Appendix H

Water Resource and Human Use Assessment of the Rainbow River in Marion County, Florida, Draft. Prepared by HSW Engineering, Inc. for the Southwest Florida Water Management District, Brooksville, Florida. 2009.

WATER RESOURCE AND HUMAN USE ASSESSMENT OF THE RAINBOW RIVER IN MARION COUNTY, FLORIDA (DRAFT)

MAY 2009

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Southwest Florida Water Management District

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1.0 INTRODUCTION

HSW Engineering, Inc. (HSW), was contracted by Southwest Florida Water Management District (SWFWMD or the District) to evaluate flow reduction scenarios that would result in a hydrologic regime that will protect ten water resources and human use values for the Rainbow River in Marion County, Florida (Figure 1-1). This effort is part of a larger effort by the District to develop MFLs for the Rainbow River.

Figure 1-1. The Rainbow River located in Marion County, Florida *(HSW 2007)*

The MFLs Program is based on Chapter 373.042, *Florida Statutes*, which requires that either a water management district (WMD) or the Florida Department of Environmental Protection (FDEP) establish minimum flows for surface watercourses and minimum levels for groundwaters and surface waters. The statutory description of a minimum flow is “the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area" (*Florida Statutes*). The statutory description of a minimum level, as applies to Florida's surface water bodies, is "the level of surface water at which further withdrawals would be significantly harmful to the water resources of the area" (*Florida Statutes*).

The statute provides additional guidance to the WMDs and FDEP on how to establish MFLs. The MFLs are to be established using the "best information available" and may be calculated to reflect seasonal variations, if appropriate. Protecting non-consumptive uses also is to be considered as part of the process. The decision on whether to provide for protection of non-consumptive uses is to be made by the Governing Board of the WMD or the FDEP (*Florida Statutes*). Each WMD will develop a priority list of water courses and water bodies and a proposed schedule for the establishment of MFLs. This list is to be updated yearly and sent to the FDEP for review and approval. In developing these lists, the WMD is to examine the importance of the watercourse or water body to the State or region and the potential for significant harm to the water resources or ecology. Rainbow River is on the MFLs Priority Water Body List and Schedule (SWFWMD 2007).

In the developing MFLs, consideration should be given as to whether or not the MFLs are protective of ten water resource values (*Florida Administrative Code).* These WRVs are specified as follows.

1. Recreation in and on the water
2. Fish and wildlife habitats and the passage of fish
3. Estuarine resources
4. Transfer of detrital material
5. Maintenance of freshwater storage and supply
6. Aesthetic and scenic attributes
7. Filtration and absorption of nutrients and other pollutants
8. Sediment loads
9. Water quality
10. Navigation

The Rainbow River is located in the southwest corner of Marion County about 20 miles southwest of Ocala, 100 miles northwest of Orlando and 100 miles north of the Tampa Bay area (Figure 1-2). It is formed by a first order magnitude spring that is ranked fourth in the state for volume of discharge. In addition to the springs located at the headwaters, there are many smaller springs that discharge from numerous caves, rock crevices, and sand boils along the entire length of the river (Figure 1-3). The Rainbow River is 5.7 miles long and merges with the Withlacoochee River at Dunnellon, Florida. The headwaters are the anchor for the Rainbow Springs State Park. This first magnitude spring consists of numerous vents that discharge 400 - 600 million gallons of crystalline water every day. The Rainbow Springs State Park is a popular destination to swim, snorkel, canoe, picnic, or stroll on the walking paths to enjoy the abundant flora and fauna.

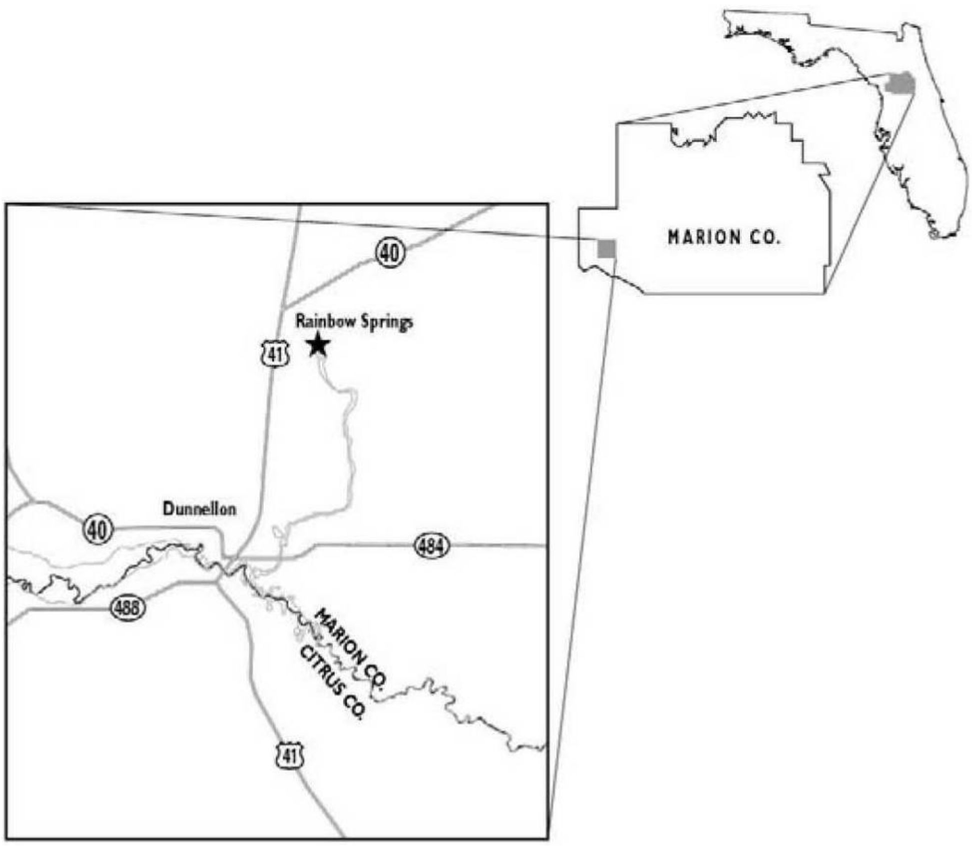

Figure 1-2. Location of the Rainbow River and Rainbow Springs (SWFWMD 2004)

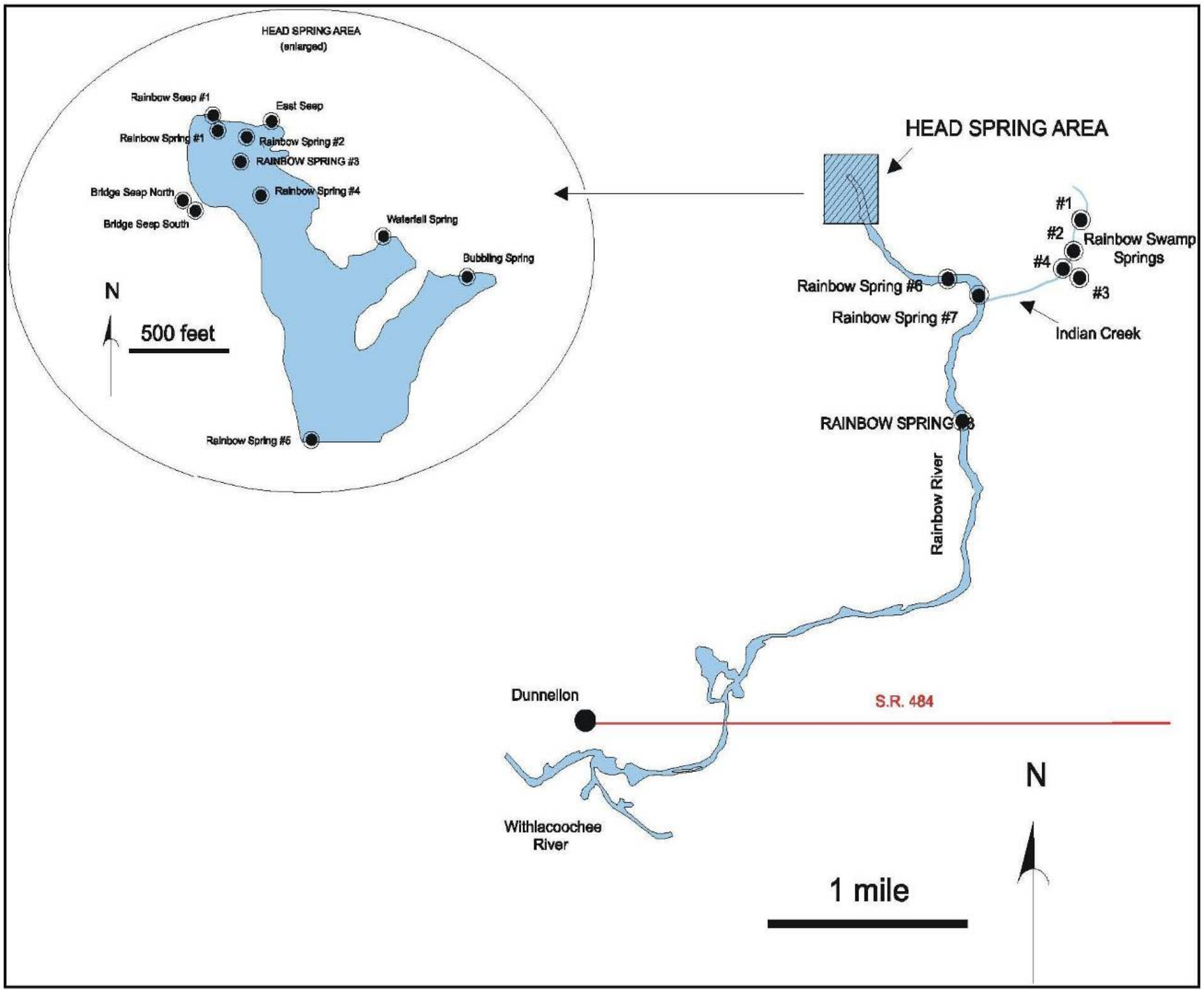

Figure 1-3. Locations of spring vents in the Rainbow Springs Complex (Jones et al. 1996)

Reference:

Florida Statutes, Title XXVIII, Ch. 373.042 (1) (a) and (b).
http://www.flsenate.gov/Statutes/index.cfm?App_mode=Display_Statute&Search_String=&URL=Ch0373/Sec042.HTM.

Southwest Florida Water Management District (SWFWMD). 2007.
http://www.swfwmd.state.fl.us/waterman/files/mfl_priority_list 2007.pdf Accessed on March 14, 2008.

2.0 DATA SUMMARY

Guidance provided in Chapter 373.042 FAC includes using “best available information” for establishing MFLs. Basic hydrologic data, including well stage and discharge, water quality, sediment, soils, and vegetation are summarized in this section. Additional data such as those for wetland and biology that are more related with specific water resource values, and detailed discussions of each, are presented in associated WRV sections.

Figure 2-1. Overview of Rainbow River Watershed

2.1 Well Stage

Daily groundwater elevations are reported for the USGS gauge, Rainbow Springs Well near Dunnellon, FL (ID: 290514082270701, 29°05'14" N, 80°27'07" W), an artesian well completed in the Upper Floridan Aquifer located on the east side of U.S. highway 41, 2.8 mile north of Dunnellon (Figure 2-1). The minimum, average, and maximum recorded daily stage during the period from January 1965 through June 2008 are 29.68, 31.42, and 34.79 ft-NGVD 1929, respectively (Figure 2.1-1).

The 90 percent exceeded, median, and 10 percent exceeded water elevations at this gage are 30.36, 31.24, and 32.77 ft-NGVD 1929, respectively (Figure 2.1-2). The lower elevations typically occur in June, and the higher elevations typically occur in October (Figure 2.1-3).

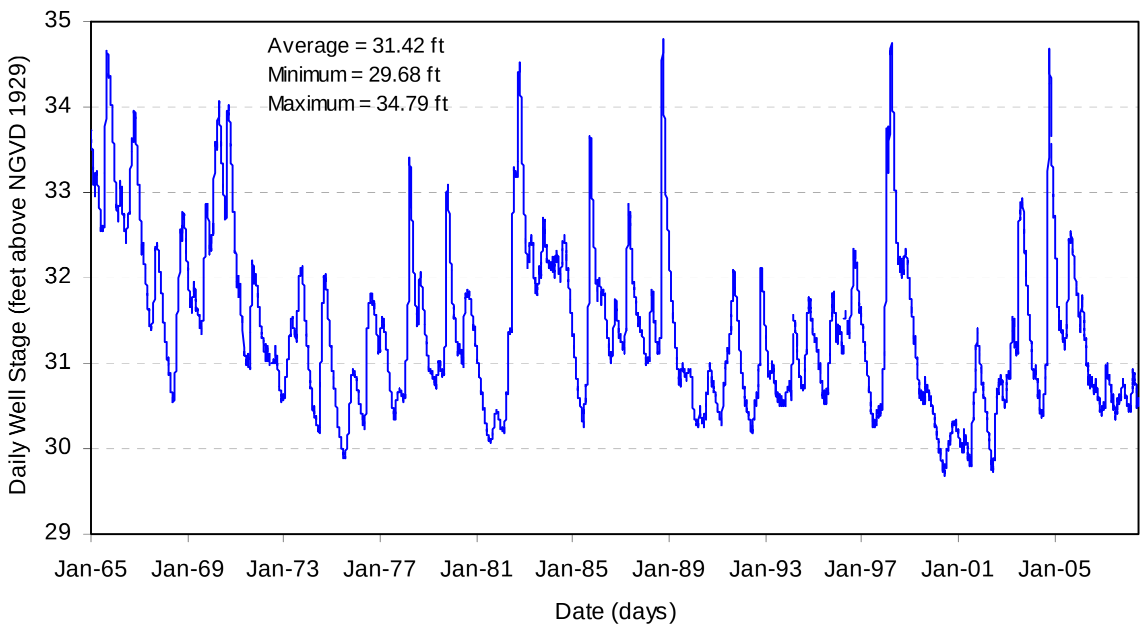

Figure 2.1-1. Daily well stage (1965-2008) at USGS 290514082270701 Rainbow Springs Well near Dunnellon, FL

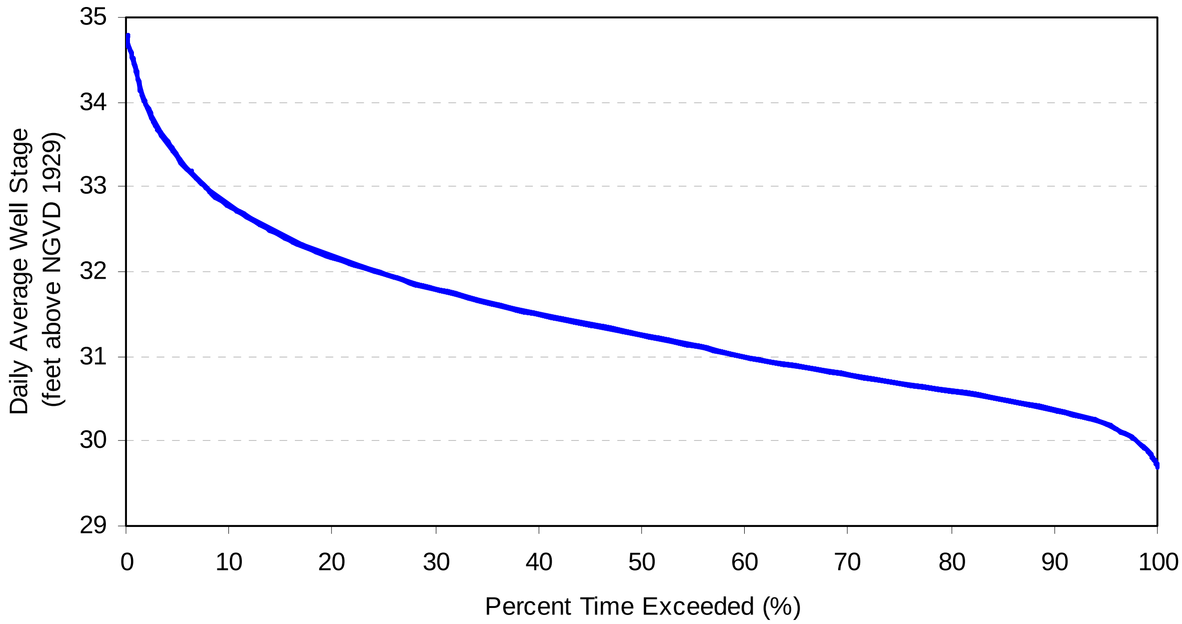

Figure 2.1-2. Daily water level elevation duration curve (1965-2008) at USGS 290514082270701 Rainbow Springs Well near Dunnellon, FL

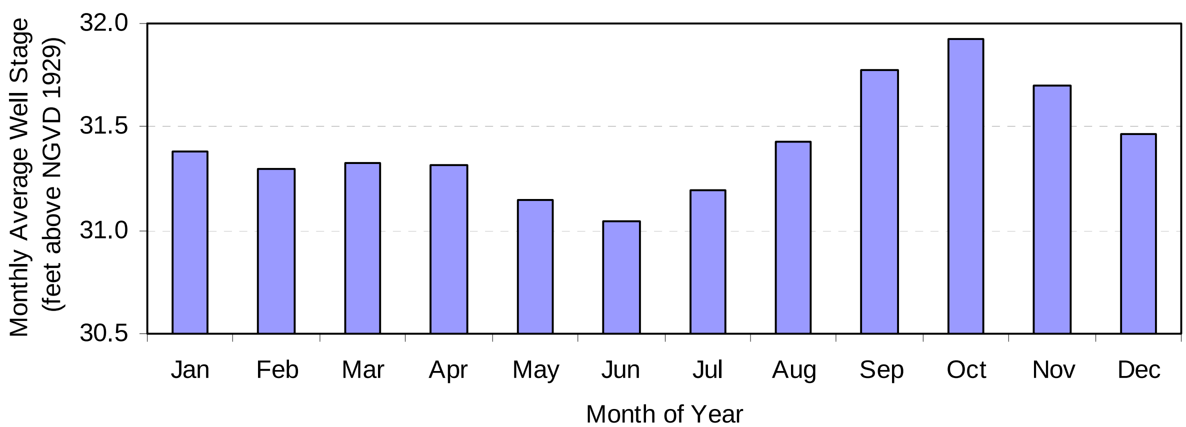

Figure 2.1-3. Monthly average water level elevation (1965-2008) at USGS 290514082270701 Rainbow Springs Well near Dunnellon, FL

2.2 Discharge

Discharge data are published for USGS gauge Rainbow Springs near Dunnellon, FL (gage ID: 02313100, 29°06'08" N, 82°26'16" W), which is located approximately 0.25 mile upstream of the State Highway 484 Bridge over the Rainbow River and about 5 miles downstream from the headsprings (Figure 2-1). It is a non-recording gage in that the daily discharge is calculated using a well rating curve, which associates the groundwater elevations (discussed in Section 2.1) and discharges measured near the State Highway 484 bridge (Pearman 2008). The well rating curve is used instead of a river stage-discharge rating curve to avoid the backwater effects from the Withlacoochee River near Dunnellon in southwest Marion County.

