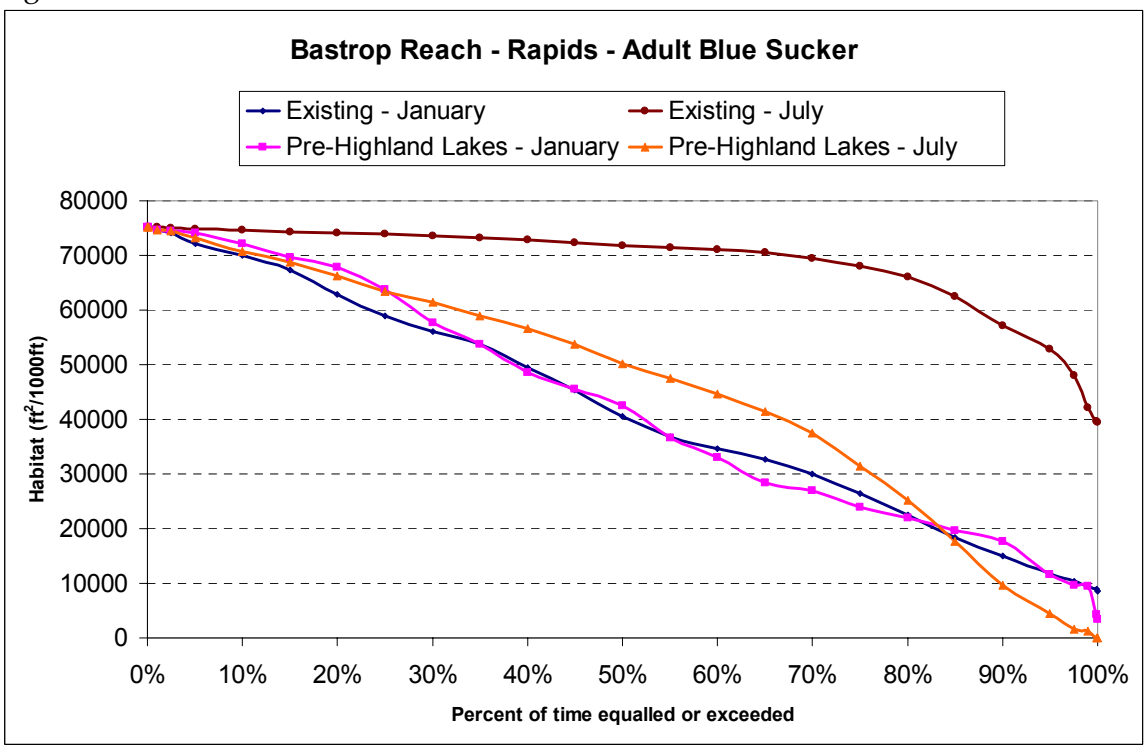


**Figure 4.16.** Habitat durations for rapids/adult blue sucker for January and July at the Bastrop Reach for both flow regimes.

The higher summer time flows under the existing regime fosters deeper and faster habitats (i.e Rapids, Figure 4.16) while decreasing shallow water habitats and riffles (Figures 4.14 and 4.15). Most of the time the winter conditions between the two regimes are similar. However, at the low flow extreme (>90$^{th}$ percent exceedence), the lower winter flows under the existing flow regime provide less shallow water and riffle habitat but the deeper and faster habitats remain similar.

The Wharton reach is the exception to the trends discussed above as withdrawals in this reach over the last 30 years have kept discharge conditions more similar to pre-1940 conditions than the other upstream reaches (Appendix D).

### 4.2.3 Natural Time Series Selection

An evaluation of the hydrology (Section 3.1), habitat time series modeling results (Section 4.2.2, Appendix D), sediment transport analysis (Section 3.3), and water quality results (Section 3.4) indicate that the pre-1940 flow regime does differ from the existing flow regime. The major differences between flow regimes are highlighted in Table 4.3.

**Table 4.3**. Summary of physical and biological differences predicted between the existing and pre-1940 flow regimes.

| | FLOW REGIME | |
|---|---|---|
| Simulated Parameters | Existing (1975-2004) | Pre-1940 (Natural) |
| Habitat Diversity | Less habitat diversity year round, particularly during summer irrigation releases | Habitat diversity present year round. |
| Larval / Juvenile Edge Habitat | Limited edge aquatic habitat during post-spawning months (May – July) | More simulated edge aquatic habitat than existing, but still reduced due to existing channel morphology. |
| Pre-Spawning migration – *Cycleptus elongatus* | Lower flows in Winter months reduce water depth thus causing more restriction to migration. | Higher flows in the Winter months cause greater water depths and thus, ease of migration. |
| Sediment Transport – Edge Habitat | Summer time base flows are high enough to provide constant sand transport, thus causing less edge aquatic habitat and adjacent riparian development. | Reduced summer time base flows mean greater potential for aquatic and riparian habitat diversity and river edge stabilization. |
| Sediment Transport - Deeper Habitats | More base flow sediment transport means more settling of materials in low-velocity habitats, thus reducing deep run/pool function. | Less sediment deposition into deep run/pools maintains this habitat function. |
| Sediment Transport - macroinvertebrate stability | More base flow sediment transport reduces substrate stability thus reducing marcroinvertebrate productivity and species richness. | Less base flow sediment transport supports substrate stability and increases macroinvertebrate productivity and species richness. |
| Water Quality | Flow maintained at levels high enough to create high dissolved oxygen (>6.0 mg/L) even during the hot summer-time months. | Modeling demonstrates that lower summertime flows still produces good dissolved oxygen (>5.0 mg/L). Greater potential for occasional low DO events during summer. |

In summary, simulated habitat conditions for the pre-1940 regime show a greater diversity of habitat conditions year round, an improvement in edge habitat, and better conditions for pre-spawning migration for adult blue suckers. Conversely, the pre-1940 regime provides

considerably less deep, fast habitat in the summer months which could be inversely critical relative to potential water quality impacts during these time periods. This is important from both a regulatory and ecological point of view. From a regulatory standpoint, water quality exceedences are to be avoided, thus making this scenario unfavorable. However, under a natural flow regime, these periods did occur, thus crafting the ecological makeup of the river system. The ecology of a river system is defined by extreme events on both the high-flow and low-flow end of the spectrum and having occasional extremes supports populations of native species who have evolved life history strategies in response to the natural flow regime (Poff and Allan 1997, Bunn and Arthington 2002).

Other factors to be considered in the base flow determinations are the sediment transport characteristics and riparian recruitment. As discussed in Section 3.3, under existing summertime conditions where flows are typically held at approximately 1,000 - 2,000 cfs, a large portion of the streambed in the river is constantly in motion. Under these existing conditions, the sand moving through riffle and run areas most likely accumulates in the flattest-gradient, lowest-velocity pool and backwater areas of the river. In a more natural flow regime with reduced transport rates, sediment would accumulate less rapidly in these low velocity habitats, and they would be retained as deeper, more diverse habitat features. In addition, less winnowing/transport of sand would occur along the channel margins. New shoreline sand deposits would likely develop in areas that are not already dominated by sand, providing more gradually-sloping banks and greater near-bank topographic complexity. These shoreline sand deposits could also provide establishment sites for emergent and herbaceous riparian vegetation. This type of vegetation provides cover and shade for shallow, slackwater-type habitats, and serves as a source of nutrients and organic matter. This type of non-woody vegetation provides ecosystem benefits as long as it is periodically scoured by high flows so that stands do not reach densities that would have negative impacts in terms of reducing channel capacity. Reduced baseflows could also lead to new deposits of fine gravel in steep riffle areas. A return to more natural summertime baseflow conditions would likely lead to more stable (i.e., less mobile) substrate conditions, which could have positive implications for macroinvertebrate productivity and species richness.

The TIFP (Draft 2006) proposes, "The goal of ensuring a 'sound ecological environment' has been equated to maintaining the ecological integrity and conserving the biological diversity of riverine ecosystems. In order to meet these goals, the Agencies recognize the importance of maintaining the natural habitat diversity, hydrologic character, and water quality of river systems." The TIFP (Draft 2006) describes "sound ecological environment" as, "a functioning ecosystem characterized by intact natural processes, resilience, and a balanced, integrated, and adaptive community of organisms comparable to that of the natural habitat of a region."

For the ecological advantages discussed above and to be consistent with the goals of the TIFP, the pre-1940 time period was selected to be used for the development of instream flow guidelines. Hardy et al. (2006) states, "Utilizing the characteristics of the natural flow regime as a "template" is widely accepted and applied at the international level as illustrated by work under the EU Water Framework Directive (Directive 2000/60/EC) by Hardy et al., (2006), Acreman et al., (2006) under EU Water Framework Directive (Directive 2005/48/EC), Dunbar et al., (1998), and Tharme and King (1998) in South Africa under river ecosystem protection legislative mandates." Therefore, the steps starting with the physical habitat time series

(flowchart reference #10 [Figure 4.1]) and beyond focus on the pre-1940 flow regime, while considering modifications that may be necessary because of existing anthropogenic influences. Since the base flow component of the analysis will focus on this condition, so must the pulse flow component of the guidelines. This re-aggregation of base flow and pulse flow is important to maintain the ecological integrity of the lower Colorado River. As noted in the hydrologic discussion (Section 3.1) the magnitude of extreme flow events has been greatly reduced since the implementation of the Highland Lakes dams. Pre-1940 extreme events cannot be re-created as that magnitude of flow would flood many of the downstream cities along the river. Therefore, the overbanking flow guidelines development will focus on existing conditions.

### 4.2.4 Habitat Duration Curves

As described above, habitat duration curves were computed for each of the habitat categories at each reach (Appendix D). The information from these curves was then converted into habitat percent exceedence tables and evaluated based on habitat diversity, percent of maximum habitat, percent declines in habitat, and overall summaries of conditions. When evaluating the seven habitat categories, all habitat guilds and adult blue sucker/rapids habitat are applied with equal weighting per month. Spawning blue sucker habitat is also weighted equally but only applied during February through April. Additionally, no adult blue sucker/rapids habitat or spawning blue sucker habitat was applied to the Wharton Reach as this type of physical habitat does not currently exist in this reach due to substrate limitations nor have blue suckers been collected in this stretch of river.

Figure 4.17 and Tables 4.4 and 4.5 display the habitat duration curves, the percent of maximum habitat, and percent decline in each of the habitat categories in the Bastrop Reach in April, respectively. The percentage of maximum table (Table 4.4) shows the percent of maximum habitat available at each of the percent exceedence levels, whereas the percent decline table (Table 4.5) shows the percentage decline between percent exceedence levels from low to high.

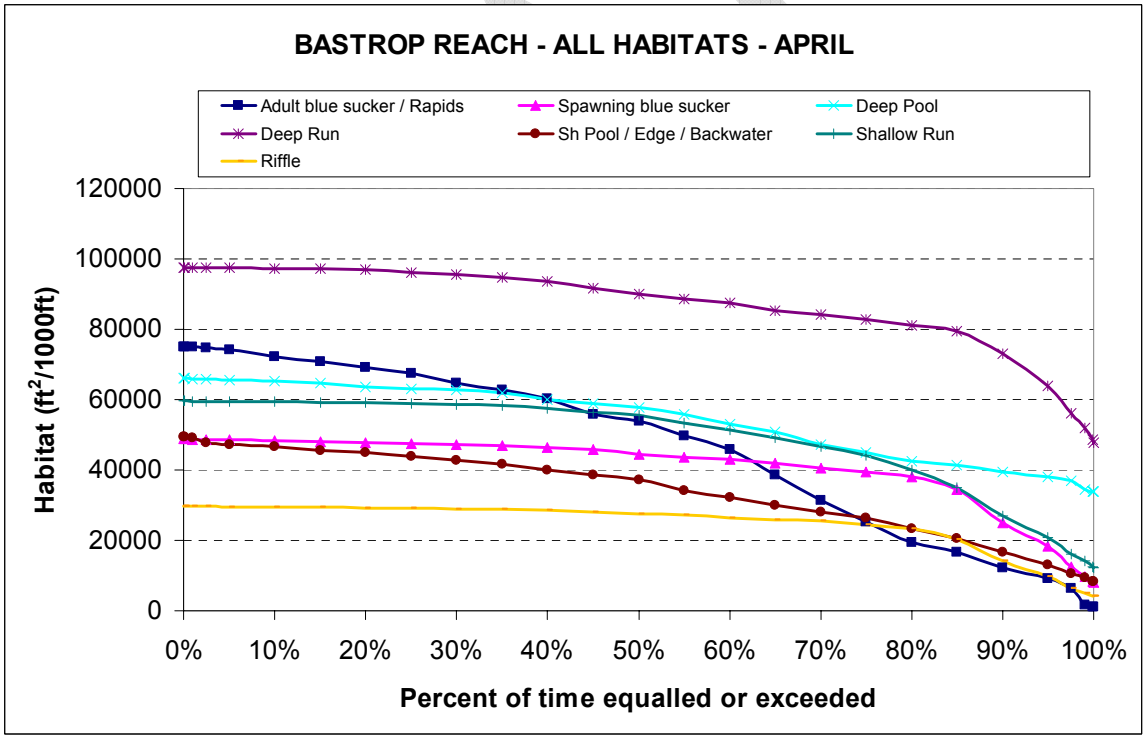


**Figure 4.17.** Habitat durations for all habitat types for April at the Bastrop Reach.

**Table 4.4.** Percentage of maximum available habitat at each percent exceedence level in April at the Bastrop Reach.

| | Percentage of Maximum Available Habitat | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedance Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 2% | 20% | 52% | 53% | 19% | 24% | 17% |
| 0.95 | 12% | 38% | 58% | 66% | 27% | 35% | 33% |
| 0.90 | 16% | 51% | 60% | 75% | 34% | 45% | 48% |
| 0.85 | 22% | 71% | 63% | 81% | 42% | 59% | 68% |
| 0.80 | 26% | 78% | 64% | 83% | 47% | 67% | 79% |
| 0.75 | 34% | 81% | 68% | 85% | 53% | 74% | 83% |
| 0.70 | 42% | 83% | 72% | 86% | 57% | 78% | 86% |
| 0.65 | 52% | 86% | 77% | 87% | 61% | 82% | 87% |
| 0.60 | 61% | 88% | 80% | 90% | 65% | 86% | 90% |
| 0.55 | 66% | 89% | 85% | 91% | 69% | 89% | 92% |
| 0.50 | 72% | 91% | 88% | 92% | 76% | 93% | 93% |
| 0.45 | 74% | 94% | 89% | 94% | 78% | 95% | 95% |
| 0.40 | 80% | 95% | 91% | 96% | 81% | 96% | 97% |
| 0.35 | 84% | 96% | 94% | 97% | 85% | 98% | 98% |
| 0.30 | 86% | 97% | 95% | 98% | 87% | 98% | 98% |
| 0.25 | 90% | 97% | 95% | 99% | 89% | 99% | 98% |
| 0.20 | 92% | 98% | 97% | 99% | 91% | 99% | 99% |
| 0.15 | 94% | 99% | 98% | 99% | 92% | 99% | 99% |
| 0.10 | 96% | 99% | 99% | 100% | 94% | 100% | 99% |
| 0.05 | 99% | 100% | 100% | 100% | 96% | 100% | 100% |
| 0.01 | 99% | 100% | 100% | 100% | 97% | 100% | 100% |

**Table 4.5.** Percent decline in maximum available habitat between percent exceedence levels in April at the Bastrop Reach.

| Percent Decline in Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedance Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 82% | 47% | 10% | 19% | 28% | 32% | 49% |
| 0.95 | 25% | 27% | 3% | 13% | 21% | 23% | 31% |
| 0.90 | 27% | 28% | 5% | 8% | 19% | 23% | 30% |
| 0.85 | 14% | 9% | 3% | 2% | 11% | 13% | 13% |
| 0.80 | 23% | 4% | 5% | 2% | 12% | 9% | 5% |
| 0.75 | 20% | 2% | 5% | 2% | 7% | 5% | 4% |
| 0.70 | 19% | 3% | 7% | 1% | 6% | 5% | 2% |
| 0.65 | 16% | 3% | 4% | 3% | 7% | 4% | 2% |
| 0.60 | 8% | 1% | 5% | 1% | 6% | 4% | 2% |
| 0.55 | 8% | 2% | 3% | 2% | 8% | 4% | 1% |
| 0.50 | 4% | 3% | 2% | 2% | 3% | 2% | 2% |
| 0.45 | 7% | 1% | 2% | 2% | 4% | 2% | 2% |
| 0.40 | 4% | 1% | 3% | 1% | 4% | 1% | 1% |
| 0.35 | 3% | 1% | 1% | 1% | 2% | 1% | 0% |
| 0.30 | 4% | 1% | 0% | 1% | 2% | 0% | 0% |
| 0.25 | 3% | 1% | 1% | 1% | 3% | 0% | 0% |
| 0.20 | 2% | 1% | 2% | 0% | 1% | 0% | 1% |
| 0.15 | 2% | 0% | 1% | 0% | 2% | 0% | 0% |
| 0.10 | 2% | 0% | 1% | 0% | 1% | 0% | 0% |
| 0.05 | 1% | 0% | 0% | 0% | 4% | 0% | 0% |

As there are five reaches and twelve months, a total of 60 tables were generated for each evaluation technique. As previously referenced, all the habitat duration curves are presented in Appendix D and the series of tables for each reach are presented in Appendix E.

### 4.2.5 LSWP Subsistence Flow Recommendation

Selection of a habitat percent exceedence level, flowchart reference #11 (Figure 4.1) is needed to initiate flow recommendation development. Hardy et al. (2006) selected the 95% habitat exceedence level for their ecological base flow determination citing several international studies that led to that recommendation. The ecological base flow category as defined by Hardy et al. (2006) is equivalent to the subsistence flow for the lower Colorado River. Therefore, we initiated an evaluation of the 95% habitat exceedence level at each of our five reaches.

Table 4.6 displays a summary of the percent of maximum habitat area for each reach according to 55$^{th}$ -99$^{th}$ percent exceedence levels of habitat area. The count columns reflect how many habitat categories out of 75 possible (6 habitat categories * 12 months = 72 + spawning blue sucker habitat for 3 months = 75 total) for Austin, Bastrop, Smithville, and Columbus reaches have zero habitat area, <5% of maximum, <10% of maximum, etc. For Wharton, there are only 60 total as spawning blue sucker habitat and adult blue sucker/rapids habitat are not applied. The Annual Habitat Average columns show the twelve month average percent of maximum habitat (3 months [February-April] for spawning blue suckers) per habitat guild or life stage. The total column is an average of the seven habitat categories. It is important to recognize that this is a summary and the annual averages per habitat category can mask the intra-year variability. Therefore, a detailed evaluation of all the habitat duration curves and tables (presented in Appendices D and E) was conducted along with a visual evaluation of the simulated habitat output. Overall, viewing the count and annual averages together does provide a good summary of habitat conditions.

**Table 4.6.** Summary of the 55th -99th percent exceedence levels of habitat area presented as percent of maximum habitat for each reach. Recommended Subsistence flow conditions highlighted.

| Percent of Maximum Habitat | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reach | % Exc. level | Count [1] | | | | | Annual Habitat Average[2] | | | | | | | |
| | | Zero | < 5% | < 10% | < 25% | < 50% | Rapids / Adult blue sucker | Spawn blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle | TOTAL |
| **Austin** | 99 | 4 | 21 | 34 | 51 | 73 | 3% | 7% | 30% | 45% | 11% | 11% | 4% | 17% |
| | 95 | 1 | 5 | 15 | 41 | 64 | 7% | 24% | 33% | 58% | 22% | 24% | 14% | 26% |
| | 90 | 1 | 1 | 6 | 20 | 61 | 11% | 45% | 34% | 65% | 31% | 38% | 29% | 35% |
| | 85 | 0 | 1 | 3 | 14 | 50 | 14% | 61% | 36% | 69% | 38% | 50% | 43% | 43% |
| | 80 | 0 | 0 | 1 | 11 | 37 | 18% | 68% | 38% | 73% | 45% | 61% | 55% | 49% |
| | 75 | 0 | 0 | 0 | 9 | 31 | 22% | 71% | 40% | 76% | 53% | 68% | 62% | 54% |
| | 70 | 0 | 0 | 0 | 8 | 26 | 26% | 76% | 41% | 79% | 62% | 74% | 67% | 59% |
| | 65 | 0 | 0 | 0 | 5 | 23 | 31% | 78% | 43% | 82% | 69% | 79% | 72% | 63% |
| | 60 | 0 | 0 | 0 | 1 | 22 | 36% | 82% | 46% | 85% | 74% | 83% | 77% | 67% |
| | 55 | 0 | 0 | 0 | 0 | 18 | 41% | 84% | 49% | 88% | 79% | 85% | 81% | 71% |
| **Bastrop** | 99 | 3 | 8 | 10 | 46 | 55 | 4% | 24% | 53% | 54% | 19% | 24% | 18% | 28% |
| | 95 | 0 | 3 | 4 | 19 | 50 | 11% | 43% | 57% | 66% | 27% | 36% | 35% | 39% |
| | 90 | 0 | 1 | 2 | 11 | 35 | 17% | 60% | 60% | 75% | 35% | 49% | 53% | 49% |
| | 85 | 0 | 1 | 1 | 9 | 26 | 23% | 76% | 63% | 79% | 43% | 61% | 69% | 57% |
| | 80 | 0 | 0 | 0 | 4 | 18 | 29% | 80% | 66% | 82% | 51% | 71% | 77% | 63% |
| | 75 | 0 | 0 | 0 | 1 | 12 | 35% | 83% | 68% | 84% | 57% | 78% | 81% | 68% |
| | 70 | 0 | 0 | 0 | 1 | 12 | 40% | 86% | 71% | 86% | 63% | 84% | 85% | 72% |
| | 65 | 0 | 0 | 0 | 0 | 9 | 46% | 88% | 74% | 88% | 68% | 88% | 88% | 76% |
| | 60 | 0 | 0 | 0 | 0 | 6 | 52% | 90% | 77% | 89% | 72% | 90% | 91% | 79% |
| | 55 | 0 | 0 | 0 | 0 | 3 | 57% | 92% | 80% | 91% | 74% | 92% | 93% | 82% |
| **Smithville** | 99 | 5 | 23 | 49 | 51 | 66 | 2% | 5% | 53% | 38% | 6% | 8% | 3% | 18% |
| | 95 | 1 | 6 | 21 | 48 | 54 | 6% | 18% | 55% | 56% | 13% | 21% | 11% | 27% |
| | 90 | 1 | 2 | 8 | 28 | 50 | 11% | 33% | 58% | 70% | 22% | 34% | 24% | 36% |
| | 85 | 0 | 1 | 3 | 16 | 41 | 15% | 49% | 60% | 77% | 33% | 48% | 39% | 45% |
| | 80 | 0 | 0 | 1 | 13 | 25 | 19% | 63% | 62% | 80% | 44% | 59% | 52% | 53% |
| | 75 | 0 | 0 | 0 | 10 | 18 | 24% | 69% | 64% | 83% | 53% | 67% | 61% | 59% |
| | 70 | 0 | 0 | 0 | 7 | 16 | 29% | 74% | 66% | 85% | 61% | 74% | 68% | 64% |
| | 65 | 0 | 0 | 0 | 2 | 13 | 34% | 77% | 68% | 87% | 67% | 80% | 72% | 68% |
| | 60 | 0 | 0 | 0 | 0 | 12 | 39% | 80% | 71% | 89% | 72% | 84% | 76% | 72% |
| | 55 | 0 | 0 | 0 | 0 | 8 | 45% | 83% | 73% | 90% | 76% | 87% | 80% | 76% |
| **Columbus** | 99 | 0 | 4 | 8 | 51 | 53 | 8% | 23% | 53% | 59% | 16% | 18% | 14% | 28% |
| | 95 | 0 | 2 | 3 | 46 | 52 | 14% | 30% | 56% | 67% | 19% | 22% | 16% | 32% |
| | 90 | 0 | 0 | 2 | 33 | 51 | 22% | 36% | 60% | 75% | 24% | 31% | 19% | 38% |
| | 85 | 0 | 0 | 0 | 20 | 47 | 27% | 44% | 62% | 80% | 29% | 40% | 25% | 44% |
| | 80 | 0 | 0 | 0 | 10 | 38 | 33% | 54% | 65% | 84% | 36% | 49% | 35% | 51% |
| | 75 | 0 | 0 | 0 | 4 | 30 | 38% | 64% | 67% | 87% | 44% | 58% | 47% | 57% |
| | 70 | 0 | 0 | 0 | 3 | 19 | 45% | 71% | 70% | 89% | 51% | 65% | 58% | 63% |
| | 65 | 0 | 0 | 0 | 0 | 14 | 50% | 77% | 72% | 90% | 57% | 70% | 66% | 68% |
| | 60 | 0 | 0 | 0 | 0 | 8 | 56% | 83% | 75% | 91% | 63% | 75% | 74% | 73% |
| | 55 | 0 | 0 | 0 | 0 | 6 | 60% | 87% | 77% | 93% | 68% | 79% | 79% | 76% |
| **Wharton** | 99 | 0 | 0 | 0 | 31 | 48 | N/A | N/A | 35% | 64% | 24% | 25% | 13% | 32% |
| | 95 | 0 | 0 | 0 | 12 | 48 | N/A | N/A | 39% | 72% | 29% | 32% | 17% | 38% |
| | 90 | 0 | 0 | 0 | 10 | 45 | N/A | N/A | 44% | 76% | 35% | 40% | 22% | 43% |
| | 85 | 0 | 0 | 0 | 5 | 40 | N/A | N/A | 47% | 79% | 40% | 49% | 28% | 49% |
| | 80 | 0 | 0 | 0 | 2 | 28 | N/A | N/A | 50% | 81% | 47% | 58% | 37% | 54% |
| | 75 | 0 | 0 | 0 | 1 | 19 | N/A | N/A | 53% | 82% | 53% | 66% | 45% | 60% |
| | 70 | 0 | 0 | 0 | 0 | 10 | N/A | N/A | 57% | 84% | 58% | 73% | 53% | 65% |
| | 65 | 0 | 0 | 0 | 0 | 8 | N/A | N/A | 60% | 86% | 62% | 77% | 60% | 69% |
| | 60 | 0 | 0 | 0 | 0 | 3 | N/A | N/A | 64% | 88% | 66% | 82% | 68% | 73% |
| | 55 | 0 | 0 | 0 | 0 | 2 | N/A | N/A | 67% | 89% | 69% | 85% | 74% | 77% |

[1] ([Six habitat catagories * 12 months] + Spawning blue sucker habitat * 3 months = 75 Total) -- Wharton (60 possible - [Five habitat catagories * 12 months])

[2] February - April only for Spawning blue sucker

**Subsistence Flow recommended habitat percent exceedence level**

A review of the habitat duration curves, exceedence tables, and summary (Table 4.6) reveals that the 95th percent habitat exceedence level appears appropriate for a subsistence flow recommendation at the Austin, Bastrop, Smithville, and Columbus reaches. This level maintains very few instances where individual habitat categories during individual months (Count summary) go to zero or below 5%. Additionally, on average approximately 25% of the total habitat is available for these reaches at that level. At the Wharton Reach, the 99th percent exceedence level provides a comparable level of habitat to the other four reaches (Table 4.6). This happens because of the changing habitat conditions in this coastal plain reach of the lower Colorado River. Recall that rapids/adult blue sucker habitat and spawning blue sucker habitat categories are not found in the Wharton reach thus eliminating them from consideration. Mosier and Ray (1992) made a similar observation and adjustment for this lower reach, "The Egypt study reach lacked suitable habitat for *Cycleptus elongatus* adults…" Mosier and Ray (1992) went on to explain that "The disparity in base flows among the reaches is a direct result of differences in the quality of habitat available among the study reaches. Consequently, there are substantial differences in the structure of the fish community that may be found in each study reach." Ultimately Mosier and Ray (1992) recommended target flows for this lower reach that were lower than the upstream reaches "due to differences in physical habitat availability".

Upon complete evaluation, the 95th percent habitat exceedence level for the Austin, Bastrop, Smithville, and Columbus reaches and the 99th percent habitat exceedence level for the Wharton Reach was input into the flow calculation tool (flowchart reference #12 [Figure 4.1]). The flow calculation tool calculates the lowest and highest discharge that will meet all of the monthly habitat amounts generated per reach for that exceedence level (95th [four reaches] and 99th [Wharton] in this case). Table 4.7 presents the monthly flows (low end) necessary to meet percent habitat exceedence level per reach.

**Table 4.7.** Calculated monthly flows to meet the selected subsistence flow habitat percent exceedence levels per reach.

| Reach | Initially Calculated Monthly Flows (Instantaneous minimum [cfs]) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | June | July | Aug | Sep | Oct | Nov | Dec |
| **Austin** | 201 | 200 | 171 | 178 | 266 | 195 | 132 | 60 | 97 | 122 | 174 | 180 |
| **Bastrop** | 201 | 200 | 171 | 178 | 266 | 195 | 132 | 60 | 97 | 122 | 174 | 180 |
| **Smithville** | 201 | 200 | 171 | 178 | 266 | 195 | 132 | 60 | 97 | 122 | 174 | 180 |
| **Columbus** | 340 | 373 | 296 | 299 | 425 | 534 | 342 | 132 | 279 | 187 | 202 | 301 |
| **Wharton** | 311 | 299 | 202 | 267 | 301 | 367 | 209 | 106 | 186 | 145 | 171 | 200 |

On the low flow end the calculated flows were identical for reaches (Austin, Bastrop, and Smithville) using the same time series discharge data (Austin gage). Since the percentages of habitats created per these reaches at all flows were similar and the Bastrop reach is spatially located in the middle, it was chosen as the reach for which flow recommendations from this time series would be made.

The discharges presented in Table 4.7 were then evaluated for water quality and sediment transport implications. As discussed in Section 3.4, the predicted DO concentrations at

simulated discharges in this range were consistently greater than 5mg/L. The sediment transport analysis also confirms that these discharges would provide more natural sediment transport conditions.

Three flow modifications are proposed for incorporation into the subsistence flow recommendation. The first involves the addition of a specific water quality protective release for pass through at Longhorn Dam. The subsistence flow recommendation for pass though at Longhorn Dam is 50 cfs minimum. The Austin reach extends approximately 2.5 river miles before the first major CoA return flow which discharges greater than 100 cfs into the river. Under this scenario, the Decker lake diversion immediately downstream of the CoA WWTP withdraws approximately 40% of the discharge from the river, but less than 10 river miles downstream from this point, the second major CoA return flow of greater than 100 cfs is added to the river. Under the proposed 50 cfs subsistence flow release from Austin and projected CoA WWTP operating conditions, greater than 200 cfs would be present in the lower Colorado River before reaching the Utley intensive site. The water quality model predicts DO concentrations of greater than 5.0 mg/L for the entire Austin Reach with the 50 cfs headwater flow.

The second modification is an adjustment of the August and September monthly discharges for the Bastrop Reach to account for current-period conditions. The 60 cfs and 97 cfs for August and September, respectively is replaced with a 115 cfs minimum discharge during these months. Using assumptions based upon a more current flow regime, the water quality modeling predicts greater than 5.0 mg/L through the entire Austin through Smithville reaches with the 50 cfs headwater flow requirement and a minimum of 100 cfs at Bastrop during August and September. The shift to 115 cfs is an attempt to address the higher nutrient concentrations in the river today by providing slightly higher than habitat model predicted flows during the summer time months. The goal is to limit areas of stagnant water and warmer temperatures to avoid conditions favorable for excessive macrophyte growth. As no macrophyte model was developed for this project, the project team looked to existing conditions as a guide. The lowest discharge recorded at the Bastrop gage for the current (1975 to 2004) time period was 114 cfs. As discussed in Section 6, low summer time subsistence flow recommendations will need to be monitored closely relative to excess aquatic macrophyte growth, in particular exotics such as hydrilla.

The final modification addresses concerns specific to the lower Colorado River blue sucker recruitment. The inability to collect larval or juvenile blue suckers in the lower Colorado River during the existing time period and again during intensive field activities in 2004-2006 leads to recruitment concerns for this species. As such, specific studies relative to long-term monitoring will be recommended in the long-term monitoring plan prepared in 2007. However, in the interim, the project team recommends higher levels of blue sucker spawning habitat to be maintained during February and March for subsistence flow recommendations at the Bastrop reach. An increase in the discharge to 265 cfs (Bastrop) and 525 cfs (Columbus) for February and March approximately doubles (~30% to ~60%) the percent of maximum spawning habitat available during these months. The underlying assumption is that if you enhance spawning opportunities recruitment will also be enhanced. Clearly, many other factors are also important including maintaining available larval and juvenile habitat in subsequent months. Should this assumption be proven false during the completion of this project or long-term monitoring activities, adjustments to these modifications would be appropriate. This provides a glimpse

into the importance of long-term monitoring and adaptive management discussed below. Table 4.8 presents the proposed monthly LSWP subsistence flow recommendations for the lower Colorado River.

**Table 4.8.** LSWP Subsistence Flow recommendations per reach for the lower Colorado River.

| Reach | LSWP Subsistence Flow Monthly Recommendations (Instantaneous minimum [cfs]) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | June | July | Aug | Sep | Oct | Nov | Dec |
| **Austin** | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| **Bastrop** | 201 | 265 | 265 | 178 | 266 | 195 | 132 | 115 | 115 | 122 | 174 | 180 |
| **Columbus** | 340 | 525 | 525 | 299 | 425 | 534 | 342 | 132 | 279 | 187 | 202 | 301 |
| **Wharton** | 311 | 299 | 202 | 267 | 301 | 367 | 209 | 106 | 186 | 145 | 171 | 200 |

### 4.2.6 LSWP Base Flow Recommendation

The base flow recommendation development follows the same framework as subsistence but does not carry with it literature recommendations for what levels of habitat this recommendation should protect. Nor is specific guidance relative to different levels of base flows provided in the TIFP (2006). The goal of the following base flow recommendation is to assist in the year to year variability for periods outside of extreme drought. Therefore, an investigation of two base flow recommendations was pursued. A base flow greater than subsistence but still representative of dry weather conditions and a base flow more representative of average weather conditions (realizing there is really no average condition in Texas river hydrology). An evaluation of the habitat duration curves, exceedence tables, and summary (Table 4.9) reveals that the 80$^{th}$ and 60$^{th}$ percent habitat exceedence levels appear appropriate for a Base-DRY and Base-AVERAGE recommendation.

Table 4.9 shows that at the 80$^{th}$ percent habitat exceedence level, there are only two instances when individual habitat categories in any month falls to less than 10 percent of the maximum habitat. Also, habitat diversity is maintained and the total annual average percent of maximum habitat is approximately equal to or greater than 50% for each reach. The 60$^{th}$ percent habitat exceedence level exhibits only one case where an individual habitat category in any month falls to less than 25 percent of maximum habitat. At the 60$^{th}$ percent habitat exceedence level, habitat diversity is maintained and the total annual average percent of maximum habitat is approximately equal to or greater than 70 percent of the maximum habitat per reach. Table 4.10 presents the monthly flows necessary to meet these percent habitat exceedence levels at the same reaches as selected for subsistence flow recommendations.

**Table 4.9.** Summary of the 55th -99th percent exceedence levels of habitat area presented as percent of maximum habitat for each reach. Recommended Base flow conditions highlighted.

| Percent of Maximum Habitat | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reach | % Exc. level | Count [1] | | | | | Annual Habitat Average [2] | | | | | | | |
| | | Zero | < 5% | < 10% | < 25% | < 50% | Rapids / Adult blue sucker | Spawn blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle | TOTAL |
| Austin | 99 | 4 | 21 | 34 | 51 | 73 | 3% | 7% | 30% | 45% | 11% | 11% | 4% | 17% |
| | 95 | 1 | 5 | 15 | 41 | 64 | 7% | 24% | 33% | 58% | 22% | 24% | 14% | 26% |
| | 90 | 1 | 1 | 6 | 20 | 61 | 11% | 45% | 34% | 65% | 31% | 38% | 29% | 35% |
| | 85 | 0 | 1 | 3 | 14 | 50 | 14% | 61% | 36% | 69% | 38% | 50% | 43% | 43% |
| | 80 | 0 | 0 | 1 | 11 | 37 | 18% | 68% | 38% | 73% | 45% | 61% | 55% | 49% |
| | 75 | 0 | 0 | 0 | 9 | 31 | 22% | 71% | 40% | 76% | 53% | 68% | 62% | 54% |
| | 70 | 0 | 0 | 0 | 8 | 26 | 26% | 76% | 41% | 79% | 62% | 74% | 67% | 59% |
| | 65 | 0 | 0 | 0 | 5 | 23 | 31% | 78% | 43% | 82% | 69% | 79% | 72% | 63% |
| | 60 | 0 | 0 | 0 | 1 | 22 | 36% | 82% | 46% | 85% | 74% | 83% | 77% | 67% |
| | 55 | 0 | 0 | 0 | 0 | 18 | 41% | 84% | 49% | 88% | 79% | 85% | 81% | 71% |
| Bastrop | 99 | 3 | 8 | 10 | 46 | 55 | 4% | 24% | 53% | 54% | 19% | 24% | 18% | 28% |
| | 95 | 0 | 3 | 4 | 19 | 50 | 11% | 43% | 57% | 66% | 27% | 36% | 35% | 39% |
| | 90 | 0 | 1 | 2 | 11 | 35 | 17% | 60% | 60% | 75% | 35% | 49% | 53% | 49% |
| | 85 | 0 | 1 | 1 | 9 | 26 | 23% | 76% | 63% | 79% | 43% | 61% | 69% | 57% |
| | 80 | 0 | 0 | 0 | 4 | 18 | 29% | 80% | 66% | 82% | 51% | 71% | 77% | 63% |
| | 75 | 0 | 0 | 0 | 1 | 12 | 35% | 83% | 68% | 84% | 57% | 78% | 81% | 68% |
| | 70 | 0 | 0 | 0 | 1 | 12 | 40% | 86% | 71% | 86% | 63% | 84% | 85% | 72% |
| | 65 | 0 | 0 | 0 | 0 | 9 | 46% | 88% | 74% | 88% | 68% | 88% | 88% | 76% |
| | 60 | 0 | 0 | 0 | 0 | 6 | 52% | 90% | 77% | 89% | 72% | 90% | 91% | 79% |
| | 55 | 0 | 0 | 0 | 0 | 3 | 57% | 92% | 80% | 91% | 74% | 92% | 93% | 82% |
| Smithville | 99 | 5 | 23 | 49 | 51 | 66 | 2% | 5% | 53% | 38% | 6% | 8% | 3% | 18% |
| | 95 | 1 | 6 | 21 | 48 | 54 | 6% | 18% | 55% | 56% | 13% | 21% | 11% | 27% |
| | 90 | 1 | 2 | 8 | 28 | 50 | 11% | 33% | 58% | 70% | 22% | 34% | 24% | 36% |
| | 85 | 0 | 1 | 3 | 16 | 41 | 15% | 49% | 60% | 77% | 33% | 48% | 39% | 45% |
| | 80 | 0 | 0 | 1 | 13 | 25 | 19% | 63% | 62% | 80% | 44% | 59% | 52% | 53% |
| | 75 | 0 | 0 | 0 | 10 | 18 | 24% | 69% | 64% | 83% | 53% | 67% | 61% | 59% |
| | 70 | 0 | 0 | 0 | 7 | 16 | 29% | 74% | 66% | 85% | 61% | 74% | 68% | 64% |
| | 65 | 0 | 0 | 0 | 2 | 13 | 34% | 77% | 68% | 87% | 67% | 80% | 72% | 68% |
| | 60 | 0 | 0 | 0 | 0 | 12 | 39% | 80% | 71% | 89% | 72% | 84% | 76% | 72% |
| | 55 | 0 | 0 | 0 | 0 | 8 | 45% | 83% | 73% | 90% | 76% | 87% | 80% | 76% |
| Columbus | 99 | 0 | 4 | 8 | 51 | 53 | 8% | 23% | 53% | 59% | 16% | 18% | 14% | 28% |
| | 95 | 0 | 2 | 3 | 46 | 52 | 14% | 30% | 56% | 67% | 19% | 22% | 16% | 32% |
| | 90 | 0 | 0 | 2 | 33 | 51 | 22% | 36% | 60% | 75% | 24% | 31% | 19% | 38% |
| | 85 | 0 | 0 | 0 | 20 | 47 | 27% | 44% | 62% | 80% | 29% | 40% | 25% | 44% |
| | 80 | 0 | 0 | 0 | 10 | 38 | 33% | 54% | 65% | 84% | 36% | 49% | 35% | 51% |
| | 75 | 0 | 0 | 0 | 4 | 30 | 38% | 64% | 67% | 87% | 44% | 58% | 47% | 57% |
| | 70 | 0 | 0 | 0 | 3 | 19 | 45% | 71% | 70% | 89% | 51% | 65% | 58% | 63% |
| | 65 | 0 | 0 | 0 | 0 | 14 | 50% | 77% | 72% | 90% | 57% | 70% | 66% | 68% |
| | 60 | 0 | 0 | 0 | 0 | 8 | 56% | 83% | 75% | 91% | 63% | 75% | 74% | 73% |
| | 55 | 0 | 0 | 0 | 0 | 6 | 60% | 87% | 77% | 93% | 68% | 79% | 79% | 76% |
| Wharton | 99 | 0 | 0 | 0 | 31 | 48 | N/A | N/A | 35% | 64% | 24% | 25% | 13% | 32% |
| | 95 | 0 | 0 | 0 | 12 | 48 | N/A | N/A | 39% | 72% | 29% | 32% | 17% | 38% |
| | 90 | 0 | 0 | 0 | 10 | 45 | N/A | N/A | 44% | 76% | 35% | 40% | 22% | 43% |
| | 85 | 0 | 0 | 0 | 5 | 40 | N/A | N/A | 47% | 79% | 40% | 49% | 28% | 49% |
| | 80 | 0 | 0 | 0 | 2 | 28 | N/A | N/A | 50% | 81% | 47% | 58% | 37% | 54% |
| | 75 | 0 | 0 | 0 | 1 | 19 | N/A | N/A | 53% | 82% | 53% | 66% | 45% | 60% |
| | 70 | 0 | 0 | 0 | 0 | 10 | N/A | N/A | 57% | 84% | 58% | 73% | 53% | 65% |
| | 65 | 0 | 0 | 0 | 0 | 8 | N/A | N/A | 60% | 86% | 62% | 77% | 60% | 69% |
| | 60 | 0 | 0 | 0 | 0 | 3 | N/A | N/A | 64% | 88% | 66% | 82% | 68% | 73% |
| | 55 | 0 | 0 | 0 | 0 | 2 | N/A | N/A | 67% | 89% | 69% | 85% | 74% | 77% |

[1] ([Six habitat catagories * 12 months] + Spawning blue sucker habitat * 3 months = 75 Total) -- Wharton (60 possible - [Five habitat catagories * 12 months])

[2] February - April only for Spawning blue sucker

**Base Flow - DRY (80) recommended habitat percent exceedence level**

**Base Flow - AVERAGE (60) recommended habitat percent exceedence level**

**Table 4.10.** Calculated monthly flows to meet the selected base flow habitat percent exceedence levels per reach.

| Reach | Initially Calculated Monthly Flows - Base DRY (80th) (Instantaneous minimum [cfs]) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | June | July | Aug | Sep | Oct | Nov | Dec |
| **Bastrop** | 303 | 306 | 265 | 277 | 559 | 404 | 335 | 187 | 228 | 237 | 273 | 300 |
| **Columbus** | 487 | 590 | 525 | 554 | 966 | 967 | 570 | 310 | 405 | 356 | 480 | 464 |
| **Wharton** | 487 | 590 | 525 | 554 | 974 | 972 | 570 | 310 | 405 | 356 | 480 | 464 |
| | Initially Calculated Monthly Flows - Base AVERAGE (60th) (Instantaneous minimum [cfs]) | | | | | | | | | | | |
| | Jan | Feb | Mar | Apr | May | June | July | Aug | Sep | Oct | Nov | Dec |
| **Bastrop** | 418 | 480 | 480 | 613 | 796 | 708 | 590 | 368 | 409 | 418 | 410 | 435 |
| **Columbus** | 828 | 895 | 1020 | 977 | 1316 | 1440 | 895 | 516 | 610 | 741 | 755 | 737 |
| **Wharton** | 828 | 895 | 1024 | 999 | 1380 | 1495 | 895 | 516 | 610 | 741 | 755 | 737 |

The DO modeling and sediment transport analysis confirm that these discharges would be acceptable as base flow recommendations. These discharges also provide greater than 80 percent of the maximum available spawning blue sucker habitat and thus, further modifications during February and March were not proposed. Table 4.11 presents the proposed monthly LSWP base flow recommendations for the lower Colorado River, which are the same as the initially calculated monthly flows.

**Table 4.11.** LSWP Base Flow (DRY and AVERAGE) recommendations per reach for the lower Colorado River.

| Reach | LSWP Base - DRY Monthly Flow Recommendations (Instantaneous minimum [cfs]) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | June | July | Aug | Sep | Oct | Nov | Dec |
| **Bastrop** | 303 | 306 | 265 | 277 | 559 | 404 | 335 | 187 | 228 | 237 | 273 | 300 |
| **Columbus** | 487 | 590 | 525 | 554 | 966 | 967 | 570 | 310 | 405 | 356 | 480 | 464 |
| **Wharton** | 487 | 590 | 525 | 554 | 974 | 972 | 570 | 310 | 405 | 356 | 480 | 464 |
| | LSWP Base - AVERAGE Monthly Flow Recommendations (Instantaneous minimum [cfs]) | | | | | | | | | | | |
| | Jan | Feb | Mar | Apr | May | June | July | Aug | Sep | Oct | Nov | Dec |
| **Bastrop** | 418 | 480 | 480 | 613 | 796 | 708 | 590 | 368 | 409 | 418 | 410 | 435 |
| **Columbus** | 828 | 895 | 1020 | 977 | 1316 | 1440 | 895 | 516 | 610 | 741 | 755 | 737 |
| **Wharton** | 828 | 895 | 1024 | 999 | 1380 | 1495 | 895 | 516 | 610 | 741 | 755 | 737 |

## 4.3 Pulse Flow and Overbanking Flow Development

Mosier and Ray (1992) stated that "Periodic spates of high flows are needed to prevent siltation and dense macrophyte growth." Mosier and Ray (1992) did not include any pulse flow recommendations in their report but did recommend that the frequency and duration of maintenance (pulse) flows should be evaluated based on historical flow data on the lower Colorado River. As limited data was available for sediment transport and ecological function of pulse flows on the lower Colorado River, the project team based the pulse and overbanking flow recommendations on sediment transport analysis conducted during this study and a hydrologic (IHA) analysis of existing and pre-1940 flow regimes (Section 3.3).

### 4.3.1 LSWP Pulse Flow Recommendation

Two levels of pulse flows are recommended to support the ecological function of the river. These include base pulses and high flow pulses. The base pulse recommendation involves flows in the 2,000 to 3,000 cfs range. This magnitude of flow is recommended 8 to 10 times annually with a 3 to 5 day duration each. The ecological functions to be supported by these flows include 1) nutrient and organic matter exchange with streamside vegetation, 2) partial flushing of accumulated silt and sand material from riffles and gravel bars, 3) partial removal of herbaceous riparian vegetation on low elevation depositional features, limiting the encroachment of woody riparian vegetation on low elevation depositional features thus preventing the loss of channel capacity, and 4) relief from extended low flows during warm periods that can lead to elevated temperatures and critical dissolved oxygen concentrations.

Less frequent greater magnitude high flow pulses are also recommended. The high flow pulse magnitude recommended is approximately 8,000 cfs. A duration of 2 to 3 days for each pulse is recommended along with a frequency of two events within a three year period. These high flow pulses would mobilize the surface armor layer in steep riffle habitats such as the LA Site, mobilize smaller gravel (10mm diameter size) fractions in less-steep riffles such as CO Site, and mobilize significant volumes of sand in flat pool areas such as those similar to CO gage area. The ecological functions supported by these processes include:

- flushing of spawning areas (riffles and cobble bars);
- partial reworking of physical features (sand bars, cobble bars, etc.) to support habitat diversity;
- maintenance of deep habitat availability;
- providing nutrient and organics exchange both within the river and adjacent lower riparian tier;
- aquatic and riparian vegetation scouring
    - periodically scour herbaceous riparian vegetation to limit stand densities and help maintain channel capacity;
    - limiting the establishment of "high-strength", woody vegetation adjacent to low-flow channel;
- providing moisture to riparian plants;
- providing sediment deposition and seed dispersal to lower riparian tier.

**Monitoring Recommendations**

As limited cause and effect pulse flow data exist for the lower Colorado River, the project team recommends some additional monitoring to better define these ecological responses to the proposed pulse flow recommendations. One activity would be measuring bedload transport during lower-magnitude "base pulse" events to help determine whether the modeled sand and gravel transport thresholds are accurate. Because of the logistical challenges and cost of field-measuring total bedload transport on a large river such as the lower Colorado, we recommend focusing bedload transport measurements in specific habitats for specific size fractions, and that surrogate techniques such as painted rock studies and pre- and post-base pulse event transect surveys be investigated. These techniques would be helpful in determining the threshold flow for gravel transport in riffles and the effectiveness of specific flow events in scouring pool areas. Pre-and post- high flow event surveys and photography could also be used to help determine the flow magnitude that effectively scours aquatic and herbaceous/emergent riparian vegetation.

The results of these monitoring studies could be used to determine whether or not the proposed pulse flows recommendations are adequate to protect ecosystem resources, and, if not, guideline modifications may be required. This type of monitoring and potential response documents the linkage of recommendations and adaptive management. If logistically possible, monitoring studies that examine the effects of "test flow" dam releases of varying magnitudes, durations, and rising/falling limb rates could be used to help refine dam operations (within current operational and permitted constraints) to maximize the ecosystem benefits of high flow pulse events.

### 4.3.2 LSWP Overbanking Flow Recommendation

Based on the results of our sediment transport analyses (Section 3.3), we identify flows in the range of 27,000-32,000 cfs as an "overbank flow" recommendation. Flows of this magnitude match the gravel-based effective discharge values calculated at the analysis transects, and based on hydraulic calculations would be able to mobilize the coarse armor layer at the transects (gravel particles between 20-40 mm in size). Flows in this range would provide for channel maintenance (i.e., maintenance of channel capacity) and would thoroughly flush accumulated fine sediments from important gravel bar and riffle habitats. The overbank flow recommendation should also effectively scour accumulated sediments from pool habitats and periodically re-establish greater pool depths. In addition, flows of 27,000-32,000 cfs would inundate low floodplain areas adjacent to the riffle transects analyzed, providing for lateral floodplain and riparian connectivity, floodplain maintenance/nutrient deposition, and recruitment of organic material and woody debris. Flows of this magnitude are recommended with a frequency of 1 in 3 years (i.e., with a 3-yr recurrence interval) and a minimum duration of 3 days.

**Monitoring Recommendations**

Although the sediment analysis transects were calibrated based on project team field measurements up to 8,000 cfs and using outputs from LCRA's HEC-RAS model, transect hydraulics were not able to be field-verified at overbank flood flow levels as part of this

effort. As field measurements of bedload transport were not made as part of this study, it is difficult to know exactly how long of a duration is required to fully mobilize the substrate armor layer and enter the "equal mobility" sediment transport phase. However, studies and bedload measurements on other rivers have found that multi-day durations of high flows are needed to fully mobilize the entire bed and allow for effective flushing/channel maintenance. Therefore, we recommend completing field visits, water surface elevation surveys, and bedload transport measurements in riffle and gravel bar areas at flows in the 27,000-32,000 range to confirm that low floodplains are inundated, that surface/armor layer is in active transport, and recommended 3-day overbank flow duration is adequate to achieve full mobilization of the coarser sediment fractions. These measurements and observations could be used to help refine the recommended overbank flood flow magnitude, duration, and frequency to ensure that all relevant ecological processes are adequately protected.

## 4.4 LSWP Flow Regime Guidelines Summary

As described in Section 4.3, specific flow recommendations (subsistence flows, base flows, pulse flows, and overbank flows) specific to the LSWP are recommended for the lower Colorado River. Figures 4.18-4.20 summarize the integration of those recommendations into one proposed regime for the Bastrop, Columbus, and Wharton reaches of the lower Colorado River and provide an overview of ecological functions supported by each flow category. Although each reach has a proposed regime, the pulse flows and overbanking flows are the same amongst reaches while subsistence and base flows differ.

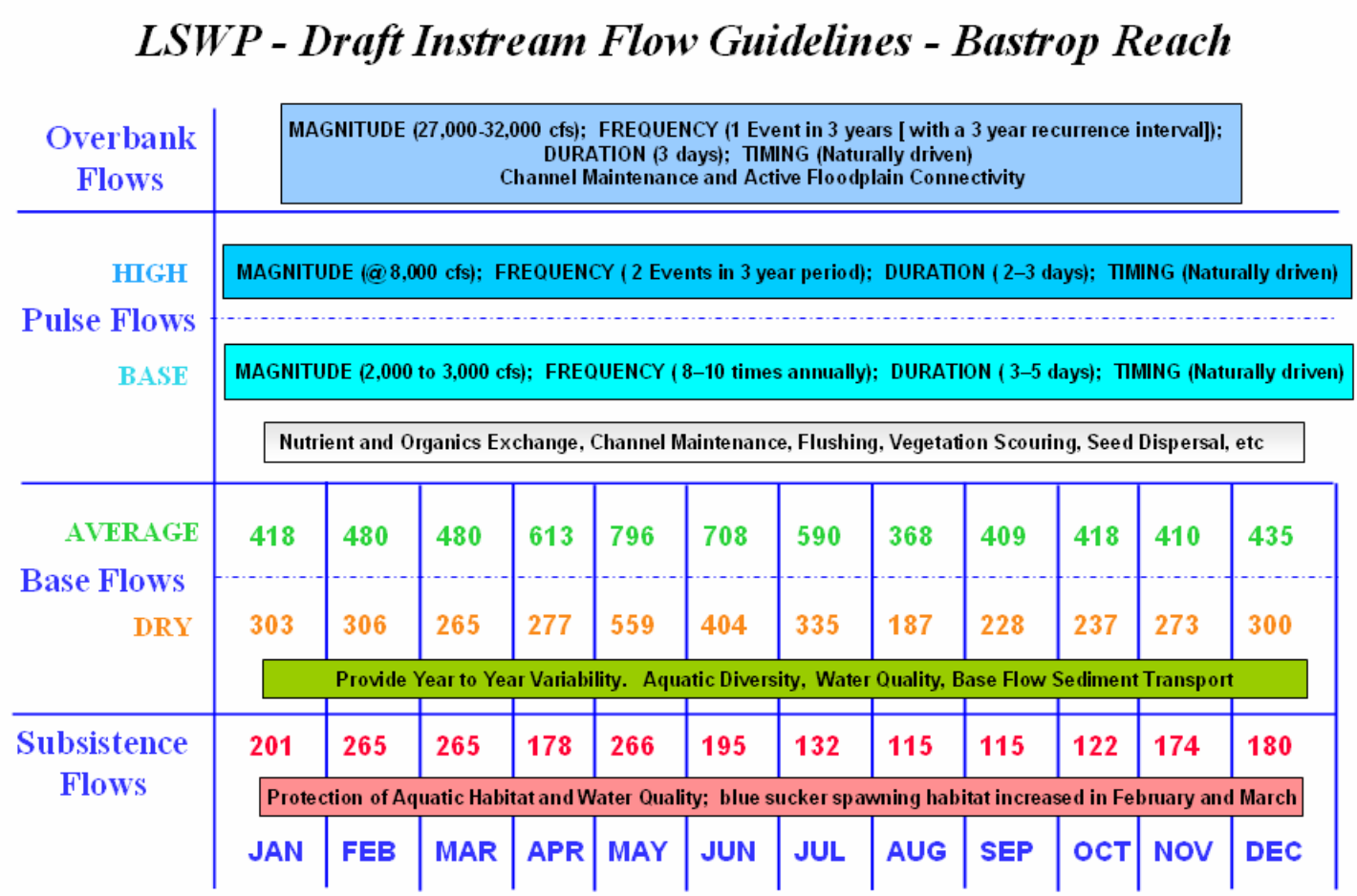


**Figure 4.18.** LSWP Draft Instream Flow Guidelines Flow Regime at Bastrop.

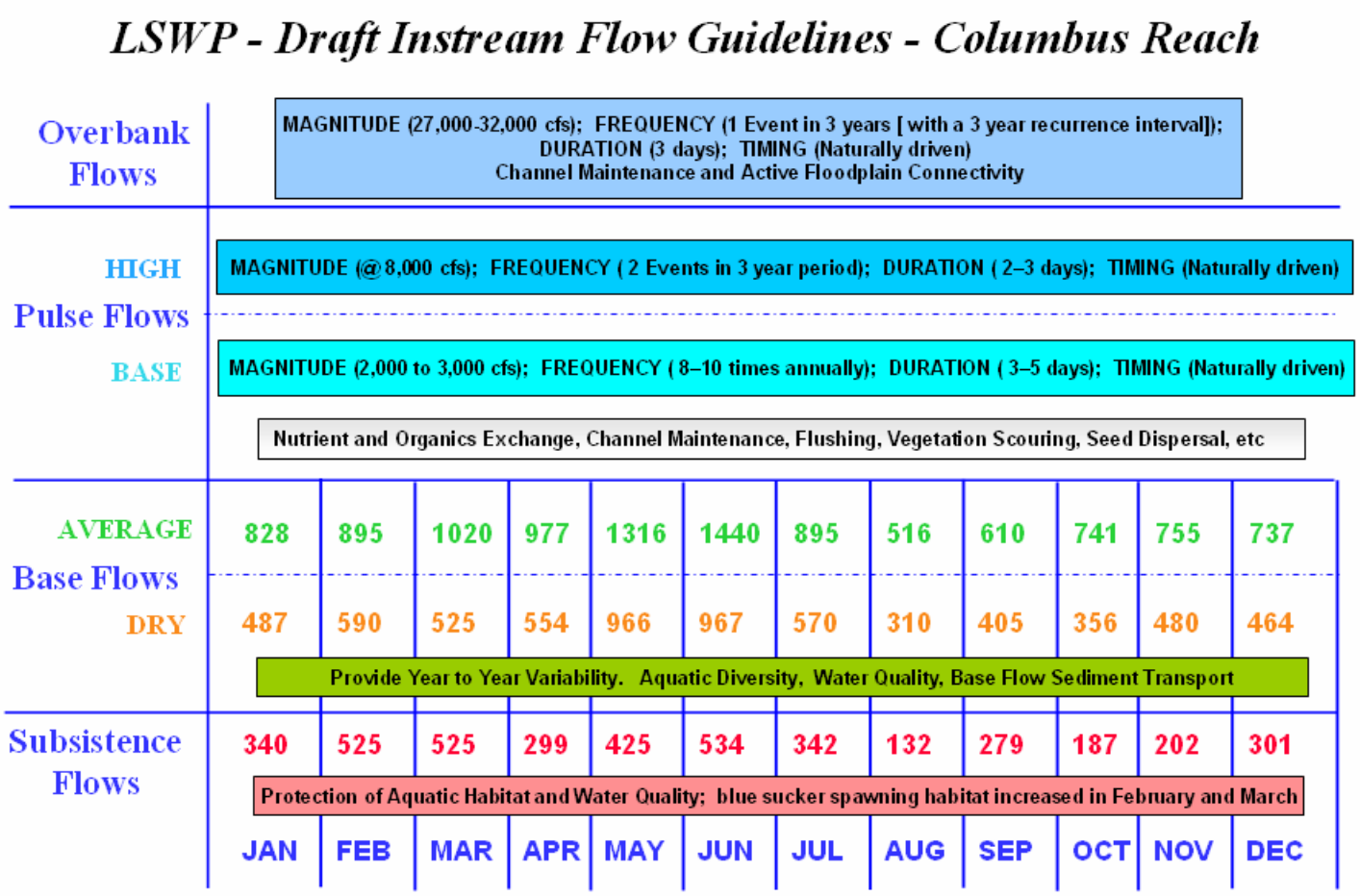


**Figure 4.19.** LSWP Draft Instream Flow Guidelines Flow Regime at Columbus.

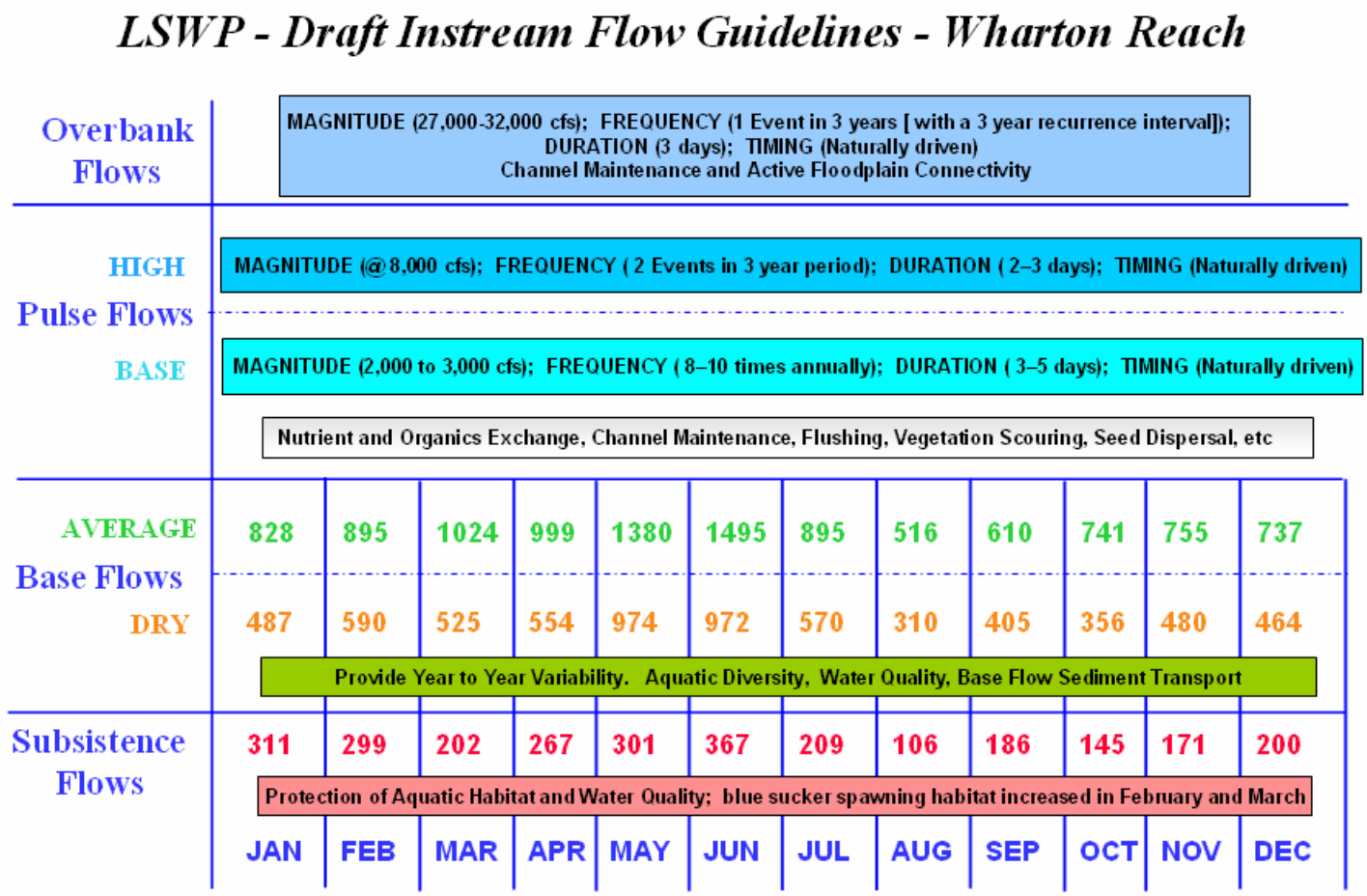


**Figure 4.20.** LSWP Draft Instream Flow Guidelines Flow Regime at Wharton.

# 5.0 APPLICATION

Often, the most difficult part of an instream flow study are the decisions regarding application and implementation. These decisions involve environmental considerations, operational constraints, social implications (human needs), political implications (legislative mandate for the LSWP), etc. The following discussion focuses on the environmental considerations relative to the LSWP.