The daily discharges are available in 1899, 1905, 1907, 1917, 1929-30 (one discharge measurement per water year), October 1930 to November 1964 (discharge measurements only), and January 1965 to current year. Prior to October 1940, the flow records were published as Blue Springs near Dunnellon.

The District adjusted the published daily discharge for the period of January 1, 1965, through June 24, 2008, for use as a baseline flow record. The published discharge is used, in this report, as the historical flow. The period of record for baseline flow used for frequency analysis in this report is from June 1965 through September 2007 (Figures A-1 through A-10 in Appendix A). A plot of the concurrent daily well stage and baseline and historical discharge over the period of record indicate a linear association (Figure 2.2-1). The deviation of the rating curve from linear reflects the numerous changes in the rating curve over the period of record.

The minimum, mean, and maximum daily baseline and historical discharges are 470, 692, and 1,060 cubic feet per second (cfs), and 477, 698, and 1066 cfs, respectively, for the period of record (Figure 2.2-2). The 90 percent exceeded, median, and 10 percent exceeded baseline and historical discharges at this gage are 570, 679, and 856 cfs, and 565, 674, and 853 cfs, respectively (Figure 2.2-3). Low discharges typically occur in June, and high discharges typically occur in October (Figure 2.2-4).

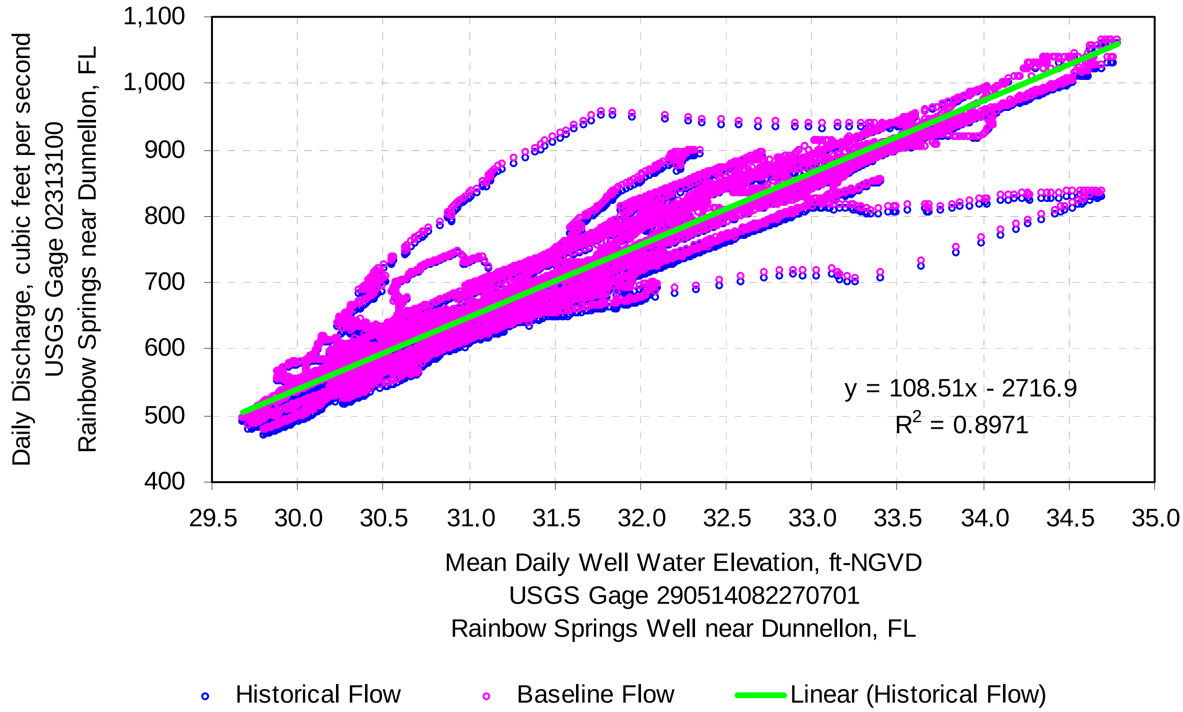

Figure 2.2-1. Daily average discharge at USGS 02313100 Rainbow Springs near Dunnellon, FL versus daily average well stage (1965-2008) at USGS 290514082270701 Rainbow Springs Well near Dunnellon, FL

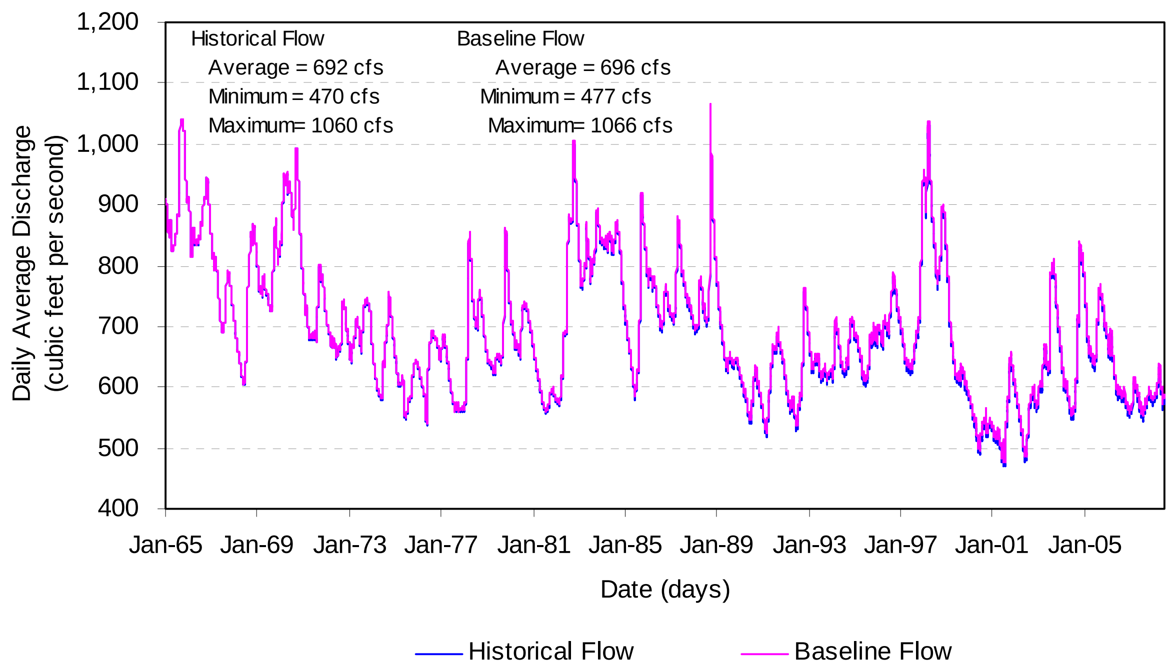

Figure 2.2-2. Baseline and historical daily average discharge (1965-2008) at USGS 02313100 Rainbow Springs near Dunnellon, FL

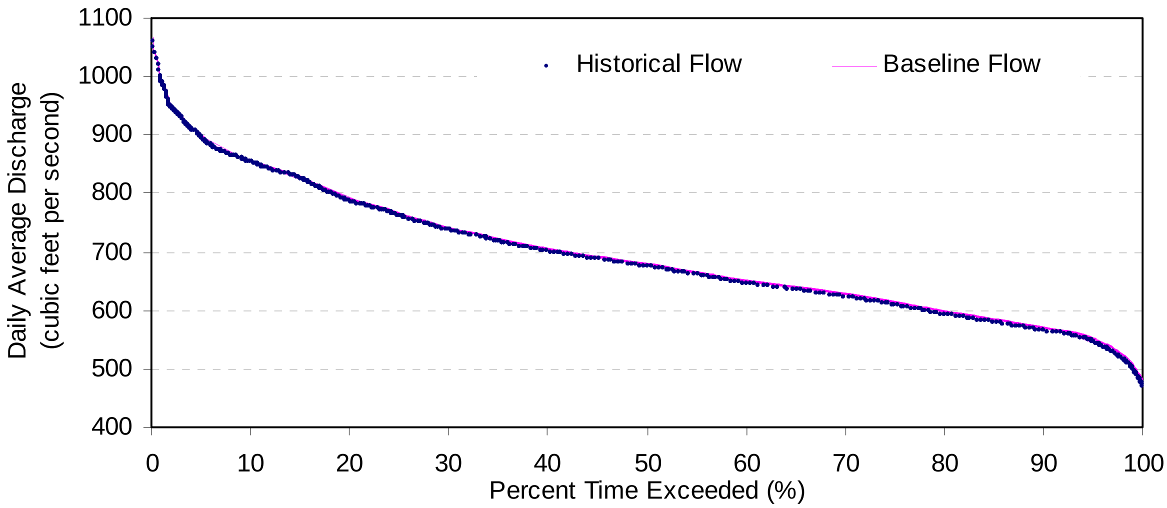

Figure 2.2-3. Baseline and historical daily average discharge duration curve (1965-2008) at USGS 02313100 Rainbow Springs near Dunnellon, FL

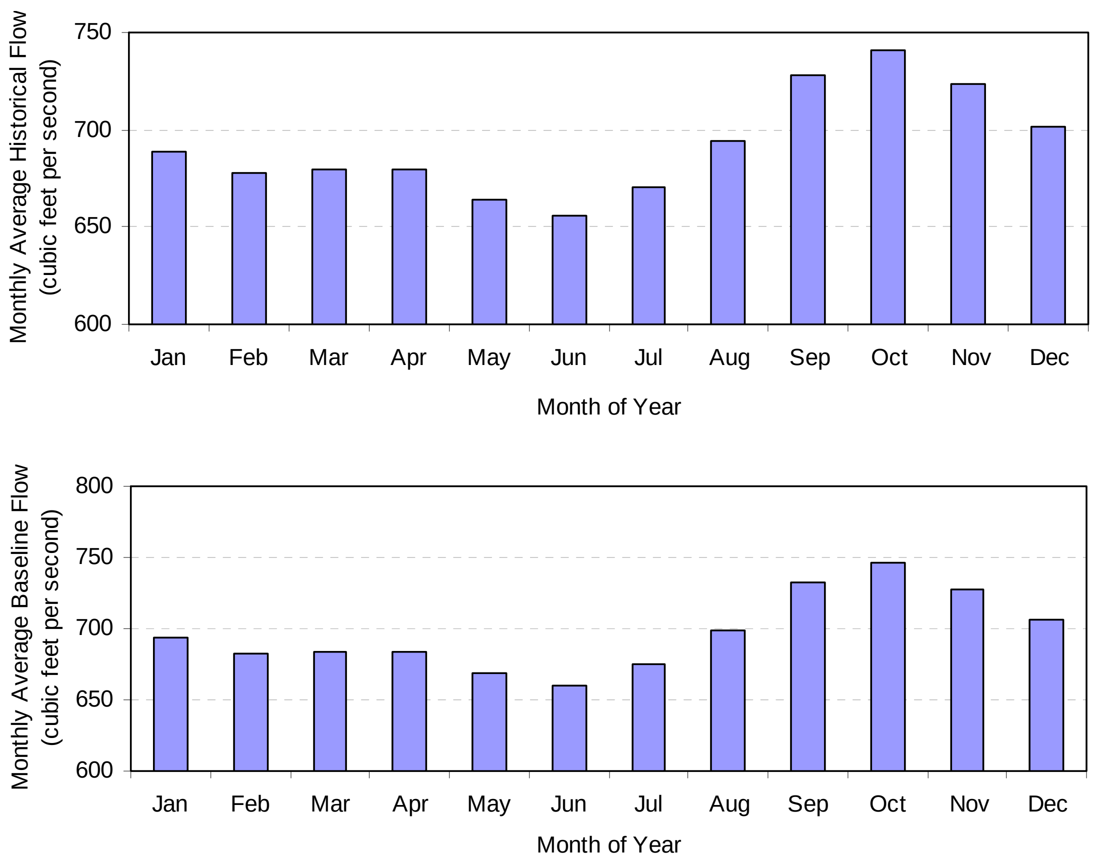

Figure 2.2-4. Baseline (top 1965-2008) and historical (middle 1965-2008) monthly average flows at USGS 02313100 Rainbow Springs near Dunnellon, FL

2.3 Water Quality

Water quality data have been collected by different agencies from the head springs to the confluence with Withlacoochee River (Figure 2.3-1), including three Florida Department of Environmental Protection (FDEP) water quality sampling sites (listed as 23010409, 23010055, and 23010404 in Figure 2.3-1), nine District sampling site (RR1 to RR9 in Figure 2.3-1) and one United State Geological Survey (USGS) sampling site (02313100). Using these data, water quality tables were prepared for three different locations (Rainbow Headsprings, Devil's Elbow, and CR484, Tables B-1 to B-3 in Appendix B).

The water quality tables provide the water quality index (WQI), base water quality constituents, along with the well stage at USGS gauge at Dunnellon. Sites from different agencies that were near each other were considered to be the same site for the WQI analysis. Four sites (23010055, 23010404, 2313100, and RR7) were considered as the same location in terms of the WQI calculation. Scatter plots of WQI and the constituent water quality components versus well stage also were generated (Figures B-1 to B-3 in Appendix B).

The water quality index was originally developed by U.S. Environmental Protection Agency (USEPA), and modified by FDEP for use in Florida (Hand et al. 2000; SJRWMD 2004). The WQI combines dissolved oxygen, pH, bacteria, nutrients, turbidity, and inorganic and organic toxics into a single index with values ranging from 0 to 100. The underlying concept behind the WQI is that different constituents contribute to water quality and these constituents can be grouped into appropriate classes. An overall index can be derived by averaging over classes for a site. The Florida WQI less than 45 is considered good quality, those between 45 and 60 were fair quality, and those over 60 are considered poor quality. Overall, the Rainbow River exhibits good water quality with additional details discussed in Section 4.9 Water Quality WRV.

2.4 Sediment

A sediment study for Rainbow River was conducted and documented in detail by Gulf Archaeology Research Institute (Ellis et al. 2007). The study produced baseline data on the nature and extent of sediment within the Rainbow River based on an analysis of 130 cores along the entire length of the river. It also assessed the sediment deposition, depth, and constituency.

The spring run contains a sediment regime dominated by medium to fine sand mixed with coarse sand, very fine sand, silt and clay, and organic debris/detritus. The majority of sediment is quartz sand derived from Miocene and Pliocene marine deposits. A low density of phosphorite particles is present in the sediments throughout the length of the river. This is expected where historic mining of phosphates has produced large talus piles along the river banks of lower strata sediments. For a majority of the river reach, the top of the sediment column is clean white sand where current and channel configuration dictate transportation conditions for finer particles and organic debris (Ellis et al. 2007). The finer materials, such as silt and clay and organic debris, are constantly transported downstream under the river current and tend to deposit in the lower reaches of the river near the SR484 bridge where the river widens and the channel definition has been changed by accretion deposits. In the lower river, the opportunity for disruptive high water events from interaction with the Withlacoochee River increases and mixed sediment strata are more common. This is reflected in deep, mixed organic-shelly-sandy strata. Since this area receives the settlement outfall from up-river transport, the net effect is a different sediment regime. This sediment regime is nutrient enriched from the phosphate contributory soils and organic debris settlement and less amenable to the growth and establishment of natural submerged aquatic vegetation communities. These loose, unconsolidated fine sediments appear more favorable to rapidly growing exotic vegetation communities.

2.5 Vegetation, Soils, and Transects

Eleven transect lines, including three PHABSIM and eight vegetation transects, were surveyed by PBSJ (Figure 2.5-1). Soil series distributions along transects were also determined by PBSJ (Figure 2.5-2) with detailed transect information in Appendix C. Hydric and muck soils occurred along all 11 study transects and in all vegetation classes except the hackberry upland. Only in the cypress swamp were exclusively hydric soils found. Median elevations of hydric soils were lower when compared with nonhydric soils. Elevation differences between hydric and nonhydric soils were smaller (0.6 feet to 0.8 feet) at two transects associated with shoals and larger (2.0 to 4.0 feet) at the two most upstream and two most downstream transects (PBSJ 2008).

River channel elevations ranged from 20.0 to 22.6 feet NGVD among the three upstream transects in the study corridor and from 19.8 feet NGVD to 23.6 feet NGVD at five transects along the middle reaches. Channel elevations decreased at the three downstream transects and ranged from 11.8 to 17.7 feet NGVD. The net decline in elevation along the study corridor from the most upstream transect (VEG 7) to the most downstream transect (below the borrow pit) was 2.6 feet over 5.7 miles (0.46 feet/mile). Median elevations along transects ranged from 22.6 feet NGVD to 28.3 feet NGVD (PBSJ 2008).

Differences in vegetation classes along the Rainbow River study corridor were significant based on importance values (IVs) that were calculated using tree species density and basal area and provided a relative measure of species dominance. Three vegetation classes were characterized as wetland classes, two as transition classes between wetlands and uplands, and one as upland vegetation. The three wetland classes could be differentiated based on dominance of cypress (*Taxodiuim distichum*), red maple (*Acer rubrum*), and ironwood (*Carpinus caroliniana*).

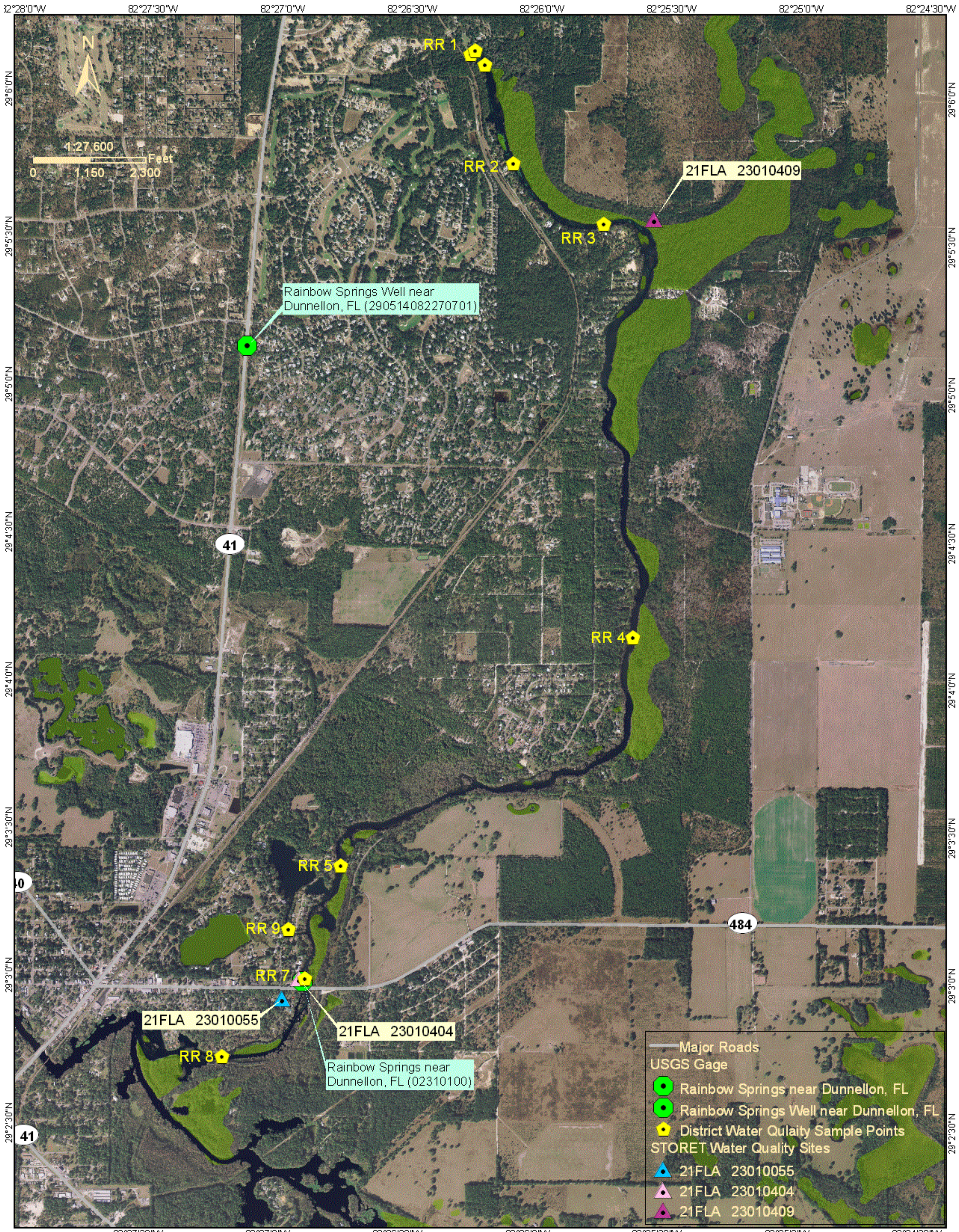

Figure 2.3-1. Water quality collection sites, Rainbow River, Marion County, Florida

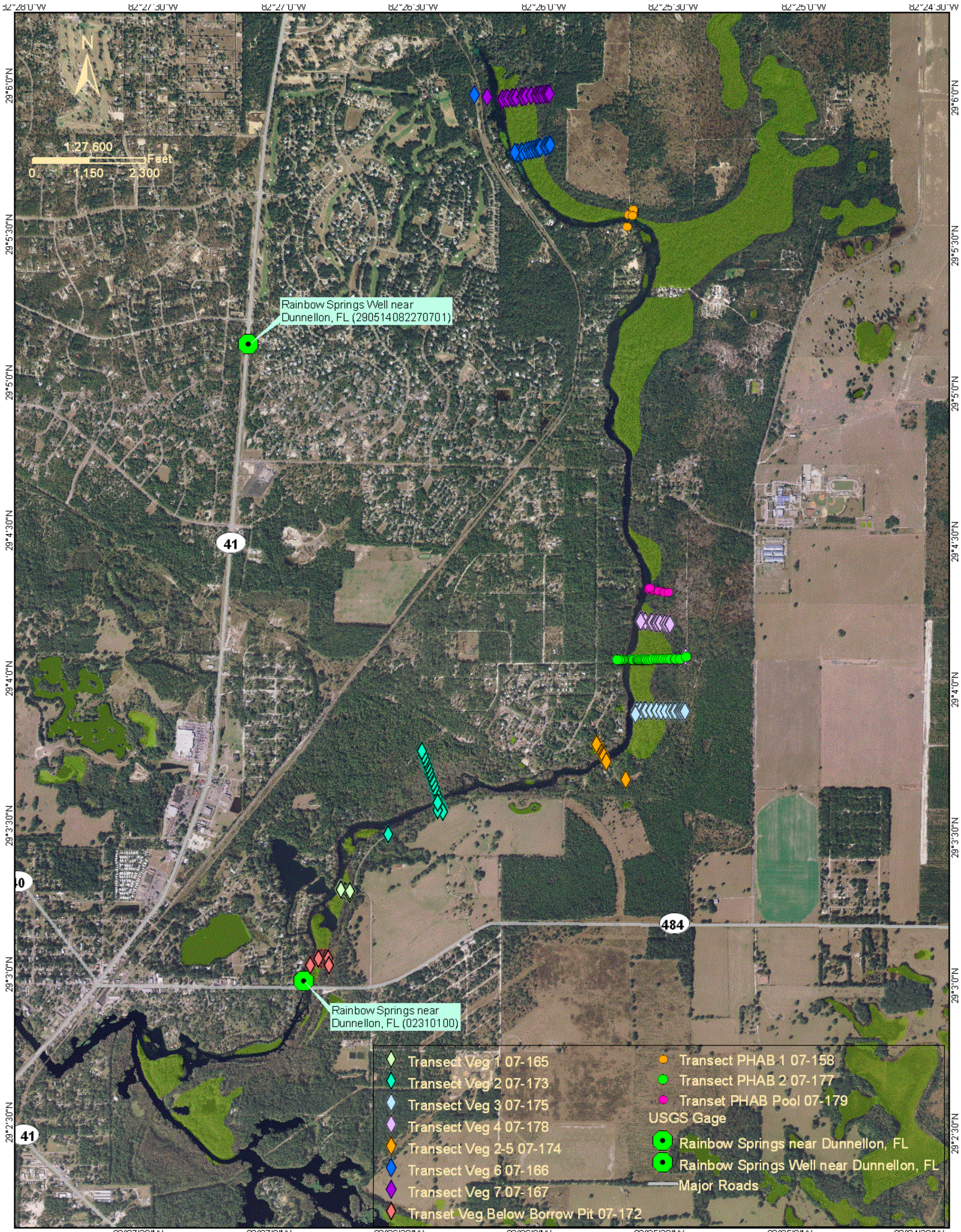

Figure 2.5-1. PHAB and vegetation transect lines, Rainbow River, Marion County, Florida

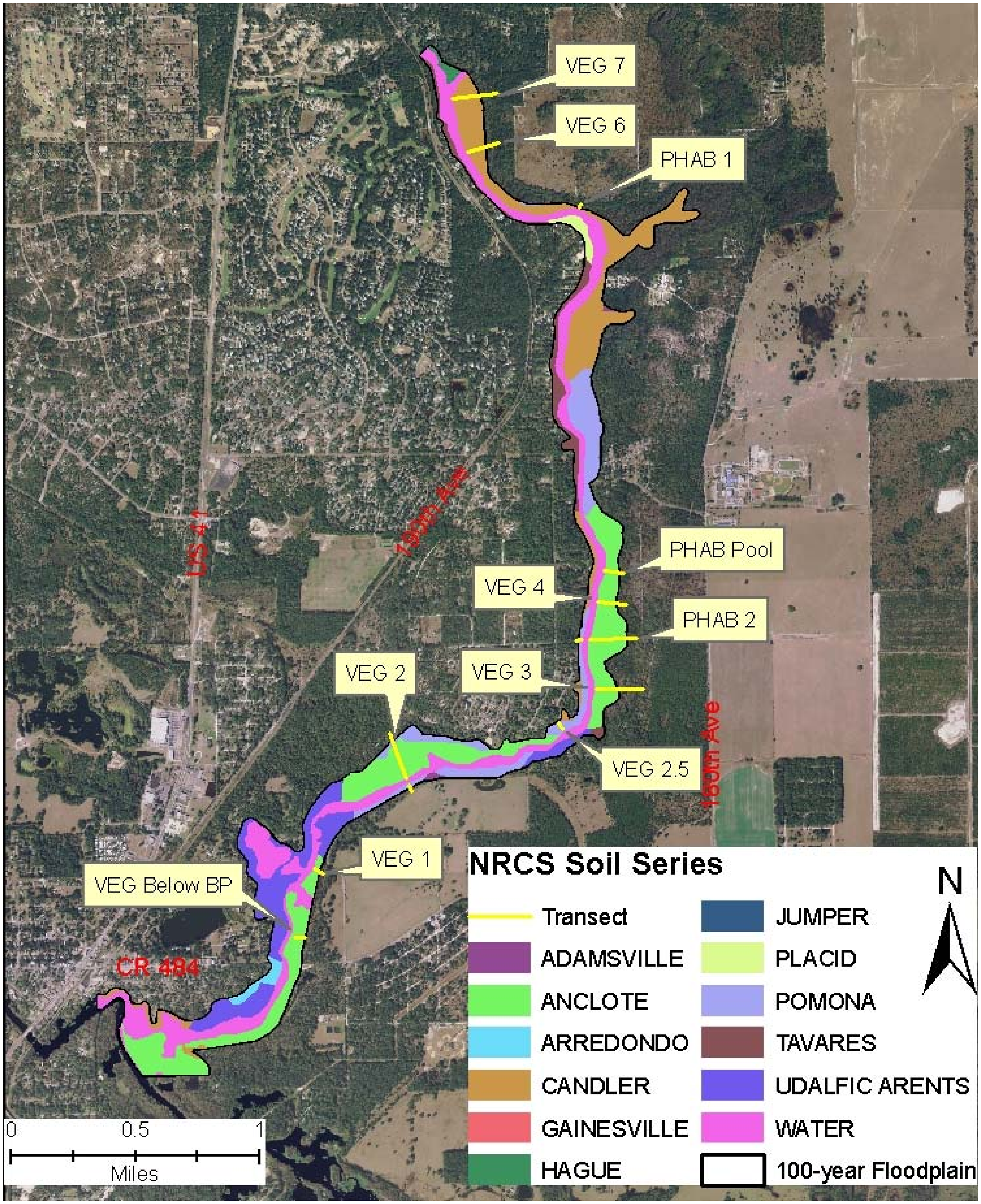

Figure 2.5-2. Transect locations and soils along the Rainbow River Study Corridor (PBSJ 2008)

References:

Ellis, G.D., Nash, K., Dean, J., and Martin, R. 2007. Rainbow River Sediment Study. A report submitted to the Southwest Florida Water Management District, 2379 Board Street, Brooksville, Florida 34605. October 2007.

Hand, J., Od, J., Tterlikkis, D., Jackson, J., Odom, R., Lord, L., and Clemens, L. 2000. Florida Water Quality Assessment: 305 (b) Report. Florida Department of Environmental Protection, Tallahassee, FL.

St. Johns River Water Management District (SJRWMD). 2004. Status and Trends in Water Quality in Selected Sites in the SJRWMD. Technical Publication SJ2004-3.

PBSJ. Draft. May 2008. Characterization of Woody Wetland Vegetation Communities along the Rainbow River. Submitted to Southwest Florida Water Management District. Submitted by PBSJ, 5300 West Cypress Street, Tampa, Florida 33607.

Pearman, J. 2008. Personal communication with James L. Pearman of USGS, July 10, 2008.

3.0 MINIMUM FLOWS AND LEVELS DEVELOPMENT

The specific method that was used to evaluate protection of the WRVs comes under the general heading of frequency analysis. This method parallels that used by the SJRWMD in implementing the MFLs, whereby the return intervals (i.e., number of events per 100 years) of hydrologic events that are biologically meaningful are evaluated (Neubauer et al. 2008).

Frequency analysis is commonly used in hydrology to indicate the probability of an event by evaluating the return period or recurrence interval of an extreme event (Bedient and Huber 1988). An annual event (e.g., a river's peak discharge during the water year) has a return period of T years if its magnitude is equaled or exceeded once, on the average, every T years. The reciprocal of T is the exceedance probability of the event, or the probability that the event is equaled or exceeded in any one year. Thus, a 25-year, 24-hour storm event has a probability of 0.04, or 4%, of being equaled or exceeded in any single year. Expressed another way, four such 24-hour storm events are expected to occur in a 100 year time period. It is assumed that the annual events are random and statistically independent. A relation based upon nonrandom data will have a degree of reliability attainable from a lesser sample of random data.

In this storm event example, three parameters are described or implied: the **magnitude** of the event (e.g., an annual maximum value that is equaled or exceeded or minimum value that is not equaled or exceeded), **duration** of 24 hours, and **return interval** of 25 years. These concepts are used extensively in flood frequency analysis but can also be applied to other aspects of river hydrology (e.g., low water events).

Each WRV may represent a broad class of functions, processes, and/or activities that require consideration of protection. To facilitate the process of determining if the proposed MFLs are protective of these classes of functions/processes/activities, a four-level hierarchical classification based on frequency analysis is used. This approach, similar to that used for wetland delineation (National Research Council 1995), starts with broad, general definitions and moves to more specific criteria of protection, then to general indicators of protection and, finally, to specific indicators of protection that can be measured and assessed.

Level	Descriptor of WRV Function, Process and Activity
1	Identify general **criteria** for each WRV that are specific to the water body being evaluated.
2	Identify a **representative function, process,** or **activity** that is very sensitive or possibly the most sensitive to changes in the return interval of high or low water events (defined by magnitude and duration components).
3	Identify a **general indicator** parameter for the protection of that function, process, or activity, such as river flow and/or depth. This indicator might include the appropriate definition of protection for either high or low water events that are directly related to each WRV.
4	Identify **specific indicator** parameter(s) for the protection of the river specific WRV in terms of magnitude (flow and/or water level), duration (number of days), and return interval. This criterion will include an assessment of the change in the number of events per 100 years under existing long-term hydrologic conditions and MFLs hydrologic conditions.

The guiding premise is that hydrologic processes that may affect the ten WRVs are event-driven (e.g., flood impacts on sediment transport) or can be characterized by extreme events (e.g., minimum annual stage impacts on navigation). **High flow (flood) -related WRVs** are considered to be protected if, under the proposed MFLs regime, the high flow event of a specified magnitude and duration **does not occur too infrequently** when compared to the high flow event frequency under long-term existing conditions. **Low flow (drought or drawdown) -related WRVs** are considered to be protected if, under the proposed MFLs regime, the low flow event of a specified magnitude and duration **does not occur too frequently** when compared to the low flow event frequency under long-term existing conditions. By using this approach, it is assumed that if the MFLs regime does not result in an unacceptable change at the most descriptive classification (Level 4 - **specific indicator**), then the broader, more general classification of function, process, or activity is protected.

The numerical comparisons are made between baseline conditions and long-term existing conditions (i.e., historic conditions) and with hypothetical reductions from baseline conditions of 2-, 5-, 7, 10-, and 15- percent of baseline flow. Stage discharge relationships were developed for the Rainbow River along the length of the river using HEC-RAS and then frequency tables of events of various durations were developed for the downstream boundary of the project reach (USGS Gauge for Rainbow River at Dunnellon) for baseline conditions, historical conditions, and the various percent withdrawal scenarios.

Because only the river hydrology is being altered under the withdrawal scenarios, frequency analysis clearly is ideal for assessments of WRVs that are directly impacted by river hydrology, such as navigation and fish passage. It also is posited that each of the WRVs can be evaluated by identifying key hydrologic conditions that are relevant to that WRV.

This hierarchical approach to MFLs classification was applied to each relevant WRV for the Rainbow River. The various levels of classifications are summarized in Table 3-1. The following example using WRV 1 (recreation in and on the water), discussed more fully in Section 4.1, is used an illustration.

Level	Descriptor of WRV1 Function, Process and Activity
1	Recreation in and on the water is defined as the active use of water resources and associated natural systems for personal activity and enjoyment. These legal water sports and activities include such things as swimming, floating or tubing, scuba diving, boating, and fishing. Illegal water sports and activities are precluded from consideration.
2	**Activities** sensitive to hydrologic alteration along this stretch of the river are swimming, **recreational tubing, and boating**. These activities are potentially impacted by **low flow events** to a much greater extent than they would be by high flow events.
3	This WRV will be protected if, under the proposed MFLs regime, the stage associated with minimum channel depth to allow tubing, for example, **does not occur too frequently** when compared to the frequency of this same low flow event under long-term existing conditions.
4	The **specific indicators** for this WRV are: a) discharge associated with rule-based required public bathing-based health criteria for the springbowl swimming area, b) stage associated with safe boating operation water depth of 3-feet, c) stage associated with boating propeller clearance of 1.5 feet, d) the hydraulic channel depth, under withdrawal scenarios, required for maintaining a 5-foot swimmer/tuber clearance allowing for the protection of submerged aquatic vegetation of the river.