## 5.1 LSWP Subsistence Flow Guidelines

Modern scientific literature suggests that subsistence flows or ecological base flows are "hands off flows" (Hardy et al. 2006, Acreman et al. 2006). Therefore, the goal is for the LSWP to meet the subsistence flow guidelines at all times. This would be similar in application to the existing LCRA water management plan critical flow releases.

## 5.2 LSWP Base Flow Guidelines

The application of base flow recommendations in the literature is highly variable and river-specific in most cases. From a purely environmental consideration, the LSWP goal would be to achieve the base flow guidelines the equivalent percentage of time (80% for base-DRY, and 60% for base-NORMAL). However, it is recognized that other considerations clearly need to be factored into this decision. An approach similar to the existing LCRA water management plan target flow releases application may be applicable. Under this approach, guidelines would be achieved when Highland Lakes conditions were met and pass through flows were available.

## 5.3 LSWP Pulse and Overbanking Flow Guidelines

Pulse and overbanking flow recommendations are relatively new in the scheme of instream flow science although the concept has been around for many years. Mosier and Ray (1992) suggested that "maintenance flows" (equivalent to the proposed base pulses) be "provided by natural rainfall events but may occasionally require dam releases in excess of generation capacity for short periods." From an environmental consideration only, the project team supports that description for base pulses. High flow pulses and overbanking flows will be provided by natural rainfall events and the recommendations in this report are included only so that evaluations over time can be conducted to assess the natural achievement of these recommendations. If additional studies indicate that the release pattern for these events could be adjusted somehow (again within the existing operational and permitting constraints) to increase the ecological benefit to the lower Colorado River without impacting other important interests, such adjustments should be considered in the adaptive management program.

# 6.0 MONITORING AND ADAPTIVE MANAGEMENT

The biggest omission from many instream flow studies has been an evaluation of the effectiveness of proposed recommendations. Recent studies in this field have immensely improved this component. The project team concurs with the TIFP and recognizes that a critical component of all recommendations for this project is a long-term monitoring program to evaluate the effectiveness of the recommended instream flow guidelines for the lower Colorado River. A comprehensive long-term monitoring plan is currently under development and will be submitted as a section within the final technical report in summer 2007.

A few specific examples of proposed activities were provided in the pulse and overbanking flow sections. An additional consideration is the affect of the summertime subsistence flow recommendations on exotic aquatic vegetation establishment. Although low summertime flows would have been experienced under a more natural condition, the difference today is the additional nutrient load that the river carries. During future low-flow summertime conditions, clear warm water coupled with higher nutrient conditions may cause an increase in native aquatic plants and/or possibly invasive exotic plants such as hydrilla. In a natural flow regime, excessive vegetation growth is controlled by scouring during high flow pulses and overbanking events. This supports the importance of multi-faceted instream flow recommendations as developed for the LSWP. Although the higher nutrient load did not affect the predicted DO concentrations by the WQ model at these lower summertime flows, aquatic macrophyte establishment should be monitored. Therefore, evaluating native and exotic aquatic plant responses in the future will be an important component of the long-term monitoring program.

In conjunction with the long-term monitoring, adaptive management will be a vital component to assist in ensuring the success of the environmental principles associated with the LSWP and goals of the TIFP. Brief examples of the linkage between monitoring and adaptive management were provided in the spawning blue sucker flow modification discussion and pulse flows section. However, a comprehensive adaptive management approach is being developed and will also be included as a section in the final technical report in summer 2007.

# 7.0 CONTINUED EVALUATION AND REFINEMENT

Additional validation data will be collected in spring 2007, which is not anticipated to drastically change any model parameters, but may result in fine-scale changes to improve model predictions. The final instream flows guidelines report will be submitted in summer 2007 as part of the comprehensive technical report that will detail all components of the Aquatic Habitat Study and instream flow guidelines development.

## 7.1 Violated Assumption

One component of the project that has not proceeded as anticipated is the identification of selected habitat for juvenile blue suckers. The assumption that has been violated to date is, "*The ability to capture ecologically meaningful numbers of larval/juvenile blue suckers.*" Despite intensive efforts to locate these life stages, no individuals have been captured as of the preparation of this report. Previous sampling by LCRA, TPWD and others on the lower Colorado River, though not specifically targeting these life stages, also found only adults. This difficulty does not prevent development of instream flow guidelines, but it does provide some level of uncertainty relative to protecting *all* aquatic resources in the river. We believe that the juvenile blue suckers use habitat that is similar to adults, but because of the sampling methods and habitat conditions, are difficult to sample effectively. Individuals captured in the Rio Grande occupied cobble riffles in 1.5 to 2 feet depths (T. Bonner, Texas State University, personal communication). These types of habitats were targeted and sampled extensively in the lower Colorado River with no captures. Nevertheless, this type of habitat would fall within the selected habitat for the riffle habitat guild in the hydraulic and habitat model produced for this project. Although we believe that habitat for this life stage is covered by the existing habitat guilds, it would be valuable to identify the habitat preferences for juvenile blue suckers with field data. Therefore, specific activities relative to this concern will be recommended in the long-term monitoring program. Validation data will be collected on habitat preferences into 2007 and may yet yield some information for juvenile blue suckers.

## 7.2 Matagorda Bay Freshwater Inflow Evaluation

This study has been conducted independent of the Matagorda Bay Health Evaluation (MBHE) for the LSWP. However, the project team understands the need to evaluate the instream flow recommendations for the lower Colorado River presented here in context with the freshwater inflow recommendations proposed (2007 deliverable) by the MBHE team. The "natural" flow regime approach used in the river should lend itself well to the linkage of what Matagorda Bay requires for ecological health and productivity. This evaluation will be included in the final technical report to be submitted in summer 2007.

## 7.3 Science Review Panel, Advisory Group, Stakeholders Review

This project has been subject to peer review at several milestone points during the project design and while being conducted. A Science Review Panel of respected biologists, water quality experts, and instream flow modelers has interacted with the study team throughout the project. In addition, several Advisory Group meetings have been held at which this study was discussed. Additional meetings have been conducted with resource agency personnel during the course of the study to gather information and seek guidance in study methodology and data interpretation.

The Science Review Panel and Advisory Group will remain actively involved in the review of this study and all outputs including instream flow guidelines for the lower Colorado River. All interested parties will have an opportunity to review the findings of this study according to the LSWP stakeholder review process.

# 8.0 COMPARISON TO EXISTING CRITERIA

Figures 8.1-8.3 provide a comparison of the draft LSWP instream flow guidelines for the Bastrop, Columbus, and Wharton reaches with the current LCRA water management (WMP) plan instream flow requirements and Lyon's method instream flow requirements currently being used by the LSWP Surface Water Availability team. Only the subsistence and base flow draft LSWP instream flow guidelines are included in the comparison as the LCRA WMP does not include pulse or overbanking flow requirements. The subsistence flow recommendations represent minimum conditions at which water quality is maintained at acceptable levels and aquatic habitats are expected to resemble those found during extreme conditions in a more natural setting. The base flow recommendations provide a range of suitable conditions with the goal of maintaining year to year variability and the ecological functions associated with this level of variability.

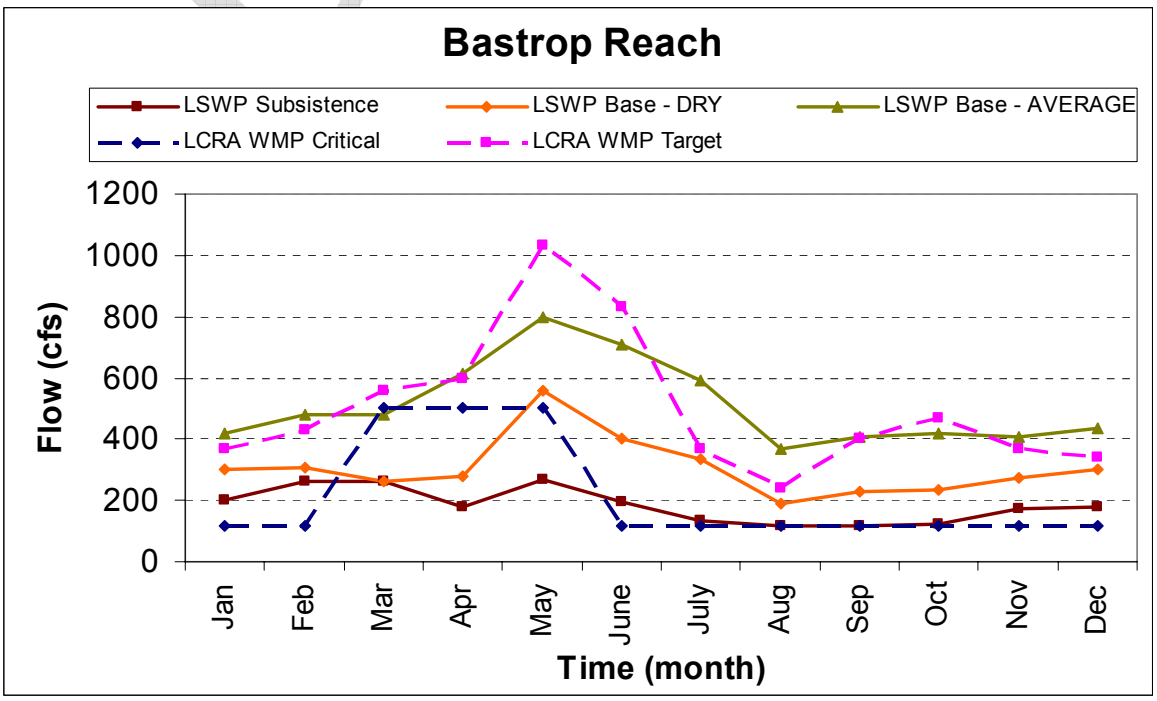


**Figure 8.1.** LSWP Draft Instream Flow Guidelines for subsistence and base flow compared to the LCRA Water Management Plan critical and target instream flow requirements at Bastrop.

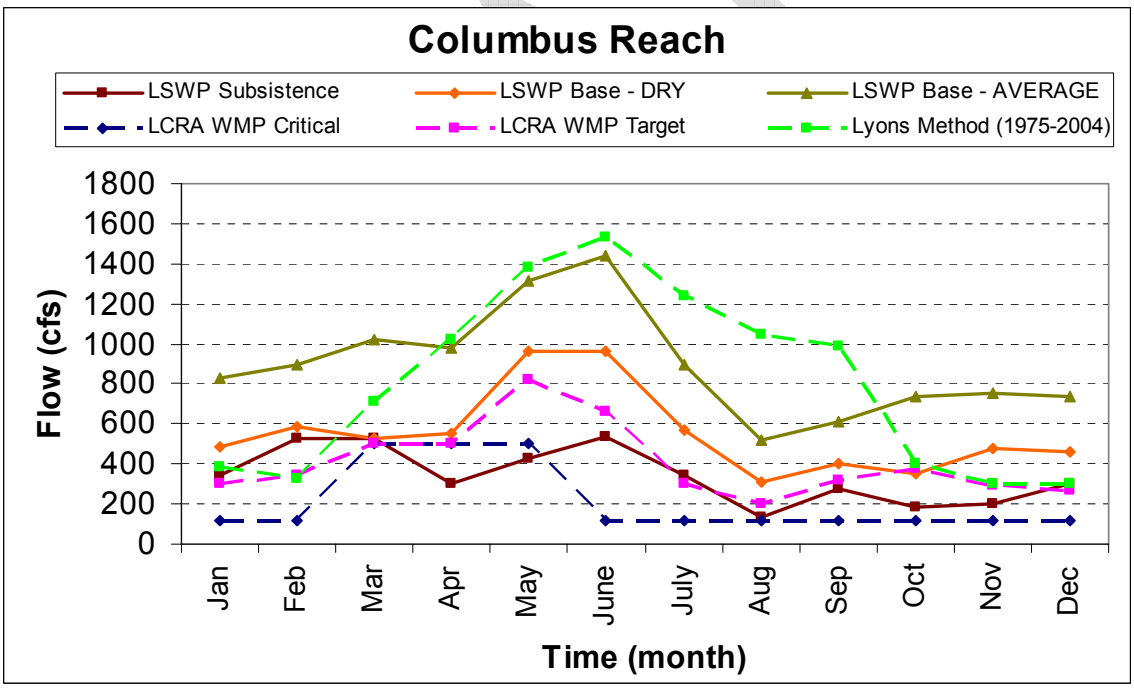


**Figure 8.2.** LSWP Draft Instream Flow Guidelines for subsistence and base flow compared to the LCRA Water Management Plan critical and target instream flow requirements and Lyons Method using existing (1975-2004) hydrology at Columbus.

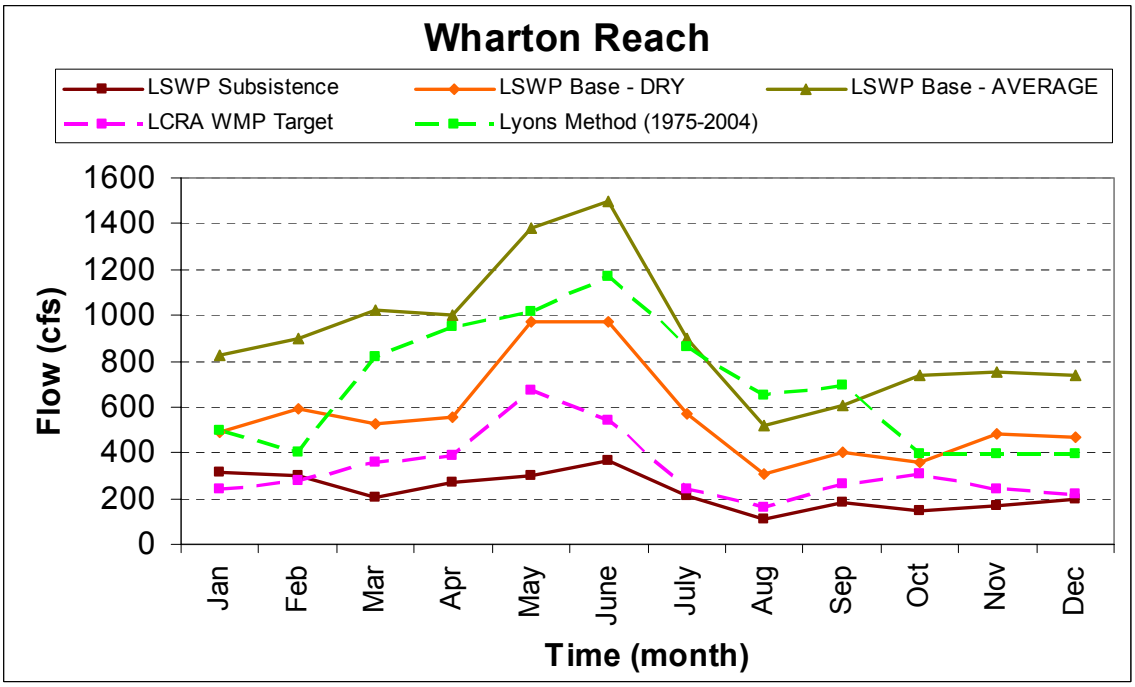


**Figure 8.3.** LSWP Draft Instream Flow Guidelines for subsistence and base flow compared to the LCRA Water Management Plan critical and target instream flow requirements and Lyons Method using existing (1975-2004) hydrology at Wharton.

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# Draft Instream Flow Guidelines Development - Appendices

# Colorado River Flow Relationships to Aquatic Habitat and State Threatened Species: Blue Sucker

Prepared for

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**and San Antonio Water System**

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December 15, 2006

# Appendix A – Life History Summaries

Life history summaries for species and life stages in the lower Colorado River, Texas included in the seven habitat categories used in aquatic habitat modeling.

**RIFFLES**

*Percina sciera* – dusky darter

The dusky darter is a fairly large darter (maximum size ≈ 110 mm) found in the Mississippi River drainage as far north as Illinois, Indiana, and Ohio, and in Gulf of Mexico drainages from the Mobile Bay system in Alabama south and west to the Guadalupe River in Texas. Dusky darters usually occur in riffles and raceways of moderate to large streams over gravel substrates, often associated with some type of cover such as boulders or logs (Miller and Robison 1973). They feed on a variety of aquatic insects, and spawn from February through June in the Colorado River over gravelly substrates (Hubbs 1961). Maximum life span is approximately four years (Page 1983, Robison and Buchanan 1988). Dusky darters are relatively abundant in riffle areas over gravel and cobble substrates throughout the Colorado River.

*Percina carbonaria* – Texas logperch

The Texas logperch is another relatively large darter (maximum size ≈ 112 mm) endemic to the Brazos, Colorado, Guadalupe, and San Antonio rivers of Texas. Due to its small native range, little life history information has been published on this species. However, they are assumed to be similar in habitat use and biology to the closely related and more widely distributed logperch *Percina caprodes*. Logperch inhabit rocky riffles, feed on a variety of aquatic insect larvae, and spawn demersal adhesive eggs in moderate current over gravel substrates (Boschung and Mayden 2003). Hubbs (1961) found that Texas logperch spawn from January through June in the Colorado River. They are common in relatively deep fast riffles throughout the Colorado River over gravel and cobble substrates.

*Ictalurus punctatus* – channel catfish (<180 mm)

The channel catfish is native to the Mississippi River drainage as well as Gulf Slope drainages from Florida to Texas, including the Colorado River. Due to their popularity as a game and food fish, introductions of channel catfish into new areas have greatly expanded their range. This widely adaptable fish occupies a variety of habitats including rivers, reservoirs, and farm ponds. Channel catfish consume a wide variety of food, including small aquatic insects, crustaceans, mollusks, and some plant material. Fish generally becomes more important in their diet as they grow (Boschung and Mayden 2003). After fry leave the nest, they form tight schools for several weeks until they reach fingerling size (Robison and Buchanan 1988, Mettee et al. 1996). Such schools of juvenile channel catfish are abundant in riffle habitats over gravel and cobble substrates throughout the Colorado River in the late summer and fall. Conversely, adults are more common in deeper areas and were thus included in the Deep Run guild.

*Phenacobius mirabilis* – suckermouth minnow

The suckermouth minnow is a relatively large robust minnow (maximum size ≈ 102 mm) found throughout the Mississippi River drainage as well as Western Gulf slope drainages of Texas. Although it is found in a variety of habitats, the suckermouth minnow seems to prefer riffle areas of medium-sized prairie streams over gravel substrates. It is a bottom dwelling species that forages in the substrate to capture benthic invertebrates and also consumes some plant material (Robison and Buchanan 1988, Mettee et al. 1996). Suckermouth minnows spawn between April and August in Kansas (Cross 1967). Although suckermouth minnows are not particularly abundant in the Colorado River, when found, they are usually collected in swift riffle habitats over gravel and cobble substrates.

*Etheostoma spectabile* - orangethroat darter

The orangethroat darter is a small percid (maximum size ≈ 60 mm) that ranges from central Texas north as far as eastern Wyoming and east as far as central Ohio. They inhabit shallow, moderately-fast, gravel riffles where they feed on a variety of aquatic insects and fish eggs. Eggs are deposited in the gravel substrate, and spawning usually occurs from November through July in Texas (Page 1983, Hubbs 1985). In the Colorado River, orangethroat darters are fairly common on shallow gravel riffles from Austin downstream to Columbus. Their abundance decreases downstream most likely due to increased turbidity and decreasing amounts of gravel riffle habitat.

*Campostoma anomalum* - central stoneroller

The central stoneroller is a wide ranging herbivorous cyprinid that occurs throughout the Mississippi River drainage as well as several Gulf Coastal drainages including the Colorado River. Stonerollers are most abundant in small generally clear streams over gravel substrates where they use a special cartilaginous ridge on their lower lip to scrape algae and associated materials from the rocky substrate. Spawning occurs in riffle areas during spring at water temperatures of about 15C (Robison and Buchanan 1988). Males move small rocks and pebbles to create a nest and eggs are laid in the interstitial spaces between the rocks (Miller 1962). After hatching, small stonerollers occupy slow stream margins and backwaters until they reach larger sizes and move into the main flow. In the Colorado River, stonerollers were most commonly collected in shallow gravel riffles of moderate current from Austin downstream to Columbus. Similar to orangethroat darters, their abundance decreases downstream most likely as a result of increased turbidity and decreasing amounts of gravel riffle habitat.

*Macrhybopsis spp.* - shoal chub and burrhead chub

The species complex previously known as the speckled chub *Macrhybopsis aestivalis* is distributed throughout the Mississippi River drainage and Gulf Coastal drainages from the Choctawhatchee River in Florida to the Rio San Fernando in Mexico. However, recent analyses have split this complex into five species west of the Mississippi River, two of which (shoal chub *M. hyostoma* and burrhead chub *M. marconis*) occur in the Lower Colorado River (Eisenhour 2004). However, because these two species were only recently differentiated, no attempt was made to distinguish them in field collections, and given that they occupy similar habitats they were grouped as one ecological unit for guild analysis. These fish inhabit moderate to swift flowing waters over sandy and gravelly substrates in large rivers. They use taste buds located on their head, body, fins,

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and small barbels to feed along the bottom of turbid rivers. Food consists of aquatic insects, small crustaceans, and some plant material. They spawn throughout the summer months and eggs develop as they drift in the current, hatching in about 25-28 hours. Maximum life span is approximately 1.5 years (Robison and Buchanan 1988). In the Colorado River, *Macrhybopsis spp*. are relatively abundant in shallow riffles over sand and small gravel throughout the river.

**DEEP RUNS**

*Pylodictis olivaris* – flathead catfish

The flathead catfish is a large long-lived catfish (maximum size ≈ 100 pounds, life span up to 20 years) native to the Mississippi River drainage as well as Western Gulf Slope drainages of Texas. It is most common in deeper areas of large turbid rivers around moderate current and heavy cover such as rocks, riprap, or submerged logs. It is a solitary species which feeds at night on live fish and crayfish. Spawning occurs in late June and July when parents construct a nest in a natural cavity. Females may lay up to 100,000 eggs which are guarded by the male. After hatching the young catfish form a compact school for a few days before dispersing (Robison and Buchanan 1988, Mettee et al. 1996). Flathead catfish are common throughout the Colorado River in deep runs and pools with slow to moderate currents often near large boulders or other dense cover.

*Ictalurus punctatus* – channel catfish (>180 mm)

The channel catfish is native to the Mississippi River drainage as well as Gulf Slope drainages from Florida to Texas, including the Colorado River. Due to their popularity as a game and food fish, introductions of channel catfish into new areas have greatly expanded their range. In rivers adults usually occupy deep pools near cover and overhanging banks during the day and venture out to feed in shallower areas at night. Fish generally become increasingly important in the diet as they grow (Boschung and Mayden 2003). Spawning usually occurs from May to July in a cavernous nest dug out by the male along an undercut bank or under logs or other debris. The male guards the small fry until they leave the nest. In the Colorado River, adult channel catfish were collected from a variety of habitats; however, they were most abundant in deeper runs often near some type of cover.

*Moxostoma congestum* – gray redhorse

The gray redhorse is a large catostomid fish endemic to streams of the Edwards Plateau region of Texas including the Brazos, Colorado, Guadalupe, San Antonio, Nueces, and Rio Grande drainages. It is also found in extreme southeastern New Mexico, and a few coastal streams along the Gulf Coast of Mexico. Detailed life history studies are lacking for this species. However, gray redhorse have been found to consume a variety of aquatic insects, mainly dipteran and trichopteran larvae (Cowley and Sublette 1987). In central Texas, they spawn in small groups during late March and early April over shallow gravelly runs (Martin 1986). Gray redhorse are abundant in the Colorado River from Austin downstream to Columbus. Their abundance declines below Columbus where sand substrates are more common and river carpsuckers (*Carpiodes carpio*) become more abundant.

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*Micropterus treculii* – Guadalupe bass (>170 mm)

The Guadalupe bass is endemic to the Edwards Plateau region of central Texas, including portions of the Brazos River, Colorado River, Guadalupe River, and San Antonio River basins (Hubbs et al. 1991). In 1989, the Guadalupe bass was recognized as the State Fish of Texas. These fish most commonly inhabit swift deep runs and pools below riffles where they prey on insects, crayfish, and small fish. Guadalupe bass spawn in spring over nests constructed by the male in shallow water. Edwards (1980) found that the females produce approximately 400 to 10,000 eggs depending on body size. They can live up to 6 years and reach sizes of approximately 3.5 lbs. Adult Guadalupe bass are common in deep flowing runs throughout the Lower Colorado River; however, they appear to be most abundant in the clearer upper reaches from Austin downstream to La Grange.

*Carpiodes carpio* – river carpsucker

River carpsuckers are native to the Mississippi River basin as well as Western Gulf Slope drainages in Texas. They are most common in medium to large rivers over sand and silt bottoms in slow current where they browse along the bottom feeding on attached algae, small crustaceans, molluscs, and small aquatic insects. Spawning occurs from May to August when adhesive eggs are broadcast over the substrate. River carpsuckers can live up to ten years and grow to sizes of approximately 10 pounds (Robison and Buchanan 1988, Mettee et al. 1996). They are abundant throughout the Colorado River, especially downstream of Columbus where sand is the predominant substrate.

*Dorosoma cepedianum* – Gizzard shad

Gizzard shad are common inhabitants of large rivers and reservoirs throughout the eastern United States. They are a pelagic schooling species usually found in deep calm water, although they are often found in strong currents as well. Gizzard shad use their long gill rakers to filter plankton from the water, and sometimes feed along the bottom ingesting detritus. Spawning occurs from April through June when adults congregate in open water and simultaneously release eggs and sperm. The adhesive eggs become attached to the substrate or float in the current for a few days until they hatch. Young gizzard shad provide an important food source for many predatory species. However, gizzard shad can live up to 6 years and grow to approximately 20 inches in length (Robison and Buchanan 1988, Mettee et al. 1996). Gizzard shad are abundant in deep runs and pools over a variety of substrates throughout the Colorado River.

**SHALLOW RUNS**

*Cyprinella lutrensis* – red shiner

The red shiner is a small cyprinid fish native to the Mississippi River drainage as well as Gulf slope drainages west of the Mississippi. Red shiners occupy a wide-range of habitats from sluggish backwaters to swift riffles over a variety of substrates. Their diet consists of aquatic and terrestrial invertebrates and algae. They are classified as crevice spawners that reproduce from April through September by attaching their adhesive eggs to crevices in rocks, wood, or onto submerged vegetation. They have also been known to broadcast their eggs over the nests of various sunfishes. Growth is fast and red shiners spawned early in the year can reproduce before the end of their first summer

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(Marsh-Matthews et al. 2002). They live approximately two years and reach a maximum size of about 75 mm (Robison and Buchanan 1988, Mettee et al. 1996). The red shiners ability to persist under a wide variety of habitats and environmental conditions as well as their high reproductive potential make them one of the most abundant species in many large rivers within their range. They are one of the most abundant species in the lower Colorado River and are collected in a wide variety of habitats over various substrates throughout the river. However, they are most abundant in shallow runs with moderate current. Their abundance increases in turbid downstream areas of the Colorado River where closely related blacktail shiners become less abundant.

*Cyprinella venusta* – blacktail shiner

The blacktail shiner occurs in Gulf Coast drainages from the Rio Grande in Texas to the Suwannee River, Florida, and as far north as the Ohio River. This species, which is a close relative of the red shiner, occurs in a variety of habitats over varied substrates from fast gravel riffles to silty reservoirs (Robison and Buchanan 1988, Mettee et al. 1996). Their diet fluctuates depending on food availability, and they consume a variety of aquatic and terrestrial invertebrates as well as algae (Hale 1962, Hambrick and Hibbs 1977). In central Texas they reproduce from April through September by expelling adhesive eggs into crevices in the substrate. Blacktail shiners can live up to four years (Ross 2001), and reach sizes of approximately 150 mm. They are one of the most abundant species in the Lower Colorado River, and occur in a variety of habitats; however, they seem to be most abundant in shallow runs with moderate current in the upper portion of the river from Austin downstream to La Grange. In the lower portion of the river they are usually less abundant than red shiners.

*Pimephales vigilax* – bullhead minnow

Bullhead minnows are a common inhabitant of large Gulf Slope streams and rivers from the Rio Grande basin of Texas north and east to the Mobile basin and north in the Mississippi drainage as far as Wisconsin. Although sometimes found in strong currents they are most common in sluggish currents over sand and silt substrates. Bullhead minnows feed in schools along the bottom on aquatic insects, snails, and plant material. Reproduction takes place in late spring and summer when eggs are laid on the undersides of rocks, logs, or other structures. Males guard the egg clusters and keep them clean and aerated by brushing against them with their fleshy backs. After hatching young bullhead minnows congregate in large schools over silt substrates feeding on bottom ooze and diatoms (Robison and Buchanan 1988, Johnston and Page 1992, Mettee et al. 1996). In the Colorado River, bullhead minnows are abundant throughout the river ranking third in overall abundance behind red and blacktail shiners. They are most commonly collected in shallow water over silt, sand, or gravel in slow to moderate currents.

*Notropis volucellus* – mimic shiner

The mimic shiner is commonly yet somewhat sporadically found in large Gulf slope streams and rivers from the Guadalupe River, Texas north and east to the Mobile basin, and north as far as Canada in the Mississippi River drainage. Mimic shiners are commonly collected in schools near the surface or midwater over sand and gravel substrates. They feed mainly on small crustaceans, aquatic insects, and algae (Black

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1945). Spawning reportedly occurs between April and August (Robison and Buchanan 1988, Mettee et al. 1996). Mimic shiners are an abundant species throughout the Lower Colorado River, and are often found in shallow runs in association with blacktail shiners and red shiners.

*Micropterus treculii* – Guadalupe bass (<180 mm)

The Guadalupe bass is endemic to the Edwards Plateau region of central Texas, including portions of the Brazos River, Colorado River, Guadalupe River, and San Antonio River basins (Hubbs et al. 1991). These fish most commonly inhabit swift runs and pools below riffles where they prey on insects, crayfish, and small fish. In the Colorado River, young Guadalupe bass inhabited shallower and often somewhat slower areas than adults, which were placed in the deep run guild. Juvenile Guadalupe bass were most common in shallow runs over various substrates, and seem to be most abundant in the clearer upper reaches from Austin downstream to La Grange.

**DEEP POOLS**

*Ictiobus bubalus* – smallmouth buffalo

The smallmouth buffalo is a large catostomid fish native to large Gulf Coast drainages from the Rio Grande, Texas to the Mobile Bay drainage in Alabama. They are common in deep slow pools of rivers and reservoirs throughout their range, where they feed along the bottom on small aquatic insects, mollusks, algae, and detritus. Spawning occurs in early to middle spring when adhesive eggs are scattered over the substrate or onto submerged vegetation. Smallmouth buffalo are a large long-lived fish with a maximum life span of approximately 15 years and maximum size approaching 70 pounds (Robison and Buchanan 1988, Mettee et al. 1996, Boschung and Mayden 2003). They are common in deep slow pools and runs throughout the Colorado River.

*Cyprinus carpio* – common carp

The common carp is an exotic cyprinid fish first introduced into the United States in the 1870s. They are now common in a variety of habitats of small streams, large rivers, and reservoirs throughout the United States. Common carp feed along the bottom, especially in muddy areas, where they consume insect larvae, crustaceans, detritus, and plant material. They spawn in large groups in shallow water during spring and early summer. Small adhesive eggs, once fertilized, attach to aquatic vegetation or sink to the bottom. Common carp are extremely tolerant of pollution and siltation and are often one of the most abundant fish in large reservoirs. They are a large minnow that can live for several years and attain weights exceeding 50 pounds (Robison and Buchanan 1988, Mettee et al. 1996). Common carp are common in a variety of habitats throughout the Colorado River; however, they are most abundant in deep silty pools along with smallmouth buffalo.

**SHALLOW POOLS / EDGE / BACKWATER**

*Micropterus salmoides* – largemouth bass

Largemouth bass are native to eastern North America including most of Texas, and are arguably the most popular gamefish in the United States. This popularity as a sport fish

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has led to their introduction into many areas outside their native range. Although they are most abundant in reservoirs, lakes, and ponds, largemouth bass are also common in low velocity habitats of rivers such as pools and backwaters. They are a predatory species which feed on a variety of fish and invertebrates. Young largemouth bass consume zooplankton and aquatic insects, while adults feed mainly on smaller fish and crayfish. They spawn over nests excavated by the male bass in shallow still water during the spring, usually from February to May in Texas. Eggs and fry are protected by the male bass for several days after hatching. Largemouth bass commonly live 10+ years and can grow to sizes exceeding 20 pounds (Robison and Buchanan 1988, Mettee et al. 1996). In the Colorado River, largemouth bass are common in pool habitats over a variety of substrates throughout the river.

*Lepomis megalotis* – longear sunfish

The longear sunfish is a small centrarchid found throughout the Mississippi River drainage, as well as Gulf Coastal drainages from Florida to Mexico. They are common in pools of small streams and large rivers where they feed on a variety of aquatic invertebrates, terrestrial insects, and the occasional small fish. They spawn in late spring and summer in shallow slow-moving water where the male builds a small saucer shaped nest in the substrate. Spawning often takes place in colonies, with several nests located in close proximity to each other. Longear sunfish reach sizes of 5–7 inches over a maximum life span of about six years (Robison and Buchanan 1988, Mettee et al. 1996, Boschung and Mayden 2003). They are common in slow-moving shallow pools and backwaters throughout the Lower Colorado River.

*Lepomis macrochirus* – bluegill

Bluegill are common in rivers, lakes, and ponds throughout the eastern United States and south into Mexico. Since they provide an excellent forage species for the widely introduced largemouth bass, and are also popular with fishermen, bluegill have been extensively introduced outside their native range. In rivers, they are most commonly found in slow moving pools and backwaters where they feed on aquatic invertebrates and small fish. They reproduce during late spring and summer in shallow colonial nesting sites similar to other sunfish. Males guard the eggs, and fan them to discourage siltation until hatching. Growth of bluegill is highly variable depending on local conditions. However, they can live up to six years and grow to sizes of approximately 10 inches (Robison and Buchanan 1988, Mettee et al. 1996). Bluegill are common in shallow pools throughout the Colorado River, often in association with other *Lepomis* species.

*Lepomis cyanellus* – green sunfish

Green sunfish are native to the central United States from the Great Lakes south to the Gulf Coast; however, introductions have greatly expanded their range in North America. They are tolerant of a wide range of environmental conditions and are often found in stagnant creeks and ditches where other sunfish species cannot survive. In rivers and streams, they are most common in slow moving pools and backwaters where they feed on aquatic and terrestrial insects, small fish, and crayfish. Similar to other sunfish, they spawn in shallow saucer shaped nests during late spring and summer. Growth rates are faster than those of other sunfish, and green sunfish can quickly

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overpopulate small ponds and lakes. They can live 5-6 years and reach 8-10 inches in size (Robison and Buchanan 1988, Mettee et al. 1996, Boschung and Mayden 2003). Green sunfish are common in pools and backwaters throughout the Lower Colorado River, often in association with other sunfish species.

*Cichlasoma cyanoguttatum* – Rio Grande cichlid

The Rio Grande cichlid is the only member of the family Cichlidae native to the United States. Its native distribution was limited to the Rio Grande and Pecos River drainages of Texas and Northeastern Mexico (Hubbs et al. 1991); however, its range has been greatly expanded as a result of accidental and intentional introductions (Fuentes and Cashner 2002). The diet of Rio Grande cichlid has not been well studied. In central Texas, spawning has been documented in May when a monogamous pair defends a spawning territory usually established over rocky substrate. Both parents aggressively defend the eggs and fry for several days after hatching (Itzkowitz and Nyby 1982). Rio Grande cichlids are commonly collected in shallow pools and weedy backwaters throughout the Lower Colorado River. Temperature is thought to be one factor limiting the distribution of this species in the Colorado River (Tilton 1961).

*Gambusia affinis* – western mosquitofish

The western mosquitofish is a small surface-dwelling fish which occurs in Gulf Coastal drainages from Alabama to Mexico, and in the Mississippi River drainage as far north as Illinois. They inhabit shallow areas of little to no current in streams, rivers, ponds, lakes, and swamps where they feed on small aquatic and terrestrial insects, fish larvae, and plant material. Mosquitofish can tolerate an extremely wide range of environmental conditions, often occurring in areas of low dissolved oxygen, elevated temperatures, and high salinities. Reproduction takes place throughout the summer, when females give birth to live young. Males have a modified anal fin that allows transfer of sperm to the female who can store it in her reproductive tract for several months. With a gestation period of 21-28 days, three to four broods of young can be produced by each female each summer. Females grow larger than males, and can reach sizes of approximately 70 mm (Robison and Buchanan 1988, Mettee et al. 1996). Western mosquitofish are abundant in shallow vegetated stream margins, pools, and backwaters throughout the Lower Colorado River.

*Poecilia latipinna* – sailfin molly

The sailfin molly is a surface-dwelling poeciliid fish distributed in brackish waters from Cape Fear, North Carolina to the Yucatan Peninsula of Mexico. Inland freshwater populations also exist in Texas, Louisiana, and Florida. The species gets its name from the large, elongate, and colorful dorsal fins present on males. Sailfin mollies, like mosquitofish, can tolerate a wide range of salinities and can occur in ditches and small pools with very little dissolved oxygen. They are often abundant in severely degraded habitats where other species cannot survive (Felley and Daniels 1992). Females give birth to live young after a gestation period of 23 to 27 days, usually producing 6 to 36 individuals. Sailfin mollies feed on algae, vascular plants, and small invertebrates; however, they become more herbivorous as they grow (Boschung and Mayden 2003). Although not particularly abundant in the Colorado River, sailfin mollies are common in shallow pools and weedy backwaters throughout the river.

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*Fundulus notatus* – blackstripe topminnow

The blackstripe topminnow is a small surface-dwelling fish which occurs in Gulf Coast drainages from the San Antonio Bay drainage of Texas, north and east to the Tombigbee River drainage Alabama, and as far north in the Mississippi River drainage as southern Wisconsin. They prefer pools and margins of slow low-gradient streams and rivers. The majority of their diet is comprised of terrestrial insects taken from the surface, however, aquatic insects and crustaceans are also consumed. Spawning occurs in late spring and early summer when the female deposits 20-30 unguarded eggs on vegetation or detritus (Robison and Buchanan 1988, Mettee et al. 1996). Blackstripe topminnows occur in low abundance in shallow pools and backwaters throughout the Colorado River.

**RAPIDS / ADULT BLUE SUCKER**

*Cycleptus elongatus* - blue sucker

The blue sucker is a large long-lived catostomid native to large rivers of the Mississippi Basin and occurring sporadically in some Western Gulf Slope drainages of Texas as far south as the Rio Grande. A similar and closely-related species, the southeastern blue sucker *Cycleptus meridionalis,* was recently recognized from Eastern Gulf Slope drainages of Alabama, Mississippi, and Louisiana (Burr and Mayden 1999). Commercial harvest records from the Mississippi River indicate that the blue sucker was once abundant, however, they are now considered rare throughout most of their range and have been listed as threatened or endangered by several agencies including the Texas Parks and Wildlife Department. Blue suckers occupy deep high-velocity habitats over firm substrates (Rupprecht and Jahn 1980, Vokoun et al. 2003). They feed on aquatic insects, mainly Trichopteran and Dipteran larvae and pupae, and can grow to over 800 mm total length (Peterson et al. 1999, Moss et al. 1983, Cowley and Sublette 1987). Age and growth studies of blue suckers have yielded varying results. Previous studies using scale-aging have suggested that blue suckers live anywhere from 9-22 years (Moss et al. 1983, Rupprecht and Jahn 1980, Vokoun et al. 2003, Morey and Berry 2003). However, scale-aging is thought to underestimate the ages of large fish, and examination of annuli on opercular bones has suggested that southeastern blue suckers reach ages of 30+ years (Peterson et al. 1999, Burr and Mayden 1999). Reproduction occurs in early to late spring at temperatures of 12 – 20C when blue suckers migrate to spawning riffles where their adhesive eggs are deposited on the substrate (Moss et al. 1983, Semmens 1985, Peterson et al. 2000, Mettee et al. 2003, Vokoun et al. 2003). Eggs hatch in about 6 days (Semmens 1985). Although larval blue suckers have occasionally been collected in backwater and off-channel habitats (Fisher and Willis 2000, Adams et al. 2006), information on the ecology of young blue suckers is limited because juveniles are rarely collected (Morey and Berry 2003). In the Colorado River, adult blue suckers are fairly common in deep fast rapids over gravel, cobble, boulder, and bedrock substrates throughout the upper two-thirds of the river. Blue suckers were the only species collected in abundance in these deep high-velocity areas, and therefore, were the only species included in the rapids guild. Despite considerable effort, there have been no confirmed collections of juvenile blue suckers from the Lower Colorado River.

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## SPAWNING BLUE SUCKER

*Cycleptus elongatus* – blue sucker

Blue suckers reportedly spawn in deep riffles over cobble and bedrock from early February to May when water temperatures are between 10 and 23C (Moss et al. 1983, Boschung and Mayden 2003, Vokoun et al. 2003). Four spawning aggregations have been documented on the Lower Colorado River - one site in March 2005 below Longhorn Dam, and three sites in February 2006 (near Altair, LaGrange, and Utley). Habitat data from these confirmed spawning areas were used in constructing the spawning blue sucker guild.

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# APPENDIX B – Habitat Suitability Criteria

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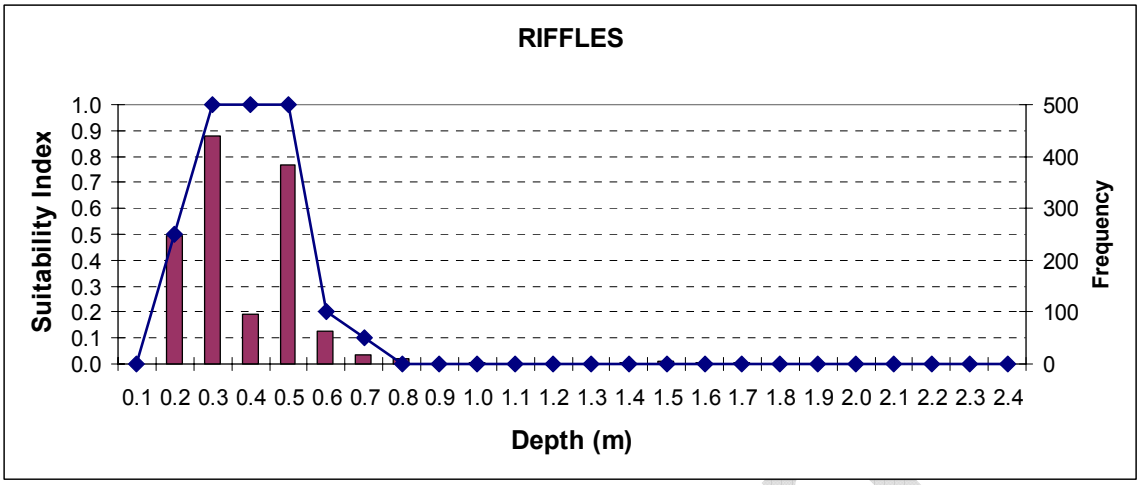


Figure B1 – Frequency distribution and HSC values for Riffles Habitat Guild for depth in the lower Colorado River.

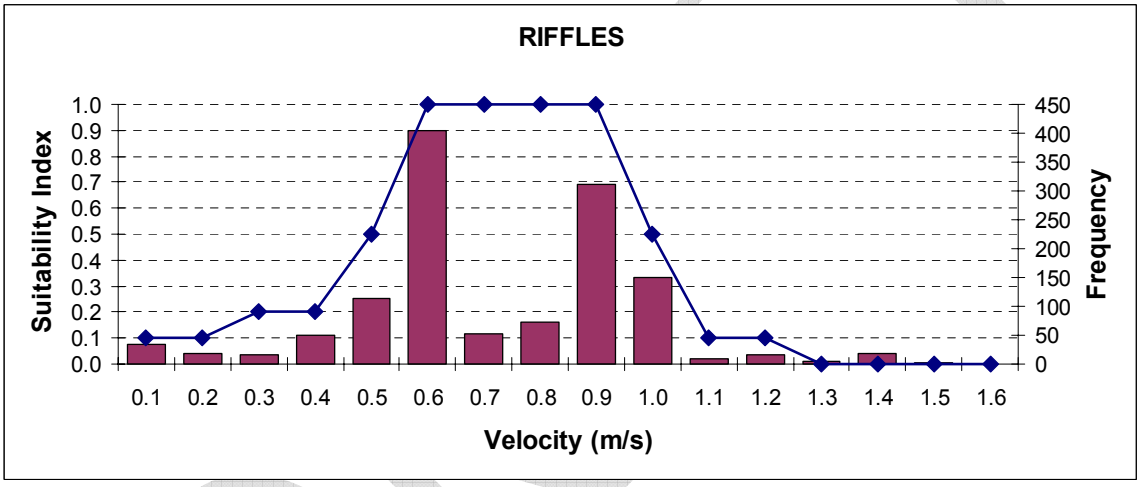


Figure B2 – Frequency distribution and HSC values for Riffles Habitat Guild for velocity in the lower Colorado River.

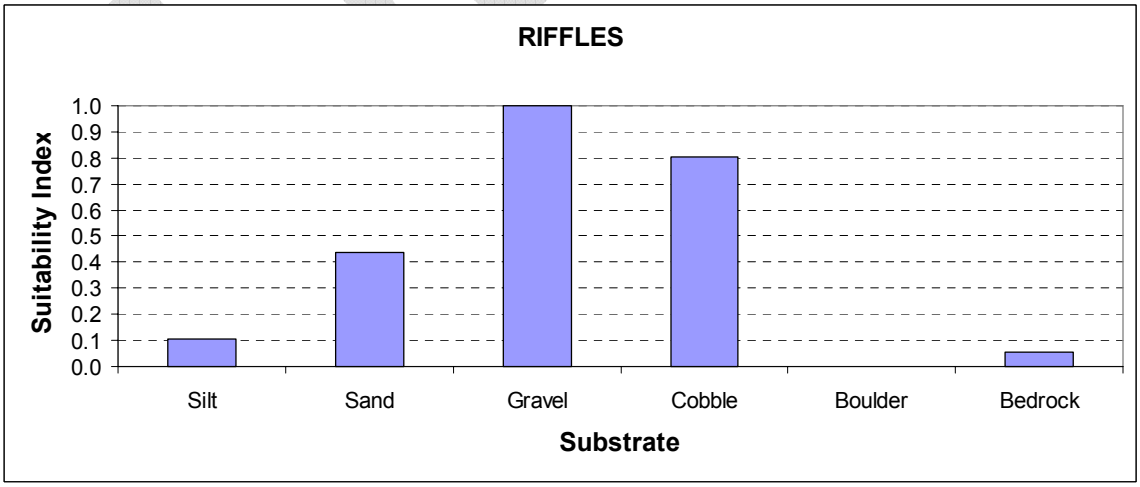


Figure B3 – Frequency distribution and HSC values for Riffles Habitat Guild for substrate in the lower Colorado River.

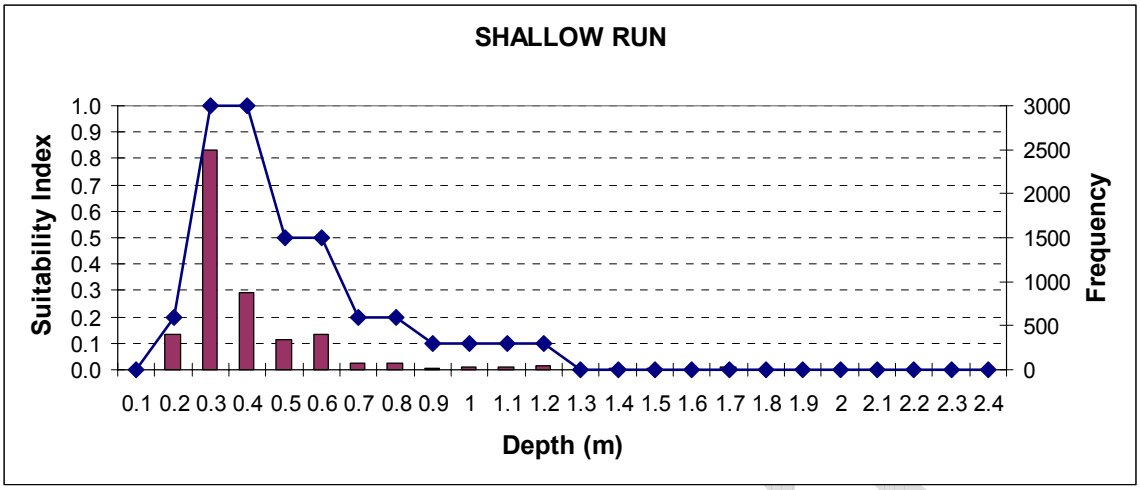


Figure B4 – Frequency distribution and HSC values for Shallow Runs Habitat Guild for depth in the lower Colorado River.

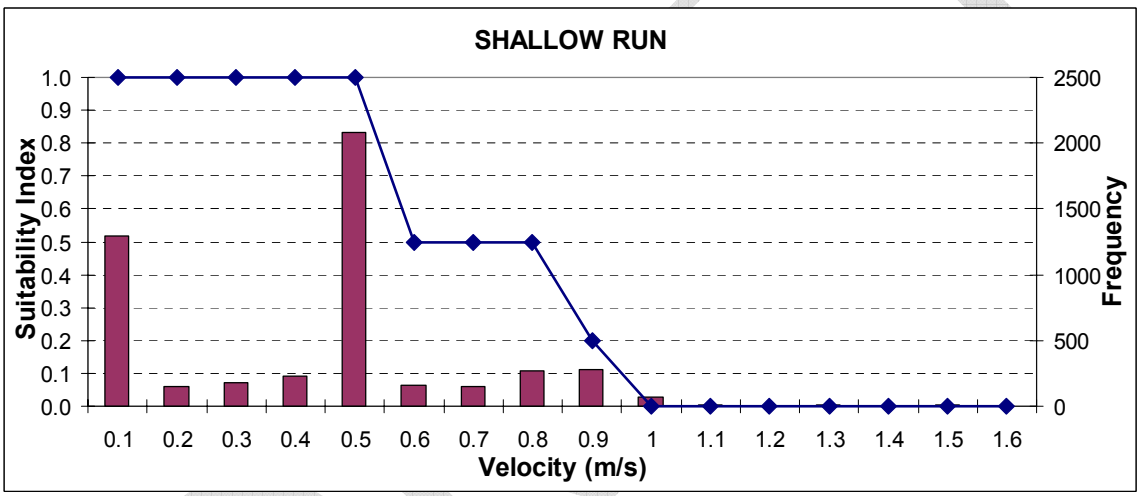


Figure B5 – Frequency distribution and HSC values for Shallow Runs Habitat Guild for velocity in the lower Colorado River.

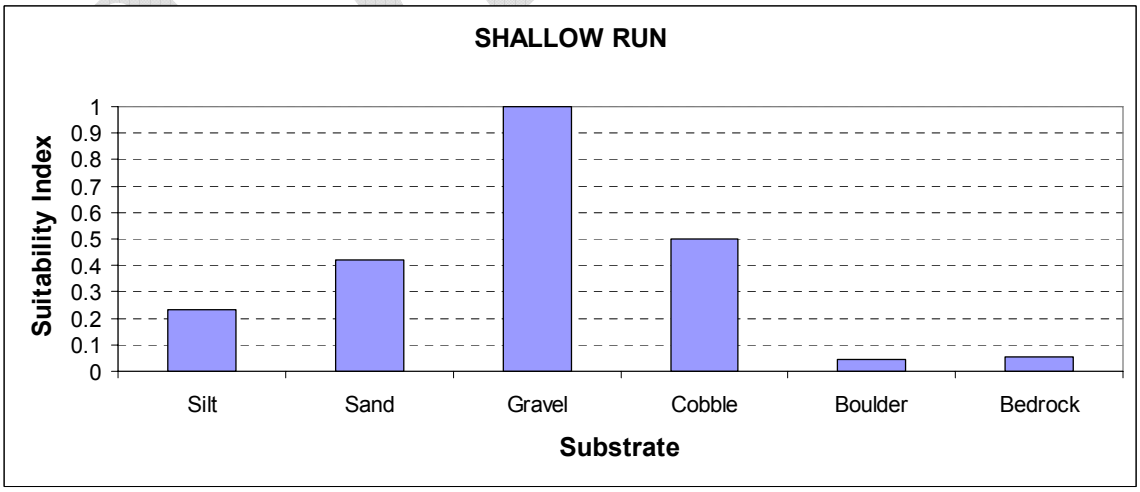


Figure B6 – Frequency distribution and HSC values for Shallow Runs Habitat Guild for substrate in the lower Colorado River.

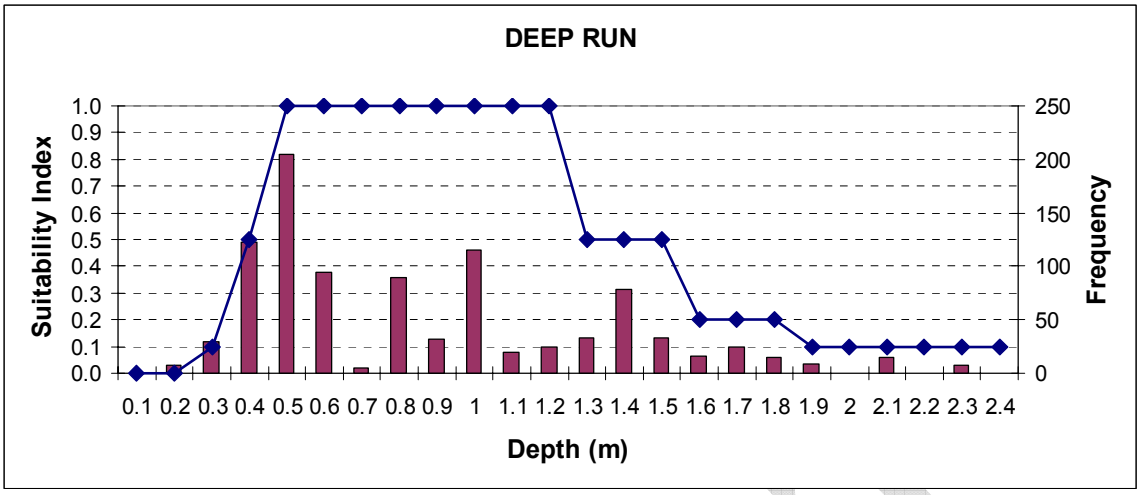


Figure B7 – Frequency distribution and HSC values for Deep Runs Habitat Guild for depth in the lower Colorado River.

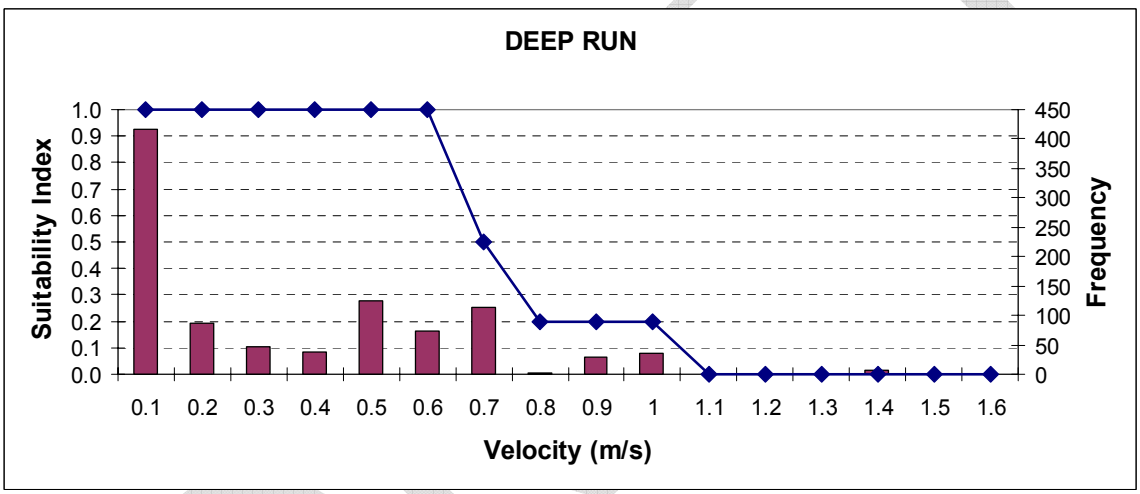


Figure B8 – Frequency distribution and HSC values for Deep Runs Habitat Guild for velocity in the lower Colorado River.

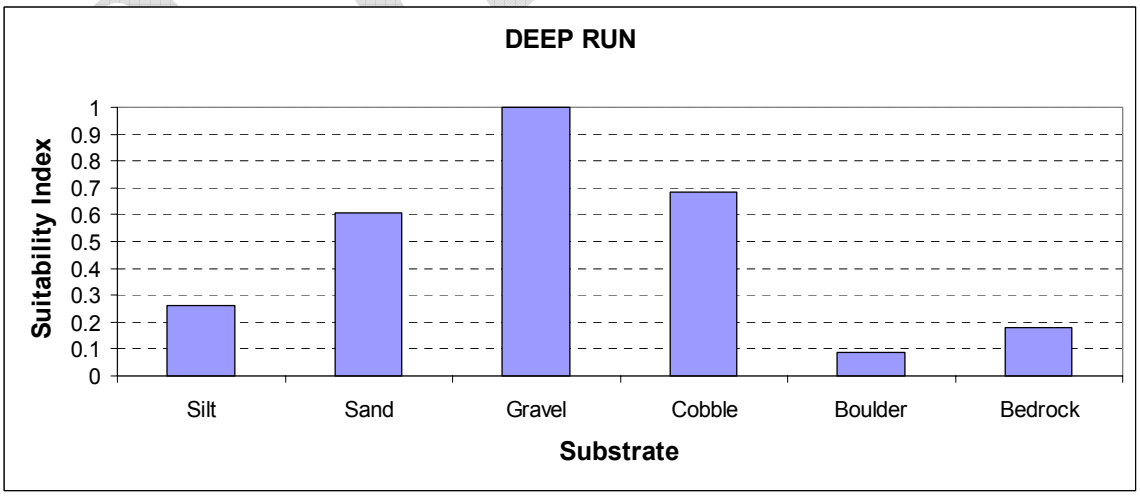


Figure B9 – Frequency distribution and HSC values for Deep Runs Habitat Guild for substrate in the lower Colorado River.