A condition specified in 373.042 Florida Statute is that “best available information” shall be used to determine MFLs. HSW researched available information to support the selection of the specific indicator parameter(s) and duration(s) for the protection of each WRV. However, it must be emphasized that the conditions associated with the specific indicator parameters (and durations) will still occur, more or less frequently depending upon the MFLs. Also, while each WRV is considered in this evaluation, certain WRVs may be more or less relevant, based on physical conditions of the water body.

Discharge data were provided by the District for the USGS Rainbow River gauge near Dunnellon, FL located at the SR484 Bridge, which is the downstream boundary of the project area. The raw data are defined as historical data. The District also provided a data record that represents certain adjustments in flow as a result of groundwater withdrawals in the springshed. This adjusted data record is referred to as the baseline record. Extreme value data sets were generated from the discharge records for low flow (non-exceedance) and high flow (exceedance) events. For the low flow record, an annual event is the minimum flow that was not continuously exceeded for some defined duration (Figure 3-1) For the high flow record, an annual event is the maximum flow that was continuously exceeded for a specified duration (Figure 3-2). In this report, a change from the baseline condition to the historical condition (the actual discharge record) and reductions in flow of 2, 5, 7, 10, and 15 % were examined. Gamma cumulative probability functions were fit to each extreme value data set (Figures 3-1 and 3-2). A complete set of frequency plots on probability graphs are in Appendix B

The relevant analysis for evaluating WRVs is the change in the number of events per 100 years as a result of a reduction in flow from the baseline condition (Figures 3-3 and 3-4). For example, a one-day duration annual minimum event of 600 cfs occurs about 45 times every 100 years under baseline conditions and about 86 times per 100 years under a 15% flow reduction scenario, or a change in the number of events of about 41 per 100 years.

The relative change in the number of events is defined as the change in the number of events as a result of a flow reduction from baseline divided by the baseline number of events. For example, the 600 cfs one-day minimum event is increased by about 90 percent (Figure 3-5) when flow is reduced by 15 percent. For low flow infrequent events (i.e., extreme low flows), the relative increase in the number of events can be quite substantial with the maximum relative change approaching infinity. These events rarely occur and even a small absolute increase results in a large relative change. For low flow events, the relative increase in the number of events decreases with increasing flow. For extreme maximum events (i.e., extreme high flows), the relative decrease in the number of events increases with flow, but is much less pronounced when compared to the low flow events because the maximum relative decrease can only be 100 percent.

The period of record over which the frequency evaluations were made is only 42 years. Events that are estimated to occur less than 10 times in 100 years are those events that occurred about 4 times over the period of record. For this reason, key events for each WRV that occur less than 10 years out of 100 (or once every 10 years) should be viewed cautiously.

The District developed a HEC-RAS model of the Rainbow River. HSW used the HEC-RAS model results to develop stage, discharge, velocity, hydraulic depth, and other hydraulic parameters at all HEC-RAS cross-sections along the river, including at the USGS gauge at the SR 484 Bridge (see Figure D-1 in Appendix D). Key hydraulic metrics at the various cross-section locations were then associated with flow at the critical cross sections and translated to the corresponding flow at the SR 484 Bridge. In this way, the frequency of occurrence of a particular event at a particular cross section along the river could be determined by relating to the frequency data at the USGS gauge.

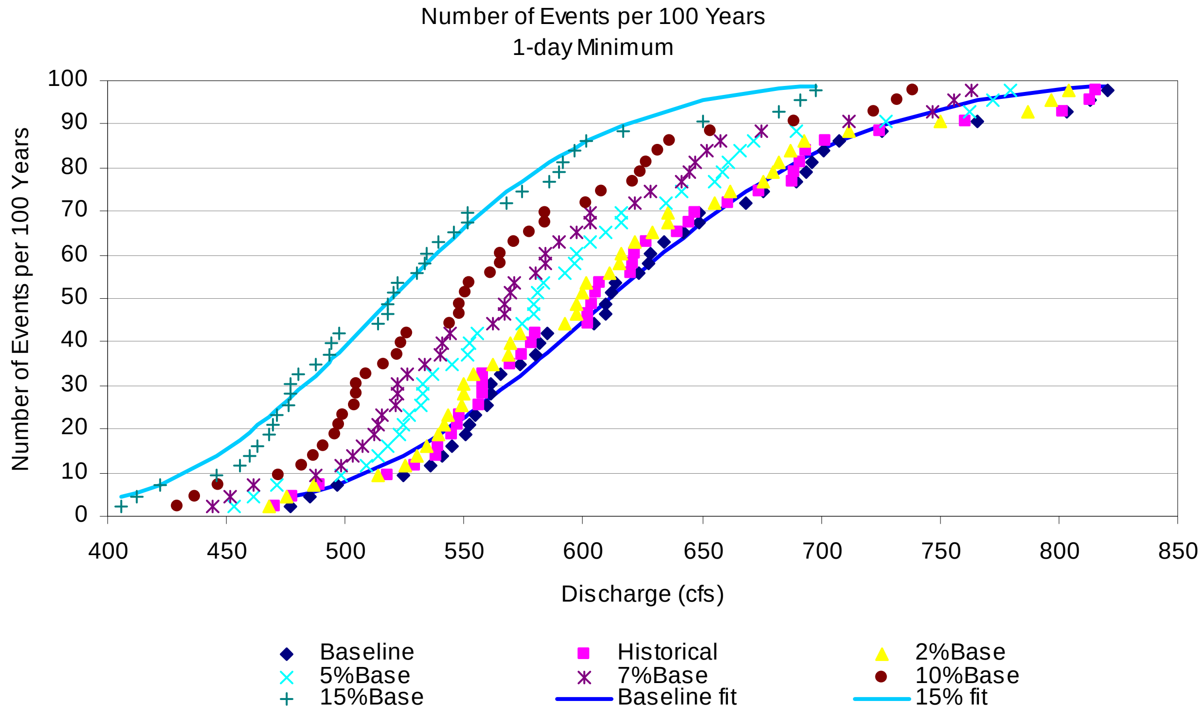

Figure 3-1. Low flow one-day duration frequency curves

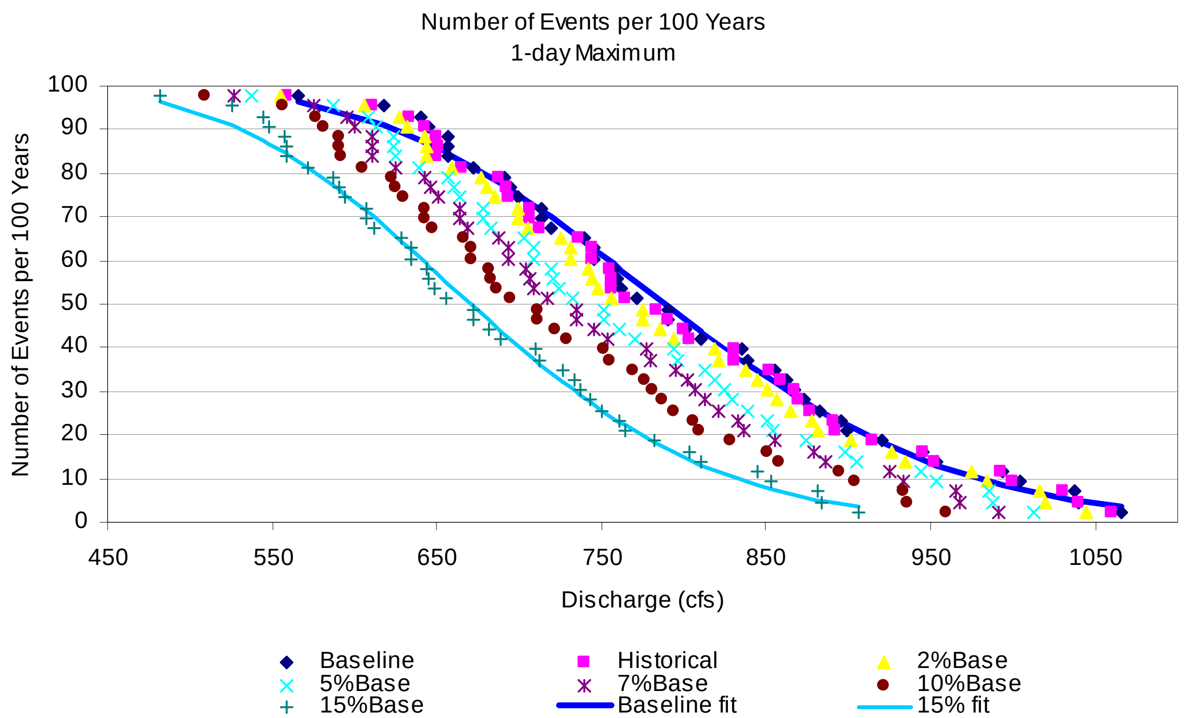

Figure 3-2. High flow one-day duration frequency curves

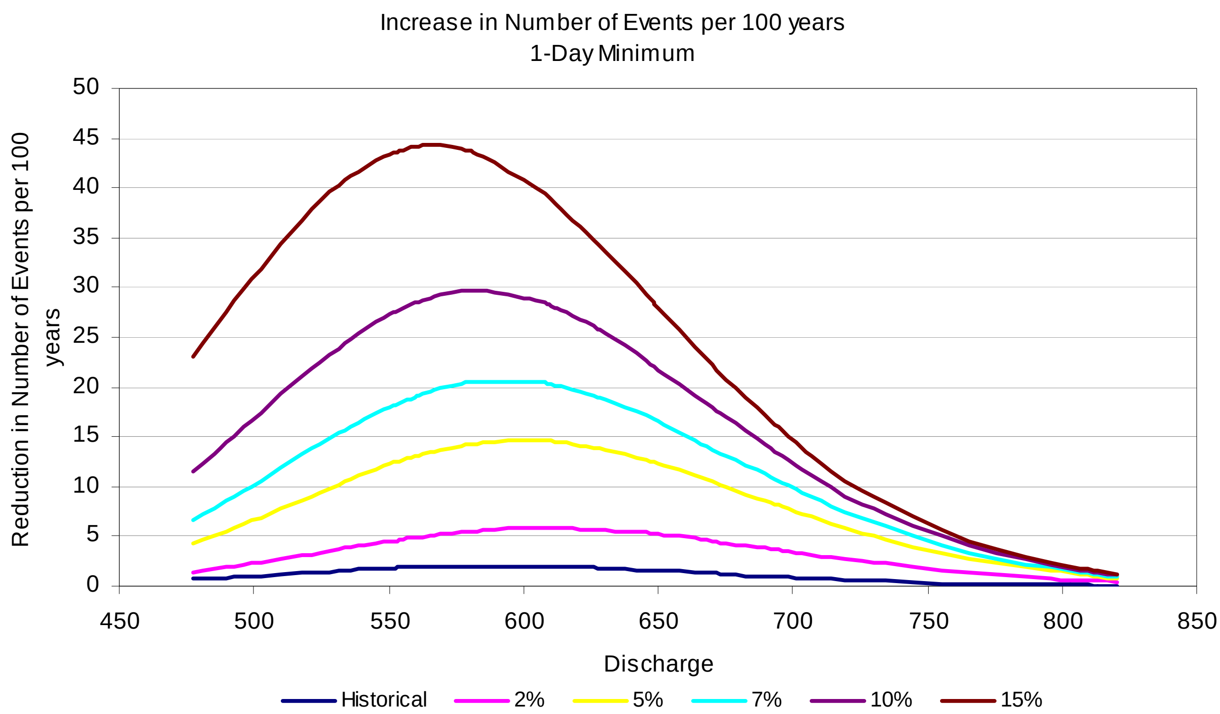

Figure 3-3. Change in one-day low flow events

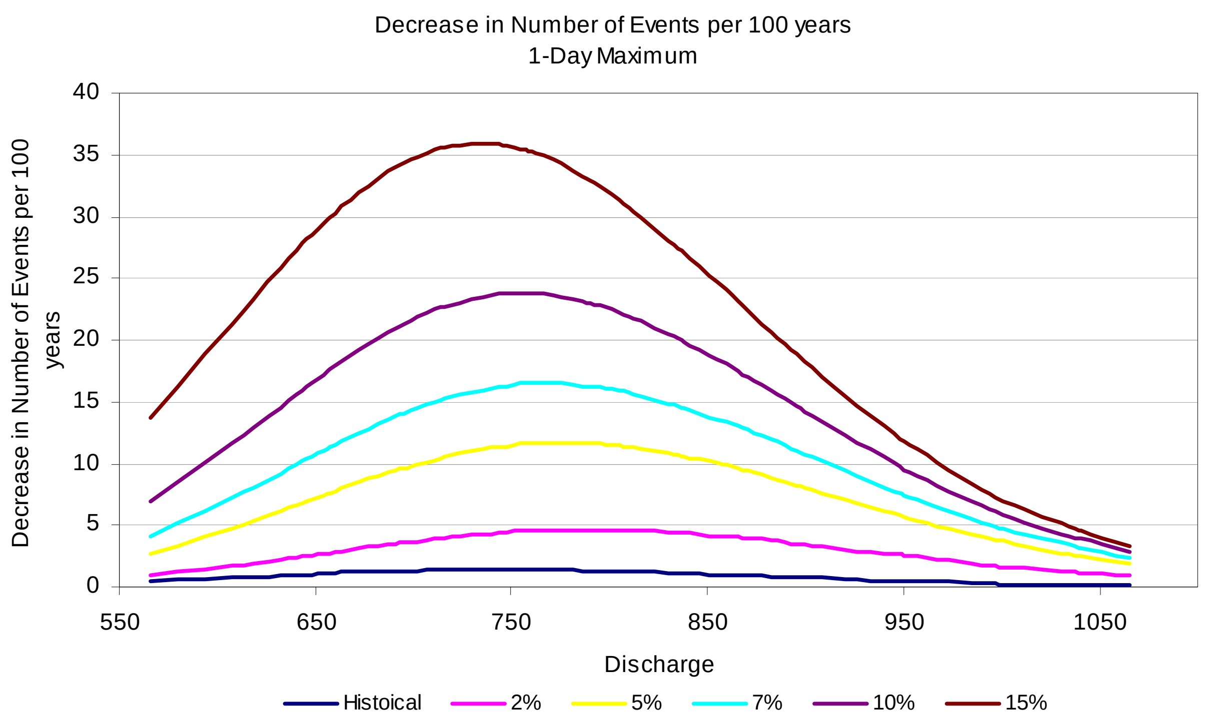

Figure 3-4. Change in one-day high flow events

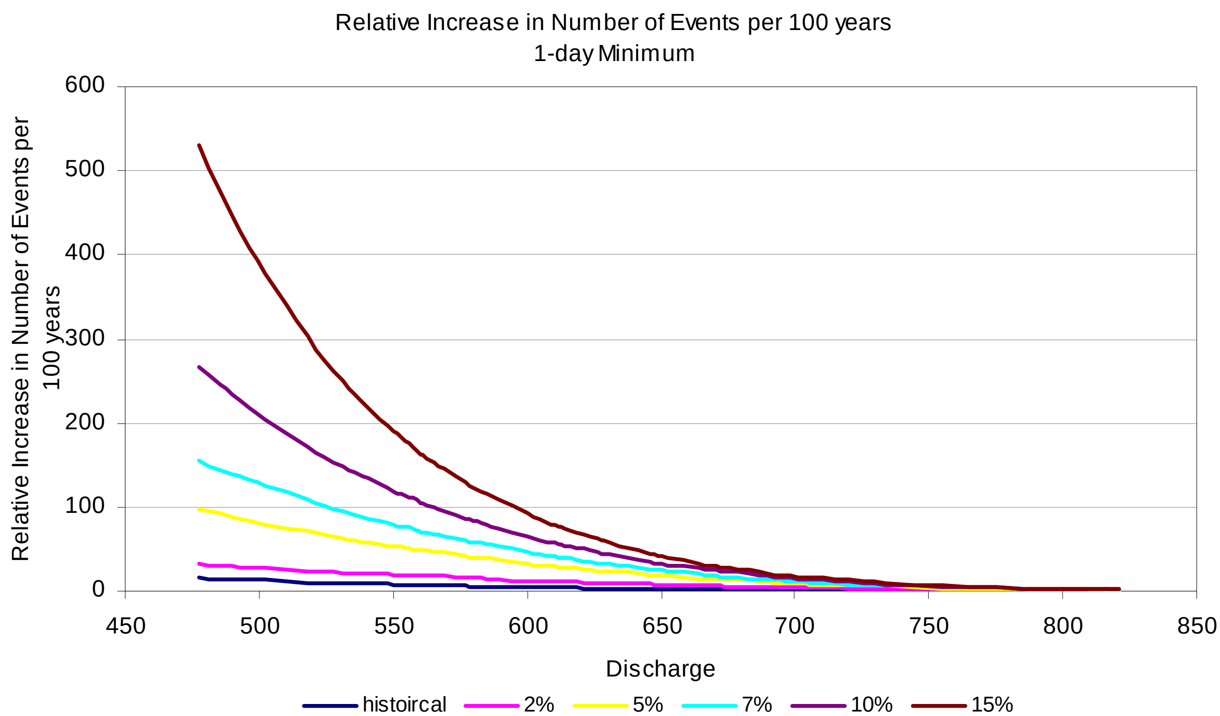

Figure 3-5. Relative Change in one-day low flow events

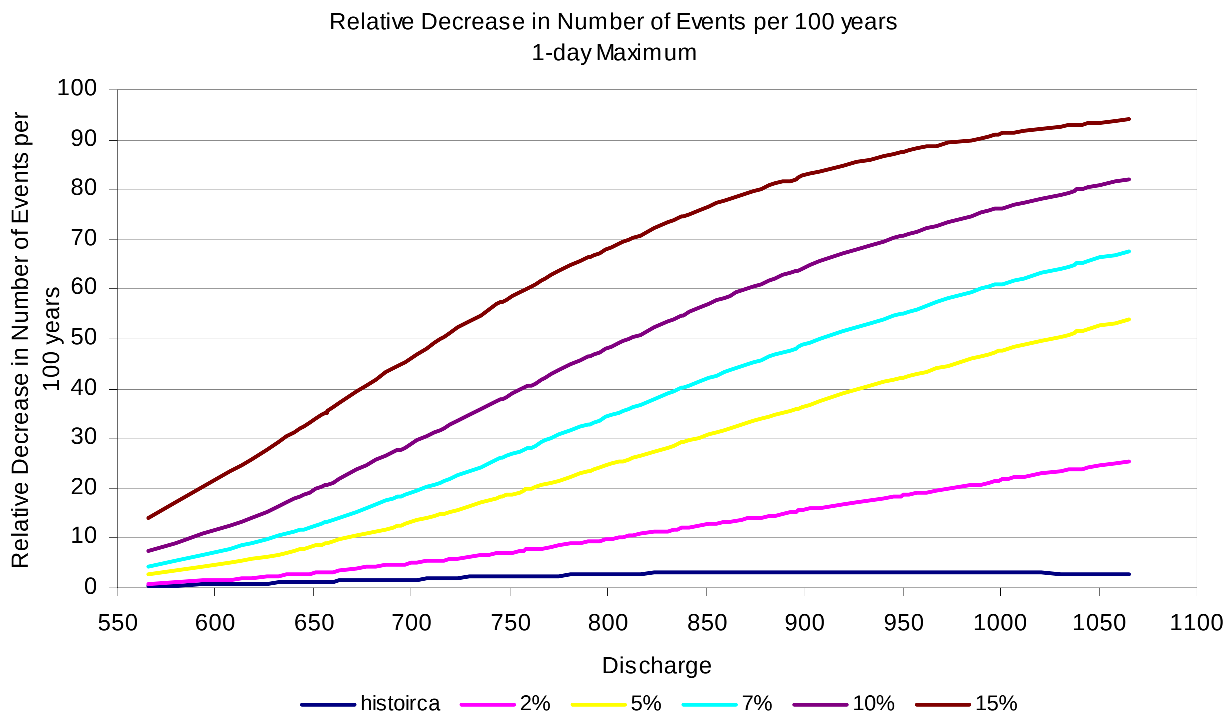

Figure 3-6. Change in one-day high flow events

Table 3.1. Hierarchical classifications for evaluating the WRVs for the Rainbow River

WRV	Classifications			
	Criteria	Function, Process, or Activity	General Indicator	Basis for Specific Indicator
1. Recreation In and On the Water	Legal water sports and activities	Recreational swimming, tubing, boat passage	Carrying capacity and water depth required for safe recreational boat and swimmer passage that does not impact submerged aquatic vegetation	Discharge associated with public bathing-based health criteria, stage associated with minimum channel depth for boat access/propeller clearance, and hydraulic channel depth required for swimmer/tuber clearance
2. Fish and Wildlife Habitat and the Passage of Fish	Aquatic and wetland environments required by fish and wildlife	Fish passage for a large fish species (e.g., Largemouth bass, bowfin, gar or sunfish) and habitat requirements for fish and wildlife	Floodplain access/inundation and fish passage in the main channel	Stages associated with water depths to allow passage of large fish, floodplain inundation for sufficient durations to allow small fish recruitment, and water depth within floodplain to maintain existing vegetative zones/habitats
3. Estuarine Resources	Coastal systems and associated natural resources	Salinity fluctuations in the estuary	Not applicable	Not applicable
4. Transfer of Detrital Material	The transfer of loose organic material	Detrital supply and distribution	Stage of the river	Stage associated with water depth and floodplain connectivity for transfer of detrital material into suspension
5. Maintenance of Freshwater Storage and Supply	Current permitted quantity of surface water and groundwater	The maintenance of adequate surface water and aquifer levels in the area adjacent to the water withdrawals	Stage that protects surface water and aquifer levels that do not result in adverse impacts	Types of existing surface and groundwater withdrawals, historical aquifer levels, and evaluation as to whether the groundwater-surface water interactions will change as a result of MFL to the extent that existing permitted withdrawals will result in new low pressure levels in the aquifer

Table 3.1. Hierarchical classifications for evaluating the WRVs for the Rainbow River (continue)

6. Aesthetics and Scenic Attributes	Passive recreation	Visual setting of river at selected points	Stage of the river	Stage associated with optimal scenic and wildlife viewing
7. Filtration and Absorption of Nutrients and Other Pollutants	The process of absorption and filtration	Concentration and load of key nutrients	Maintenance of stage and inundation of floodplain and residence time in system.	Stage associated with riparian vegetation connectivity and hydraulic residence time.
8. Sediment Loads	Transport of inorganic materials	The maintenance of fine sediment transport	Changes in stage, velocity, and bed shear stress	Stages associated with velocity and shear stress necessary for sediment mobilization and transport
9. Water Quality	Chemical and physical properties of the water	Ability of water to assimilate chemical constituents, which affect aquatic community health	Key water quality characteristics influenced by stage that affect community health	Stages that maintain key water quality characteristics similar to baseline conditions
10. Navigation	Legal operation of eco-tourism and commercial fishing vessels	Commercial watercraft access and passage	Not Applicable	Not Applicable

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4.0 EVALUATION OF WATER RESOURCE VALUES

4.1 WRV-1: Recreation In and On the Water

Florida and water-based recreation are synonymous around much of the world, and a major portion of the State's economy depends on water-based recreational activities (Marine Industries Association of Florida 2004; American Sportsfishing Association 2004; Southwick Associates 2008). To evaluate the impacts of water withdrawals on recreational activities associated with the Rainbow River, recreation in and on the water is defined as the active use of water resources and associated natural systems for personal activity and enjoyment. Activities of a more passive nature, such as wildlife viewing from boats, are discussed in Section 4.6 (WRV-6: Aesthetic and Scenic Attributes). The **criteria** for protection of this WRV are "legal water sports and activities."

The primary recreational activities in and on the water of Rainbow River include but are not limited to swimming, snorkeling, boating, canoeing, kayaking and tubing. These activities within the river run involve physical contact with the water and some require access using some type of vessel that requires draft clearance. Therefore, recreational swimmer safety, boat passage, and swimmer/tuber clearance are the **representative functions** used to assess protection of this WRV. The **general indicator**s of protection are the carrying capacity for bathing-based health criteria and the depth of water needed to allow for safe recreational boat and non-destructive swimmer passage. The **specific indicators** for this WRV are: a) discharge associated with rule-based required public bathing-based health criteria for the springbowl swimming area, b) stage associated with a safe boat launch water depth of 3-feet, c) stage associated with boating propeller clearance of 1.5 feet, d) the hydraulic channel depth, under withdrawal scenarios, required for maintaining a 5-foot swimmer/tuber clearance allowing for the protection of submerged aquatic vegetation of the river.

From the headwater area to the confluence area with Withlacoochee River at Dunnellon (Figure 4.1-1), the Rainbow River runs about 5.7 miles with a depth ranging from about 4 to 25 ft and a channel width ranging from 60 to 220 ft (Grand Park 2008). Water temperature stays at about 72 ºF year round. Rainbow River is a valuable aesthetic, recreational, and economic resource to the local area and the entire state, attracting over 220,000 visitors each year (Pridgen *et al.* 1993; SWFWMD 2004). The Rainbow Springs and River primarily serve as a tourism attraction. Nevertheless, a number of rules are in place to prohibit tubing, swimming, snorkeling, and motors within 1,800 ft of the headsprings to prevent injury and uprooting of water plants (The Rainbow River 2009). Motorboats are not allowed within the park boundary in any way to anchor, land, or drop passengers other than at the designated canoe dock. Fishing is prohibited within the entire headsprings area but is allowed in the rest of the river. Boats can be launched at either KP Hole County Park or the Rainbow Springs Campground, both of which are about 1.5 miles downstream from the state park (Figure 4.1-1).

Figure 4.1-1. Recreational area and activities in Rainbow Springs and River (Florida State Parks 2009)

Carrying capacity was considered in some swimming areas as a public bathing-based health criteria. Chapter 64E-9.013 FAC requires at least 500 gallons per anticipated bather per day unless the bathing area is 2 acres and more. Numerous vents discharge on average 400 to 600 million gallons of water daily (mgd) in the headwater area (SWFWMD 2004) and provide sufficient discharge for the anticipated visitors per year (Figure 1-3). Even if half of the 220,000 recreators per year swam together on one day, only 55 mgd would be required for that population that day. This is only a fraction (approximately 14% of the minimum daily discharge) of the average vent discharge of 400 to 600 mgd. Therefore carrying capacity will not be an issue for Rainbow River under any of the MFL scenarios, so additional frequency analysis was not performed on this metric.

Yingling (1997) compiled information on boating safety and recreational use indicating 3 to 4 ft of water at the toe of a boat ramp is the minimum recommended for boat launching. Wagner (1991) reported that for boats with outboard motors, a minimum of 3 ft of water is usually recommended for safe operation. However, this general recommendation needs to be viewed in light of the fact that the largest motorized boats observed on Rainbow River are pontoon or fishing charter boats. Pontoon boats may have a length of as much as 30 feet, pontoon diameter of approximately 25 inches, width of as much as 10 feet and require a draft of less than 1.5 ft (Leslie and Sherwood 2009, Evo 2009). Typical 18 to 20 foot fishing boats on this river draw around 15 inches (HSW 2007, Leslie and Sherwood 2009, Skeeter 2009). Based on HEC-RAS modeling results (Table D-1 in Appendix D), even at the 42-year historic low of 477.3 cfs, water depth in the channel does not go below a depth of 3.5-ft along the study reach from just downstream of the springhead to the bridge at SR 484. None of the flow reduction scenarios would result in a channel depth of less than 3 ft, so additional frequency analysis was not performed on this metric.

Safe boating operation also includes adequate propeller clearance of typical vessels on the Rainbow River. Typical fishing and pontoon propeller engine shaft lengths run from 20 to 25 inches (Iboats 2009). This length includes the boat transom height above the water which means propeller clearance below the hull would be considerably less. As a result, a water depth of 1.5 feet for outboard motor clearance between the bottom of these vehicles and the channel bottom should be adequate and is an appropriate metric for evaluating WRV-1. None of the flow reduction scenarios would result in a channel depth of less than 3 ft, therefore, additional frequency analysis was not performed on this metric. HEC-RAS data modeled below the 42-year historic low of 477.3 cfs (Table D-1 in Appendix D) indicate that between the river mouth and

1,800 feet downstream from the headsprings, the shallowest reach exists in the river run at river mile 2.08 with a maximum channel depth of 5.66 feet (at a river stage of 28.26 feet, flow rate of 412.9 cfs), which still provides clearance of more than 1.5 ft. Additionally, tubes, kayaks and canoes used on the river have lengths of about 9 to 16 ft, but require only a few inches of water depth to navigate. Since this low flow extreme has not been experienced, it is safe to assume that the main channel depth will allow for propeller clearance and safe passage.

The spring and river run remain popular for recreational use from June through April (with some time off around September when students return to school; phone conversation with rental shop on March 26, 2008). Mumma et al. (1996) found a significant correlation between damaged submerged aquatic vegetation and upstream recreational activity. The damaged plants were positively and significantly correlated to the number of power boats, canoes, and tubers. By protecting the submerged aquatic vegetation, recreational activities of swimming and floating/tubing down the river could be preserved and protected. Tubers typically drift down the river either draped across a tire inner tube or dangling the full extent of their legs from the middle of the tube while holding on. The average person is approximately 5.5 feet tall. Taking into account the length of extremity, the possibility of using fins, and the length of the submerged aquatic vegetation, a maximum hydraulic depth of 5 feet should minimize damage to the aquatic vegetation. The hydraulic depth (flow area divided by the channel width at water surface elevation) was used to approximate the average channel depth. This measure not only takes into account the main river channel, but also the shallower edges.

To examine the extent various MFL withdrawal scenarios are expected to reduce the frequency of maintaining a hydraulic depth of 5 feet in the river during low flow, HEC-RAS was used to determine areas where it was likely the stage would go below that swimmer/tuber clearance depth required to protect the submerged aquatic vegetation and therefore protect recreational use of the river. Reductions in water elevations under historical and 2%, 5%, 7%, 10%, and 15% withdrawal scenarios were examined with respect to these 8 locations (Table 4.1-1). One extreme location at river mile (RM) 5.02, near the headspring, was used to demonstrate that even at baseline, this location will always (99.9 times per 100 years) be shallower than the required 5 foot clearance. Therefore, under 2% and 15% withdrawal scenarios for a 1-day and 7-day duration, this location will continue to be shallower than 5 feet (100 events per 100 years will go shallower than 5 feet for all scenarios). Damage is always occurring at this location and withdrawing additional water will not worsen this condition.

The 1-day and 7-day durations correspond to high intensity boating and swimming/tubing events during the highest use times reported in July and September (Mumma 1996) and an extended period typical of summer vacations corresponding to average use over the tourist season. Given that the vegetation could recuperate from the swimmer/tuber damage of a 1-day event, the longer 7-day event also is considered for protecting SAV.

For locations where baseline 1-day low events occur more frequently than once very ten years, the increase in the number of event ranges from about 2 to 6 events per 100 years for a 2 % withdrawal scenario. The upper range increases to about 15 more events per 100 years for a 5 % withdrawal scenario. The results for the 7-day duration are very similar. For a longer duration frequency of 7 days, the vegetation is less likely to recuperate from repeated damage by vacationing swimmers/tubers. Based on these data, a flow reduction up to 5 percent would remain protective of the metric for this WRV.

Table 4.1-1. Frequency and duration parameters for WRV-1 under baseline and MFL scenarios

HEC-RAS Station	Discharge (cfs)		Baseline	Historical	Percent flow reduction from Baseline 2%	5%	7%	10%	15%
				1- Day Duration					
		Events[1]	99.9	99.9	100	100	100	100	100
5.02	931	Difference[2]		0.0	0.0	0.0	0.0	0.1	0.1
		RPD[3]		0.0	0.0	0.0	0.0	0.1	0.1
		Events	10.7	12.0	13.5	18.7	22.9	30.5	45.8
4.63	512	Difference		1.3	2.8	8.0	12.2	19.7	35.1
		RPD		11.7	25.8	74.2	113.6	183.7	326.8
		Events	41.4	43.4	47.1	56.1	62.1	70.8	83.5
3.63	593	Difference		2.0	5.7	14.6	20.7	29.4	42.1
		RPD		4.9	13.8	35.4	49.9	71.1	101.7
		Events	13.4	14.8	16.6	22.5	27.2	35.4	51.4
3.11	522	Difference		1.4	3.2	9.1	13.9	22.0	38.0
		RPD		10.6	24.1	68.4	103.5	164.5	283.9
		Events	8.1	9.1	10.3	14.6	18.3	24.9	39.2
2.33	500	Difference		1.1	2.2	6.6	10.2	16.8	31.1
		RPD		13.1	27.9	81.7	126.7	209.1	386.5
		Events	22.0	23.8	26.4	34.0	39.7	48.9	65.1
1.98	548	Difference		1.8	4.4	12.0	17.7	26.9	43.1
		RPD		8.2	20.0	54.6	80.5	122.6	196.3
		Events	94.0	94.4	95.7	97.5	98.3	99.2	99.8
1.55	753	Difference		0.3	1.6	3.4	4.3	5.1	5.7
		RPD		0.4	1.7	3.7	4.6	5.4	6.1
		Events	3.5	4.1	4.6	7.0	9.2	13.4	23.9
0.77	470	Difference		0.6	1.2	3.6	5.7	10.0	20.4
		RPD		17.2	33.5	102.6	164.5	286.8	586.8
				7- Day Duration					
		Events[1]	99.9	99.9	100	100	100	100	100
5.02	931	Difference[2]		0.0	0.0	0.1	0.1	0.1	0.1
		RPD[3]		0.0	0.0	0.1	0.1	0.1	0.1
		Events	9.4	10.5	11.9	16.7	20.6	27.7	42.6
4.63	512	Difference		1.2	2.5	7.3	11.2	18.3	33.2
		RPD		12.4	26.8	77.8	119.8	185.6	354.4
		Events	38.3	40.3	43.9	52.8	58.9	67.9	81.3
3.63	593	Difference		2.0	5.6	14.5	20.6	29.6	43.0
		RPD		5.3	14.6	37.9	53.8	77.4	112.5
		Events	11.8	13.1	14.7	20.2	24.6	32.4	48.1
3.11	522	Difference		1.3	3.0	8.4	12.9	20.7	36.3
		RPD		11.3	25.1	71.8	109.4	175.6	308.5
		Events	7.0	7.9	9.0	12.9	16.2	22.4	36.1
2.33	500	Difference		1.0	2.0	5.9	9.3	15.5	29.1
		RPD		13.9	28.9	85.4	133.2	222.1	418.2
		Events	19.7	21.4	23.8	31.1	36.6	45.6	62.0
1.98	548	Difference		1.7	4.1	11.4	16.9	25.9	42.3
		RPD		8.7	20.9	57.7	85.6	131.7	214.5
		Events	92.9	93.3	94.8	96.9	97.9	98.9	99.7
1.55	753	Difference		0.4	1.9	4.0	5.0	6.0	6.8
		RPD		0.4	2.0	4.3	5.4	6.5	7.3
		Events	2.9	3.5	3.9	6.1	8.0	11.8	21.5
0.77	470	Difference		0.5	1.0	3.1	5.0	8.9	18.5
		RPD		18.1	34.5	106.6	172.0	302.9	631.5

1. Number of events per 100 years
2. Difference between number of events for flow scenario and baseline
3. Relative percent difference defined as the change in the number of events per 100 years divided by the baseline number of events times 100

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4.2 WRV-2: Fish and Wildlife Habitats and the Passage of Fish

For this report, fish and wildlife habitats are **defined** as those aquatic and wetland environments required by fish and wildlife – including endangered, endemic, listed, regionally rare, recreationally or commercially important, or keystone species – to live, grow and migrate. These environments include hydrologic conditions that affect the life cycles of wetland and wetland dependent species, including the passage of fish. Aspects of fish and wildlife that pertain to human recreation and aesthetics are examined under WRVs-1 and -6 (Sections 4.1 and 4.6). Water quality parameters, such as dissolved oxygen (DO) and temperature, which may affect fish habitat under low flow conditions, are addressed under WRV-9 (Section 4.9).