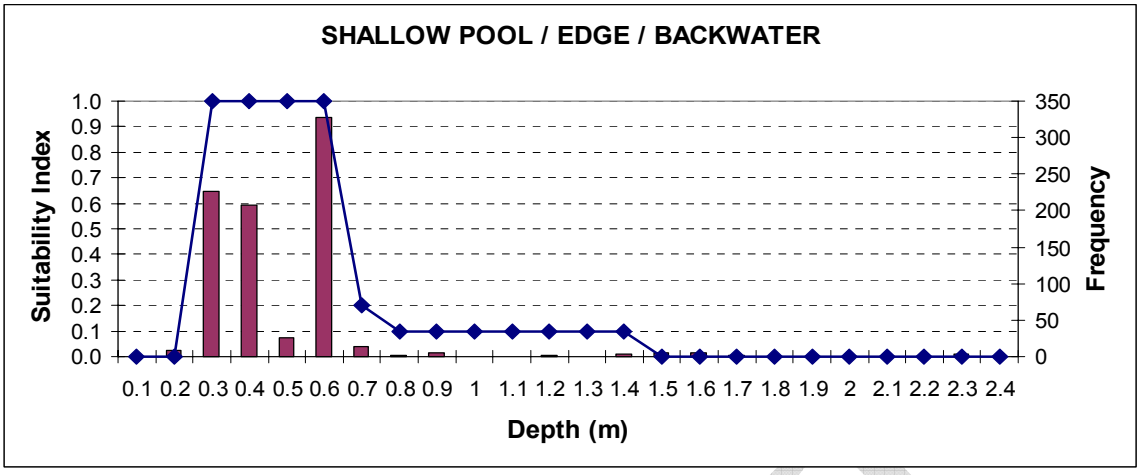


Figure B10 – Frequency distribution and HSC values for Shallow Pools / Edge / Backwater Habitat Guild for depth in the lower Colorado River.

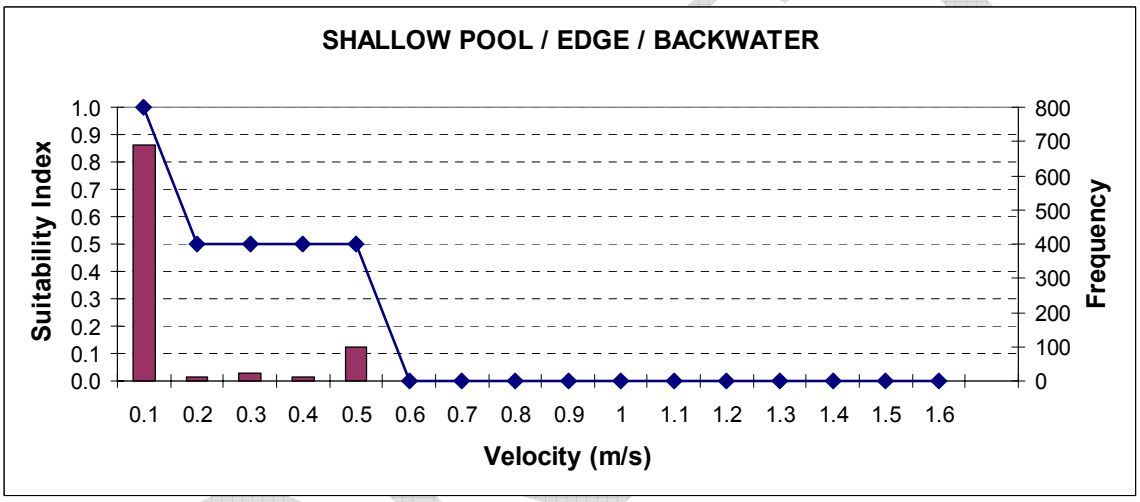


Figure B11 – Frequency distribution and HSC values for Shallow Pools / Edge / Backwater Habitat Guild for velocity in the lower Colorado River.

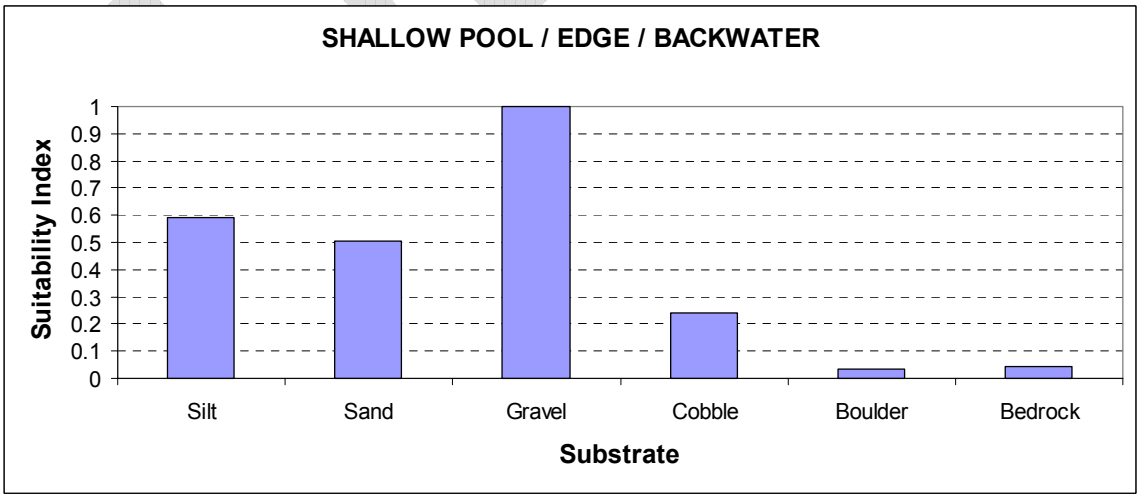


Figure B12 – Frequency distribution and HSC values for Shallow Pools / Edge / Backwater Habitat Guild for substrate in the lower Colorado River.

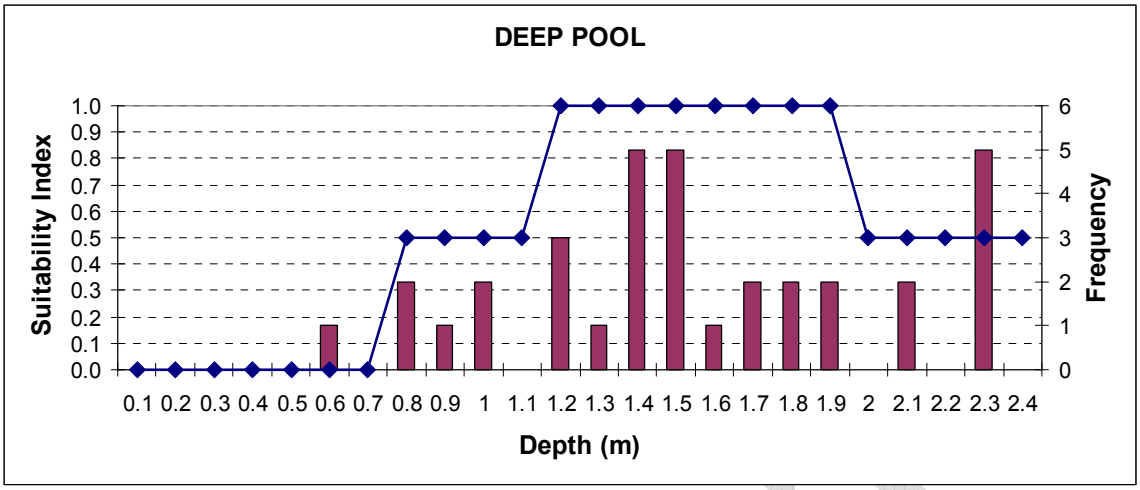


Figure B13 – Frequency distribution and HSC values for Deep Pools Habitat Guild for depth in the lower Colorado River.

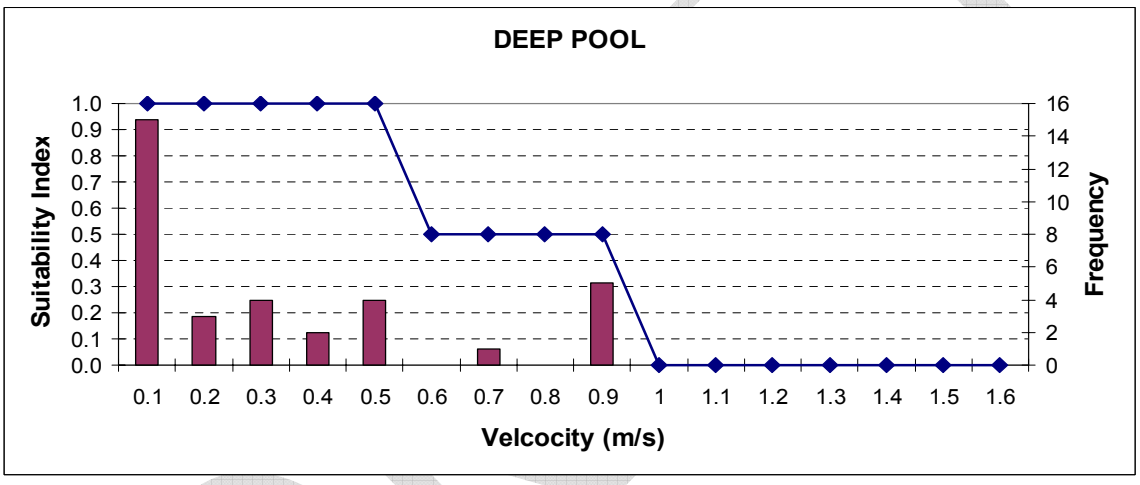


Figure B14 – Frequency distribution and HSC values for Deep Pools Habitat Guild for velocity in the lower Colorado River.

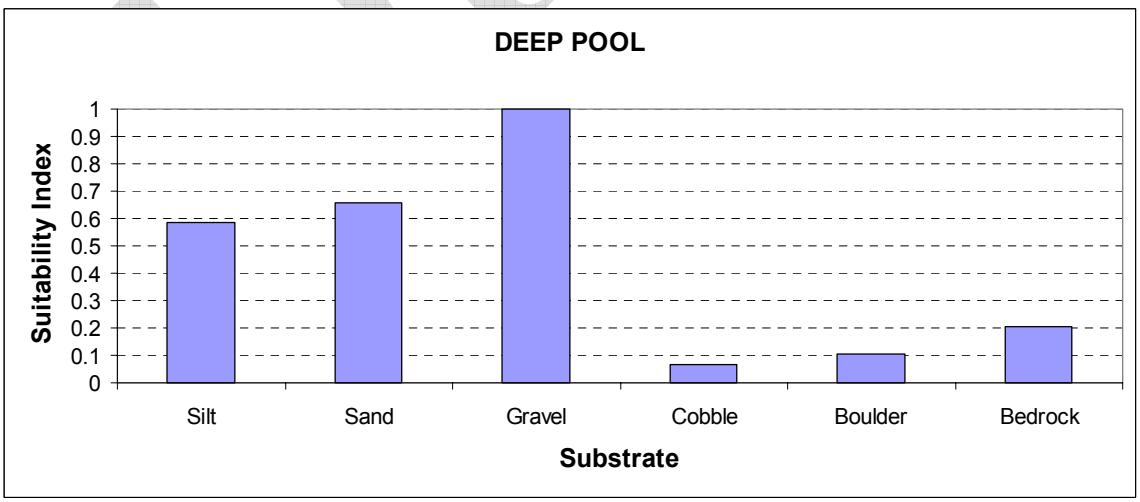


Figure B15 – Frequency distribution and HSC values for Deep Pools Habitat Guild for substrate in the lower Colorado River.

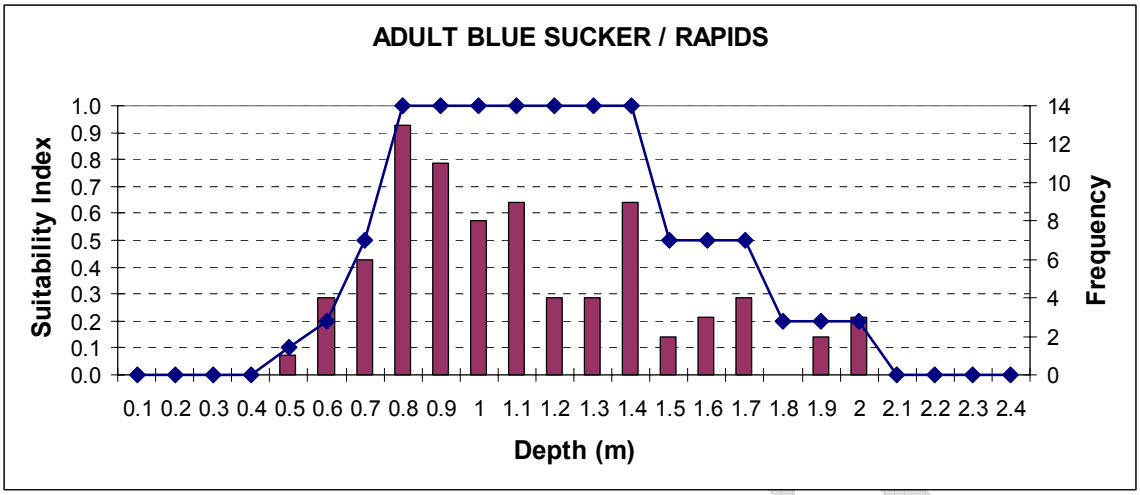


Figure B16 – Frequency distribution and HSC values for Adult Blue Sucker / Rapids Habitat Guild for depth in the lower Colorado River.

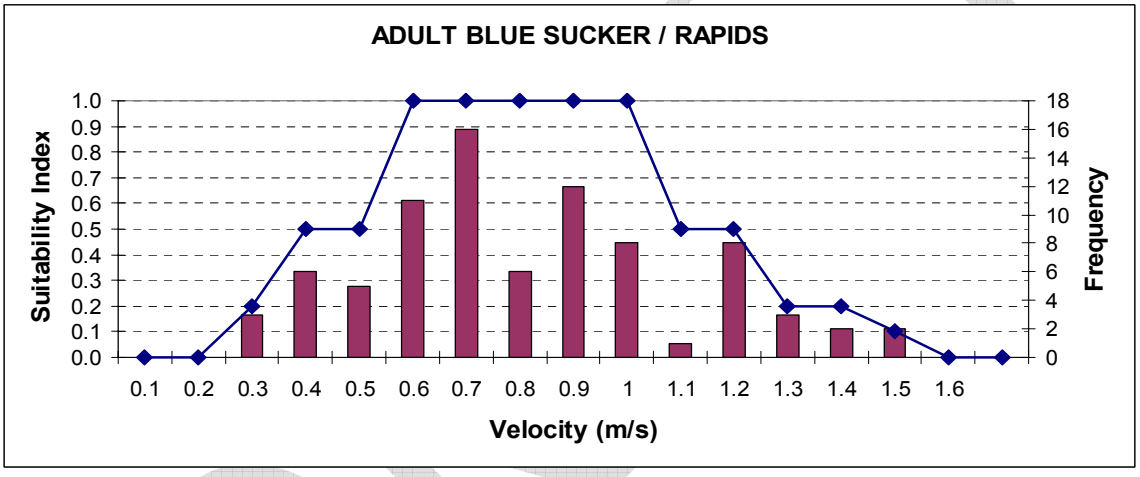


Figure B17 – Frequency distribution and HSC values for Adult Blue Sucker / Rapids Habitat Guild for velocity in the lower Colorado River.

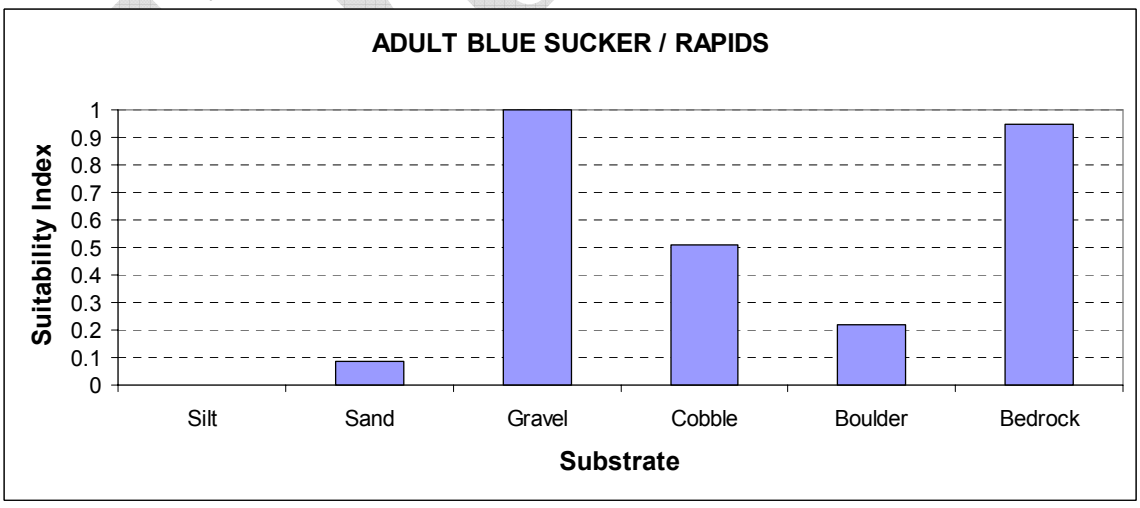


Figure B18 – Frequency distribution and HSC values for Adult Blue Sucker / Rapids Habitat Guild for substrate in the lower Colorado River.

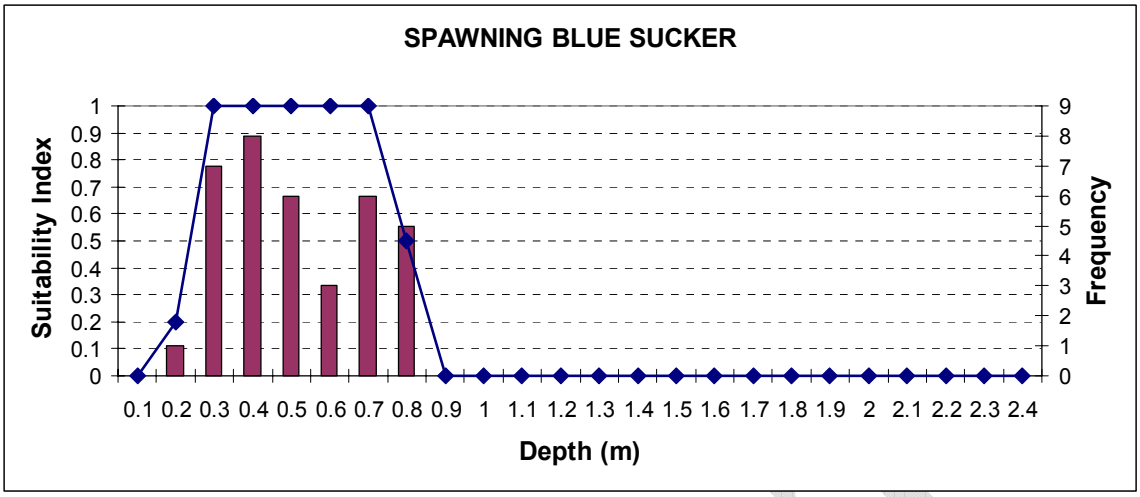


Figure B19 – Frequency distribution and HSC values for Spawning Blue Sucker for depth in the lower Colorado River.

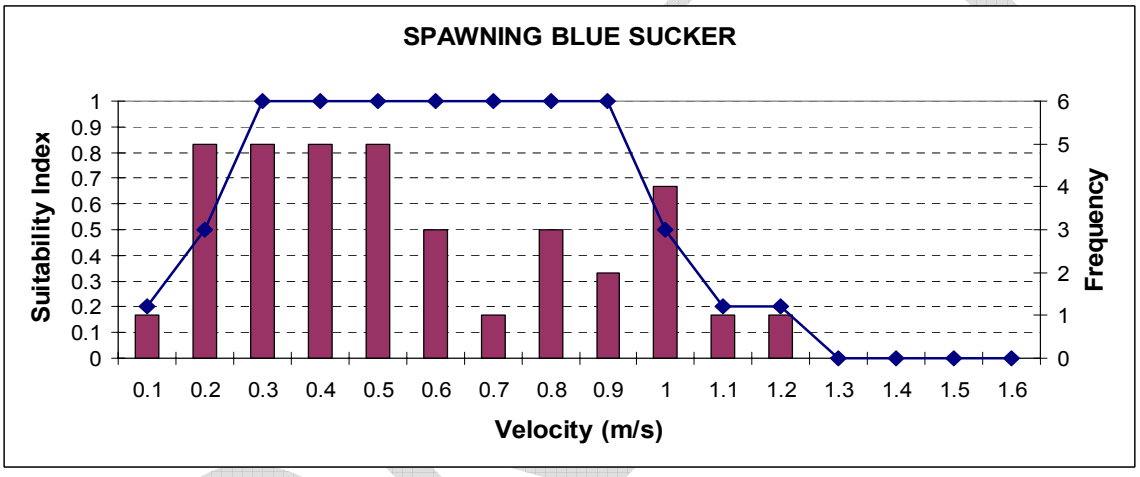


Figure B20 – Frequency distribution and HSC values for Spawning Blue Sucker for velocity in the lower Colorado River.

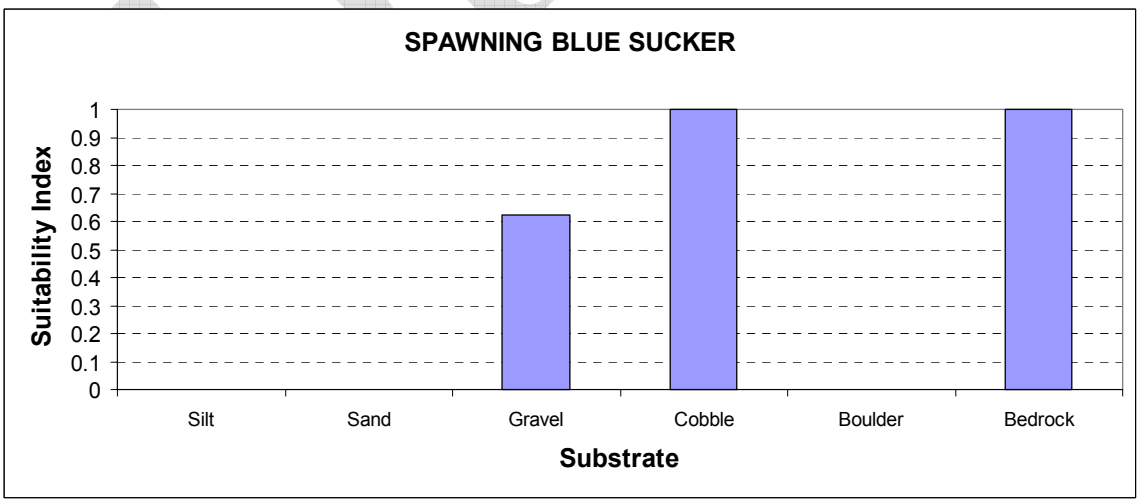


Figure B21 – Frequency distribution and HSC values for Spawning Blue Sucker for substrate in the lower Colorado River.

# APPENDIX C – WUA versus Discharge Relationships

DRAFT

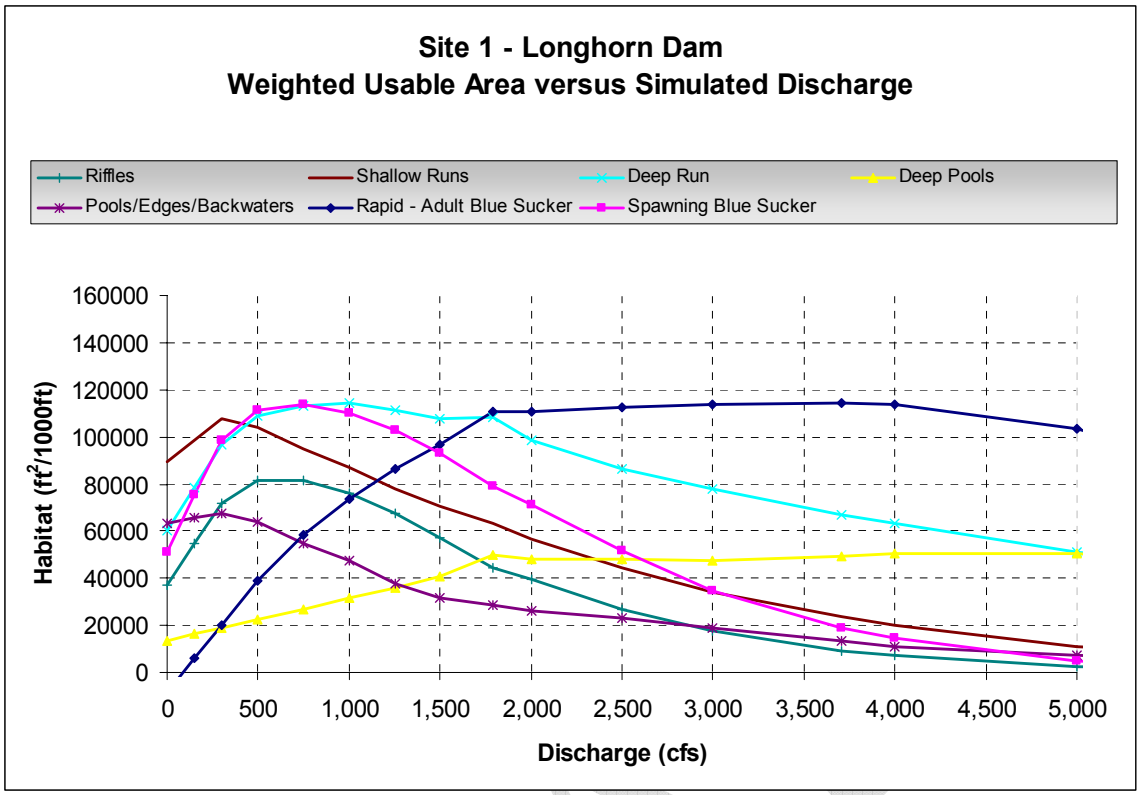


**Figure C1.** Weighted usable area versus simulated discharge at Longhorn Dam (Site 1)

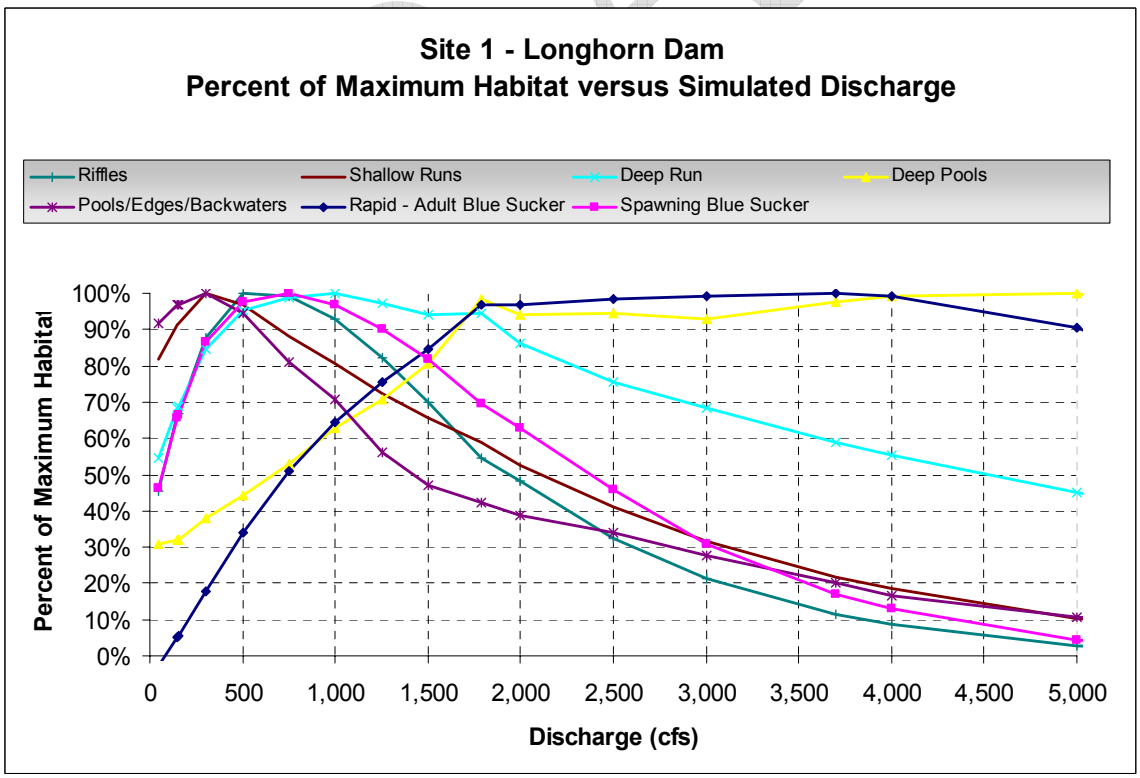


**Figure C2.** Percent of maximum habitat vs. simulated discharge at Longhorn Dam (Site 1)

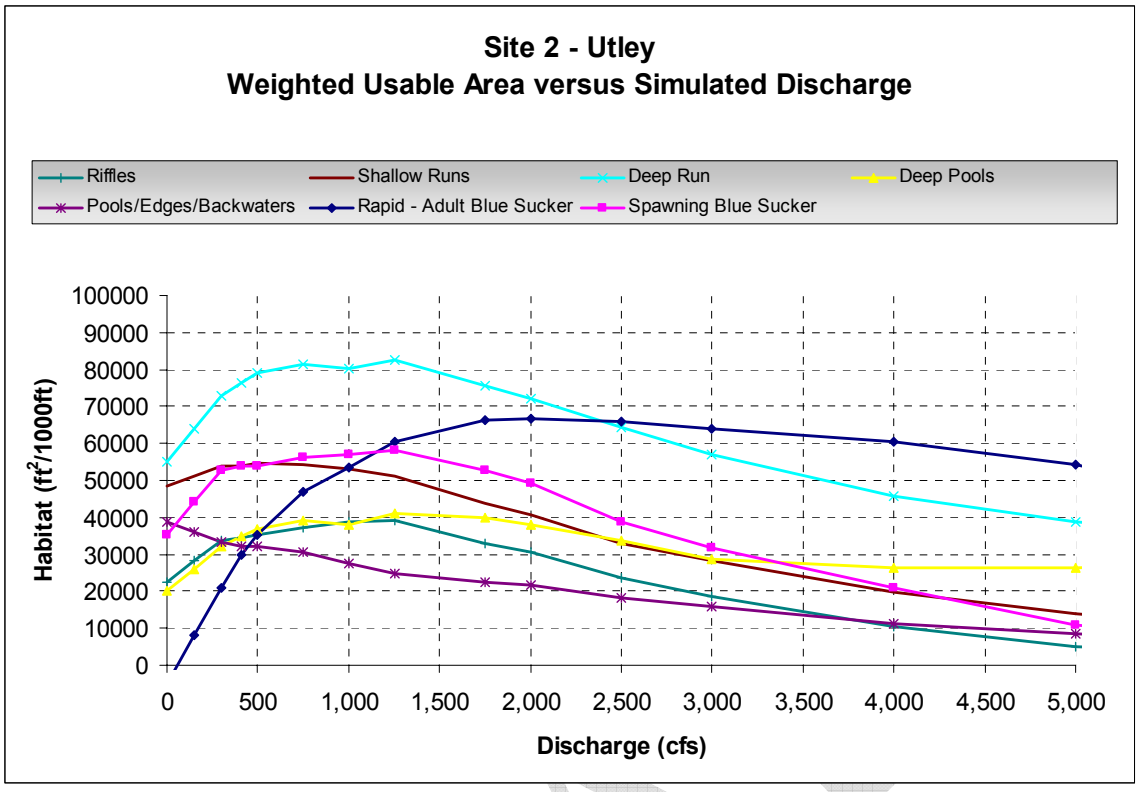


**Figure C3.** Weighted usable area versus simulated discharge at Utley (Site 2)

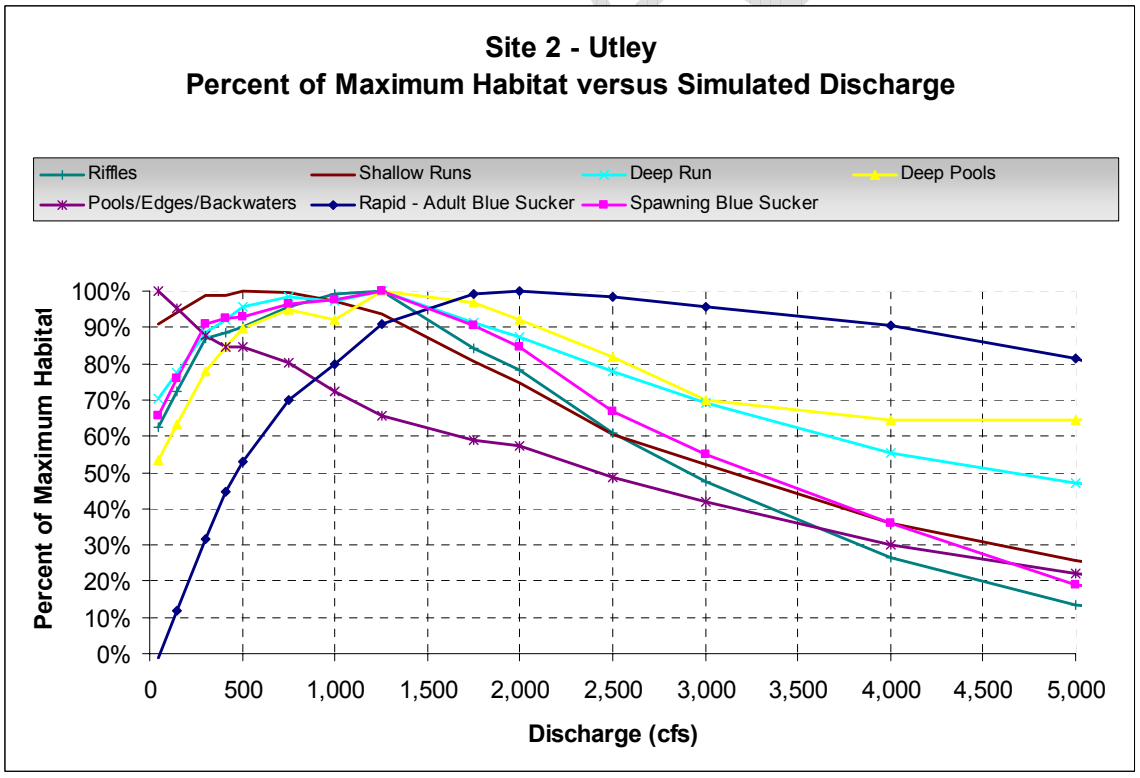


**Figure C4.** Percent of maximum habitat vs. simulated discharge at Utley (Site 2)

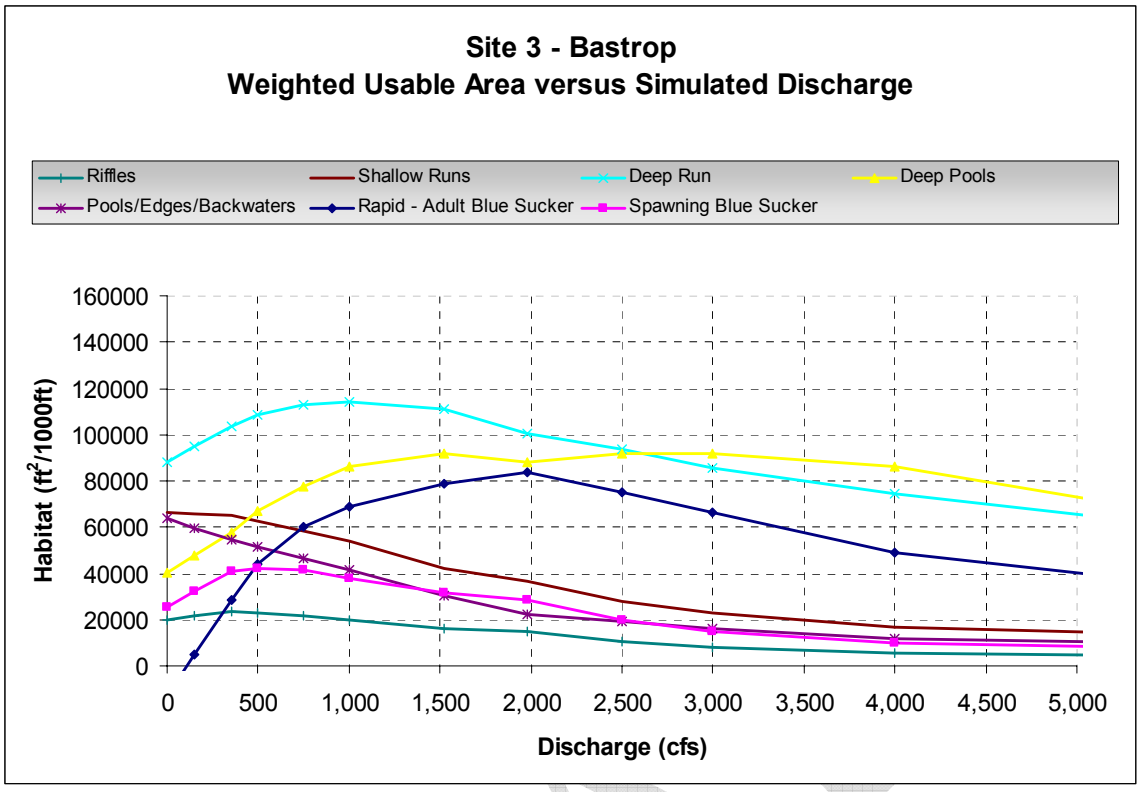


**Figure C5.** Weighted usable area versus simulated discharge at Bastrop (Site 3)

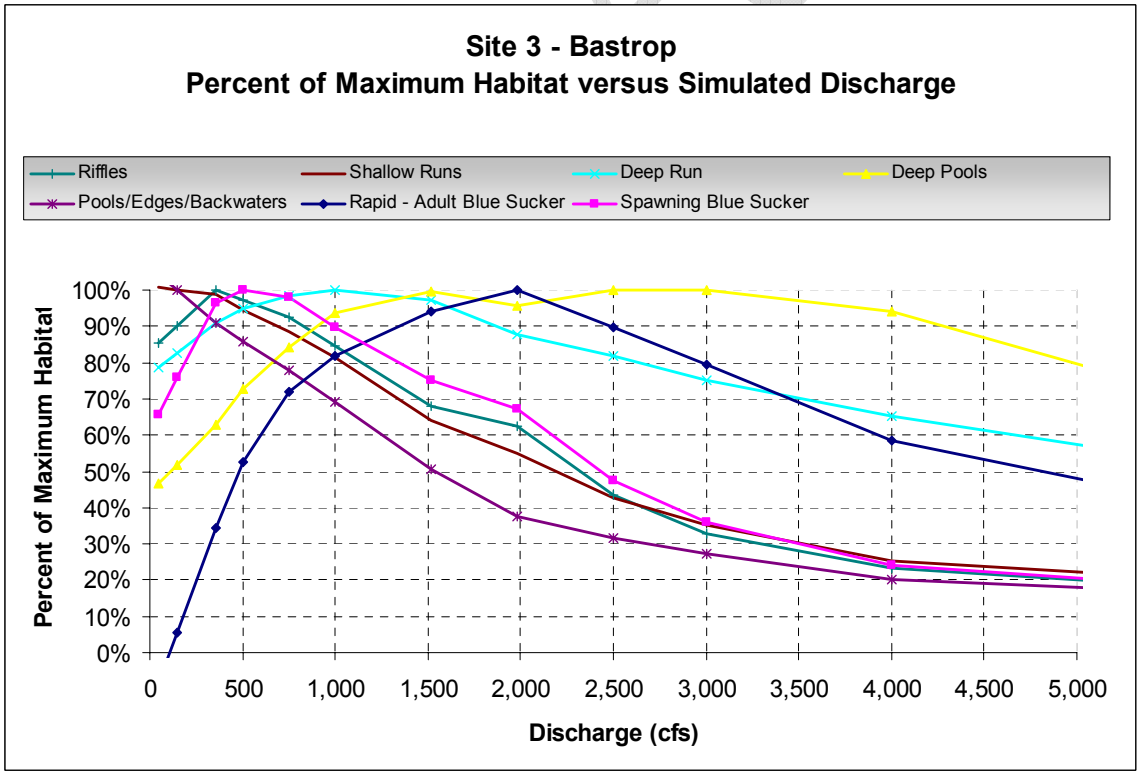


**Figure C6.** Percent of maximum habitat vs. simulated discharge at Bastrop (Site 3)

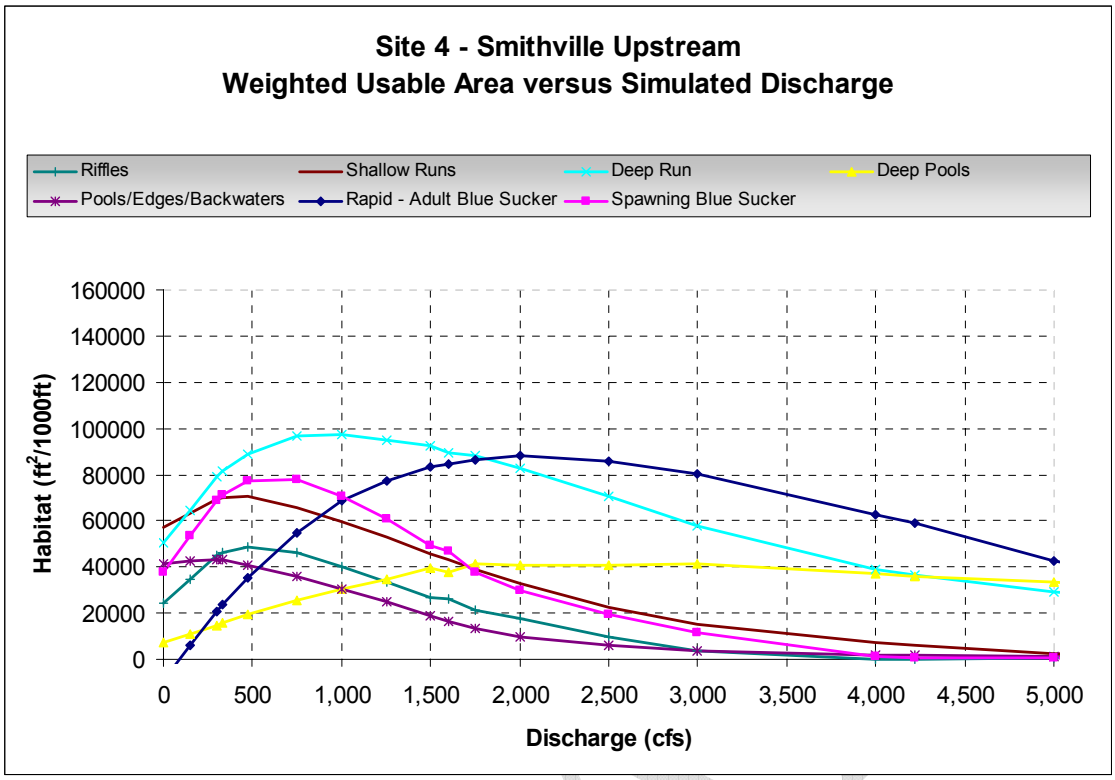


**Figure C7.** Weighted usable area versus simulated discharge at Smithville Upstream (Site 4)

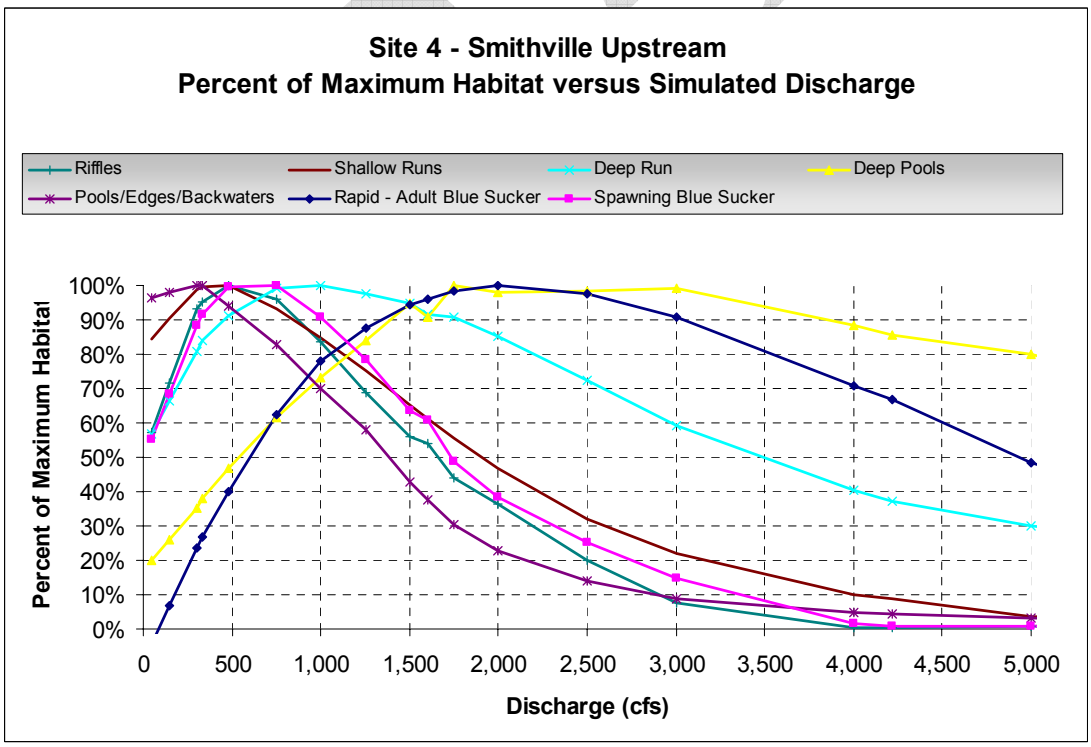


**Figure C8.** Percent of maximum habitat vs. simulated discharge at Smithville Upstream (Site 4)

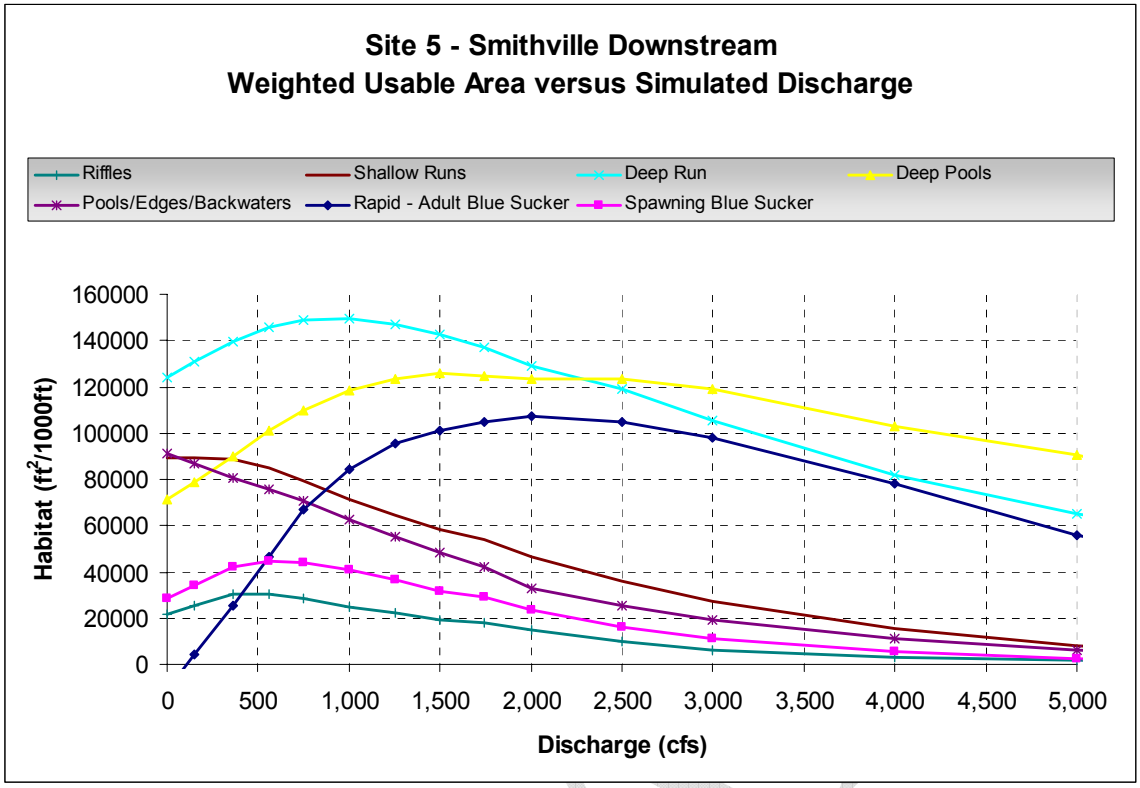


**Figure C9.** Weighted usable area versus simulated discharge at Smithville Down (Site 5)

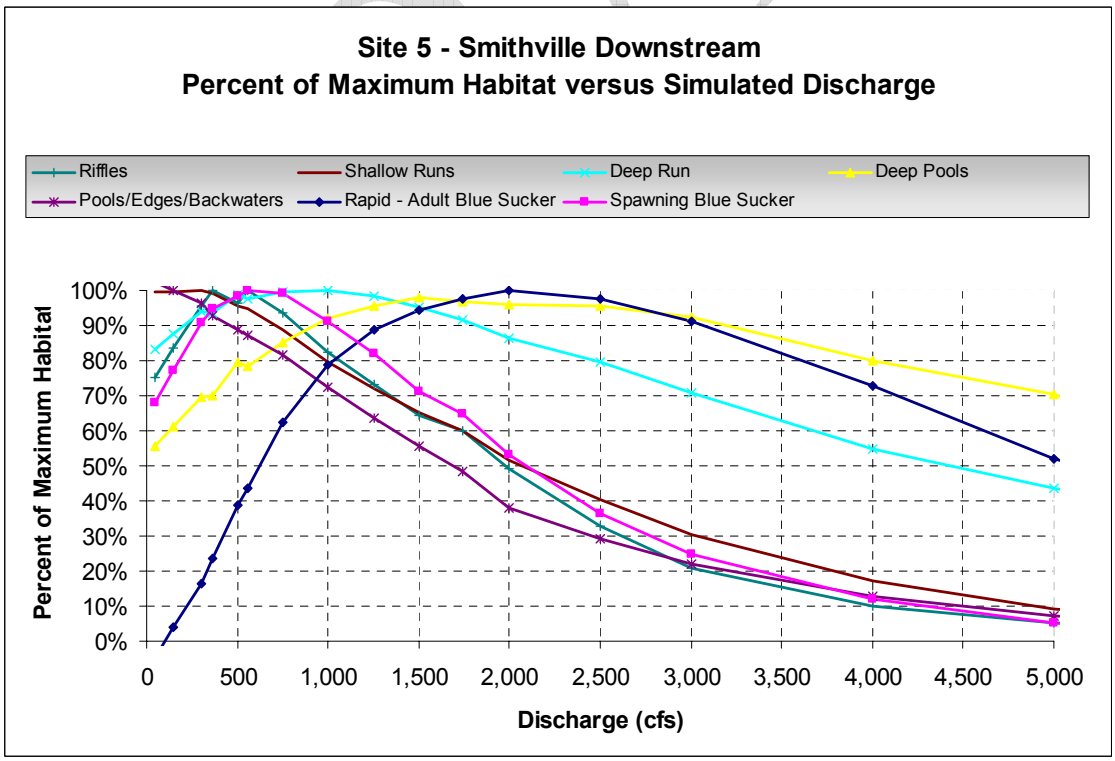


**Figure C10.** Percent of maximum habitat vs. simulated discharge at Smithville Down (Site 5)

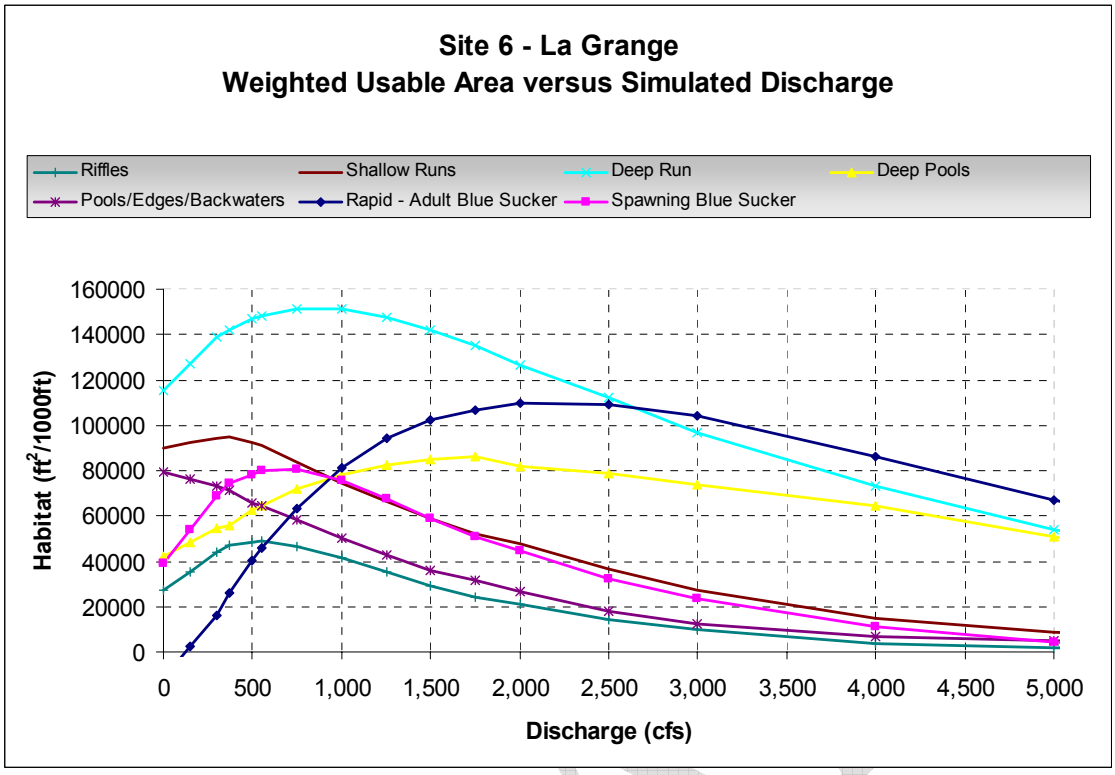


**Figure C11.** Weighted usable area versus simulated discharge at LaGrange (Site 6)

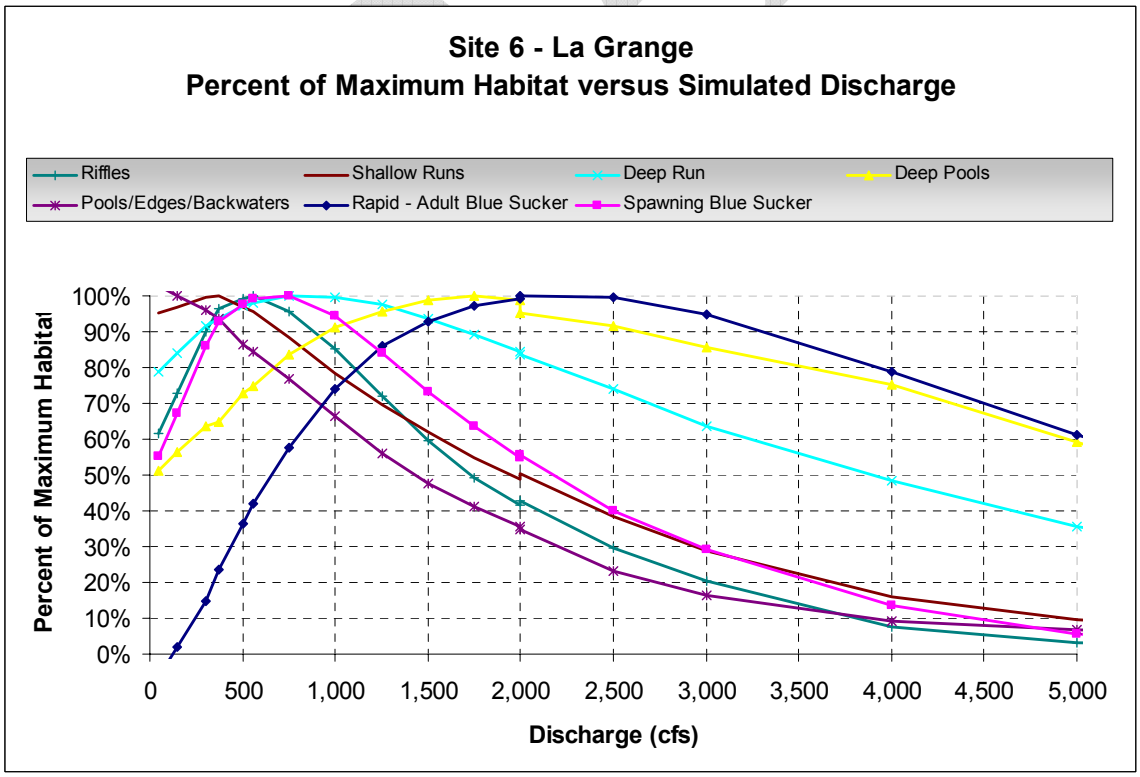


**Figure C12.** Percent of maximum habitat vs. simulated discharge at LaGrange (Site 6)

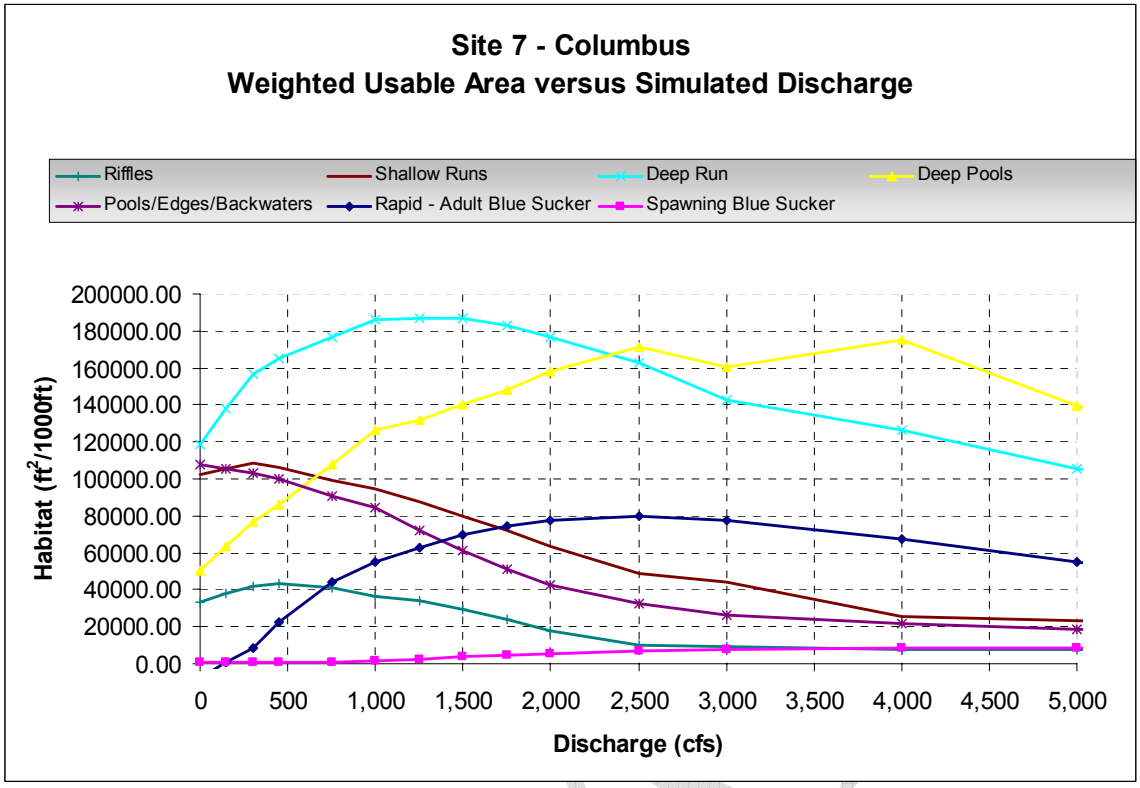


**Figure C13.** Weighted usable area versus simulated discharge at Columbus (Site 7)

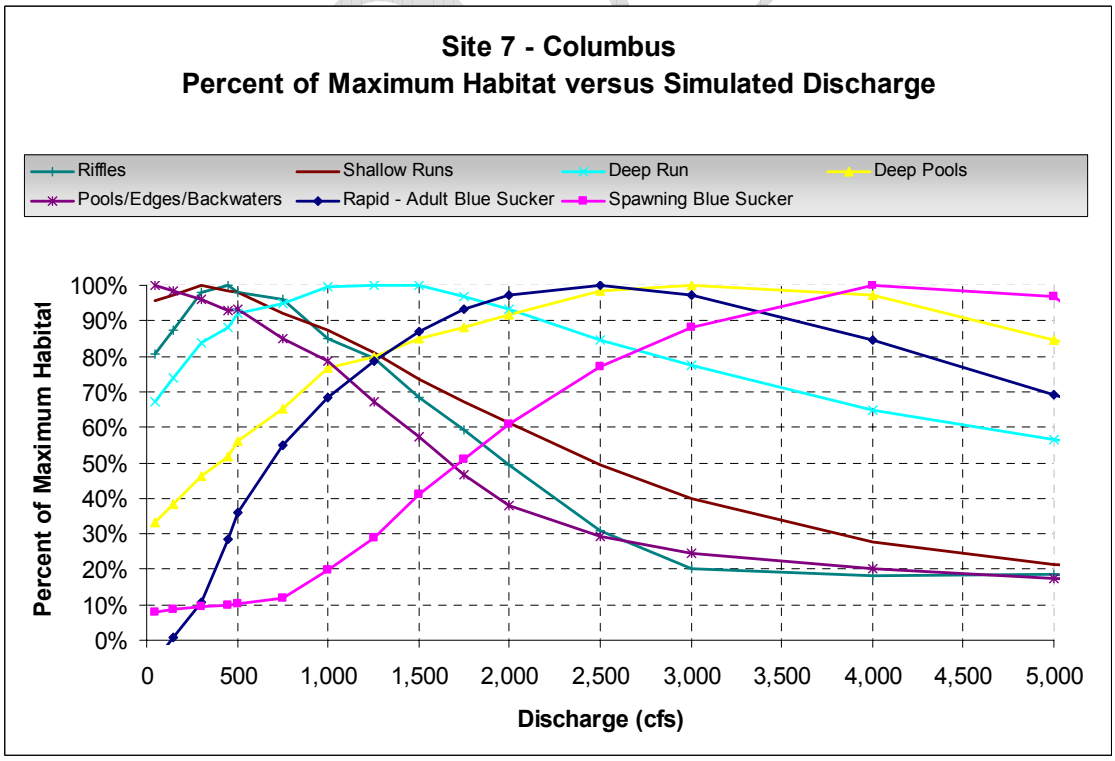


**Figure C14.** Percent of maximum habitat vs. simulated discharge at Columbus (Site 7)

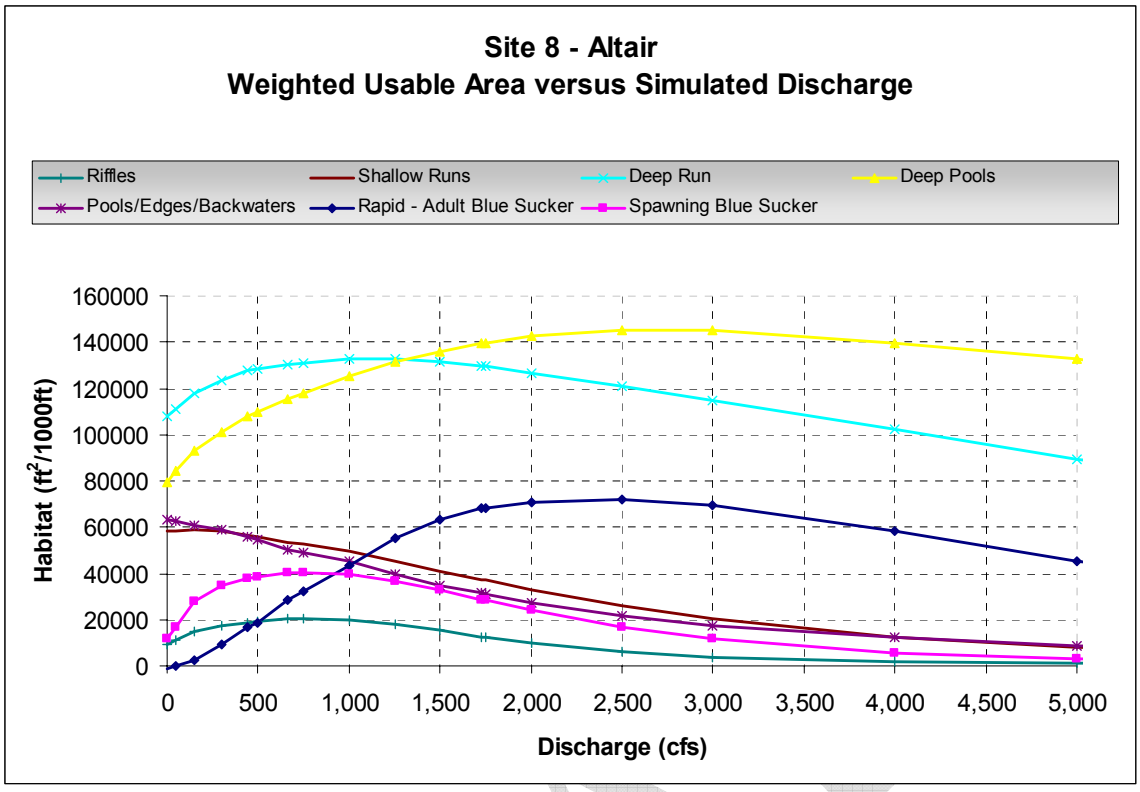


**Figure C15.** Weighted usable area versus simulated discharge at Altair (Site 8)

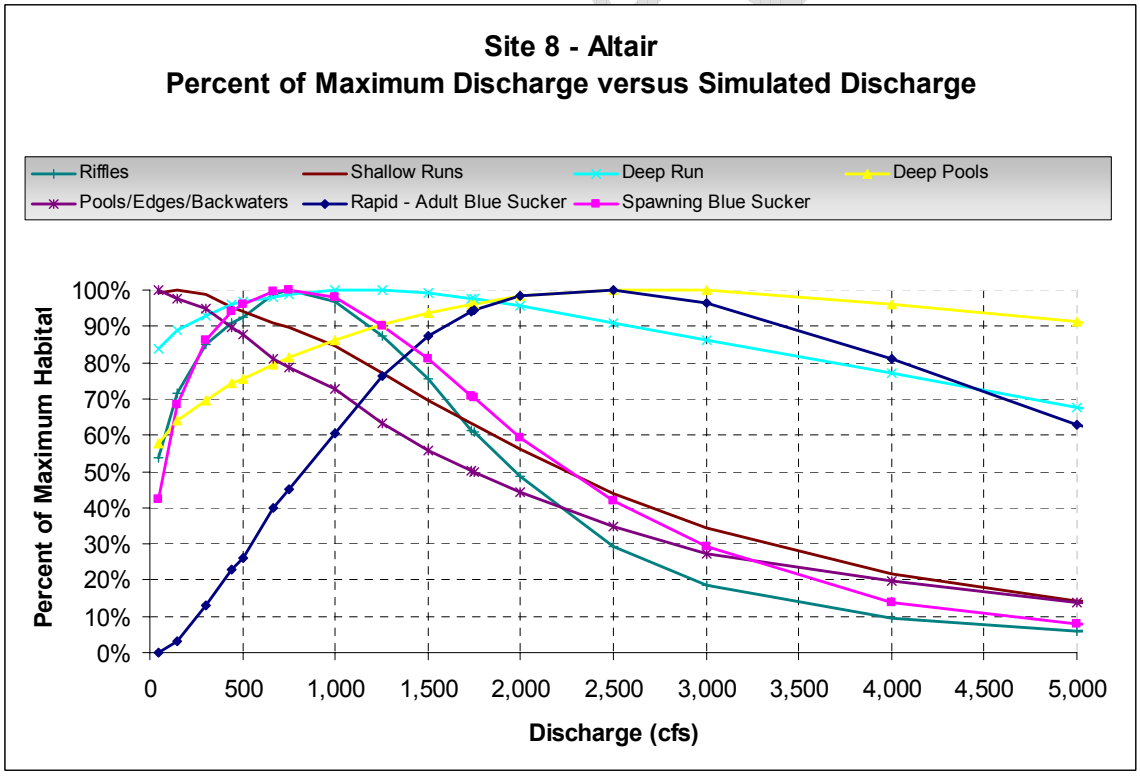


**Figure C16.** Percent of maximum habitat vs. simulated discharge at Altair (Site 8)

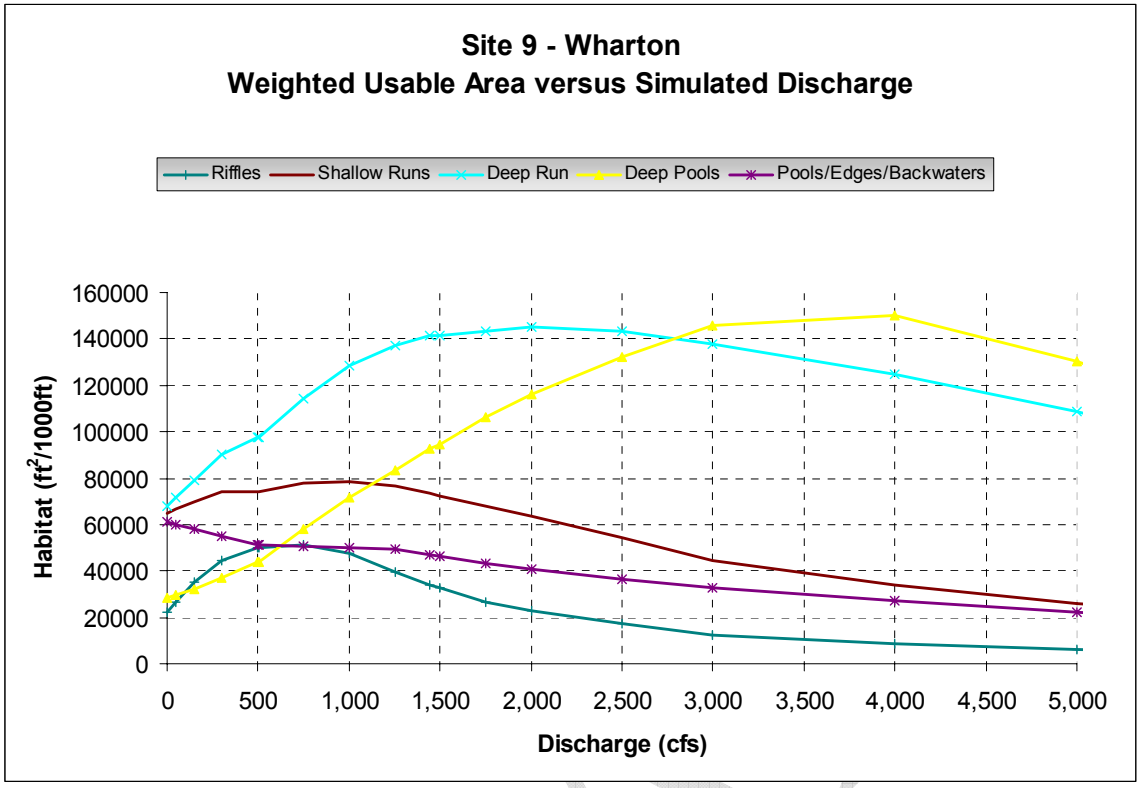


**Figure C17.** Weighted usable area versus simulated discharge at Wharton (Site 9)

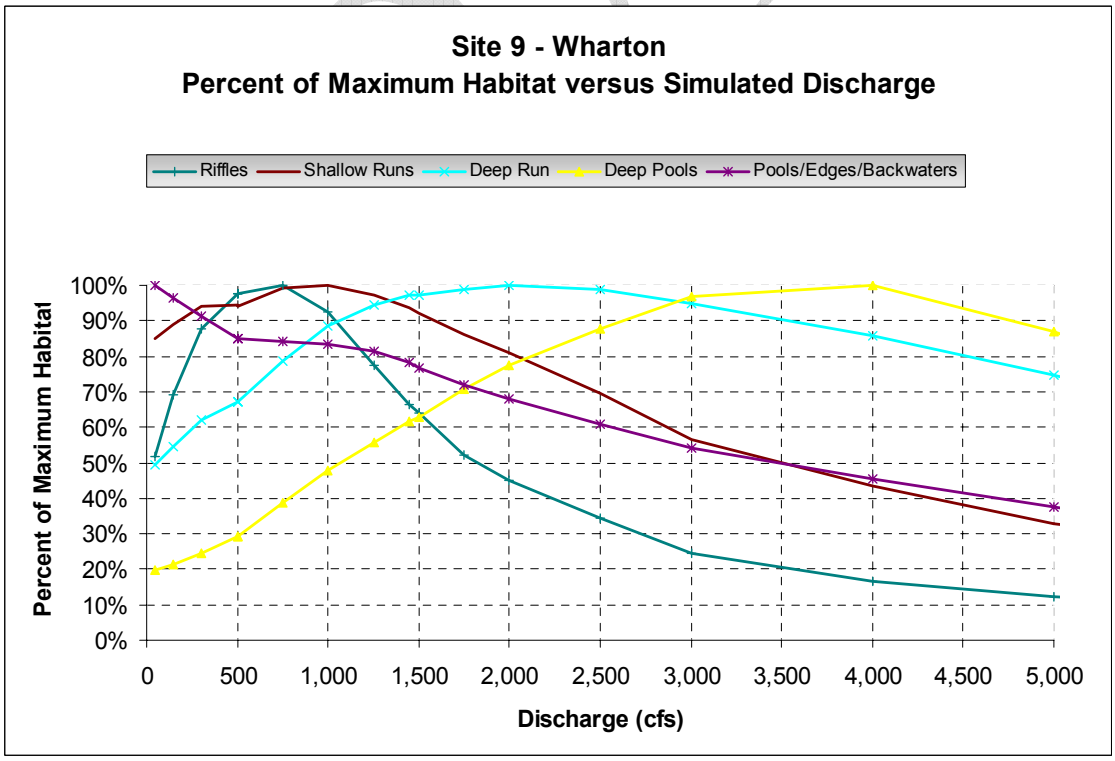


**Figure C18.** Percent of maximum habitat vs. simulated discharge at Wharton (Site 9)

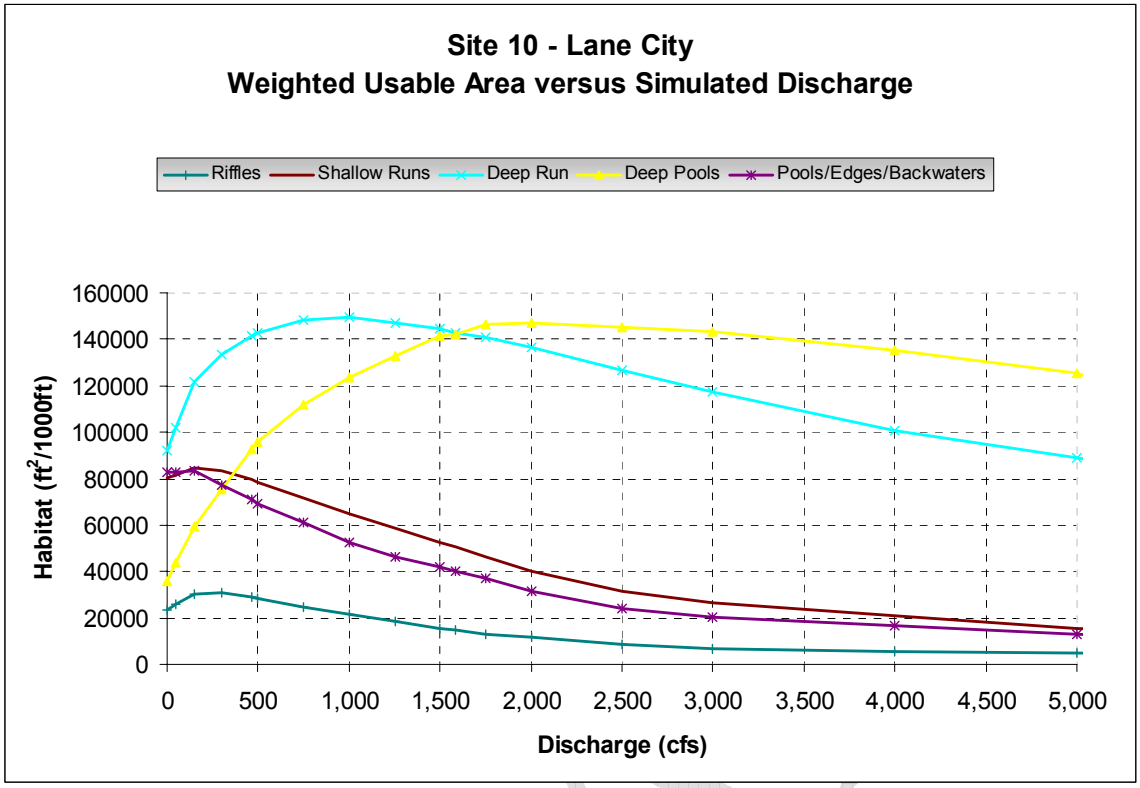


**Figure C19.** Weighted usable area versus simulated discharge at Lane City (Site 10)

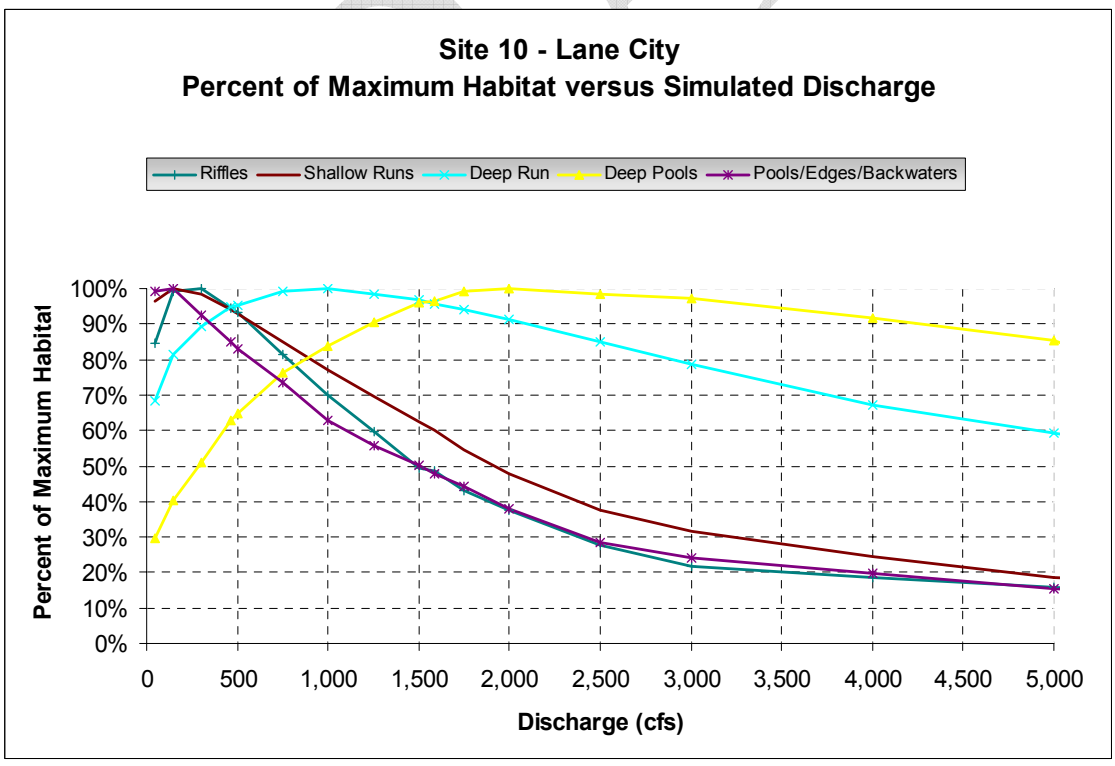


**Figure C20.** Percent of maximum habitat vs. simulated discharge at Lane City (Site 10)

# APPENDIX D – Habitat Duration Curves

DRAFT

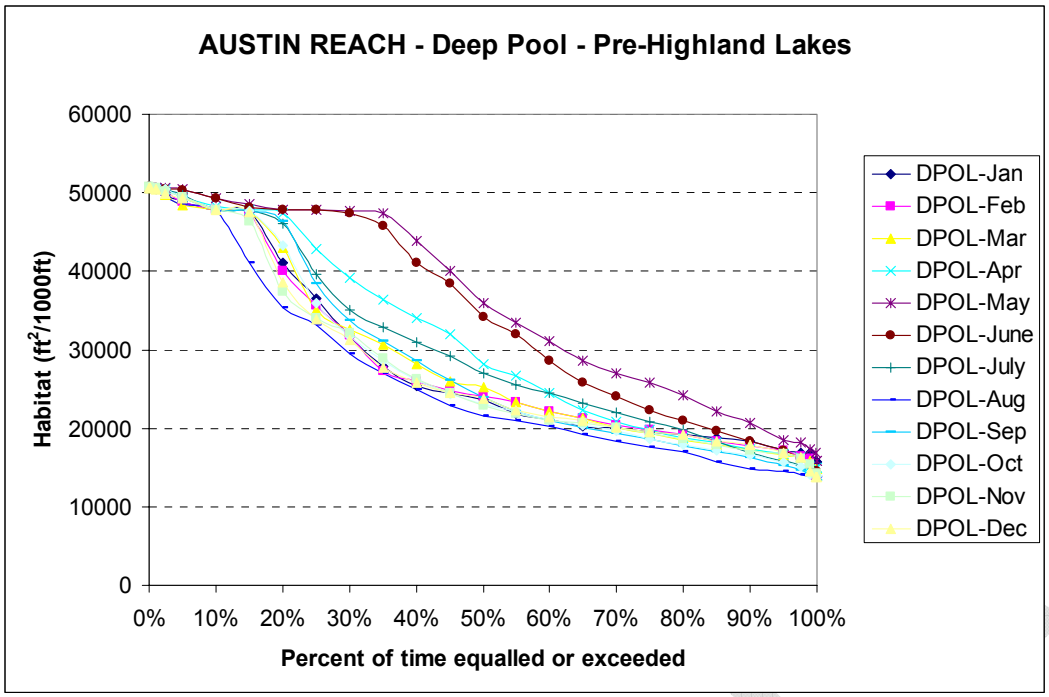


**Figure D1.** Habitat durations for deep pool for all months at the Austin Reach based on the pre-1940 flow regime.

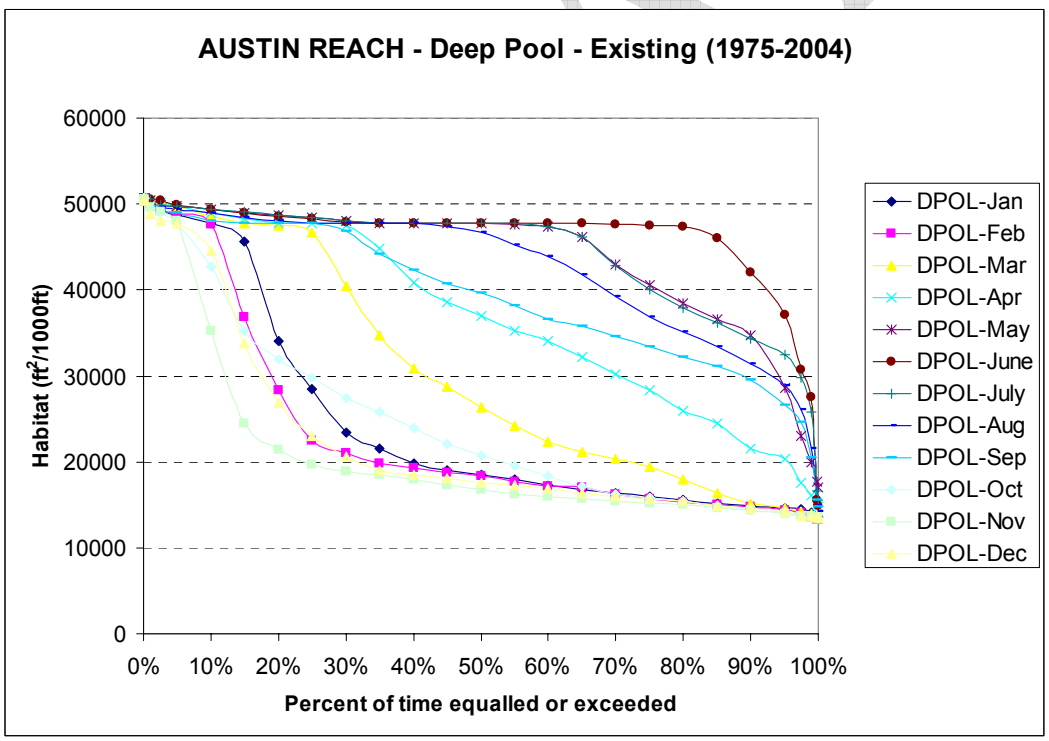


**Figure D2.** Habitat durations for deep pool for all months at the Austin Reach based on the existing flow regime.

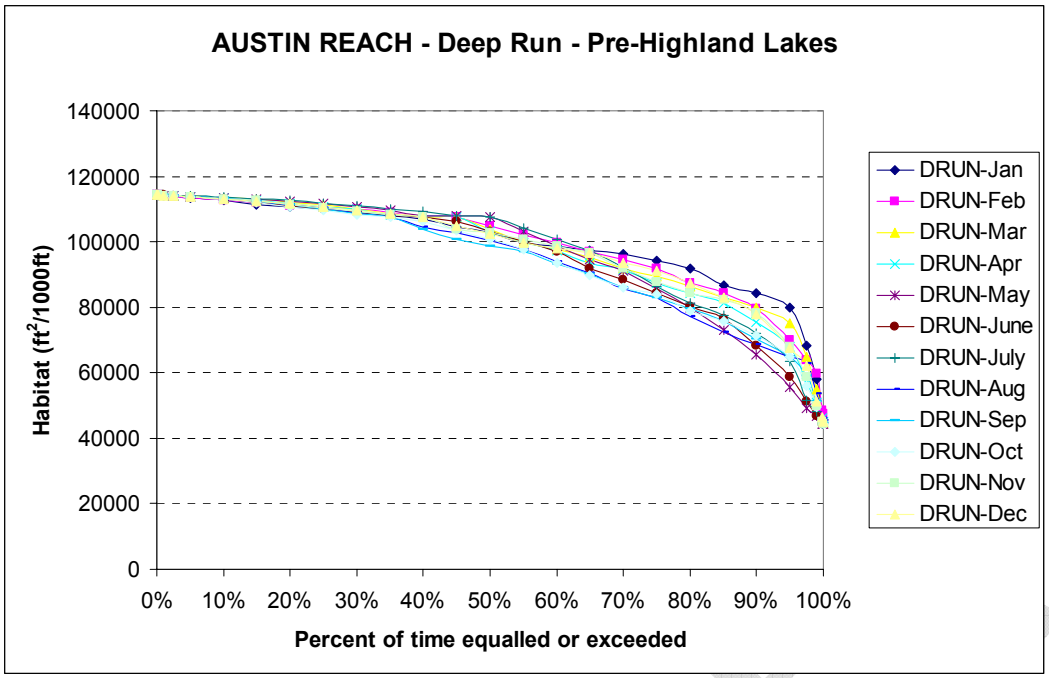


**Figure D3.** Habitat durations for deep run for all months at the Austin Reach based on the pre-1940 flow regime.

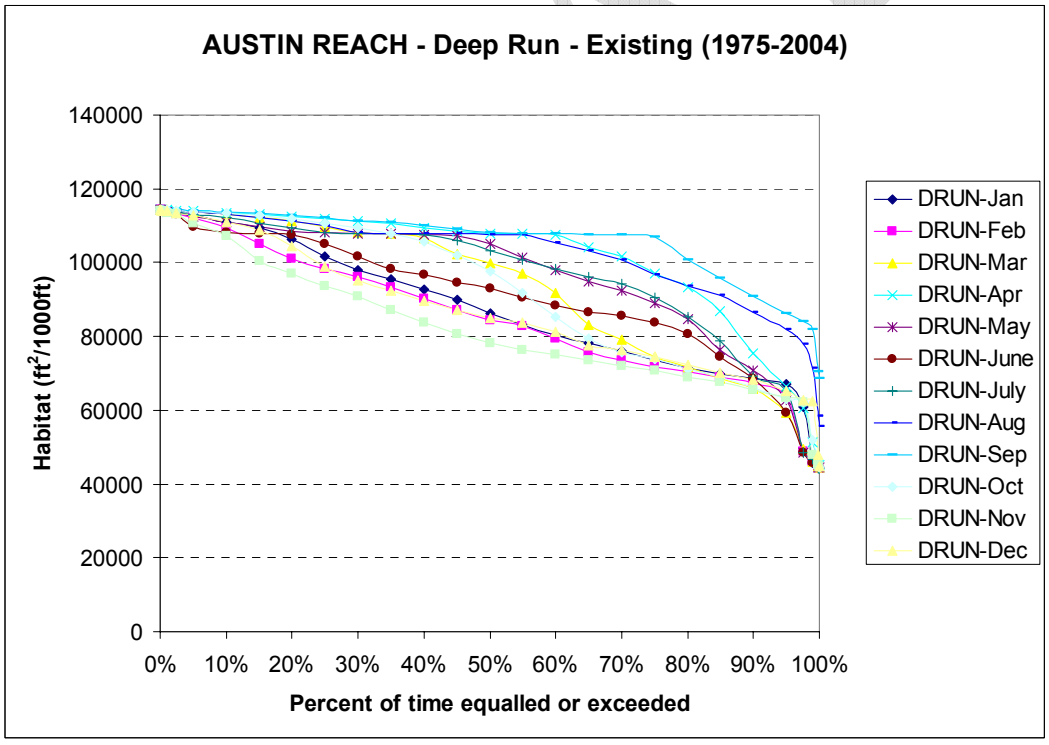


**Figure D4.** Habitat durations for deep run for all months at the Austin Reach based on the existing flow regime.

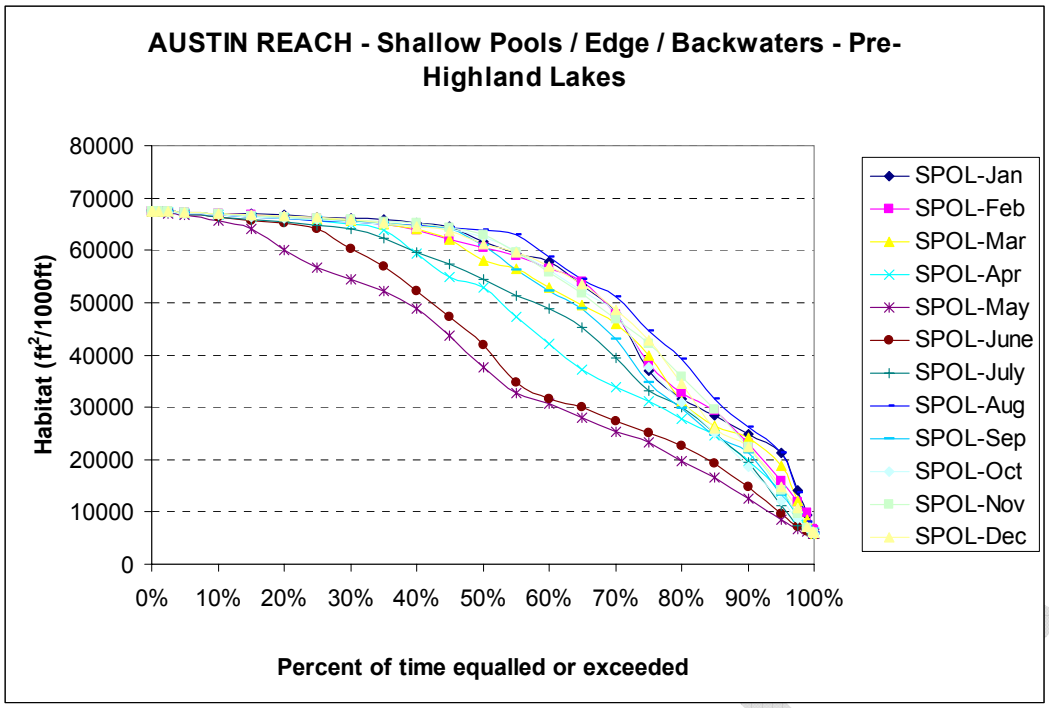


**Figure D5.** Habitat durations for shallow pools/edge/backwater for all months at the Austin Reach based on the pre-1940 flow regime.

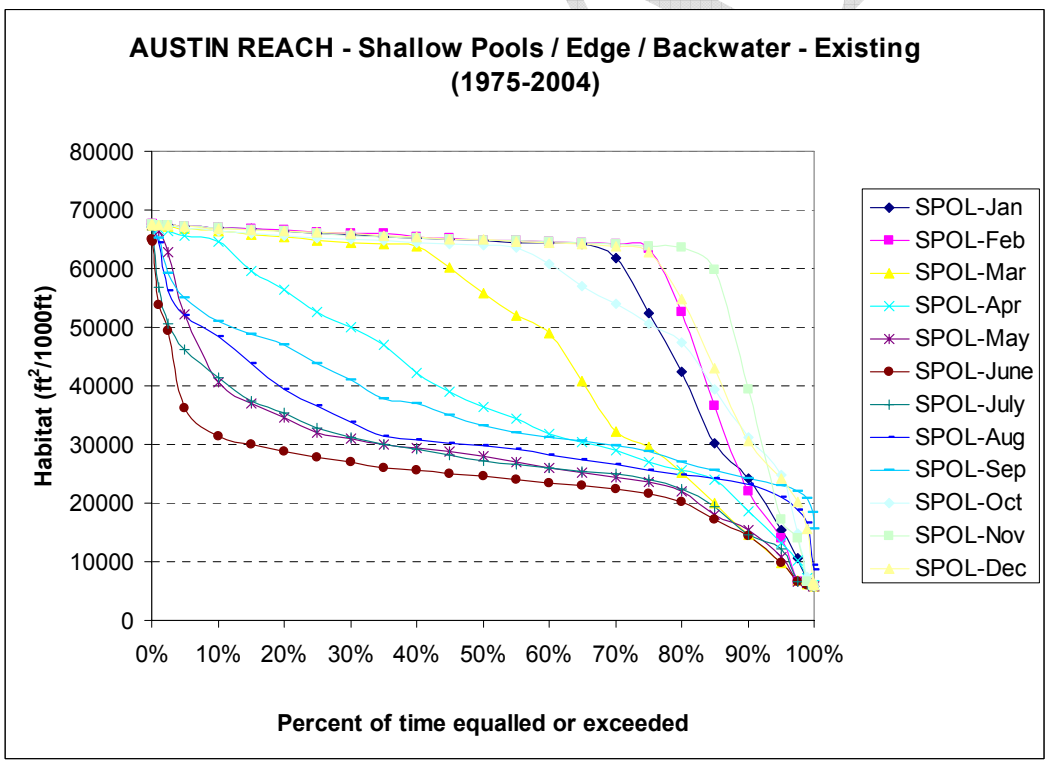


**Figure D6.** Habitat durations for shallow pools/edge/backwater for all months at the Austin Reach based on the existing flow regime.

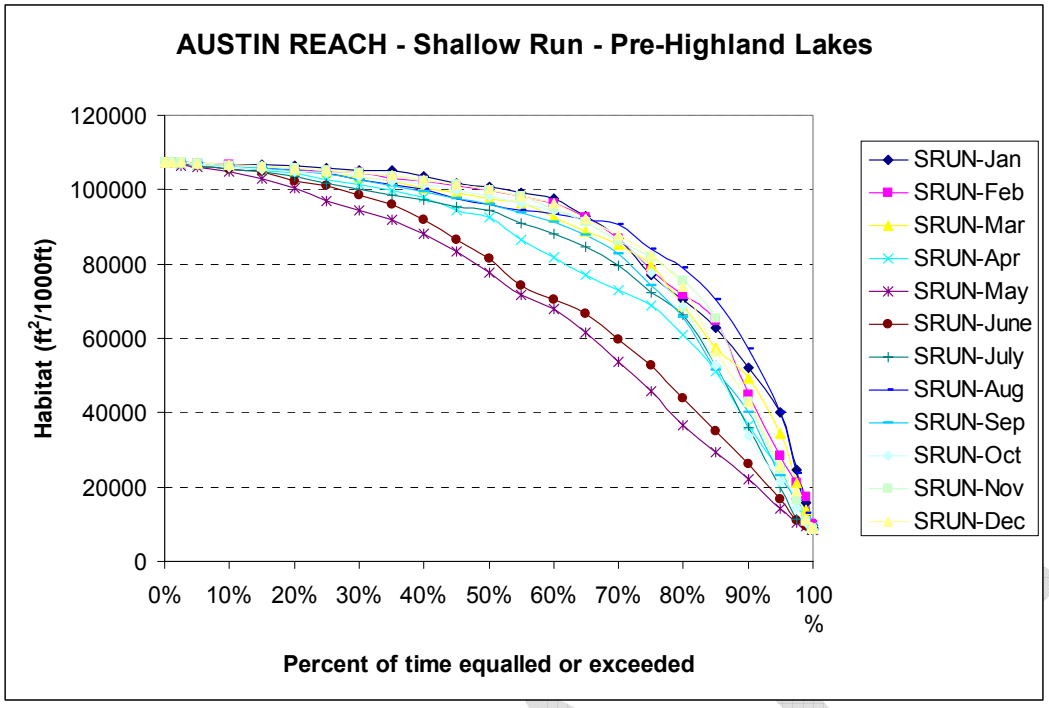


**Figure D7.** Habitat durations for shallow run for all months at the Austin Reach based on the pre-1940 flow regime.

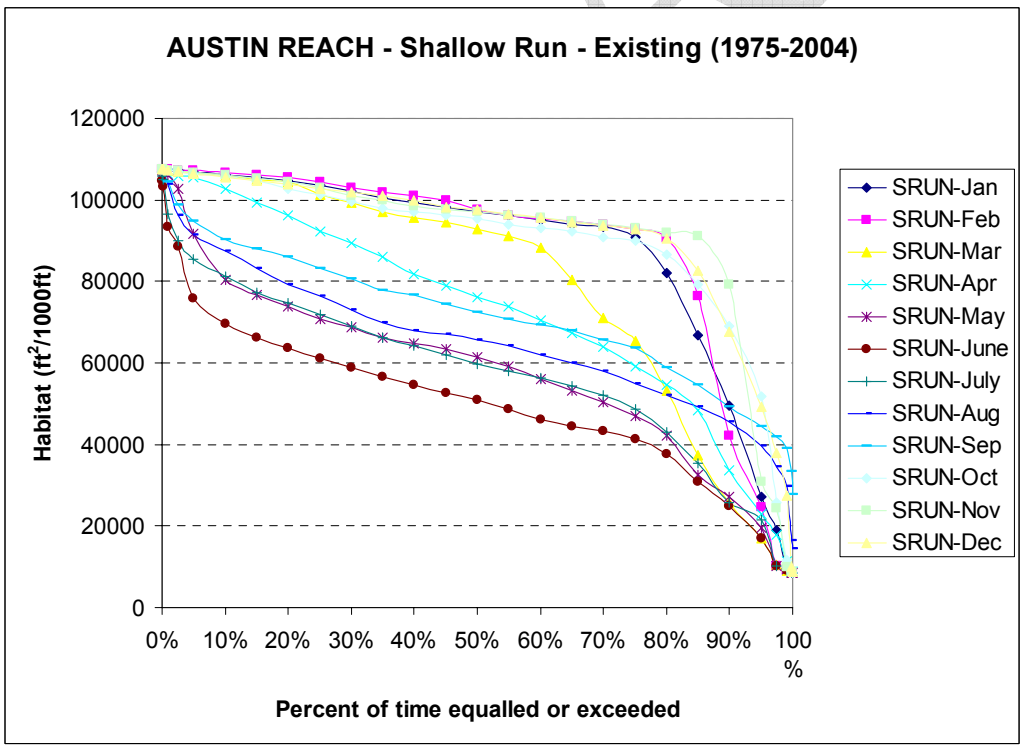


**Figure D8.** Habitat durations for shallow run for all months at the Austin Reach based on the existing flow regime.

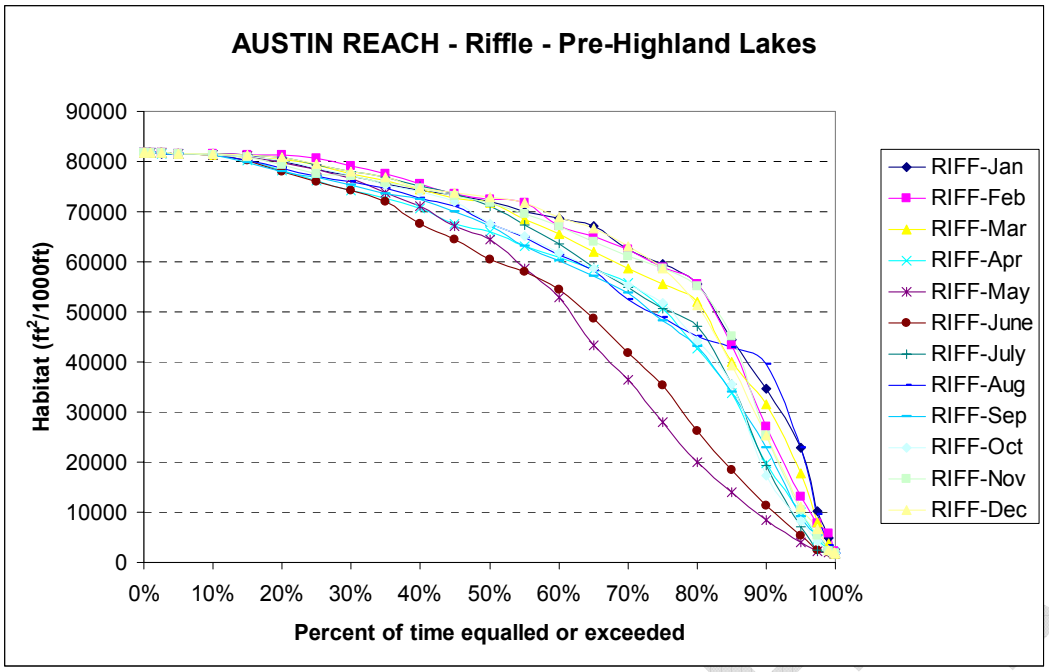


**Figure D9.** Habitat durations for riffles for all months at the Austin Reach based on the pre-1940 flow regime.

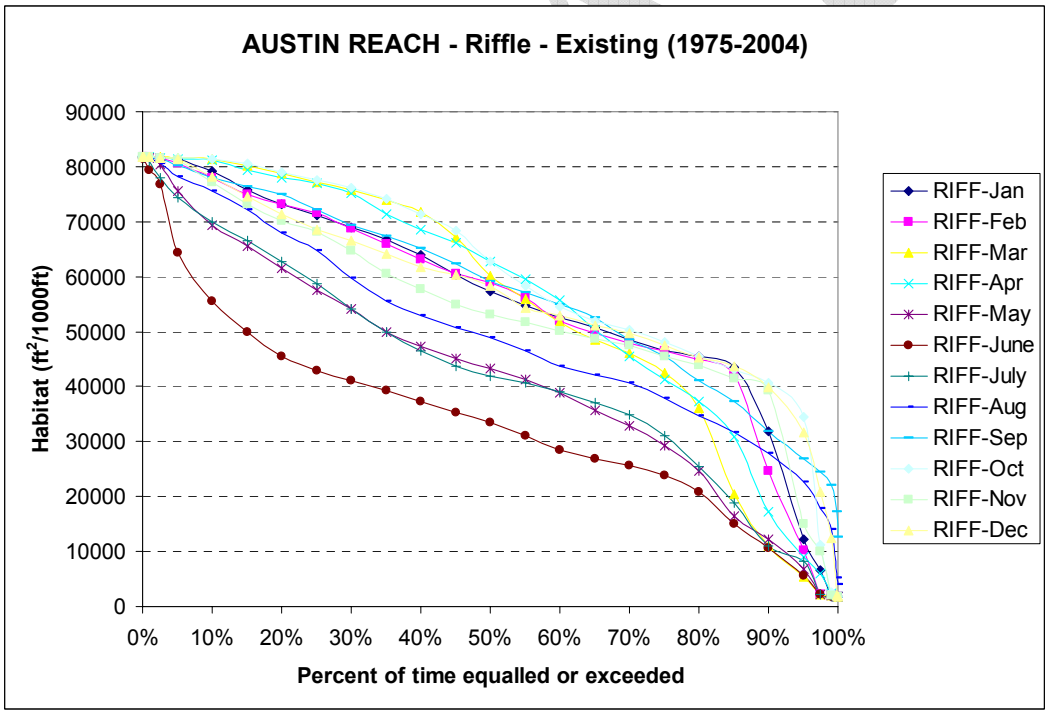


**Figure D10.** Habitat durations for riffles for all months at the Austin Reach based on the existing flow regime.

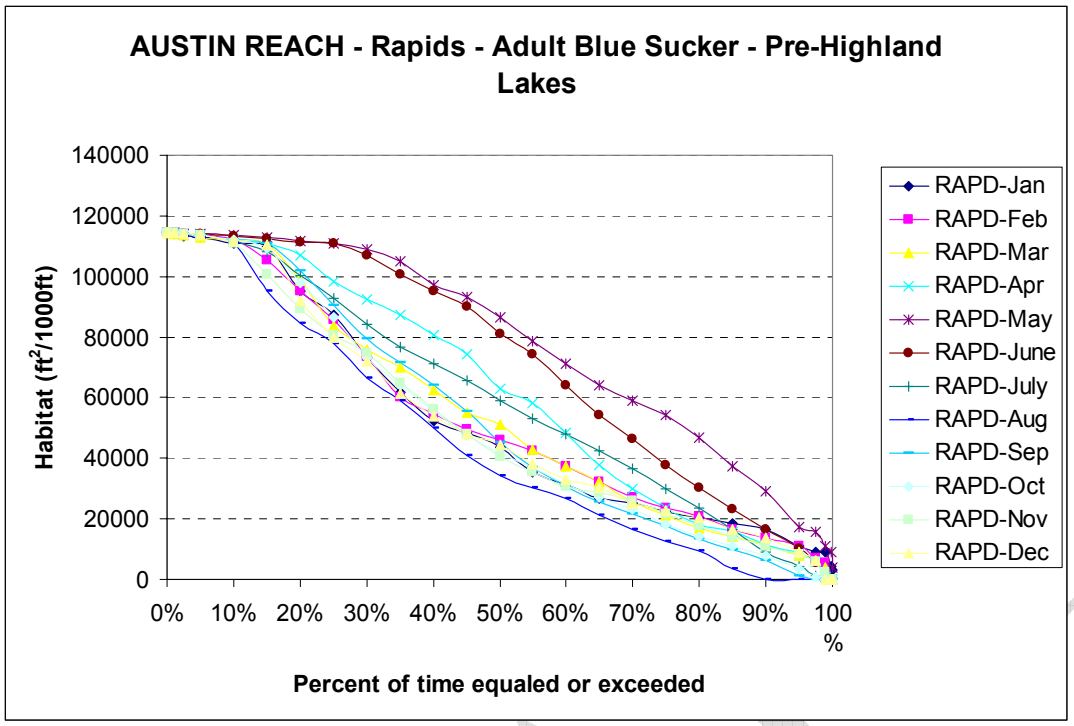


**Figure D11.** Habitat durations for rapids / adult blue sucker for all months at the Austin Reach based on the pre-1940 flow regime.

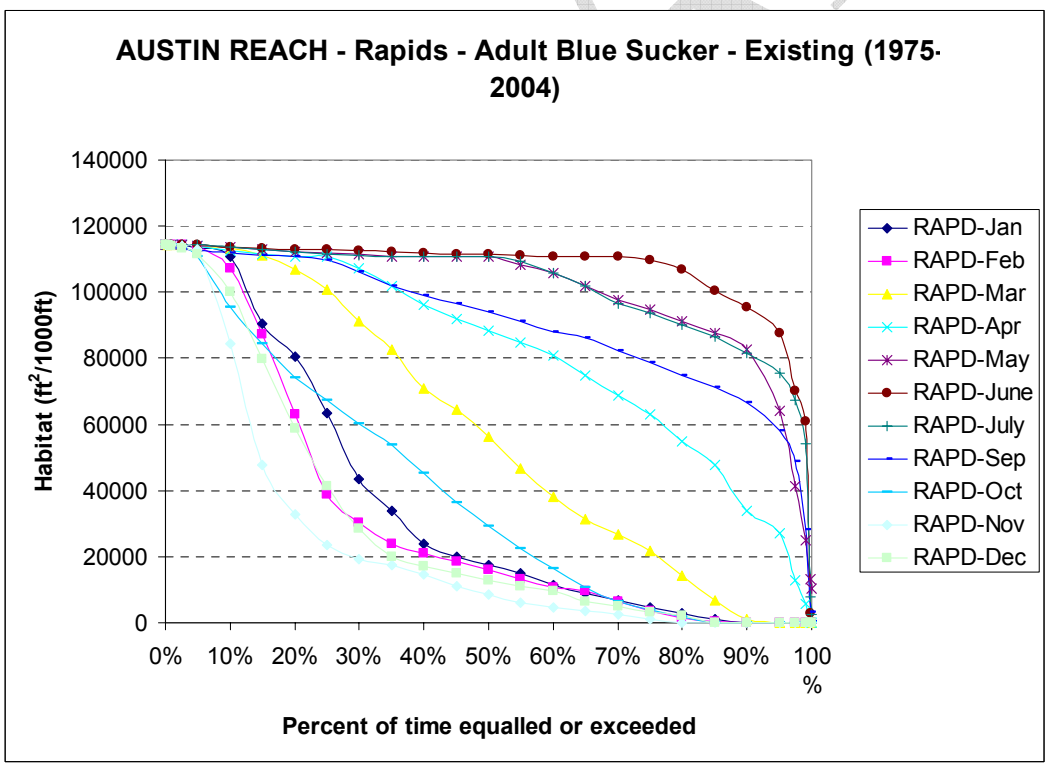


**Figure D12.** Habitat durations for rapids / adult blue sucker for all months at the Austin Reach based on the existing flow regime.

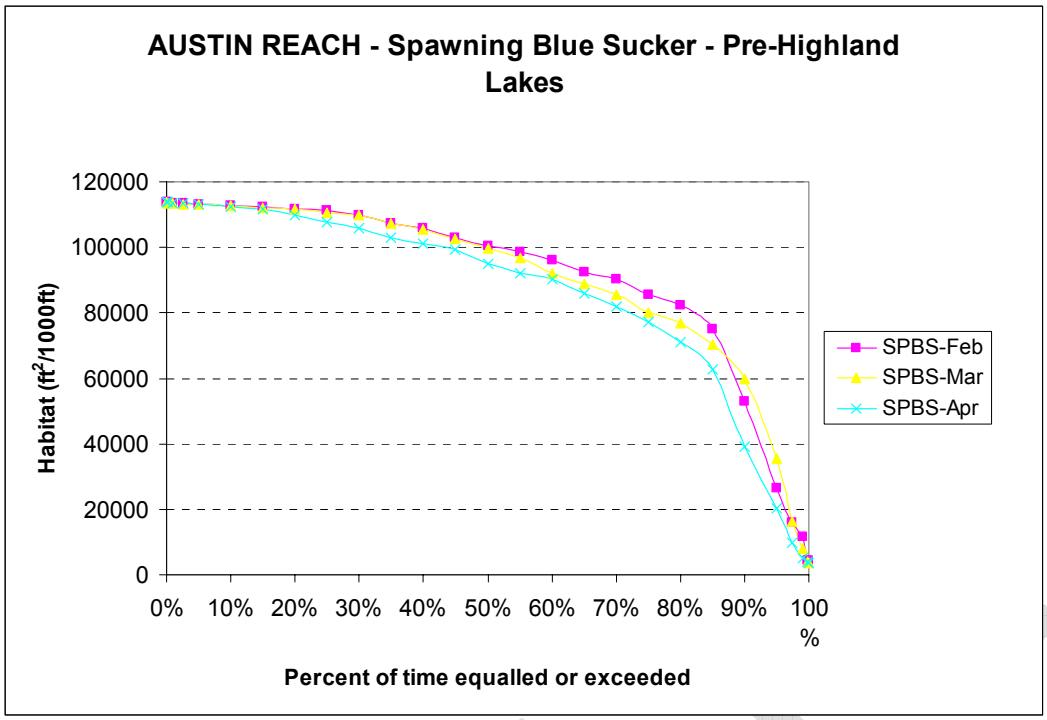


**Figure D13.** Habitat durations for spawning blue sucker habitat for February through March at the Austin Reach based on the pre-1940 flow regime.

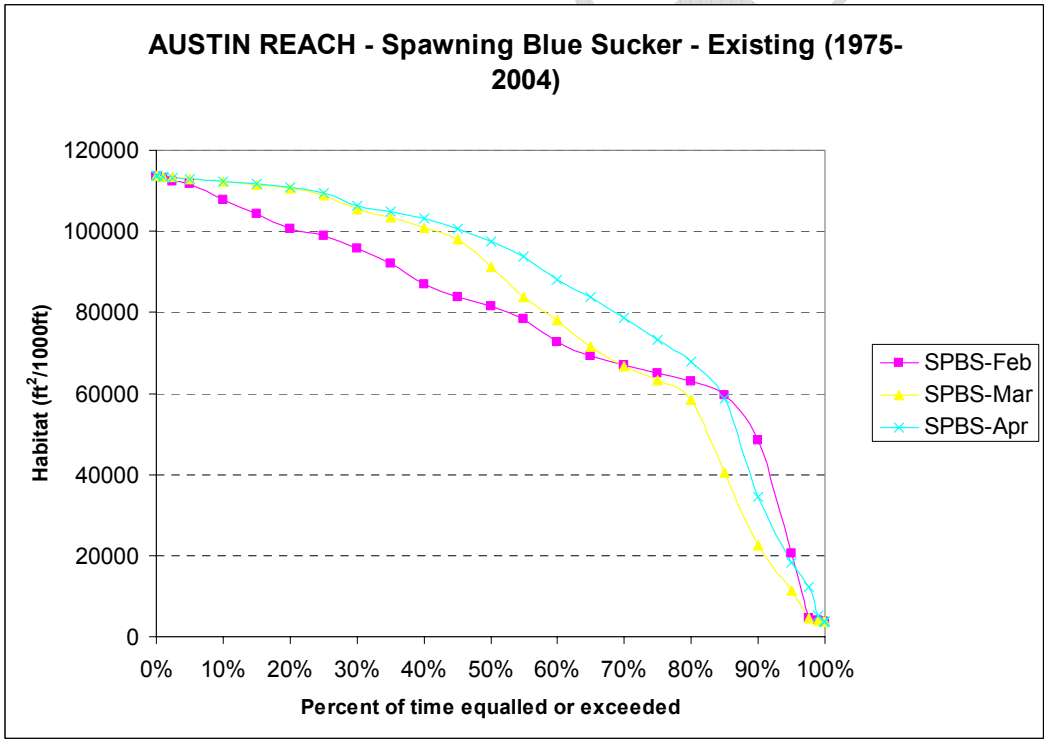


**Figure D14.** Habitat durations for spawning blue sucker habitat for February through March at the Austin Reach based on the existing flow regime.

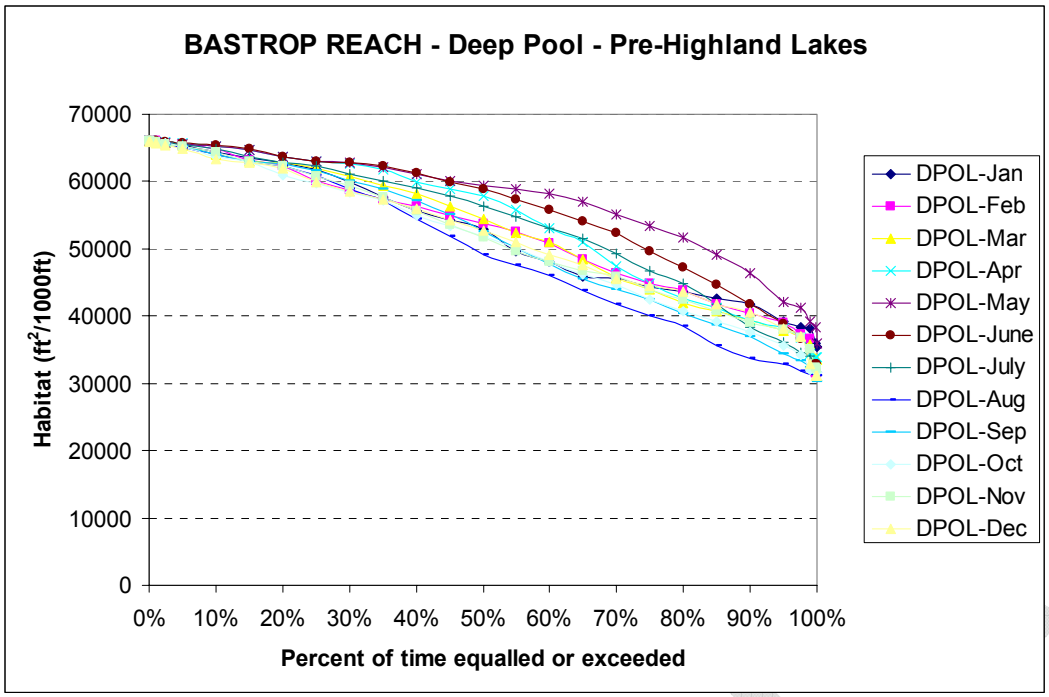


**Figure D15.** Habitat durations for deep pool for all months at the Bastrop Reach based on the pre-1940 flow regime.

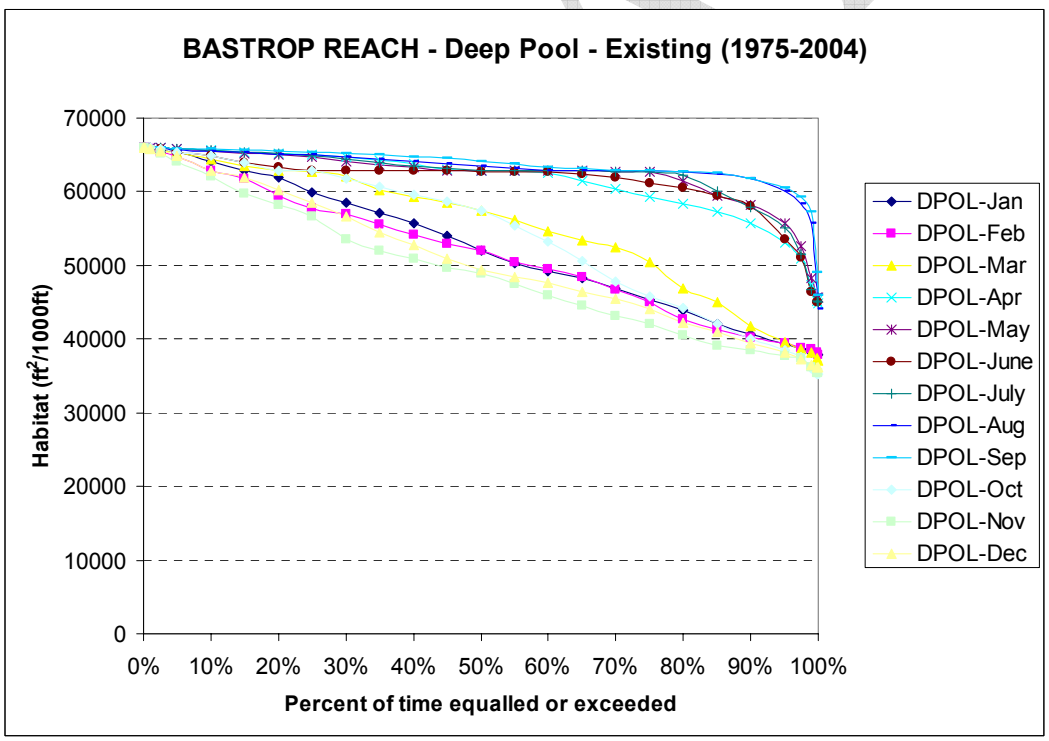


**Figure D16.** Habitat durations for deep pool for all months at the Bastrop Reach based on the existing flow regime.

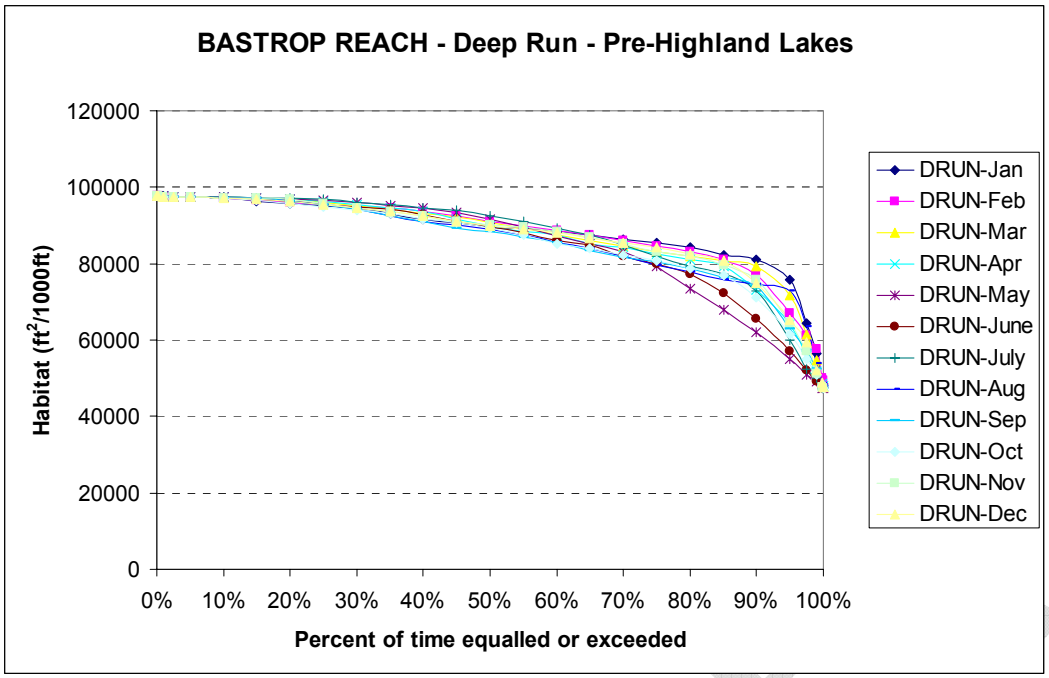


**Figure D17.** Habitat durations for deep run for all months at the Bastrop Reach based on the pre-1940 flow regime.

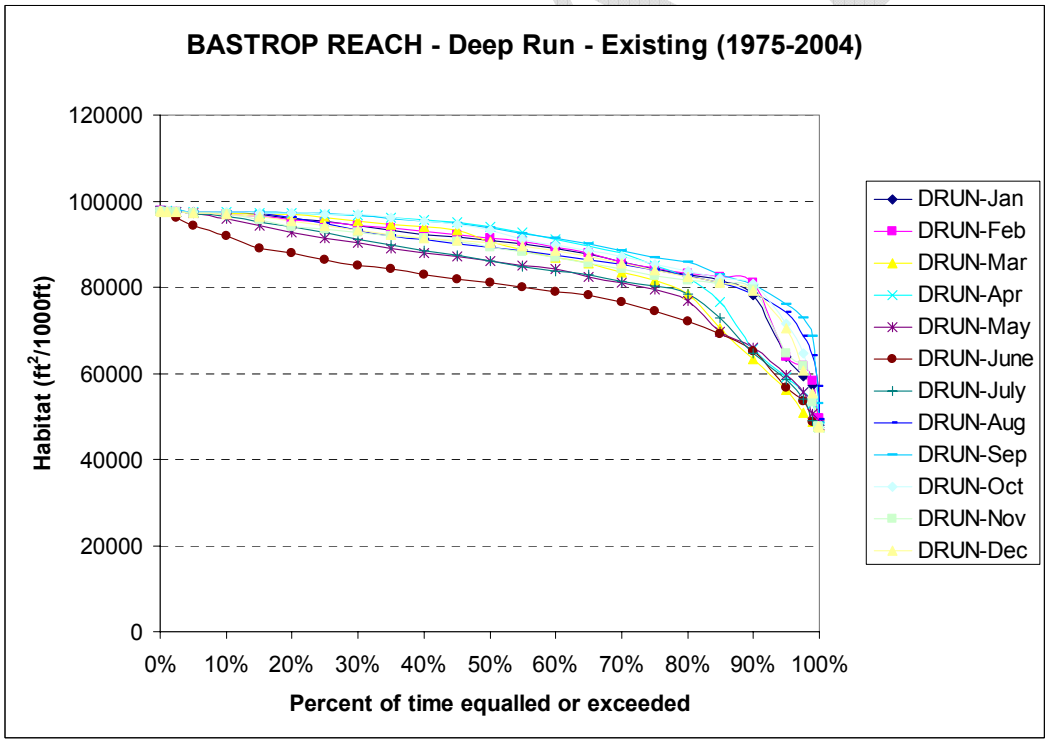


**Figure D18.** Habitat durations for deep run for all months at the Bastrop Reach based on the existing flow regime.

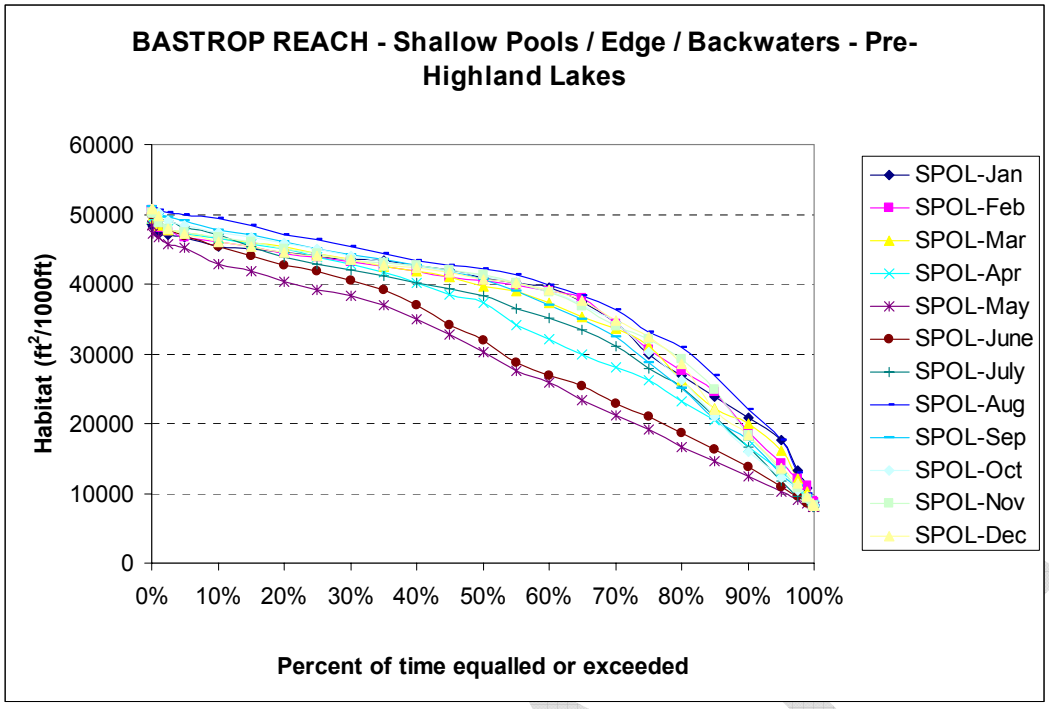


**Figure D19.** Habitat durations for shallow pools/edge/backwater for all months at the Bastrop Reach based on the pre-1940 flow regime.