Fish, vegetation and other biological field work on the Rainbow River has been undertaken by Henigar and Ray (1987), DNR (1991), Water and Air Research (1991), Mumma et al. (1996), USGS (2003), Huestis and Meylan (2004), and PBS&J (2008) among others. No additional quantitative field research on fish passage or wetlands was conducted as part of HSW's work effort. HSW has used the best information available and noted that additional research may be necessary to establish site-specific life history requirements for some species discussed in the analysis.

The **criteria** for the assessment of the protection of this WRV are "aquatic and wetland environments required by fish and wildlife." The **representative function** used to assess protection is fish passage for a large species such as a largemouth bass, bowfin, gar, or sunfish, plus habitat requirements for fish and wildlife. The **general indicator** of protection is floodplain access/inundation and fish passage in the main channel as defined by water depth. The **specific indicators** are stages associated with (a) water depth sufficient to allow passage of the larger-bodied fish species within the main channel at selected hydraulic control points for representative durations; (b) water depth for inundation of floodplain for sufficient durations to allow for recruitment of smaller species of fish, access to turtle species for basking, and foraging by wading birds; and (c) water depth within the floodplain to maintain existing vegetative zones (habitats).

Inglis Dam was constructed across the Withlacoochee River in 1909 and created Lake Rousseau (Downing *et al.* 1989). Located adjacent to the dam is Inglis Lock, which was constructed by the U.S. Army Corps of Engineers and completed in 1969 as part of the former Cross Florida Barge Canal. These structures provide at least a partial impediment to fish populations downstream of the confluence of the Rainbow and Withlacoochee Rivers. These structures also provide a barrier to upstream movement of West Indian manatees (Florida State Park at Rainbow Springs, personal communication 2009) and a significant impediment to anadromous/catadromous species of fish.

The Rainbow River System is a relatively intact portion of the Withlacoochee River Basin, supporting a broad variety of flora and fauna that could potentially be affected by a reduction in surface water discharge. The floodplain in the Rainbow River study area is at least partially contiguous with the river. The seasonal variability of water levels within this river basin is typically much less pronounced than in riverine systems not dominated by spring flows and groundwater flows. The Rainbow River exhibits one of the smaller yearly and maximum-minimum water flow ranges of any river within the District. Annual variations in water levels are usually less than 1 foot, and the difference between the maximum and minimum recorded stage is only about 2.6 feet. The maximum and minimum recorded flows at the SR 484 bridge transect station are approximately 1,100 cfs to 475 cfs or about a factor of 2. Many rivers within the District have a range of flows that varies by two orders of magnitude (for example, the Alafia River with a minimum recorded flow of 4.1 cfs and a maximum recorded flow of 40,800 cfs at Lithia; SWFWMD 2005).

The narrow range of water depths and the small range of river flows are attributable to the fact that the Rainbow River is dominated by groundwater rather than surface water contributions. This dominance by groundwater flows affects not only the river itself but the fringing floodplain wetlands. Comparison of river elevations provided by SWFWMD (2008) with floodplain wetland elevations provided in PBS&J (2008) indicate that much of the fringing wetlands appear to seldom, if ever receive inundation from the river itself. Munson (personal communication 2009) posited that the groundwater is helping maintain wetland conditions within these floodplain wetlands. River elevations at high flows are within 0.5- to 1- foot of many of the median wetland elevations as reported in PBS&J (2008) which will assist in maintaining adequate soil moisture regimes within the wetlands. Maintaining the higher flows and stages along the Rainbow River therefore is important to the continued health of these floodplain wetland systems. Since groundwater elevations also play a crucial role in the maintenance of these floodplain wetlands the entire Rainbow River system is sensitive to reductions in groundwater levels.

Permanent water persists within the main river channel along the entire length of the river, even in the driest years and seasons, due to the input from Rainbow Springs and the groundwater system. Native and non-native invertebrate and vertebrate wildlife species occur in the Rainbow River (see Henigar and Ray 1987; FDNR 1991; Water and Air Research 1991; USGS 2003). Wildlife occupies niches and unique habitats or combinations of habitats, to provide food, cover, and space, including suitable home ranges and territories.

4.2.1 Fisheries

Based on data presented in Henigar and Ray (1987), FDNR (1991) and USGS (2003), 30 species of fish have been identified as occurring in the Rainbow River (Table 4.2-1). The majority of the species are considered freshwater species (exceptions include the striped mullet and the Atlantic needlefish; note the gizzard shad can effectively reproduce and thrive in landlocked systems) and none are federally listed species (USFWS 2009). Page and Burr (1991) report total length for largemouth bass at 97 cm. While the Florida gar and bowfin can grow to greater lengths than the largemouth bass, body depth for a largemouth adult bass can be up to 29% of body length, making the largemouth bass the deepest bodied of the fish (11 in) (FISHBASE 2009). None of the species of fish listed have an absolute requirement for flowing water to complete their life cycles, but several of the species (e.g. coastal shiner, spotted sunfish, redbreast sunfish, Florida gar) are often found in flowing water systems and/or prefer sand bottom habitats (characteristic of flowing water). Some of the freshwater species listed in Table 4.2-1 utilize very shallow water along and within the wetland fringes of the river to complete their life cycles. Several examples include topminnows such as the golden topminnow, the least killifish, and the mosquito fish. The characteristics of floodplain inundation at high flow conditions play a factor in the reproductive success rates for these species.

The “storage effect” is defined as the ability of populations to “store” production of strong year classes until environmental conditions become favorable. The storage effect is likely most beneficial to highly fecund species that are long-lived or have multiple spawning events during the year (Warner and Chesson 1985). Because fish populations generally are resilient to short periods of poor spawning conditions, they can survive occasionally adverse water level conditions. Rogers and Allen (2004) have suggested that criteria to help ensure the continued viability of fish populations under MFLs scenarios should focus on the periodicity and duration of low flow events, and that special attention should be given to limiting the frequency of low flow events in order to prevent sequential years of adverse effects on fish populations. Low river stages negatively affect fish communities by reducing fish abundance. The threshold used to set withdrawal limits should consider life history attributes and stage durations less than the generation time for most species (Hill and Cichra 2002a). Unfortunately, much of these data are not available for species using this portion of the river.

Table 4.2-1. Fish species occurring in the Rainbow River

Common Name	Scientific Name	Common Name	Scientific Name
Thread fin shad	Dorosoma petenense	Coastal shiner	Notropis petersoni
Gizzard shad	Dorosoma cepediamum	Redeye chub	Notropis harperi
Golden topminnow	Fundulus chrysotus	Pirate perch	Aphredooderus sayanus
Mosquito fish	Gambusia affinus	Brookside silverside	Labidesthes sicculus
Flagfish	Jordanella floridae	Inland silverside	Menidia beryllina
Least killifish	Heterandria Formosa	Seminole killifish	Fundulus seminolis
Brown bullhead	Ictalurus rebulosus	Bluefin killifish	Lucania goodei
Yellow bullhead	Ameiurus natalis	Tadpole madtom	Noturus gyrinus
Florida gar	Lepisosteus platyrhincus	Bluegill	Lepomis macrochirus
Sunfish	Lepomis spp.	Warmouth	Lepomis gulosus
Large-mouth bass	Micropterus salmoides	Yellow bullhead	Ictalurus natalis
Sailfin molly	Poecila latipinna	Golder shiner	Notemigonus crysoleucas
Redear sunfish	Lepomis microlophus	Lake chubsucker	Erimyzon sucetta
Spotted sunfish	Lepomis punctatus	Bowfin	Amia calva
Redbreast sunfish	Lepomis auritus	Okefenokee pygmy sunfish	Elassoma okefenokee

Fish use of habitats adjacent to the main river channel and movement onto the floodplain during periods of high water vary inter-specifically (Toth 1991, 1993). Several alternative ecological paradigms have been developed to describe the response of fish assemblages to water level. The flood-pulse and river continuum concepts emphasize the importance of floodplains to river productivity and fish population maintenance. The riverine productivity model suggests that within-channel productivity is more important than allochthonous (from outside the aquatic system) inputs where floodplain inundation is unsynchronized with spawning or nutrient cycling.

High flows have been correlated with fish abundance, particularly small-bodied species, in Florida marshes (Toth 1991, 1993; DeAngelis *et al.* 1997; Jordan *et al.* 1998); however, seasonally flooded marshes may retain stranded fishes and produce a net negative demographic balance (Poizat and Crivelli 1997). Conversely, low water levels (associated with drought or drought simulating conditions) often decrease fish populations (DeAngelis *et al.* 1997; Jordan 1998). To maintain this diverse fish assemblage, water level regimes should regularly satisfy temporal and spatial reproductive requirements for channel-dependent species and for smaller species dependent on shallow and deep marshes and wet prairies (Hill and Cichra 2002a, b). These smaller fish species can complete a reproductive cycle within approximately 30 days.

Some species spawn so that the fry and juveniles hatch and grow out in the marshes and swamps of the floodplain; others respond inversely (Graff and Middleton 2002). Populations of some small fishes increase dramatically during high flows, then decrease just as dramatically during low or drought flows. As water levels drop during the dry season, floodplain fish populations retreat to the main stream channel or become concentrated in shrinking floodplain pools. If a proposed MFL provides for the necessary stages within the main river channel to allow for passage of the largemouth bass, then all the other fish species that utilize the river channel for passage also will likely be protected. If the proposed mid to high stage MFLs provide for the necessary floodplain inundation for the completion of the life cycles of the topminnows, killifish and mosquito fish, then the fish habitat component will be protected. If the proposed MFLs continue to provide adequate water velocities, then those species of fish that prefer moving water to complete their life cycles will be protected.

Periods of very low stage and flow are not conducive to high success rates for fish passage. A component of this WRV evaluation is the degree to which various withdrawal scenarios result in changes in the frequency of low flow events that inhibit fish passage. Thompson's (1972) study on minimum depth criteria for passage of fish has been widely used throughout Florida in assessing MFLs. However, given that Thompson's work was based upon dissimilar fish species and streams (large salmon such as Chinook salmon in cold, well oxygenated water), some fishery resource managers in the State of Florida (Gary Warren, FWC, personal communications, 2004) have cautioned against the direct use of Thompson's minimum depth range (0.6 ft – 0.8 ft) for Florida rivers and streams. HSW (2007) employed a safety factor of 2 to Thompson's 0.8 ft criteria when assessing MFLs within a different portion of the St. Johns River. SWFWMD does not usually apply a safety factor in the utilization of their methodology. For the Rainbow River analysis, we have elected to utilize the 1.6 ft. minimum depth, as a conservative approach.

Table 4.2-2. Hydraulic depths and associated baseline flows at 47 HEC-RAS cross sections

HEC-RAS station	Hydraulic Depth (ft)	Baseline Flow (cfs)	Hydraulic Depth at 15% Reduced Baseline Flow (ft)	HEC-RAS station	Hydraulic Depth (ft)	Baseline Flow (cfs)	Hydraulic Depth at 15% Reduced Baseline Flow (ft)
5.02	3.48	207.0	3.19	2.37	4.29	406.9	4.03
4.93	7.13	214.4	6.99	2.33	4.8	407.7	4.54
4.76	8.95	226.9	8.75	2.08	3.94	412.9	3.71
4.63	4.83	237.3	4.65	1.98	4.66	414.9	4.44
4.48	4.92	345.9	4.86	1.95	4.69	415.6	4.47
4.37	6.31	257.3	6.05	1.85	4.83	417.6	4.64
4.25	3.76	280.9	3.74	1.66	5.25	421.5	5.07
4.18	7.61	272.3	7.3	1.55	4.09	423.7	3.93
4.05	3.55	282.3	3.32	1.45	6.2	425.6	6.05
3.88	8.45	295.2	8.15	1.32	4.85	428.3	4.71
3.81	6.69	300.3	6.63	1.22	5.91	430.2	5.84
3.75	5.22	305.1	4.92	1.11	7.61	432.7	7.49
3.63	4.36	314.6	4.1	0.91	7.65	436.8	7.54
3.48	4.76	326.4	4.48	0.83	5.93	438.5	5.85
3.31	6.5	338.9	6.19	0.77	4.96	439.6	4.87
3.19	4.51	348.8	4.2	0.67	7.83	441.7	7.73
3.11	4.69	354.3	4.37	0.56	7.26	443.9	7.18
3.02	4.61	362.0	4.31	0.38	5.49	447.5	5.42
2.98	6.35	365.1	6.04	0.25	5.62	450	5.6
2.90	5.7	370.9	5.39	0.17	6.69	450	6.67
2.83	5.57	376.7	5.29	0.06	6.78	450	6.77
2.69	5.29	387.3	5	0.02	5.54	450	5.54
2.56	5.62	397.3	5.33	0.00	6.29	450	6.29
2.46	6.6	405.2	6.33				

These HEC-RAS model results indicate that even at the lowest flow ever recorded within the Rainbow River, maximum and average channel water depths remain several times greater than the 1.6 foot critical stage depth selected for fish passage requirements (Table 4.2-1). Even a 15% reduction below the lowest recorded flow on the Rainbow River would result in maximum and average depths safely greater than the 1.6 minimum depth for fish passage. Fish passage within the main channel of the Rainbow River would not be compromised under any of the MFL scenarios examined.

With respect to those species of fish that utilize the floodplain areas to complete their life cycle requirements, higher stages within the river should continue to allow for partial inundation of some of the floodplain and/or provide water elevations that remain within 1.0 foot of the median wetland elevations, for periods of at least 30-day duration (one reproductive cycle of those fish species utilizing the floodplain (Breder and Rosen, 1988)). To examine to what extent various MFL scenarios are expected to reduce the frequency of inundation of at least a portion of the floodplain wetlands, HEC-RAS was used to determine critical elevations of floodplain wetlands at 4 transect locations which, according to data provided in PBS&J (2008), occasionally experience inundation from the river itself.

Transects RM 4.93 (near the headwaters) and Transect RM 0.06, near the mouth, are inundated to the median elevation of the wetland 7.5 times and 5.3 times out of every 100 years respectively under baseline conditions (Table 4.2-3). As discussed in section 3, the relative change in very infrequent events (i.e., less than 10 years out of 100) needs to be viewed cautiously. The absolute changes in the number of events per 100 years is 3.7 and 2.7, although the relevant change in frequencies is roughly 50% under a 5% withdrawal scenario (Table 4.2-3).

At transects RM 1.98 and RM 0.91, inundation events are reduced from 42 and 44 times out of 100 years to 30 to 32 times every 100 years under a 5% withdrawal scenario. While a withdrawal scenario (5%) that reduced the number of events per 100 years by 50% might often be unacceptable, the actual vertical distance of the water surface declines resulting from a 5% withdrawal scenario is small (about 0.2 feet).

For such a groundwater dominated system, it also is prudent to consider, at least qualitatively, the affect of the different withdrawal scenarios on the groundwater potentiometric and water table elevations. Groundwater withdrawals (the more likely scenario compared with a surface water withdrawal) would not only reduce water elevation regimes in the Rainbow River itself (with possible impacts to the floodplain systems), but the contribution from the groundwater system to maintain these floodplain wetlands also will potentially be reduced. Therefore, the relative frequency of occurrence declines noted to inundate floodplain wetlands at a 5% withdrawal scenario (Table 4.2-3) would potentially compounded. There currently is insufficient information on water table and Floridan Aquifer water level regimes to quantify this potential impact.

In addition to flow and stage, dissolved oxygen (DO) is an important factor for fish survival in the Rainbow River. This parameter as it relates to water quality is discussed under WRV-9 (Water Quality). Based on available DO data, there appears to be no correlation between DO concentrations and stage. In addition, the DO levels in the Rainbow River system are consistently at levels which meet state standards. Given the overall high DO concentrations regardless of flows, DO does not appear to be a limiting factor for fish nor a stage-sensitive metric for examination, therefore DO is not further evaluated for this WRV.

Table 4.2-3. Frequency and duration parameters for WRV-2 under MFL scenarios

Wetland (HEC-RAS station)	Critical Discharge (cfs)		Baseline	Historical	Percent flow reduction from Baseline				
					2%	5%	7%	10%	15%
			30-Day Duration						
Maple Hardwood Hammock (4.93)	978	Events[1]	7.5	7.5	5.9	3.9	2.9	1.7	0.6
		Difference[2]		0.0	1.7	3.7	4.7	5.8	6.9
		RPD[3]		0.7	22.0	48.4	62.0	77.2	91.6
Cypress Swamp (1.98)	800	Events	41.7	41.0	37.1	30.3	26.0	19.9	11.6
		Difference		0.7	4.6	11.4	15.7	21.7	30.1
		RPD		1.7	11.0	27.3	37.7	52.1	72.2
Cypress Swamp (0.91)	791	Events	44.2	43.4	39.5	32.6	28.2	21.9	13.0
		Difference		0.7	4.7	11.6	16.0	22.3	31.2
		RPD		1.7	10.5	26.2	36.3	50.5	70.7
Maple Hardwood Hammock (0.06)	1006	Events	5.3	5.3	4.0	2.6	1.8	1.1	0.4
		Difference		0.0	1.3	2.7	3.4	4.2	4.9
		RPD		0.3	23.7	51.4	65.1	79.8	93.1

1. Number of events per 100 years
2. Difference between number of events for flow scenario and baseline.
3. Relative percent difference defined as the change in the number of events per 100 years divided by the baseline number of events times 100.