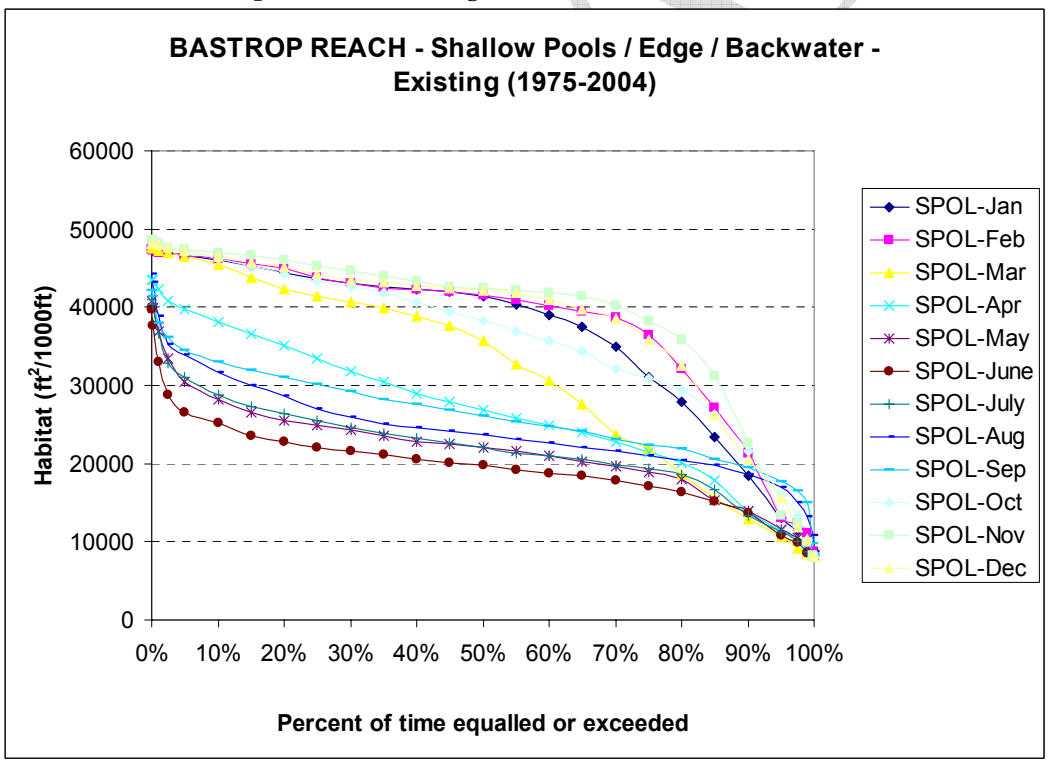


**Figure D20.** Habitat durations for shallow pools/edge/backwater for all months at the Bastrop Reach based on the existing flow regime.

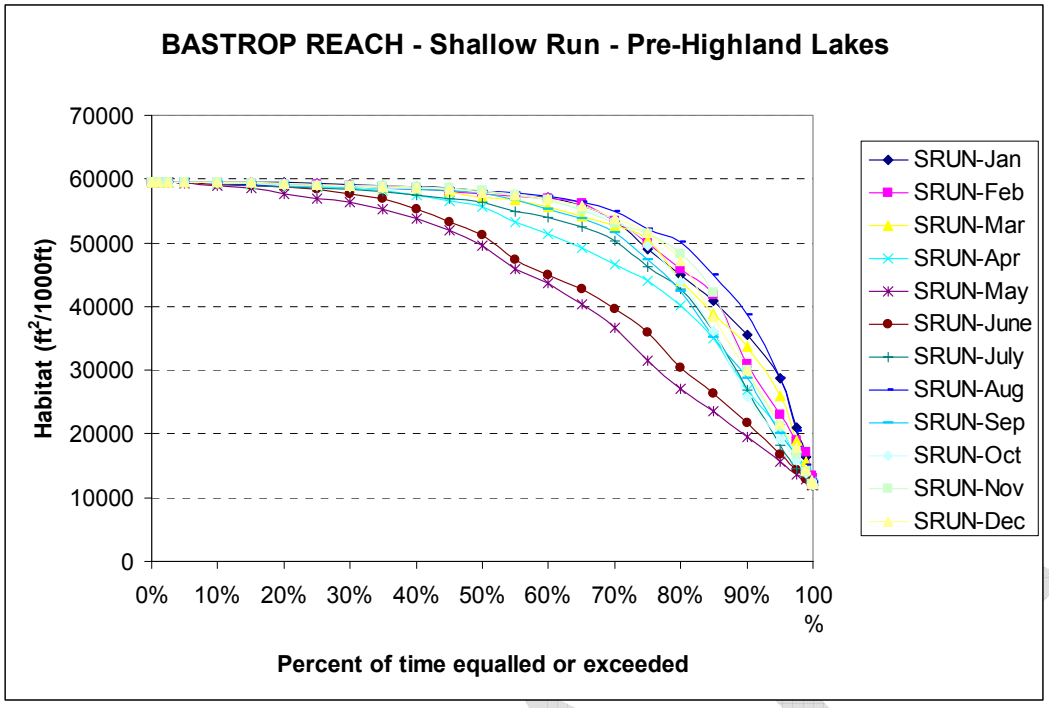


**Figure D21.** Habitat durations for shallow run for all months at the Bastrop Reach based on the pre-1940 flow regime.

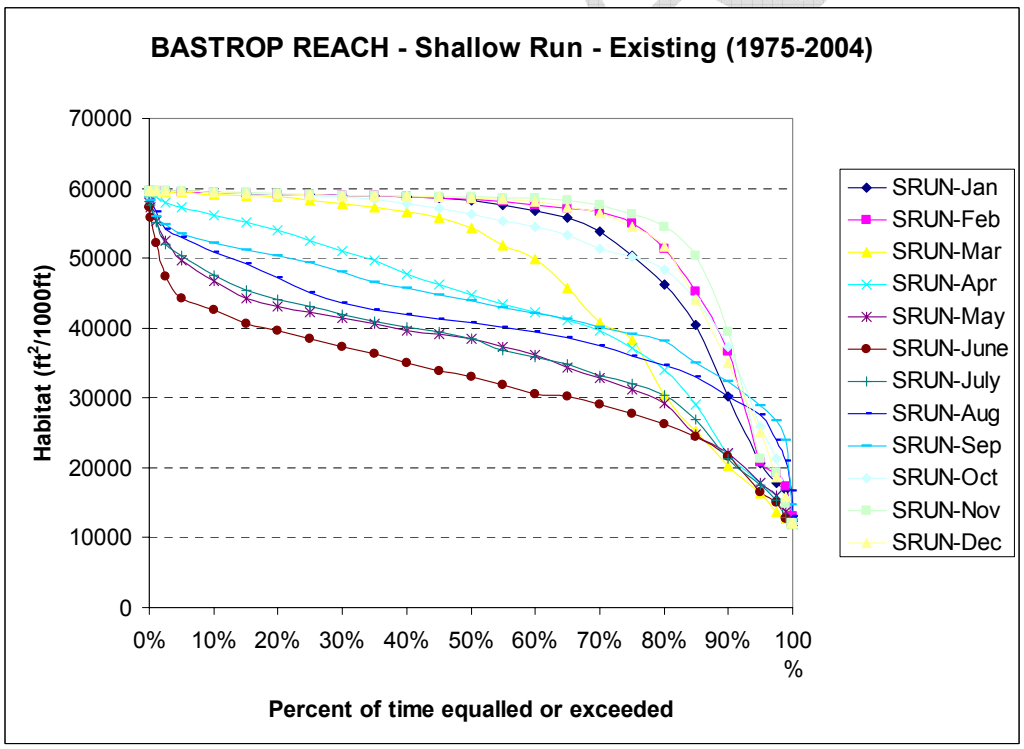


**Figure D22.** Habitat durations for shallow run for all months at the Bastrop Reach based on the existing flow regime.

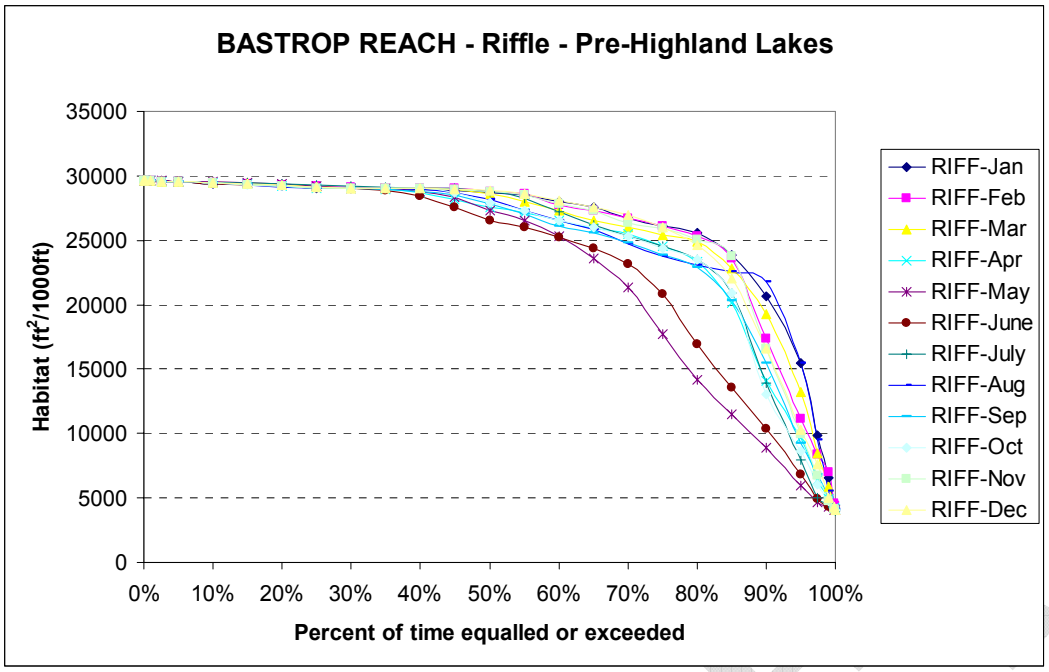


**Figure D23.** Habitat durations for riffles for all months at the Bastrop Reach based on the pre-1940 flow regime.

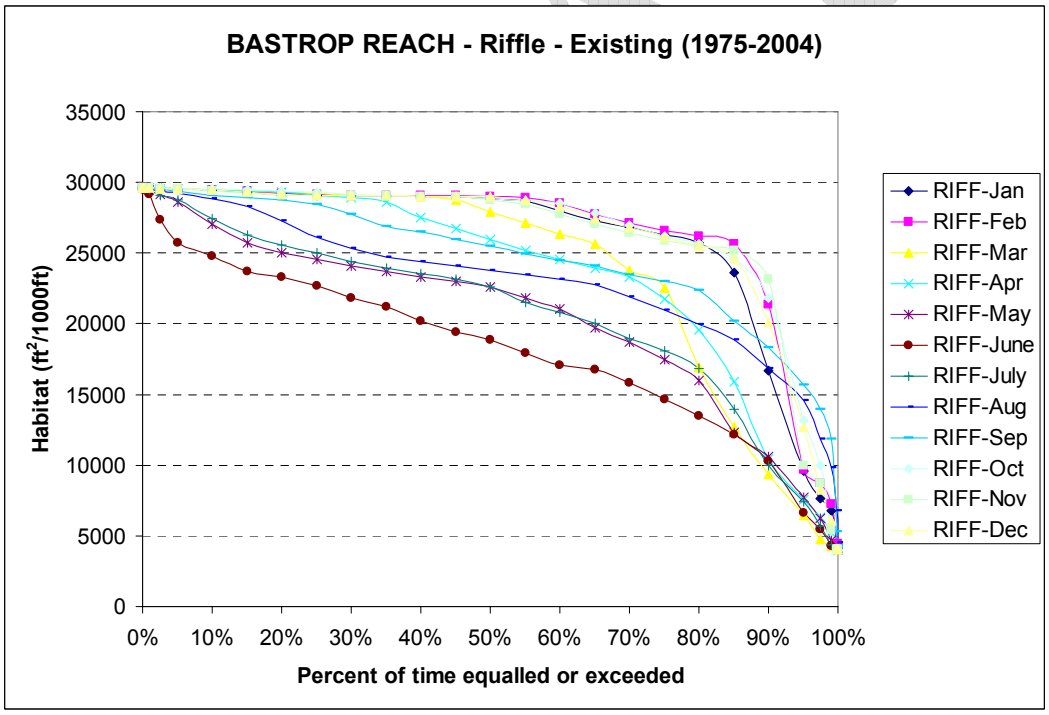


**Figure D24.** Habitat durations for riffles for all months at the Bastrop Reach based on the existing flow regime.

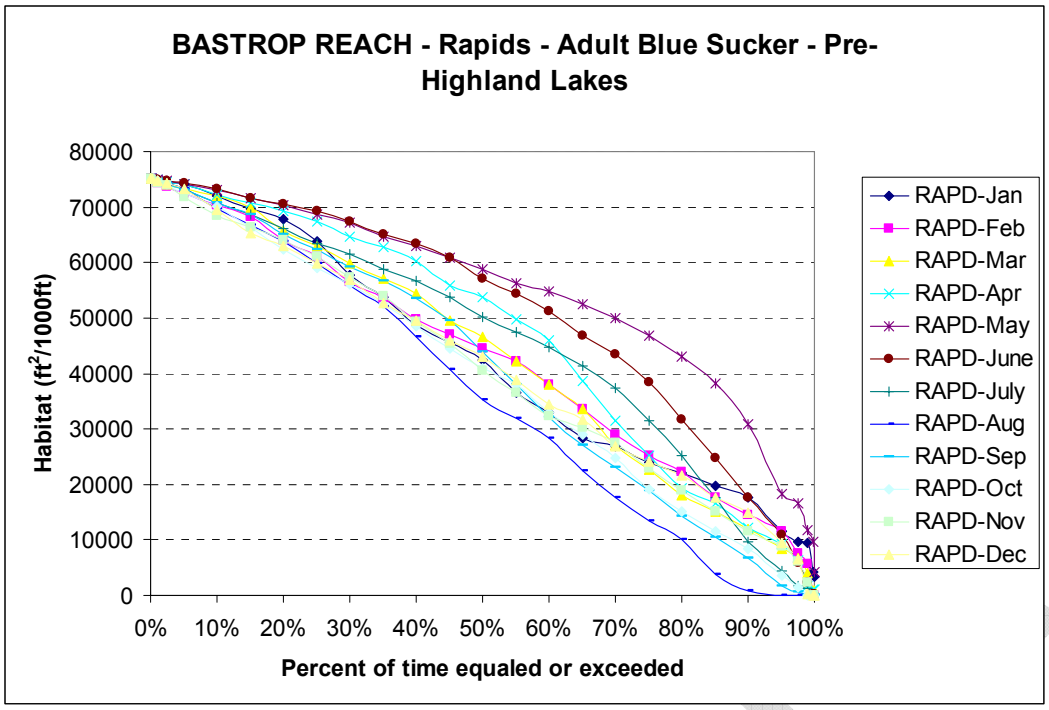


**Figure D25.** Habitat durations for rapids / adult blue sucker for all months at the Bastrop Reach based on the pre-1940 flow regime.

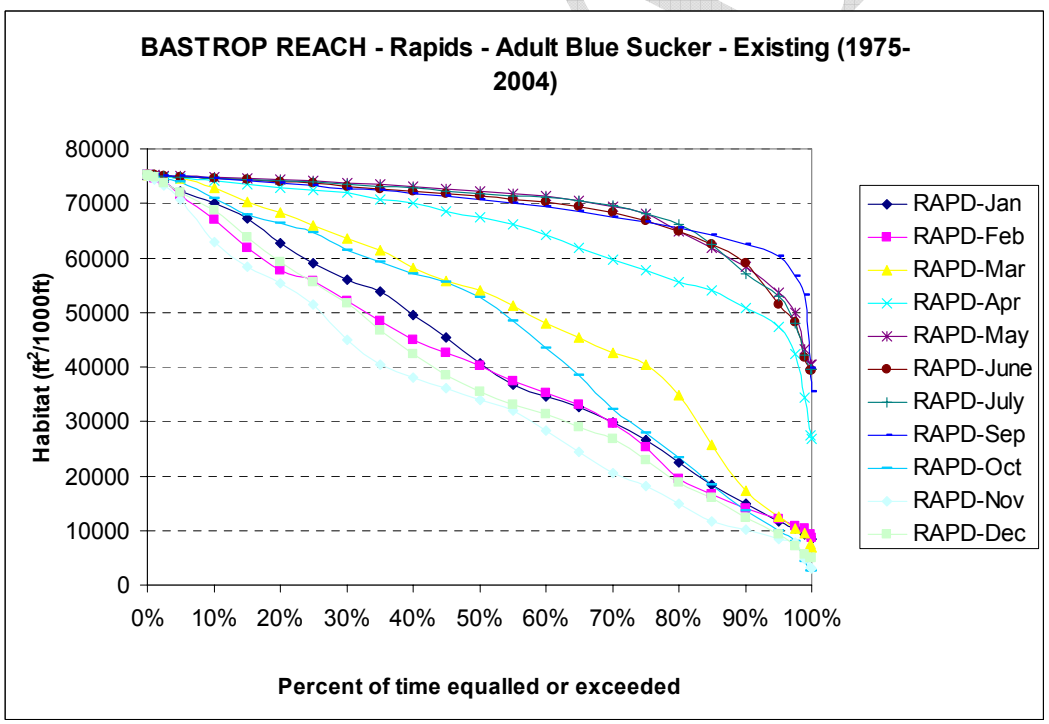


**Figure D26.** Habitat durations for rapids / adult blue sucker for all months at the Bastrop Reach based on the existing flow regime.

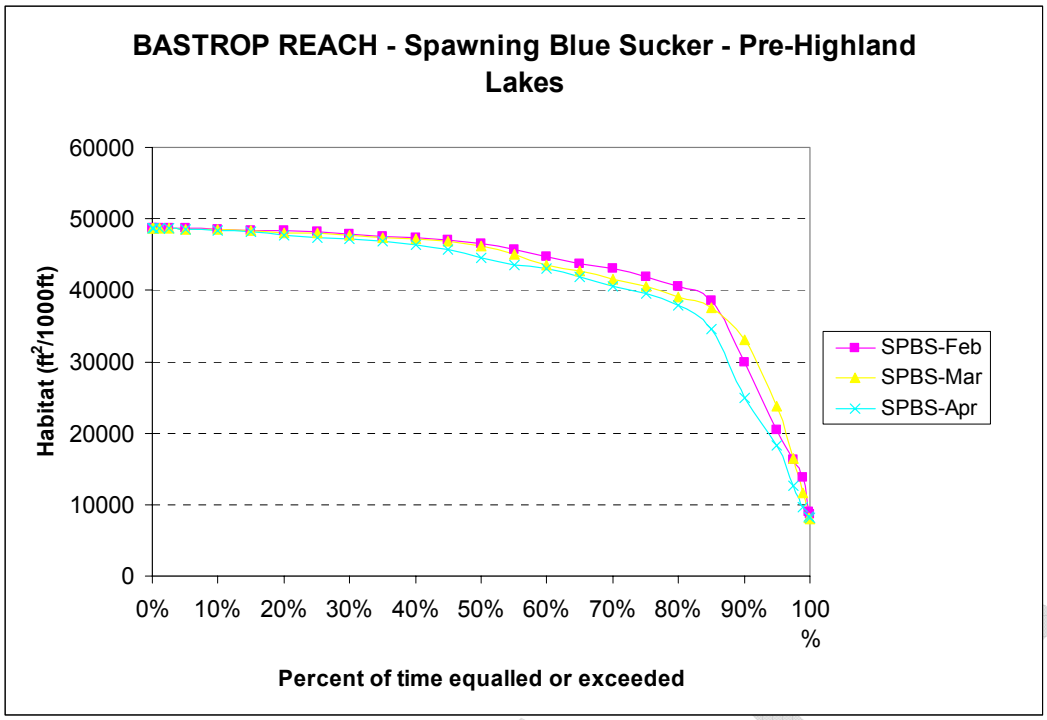


**Figure D27.** Habitat durations for spawning blue sucker habitat for February through March at the Bastrop Reach based on the pre-1940 flow regime.

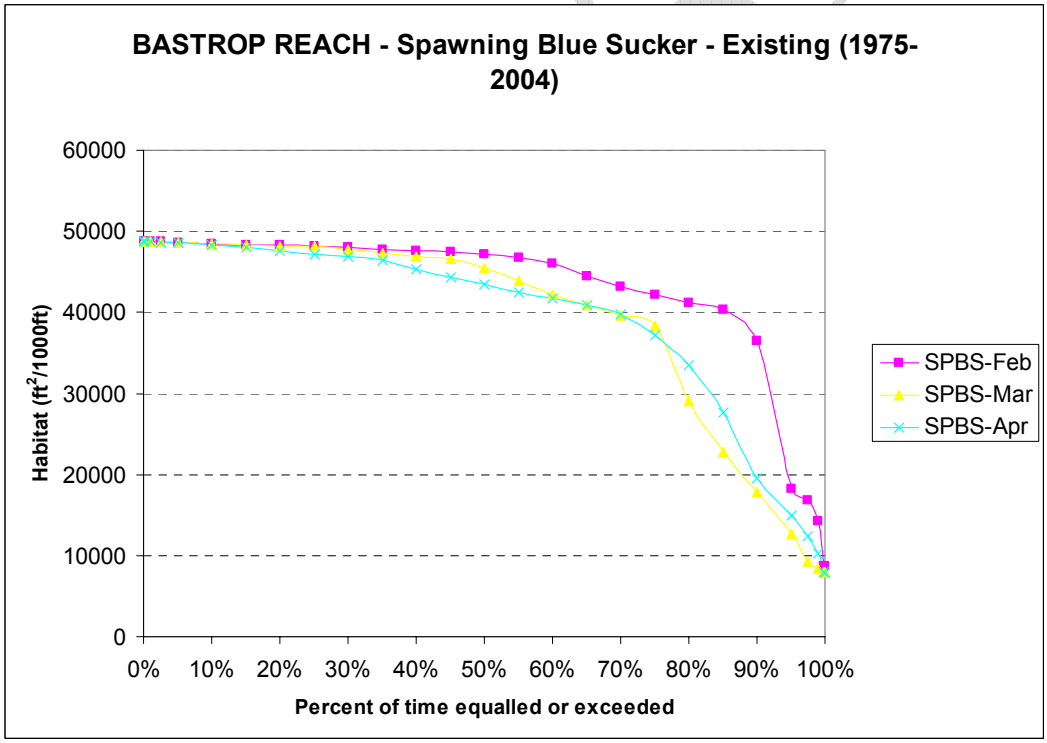


**Figure D28.** Habitat durations for spawning blue sucker habitat for February through March at the Bastrop Reach based on the existing flow regime.

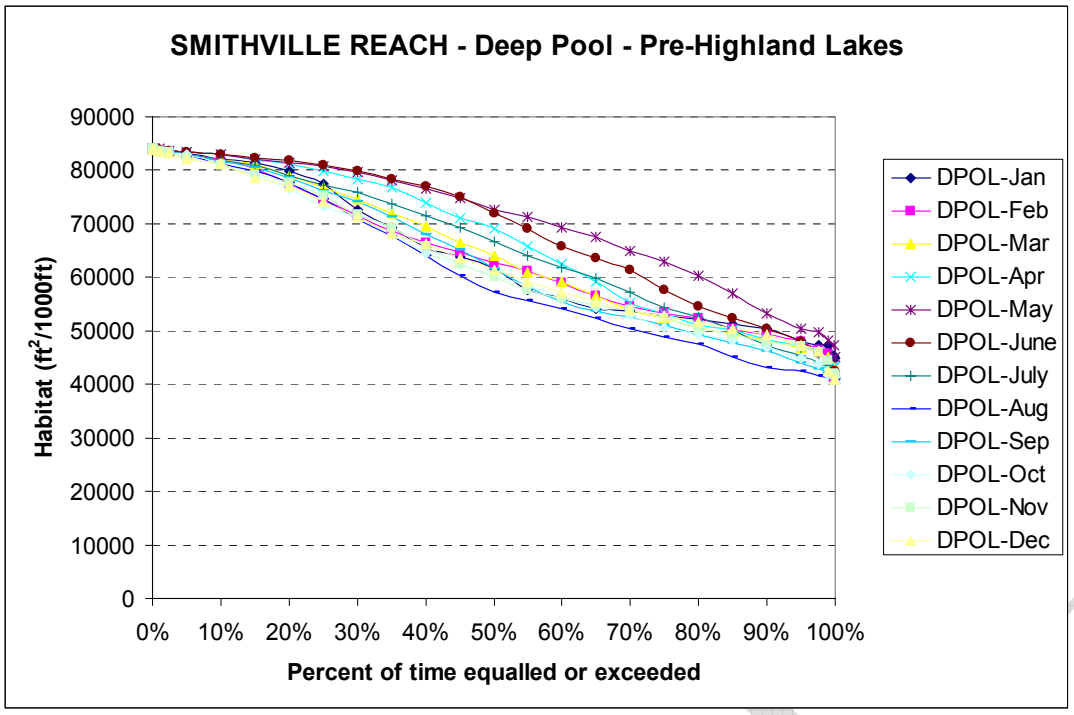


**Figure D29.** Habitat durations for deep pool for all months at the Smithville Reach based on the pre-1940 flow regime.

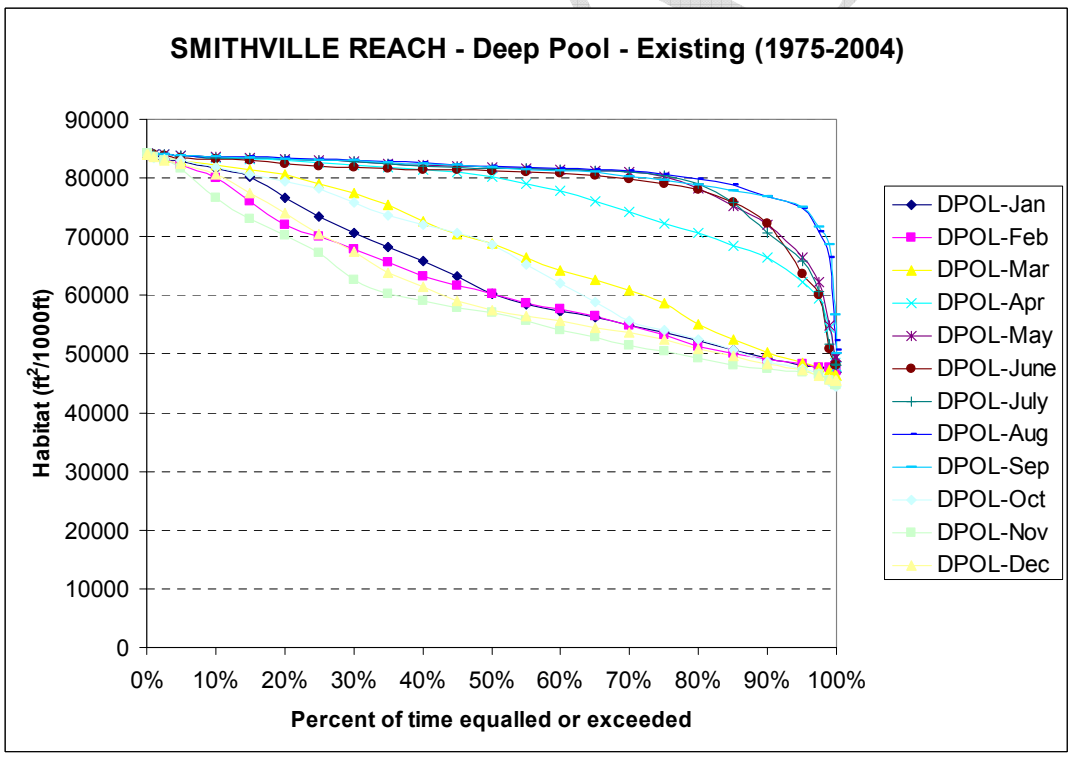


**Figure D30.** Habitat durations for deep pool for all months at the Smithville Reach based on the existing flow regime.

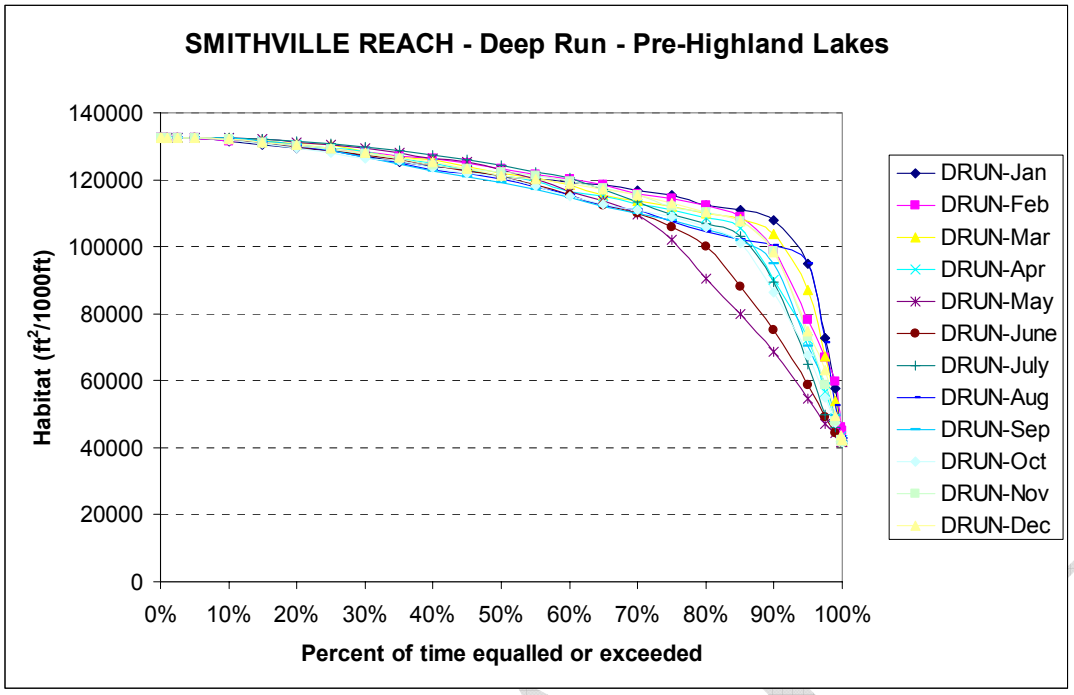


**Figure D31.** Habitat durations for deep run for all months at the Smithville Reach based on the pre-1940 flow regime.

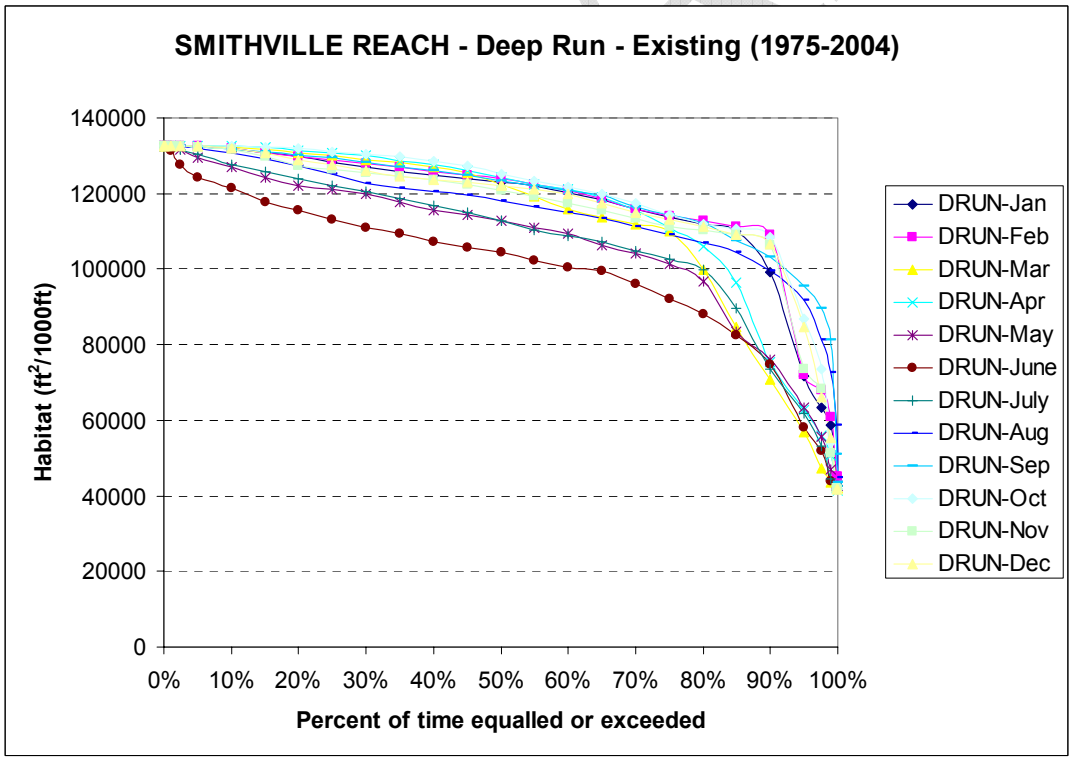


**Figure D32.** Habitat durations for deep run for all months at the Smithville Reach based on the existing flow regime.

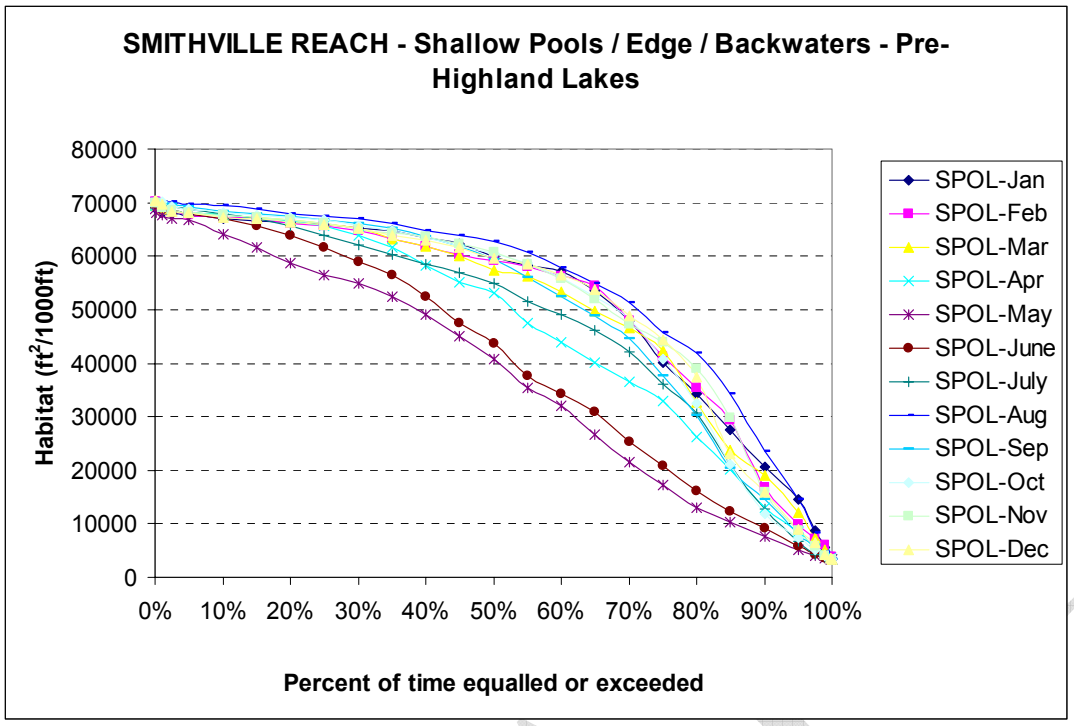


**Figure D33.** Habitat durations for shallow pools/edge/backwater for all months at the Smithville Reach based on the pre-1940 flow regime.

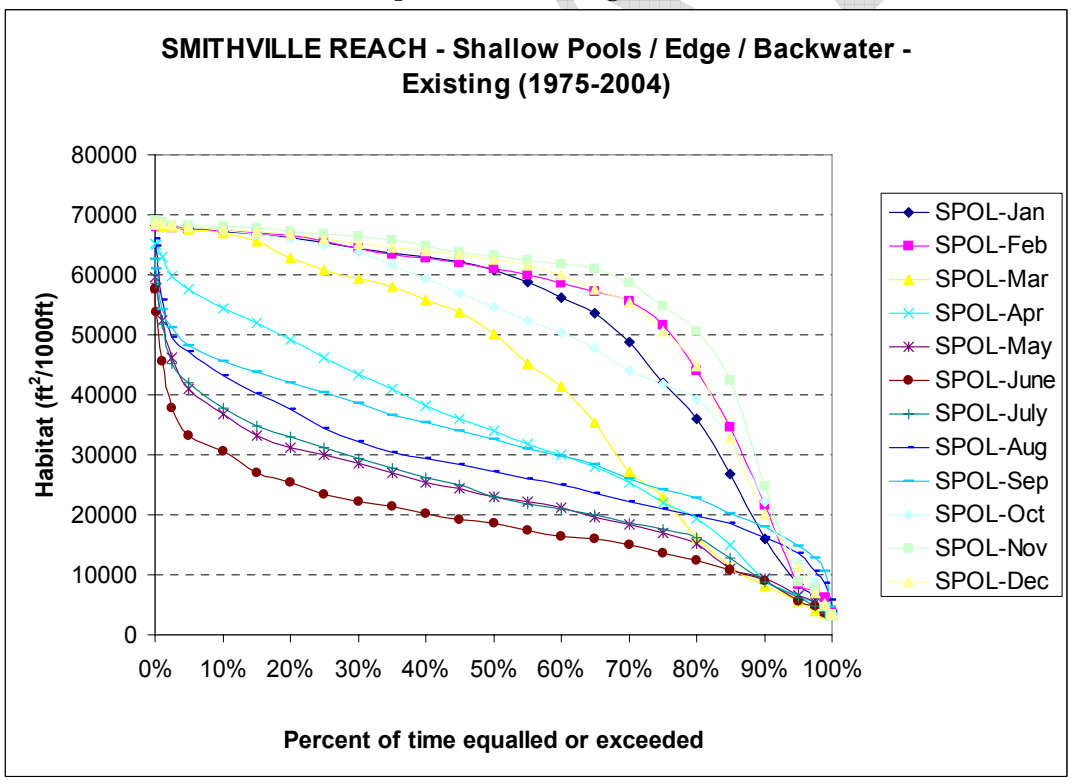


**Figure D34.** Habitat durations for shallow pools/edge/backwater for all months at the Smithville Reach based on the existing flow regime.

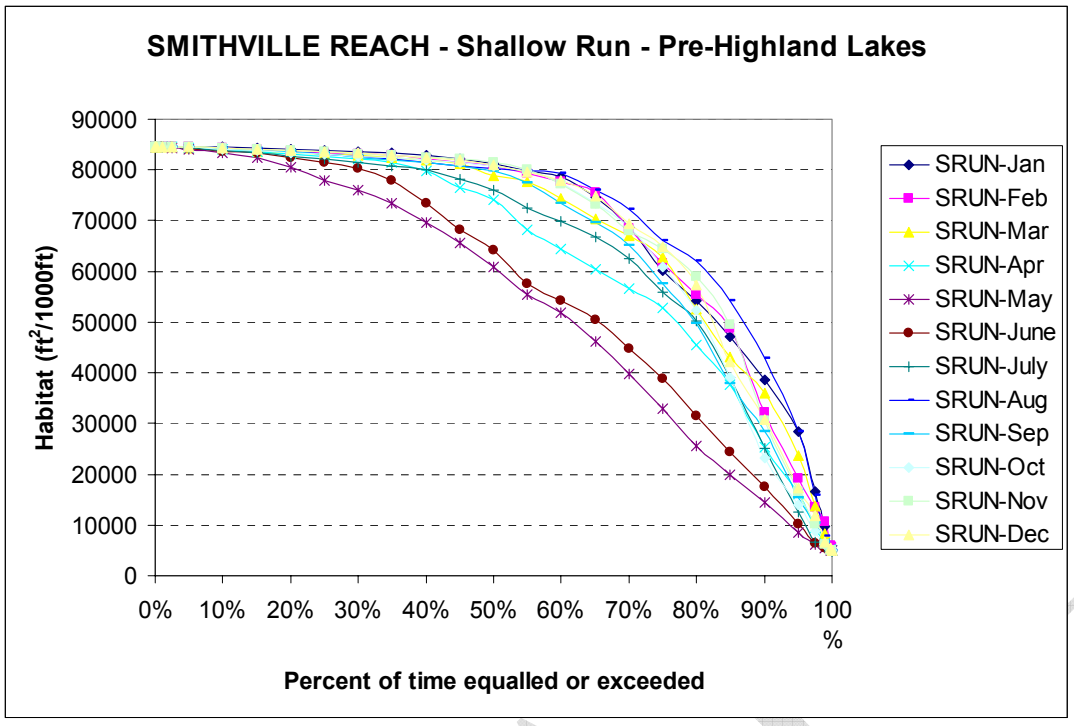


**Figure D35.** Habitat durations for shallow run for all months at the Smithville Reach based on the pre-1940 flow regime.

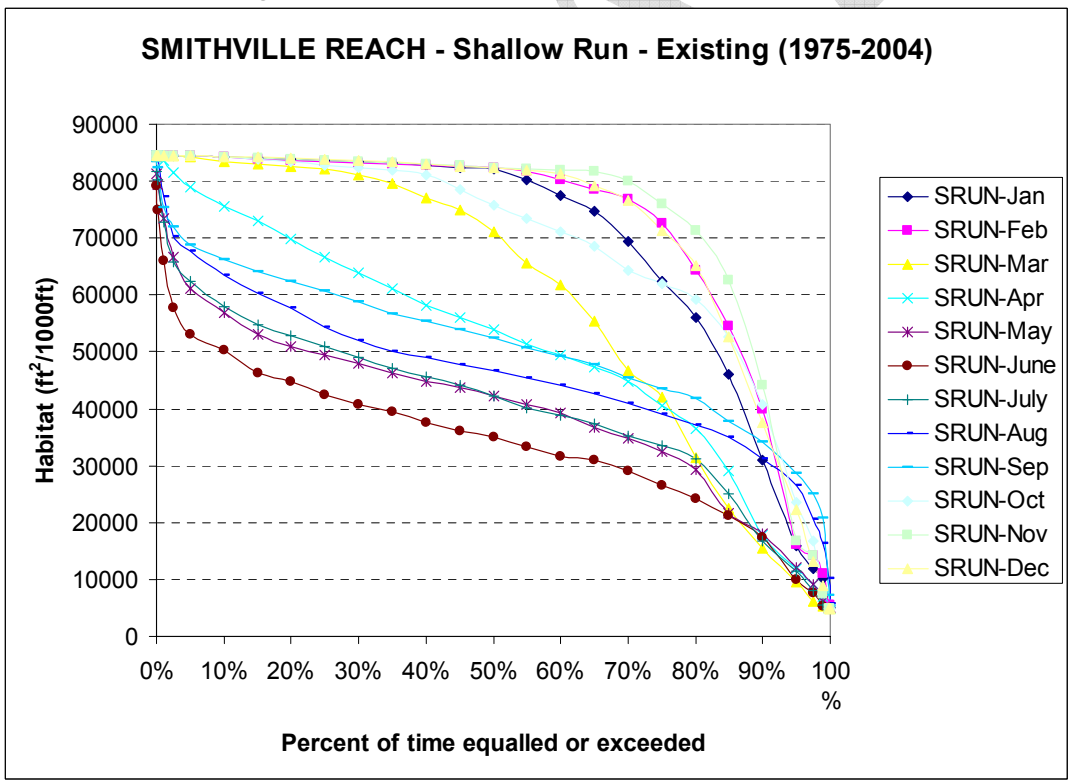


**Figure D36.** Habitat durations for shallow run for all months at the Smithville Reach based on the existing flow regime.

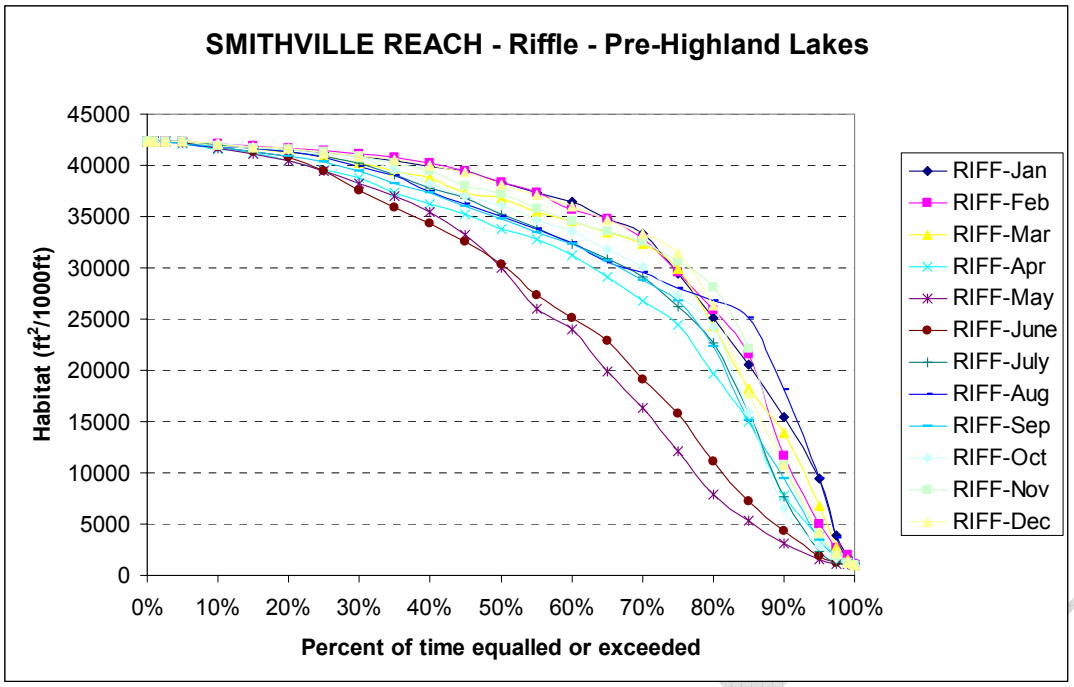


**Figure D37.** Habitat durations for riffles for all months at the Smithville Reach based on the pre-1940 flow regime.

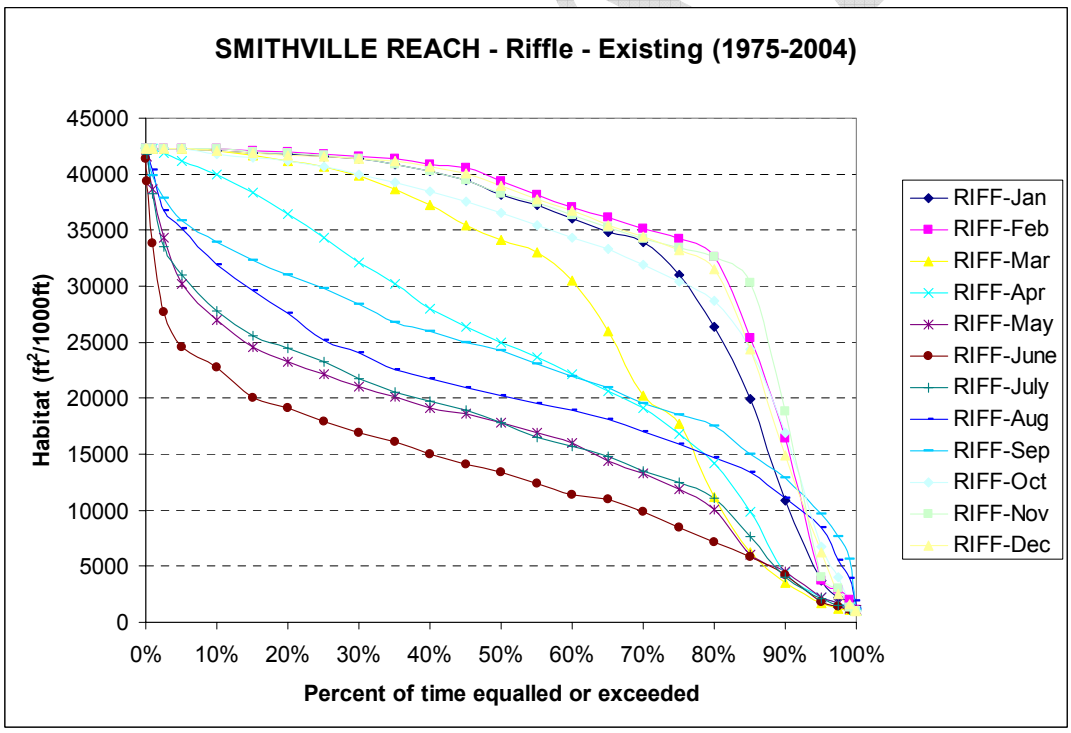


**Figure D38.** Habitat durations for riffles for all months at the Smithville Reach based on the existing flow regime.

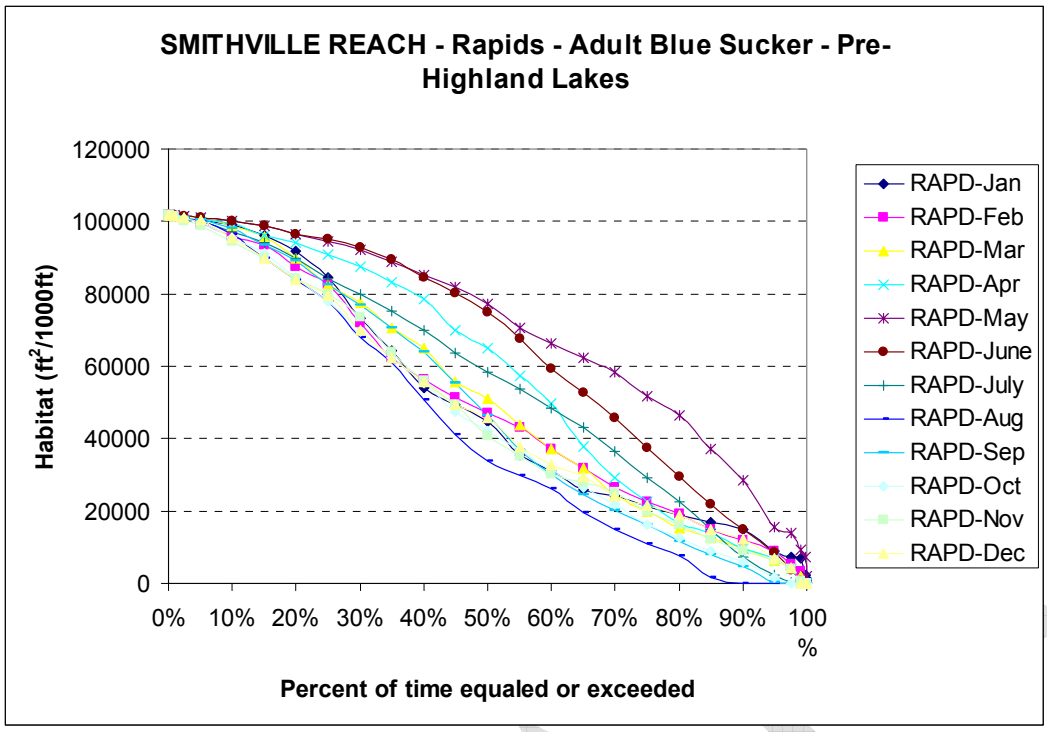


**Figure D39.** Habitat durations for rapids / adult blue sucker for all months at the Smithville Reach based on the pre-1940 flow regime.

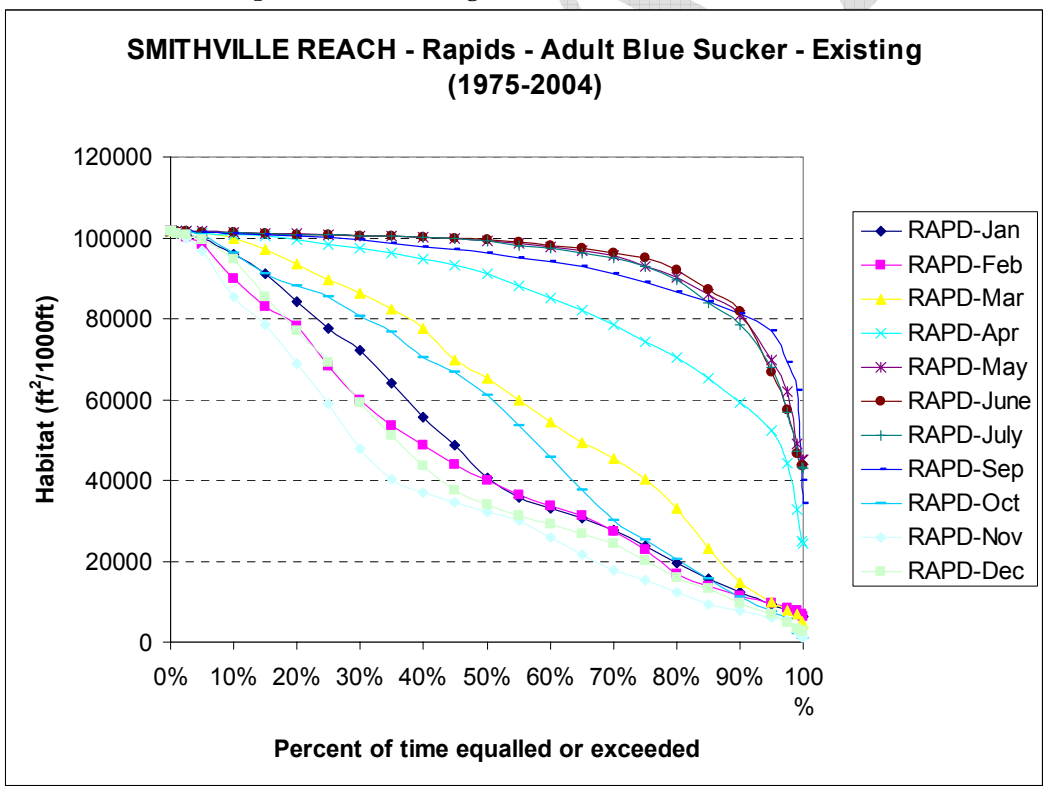


**Figure D40.** Habitat durations for rapids / adult blue sucker for all months at the Smithville Reach based on the existing flow regime.

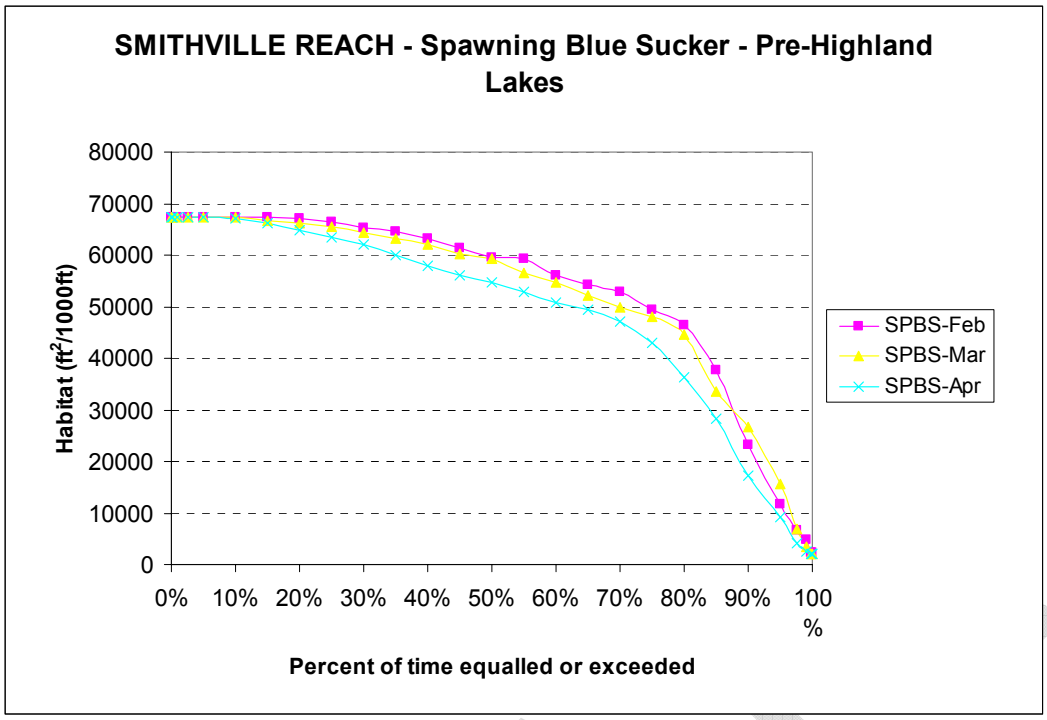


**Figure D41.** Habitat durations for spawning blue sucker habitat for February through March at the Smithville Reach based on the pre-1940 flow regime.

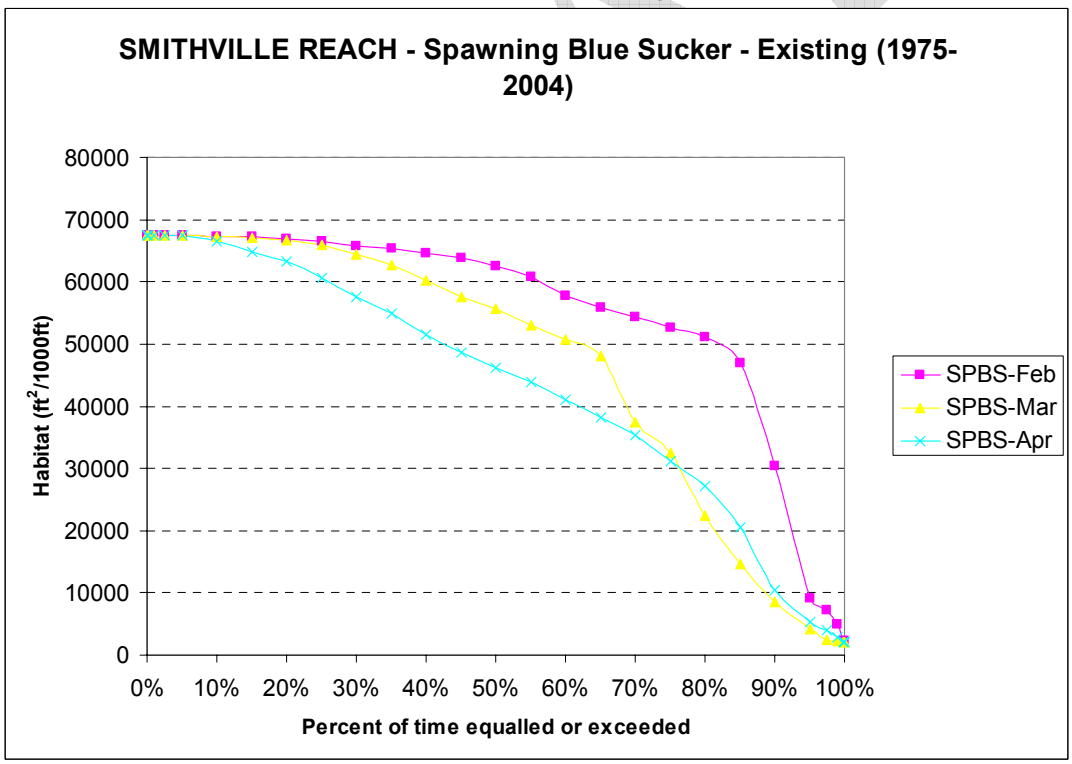


**Figure D42.** Habitat durations for spawning blue sucker habitat for February through March at the Smithville Reach based on the existing flow regime.

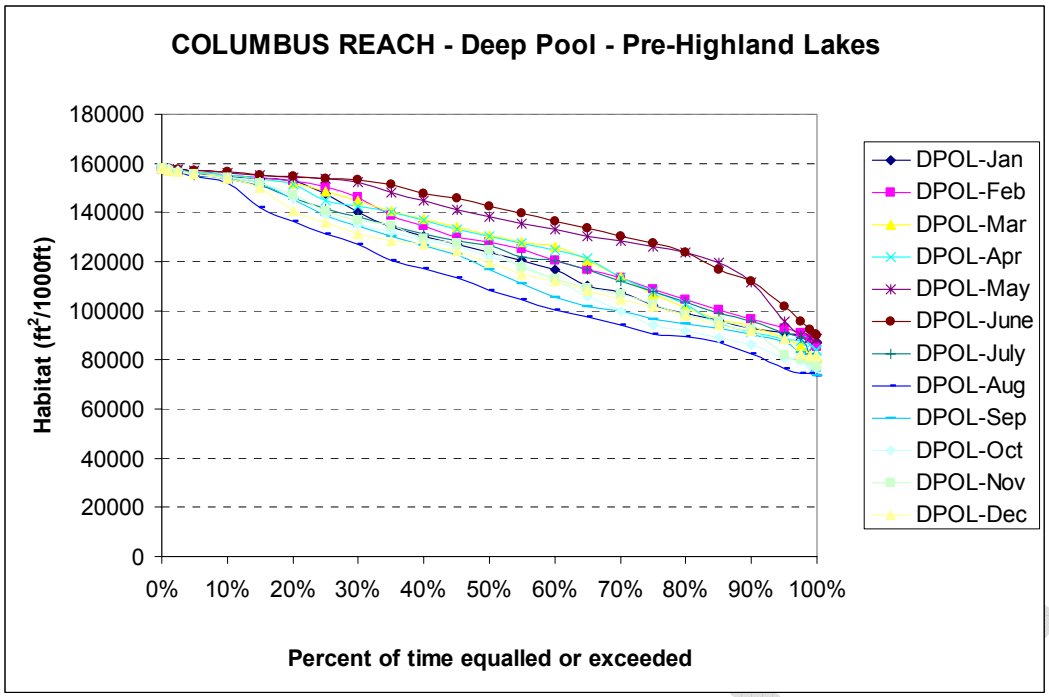


**Figure D43.** Habitat durations for deep pool for all months at the Columbus Reach based on the pre-1940 flow regime.

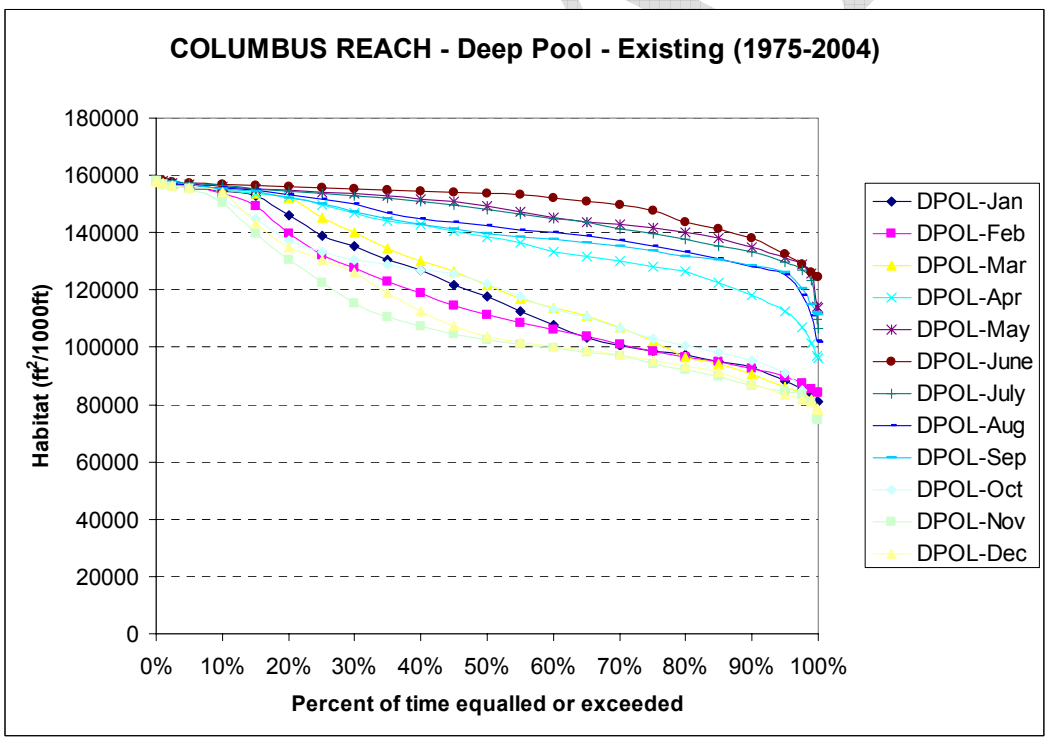


**Figure D44.** Habitat durations for deep pool for all months at the Columbus Reach based on the existing flow regime.

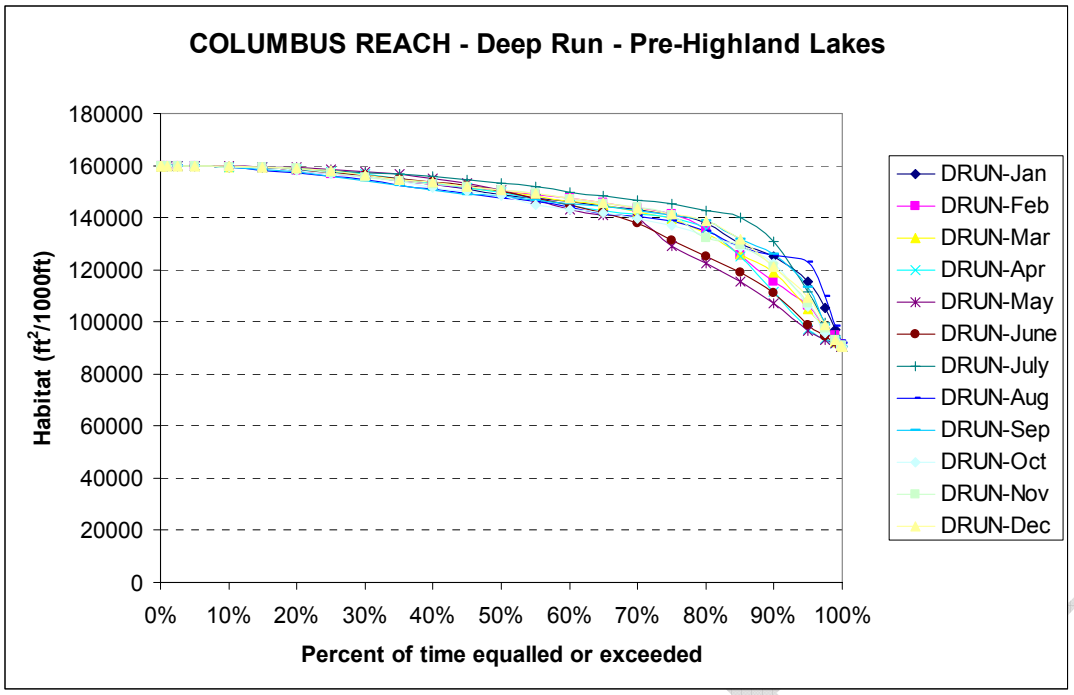


**Figure D45.** Habitat durations for deep run for all months at the Columbus Reach based on the pre-1940 flow regime.

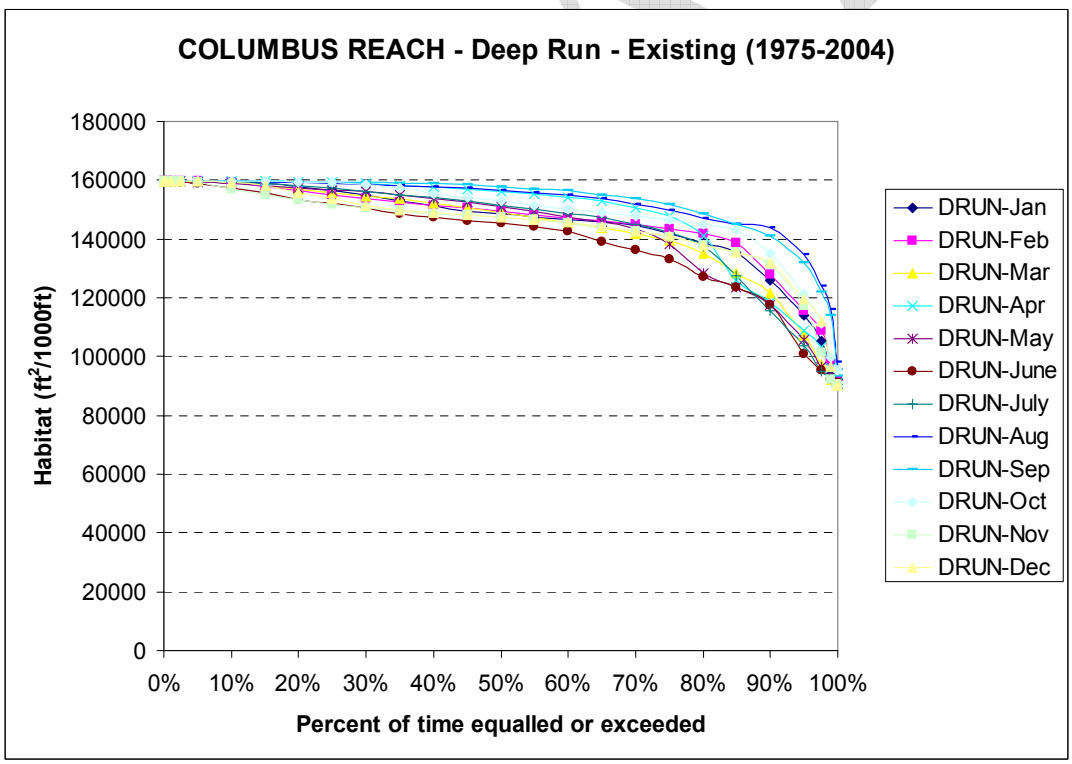


**Figure D46.** Habitat durations for deep run for all months at the Columbus Reach based on the existing flow regime.

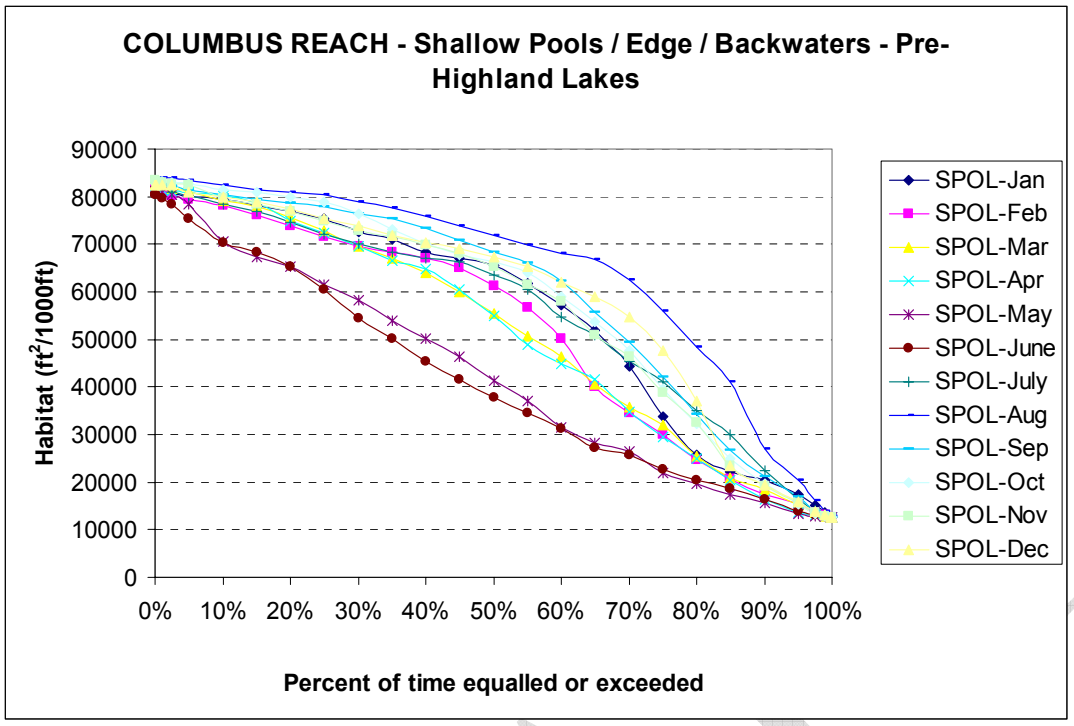


**Figure D47.** Habitat durations for shallow pools/edge/backwater for all months at the Columbus Reach based on the pre-1940 flow regime.

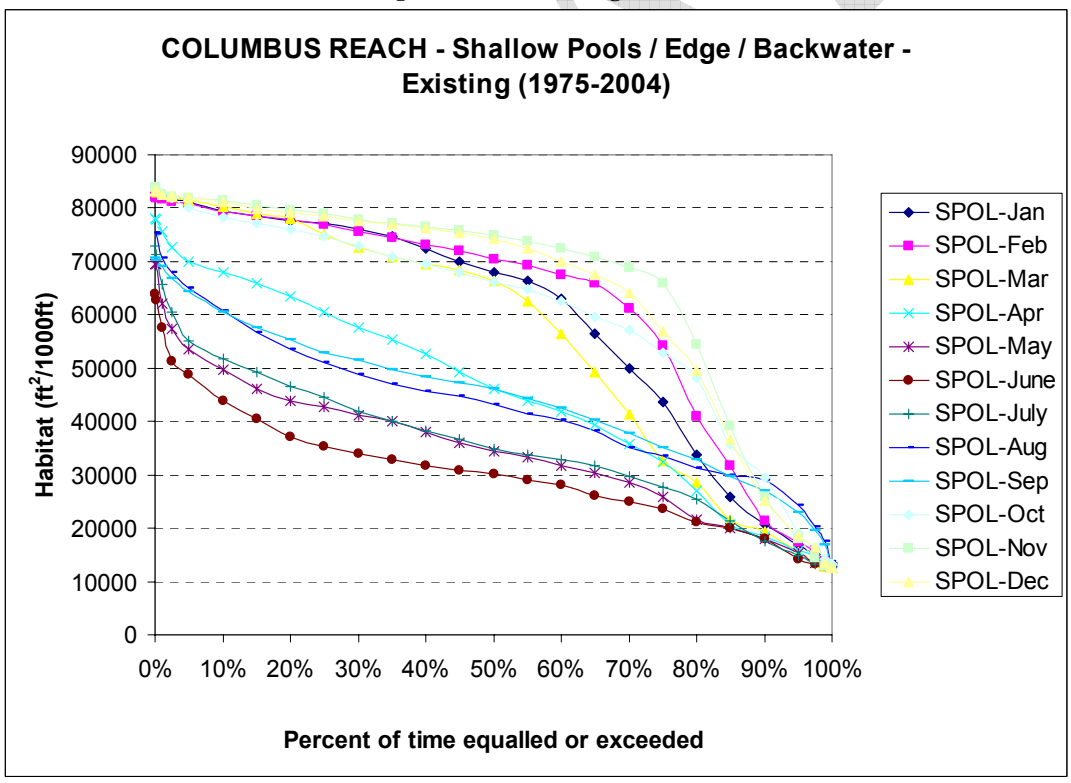


**Figure D48.** Habitat durations for shallow pools/edge/backwater for all months at the Columbus Reach based on the existing flow regime.

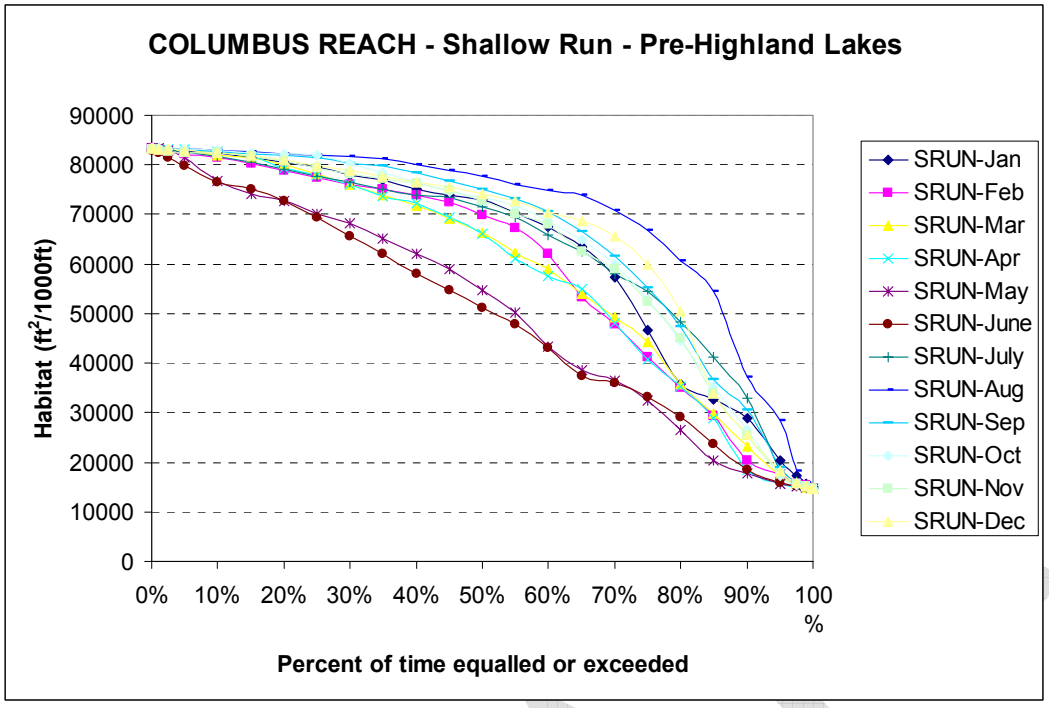


**Figure D49.** Habitat durations for shallow run for all months at the Columbus Reach based on the pre-1940 flow regime.

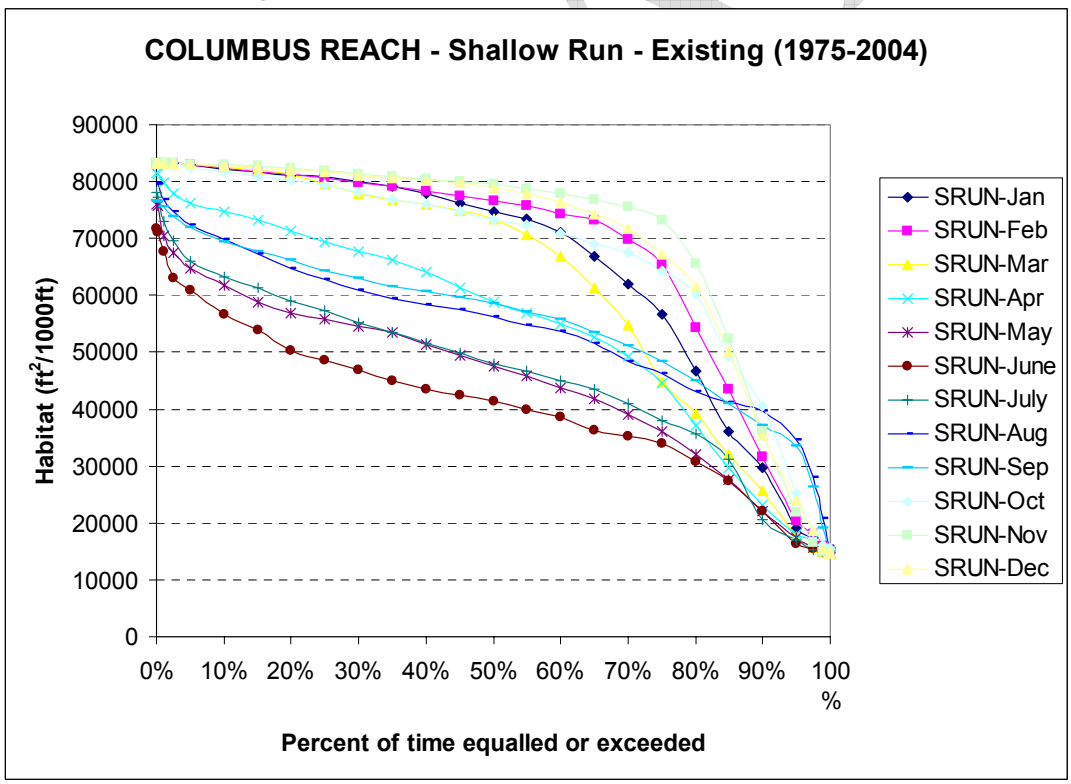


**Figure D50.** Habitat durations for shallow run for all months at the Columbus Reach based on the existing flow regime.

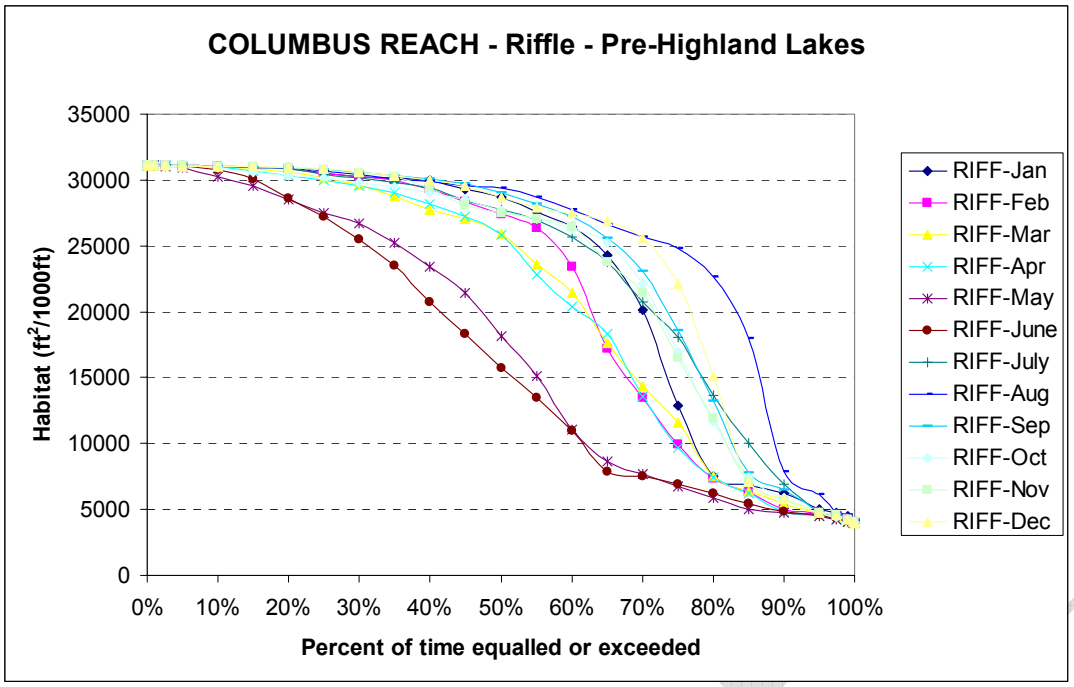


**Figure D51.** Habitat durations for riffles for all months at the Columbus Reach based on the pre-1940 flow regime.

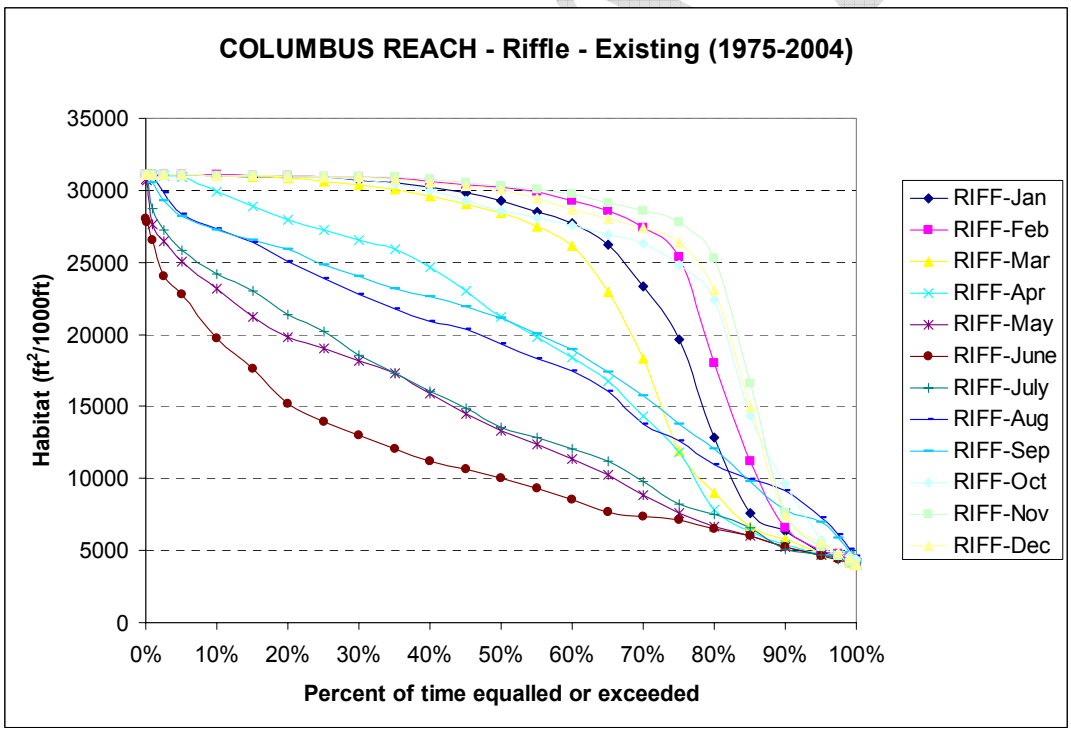


**Figure D52.** Habitat durations for riffles for all months at the Columbus Reach based on the existing flow regime.

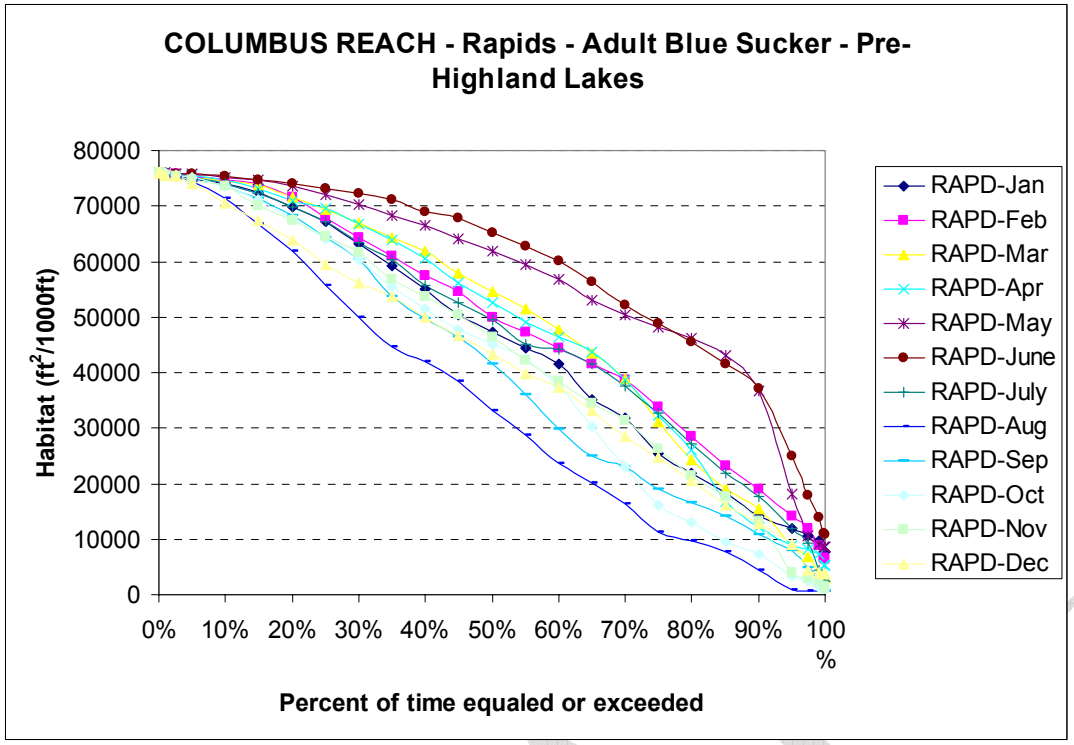


**Figure D53.** Habitat durations for rapids / adult blue sucker for all months at the Columbus Reach based on the pre-1940 flow regime.

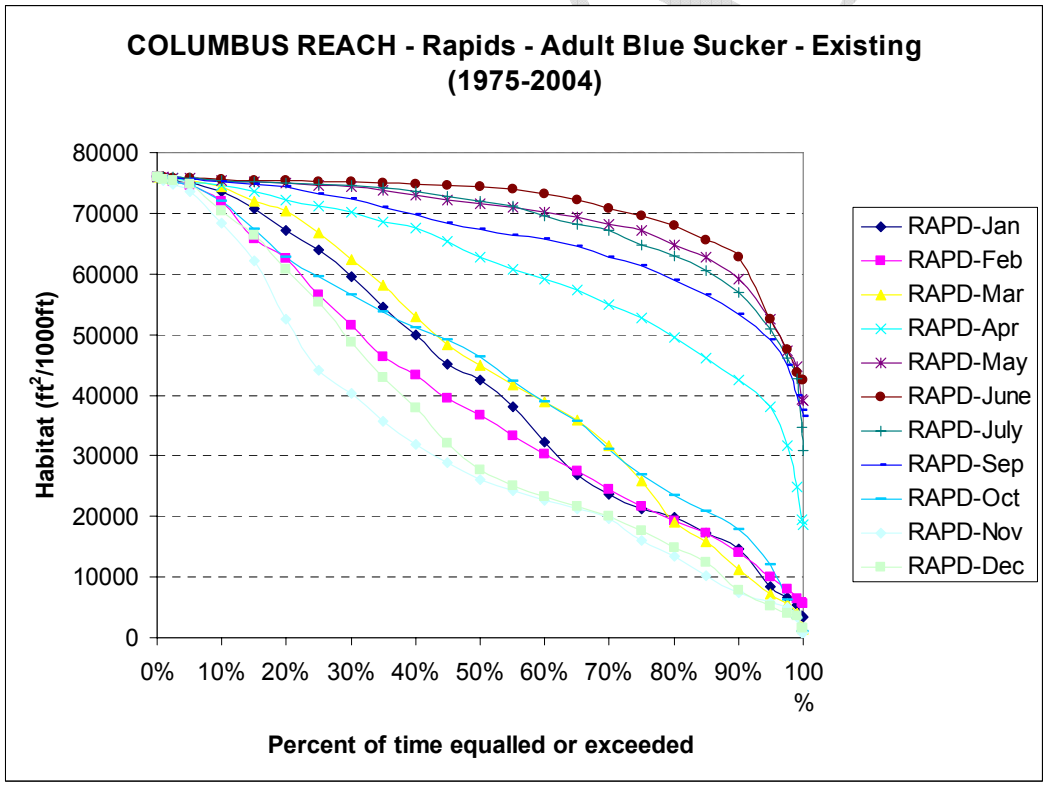


**Figure D54.** Habitat durations for rapids / adult blue sucker for all months at the Columbus Reach based on the existing flow regime.

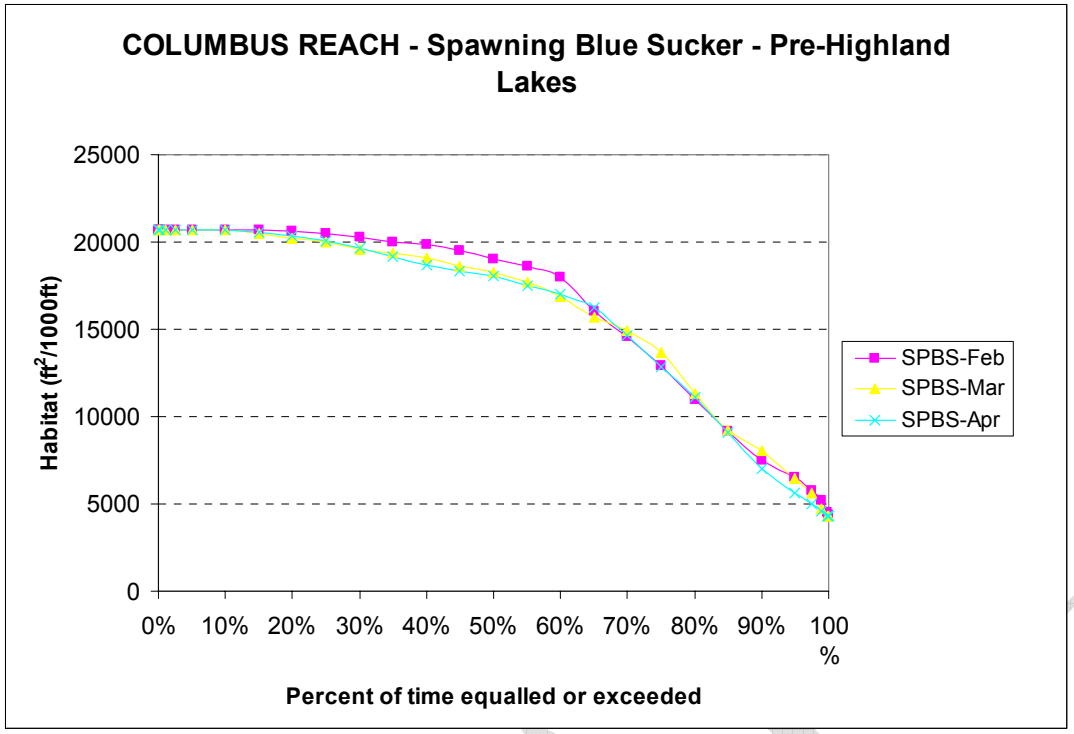


**Figure D55.** Habitat durations for spawning blue sucker habitat for February through March at the Columbus Reach based on the pre-1940 flow regime.

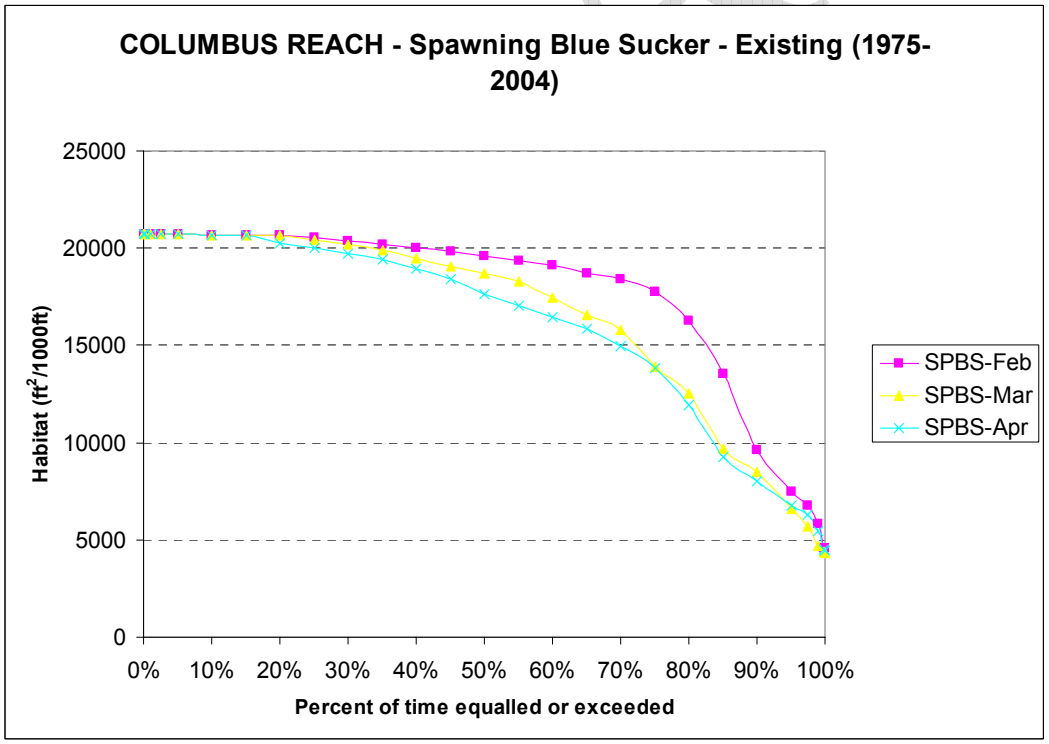


**Figure D56.** Habitat durations for spawning blue sucker habitat for February through March at the Columbus Reach based on the existing flow regime.

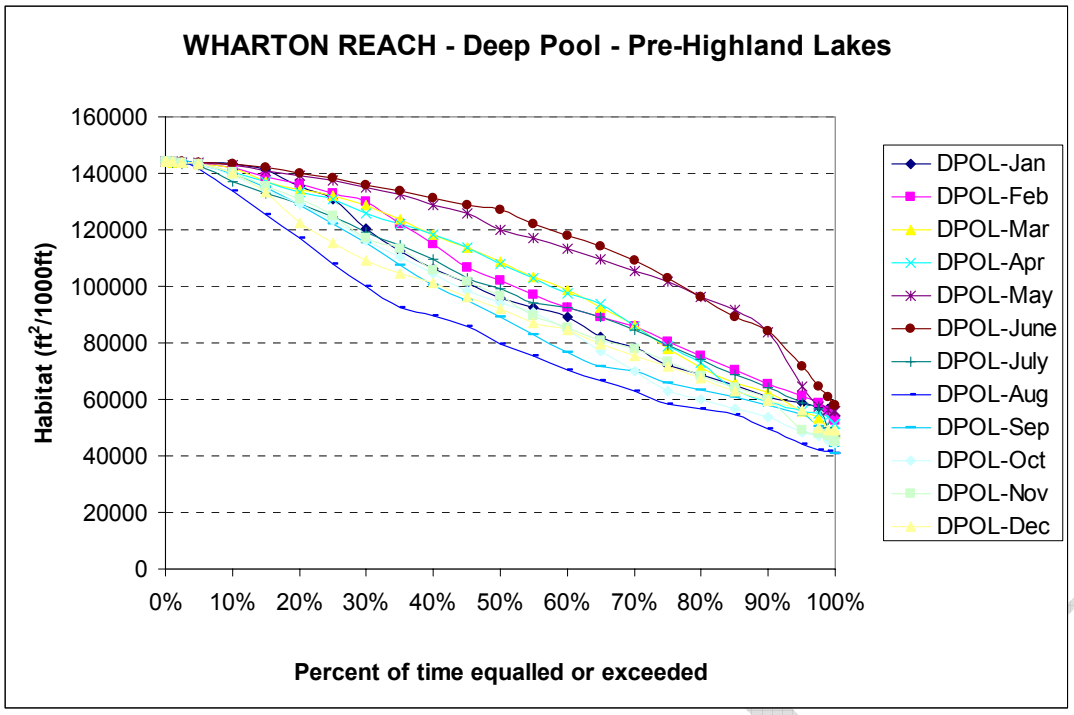


**Figure D57.** Habitat durations for deep pool for all months at the Wharton Reach based on the pre-1940 flow regime.

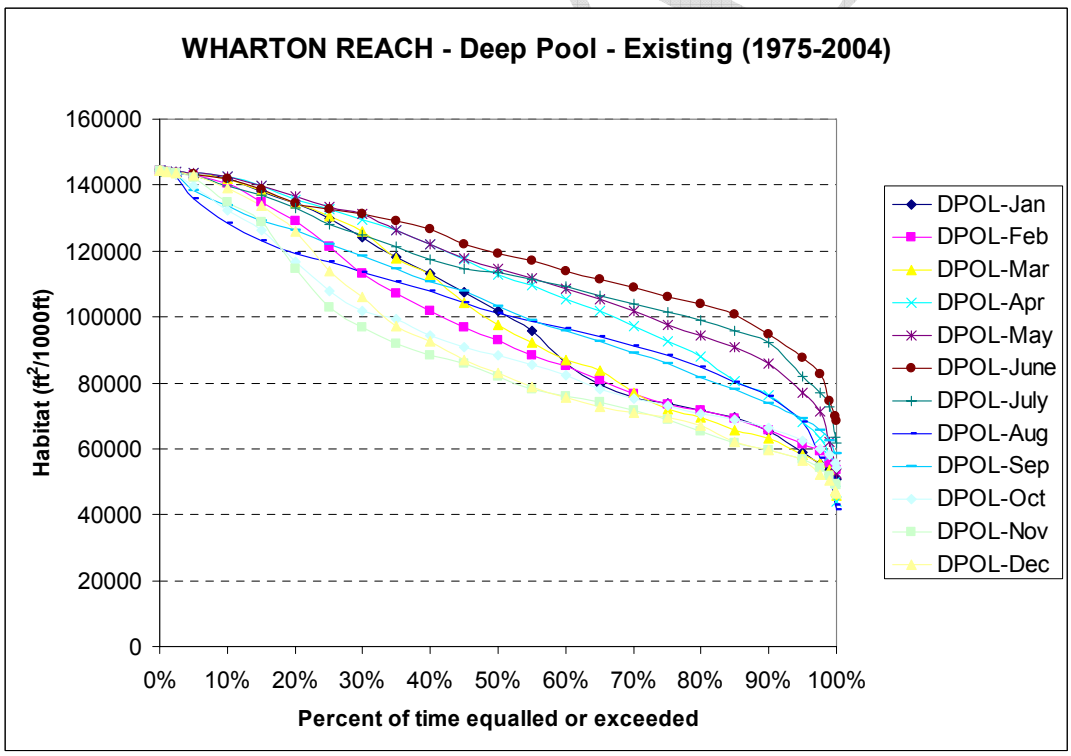


**Figure D58.** Habitat durations for deep pool for all months at the Wharton Reach based on the existing flow regime.

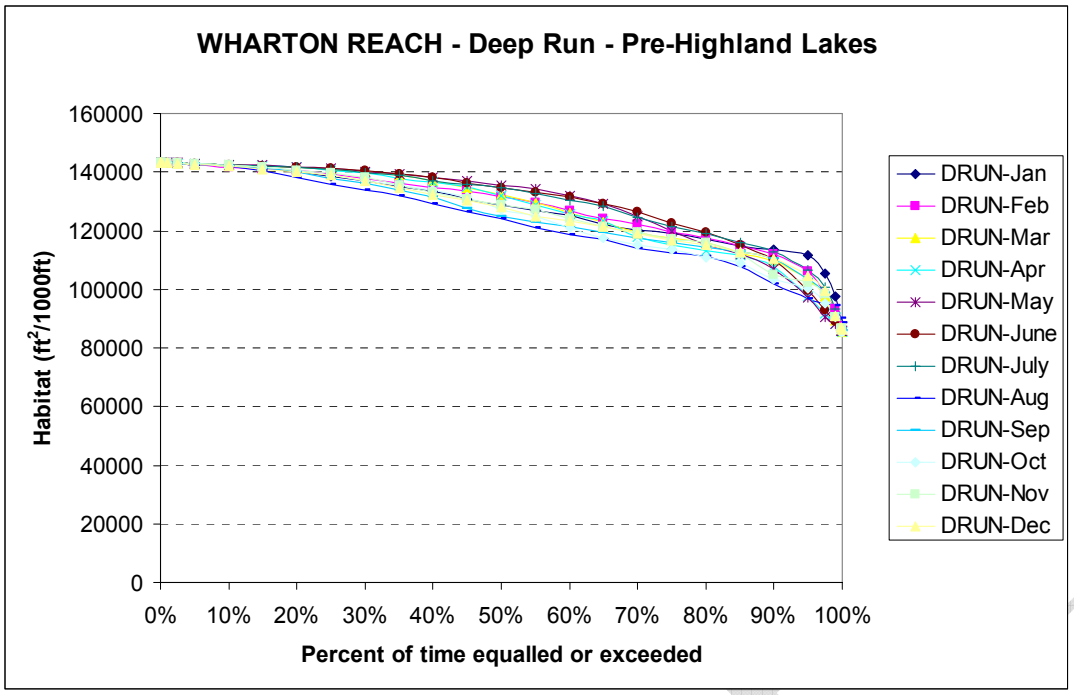


**Figure D59.** Habitat durations for deep run for all months at the Wharton Reach based on the pre-1940 flow regime.

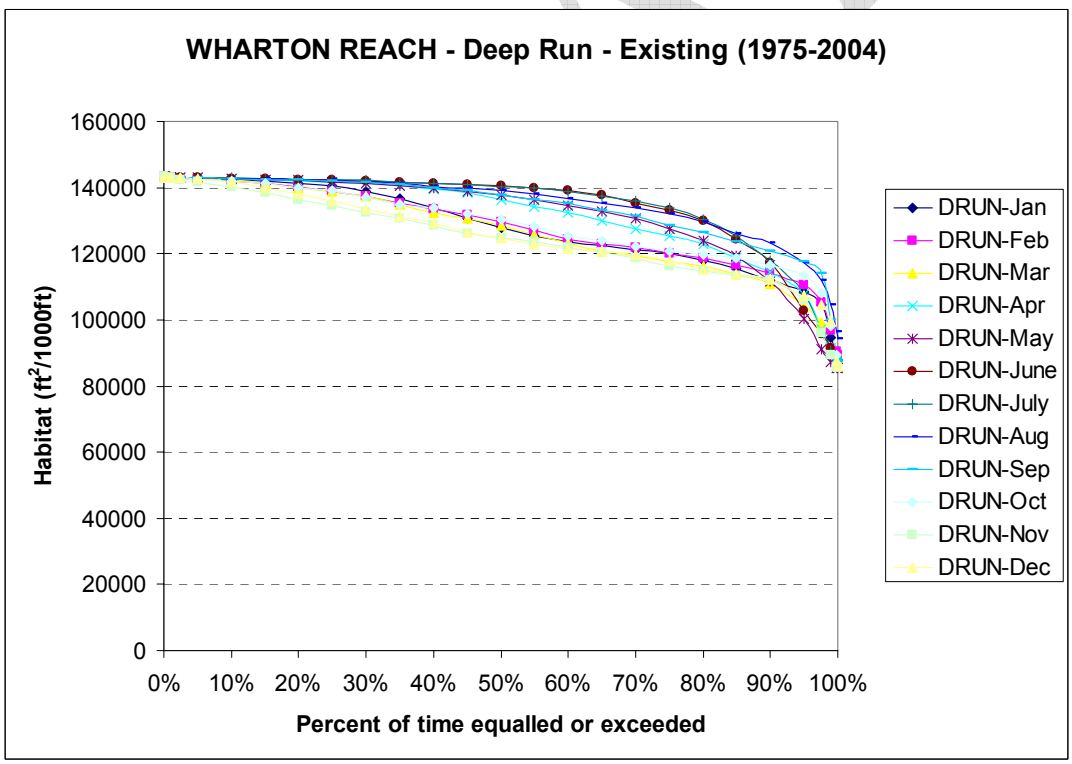


**Figure D60.** Habitat durations for deep run for all months at the Wharton Reach based on the existing flow regime.

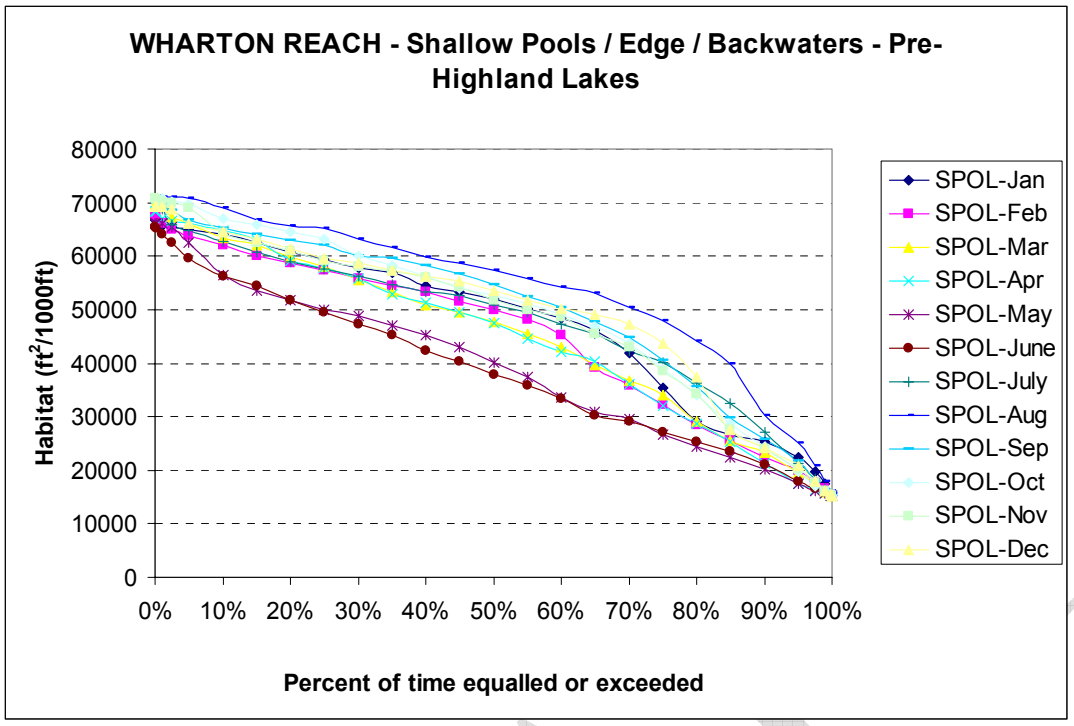


**Figure D61.** Habitat durations for shallow pools/edge/backwater for all months at the Wharton Reach based on the pre-1940 flow regime.

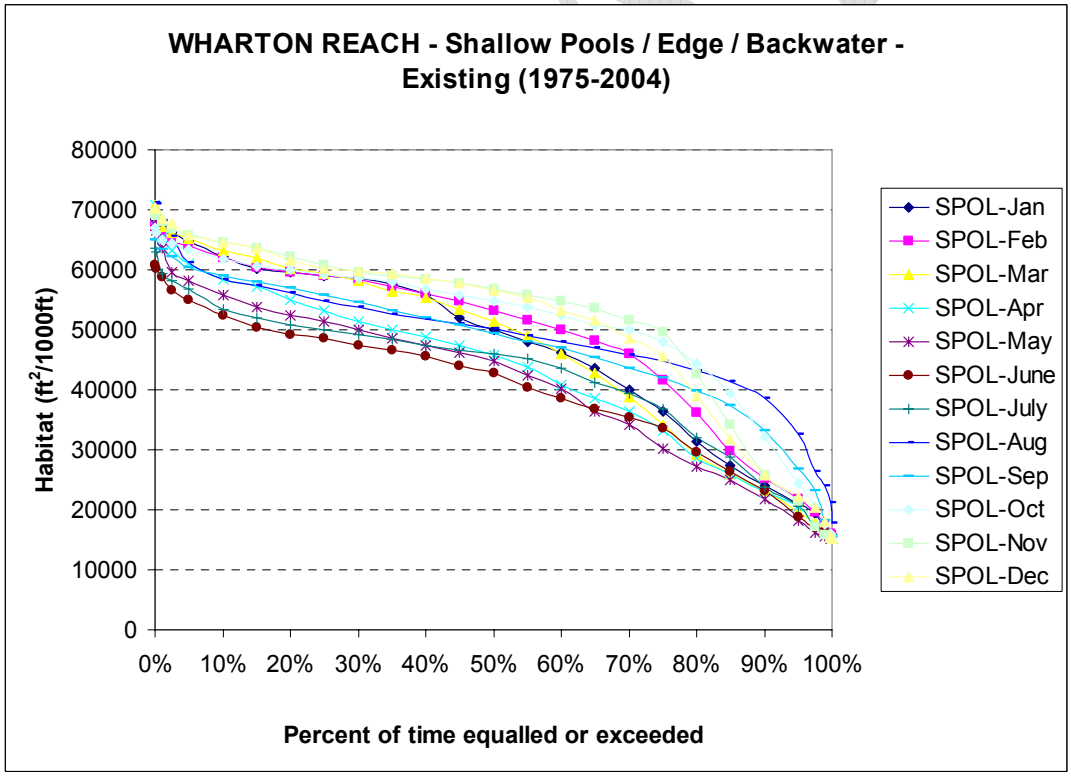


**Figure D62.** Habitat durations for shallow pools/edge/backwater for all months at the Wharton Reach based on the existing flow regime.