Fisheries data (FISHBASE 2009) suggests that some of the species (i.e. coastal shiner, spotted sunfish, redbreast sunfish, Florida Gar) are commonly found in flowing water systems, hence water velocities may be important to examine. None of the freshwater species of fish present in the Rainbow River appear to require flowing water to complete their life cycles. In the absence of site-specific information related to minimum current velocities “preferred” by the local fish populations in the Rainbow River, we relied upon the HEC-RAS model results (Appendix D, Table D-1) that span a wide range of flows at many locations on the river. Detailed frequency analyses of changes in occurrence of critical velocities under different MFL scenarios are provided in WRV-8. From those analyses, it appears that at many transect locations, reductions in frequency of occurrence of a velocity of at least 0.6 ft/sec are relatively small (for example, at RM 0.56, frequencies of 30 day durations were only reduced from 96.3

times per 100 years under baseline conditions to 83.4 times per 100 years under the 15% withdrawal scenario. Regardless of a starting baseline flow and transect location selected from the HEC-RAS analysis (Appendix D Table D-1), even a 15% reduction from baseline flow does not translate into greater than a 0.05 ft/sec decrease in velocity for that 15% reduction in flow. Given this information, we conclude that velocity reductions do not appear to be an important metric within the Rainbow River for the range of MFL scenarios being considered.

4.2.2 Floodplain Wetlands and Hydric Soils

The indicator for protection of floodplain wetland (and therefore wildlife habitat protection) is the evaluation of floodplain community types under baseline and MFL withdrawal scenarios. Reductions in wetland hydroperiods can result in changes to species composition and structure of wetland communities (USGS 2002, SWFWMD 1996). The SJRWMD has developed the Surface Water Inundation/Dewatering Signature (SWIDS) system that defines a distribution of frequencies or return intervals for various duration flooding and dewatering events for each wetland community type. SJRWMD has utilized the drier to driest SWIDS to establish MFLs that should not result in any downward shifts in wetland communities caused by water withdrawals.

Mean threshold minimum elevations for different floodplain wetland vegetation and hydric soils were developed based on transect measurements made by PBS&J (2008) (Table 4.2-3). Minimum and maximum stream flows from 1930 to 2007 (USGS Well 29051408227071 at Dunnellon) were 538 and 1,060 cfs, respectively. The average difference in flows between wet and dry season is approximately 10% of the historic average (PBSJ 2008). Seasonal water level changes at the head springs of the Rainbow River (USGS 2009) average about 0.72 feet for the period of record.

For the Rainbow River, floodplain wetland systems are inundated very infrequently and even then it appears that high groundwater elevations play a role in maintaining these floodplain wetlands. Consequently, our analysis for the inundation of the floodplain as a means of ensuring continued wetland health is the same as used for the maintenance of fish habitat in the floodplain system (inundation to the median wetland type elevation for 30 day duration). While a 30-day duration may not be sufficient to maintain a cypress wetland system in most river systems, it is clear from the baseline analyses that the cypress swamps along the Rainbow River are inundated for 30 days less than 50 years out of 100 under baseline conditions, underscoring the importance of the groundwater contribution. Modeling of longer durations (such as 180 days for cypress swamp inundation) results in such small occurrences per century even under baseline conditions as to be non-useful. A 30 day inundation period is sufficient to consider an area a wetland, and to maintain hydric soil indicators (FDEP 2000). As described in the previous section, a 5% withdrawal scenario results in a substantial reduction in return frequencies of inundation per 100 years.

Table 4.2-4. Median elevation (ft-NGVD) of vegetation classes along select Rainbow River transects

Transect		HEC-RAS Station (river mile)	Cypress Swamp	Maple Hardwood Hammock	Ironwood Hardwood Hammock	Lowest Median Hydric Soil Elevation
Downstream Upstream	Veg 7	4.93	-*	31.3	32.7	31.8
	Veg 6	4.63	-	32.0	-	31.8
	PHAB 1	4.05	-	-	-	-
	PHAB Pool	2.46	-	-	-	-
	Veg 4	2.33	-	-	31.7	30.8
	Veg 3	1.98	29.4	-	31.6	30.3
	Veg 2.5	1.66	-	29.1	-	29.3
	Veg 2	1.11	28.4	29.4	-	28.8
	Veg 1	0.38	-	29.2	-	29.3

* - indicated information not available

The elevation of various wetland community types and hydric soil indicators (Table 4.2-4) and a representative sample of the change in the frequency of inundation events (Table 4.2-3) provide a conceptual substitute for the SWIDS approach. Initially, the median elevations of different wetland communities of cypress swamp, maple hardwood hammock, ironwood hardwood hammock; as well as transitional communities of laurel oak mix, laurel oak/pine upland and the upland community of hackberry uplands were evaluated as these elevations compared with river stages under multiple flow scenarios (Appendix D Table D-1, HEC-RAS results). Only cypress swamp and maple hardwood habitats are periodically inundated, and for only a few of the vegetation transects. Lowest median hydric soils elevations at these vegetation transects (PBS&J

2008) are always at a higher elevation than is the lowest median wetland elevation, hence are inundated less frequently under baseline conditions than the wetlands identified in Table 4.2-3.

Four wetlands were used to examine impacts from different withdrawal scenarios (Table 4.2-3). Withdrawals greater than 5% will decrease the frequency of events substantially, notably in the Cypress Swamp. The actual vertical differences between any given baseline stage and a 5% withdrawal scenario are only on the order of 0.2 feet.

4.2.3 Usage of Floodplains by Wading Birds

In general, colonial nesting water bird breeding success appears to be correlated to low water levels during nesting, when forage availability increases as fish become concentrated in small areas (Hodgson, Audubon Coastal Sanctuaries, personal communication 2007). It is advantageous for wading birds to obtain fishes in temporarily isolated marshes and sloughs. To the extent that declining levels in the main river will tend to make foraging easier, wading birds would not be impacted from lower stage events within the river, as long as these events do not adversely impact the recruitment of those fish species that rely upon the channels for that function. Most species of wading birds are able to forage for fish and invertebrates in up to 6 to10 inches (0.5 to 0.8 ft) of water, depending on bird size. Those smaller fish species that comprise a large part of the diet of these birds, and which reproduce within the floodplain, could easily swim in water depths of less than 0.5 ft.

Of the 67 bird species that occur on and around the Rainbow River cited in past literature (see Henigar & Ray 1987), four are federally listed species (USFWS 2009). Of those four (i.e. Everglade snail kite, Florida scrub-jay, Wood stork, and Red-cockaded woodpecker), the Wood stork is of most concern since it is a wading bird species. Other birds that forage along the shores of the Rainbow River that are on the State’s list include the Little blue heron, Tri-colored heron, Snowy egret, Limpkin and Bald eagle (DNR 1991).

In Section 4.2.1, inundation events in different wetland systems along and adjacent to the river banks under the MFL scenarios were examined. To the limited extent that the small decreases under the MFL withdrawal scenarios might serve to better concentrate fish in isolated pools, the efficiency of wading bird feeding may be enhanced. The baseline frequency of occurrence of an inundation to the median wetland elevations at the four locations listed in Table 4.2-3 is considered to be optimal for the Rainbow River with respect to wading bird foraging.

Under the 5% withdrawal scenario, there will be reductions in the frequency of occurrence of the optimal inundation scenario as described in sub-section 4.2-1. With a small vertical change in stage reduction predicted (approximately 0.2 ft) under the 5% MFL scenario, the reduction of foraging habitat will be small. Wading birds will still be able to forage much of the same wetland habitat areas under the 5% MFL scenarios as they have under the baseline scenario with little change in the actual water level regime (Appendix D Table D-1, HEC-RAS).

4.2.4 Other Factors for Consideration

Huestis and Meylan (2004) reported on a 13 year effort on the Rainbow River involving 8 species of freshwater turtles. They noted shift towards smaller species when compared with an earlier study at the same locality. However, over the duration of their study, sizes of River cooter (*Pseudemys concinna)* and the Peninsula cooter (*P. floridana)* populations appeared to increase (though not to the levels of six decades previously). The authors suggest that these size increases may reflect enhanced levels of protection. Growth rates appear to be strongly seasonal. Given the relatively constant water temperature and abundant food, the authors suggest that basking behaviors may limit growth, and the availability of basking sites may be critical to the health of the population. This last finding was considered potentially relevant to the MFL analysis, in that MFLs should be protective of shoreline basking sites (not lower water levels to a point where favored basking sites are out of reach). This question was posed to Dr. Peter Meylan (Meylan personal communication 2009). Dr. Meylan did not express concern over a decrease in accessibility of basking sites under the MFL scenarios, but did express concern over possible increases in turtle mortality from motor boat propellers coming closer to the bottom habitats used by the turtles (Dr. Meylan and co-workers maintain a database of evidence of scarring of turtle shells). The maintenance of adequate water depths for boat traffic is examined in WRV-1.

4.2.5 Summary

Fish passage in the main channel of the river, inundation of floodplain area for small fish reproduction, floodplain wetland inundation for continued wetland viability, floodplain inundation as it relates to usage by wading birds and freshwater turtles were all examined as part of WRV-2. The hydraulic depths within the main channel throughout the length of the river are sufficient to continue to allow for fish passage of the largest fish species under all proposed withdrawal scenarios. However, withdrawal scenarios of greater than 5% may not be protective of the floodplain habitat on the Rainbow River. For the 5% withdrawal scenario, a 50% reduction in inundation frequency is calculated for maple hardwood hammocks and reduction of about 25% is calculated for the cypress swamps. This finding also is applicable to use of the floodplain by small species of fish to complete their life cycle requirements and for the use of floodplain habitats by wading birds for foraging

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4.3 WRV-3: Estuarine Resources

An estuary is a partially enclosed body of water along the coast where freshwater from rivers and streams meet and mix with salt water from the ocean (EPA 2008). The Rainbow River is located upstream of Lake Rousseau, which is a 5.7-mile long, human-made impoundment formed by the Inglis Dam near the city of Inglis (FDEP 2005). The structures controlling flow from the reservoir are part of the Cross-Florida Barge Canal facilities that were built between January 1965 and December 1969 (FDEP 2005). The control facilities at the west end of Lake Rousseau and westward to the Gulf of Mexico remain authorized and operational. Therefore, it is reasonable to conclude that the Rainbow River is a freshwater resource. No additional evaluation is provided for this WRV.

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4.4 WRV-4: Transfer of Detrital Material

The term "detritus" has different meanings, depending on the field of study. For this analysis, the transport of detritus is defined as the movement by water of loose organic material and debris and associated decomposing biota. The organic particles consist of microbially altered vegetation, including leaves and wood, and the particles are consumed as high quality food by organisms living in the stream. In other contexts, detritus may refer to either inorganic or organic disintegrated matter. In this report, inorganic constituents are discussed under WRV-8.

The **criterion** for protection will be "the transfer of loose organic material." The **representative function(s)** used to assess protection are detrital supply and distribution associated with flood plain inundation. **General indicators** of protection will be water stage to maintain detrital transfer to the Rainbow River. **Specific indicators** of protection will be the number of events per 100 years of flow associated with water depth and area of inundation necessary for adequate detrital transfer to the water column that does not differ unacceptably from baseline conditions.

The Rainbow River is a swift flowing spring run that is dominated by well to moderately well sorted medium to fine sand (Ellis et al. 2007) over a majority of its length. According to the Rainbow River Sediment Study (Ellis et al 2007), "clear quartz sand" and "clear quartz sand mixed with woody detritus" are overwhelming the most common occurring sediment types found in the core samples. Detritus in the samples is from adjacent riverine swamps, from seasonal floodplain inundation, and from overhanging vegetation. Detritus can be transferred into a stream from the floodplain during both low and high water events. Total detrital transfer to the stream itself also depends on the season and vegetative growth; however, this effect is difficult to quantify and would require additional study beyond the scope of evaluating protection of this WRV.

The Rainbow River has three classes of wetland vegetation adjacent to the river channel, Cypress Swamp, Maple Hardwood Hammock, and Ironwood Hardwood Hammock as demonstrated by the vegetation cross-sections in Chapter 2 (PBSJ 2008). Unlike stormwater run-off dominated systems, the spring fed dominated Rainbow River receives 98% of its discharge from groundwater and does not experience significant water level fluctuations (PBSJ 2008). The cypress swamps immediately adjacent to the channel in the lower two miles of the river represent the only wetlands that are permanently or semi-permanently inundated with the remaining hardwood swamps only seasonally inundated and receiving much of the their moisture from groundwater capillarity (Munson 2009).

A summary of vegetation transect information can be found in Table 4.4-1 including the mean elevations of the cypress swamp and the hardwood hammocks (PBSJ 2008). The transects are listed from upstream to downstream with the location identified in Figure 2-10. Table 4.4-1 also includes the nearest corresponding HEC-RAS cross-section station in river miles (as depicted in Figure D-1 in the Appendix D) and the elevation of the wetted perimeter breakpoint.

Table 4.4-1. Median elevation (ft-NGVD) of vegetation classes and wetted perimeter breakpoint along the Rainbow River Transects

Transect		HEC-RAS Station (river mile)	Cypress Swamp	Maple Hardwood Hammock	Ironwood Hardwood Hammock	Wetted Perimeter Breakpoint
Upstream	Veg 7	4.93	-*	31.3	32.7	30.9
	Veg 6	4.63	-	32.0	-	31.2
	PHAB 1	4.05	-	-	-	32.3
	PHAB Pool	2.46	-	-	-	30.7
	Veg 4	2.33	-	-	31.7	30.9
	Veg 3	1.98	29.4	-	31.6	30.1
	Veg 2.5	1.66	-	29.1	-	29.1
	Veg 2	1.11	28.4	29.4	-	28.7
Downstream	Veg 1	0.38	-	29.2	-	29.2

* - indicated vegetation classification not present

A water surface elevation of 30.9 ft-NGVD will cause the river to rise over its banks and begin to inundate the floodplain (Figure 5.4-2). As such, water levels above 30.9 ft-NGVD will correspond to large increases in wetted perimeter (the portion of the channel that is inundated or wet) for modest increases in water surface elevation. This is the physical phenomena depicted in Figure 4.4-3 and the break in the curve is the wetted perimeter breakpoint elevation listed in Table 4.4-1 (30.9 ft-NGVD for VEG 7 Transect) and marked with a blue arrow in Figure 4.4-3..

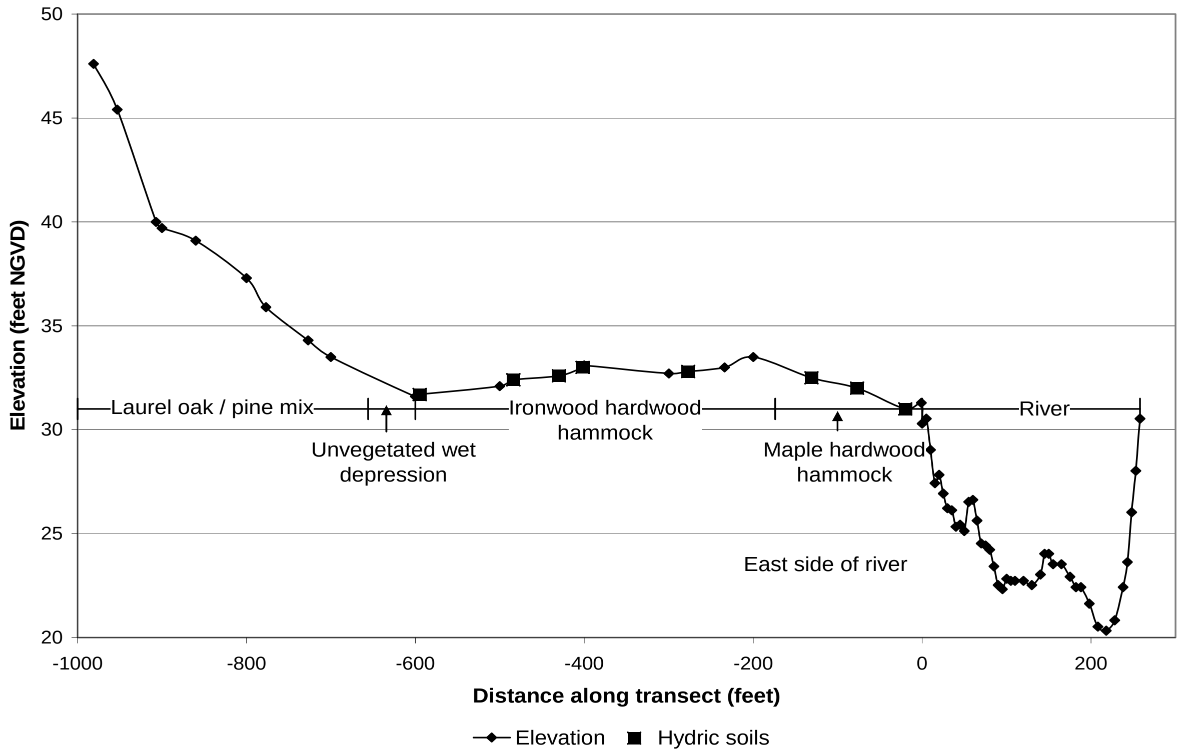

Figure 4.4-2. Vegetation cross-section VEG 7 (PBSJ 2008)

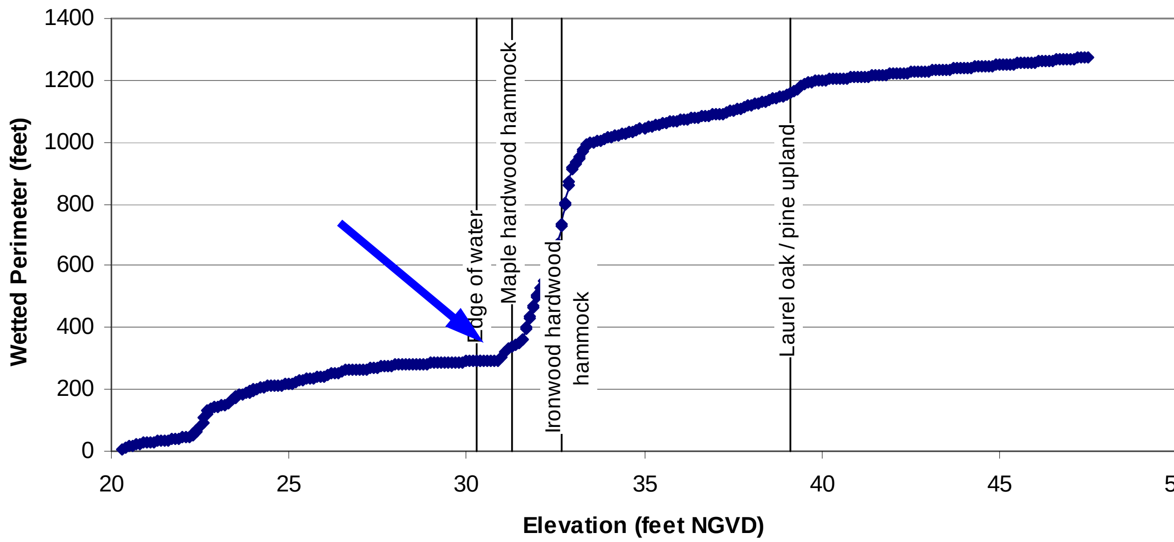

Figure 4.4-3. Wetted perimeter versus elevation for cross-section VEG 7 (PBSJ 2008)

The highest discharge simulated in District calibrated HEC-RAS model was 798 cfs (EAS 2008), which results in modeled surface water elevations well below the mean hardwood swamp elevations listed in Table 4.4-1. A discharge of 798 cfs is exceeded only 18.5% of the time (Figure 2-7). Therefore, complete inundation of the adjacent hardwood swamp represents an infrequent occurrence.