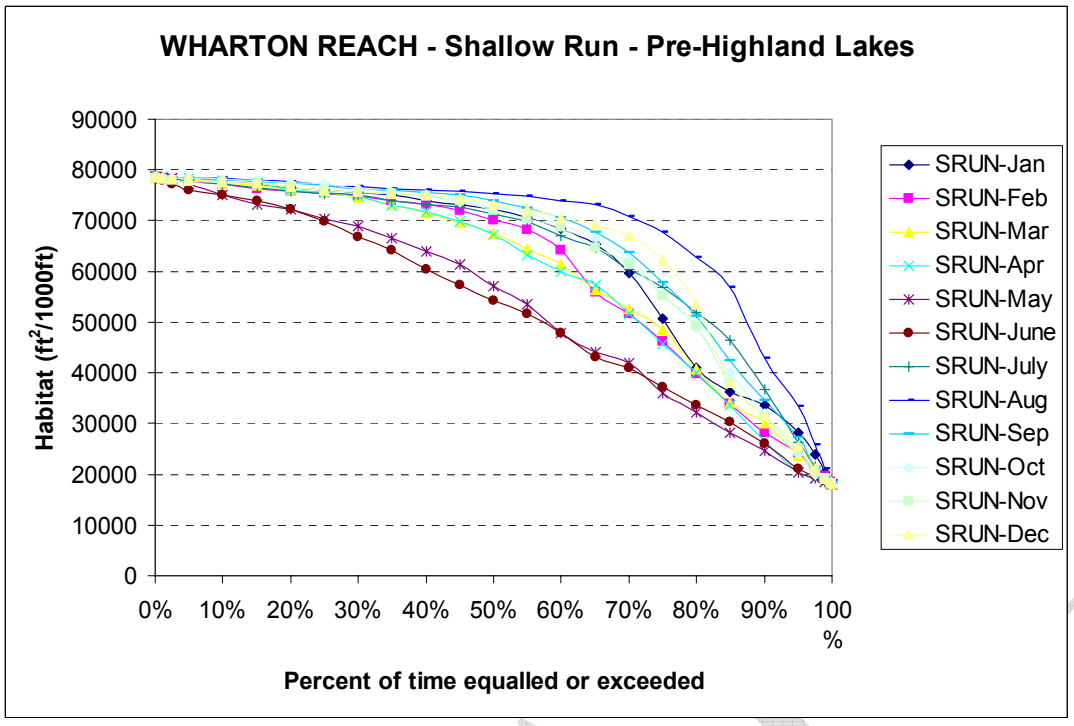


**Figure D63.** Habitat durations for shallow run for all months at the Wharton Reach based on the pre-1940 flow regime.

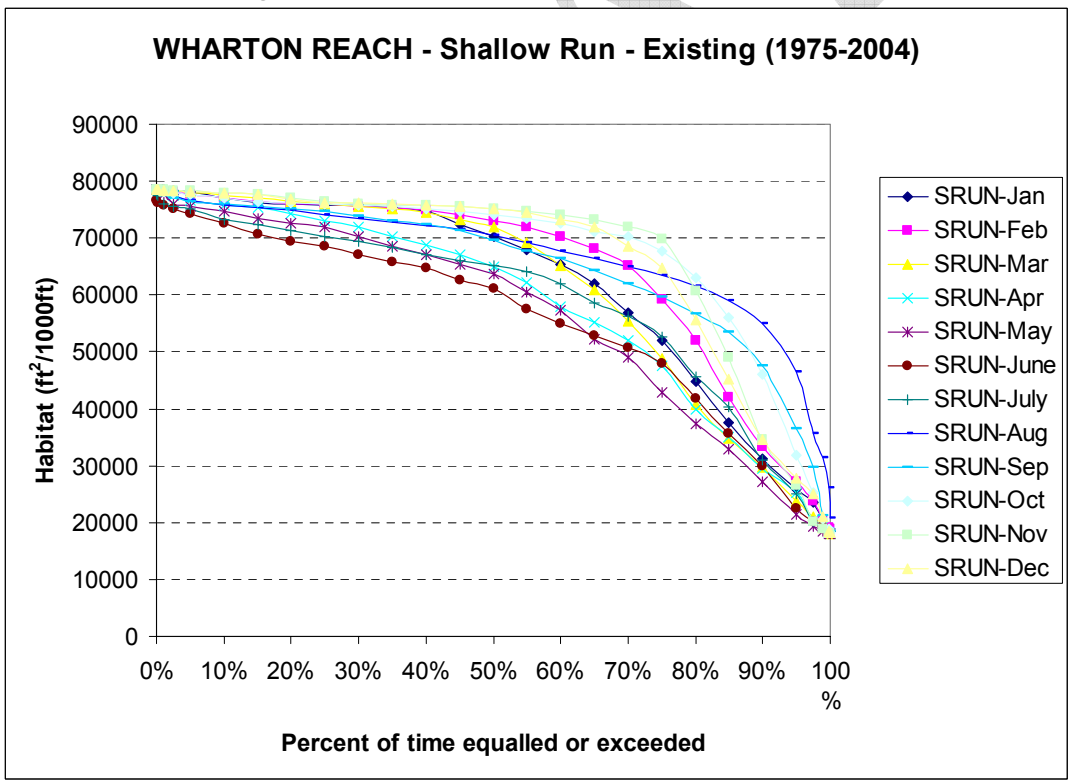


**Figure D64.** Habitat durations for shallow run for all months at the Wharton Reach based on the existing flow regime.

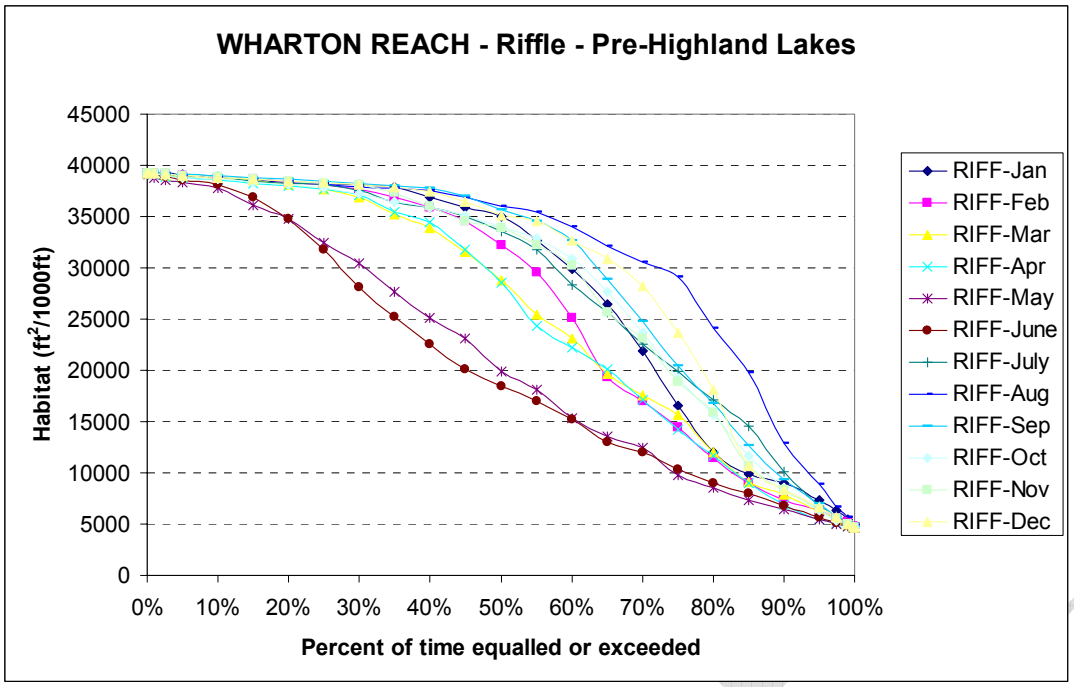


**Figure D65.** Habitat durations for riffles for all months at the Wharton Reach based on the pre-1940 flow regime.

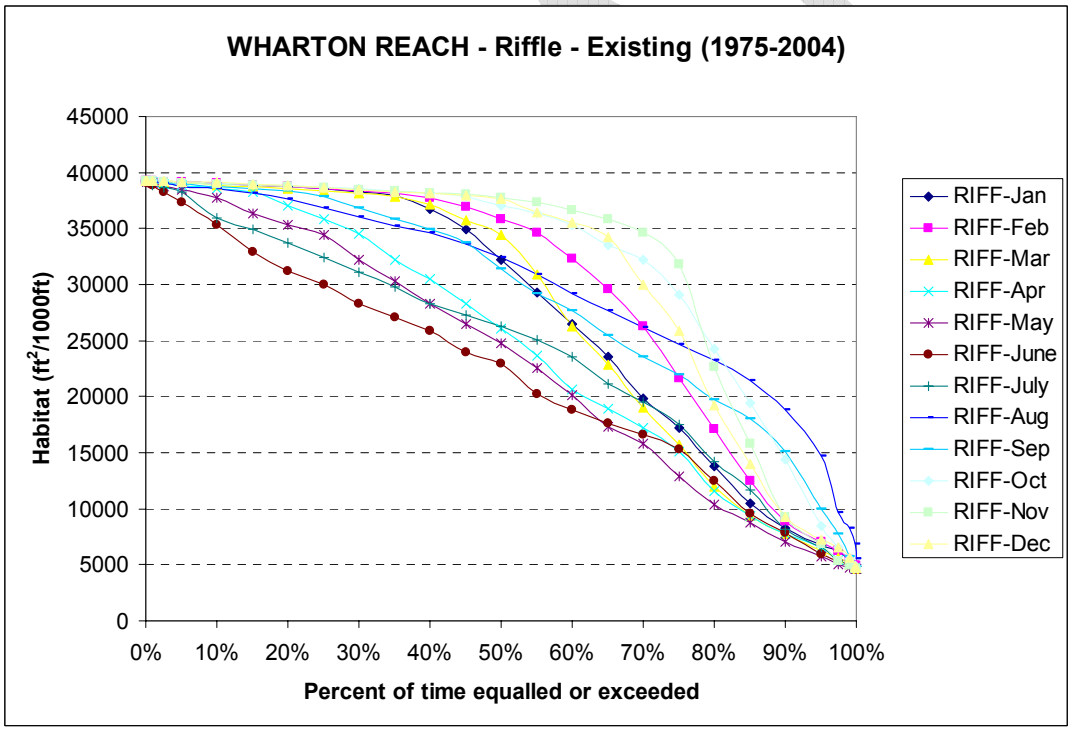


**Figure D66.** Habitat durations for riffles for all months at the Wharton Reach based on the existing flow regime.

# APPENDIX E – Habitat Percent Exceedence Level Evaluation Tables

**Table E1** Percentage of maximum available habitat at each percent exceedence level in January at the Austin Reach.

| AUSTIN REACH - JANUARY<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 8% | N/A | 33% | 51% | 14% | 15% | 6% |
| 0.95 | 10% | N/A | 34% | 70% | 31% | 37% | 28% |
| 0.90 | 14% | N/A | 36% | 74% | 37% | 49% | 42% |
| 0.85 | 16% | N/A | 37% | 76% | 42% | 59% | 54% |
| 0.80 | 18% | N/A | 38% | 80% | 47% | 65% | 68% |
| 0.75 | 20% | N/A | 39% | 82% | 55% | 72% | 73% |
| 0.70 | 22% | N/A | 40% | 84% | 71% | 81% | 76% |
| 0.65 | 23% | N/A | 40% | 85% | 79% | 86% | 82% |
| 0.60 | 27% | N/A | 42% | 86% | 85% | 91% | 84% |
| 0.55 | 31% | N/A | 43% | 87% | 88% | 92% | 86% |
| 0.50 | 38% | N/A | 46% | 90% | 91% | 94% | 88% |
| 0.45 | 42% | N/A | 48% | 91% | 95% | 95% | 90% |
| 0.40 | 46% | N/A | 50% | 93% | 97% | 96% | 91% |
| 0.35 | 54% | N/A | 55% | 94% | 98% | 98% | 92% |
| 0.30 | 64% | N/A | 63% | 95% | 98% | 98% | 94% |
| 0.25 | 76% | N/A | 72% | 96% | 98% | 98% | 96% |
| 0.20 | 83% | N/A | 81% | 97% | 99% | 99% | 98% |
| 0.15 | 96% | N/A | 94% | 98% | 99% | 99% | 99% |
| 0.10 | 97% | N/A | 94% | 98% | 99% | 99% | 100% |
| 0.05 | 99% | N/A | 96% | 99% | 100% | 100% | 100% |
| 0.01 | 99% | N/A | 98% | 100% | 100% | 100% | 100% |

**Table E2** Percentage of maximum available habitat at each percent exceedence level in February at the Austin Reach.

| AUSTIN REACH - FEBRUARY<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 5% | 10% | 32% | 52% | 15% | 16% | 7% |
| 0.95 | 9% | 23% | 34% | 61% | 24% | 26% | 16% |
| 0.90 | 12% | 47% | 35% | 70% | 34% | 42% | 33% |
| 0.85 | 14% | 66% | 36% | 74% | 43% | 60% | 53% |
| 0.80 | 18% | 72% | 38% | 76% | 49% | 67% | 68% |
| 0.75 | 21% | 75% | 39% | 80% | 57% | 73% | 72% |
| 0.70 | 24% | 80% | 40% | 83% | 71% | 81% | 76% |
| 0.65 | 28% | 81% | 42% | 85% | 80% | 86% | 80% |
| 0.60 | 33% | 85% | 44% | 87% | 84% | 90% | 82% |
| 0.55 | 37% | 87% | 46% | 89% | 87% | 91% | 88% |
| 0.50 | 40% | 88% | 47% | 92% | 90% | 93% | 89% |
| 0.45 | 43% | 91% | 49% | 94% | 92% | 94% | 90% |
| 0.40 | 48% | 93% | 51% | 94% | 95% | 95% | 92% |
| 0.35 | 52% | 94% | 54% | 95% | 96% | 96% | 95% |
| 0.30 | 64% | 97% | 63% | 96% | 97% | 97% | 97% |
| 0.25 | 75% | 98% | 70% | 97% | 98% | 98% | 99% |
| 0.20 | 83% | 98% | 79% | 97% | 98% | 98% | 99% |
| 0.15 | 92% | 99% | 93% | 98% | 99% | 99% | 100% |
| 0.10 | 98% | 99% | 94% | 99% | 99% | 99% | 100% |
| 0.05 | 99% | 100% | 96% | 99% | 100% | 100% | 100% |
| 0.01 | 100% | 100% | 99% | 99% | 100% | 100% | 100% |

**Table E3** Percentage of maximum available habitat at each percent exceedence level in March at the Austin Reach.

| AUSTIN REACH - MARCH<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 3% | 7% | 31% | 48% | 12% | 13% | 5% |
| 0.95 | 7% | 31% | 33% | 66% | 28% | 32% | 22% |
| 0.90 | 10% | 53% | 34% | 70% | 36% | 46% | 39% |
| 0.85 | 12% | 62% | 35% | 72% | 39% | 53% | 49% |
| 0.80 | 15% | 68% | 36% | 76% | 46% | 64% | 64% |
| 0.75 | 19% | 70% | 38% | 78% | 59% | 74% | 68% |
| 0.70 | 22% | 75% | 40% | 80% | 68% | 79% | 72% |
| 0.65 | 28% | 78% | 42% | 83% | 73% | 83% | 76% |
| 0.60 | 33% | 81% | 44% | 86% | 78% | 86% | 80% |
| 0.55 | 37% | 85% | 46% | 87% | 84% | 90% | 84% |
| 0.50 | 45% | 88% | 50% | 91% | 86% | 91% | 88% |
| 0.45 | 48% | 90% | 51% | 94% | 92% | 92% | 89% |
| 0.40 | 55% | 93% | 55% | 94% | 95% | 93% | 91% |
| 0.35 | 61% | 94% | 60% | 95% | 96% | 95% | 93% |
| 0.30 | 66% | 97% | 64% | 96% | 97% | 96% | 95% |
| 0.25 | 73% | 97% | 69% | 98% | 98% | 97% | 97% |
| 0.20 | 86% | 98% | 85% | 98% | 98% | 98% | 98% |
| 0.15 | 97% | 98% | 94% | 99% | 99% | 98% | 99% |
| 0.10 | 98% | 99% | 94% | 99% | 99% | 99% | 100% |
| 0.05 | 99% | 99% | 95% | 100% | 100% | 100% | 100% |
| 0.01 | 99% | 100% | 98% | 100% | 100% | 100% | 100% |

**Table E4** Percentage of maximum available habitat at each percent exceedence level in April at the Austin Reach.

| AUSTIN REACH - APRIL<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 1% | 4% | 30% | 44% | 11% | 10% | 3% |
| 0.95 | 8% | 18% | 33% | 59% | 21% | 23% | 12% |
| 0.90 | 10% | 34% | 34% | 66% | 29% | 34% | 24% |
| 0.85 | 14% | 55% | 36% | 71% | 37% | 48% | 41% |
| 0.80 | 16% | 63% | 37% | 74% | 41% | 57% | 52% |
| 0.75 | 21% | 68% | 39% | 76% | 46% | 64% | 62% |
| 0.70 | 26% | 72% | 41% | 80% | 50% | 68% | 68% |
| 0.65 | 33% | 76% | 44% | 82% | 55% | 72% | 71% |
| 0.60 | 42% | 80% | 48% | 85% | 63% | 76% | 74% |
| 0.55 | 51% | 81% | 53% | 87% | 70% | 80% | 77% |
| 0.50 | 55% | 84% | 56% | 90% | 78% | 86% | 81% |
| 0.45 | 65% | 87% | 63% | 94% | 81% | 88% | 83% |
| 0.40 | 71% | 89% | 67% | 94% | 88% | 91% | 86% |
| 0.35 | 76% | 91% | 72% | 95% | 95% | 93% | 89% |
| 0.30 | 81% | 93% | 77% | 96% | 96% | 94% | 91% |
| 0.25 | 86% | 95% | 85% | 97% | 97% | 96% | 93% |
| 0.20 | 93% | 97% | 94% | 98% | 98% | 97% | 96% |
| 0.15 | 97% | 98% | 94% | 99% | 98% | 98% | 98% |
| 0.10 | 98% | 99% | 95% | 99% | 99% | 99% | 99% |
| 0.05 | 99% | 99% | 97% | 99% | 99% | 99% | 100% |
| 0.01 | 100% | 100% | 99% | 100% | 100% | 100% | 100% |

**Table E5** Percentage of maximum available habitat at each percent exceedence level in May at the Austin Reach.

| AUSTIN REACH - MAY<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 10% | N/A | 34% | 41% | 9% | 9% | 2% |
| 0.95 | 15% | N/A | 36% | 49% | 13% | 13% | 5% |
| 0.90 | 25% | N/A | 41% | 57% | 19% | 21% | 10% |
| 0.85 | 33% | N/A | 44% | 64% | 24% | 27% | 17% |
| 0.80 | 41% | N/A | 48% | 70% | 29% | 34% | 24% |
| 0.75 | 47% | N/A | 51% | 75% | 34% | 43% | 34% |
| 0.70 | 52% | N/A | 53% | 80% | 38% | 50% | 45% |
| 0.65 | 56% | N/A | 56% | 83% | 42% | 57% | 53% |
| 0.60 | 62% | N/A | 61% | 86% | 46% | 63% | 65% |
| 0.55 | 69% | N/A | 66% | 90% | 49% | 67% | 72% |
| 0.50 | 76% | N/A | 71% | 94% | 56% | 72% | 79% |
| 0.45 | 82% | N/A | 79% | 94% | 65% | 77% | 82% |
| 0.40 | 85% | N/A | 87% | 95% | 72% | 82% | 87% |
| 0.35 | 92% | N/A | 93% | 96% | 77% | 85% | 90% |
| 0.30 | 95% | N/A | 94% | 97% | 81% | 88% | 94% |
| 0.25 | 97% | N/A | 94% | 98% | 84% | 90% | 96% |
| 0.20 | 98% | N/A | 94% | 98% | 89% | 93% | 98% |
| 0.15 | 99% | N/A | 96% | 99% | 95% | 96% | 99% |
| 0.10 | 99% | N/A | 97% | 99% | 97% | 97% | 99% |
| 0.05 | 100% | N/A | 100% | 100% | 99% | 99% | 100% |
| 0.01 | 100% | N/A | 100% | 100% | 99% | 99% | 100% |

**Table E6** Percentage of maximum available habitat at each percent exceedence level in June at the Austin Reach.

| AUSTIN REACH - JUNE<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 2% | N/A | 30% | 41% | 9% | 9% | 2% |
| 0.95 | 9% | N/A | 34% | 51% | 14% | 15% | 7% |
| 0.90 | 14% | N/A | 36% | 60% | 22% | 24% | 14% |
| 0.85 | 20% | N/A | 39% | 67% | 28% | 33% | 23% |
| 0.80 | 26% | N/A | 41% | 70% | 34% | 41% | 32% |
| 0.75 | 33% | N/A | 44% | 74% | 37% | 49% | 43% |
| 0.70 | 40% | N/A | 48% | 77% | 40% | 56% | 51% |
| 0.65 | 47% | N/A | 51% | 80% | 45% | 62% | 59% |
| 0.60 | 56% | N/A | 56% | 85% | 47% | 65% | 66% |
| 0.55 | 65% | N/A | 63% | 87% | 51% | 69% | 71% |
| 0.50 | 71% | N/A | 68% | 90% | 62% | 76% | 74% |
| 0.45 | 79% | N/A | 76% | 93% | 70% | 80% | 79% |
| 0.40 | 83% | N/A | 81% | 94% | 77% | 85% | 83% |
| 0.35 | 88% | N/A | 90% | 94% | 84% | 89% | 88% |
| 0.30 | 93% | N/A | 94% | 95% | 89% | 92% | 91% |
| 0.25 | 97% | N/A | 94% | 96% | 95% | 94% | 93% |
| 0.20 | 97% | N/A | 94% | 97% | 97% | 95% | 95% |
| 0.15 | 98% | N/A | 95% | 98% | 97% | 97% | 98% |
| 0.10 | 99% | N/A | 97% | 99% | 98% | 98% | 99% |
| 0.05 | 100% | N/A | 99% | 99% | 99% | 99% | 100% |
| 0.01 | 100% | N/A | 100% | 100% | 100% | 100% | 100% |

**Table E7** Percentage of maximum available habitat at each percent exceedence level in July at the Austin Reach.

| AUSTIN REACH - JULY<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 0% | N/A | 30% | 42% | 10% | 9% | 3% |
| 0.95 | 4% | N/A | 31% | 55% | 17% | 19% | 9% |
| 0.90 | 8% | N/A | 33% | 63% | 29% | 34% | 24% |
| 0.85 | 14% | N/A | 36% | 68% | 37% | 49% | 43% |
| 0.80 | 21% | N/A | 39% | 71% | 44% | 62% | 58% |
| 0.75 | 26% | N/A | 41% | 75% | 49% | 67% | 62% |
| 0.70 | 32% | N/A | 44% | 81% | 59% | 74% | 67% |
| 0.65 | 37% | N/A | 46% | 85% | 67% | 79% | 72% |
| 0.60 | 42% | N/A | 48% | 88% | 73% | 82% | 78% |
| 0.55 | 46% | N/A | 50% | 91% | 76% | 85% | 82% |
| 0.50 | 52% | N/A | 53% | 94% | 81% | 88% | 87% |
| 0.45 | 57% | N/A | 58% | 94% | 85% | 89% | 90% |
| 0.40 | 62% | N/A | 61% | 96% | 88% | 91% | 92% |
| 0.35 | 67% | N/A | 65% | 96% | 92% | 92% | 94% |
| 0.30 | 74% | N/A | 69% | 97% | 95% | 93% | 95% |
| 0.25 | 81% | N/A | 78% | 98% | 96% | 95% | 97% |
| 0.20 | 88% | N/A | 91% | 98% | 97% | 96% | 99% |
| 0.15 | 95% | N/A | 94% | 99% | 98% | 97% | 99% |
| 0.10 | 98% | N/A | 94% | 99% | 98% | 98% | 100% |
| 0.05 | 99% | N/A | 98% | 100% | 99% | 99% | 100% |
| 0.01 | 100% | N/A | 99% | 100% | 99% | 99% | 100% |

**Table E8** Percentage of maximum available habitat at each percent exceedence level in August at the Austin Reach.

| AUSTIN REACH - AUGUST<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 0% | N/A | 27% | 47% | 12% | 12% | 4% |
| 0.95 | 0% | N/A | 29% | 57% | 31% | 37% | 28% |
| 0.90 | 0% | N/A | 29% | 60% | 39% | 53% | 48% |
| 0.85 | 3% | N/A | 31% | 63% | 47% | 65% | 52% |
| 0.80 | 8% | N/A | 33% | 67% | 58% | 74% | 55% |
| 0.75 | 11% | N/A | 35% | 73% | 66% | 78% | 60% |
| 0.70 | 14% | N/A | 36% | 75% | 76% | 84% | 64% |
| 0.65 | 18% | N/A | 38% | 79% | 81% | 85% | 71% |
| 0.60 | 23% | N/A | 40% | 82% | 87% | 87% | 75% |
| 0.55 | 26% | N/A | 41% | 86% | 93% | 88% | 79% |
| 0.50 | 30% | N/A | 43% | 88% | 95% | 89% | 83% |
| 0.45 | 36% | N/A | 45% | 90% | 95% | 91% | 87% |
| 0.40 | 44% | N/A | 49% | 91% | 96% | 93% | 89% |
| 0.35 | 52% | N/A | 53% | 94% | 96% | 94% | 91% |
| 0.30 | 58% | N/A | 58% | 95% | 97% | 96% | 93% |
| 0.25 | 68% | N/A | 65% | 96% | 97% | 97% | 94% |
| 0.20 | 74% | N/A | 70% | 97% | 98% | 98% | 96% |
| 0.15 | 83% | N/A | 81% | 98% | 98% | 98% | 98% |
| 0.10 | 97% | N/A | 94% | 99% | 99% | 99% | 99% |
| 0.05 | 99% | N/A | 96% | 99% | 99% | 99% | 100% |
| 0.01 | 99% | N/A | 98% | 100% | 100% | 100% | 100% |

**Table E9** Percentage of maximum available habitat at each percent exceedence level in September at the Austin Reach.

| AUSTIN REACH - SEPTEMBER<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 0% | N/A | 28% | 45% | 11% | 10% | 3% |
| 0.95 | 1% | N/A | 30% | 57% | 20% | 21% | 11% |
| 0.90 | 6% | N/A | 32% | 62% | 31% | 37% | 28% |
| 0.85 | 9% | N/A | 34% | 66% | 37% | 48% | 42% |
| 0.80 | 12% | N/A | 35% | 70% | 44% | 61% | 53% |
| 0.75 | 16% | N/A | 37% | 73% | 51% | 69% | 59% |
| 0.70 | 19% | N/A | 38% | 75% | 64% | 77% | 66% |
| 0.65 | 22% | N/A | 40% | 79% | 72% | 82% | 70% |
| 0.60 | 27% | N/A | 41% | 82% | 77% | 85% | 74% |
| 0.55 | 32% | N/A | 44% | 85% | 83% | 87% | 77% |
| 0.50 | 40% | N/A | 47% | 86% | 90% | 89% | 82% |
| 0.45 | 48% | N/A | 51% | 88% | 95% | 91% | 86% |
| 0.40 | 56% | N/A | 56% | 91% | 96% | 92% | 88% |
| 0.35 | 62% | N/A | 61% | 94% | 96% | 94% | 90% |
| 0.30 | 70% | N/A | 66% | 95% | 97% | 95% | 92% |
| 0.25 | 79% | N/A | 76% | 96% | 98% | 97% | 94% |
| 0.20 | 89% | N/A | 92% | 97% | 98% | 98% | 95% |
| 0.15 | 97% | N/A | 94% | 98% | 99% | 98% | 98% |
| 0.10 | 98% | N/A | 94% | 99% | 99% | 99% | 99% |
| 0.05 | 99% | N/A | 97% | 100% | 100% | 100% | 100% |
| 0.01 | 100% | N/A | 100% | 100% | 100% | 100% | 100% |

**Table E10** Percentage of maximum available habitat at each percent exceedence level in October at the Austin Reach.

| AUSTIN REACH - OCTOBER<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 0% | N/A | 28% | 43% | 10% | 10% | 3% |
| 0.95 | 3% | N/A | 31% | 57% | 18% | 20% | 10% |
| 0.90 | 7% | N/A | 33% | 62% | 28% | 31% | 21% |
| 0.85 | 10% | N/A | 34% | 66% | 37% | 49% | 43% |
| 0.80 | 13% | N/A | 35% | 69% | 46% | 64% | 54% |
| 0.75 | 16% | N/A | 37% | 73% | 56% | 72% | 63% |
| 0.70 | 20% | N/A | 39% | 75% | 71% | 81% | 68% |
| 0.65 | 24% | N/A | 40% | 79% | 77% | 85% | 72% |
| 0.60 | 27% | N/A | 42% | 82% | 83% | 88% | 76% |
| 0.55 | 32% | N/A | 44% | 85% | 89% | 90% | 80% |
| 0.50 | 36% | N/A | 45% | 88% | 93% | 91% | 83% |
| 0.45 | 42% | N/A | 48% | 90% | 95% | 93% | 88% |
| 0.40 | 48% | N/A | 51% | 93% | 96% | 94% | 91% |
| 0.35 | 56% | N/A | 56% | 94% | 96% | 95% | 92% |
| 0.30 | 64% | N/A | 62% | 95% | 97% | 96% | 94% |
| 0.25 | 76% | N/A | 71% | 96% | 97% | 97% | 96% |
| 0.20 | 86% | N/A | 85% | 97% | 98% | 98% | 98% |
| 0.15 | 96% | N/A | 94% | 98% | 98% | 98% | 99% |
| 0.10 | 98% | N/A | 95% | 99% | 99% | 99% | 100% |
| 0.05 | 99% | N/A | 98% | 99% | 99% | 99% | 100% |
| 0.01 | 100% | N/A | 100% | 100% | 100% | 100% | 100% |

**Table E11** Percentage of maximum available habitat at each percent exceedence level in November at the Austin Reach.

| AUSTIN REACH - NOVEMBER<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 2% | N/A | 30% | 44% | 10% | 10% | 3% |
| 0.95 | 7% | N/A | 33% | 59% | 21% | 23% | 13% |
| 0.90 | 9% | N/A | 34% | 68% | 33% | 40% | 31% |
| 0.85 | 12% | N/A | 35% | 72% | 44% | 61% | 55% |
| 0.80 | 16% | N/A | 37% | 74% | 53% | 70% | 67% |
| 0.75 | 19% | N/A | 38% | 77% | 63% | 76% | 72% |
| 0.70 | 23% | N/A | 40% | 80% | 70% | 80% | 75% |
| 0.65 | 25% | N/A | 41% | 84% | 77% | 85% | 78% |
| 0.60 | 27% | N/A | 41% | 86% | 83% | 88% | 82% |
| 0.55 | 31% | N/A | 43% | 88% | 88% | 91% | 85% |
| 0.50 | 35% | N/A | 45% | 90% | 93% | 93% | 88% |
| 0.45 | 42% | N/A | 48% | 91% | 95% | 94% | 90% |
| 0.40 | 49% | N/A | 52% | 94% | 97% | 95% | 91% |
| 0.35 | 57% | N/A | 57% | 95% | 97% | 96% | 93% |
| 0.30 | 65% | N/A | 63% | 96% | 98% | 97% | 94% |
| 0.25 | 71% | N/A | 67% | 97% | 98% | 98% | 95% |
| 0.20 | 78% | N/A | 74% | 97% | 98% | 98% | 97% |
| 0.15 | 88% | N/A | 91% | 98% | 99% | 99% | 99% |
| 0.10 | 97% | N/A | 94% | 99% | 99% | 99% | 100% |
| 0.05 | 99% | N/A | 97% | 99% | 99% | 100% | 100% |
| 0.01 | 100% | N/A | 99% | 100% | 100% | 100% | 100% |

**Table E12** Percentage of maximum available habitat at each percent exceedence level in December at the Austin Reach.

| AUSTIN REACH - DECEMBER<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 0% | N/A | 29% | 45% | 11% | 10% | 3% |
| 0.95 | 8% | N/A | 33% | 59% | 22% | 24% | 14% |
| 0.90 | 12% | N/A | 35% | 68% | 33% | 40% | 31% |
| 0.85 | 14% | N/A | 36% | 73% | 39% | 53% | 48% |
| 0.80 | 18% | N/A | 38% | 76% | 51% | 69% | 63% |
| 0.75 | 20% | N/A | 39% | 80% | 63% | 77% | 72% |
| 0.70 | 22% | N/A | 40% | 82% | 72% | 82% | 77% |
| 0.65 | 26% | N/A | 41% | 84% | 79% | 86% | 81% |
| 0.60 | 29% | N/A | 42% | 86% | 84% | 90% | 84% |
| 0.55 | 33% | N/A | 44% | 87% | 88% | 91% | 88% |
| 0.50 | 39% | N/A | 47% | 90% | 91% | 93% | 89% |
| 0.45 | 42% | N/A | 48% | 92% | 94% | 94% | 90% |
| 0.40 | 47% | N/A | 51% | 94% | 96% | 95% | 91% |
| 0.35 | 53% | N/A | 55% | 95% | 97% | 97% | 94% |
| 0.30 | 63% | N/A | 62% | 96% | 97% | 97% | 95% |
| 0.25 | 70% | N/A | 67% | 97% | 98% | 98% | 97% |
| 0.20 | 80% | N/A | 76% | 98% | 99% | 98% | 99% |
| 0.15 | 97% | N/A | 94% | 98% | 99% | 99% | 99% |
| 0.10 | 98% | N/A | 94% | 99% | 99% | 99% | 100% |
| 0.05 | 99% | N/A | 97% | 99% | 100% | 100% | 100% |
| 0.01 | 100% | N/A | 98% | 100% | 100% | 100% | 100% |

**Table E13** Percentage of maximum available habitat at each percent exceedence level in January at the Bastrop Reach.

| BASTROP REACH - JANUARY<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 13% | N/A | 58% | 58% | 22% | 28% | 22% |
| 0.95 | 15% | N/A | 59% | 78% | 36% | 48% | 52% |
| 0.90 | 23% | N/A | 63% | 83% | 43% | 60% | 70% |
| 0.85 | 26% | N/A | 65% | 84% | 49% | 69% | 81% |
| 0.80 | 29% | N/A | 66% | 86% | 56% | 75% | 86% |
| 0.75 | 32% | N/A | 67% | 87% | 62% | 82% | 88% |
| 0.70 | 36% | N/A | 69% | 88% | 71% | 90% | 90% |
| 0.65 | 38% | N/A | 69% | 90% | 77% | 94% | 93% |
| 0.60 | 44% | N/A | 73% | 90% | 81% | 96% | 95% |
| 0.55 | 49% | N/A | 75% | 91% | 83% | 96% | 96% |
| 0.50 | 57% | N/A | 80% | 92% | 84% | 97% | 97% |
| 0.45 | 61% | N/A | 82% | 93% | 87% | 98% | 97% |
| 0.40 | 65% | N/A | 84% | 94% | 88% | 99% | 98% |
| 0.35 | 72% | N/A | 87% | 95% | 89% | 99% | 98% |
| 0.30 | 77% | N/A | 91% | 97% | 90% | 99% | 98% |
| 0.25 | 85% | N/A | 94% | 97% | 91% | 100% | 98% |
| 0.20 | 90% | N/A | 95% | 98% | 92% | 100% | 99% |
| 0.15 | 93% | N/A | 96% | 99% | 93% | 100% | 99% |
| 0.10 | 96% | N/A | 98% | 99% | 94% | 100% | 99% |
| 0.05 | 99% | N/A | 99% | 100% | 96% | 100% | 100% |
| 0.01 | 99% | N/A | 100% | 100% | 97% | 100% | 100% |

**Table E14** Percentage of maximum available habitat at each percent exceedence level in February at the Bastrop Reach.

| BASTROP REACH - FEBRUARY<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 8% | 28% | 55% | 59% | 22% | 29% | 24% |
| 0.95 | 15% | 42% | 59% | 69% | 28% | 38% | 38% |
| 0.90 | 19% | 61% | 61% | 79% | 37% | 52% | 59% |
| 0.85 | 23% | 79% | 63% | 83% | 49% | 70% | 80% |
| 0.80 | 30% | 83% | 66% | 85% | 55% | 77% | 85% |
| 0.75 | 34% | 86% | 68% | 87% | 60% | 84% | 88% |
| 0.70 | 39% | 88% | 70% | 88% | 68% | 90% | 90% |
| 0.65 | 45% | 90% | 73% | 90% | 75% | 94% | 92% |
| 0.60 | 51% | 92% | 77% | 91% | 77% | 95% | 94% |
| 0.55 | 56% | 94% | 80% | 92% | 79% | 96% | 96% |
| 0.50 | 59% | 95% | 81% | 93% | 80% | 97% | 97% |
| 0.45 | 63% | 97% | 83% | 95% | 81% | 97% | 98% |
| 0.40 | 66% | 97% | 85% | 96% | 83% | 98% | 98% |
| 0.35 | 71% | 98% | 87% | 97% | 84% | 99% | 98% |
| 0.30 | 75% | 98% | 89% | 97% | 86% | 99% | 98% |
| 0.25 | 81% | 99% | 91% | 98% | 87% | 99% | 99% |
| 0.20 | 85% | 99% | 94% | 98% | 88% | 99% | 99% |
| 0.15 | 91% | 99% | 96% | 99% | 90% | 100% | 99% |
| 0.10 | 94% | 99% | 98% | 99% | 91% | 100% | 100% |
| 0.05 | 96% | 100% | 99% | 100% | 93% | 100% | 100% |
| 0.01 | 98% | 100% | 100% | 100% | 94% | 100% | 100% |

**Table E15** Percentage of maximum available habitat at each percent exceedence level in March at the Bastrop Reach.

| BASTROP REACH - MARCH<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 5% | 24% | 54% | 56% | 21% | 26% | 20% |
| 0.95 | 11% | 49% | 57% | 73% | 33% | 44% | 45% |
| 0.90 | 16% | 68% | 60% | 81% | 40% | 57% | 65% |
| 0.85 | 20% | 77% | 62% | 83% | 45% | 65% | 77% |
| 0.80 | 24% | 80% | 64% | 84% | 53% | 74% | 84% |
| 0.75 | 30% | 83% | 67% | 85% | 63% | 85% | 86% |
| 0.70 | 36% | 85% | 69% | 87% | 68% | 88% | 88% |
| 0.65 | 45% | 88% | 73% | 88% | 71% | 91% | 90% |
| 0.60 | 51% | 89% | 77% | 90% | 76% | 93% | 92% |
| 0.55 | 56% | 92% | 79% | 91% | 79% | 95% | 94% |
| 0.50 | 62% | 95% | 83% | 93% | 80% | 96% | 97% |
| 0.45 | 66% | 96% | 85% | 95% | 83% | 97% | 98% |
| 0.40 | 72% | 97% | 88% | 95% | 85% | 98% | 98% |
| 0.35 | 76% | 97% | 90% | 96% | 86% | 98% | 98% |
| 0.30 | 80% | 98% | 92% | 97% | 88% | 99% | 98% |
| 0.25 | 84% | 98% | 94% | 98% | 90% | 99% | 99% |
| 0.20 | 88% | 99% | 95% | 99% | 92% | 99% | 99% |
| 0.15 | 93% | 99% | 95% | 99% | 93% | 99% | 99% |
| 0.10 | 96% | 99% | 97% | 100% | 94% | 100% | 100% |
| 0.05 | 98% | 100% | 99% | 100% | 96% | 100% | 100% |
| 0.01 | 99% | 100% | 100% | 100% | 97% | 100% | 100% |

**Table E16** Percentage of maximum available habitat at each percent exceedence level in April at the Bastrop Reach.

| BASTROP REACH - APRIL<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 2% | 20% | 52% | 53% | 19% | 24% | 17% |
| 0.95 | 12% | 38% | 58% | 66% | 27% | 35% | 33% |
| 0.90 | 16% | 51% | 60% | 75% | 34% | 45% | 48% |
| 0.85 | 22% | 71% | 63% | 81% | 42% | 59% | 68% |
| 0.80 | 26% | 78% | 64% | 83% | 47% | 67% | 79% |
| 0.75 | 34% | 81% | 68% | 85% | 53% | 74% | 83% |
| 0.70 | 42% | 83% | 72% | 86% | 57% | 78% | 86% |
| 0.65 | 52% | 86% | 77% | 87% | 61% | 82% | 87% |
| 0.60 | 61% | 88% | 80% | 90% | 65% | 86% | 90% |
| 0.55 | 66% | 89% | 85% | 91% | 69% | 89% | 92% |
| 0.50 | 72% | 91% | 88% | 92% | 76% | 93% | 93% |
| 0.45 | 74% | 94% | 89% | 94% | 78% | 95% | 95% |
| 0.40 | 80% | 95% | 91% | 96% | 81% | 96% | 97% |
| 0.35 | 84% | 96% | 94% | 97% | 85% | 98% | 98% |
| 0.30 | 86% | 97% | 95% | 98% | 87% | 98% | 98% |
| 0.25 | 90% | 97% | 95% | 99% | 89% | 99% | 98% |
| 0.20 | 92% | 98% | 97% | 99% | 91% | 99% | 99% |
| 0.15 | 94% | 99% | 98% | 99% | 92% | 99% | 99% |
| 0.10 | 96% | 99% | 99% | 100% | 94% | 100% | 99% |
| 0.05 | 99% | 100% | 100% | 100% | 96% | 100% | 100% |
| 0.01 | 99% | 100% | 100% | 100% | 97% | 100% | 100% |

**Table E17** Percentage of maximum available habitat at each percent exceedence level in May at the Bastrop Reach.

| BASTROP REACH - MAY<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 16% | N/A | 59% | 50% | 18% | 21% | 15% |
| 0.95 | 24% | N/A | 64% | 56% | 21% | 26% | 20% |
| 0.90 | 41% | N/A | 70% | 64% | 26% | 33% | 30% |
| 0.85 | 51% | N/A | 74% | 70% | 30% | 39% | 39% |
| 0.80 | 57% | N/A | 78% | 75% | 35% | 45% | 48% |
| 0.75 | 62% | N/A | 81% | 81% | 39% | 53% | 60% |
| 0.70 | 67% | N/A | 84% | 85% | 44% | 61% | 72% |
| 0.65 | 70% | N/A | 86% | 87% | 48% | 68% | 80% |
| 0.60 | 73% | N/A | 88% | 89% | 54% | 73% | 85% |
| 0.55 | 75% | N/A | 89% | 92% | 57% | 77% | 90% |
| 0.50 | 78% | N/A | 90% | 94% | 63% | 83% | 92% |
| 0.45 | 81% | N/A | 91% | 96% | 68% | 87% | 96% |
| 0.40 | 84% | N/A | 93% | 97% | 72% | 90% | 97% |
| 0.35 | 86% | N/A | 94% | 98% | 76% | 93% | 98% |
| 0.30 | 89% | N/A | 95% | 98% | 79% | 94% | 98% |
| 0.25 | 91% | N/A | 95% | 99% | 81% | 95% | 99% |
| 0.20 | 94% | N/A | 96% | 99% | 83% | 97% | 99% |
| 0.15 | 95% | N/A | 98% | 99% | 87% | 98% | 99% |
| 0.10 | 97% | N/A | 99% | 100% | 89% | 99% | 100% |
| 0.05 | 99% | N/A | 99% | 100% | 94% | 100% | 100% |
| 0.01 | 99% | N/A | 100% | 100% | 94% | 100% | 100% |

**Table E18** Percentage of maximum available habitat at each percent exceedence level in June at the Bastrop Reach.

| BASTROP REACH - JUNE<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 3% | N/A | 53% | 50% | 17% | 22% | 15% |
| 0.95 | 15% | N/A | 59% | 58% | 22% | 28% | 23% |
| 0.90 | 23% | N/A | 63% | 67% | 27% | 37% | 35% |
| 0.85 | 33% | N/A | 68% | 74% | 33% | 44% | 46% |
| 0.80 | 42% | N/A | 71% | 79% | 37% | 51% | 57% |
| 0.75 | 51% | N/A | 75% | 82% | 42% | 60% | 70% |
| 0.70 | 58% | N/A | 79% | 84% | 46% | 67% | 78% |
| 0.65 | 62% | N/A | 82% | 87% | 51% | 72% | 82% |
| 0.60 | 68% | N/A | 85% | 88% | 54% | 75% | 85% |
| 0.55 | 72% | N/A | 87% | 90% | 57% | 79% | 88% |
| 0.50 | 76% | N/A | 89% | 92% | 64% | 86% | 90% |
| 0.45 | 81% | N/A | 91% | 93% | 69% | 89% | 93% |
| 0.40 | 84% | N/A | 93% | 95% | 74% | 93% | 96% |
| 0.35 | 87% | N/A | 94% | 97% | 79% | 95% | 97% |
| 0.30 | 90% | N/A | 95% | 97% | 81% | 97% | 98% |
| 0.25 | 92% | N/A | 95% | 98% | 84% | 98% | 98% |
| 0.20 | 94% | N/A | 97% | 99% | 86% | 98% | 99% |
| 0.15 | 95% | N/A | 98% | 99% | 88% | 99% | 99% |
| 0.10 | 97% | N/A | 99% | 100% | 91% | 99% | 99% |
| 0.05 | 99% | N/A | 100% | 100% | 94% | 100% | 100% |
| 0.01 | 99% | N/A | 100% | 100% | 96% | 100% | 100% |

**Table E19** Percentage of maximum available habitat at each percent exceedence level in July at the Bastrop Reach.

| BASTROP REACH - JULY<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 2% | N/A | 52% | 51% | 18% | 22% | 15% |
| 0.95 | 6% | N/A | 55% | 62% | 23% | 31% | 27% |
| 0.90 | 13% | N/A | 58% | 75% | 33% | 45% | 47% |
| 0.85 | 23% | N/A | 63% | 79% | 42% | 60% | 71% |
| 0.80 | 34% | N/A | 68% | 81% | 50% | 72% | 79% |
| 0.75 | 42% | N/A | 71% | 84% | 55% | 77% | 83% |
| 0.70 | 50% | N/A | 75% | 87% | 62% | 84% | 85% |
| 0.65 | 55% | N/A | 78% | 90% | 66% | 88% | 89% |
| 0.60 | 59% | N/A | 80% | 91% | 70% | 90% | 92% |
| 0.55 | 63% | N/A | 83% | 93% | 72% | 92% | 95% |
| 0.50 | 67% | N/A | 85% | 95% | 76% | 94% | 97% |
| 0.45 | 72% | N/A | 88% | 96% | 78% | 96% | 98% |
| 0.40 | 75% | N/A | 90% | 97% | 80% | 97% | 98% |
| 0.35 | 78% | N/A | 91% | 98% | 82% | 97% | 98% |
| 0.30 | 82% | N/A | 93% | 98% | 83% | 98% | 99% |
| 0.25 | 84% | N/A | 94% | 99% | 85% | 98% | 99% |
| 0.20 | 88% | N/A | 95% | 99% | 87% | 99% | 99% |
| 0.15 | 91% | N/A | 96% | 100% | 90% | 99% | 99% |
| 0.10 | 94% | N/A | 98% | 100% | 94% | 99% | 100% |
| 0.05 | 97% | N/A | 99% | 100% | 96% | 100% | 100% |
| 0.01 | 99% | N/A | 100% | 100% | 97% | 100% | 100% |

**Table E20** Percentage of maximum available habitat at each percent exceedence level in August at the Bastrop Reach.

| BASTROP REACH - AUGUST<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 0% | N/A | 48% | 55% | 20% | 25% | 19% |
| 0.95 | 0% | N/A | 50% | 75% | 35% | 48% | 52% |
| 0.90 | 1% | N/A | 51% | 77% | 44% | 65% | 74% |
| 0.85 | 5% | N/A | 54% | 78% | 53% | 75% | 76% |
| 0.80 | 13% | N/A | 58% | 80% | 61% | 84% | 78% |
| 0.75 | 18% | N/A | 61% | 82% | 65% | 88% | 80% |
| 0.70 | 23% | N/A | 63% | 84% | 72% | 92% | 83% |
| 0.65 | 30% | N/A | 66% | 86% | 75% | 94% | 87% |
| 0.60 | 38% | N/A | 70% | 87% | 79% | 96% | 89% |
| 0.55 | 42% | N/A | 72% | 90% | 82% | 97% | 92% |
| 0.50 | 47% | N/A | 74% | 91% | 83% | 97% | 95% |
| 0.45 | 54% | N/A | 79% | 92% | 84% | 98% | 97% |
| 0.40 | 62% | N/A | 82% | 93% | 85% | 98% | 98% |
| 0.35 | 69% | N/A | 86% | 95% | 87% | 98% | 98% |
| 0.30 | 74% | N/A | 89% | 96% | 90% | 99% | 98% |
| 0.25 | 79% | N/A | 92% | 98% | 91% | 99% | 98% |
| 0.20 | 85% | N/A | 94% | 99% | 93% | 99% | 98% |
| 0.15 | 89% | N/A | 95% | 99% | 96% | 99% | 99% |
| 0.10 | 93% | N/A | 97% | 100% | 97% | 100% | 99% |
| 0.05 | 97% | N/A | 99% | 100% | 98% | 100% | 100% |
| 0.01 | 99% | N/A | 99% | 100% | 99% | 100% | 100% |

**Table E21** Percentage of maximum available habitat at each percent exceedence level in September at the Bastrop Reach

| BASTROP REACH - SEPTEMBER<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 0% | N/A | 49% | 54% | 19% | 24% | 17% |
| 0.95 | 2% | N/A | 52% | 65% | 25% | 34% | 31% |
| 0.90 | 9% | N/A | 56% | 76% | 34% | 48% | 52% |
| 0.85 | 14% | N/A | 59% | 78% | 40% | 59% | 69% |
| 0.80 | 19% | N/A | 61% | 81% | 49% | 71% | 77% |
| 0.75 | 25% | N/A | 64% | 82% | 56% | 79% | 81% |
| 0.70 | 31% | N/A | 67% | 84% | 64% | 87% | 84% |
| 0.65 | 36% | N/A | 69% | 85% | 68% | 90% | 86% |
| 0.60 | 43% | N/A | 72% | 87% | 72% | 93% | 88% |
| 0.55 | 51% | N/A | 76% | 89% | 76% | 95% | 91% |
| 0.50 | 58% | N/A | 80% | 91% | 79% | 97% | 94% |
| 0.45 | 66% | N/A | 84% | 92% | 82% | 98% | 96% |
| 0.40 | 71% | N/A | 87% | 93% | 83% | 98% | 97% |
| 0.35 | 75% | N/A | 89% | 95% | 85% | 98% | 98% |
| 0.30 | 79% | N/A | 91% | 96% | 87% | 99% | 98% |
| 0.25 | 83% | N/A | 93% | 98% | 88% | 99% | 98% |
| 0.20 | 87% | N/A | 95% | 99% | 90% | 99% | 99% |
| 0.15 | 91% | N/A | 95% | 99% | 92% | 100% | 99% |
| 0.10 | 94% | N/A | 97% | 100% | 93% | 100% | 99% |
| 0.05 | 97% | N/A | 99% | 100% | 96% | 100% | 100% |
| 0.01 | 99% | N/A | 99% | 100% | 97% | 100% | 100% |

**Table E22** Percentage of maximum available habitat at each percent exceedence level in October at the Bastrop Reach.

| BASTROP REACH - OCTOBER<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 0% | N/A | 49% | 52% | 18% | 23% | 16% |
| 0.95 | 5% | N/A | 54% | 63% | 24% | 32% | 29% |
| 0.90 | 11% | N/A | 57% | 73% | 32% | 43% | 44% |
| 0.85 | 15% | N/A | 59% | 79% | 42% | 60% | 71% |
| 0.80 | 20% | N/A | 62% | 81% | 52% | 74% | 79% |
| 0.75 | 25% | N/A | 64% | 83% | 60% | 83% | 82% |
| 0.70 | 33% | N/A | 68% | 84% | 68% | 90% | 85% |
| 0.65 | 39% | N/A | 70% | 86% | 73% | 93% | 88% |
| 0.60 | 44% | N/A | 73% | 87% | 77% | 95% | 90% |
| 0.55 | 50% | N/A | 76% | 90% | 80% | 97% | 92% |
| 0.50 | 54% | N/A | 79% | 92% | 82% | 97% | 94% |
| 0.45 | 59% | N/A | 81% | 93% | 83% | 98% | 97% |
| 0.40 | 65% | N/A | 83% | 94% | 84% | 98% | 98% |
| 0.35 | 70% | N/A | 87% | 95% | 86% | 98% | 98% |
| 0.30 | 75% | N/A | 88% | 96% | 87% | 99% | 98% |
| 0.25 | 79% | N/A | 91% | 97% | 89% | 99% | 98% |
| 0.20 | 83% | N/A | 92% | 98% | 91% | 99% | 99% |
| 0.15 | 88% | N/A | 95% | 99% | 93% | 99% | 99% |
| 0.10 | 93% | N/A | 96% | 99% | 94% | 100% | 99% |
| 0.05 | 96% | N/A | 99% | 100% | 96% | 100% | 100% |
| 0.01 | 99% | N/A | 100% | 100% | 97% | 100% | 100% |

**Table E23** Percentage of maximum available habitat at each percent exceedence level in November at the Bastrop Reach.

| BASTROP REACH - NOVEMBER<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 3% | N/A | 53% | 53% | 18% | 23% | 16% |
| 0.95 | 12% | N/A | 57% | 66% | 27% | 35% | 33% |
| 0.90 | 15% | N/A | 59% | 78% | 37% | 50% | 56% |
| 0.85 | 20% | N/A | 62% | 82% | 50% | 71% | 80% |
| 0.80 | 25% | N/A | 64% | 84% | 58% | 81% | 84% |
| 0.75 | 30% | N/A | 67% | 85% | 64% | 86% | 88% |
| 0.70 | 37% | N/A | 69% | 87% | 68% | 89% | 89% |
| 0.65 | 40% | N/A | 71% | 89% | 73% | 93% | 92% |
| 0.60 | 43% | N/A | 73% | 90% | 77% | 95% | 94% |
| 0.55 | 49% | N/A | 75% | 92% | 80% | 97% | 96% |
| 0.50 | 54% | N/A | 78% | 92% | 82% | 98% | 97% |
| 0.45 | 60% | N/A | 81% | 93% | 84% | 98% | 98% |
| 0.40 | 66% | N/A | 84% | 95% | 85% | 98% | 98% |
| 0.35 | 72% | N/A | 88% | 96% | 86% | 99% | 98% |
| 0.30 | 76% | N/A | 90% | 97% | 87% | 99% | 98% |
| 0.25 | 81% | N/A | 92% | 98% | 88% | 99% | 98% |
| 0.20 | 85% | N/A | 94% | 99% | 90% | 99% | 99% |
| 0.15 | 88% | N/A | 96% | 99% | 92% | 100% | 99% |
| 0.10 | 91% | N/A | 97% | 100% | 93% | 100% | 99% |
| 0.05 | 96% | N/A | 99% | 100% | 94% | 100% | 100% |
| 0.01 | 98% | N/A | 99% | 100% | 95% | 100% | 100% |

**Table E24** Percentage of maximum available habitat at each percent exceedence level in December at the Bastrop Reach.

| BASTROP REACH - DECEMBER<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 0% | N/A | 50% | 53% | 19% | 24% | 17% |
| 0.95 | 13% | N/A | 58% | 67% | 27% | 36% | 35% |
| 0.90 | 20% | N/A | 61% | 77% | 36% | 50% | 56% |
| 0.85 | 23% | N/A | 63% | 83% | 43% | 64% | 74% |
| 0.80 | 29% | N/A | 66% | 85% | 56% | 79% | 83% |
| 0.75 | 32% | N/A | 67% | 86% | 64% | 86% | 88% |
| 0.70 | 36% | N/A | 69% | 87% | 69% | 90% | 91% |
| 0.65 | 42% | N/A | 72% | 89% | 74% | 94% | 93% |
| 0.60 | 46% | N/A | 74% | 90% | 77% | 95% | 95% |
| 0.55 | 52% | N/A | 77% | 91% | 79% | 97% | 97% |
| 0.50 | 57% | N/A | 80% | 92% | 80% | 97% | 97% |
| 0.45 | 61% | N/A | 82% | 93% | 82% | 98% | 98% |
| 0.40 | 66% | N/A | 85% | 95% | 84% | 98% | 98% |
| 0.35 | 70% | N/A | 87% | 96% | 84% | 99% | 98% |
| 0.30 | 76% | N/A | 89% | 97% | 86% | 99% | 98% |
| 0.25 | 80% | N/A | 91% | 98% | 87% | 99% | 98% |
| 0.20 | 84% | N/A | 94% | 98% | 88% | 99% | 99% |
| 0.15 | 87% | N/A | 95% | 99% | 90% | 100% | 99% |
| 0.10 | 92% | N/A | 96% | 100% | 91% | 100% | 99% |
| 0.05 | 97% | N/A | 98% | 100% | 93% | 100% | 100% |
| 0.01 | 99% | N/A | 99% | 100% | 94% | 100% | 100% |

**Table E25** Percentage of maximum available habitat at each percent exceedence level in January at the Smithville Reach.

| SMITHVILLE REACH - JANUARY<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 7% | N/A | 56% | 43% | 8% | 12% | 4% |
| 0.95 | 9% | N/A | 57% | 72% | 21% | 34% | 22% |
| 0.90 | 15% | N/A | 60% | 81% | 30% | 46% | 37% |
| 0.85 | 17% | N/A | 61% | 84% | 40% | 56% | 48% |
| 0.80 | 19% | N/A | 62% | 85% | 50% | 64% | 59% |
| 0.75 | 21% | N/A | 63% | 87% | 58% | 71% | 70% |
| 0.70 | 24% | N/A | 64% | 88% | 70% | 81% | 79% |
| 0.65 | 26% | N/A | 64% | 89% | 78% | 88% | 82% |
| 0.60 | 30% | N/A | 67% | 90% | 83% | 93% | 86% |
| 0.55 | 35% | N/A | 69% | 91% | 85% | 94% | 88% |
| 0.50 | 44% | N/A | 73% | 91% | 87% | 96% | 90% |
| 0.45 | 49% | N/A | 76% | 93% | 90% | 97% | 93% |
| 0.40 | 53% | N/A | 78% | 94% | 92% | 98% | 94% |
| 0.35 | 63% | N/A | 82% | 94% | 94% | 99% | 96% |
| 0.30 | 72% | N/A | 86% | 96% | 95% | 99% | 97% |
| 0.25 | 83% | N/A | 92% | 97% | 96% | 99% | 97% |
| 0.20 | 90% | N/A | 95% | 98% | 96% | 99% | 98% |
| 0.15 | 95% | N/A | 97% | 98% | 97% | 100% | 99% |
| 0.10 | 97% | N/A | 98% | 99% | 97% | 100% | 99% |
| 0.05 | 99% | N/A | 99% | 100% | 98% | 100% | 100% |
| 0.01 | 99% | N/A | 99% | 100% | 99% | 100% | 100% |

**Table E26** Percentage of maximum available habitat at each percent exceedence level in February at the Smithville Reach.

| SMITHVILLE REACH - FEBRUARY<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 3% | 7% | 54% | 45% | 9% | 13% | 5% |
| 0.95 | 9% | 17% | 57% | 59% | 14% | 23% | 12% |
| 0.90 | 12% | 34% | 59% | 75% | 24% | 38% | 28% |
| 0.85 | 15% | 56% | 60% | 82% | 42% | 58% | 51% |
| 0.80 | 19% | 69% | 62% | 85% | 51% | 66% | 61% |
| 0.75 | 22% | 73% | 63% | 86% | 59% | 73% | 70% |
| 0.70 | 26% | 78% | 65% | 87% | 68% | 81% | 78% |
| 0.65 | 31% | 81% | 67% | 89% | 77% | 89% | 82% |
| 0.60 | 37% | 83% | 70% | 91% | 80% | 92% | 84% |
| 0.55 | 42% | 88% | 73% | 92% | 83% | 94% | 88% |
| 0.50 | 46% | 88% | 75% | 93% | 84% | 95% | 91% |
| 0.45 | 51% | 91% | 77% | 94% | 86% | 96% | 93% |
| 0.40 | 55% | 94% | 79% | 95% | 88% | 97% | 95% |
| 0.35 | 61% | 96% | 82% | 96% | 90% | 98% | 96% |
| 0.30 | 71% | 97% | 85% | 97% | 92% | 98% | 97% |
| 0.25 | 81% | 98% | 89% | 97% | 93% | 99% | 98% |
| 0.20 | 86% | 99% | 92% | 98% | 94% | 99% | 99% |
| 0.15 | 92% | 100% | 96% | 99% | 95% | 99% | 99% |
| 0.10 | 94% | 100% | 98% | 99% | 96% | 100% | 100% |
| 0.05 | 98% | 100% | 99% | 100% | 97% | 100% | 100% |
| 0.01 | 99% | 100% | 99% | 100% | 97% | 100% | 100% |

**Table E27** Percentage of maximum available habitat at each percent exceedence level in March at the Smithville Reach.

| SMITHVILLE REACH - MARCH<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 2% | 5% | 54% | 41% | 7% | 10% | 4% |
| 0.95 | 6% | 23% | 56% | 66% | 17% | 28% | 16% |
| 0.90 | 9% | 40% | 57% | 78% | 27% | 43% | 33% |
| 0.85 | 12% | 50% | 59% | 82% | 34% | 51% | 43% |
| 0.80 | 15% | 66% | 60% | 83% | 47% | 62% | 58% |
| 0.75 | 19% | 71% | 62% | 84% | 61% | 74% | 71% |
| 0.70 | 24% | 74% | 64% | 86% | 67% | 79% | 76% |
| 0.65 | 31% | 77% | 67% | 87% | 71% | 83% | 79% |
| 0.60 | 37% | 81% | 70% | 89% | 77% | 88% | 82% |
| 0.55 | 43% | 84% | 73% | 91% | 81% | 92% | 84% |
| 0.50 | 50% | 88% | 76% | 92% | 83% | 93% | 87% |
| 0.45 | 55% | 89% | 79% | 93% | 86% | 96% | 88% |
| 0.40 | 64% | 92% | 83% | 95% | 89% | 97% | 92% |
| 0.35 | 69% | 94% | 86% | 96% | 91% | 97% | 93% |
| 0.30 | 76% | 95% | 89% | 97% | 94% | 98% | 95% |
| 0.25 | 81% | 97% | 91% | 98% | 95% | 98% | 97% |
| 0.20 | 88% | 98% | 94% | 99% | 96% | 99% | 98% |
| 0.15 | 94% | 99% | 97% | 99% | 97% | 99% | 99% |
| 0.10 | 97% | 100% | 97% | 100% | 97% | 100% | 100% |
| 0.05 | 99% | 100% | 99% | 100% | 98% | 100% | 100% |
| 0.01 | 99% | 100% | 99% | 100% | 98% | 100% | 100% |

**Table E28** Percentage of maximum available habitat at each percent exceedence level in April at the Smithville Reach.

| SMITHVILLE REACH - APRIL<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 0% | 4% | 52% | 37% | 6% | 8% | 3% |
| 0.95 | 7% | 14% | 56% | 55% | 12% | 19% | 9% |
| 0.90 | 10% | 25% | 57% | 68% | 19% | 30% | 18% |
| 0.85 | 14% | 42% | 60% | 79% | 29% | 45% | 35% |
| 0.80 | 16% | 54% | 61% | 82% | 38% | 54% | 46% |
| 0.75 | 22% | 64% | 63% | 84% | 47% | 62% | 58% |
| 0.70 | 29% | 70% | 66% | 85% | 53% | 67% | 63% |
| 0.65 | 37% | 73% | 70% | 87% | 58% | 71% | 69% |
| 0.60 | 49% | 75% | 74% | 88% | 63% | 76% | 74% |
| 0.55 | 56% | 78% | 78% | 90% | 69% | 81% | 77% |
| 0.50 | 64% | 81% | 82% | 91% | 76% | 88% | 80% |
| 0.45 | 69% | 83% | 84% | 93% | 80% | 90% | 83% |
| 0.40 | 77% | 86% | 88% | 94% | 84% | 94% | 86% |
| 0.35 | 82% | 89% | 91% | 95% | 89% | 96% | 88% |
| 0.30 | 86% | 92% | 93% | 97% | 92% | 97% | 92% |
| 0.25 | 89% | 94% | 95% | 98% | 95% | 98% | 93% |
| 0.20 | 93% | 96% | 97% | 98% | 96% | 98% | 96% |
| 0.15 | 95% | 98% | 97% | 99% | 97% | 99% | 98% |
| 0.10 | 98% | 100% | 99% | 100% | 97% | 99% | 98% |
| 0.05 | 99% | 100% | 99% | 100% | 98% | 100% | 100% |
| 0.01 | 100% | 100% | 99% | 100% | 99% | 100% | 100% |

**Table E29** Percentage of maximum available habitat at each percent exceedence level in May at the Smithville Reach.

| SMITHVILLE REACH - MAY<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 9% | N/A | 57% | 33% | 5% | 6% | 3% |
| 0.95 | 15% | N/A | 60% | 41% | 7% | 10% | 4% |
| 0.90 | 28% | N/A | 63% | 52% | 11% | 17% | 7% |
| 0.85 | 37% | N/A | 68% | 60% | 15% | 24% | 13% |
| 0.80 | 46% | N/A | 72% | 68% | 19% | 30% | 19% |
| 0.75 | 51% | N/A | 75% | 77% | 25% | 39% | 29% |
| 0.70 | 57% | N/A | 77% | 83% | 31% | 47% | 39% |
| 0.65 | 61% | N/A | 80% | 86% | 39% | 55% | 47% |
| 0.60 | 65% | N/A | 83% | 88% | 47% | 61% | 57% |
| 0.55 | 70% | N/A | 85% | 91% | 52% | 66% | 61% |
| 0.50 | 76% | N/A | 86% | 93% | 59% | 72% | 71% |
| 0.45 | 81% | N/A | 89% | 94% | 66% | 78% | 78% |
| 0.40 | 84% | N/A | 91% | 95% | 71% | 83% | 84% |
| 0.35 | 87% | N/A | 93% | 97% | 76% | 87% | 87% |
| 0.30 | 91% | N/A | 95% | 98% | 80% | 90% | 90% |
| 0.25 | 93% | N/A | 96% | 98% | 82% | 92% | 93% |
| 0.20 | 95% | N/A | 97% | 99% | 86% | 95% | 96% |
| 0.15 | 97% | N/A | 97% | 100% | 90% | 98% | 97% |
| 0.10 | 99% | N/A | 99% | 100% | 93% | 99% | 99% |
| 0.05 | 99% | N/A | 99% | 100% | 97% | 99% | 100% |
| 0.01 | 100% | N/A | 99% | 100% | 97% | 100% | 100% |

**Table E30** Percentage of maximum available habitat at each percent exceedence level in June at the Smithville Reach.

| SMITHVILLE REACH - JUNE<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 1% | N/A | 53% | 33% | 5% | 6% | 3% |
| 0.95 | 8% | N/A | 57% | 44% | 8% | 12% | 4% |
| 0.90 | 15% | N/A | 60% | 57% | 13% | 21% | 10% |
| 0.85 | 22% | N/A | 62% | 67% | 18% | 29% | 17% |
| 0.80 | 29% | N/A | 65% | 75% | 23% | 37% | 26% |
| 0.75 | 37% | N/A | 69% | 80% | 30% | 46% | 37% |
| 0.70 | 45% | N/A | 73% | 83% | 36% | 53% | 45% |
| 0.65 | 52% | N/A | 76% | 85% | 44% | 60% | 54% |
| 0.60 | 58% | N/A | 78% | 87% | 49% | 64% | 59% |
| 0.55 | 66% | N/A | 82% | 89% | 54% | 68% | 65% |
| 0.50 | 74% | N/A | 85% | 91% | 63% | 76% | 72% |
| 0.45 | 79% | N/A | 89% | 93% | 68% | 81% | 77% |
| 0.40 | 83% | N/A | 91% | 94% | 75% | 87% | 81% |
| 0.35 | 88% | N/A | 93% | 95% | 81% | 92% | 85% |
| 0.30 | 91% | N/A | 95% | 96% | 85% | 95% | 89% |
| 0.25 | 94% | N/A | 96% | 97% | 88% | 96% | 93% |
| 0.20 | 95% | N/A | 97% | 98% | 92% | 97% | 96% |
| 0.15 | 97% | N/A | 98% | 99% | 94% | 99% | 98% |
| 0.10 | 99% | N/A | 99% | 99% | 96% | 99% | 99% |
| 0.05 | 99% | N/A | 99% | 100% | 97% | 100% | 100% |
| 0.01 | 100% | N/A | 99% | 100% | 98% | 100% | 100% |

**Table E31** Percentage of maximum available habitat at each percent exceedence level in July at the Smithville Reach.

| SMITHVILLE REACH - JULY<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 0% | N/A | 52% | 35% | 5% | 7% | 3% |
| 0.95 | 2% | N/A | 54% | 49% | 10% | 15% | 6% |
| 0.90 | 7% | N/A | 56% | 68% | 18% | 30% | 18% |
| 0.85 | 15% | N/A | 60% | 78% | 30% | 46% | 37% |
| 0.80 | 22% | N/A | 63% | 81% | 44% | 59% | 54% |
| 0.75 | 29% | N/A | 65% | 83% | 51% | 66% | 62% |
| 0.70 | 36% | N/A | 68% | 86% | 60% | 74% | 69% |
| 0.65 | 42% | N/A | 71% | 88% | 66% | 79% | 73% |
| 0.60 | 48% | N/A | 74% | 91% | 70% | 83% | 76% |
| 0.55 | 53% | N/A | 76% | 92% | 74% | 86% | 80% |
| 0.50 | 57% | N/A | 79% | 94% | 78% | 90% | 83% |
| 0.45 | 63% | N/A | 82% | 95% | 81% | 93% | 87% |
| 0.40 | 69% | N/A | 85% | 96% | 83% | 95% | 89% |
| 0.35 | 74% | N/A | 88% | 97% | 86% | 96% | 92% |
| 0.30 | 78% | N/A | 90% | 98% | 88% | 96% | 95% |
| 0.25 | 83% | N/A | 92% | 99% | 91% | 97% | 97% |
| 0.20 | 88% | N/A | 94% | 99% | 94% | 98% | 98% |
| 0.15 | 93% | N/A | 96% | 100% | 95% | 99% | 99% |
| 0.10 | 96% | N/A | 97% | 100% | 97% | 99% | 99% |
| 0.05 | 99% | N/A | 99% | 100% | 98% | 100% | 100% |
| 0.01 | 99% | N/A | 99% | 100% | 99% | 100% | 100% |

**Table E32** Percentage of maximum available habitat at each percent exceedence level in August at the Smithville Reach.

| SMITHVILLE REACH - AUGUST<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 0% | N/A | 49% | 40% | 7% | 9% | 3% |
| 0.95 | 0% | N/A | 50% | 72% | 21% | 34% | 22% |
| 0.90 | 0% | N/A | 51% | 76% | 33% | 51% | 43% |
| 0.85 | 2% | N/A | 54% | 77% | 49% | 64% | 59% |
| 0.80 | 8% | N/A | 57% | 79% | 60% | 74% | 63% |
| 0.75 | 11% | N/A | 58% | 81% | 65% | 78% | 66% |
| 0.70 | 15% | N/A | 60% | 84% | 73% | 85% | 70% |
| 0.65 | 19% | N/A | 62% | 85% | 78% | 90% | 72% |
| 0.60 | 26% | N/A | 64% | 87% | 82% | 94% | 77% |
| 0.55 | 29% | N/A | 66% | 89% | 86% | 94% | 80% |
| 0.50 | 33% | N/A | 68% | 91% | 89% | 95% | 83% |
| 0.45 | 40% | N/A | 72% | 92% | 91% | 96% | 86% |
| 0.40 | 50% | N/A | 76% | 93% | 92% | 96% | 89% |
| 0.35 | 60% | N/A | 81% | 94% | 94% | 97% | 92% |
| 0.30 | 67% | N/A | 84% | 96% | 95% | 98% | 94% |
| 0.25 | 77% | N/A | 89% | 97% | 96% | 98% | 96% |
| 0.20 | 82% | N/A | 92% | 98% | 97% | 99% | 98% |
| 0.15 | 88% | N/A | 95% | 99% | 98% | 99% | 98% |
| 0.10 | 95% | N/A | 97% | 100% | 99% | 100% | 99% |
| 0.05 | 98% | N/A | 99% | 100% | 99% | 100% | 100% |
| 0.01 | 99% | N/A | 99% | 100% | 100% | 100% | 100% |

**Table E33** Percentage of maximum available habitat at each percent exceedence level in September at the Smithville Reach.

| SMITHVILLE REACH - SEPTEMBER<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 0% | N/A | 50% | 37% | 6% | 8% | 3% |
| 0.95 | 0% | N/A | 52% | 53% | 11% | 18% | 8% |
| 0.90 | 4% | N/A | 55% | 72% | 21% | 34% | 22% |
| 0.85 | 8% | N/A | 57% | 77% | 29% | 45% | 36% |
| 0.80 | 12% | N/A | 59% | 79% | 43% | 59% | 53% |
| 0.75 | 16% | N/A | 61% | 81% | 53% | 68% | 63% |
| 0.70 | 20% | N/A | 62% | 83% | 63% | 77% | 68% |
| 0.65 | 24% | N/A | 64% | 85% | 69% | 82% | 72% |
| 0.60 | 30% | N/A | 66% | 87% | 74% | 87% | 76% |
| 0.55 | 36% | N/A | 69% | 88% | 79% | 92% | 79% |
| 0.50 | 46% | N/A | 73% | 90% | 84% | 94% | 82% |
| 0.45 | 55% | N/A | 78% | 91% | 88% | 95% | 85% |
| 0.40 | 63% | N/A | 81% | 92% | 90% | 96% | 88% |
| 0.35 | 69% | N/A | 85% | 94% | 92% | 97% | 90% |
| 0.30 | 76% | N/A | 88% | 96% | 94% | 98% | 93% |
| 0.25 | 81% | N/A | 91% | 97% | 94% | 98% | 95% |
| 0.20 | 88% | N/A | 93% | 98% | 95% | 99% | 97% |
| 0.15 | 92% | N/A | 96% | 99% | 96% | 99% | 98% |
| 0.10 | 96% | N/A | 97% | 100% | 97% | 100% | 99% |
| 0.05 | 99% | N/A | 99% | 100% | 98% | 100% | 100% |
| 0.01 | 99% | N/A | 99% | 100% | 99% | 100% | 100% |

**Table E34** Percentage of maximum available habitat at each percent exceedence level in October at the Smithville Reach.

| SMITHVILLE REACH - OCTOBER<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 0% | N/A | 50% | 36% | 6% | 7% | 3% |
| 0.95 | 1% | N/A | 53% | 51% | 11% | 16% | 7% |
| 0.90 | 6% | N/A | 56% | 65% | 17% | 27% | 16% |
| 0.85 | 9% | N/A | 57% | 76% | 30% | 46% | 37% |
| 0.80 | 12% | N/A | 59% | 80% | 46% | 62% | 57% |
| 0.75 | 16% | N/A | 60% | 82% | 58% | 72% | 65% |
| 0.70 | 22% | N/A | 63% | 84% | 69% | 81% | 71% |
| 0.65 | 26% | N/A | 65% | 85% | 75% | 87% | 75% |
| 0.60 | 30% | N/A | 67% | 87% | 80% | 92% | 79% |
| 0.55 | 36% | N/A | 70% | 89% | 83% | 94% | 82% |
| 0.50 | 41% | N/A | 72% | 91% | 86% | 96% | 85% |
| 0.45 | 47% | N/A | 74% | 92% | 88% | 96% | 87% |
| 0.40 | 55% | N/A | 77% | 93% | 90% | 97% | 90% |
| 0.35 | 61% | N/A | 81% | 95% | 92% | 97% | 93% |
| 0.30 | 68% | N/A | 84% | 95% | 94% | 98% | 96% |
| 0.25 | 77% | N/A | 87% | 97% | 95% | 98% | 97% |
| 0.20 | 83% | N/A | 91% | 98% | 96% | 99% | 98% |
| 0.15 | 90% | N/A | 94% | 99% | 97% | 99% | 99% |
| 0.10 | 94% | N/A | 97% | 99% | 97% | 99% | 100% |
| 0.05 | 98% | N/A | 99% | 100% | 98% | 100% | 100% |
| 0.01 | 99% | N/A | 99% | 100% | 99% | 100% | 100% |

**Table E35** Percentage of maximum available habitat at each percent exceedence level in November at the Smithville Reach.

| SMITHVILLE REACH - NOVEMBER<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 1% | N/A | 53% | 36% | 6% | 7% | 3% |
| 0.95 | 6% | N/A | 56% | 55% | 12% | 20% | 9% |
| 0.90 | 9% | N/A | 57% | 74% | 23% | 36% | 25% |
| 0.85 | 12% | N/A | 59% | 81% | 43% | 59% | 52% |
| 0.80 | 16% | N/A | 60% | 83% | 56% | 70% | 66% |
| 0.75 | 20% | N/A | 62% | 84% | 63% | 76% | 73% |
| 0.70 | 25% | N/A | 64% | 87% | 68% | 80% | 77% |
| 0.65 | 27% | N/A | 65% | 89% | 74% | 86% | 79% |
| 0.60 | 30% | N/A | 67% | 90% | 80% | 91% | 82% |
| 0.55 | 35% | N/A | 69% | 91% | 84% | 95% | 85% |
| 0.50 | 40% | N/A | 71% | 92% | 87% | 96% | 88% |
| 0.45 | 49% | N/A | 74% | 93% | 89% | 97% | 90% |
| 0.40 | 55% | N/A | 78% | 94% | 91% | 98% | 93% |
| 0.35 | 63% | N/A | 82% | 95% | 92% | 98% | 95% |
| 0.30 | 72% | N/A | 85% | 96% | 93% | 98% | 97% |
| 0.25 | 78% | N/A | 89% | 97% | 94% | 99% | 98% |
| 0.20 | 83% | N/A | 92% | 98% | 95% | 99% | 98% |
| 0.15 | 88% | N/A | 94% | 99% | 96% | 100% | 98% |
| 0.10 | 93% | N/A | 96% | 100% | 97% | 100% | 99% |
| 0.05 | 97% | N/A | 98% | 100% | 97% | 100% | 100% |
| 0.01 | 98% | N/A | 99% | 100% | 98% | 100% | 100% |

**Table E36** Percentage of maximum available habitat at each percent exceedence level in December at the Smithville Reach.

| SMITHVILLE REACH - DECEMBER<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 0% | N/A | 51% | 37% | 6% | 8% | 3% |
| 0.95 | 7% | N/A | 56% | 56% | 13% | 21% | 10% |
| 0.90 | 12% | N/A | 59% | 74% | 23% | 36% | 25% |
| 0.85 | 15% | N/A | 60% | 81% | 33% | 50% | 42% |
| 0.80 | 18% | N/A | 62% | 83% | 53% | 68% | 62% |
| 0.75 | 21% | N/A | 63% | 85% | 63% | 77% | 74% |
| 0.70 | 24% | N/A | 64% | 87% | 69% | 82% | 79% |
| 0.65 | 29% | N/A | 66% | 88% | 77% | 89% | 82% |
| 0.60 | 32% | N/A | 68% | 90% | 80% | 92% | 85% |
| 0.55 | 37% | N/A | 71% | 91% | 83% | 94% | 88% |
| 0.50 | 45% | N/A | 73% | 92% | 85% | 96% | 90% |
| 0.45 | 49% | N/A | 76% | 93% | 88% | 97% | 93% |
| 0.40 | 55% | N/A | 79% | 95% | 90% | 98% | 95% |
| 0.35 | 61% | N/A | 81% | 96% | 91% | 98% | 96% |
| 0.30 | 69% | N/A | 85% | 97% | 93% | 99% | 97% |
| 0.25 | 78% | N/A | 88% | 98% | 94% | 99% | 98% |
| 0.20 | 82% | N/A | 92% | 98% | 94% | 99% | 98% |
| 0.15 | 88% | N/A | 94% | 99% | 95% | 99% | 99% |
| 0.10 | 94% | N/A | 97% | 100% | 96% | 100% | 100% |
| 0.05 | 99% | N/A | 98% | 100% | 97% | 100% | 100% |
| 0.01 | 99% | N/A | 99% | 100% | 97% | 100% | 100% |

**Table E37** Percentage of maximum available habitat at each percent exceedence level in January at the Columbus Reach.

| COLUMBUS REACH - JANUARY<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 13% | N/A | 57% | 61% | 17% | 19% | 15% |
| 0.95 | 16% | N/A | 58% | 72% | 21% | 24% | 16% |
| 0.90 | 18% | N/A | 59% | 78% | 25% | 35% | 20% |
| 0.85 | 24% | N/A | 61% | 81% | 27% | 39% | 22% |
| 0.80 | 29% | N/A | 63% | 86% | 32% | 43% | 24% |
| 0.75 | 33% | N/A | 64% | 89% | 42% | 56% | 41% |
| 0.70 | 42% | N/A | 68% | 89% | 55% | 69% | 65% |
| 0.65 | 46% | N/A | 70% | 90% | 64% | 76% | 78% |
| 0.60 | 55% | N/A | 74% | 92% | 70% | 81% | 85% |
| 0.55 | 58% | N/A | 76% | 92% | 76% | 85% | 89% |
| 0.50 | 62% | N/A | 78% | 93% | 81% | 88% | 92% |
| 0.45 | 66% | N/A | 80% | 95% | 82% | 89% | 94% |
| 0.40 | 72% | N/A | 82% | 96% | 84% | 90% | 96% |
| 0.35 | 78% | N/A | 85% | 96% | 87% | 93% | 97% |
| 0.30 | 83% | N/A | 89% | 98% | 89% | 94% | 97% |
| 0.25 | 88% | N/A | 93% | 98% | 92% | 96% | 98% |
| 0.20 | 92% | N/A | 97% | 99% | 94% | 97% | 99% |
| 0.15 | 95% | N/A | 97% | 100% | 96% | 98% | 99% |
| 0.10 | 97% | N/A | 98% | 100% | 98% | 99% | 100% |
| 0.05 | 99% | N/A | 99% | 100% | 98% | 99% | 100% |
| 0.01 | 99% | N/A | 99% | 100% | 99% | 100% | 100% |

**Table E38** Percentage of maximum available habitat at each percent exceedence level in February at the Columbus Reach.

| COLUMBUS REACH - FEBRUARY<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 12% | 25% | 56% | 59% | 16% | 18% | 14% |
| 0.95 | 19% | 32% | 59% | 66% | 19% | 21% | 15% |
| 0.90 | 25% | 36% | 61% | 72% | 21% | 24% | 16% |
| 0.85 | 31% | 44% | 63% | 79% | 25% | 35% | 20% |
| 0.80 | 37% | 53% | 66% | 85% | 30% | 42% | 24% |
| 0.75 | 45% | 62% | 69% | 89% | 37% | 49% | 32% |
| 0.70 | 51% | 70% | 72% | 90% | 42% | 57% | 43% |
| 0.65 | 55% | 78% | 74% | 91% | 49% | 64% | 55% |
| 0.60 | 58% | 87% | 76% | 92% | 61% | 74% | 75% |
| 0.55 | 62% | 90% | 79% | 93% | 69% | 81% | 85% |
| 0.50 | 66% | 92% | 81% | 94% | 75% | 84% | 88% |
| 0.45 | 72% | 94% | 82% | 95% | 79% | 87% | 91% |
| 0.40 | 75% | 96% | 85% | 96% | 82% | 89% | 94% |
| 0.35 | 80% | 96% | 88% | 97% | 84% | 90% | 96% |
| 0.30 | 84% | 98% | 92% | 98% | 85% | 91% | 97% |
| 0.25 | 89% | 99% | 95% | 98% | 88% | 93% | 98% |
| 0.20 | 94% | 100% | 97% | 99% | 90% | 95% | 99% |
| 0.15 | 97% | 100% | 97% | 100% | 93% | 96% | 99% |
| 0.10 | 98% | 100% | 98% | 100% | 95% | 98% | 100% |
| 0.05 | 99% | 100% | 99% | 100% | 97% | 99% | 100% |
| 0.01 | 100% | 100% | 99% | 100% | 98% | 99% | 100% |

**Table E39** Percentage of maximum available habitat at each percent exceedence level in March at the Columbus Reach.

| COLUMBUS REACH - MARCH<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 5% | 23% | 52% | 58% | 16% | 18% | 13% |
| 0.95 | 12% | 31% | 56% | 66% | 18% | 21% | 15% |
| 0.90 | 20% | 39% | 59% | 74% | 22% | 28% | 17% |
| 0.85 | 25% | 45% | 61% | 79% | 25% | 36% | 20% |
| 0.80 | 32% | 55% | 64% | 84% | 31% | 43% | 24% |
| 0.75 | 41% | 66% | 68% | 87% | 39% | 53% | 37% |
| 0.70 | 51% | 72% | 72% | 89% | 43% | 59% | 46% |
| 0.65 | 57% | 76% | 76% | 91% | 49% | 65% | 57% |
| 0.60 | 63% | 81% | 80% | 92% | 56% | 71% | 69% |
| 0.55 | 68% | 86% | 81% | 93% | 61% | 75% | 76% |
| 0.50 | 72% | 88% | 83% | 94% | 67% | 80% | 83% |
| 0.45 | 76% | 90% | 85% | 95% | 73% | 83% | 87% |
| 0.40 | 81% | 92% | 87% | 96% | 77% | 86% | 89% |
| 0.35 | 85% | 94% | 89% | 97% | 81% | 89% | 93% |
| 0.30 | 88% | 95% | 92% | 98% | 84% | 91% | 95% |
| 0.25 | 91% | 96% | 94% | 99% | 88% | 94% | 97% |
| 0.20 | 94% | 98% | 96% | 99% | 92% | 96% | 98% |
| 0.15 | 97% | 99% | 97% | 100% | 94% | 98% | 99% |
| 0.10 | 98% | 100% | 98% | 100% | 96% | 98% | 99% |
| 0.05 | 99% | 100% | 99% | 100% | 98% | 99% | 100% |
| 0.01 | 99% | 100% | 99% | 100% | 99% | 100% | 100% |

**Table E40** Percentage of maximum available habitat at each percent exceedence level in April at the Columbus Reach.

| COLUMBUS REACH - APRIL<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 10% | 22% | 55% | 57% | 16% | 18% | 13% |
| 0.95 | 12% | 27% | 56% | 61% | 16% | 19% | 15% |
| 0.90 | 16% | 34% | 58% | 70% | 20% | 22% | 15% |
| 0.85 | 22% | 44% | 60% | 78% | 25% | 35% | 20% |
| 0.80 | 34% | 54% | 65% | 85% | 30% | 42% | 24% |
| 0.75 | 42% | 62% | 68% | 88% | 36% | 49% | 31% |
| 0.70 | 51% | 71% | 72% | 88% | 42% | 58% | 44% |
| 0.65 | 58% | 78% | 77% | 89% | 51% | 66% | 59% |
| 0.60 | 61% | 82% | 79% | 91% | 55% | 69% | 65% |
| 0.55 | 65% | 84% | 81% | 92% | 60% | 73% | 73% |
| 0.50 | 69% | 87% | 82% | 94% | 67% | 79% | 83% |
| 0.45 | 74% | 88% | 84% | 95% | 74% | 83% | 88% |
| 0.40 | 80% | 90% | 86% | 96% | 79% | 87% | 90% |
| 0.35 | 84% | 93% | 89% | 97% | 81% | 88% | 93% |
| 0.30 | 88% | 95% | 90% | 98% | 85% | 91% | 95% |
| 0.25 | 91% | 97% | 92% | 99% | 88% | 93% | 96% |
| 0.20 | 93% | 98% | 96% | 99% | 91% | 95% | 97% |
| 0.15 | 96% | 99% | 97% | 100% | 96% | 98% | 99% |
| 0.10 | 98% | 100% | 98% | 100% | 98% | 99% | 100% |
| 0.05 | 99% | 100% | 99% | 100% | 99% | 100% | 100% |
| 0.01 | 100% | 100% | 99% | 100% | 99% | 100% | 100% |

**Table E41** Percentage of maximum available habitat at each percent exceedence level in May at the Columbus Reach.

| COLUMBUS REACH - MAY<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 12% | N/A | 56% | 57% | 16% | 18% | 13% |
| 0.95 | 24% | N/A | 61% | 61% | 17% | 19% | 15% |
| 0.90 | 48% | N/A | 70% | 67% | 19% | 21% | 15% |
| 0.85 | 57% | N/A | 76% | 72% | 21% | 24% | 16% |
| 0.80 | 61% | N/A | 78% | 77% | 24% | 32% | 19% |
| 0.75 | 63% | N/A | 80% | 81% | 27% | 39% | 22% |
| 0.70 | 66% | N/A | 81% | 87% | 33% | 44% | 25% |
| 0.65 | 70% | N/A | 82% | 88% | 35% | 46% | 28% |
| 0.60 | 75% | N/A | 84% | 90% | 39% | 52% | 36% |
| 0.55 | 78% | N/A | 86% | 92% | 46% | 60% | 49% |
| 0.50 | 81% | N/A | 88% | 94% | 51% | 66% | 58% |
| 0.45 | 84% | N/A | 89% | 96% | 57% | 71% | 69% |
| 0.40 | 87% | N/A | 91% | 97% | 62% | 74% | 75% |
| 0.35 | 90% | N/A | 94% | 98% | 66% | 78% | 81% |
| 0.30 | 92% | N/A | 96% | 99% | 72% | 82% | 86% |
| 0.25 | 95% | N/A | 97% | 99% | 76% | 84% | 88% |
| 0.20 | 97% | N/A | 98% | 100% | 81% | 87% | 92% |
| 0.15 | 98% | N/A | 98% | 100% | 83% | 89% | 95% |
| 0.10 | 99% | N/A | 99% | 100% | 87% | 92% | 97% |
| 0.05 | 100% | N/A | 99% | 100% | 97% | 98% | 99% |
| 0.01 | 100% | N/A | 100% | 100% | 99% | 100% | 100% |

**Table E42** Percentage of maximum available habitat at each percent exceedence level in June at the Columbus Reach.

| COLUMBUS REACH - JUNE<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 18% | N/A | 58% | 58% | 16% | 18% | 13% |
| 0.95 | 33% | N/A | 64% | 62% | 17% | 19% | 15% |
| 0.90 | 49% | N/A | 71% | 70% | 20% | 22% | 15% |
| 0.85 | 55% | N/A | 74% | 75% | 23% | 28% | 18% |
| 0.80 | 60% | N/A | 78% | 78% | 26% | 35% | 20% |
| 0.75 | 64% | N/A | 81% | 82% | 28% | 40% | 22% |
| 0.70 | 69% | N/A | 83% | 86% | 32% | 43% | 24% |
| 0.65 | 74% | N/A | 85% | 89% | 34% | 45% | 25% |
| 0.60 | 79% | N/A | 86% | 91% | 39% | 52% | 35% |
| 0.55 | 83% | N/A | 88% | 92% | 43% | 58% | 43% |
| 0.50 | 86% | N/A | 90% | 94% | 47% | 62% | 51% |
| 0.45 | 89% | N/A | 92% | 95% | 52% | 66% | 59% |
| 0.40 | 91% | N/A | 93% | 96% | 56% | 70% | 67% |
| 0.35 | 93% | N/A | 96% | 97% | 62% | 75% | 75% |
| 0.30 | 95% | N/A | 97% | 98% | 68% | 79% | 82% |
| 0.25 | 96% | N/A | 97% | 98% | 75% | 84% | 88% |
| 0.20 | 97% | N/A | 98% | 99% | 81% | 88% | 92% |
| 0.15 | 98% | N/A | 98% | 100% | 85% | 90% | 97% |
| 0.10 | 99% | N/A | 99% | 100% | 87% | 92% | 99% |
| 0.05 | 100% | N/A | 99% | 100% | 94% | 96% | 100% |
| 0.01 | 100% | N/A | 100% | 100% | 97% | 98% | 100% |

**Table E43** Percentage of maximum available habitat at each percent exceedence level in July at the Columbus Reach.

| COLUMBUS REACH - JULY<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 6% | N/A | 52% | 59% | 16% | 18% | 14% |
| 0.95 | 16% | N/A | 58% | 70% | 20% | 22% | 15% |
| 0.90 | 23% | N/A | 60% | 82% | 27% | 40% | 22% |
| 0.85 | 29% | N/A | 63% | 88% | 36% | 50% | 32% |
| 0.80 | 36% | N/A | 65% | 89% | 42% | 58% | 44% |
| 0.75 | 43% | N/A | 68% | 91% | 50% | 66% | 58% |
| 0.70 | 49% | N/A | 71% | 92% | 55% | 70% | 67% |
| 0.65 | 55% | N/A | 74% | 93% | 61% | 75% | 76% |
| 0.60 | 58% | N/A | 76% | 94% | 66% | 79% | 82% |
| 0.55 | 59% | N/A | 77% | 95% | 73% | 83% | 87% |
| 0.50 | 65% | N/A | 80% | 96% | 77% | 86% | 89% |
| 0.45 | 69% | N/A | 81% | 97% | 80% | 88% | 91% |
| 0.40 | 73% | N/A | 83% | 97% | 81% | 89% | 94% |
| 0.35 | 79% | N/A | 85% | 98% | 82% | 90% | 96% |
| 0.30 | 84% | N/A | 87% | 98% | 85% | 92% | 97% |
| 0.25 | 88% | N/A | 89% | 99% | 87% | 93% | 98% |
| 0.20 | 92% | N/A | 92% | 100% | 90% | 95% | 99% |
| 0.15 | 95% | N/A | 96% | 100% | 93% | 97% | 99% |
| 0.10 | 97% | N/A | 97% | 100% | 95% | 98% | 100% |
| 0.05 | 99% | N/A | 98% | 100% | 97% | 99% | 100% |
| 0.01 | 99% | N/A | 99% | 100% | 98% | 100% | 100% |

**Table E44** Percentage of maximum available habitat at each percent exceedence level in August at the Columbus Reach.

| COLUMBUS REACH - AUGUST<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 1% | N/A | 47% | 62% | 16% | 19% | 15% |
| 0.95 | 1% | N/A | 48% | 77% | 24% | 34% | 20% |
| 0.90 | 6% | N/A | 52% | 79% | 32% | 45% | 25% |
| 0.85 | 10% | N/A | 55% | 81% | 49% | 65% | 58% |
| 0.80 | 13% | N/A | 57% | 84% | 58% | 73% | 73% |
| 0.75 | 15% | N/A | 57% | 87% | 67% | 80% | 80% |
| 0.70 | 21% | N/A | 60% | 88% | 75% | 85% | 83% |
| 0.65 | 26% | N/A | 62% | 89% | 80% | 89% | 86% |
| 0.60 | 31% | N/A | 64% | 90% | 81% | 90% | 89% |
| 0.55 | 38% | N/A | 66% | 92% | 83% | 91% | 92% |
| 0.50 | 44% | N/A | 69% | 92% | 86% | 93% | 94% |
| 0.45 | 51% | N/A | 72% | 93% | 88% | 95% | 95% |
| 0.40 | 55% | N/A | 74% | 94% | 90% | 96% | 96% |
| 0.35 | 59% | N/A | 76% | 95% | 92% | 97% | 97% |
| 0.30 | 66% | N/A | 80% | 97% | 94% | 98% | 98% |
| 0.25 | 73% | N/A | 83% | 98% | 96% | 98% | 99% |
| 0.20 | 81% | N/A | 86% | 98% | 96% | 99% | 99% |
| 0.15 | 88% | N/A | 90% | 99% | 97% | 99% | 99% |
| 0.10 | 94% | N/A | 96% | 100% | 98% | 100% | 100% |
| 0.05 | 98% | N/A | 98% | 100% | 99% | 100% | 100% |
| 0.01 | 99% | N/A | 99% | 100% | 100% | 100% | 100% |

**Table E45** Percentage of maximum available habitat at each percent exceedence level in September at the Columbus Reach.

| COLUMBUS REACH - SEPTEMBER<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 4% | N/A | 51% | 59% | 16% | 18% | 14% |
| 0.95 | 10% | N/A | 55% | 71% | 20% | 23% | 16% |
| 0.90 | 14% | N/A | 57% | 79% | 25% | 37% | 21% |
| 0.85 | 19% | N/A | 59% | 82% | 32% | 44% | 25% |
| 0.80 | 22% | N/A | 60% | 87% | 41% | 57% | 42% |
| 0.75 | 25% | N/A | 61% | 88% | 50% | 66% | 60% |
| 0.70 | 30% | N/A | 63% | 89% | 59% | 74% | 74% |
| 0.65 | 33% | N/A | 64% | 90% | 66% | 80% | 82% |
| 0.60 | 39% | N/A | 67% | 91% | 74% | 85% | 88% |
| 0.55 | 47% | N/A | 70% | 92% | 78% | 88% | 91% |
| 0.50 | 55% | N/A | 74% | 93% | 81% | 90% | 93% |
| 0.45 | 61% | N/A | 78% | 93% | 84% | 92% | 96% |
| 0.40 | 65% | N/A | 80% | 94% | 87% | 94% | 97% |
| 0.35 | 71% | N/A | 83% | 95% | 90% | 96% | 97% |
| 0.30 | 79% | N/A | 85% | 96% | 91% | 96% | 98% |
| 0.25 | 85% | N/A | 88% | 98% | 93% | 98% | 99% |
| 0.20 | 90% | N/A | 92% | 99% | 94% | 98% | 99% |
| 0.15 | 94% | N/A | 96% | 99% | 95% | 99% | 100% |
| 0.10 | 97% | N/A | 97% | 100% | 96% | 99% | 100% |
| 0.05 | 99% | N/A | 99% | 100% | 97% | 100% | 100% |
| 0.01 | 99% | N/A | 99% | 100% | 98% | 100% | 100% |

**Table E46** Percentage of maximum available habitat at each percent exceedence level in October at the Columbus Reach.

| COLUMBUS REACH - OCTOBER<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 2% | N/A | 49% | 58% | 16% | 18% | 14% |
| 0.95 | 4% | N/A | 51% | 66% | 18% | 21% | 15% |
| 0.90 | 9% | N/A | 55% | 77% | 24% | 32% | 19% |
| 0.85 | 12% | N/A | 56% | 81% | 30% | 42% | 24% |
| 0.80 | 17% | N/A | 58% | 83% | 39% | 53% | 38% |
| 0.75 | 21% | N/A | 60% | 86% | 47% | 64% | 54% |
| 0.70 | 30% | N/A | 63% | 87% | 57% | 72% | 71% |
| 0.65 | 40% | N/A | 67% | 89% | 64% | 78% | 81% |
| 0.60 | 49% | N/A | 71% | 90% | 71% | 82% | 84% |
| 0.55 | 56% | N/A | 75% | 91% | 77% | 86% | 87% |
| 0.50 | 59% | N/A | 77% | 93% | 79% | 88% | 89% |
| 0.45 | 63% | N/A | 80% | 94% | 81% | 89% | 92% |
| 0.40 | 68% | N/A | 81% | 95% | 84% | 92% | 93% |
| 0.35 | 73% | N/A | 83% | 96% | 88% | 94% | 95% |
| 0.30 | 79% | N/A | 85% | 98% | 91% | 96% | 96% |
| 0.25 | 84% | N/A | 88% | 98% | 94% | 98% | 97% |
| 0.20 | 89% | N/A | 92% | 99% | 96% | 99% | 98% |
| 0.15 | 94% | N/A | 96% | 100% | 97% | 99% | 98% |
| 0.10 | 97% | N/A | 97% | 100% | 98% | 99% | 99% |
| 0.05 | 99% | N/A | 99% | 100% | 99% | 100% | 100% |
| 0.01 | 99% | N/A | 99% | 100% | 99% | 100% | 100% |

**Table E47** Percentage of maximum available habitat at each percent exceedence level in November at the Columbus Reach.

| COLUMBUS REACH - NOVEMBER<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 3% | N/A | 50% | 58% | 16% | 18% | 14% |
| 0.95 | 5% | N/A | 52% | 67% | 19% | 21% | 15% |
| 0.90 | 17% | N/A | 58% | 76% | 23% | 30% | 18% |
| 0.85 | 23% | N/A | 60% | 81% | 28% | 41% | 23% |
| 0.80 | 28% | N/A | 62% | 83% | 39% | 54% | 38% |
| 0.75 | 35% | N/A | 65% | 88% | 47% | 63% | 53% |
| 0.70 | 41% | N/A | 68% | 90% | 56% | 71% | 69% |
| 0.65 | 45% | N/A | 69% | 91% | 61% | 75% | 76% |
| 0.60 | 50% | N/A | 71% | 92% | 69% | 82% | 85% |
| 0.55 | 55% | N/A | 74% | 93% | 74% | 84% | 87% |
| 0.50 | 61% | N/A | 79% | 94% | 78% | 87% | 88% |
| 0.45 | 66% | N/A | 81% | 95% | 82% | 90% | 90% |
| 0.40 | 71% | N/A | 82% | 96% | 84% | 92% | 94% |
| 0.35 | 75% | N/A | 85% | 96% | 86% | 93% | 97% |
| 0.30 | 81% | N/A | 87% | 97% | 87% | 94% | 98% |
| 0.25 | 85% | N/A | 89% | 98% | 90% | 95% | 99% |
| 0.20 | 89% | N/A | 93% | 99% | 92% | 97% | 99% |
| 0.15 | 92% | N/A | 96% | 100% | 94% | 98% | 100% |
| 0.10 | 97% | N/A | 98% | 100% | 96% | 99% | 100% |
| 0.05 | 98% | N/A | 98% | 100% | 99% | 99% | 100% |
| 0.01 | 99% | N/A | 99% | 100% | 99% | 99% | 100% |

**Table E48** Percentage of maximum available habitat at each percent exceedence level in December at the Columbus Reach.

| COLUMBUS REACH - DECEMBER<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | 5% | N/A | 52% | 58% | 16% | 18% | 14% |
| 0.95 | 12% | N/A | 56% | 69% | 19% | 22% | 15% |
| 0.90 | 17% | N/A | 58% | 76% | 23% | 31% | 19% |
| 0.85 | 21% | N/A | 60% | 82% | 28% | 41% | 23% |
| 0.80 | 27% | N/A | 62% | 87% | 45% | 60% | 49% |
| 0.75 | 33% | N/A | 64% | 89% | 58% | 72% | 71% |
| 0.70 | 38% | N/A | 66% | 90% | 66% | 79% | 82% |
| 0.65 | 44% | N/A | 69% | 91% | 71% | 82% | 86% |
| 0.60 | 49% | N/A | 71% | 92% | 75% | 85% | 88% |
| 0.55 | 52% | N/A | 73% | 93% | 79% | 87% | 90% |
| 0.50 | 57% | N/A | 76% | 94% | 81% | 89% | 92% |
| 0.45 | 61% | N/A | 79% | 95% | 84% | 91% | 95% |
| 0.40 | 66% | N/A | 80% | 96% | 85% | 92% | 96% |
| 0.35 | 71% | N/A | 81% | 97% | 87% | 93% | 98% |
| 0.30 | 74% | N/A | 83% | 98% | 90% | 95% | 98% |
| 0.25 | 78% | N/A | 86% | 99% | 91% | 96% | 99% |
| 0.20 | 84% | N/A | 89% | 99% | 94% | 97% | 99% |
| 0.15 | 89% | N/A | 95% | 100% | 96% | 98% | 100% |
| 0.10 | 93% | N/A | 97% | 100% | 97% | 99% | 100% |
| 0.05 | 97% | N/A | 99% | 100% | 98% | 99% | 100% |
| 0.01 | 99% | N/A | 99% | 100% | 100% | 100% | 100% |

**Table E49** Percentage of maximum available habitat at each percent exceedence level in January at the Wharton Reach.

| WHARTON REACH - JANUARY<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | N/A | N/A | 39% | 68% | 26% | 26% | 14% |
| 0.95 | N/A | N/A | 41% | 78% | 33% | 36% | 19% |
| 0.90 | N/A | N/A | 42% | 79% | 38% | 43% | 23% |
| 0.85 | N/A | N/A | 45% | 80% | 40% | 46% | 25% |
| 0.80 | N/A | N/A | 48% | 82% | 44% | 52% | 31% |
| 0.75 | N/A | N/A | 50% | 83% | 53% | 65% | 42% |
| 0.70 | N/A | N/A | 54% | 84% | 63% | 76% | 56% |
| 0.65 | N/A | N/A | 57% | 85% | 69% | 83% | 67% |
| 0.60 | N/A | N/A | 62% | 87% | 72% | 87% | 76% |
| 0.55 | N/A | N/A | 64% | 89% | 75% | 90% | 83% |
| 0.50 | N/A | N/A | 66% | 90% | 78% | 92% | 89% |
| 0.45 | N/A | N/A | 70% | 91% | 80% | 93% | 91% |
| 0.40 | N/A | N/A | 74% | 93% | 82% | 94% | 94% |
| 0.35 | N/A | N/A | 78% | 94% | 85% | 96% | 97% |
| 0.30 | N/A | N/A | 83% | 96% | 86% | 96% | 97% |
| 0.25 | N/A | N/A | 91% | 97% | 89% | 97% | 97% |
| 0.20 | N/A | N/A | 94% | 98% | 91% | 97% | 98% |
| 0.15 | N/A | N/A | 98% | 99% | 93% | 98% | 98% |
| 0.10 | N/A | N/A | 99% | 99% | 96% | 99% | 99% |
| 0.05 | N/A | N/A | 100% | 100% | 97% | 99% | 100% |
| 0.01 | N/A | N/A | 100% | 100% | 98% | 100% | 100% |

**Table E50** Percentage of maximum available habitat at each percent exceedence level in February at the Wharton Reach.

| WHARTON REACH - FEBRUARY<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | N/A | N/A | 39% | 65% | 25% | 25% | 13% |
| 0.95 | N/A | N/A | 42% | 74% | 29% | 31% | 16% |
| 0.90 | N/A | N/A | 45% | 78% | 33% | 36% | 19% |
| 0.85 | N/A | N/A | 49% | 80% | 38% | 43% | 23% |
| 0.80 | N/A | N/A | 52% | 82% | 42% | 51% | 29% |
| 0.75 | N/A | N/A | 56% | 83% | 48% | 59% | 37% |
| 0.70 | N/A | N/A | 60% | 85% | 53% | 66% | 43% |
| 0.65 | N/A | N/A | 62% | 87% | 58% | 71% | 49% |
| 0.60 | N/A | N/A | 64% | 89% | 67% | 82% | 64% |
| 0.55 | N/A | N/A | 67% | 90% | 71% | 87% | 75% |
| 0.50 | N/A | N/A | 71% | 92% | 74% | 89% | 82% |
| 0.45 | N/A | N/A | 74% | 93% | 76% | 92% | 88% |
| 0.40 | N/A | N/A | 80% | 94% | 79% | 93% | 92% |
| 0.35 | N/A | N/A | 85% | 95% | 81% | 94% | 94% |
| 0.30 | N/A | N/A | 90% | 96% | 82% | 95% | 96% |
| 0.25 | N/A | N/A | 92% | 97% | 85% | 96% | 97% |
| 0.20 | N/A | N/A | 94% | 98% | 87% | 96% | 98% |
| 0.15 | N/A | N/A | 96% | 98% | 89% | 97% | 98% |
| 0.10 | N/A | N/A | 98% | 99% | 92% | 98% | 99% |
| 0.05 | N/A | N/A | 99% | 100% | 95% | 99% | 99% |
| 0.01 | N/A | N/A | 100% | 100% | 96% | 99% | 100% |

**Table E51** Percentage of maximum available habitat at each percent exceedence level in March at the Wharton Reach.

| WHARTON REACH - MARCH<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | N/A | N/A | 34% | 62% | 23% | 24% | 13% |
| 0.95 | N/A | N/A | 39% | 72% | 28% | 30% | 16% |
| 0.90 | N/A | N/A | 43% | 77% | 34% | 38% | 20% |
| 0.85 | N/A | N/A | 46% | 78% | 37% | 44% | 23% |
| 0.80 | N/A | N/A | 49% | 81% | 42% | 52% | 31% |
| 0.75 | N/A | N/A | 54% | 82% | 49% | 62% | 40% |
| 0.70 | N/A | N/A | 60% | 83% | 53% | 67% | 45% |
| 0.65 | N/A | N/A | 64% | 86% | 57% | 72% | 50% |
| 0.60 | N/A | N/A | 68% | 88% | 62% | 78% | 59% |
| 0.55 | N/A | N/A | 71% | 90% | 65% | 82% | 65% |
| 0.50 | N/A | N/A | 75% | 92% | 68% | 86% | 73% |
| 0.45 | N/A | N/A | 79% | 94% | 71% | 89% | 80% |
| 0.40 | N/A | N/A | 82% | 96% | 73% | 91% | 86% |
| 0.35 | N/A | N/A | 86% | 97% | 76% | 93% | 90% |
| 0.30 | N/A | N/A | 89% | 98% | 80% | 95% | 94% |
| 0.25 | N/A | N/A | 91% | 98% | 83% | 96% | 96% |
| 0.20 | N/A | N/A | 93% | 99% | 86% | 97% | 97% |
| 0.15 | N/A | N/A | 95% | 99% | 89% | 98% | 98% |
| 0.10 | N/A | N/A | 98% | 99% | 91% | 99% | 99% |
| 0.05 | N/A | N/A | 99% | 100% | 95% | 99% | 99% |
| 0.01 | N/A | N/A | 100% | 100% | 96% | 100% | 99% |

**Table E52** Percentage of maximum available habitat at each percent exceedence level in April at the Wharton Reach.

| WHARTON REACH - APRIL<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | N/A | N/A | 37% | 61% | 23% | 24% | 12% |
| 0.95 | N/A | N/A | 39% | 68% | 26% | 26% | 14% |
| 0.90 | N/A | N/A | 41% | 75% | 31% | 34% | 17% |
| 0.85 | N/A | N/A | 44% | 78% | 37% | 43% | 23% |
| 0.80 | N/A | N/A | 51% | 79% | 42% | 51% | 30% |
| 0.75 | N/A | N/A | 55% | 80% | 47% | 58% | 36% |
| 0.70 | N/A | N/A | 60% | 82% | 53% | 66% | 43% |
| 0.65 | N/A | N/A | 65% | 86% | 59% | 73% | 51% |
| 0.60 | N/A | N/A | 68% | 88% | 62% | 76% | 56% |
| 0.55 | N/A | N/A | 71% | 90% | 65% | 80% | 62% |
| 0.50 | N/A | N/A | 75% | 92% | 70% | 86% | 73% |
| 0.45 | N/A | N/A | 79% | 94% | 73% | 89% | 81% |
| 0.40 | N/A | N/A | 82% | 95% | 75% | 91% | 88% |
| 0.35 | N/A | N/A | 85% | 96% | 77% | 93% | 90% |
| 0.30 | N/A | N/A | 87% | 98% | 82% | 95% | 95% |
| 0.25 | N/A | N/A | 91% | 98% | 85% | 96% | 96% |
| 0.20 | N/A | N/A | 92% | 99% | 87% | 97% | 97% |
| 0.15 | N/A | N/A | 95% | 99% | 92% | 99% | 97% |
| 0.10 | N/A | N/A | 97% | 99% | 95% | 99% | 98% |
| 0.05 | N/A | N/A | 99% | 100% | 97% | 100% | 99% |
| 0.01 | N/A | N/A | 100% | 100% | 97% | 100% | 99% |

**Table E53** Percentage of maximum available habitat at each percent exceedence level in May at the Wharton Reach.

| WHARTON REACH - MAY<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | N/A | N/A | 39% | 61% | 24% | 24% | 12% |
| 0.95 | N/A | N/A | 45% | 68% | 26% | 26% | 14% |
| 0.90 | N/A | N/A | 58% | 75% | 30% | 31% | 16% |
| 0.85 | N/A | N/A | 64% | 78% | 34% | 36% | 19% |
| 0.80 | N/A | N/A | 67% | 80% | 37% | 41% | 22% |
| 0.75 | N/A | N/A | 70% | 84% | 40% | 46% | 25% |
| 0.70 | N/A | N/A | 73% | 87% | 45% | 53% | 32% |
| 0.65 | N/A | N/A | 76% | 90% | 47% | 56% | 34% |
| 0.60 | N/A | N/A | 79% | 92% | 51% | 61% | 39% |
| 0.55 | N/A | N/A | 81% | 94% | 57% | 68% | 46% |
| 0.50 | N/A | N/A | 83% | 95% | 61% | 73% | 51% |
| 0.45 | N/A | N/A | 87% | 96% | 65% | 78% | 59% |
| 0.40 | N/A | N/A | 89% | 96% | 68% | 82% | 64% |
| 0.35 | N/A | N/A | 92% | 97% | 71% | 85% | 71% |
| 0.30 | N/A | N/A | 93% | 98% | 74% | 88% | 78% |
| 0.25 | N/A | N/A | 95% | 99% | 76% | 90% | 83% |
| 0.20 | N/A | N/A | 96% | 99% | 78% | 92% | 89% |
| 0.15 | N/A | N/A | 98% | 99% | 81% | 93% | 92% |
| 0.10 | N/A | N/A | 99% | 100% | 85% | 96% | 96% |
| 0.05 | N/A | N/A | 100% | 100% | 94% | 98% | 98% |
| 0.01 | N/A | N/A | 100% | 100% | 99% | 100% | 98% |

**Table E54** Percentage of maximum available habitat at each percent exceedence level in June at the Wharton Reach.

| WHARTON REACH - JUNE<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | N/A | N/A | 42% | 62% | 24% | 24% | 12% |
| 0.95 | N/A | N/A | 50% | 70% | 27% | 27% | 14% |
| 0.90 | N/A | N/A | 58% | 77% | 32% | 33% | 17% |
| 0.85 | N/A | N/A | 62% | 80% | 36% | 39% | 20% |
| 0.80 | N/A | N/A | 67% | 83% | 39% | 43% | 23% |
| 0.75 | N/A | N/A | 71% | 86% | 42% | 47% | 26% |
| 0.70 | N/A | N/A | 76% | 88% | 45% | 52% | 31% |
| 0.65 | N/A | N/A | 79% | 90% | 46% | 55% | 33% |
| 0.60 | N/A | N/A | 82% | 92% | 51% | 61% | 39% |
| 0.55 | N/A | N/A | 85% | 93% | 55% | 66% | 43% |
| 0.50 | N/A | N/A | 88% | 94% | 58% | 69% | 47% |
| 0.45 | N/A | N/A | 89% | 95% | 62% | 73% | 51% |
| 0.40 | N/A | N/A | 91% | 96% | 65% | 77% | 57% |
| 0.35 | N/A | N/A | 93% | 97% | 69% | 82% | 64% |
| 0.30 | N/A | N/A | 94% | 98% | 72% | 85% | 72% |
| 0.25 | N/A | N/A | 96% | 99% | 76% | 89% | 81% |
| 0.20 | N/A | N/A | 97% | 99% | 79% | 92% | 89% |
| 0.15 | N/A | N/A | 99% | 99% | 84% | 94% | 94% |
| 0.10 | N/A | N/A | 99% | 99% | 86% | 96% | 97% |
| 0.05 | N/A | N/A | 100% | 100% | 91% | 97% | 98% |
| 0.01 | N/A | N/A | 100% | 100% | 96% | 99% | 99% |

**Table E55** Percentage of maximum available habitat at each percent exceedence level in July at the Wharton Reach.

| WHARTON REACH - JULY<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | N/A | N/A | 35% | 65% | 24% | 25% | 13% |
| 0.95 | N/A | N/A | 41% | 74% | 30% | 34% | 17% |
| 0.90 | N/A | N/A | 45% | 79% | 39% | 47% | 26% |
| 0.85 | N/A | N/A | 48% | 81% | 46% | 59% | 37% |
| 0.80 | N/A | N/A | 51% | 83% | 52% | 66% | 44% |
| 0.75 | N/A | N/A | 55% | 85% | 57% | 73% | 51% |
| 0.70 | N/A | N/A | 59% | 87% | 60% | 77% | 57% |
| 0.65 | N/A | N/A | 62% | 90% | 65% | 82% | 65% |
| 0.60 | N/A | N/A | 64% | 91% | 68% | 85% | 72% |
| 0.55 | N/A | N/A | 65% | 93% | 71% | 89% | 81% |
| 0.50 | N/A | N/A | 69% | 94% | 72% | 91% | 85% |
| 0.45 | N/A | N/A | 71% | 95% | 75% | 93% | 89% |
| 0.40 | N/A | N/A | 76% | 96% | 76% | 93% | 91% |
| 0.35 | N/A | N/A | 79% | 97% | 78% | 94% | 93% |
| 0.30 | N/A | N/A | 83% | 98% | 80% | 95% | 96% |
| 0.25 | N/A | N/A | 86% | 98% | 82% | 96% | 97% |
| 0.20 | N/A | N/A | 89% | 99% | 84% | 97% | 97% |
| 0.15 | N/A | N/A | 92% | 99% | 86% | 97% | 98% |
| 0.10 | N/A | N/A | 95% | 99% | 89% | 98% | 99% |
| 0.05 | N/A | N/A | 99% | 100% | 92% | 99% | 99% |
| 0.01 | N/A | N/A | 99% | 100% | 94% | 100% | 100% |

**Table E56** Percentage of maximum available habitat at each percent exceedence level in August at the Wharton Reach.

| WHARTON REACH - AUGUST<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | N/A | N/A | 29% | 66% | 25% | 27% | 14% |
| 0.95 | N/A | N/A | 31% | 68% | 35% | 42% | 23% |
| 0.90 | N/A | N/A | 35% | 71% | 42% | 55% | 33% |
| 0.85 | N/A | N/A | 38% | 75% | 56% | 72% | 51% |
| 0.80 | N/A | N/A | 39% | 78% | 62% | 80% | 61% |
| 0.75 | N/A | N/A | 40% | 78% | 67% | 86% | 74% |
| 0.70 | N/A | N/A | 44% | 80% | 71% | 90% | 78% |
| 0.65 | N/A | N/A | 46% | 82% | 75% | 93% | 82% |
| 0.60 | N/A | N/A | 49% | 83% | 76% | 94% | 87% |
| 0.55 | N/A | N/A | 52% | 84% | 78% | 95% | 90% |
| 0.50 | N/A | N/A | 55% | 87% | 81% | 96% | 92% |
| 0.45 | N/A | N/A | 59% | 88% | 82% | 96% | 94% |
| 0.40 | N/A | N/A | 62% | 90% | 84% | 97% | 96% |
| 0.35 | N/A | N/A | 64% | 92% | 87% | 97% | 96% |
| 0.30 | N/A | N/A | 69% | 94% | 89% | 98% | 97% |
| 0.25 | N/A | N/A | 75% | 95% | 91% | 98% | 97% |
| 0.20 | N/A | N/A | 81% | 97% | 92% | 99% | 98% |
| 0.15 | N/A | N/A | 87% | 98% | 94% | 99% | 99% |
| 0.10 | N/A | N/A | 93% | 99% | 97% | 100% | 99% |
| 0.05 | N/A | N/A | 98% | 100% | 100% | 100% | 99% |
| 0.01 | N/A | N/A | 100% | 100% | 100% | 100% | 100% |

**Table E57** Percentage of maximum available habitat at each percent exceedence level in September at the Wharton Reach.

| WHARTON REACH - SEPTEMBER<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | N/A | N/A | 33% | 64% | 23% | 25% | 13% |
| 0.95 | N/A | N/A | 38% | 72% | 31% | 35% | 18% |
| 0.90 | N/A | N/A | 40% | 77% | 36% | 44% | 24% |
| 0.85 | N/A | N/A | 42% | 79% | 42% | 54% | 32% |
| 0.80 | N/A | N/A | 44% | 80% | 50% | 65% | 43% |
| 0.75 | N/A | N/A | 46% | 81% | 57% | 73% | 52% |
| 0.70 | N/A | N/A | 48% | 82% | 63% | 81% | 63% |
| 0.65 | N/A | N/A | 50% | 83% | 67% | 86% | 74% |
| 0.60 | N/A | N/A | 53% | 85% | 71% | 90% | 83% |
| 0.55 | N/A | N/A | 57% | 86% | 74% | 92% | 88% |
| 0.50 | N/A | N/A | 62% | 87% | 77% | 94% | 91% |
| 0.45 | N/A | N/A | 66% | 89% | 80% | 96% | 94% |
| 0.40 | N/A | N/A | 70% | 92% | 82% | 96% | 96% |
| 0.35 | N/A | N/A | 74% | 93% | 84% | 97% | 97% |
| 0.30 | N/A | N/A | 80% | 95% | 84% | 97% | 97% |
| 0.25 | N/A | N/A | 85% | 96% | 87% | 98% | 98% |
| 0.20 | N/A | N/A | 89% | 98% | 89% | 98% | 98% |
| 0.15 | N/A | N/A | 93% | 99% | 90% | 99% | 99% |
| 0.10 | N/A | N/A | 97% | 99% | 92% | 99% | 99% |
| 0.05 | N/A | N/A | 99% | 100% | 94% | 100% | 100% |
| 0.01 | N/A | N/A | 100% | 100% | 96% | 100% | 100% |

**Table E58** Percentage of maximum available habitat at each percent exceedence level in October at the Wharton Reach.

| WHARTON REACH - OCTOBER<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | N/A | N/A | 31% | 63% | 23% | 24% | 13% |
| 0.95 | N/A | N/A | 33% | 70% | 28% | 31% | 16% |
| 0.90 | N/A | N/A | 37% | 72% | 35% | 41% | 22% |
| 0.85 | N/A | N/A | 39% | 76% | 41% | 51% | 30% |
| 0.80 | N/A | N/A | 41% | 77% | 48% | 62% | 40% |
| 0.75 | N/A | N/A | 44% | 79% | 55% | 71% | 49% |
| 0.70 | N/A | N/A | 48% | 80% | 62% | 79% | 60% |
| 0.65 | N/A | N/A | 53% | 82% | 66% | 85% | 71% |
| 0.60 | N/A | N/A | 59% | 85% | 69% | 88% | 79% |
| 0.55 | N/A | N/A | 63% | 87% | 72% | 91% | 84% |
| 0.50 | N/A | N/A | 65% | 89% | 74% | 93% | 87% |
| 0.45 | N/A | N/A | 68% | 92% | 76% | 94% | 89% |
| 0.40 | N/A | N/A | 72% | 93% | 79% | 95% | 91% |
| 0.35 | N/A | N/A | 76% | 94% | 82% | 96% | 93% |
| 0.30 | N/A | N/A | 80% | 96% | 85% | 97% | 95% |
| 0.25 | N/A | N/A | 85% | 97% | 89% | 98% | 96% |
| 0.20 | N/A | N/A | 90% | 98% | 91% | 99% | 97% |
| 0.15 | N/A | N/A | 93% | 99% | 93% | 99% | 98% |
| 0.10 | N/A | N/A | 97% | 99% | 95% | 99% | 98% |
| 0.05 | N/A | N/A | 99% | 100% | 98% | 100% | 99% |
| 0.01 | N/A | N/A | 100% | 100% | 99% | 100% | 99% |

**Table E59** Percentage of maximum available habitat at each percent exceedence level in November at the Wharton Reach.

| WHARTON REACH - NOVEMBER<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | N/A | N/A | 33% | 63% | 23% | 24% | 13% |
| 0.95 | N/A | N/A | 34% | 71% | 28% | 31% | 16% |
| 0.90 | N/A | N/A | 42% | 73% | 34% | 40% | 21% |
| 0.85 | N/A | N/A | 45% | 78% | 39% | 48% | 27% |
| 0.80 | N/A | N/A | 47% | 81% | 49% | 63% | 40% |
| 0.75 | N/A | N/A | 51% | 82% | 55% | 70% | 48% |
| 0.70 | N/A | N/A | 54% | 83% | 61% | 78% | 59% |
| 0.65 | N/A | N/A | 56% | 85% | 64% | 82% | 65% |
| 0.60 | N/A | N/A | 59% | 87% | 69% | 87% | 77% |
| 0.55 | N/A | N/A | 62% | 89% | 71% | 90% | 82% |
| 0.50 | N/A | N/A | 67% | 90% | 73% | 92% | 86% |
| 0.45 | N/A | N/A | 70% | 91% | 77% | 94% | 88% |
| 0.40 | N/A | N/A | 73% | 93% | 79% | 95% | 92% |
| 0.35 | N/A | N/A | 79% | 95% | 81% | 96% | 95% |
| 0.30 | N/A | N/A | 81% | 97% | 82% | 96% | 97% |
| 0.25 | N/A | N/A | 87% | 98% | 84% | 97% | 98% |
| 0.20 | N/A | N/A | 91% | 98% | 86% | 98% | 98% |
| 0.15 | N/A | N/A | 94% | 99% | 88% | 98% | 98% |
| 0.10 | N/A | N/A | 97% | 99% | 91% | 99% | 99% |
| 0.05 | N/A | N/A | 99% | 100% | 98% | 99% | 99% |
| 0.01 | N/A | N/A | 100% | 100% | 99% | 99% | 100% |

**Table E60** Percentage of maximum available habitat at each percent exceedence level in December at the Wharton Reach.

| WHARTON REACH - DECEMBER<br>Percentage of Maximum Available Habitat | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percent Exceedence Level | Rapids / Adult blue sucker | Spawning blue sucker | Deep Pool | Deep Run | Shallow Pool / Edge / Backwater | Shallow Run | Riffle |
| 0.99 | N/A | N/A | 34% | 63% | 23% | 24% | 13% |
| 0.95 | N/A | N/A | 39% | 73% | 30% | 33% | 17% |
| 0.90 | N/A | N/A | 41% | 77% | 35% | 40% | 21% |
| 0.85 | N/A | N/A | 44% | 79% | 40% | 48% | 27% |
| 0.80 | N/A | N/A | 47% | 80% | 54% | 68% | 46% |
| 0.75 | N/A | N/A | 50% | 82% | 63% | 79% | 60% |
| 0.70 | N/A | N/A | 52% | 83% | 68% | 85% | 72% |
| 0.65 | N/A | N/A | 55% | 85% | 71% | 88% | 79% |
| 0.60 | N/A | N/A | 58% | 86% | 72% | 90% | 83% |
| 0.55 | N/A | N/A | 60% | 87% | 75% | 92% | 88% |
| 0.50 | N/A | N/A | 64% | 89% | 77% | 93% | 90% |
| 0.45 | N/A | N/A | 67% | 91% | 80% | 95% | 93% |
| 0.40 | N/A | N/A | 70% | 92% | 81% | 95% | 96% |
| 0.35 | N/A | N/A | 72% | 94% | 83% | 96% | 97% |
| 0.30 | N/A | N/A | 76% | 96% | 85% | 96% | 97% |
| 0.25 | N/A | N/A | 80% | 97% | 86% | 97% | 98% |
| 0.20 | N/A | N/A | 85% | 98% | 89% | 98% | 98% |
| 0.15 | N/A | N/A | 93% | 98% | 91% | 99% | 99% |
| 0.10 | N/A | N/A | 97% | 99% | 93% | 99% | 99% |
| 0.05 | N/A | N/A | 99% | 100% | 95% | 99% | 99% |
| 0.01 | N/A | N/A | 100% | 100% | 99% | 100% | 100% |