To protect connectivity between the river and the adjacent swamps that provide detrital material, the wetted perimeter breakpoint elevation is selected as the elevation for WRV protection analysis with three locations chosen to evaluate over the length of the river (Table 4.4-2). A 14-day duration will provide sufficient contact time between the river and the adjacent hardwood swamps to maintain connectivity and facilitate the transfer of detritus.

Table 4.4-2. Critical stage and discharge values for detrital transfer

Transect	HEC-RAS Station	Stage	Discharge at Station	Discharge @ SR484	% Time Exceeded
VEG 7	4.93	30.9	397	835	13.5
VEG 4	2.33	30.9	1,020	1,120	0.0
VEG 2	1.11	28.7	706	735	30.6

Table 4.4-3. Frequency and duration parameters for WRV-4 under baseline and MFL scenarios

Transect	Discharge (cfs)		Baseline	Historical	Percent flow reduction from Baseline				
					2%	5%	7%	10%	15%
14 Day Duration									
VEG 7	835	Events[1]	35.2	32.4	30.9	24.8	20.9	15.7	8.8
		Difference[2]		2.8	4.3	10.4	14.3	19.5	26.4
		RPD[3]		7.9	12.2	29.6	40.5	55.3	75.1
VEG 4	1,120	Events	1.4	1.2	1.0	0.6	0.4	0.2	0.1
		Difference		0.2	0.4	0.8	1.0	1.2	1.3
		RPD		14.3	29.0	59.5	73.1	86.3	96.3
VEG 2	735	Events	63.7	60.6	59.4	52.5	47.6	40.2	28.0
		Difference		3.1	4.3	11.3	16.1	23.5	35.7
		RPD		4.9	6.8	17.7	25.3	36.9	56.0

1. Number of events per 100 years
2. Difference between number of events for flow scenario and baseline
3. Relative percent difference defined as the change in the number of events per 100 years divided by the baseline number of events times 100

The change in the number of events ranges from 0.2 to 3.1 events per 100 years for the three transects when the historical is compared to the baseline (Table 4.4-3). This represents a relative percent difference (RPD) of between 4.9 and 14.3 percent. The most commonly occurring event in Table occurs at the VEG 2 Transect with 63.7 out of every 100 years having a

14 day event that meets or exceeds the wetted perimeter breakpoint elevation (28.7 ft-NGVD). For this event, a 5% reduction in flow is required before the RPD exceeds 15%. The key event for VEG 4 occurs very infrequently (1.4 times per 100 years), which is at the extreme end of the frequency curves and greater than observed in the historical record. Because the curves were developed using only 42 years of data, the value is outside the range of reliability of the frequency curve.

Based on these data, flow reductions on the order of 2 to 5 percent appear to be protective of this WRV.

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4.5 WRV-5: Maintenance of Freshwater Storage and Supply

For this analysis, maintenance of freshwater storage and supply is **defined** as the protection of an existing amount of freshwater for existing permitted users. The **criterion** for protection is the amount(s) of surface water and groundwater that are currently permitted to be withdrawn. Our analyses focus on the effect that additional permitted water withdrawal may have on existing permitted surface water and groundwater users. The **representative function** used to assess protection is the maintenance of adequate surface water levels and aquifer levels in the area adjacent to the water withdrawals. The **general indicators** of protection are the stage that protects surface water and aquifer levels that do not result in adverse impacts. The **specific indicators** of protection examined include the types of existing surface and groundwater withdrawal, the historical aquifer levels, and an evaluation as to whether the groundwater-surface water interactions will change as a result of the MFLs to the extent that existing, permitted groundwater withdrawals will result in new low pressure levels in the aquifer.

Maintenance of adequate aquifer levels is assessed by evaluating both surface and groundwater withdrawals and also by examining the aquifer recharge characteristics within the study area. Water withdrawal and storage relationships can be complex with respect to how they affect water bodies. Groundwater withdrawals can indirectly reduce river flows by increasing the amount of induced groundwater recharge over a given stretch of river, and by decreasing base flows to the river. Given groundwater's dominant influence on the flow in the Rainbow River, water withdrawals from the groundwater system are of special importance. The SJRWMD's evaluation of consumptive use permits (CUPs) involves a cumulative impact analysis, meaning that existing CUPs are taken into account in the evaluation of a proposed CUP or increase in an existing CUP allocation. Consequently, all existing withdrawals near Rainbow River and upstream are accounted for in the permitting process. Future withdrawal permits will be evaluated through the CUP process with respect to the MFLs.

The SWFWMD's Water Use Permit (WUP) database was searched to determine if any groundwater and/or surface water is being withdrawn from or in the vicinity of the study area that may impact flows and levels of Rainbow River (SWFWMD 2008). Slightly more than half of the Rainbow River Watershed is within the SWFWMD's water use permit boundary (Figure 4.5-1). Permitted water use within SWFWMD's part of the watershed is dominated by groundwater. All existing WUP withdrawals are included in the baseline record for MFL development and are accounted for in the cumulative consumptive use approach used by the District.

At certain other major spring systems within the SWFWMD, spring flows have declined markedly, due, at least in part, to groundwater and surface water withdrawals. A notable example is Crystal Springs, along the Upper Hillsborough River. Flows have been declining from that spring system and various estimates place the amount due to anthropogenic causes at between 40 and 75% (SWFWMD 2007).

In contrast, based on hydrograph analysis of both the Rainbow Springs Well stages (Figure 2-2) and the discharges from Rainbow Springs since 1965 (Figure 2-5), major reductions in stage or declines in flow that are not explained by rainfall events are not evident. The SWFWMD (2007) has examined Rainbow Springs flows and compared them with other spring systems and with Floridan Aquifer monitor wells that represent relatively unimpacted groundwater and surface water systems. These comparisons indicate that, currently, there is little anthropogenic impact to the flows of Rainbow Springs or to the well stages at the Rainbow Springs Well. A comparison of historic flows to baseline flows on the Rainbow River, using the method employed by SJRWMD reveals virtually no differences (Figure 2-5).

The various MFL scenarios examined compare baseline conditions with historic, 2%, 5%, 7%, 10%, and 15% withdrawal scenarios. The most extreme of these (15%) results in roughly a 0.5 foot decline in the elevations along the stage duration curve for the River. The amount of decline in the groundwater system that would result in a 0.5 foot overall decline in the river stage duration curve will depend on the location(s) of any new groundwater withdrawals. While a 0.5 foot decline in the stage duration of the river may result in unacceptable impacts to other water resource value metrics, it is doubtful that a 0.5 foot decline in the potentiometric surface would result in failed private, agricultural or commercial production wells.

Therefore, the CUP and WUP programs of the SJRWMD and the SWFWMD respectively have been protective of the Rainbow River system water users with respect to WRV-5, and the development of an MFL scenario, in conjunction with these CUP/WUP programs, will serve to protect existing permitted users from the impacts associated with the development of new water uses.

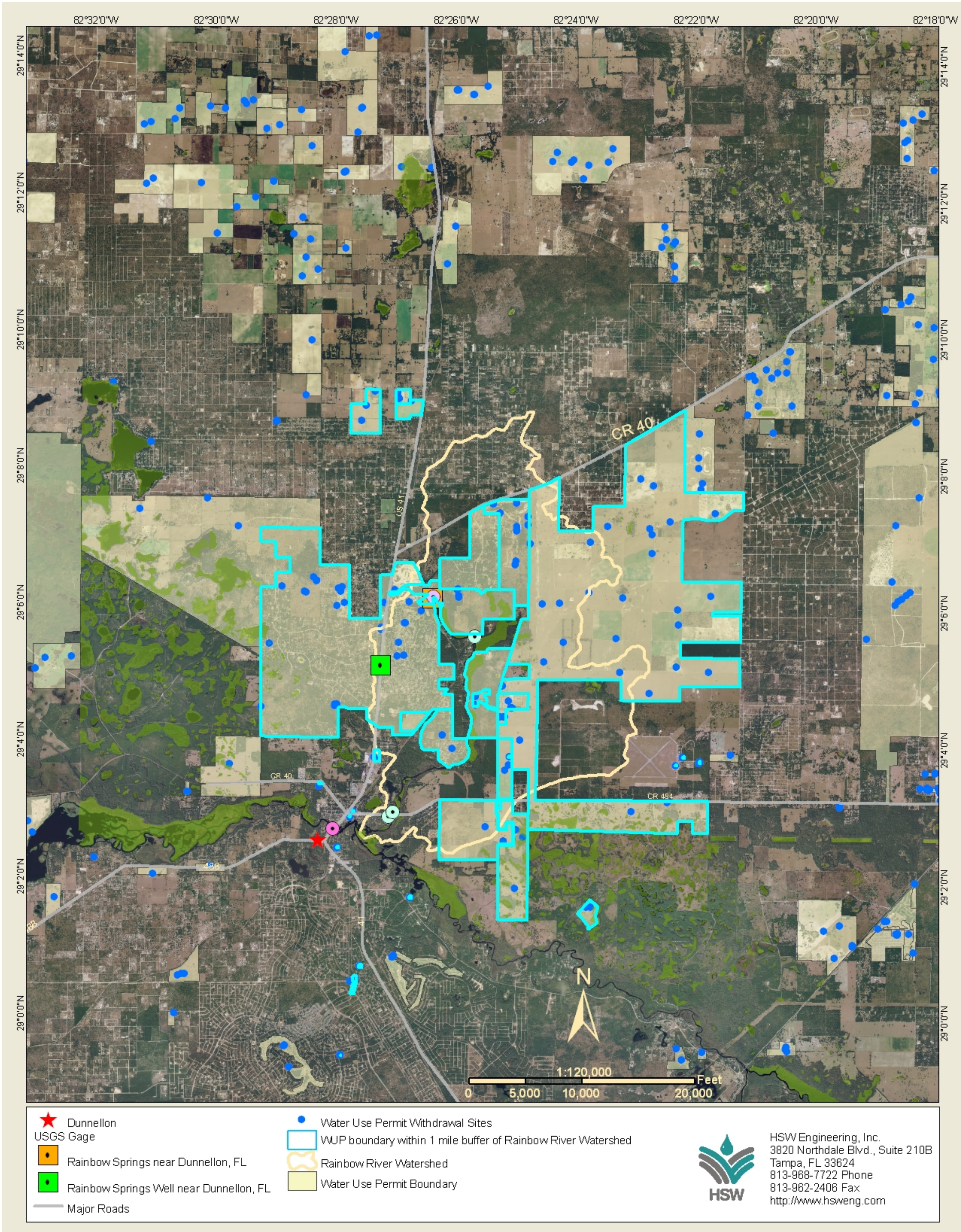

Figure 4.5-1. Location map of CUP allocations near Rainbow River

References:

Southwest Florida Water Management District. 2007. Proposed Minimum Flows and Levels for the Upper Segment of the Hillsborough River, from Crystal Springs to Morris Bridge, and Crystal Springs

Southwest Florida Water Management District. 2008. District website accessed May 2008 at http://www.swfwmd.state.fl.us/data/gis/layer_library/ for creation of GIS map.

4.6 WRV-6: Aesthetic and Scenic Attributes

For this report, aesthetics and scenic attributes is **defined** as the optimal scenic viewing, a pleasing visual setting, and wildlife viewing. HSW used the best information available and noted if any additional research or observations are necessary to establish increased visual aesthetics. The **criteria** for the assessment of the protection of this WRV are “passive recreation.” The **representative function** used to assess protection is the visual setting of the river at selected points along the study reach. The **general indicator** of protection is the stage of the river from the springhead down the extent of the study corridor. The **specific indicators** are stages associated with optimal scenic and wildlife viewing.

Rainbow Springs is a wonderful mixture of Central Florida’s natural and cultural heritage and provides a popular destination to recreation activities. High water clarity, abundant submerged vegetation, and few houses on the east bank of the river provide a scenic background and attract over 220,000 people to the river each year (SWFWMD 2004). Several aspects of aesthetics and wildlife as they pertain to human recreation are examined under the WRV-1, Recreation In and On the Water (Section 4.1). Water quality parameters, such as dissolved oxygen (DO), temperature and water clarity, which affect aesthetics under low flow conditions, are addressed under the WRV-9 (Section 4.9). Because of the Rainbow River’s exceptional scenic beauty and its ecological significance, the river has been designated by the State to be an Outstanding Florida Water, an Aquatic Preserve, and a SWIM priority water body (SWFWMD 2004). The eco-tourism drives the economy of Dunnellon, and the city provides services to people seeking passive recreation including wildlife-viewing, hiking, sightseeing, camping, photography, and other forms of relaxation that usually result in human emotional responses of well-being and contentment.

In the headwater area, Rainbow Springs State Park offers leisurely strolls through shady gardens laced with azaleas, oaks and magnolias. The walkways pass by three man-made waterfalls and a native plant garden. Benches located along the paths offer visitors an opportunity to rest while enjoying the sounds of birds and great views of flowing water.

About one mile down from the Rainbow Springs State Park is a campground on the east side of the river (Figure 4.1-1, Section 4.1), where ample opportunities for canoeing, snorkeling, camping, or sightseeing are available. A boat ramp for hand launched vessels only is available as well as canoe and tube rentals. Located a little further downstream on the west side of the river is the KP Hole County Park (Figure 4.1-1), which offers canoe and tube rentals as well as other amenities and is the only boat ramp on the Rainbow River for motorized vessels.

The river supports abundant wildlife, including otters, alligators, many species of turtles and fish, and many varieties of water birds - waders, divers and dabblers. Osprey, hawks and swallowtail kites soar along the river corridor while smaller birds and animals hide in the lush vegetation. Many animal species, including the endangered gopher tortoise, Florida pine snake, Indigo snake, Sherman's fox squirrel and the Florida mouse inhabit the uplands surrounding the springs and river (Florida State Park 2008). The river also supports a wide variety of native emergent and submerged aquatic plants (WAR 1991; FDEP 2000). These plants provide habitat, maintain water clarity, stabilize sediment, and provide an aesthetically pleasurable environment for people who visit and live on the river (SWFWMD 2004).

A large majority of the west side of the Rainbow River has been developed with many of the existing residential houses located on narrow lots and landscaped down to the water's edge. Retaining walls are often built on the water's edge along with the docks. However, a large majority of the east side of the river is either state park land or undeveloped land, where significant natural buffer zones exist between the river and upper land, allowing trees, bushes, and reed to grow throughout their lifecycles to provide food, shelter, and nesting sites for a variety of birds, fish, turtles, and amphibians.

The Rainbow River and its shorelines provide a very visible and accessible water body that allows for the passive recreational activities. The portions of the river that provide boat access for wildlife viewing from boats are subject to the same conditions as discussed in Section 4.1 (WRV-1). The protection of underwater communities and riparian zone habitats are considered in the processes of MFL development as discussed in Sections 4.1 and 4.2 (WRV-1 and WRV-2).

From both a habitat and an aesthetic perspective, the most important variable in the spring systems is light (Dennison *et al.* 1993). However, casual observations from local residents living along the Rainbow River have noted that the water clarity rapidly declines from the headsprings to the river mouth. It is not well understood whether this decline is a natural phenomenon or a result of anthropogenic impacts, or a combination of both (SWFWMD 2004). Odum (1957) attributes a diurnal pulse in chlorophyll to boats as well as natural causes. Mumma (1996) found significant and negative correlation between water clarity and the number of recreational users. Anastasiou (2006) indicated that spatial variability in water clarity can be explained in chlorophyll concentration using an exponential decay function. However, the focus of this WRV evaluation is to address whether or not water withdrawals from the baseline/existing condition will cause appreciable change in water clarity and other visual aesthetics.

Water quality index components of water clarity, dissolved oxygen, and nutrients that degrade the water quality of a river can contribute to an aesthetically unappealing experience for visitors. Decreased water clarity can minimize viewing pleasure of the underwater flora and fauna, increased levels of dissolved oxygen and nutrients can produce increased algal growth, unpleasant smells and fish kills. The water quality index for this river indicates no significant degradation of these factors of water quality, thereby maintaining a pleasant aesthetic experience for visitors' senses. A further discussion of water quality for the WRV-9 can be found in Section 4.9.

It is recognized that residents and visitors place importance on scenic viewing. A seasonal variability in water levels of less than 1 foot helps to maintain a consistent cypress fringe along the river edge and allows for year-round scenic viewing. Important locations to evaluate for aesthetics along the study are the headsprings, campground, KP Hole County Park. These points of interest correspond to river miles 5.02, 3.75, and 3.48, respectively. HEC-RAS modeling indicates a minimal decline in the water surface elevation between baseline and proposed flow reductions below historic lows at these referenced locations (Table D-1 in Appendix D). The water surface elevation changes over the historical flow range (450-1100 cfs) for these locations are 2.6, 2.53, and 2.51 feet, respectively. These ranges in water surface elevation over the spectrum of low and high flows constitute non-events. In the 42-year period of record for this river system, there have not been any events reported that resulted in any aesthetic displeasure with respect to scenic viewing. As a result, this metric does not lend itself to frequency analysis and is not significant enough to warrant using this as a metric.

Optimal water levels for birding are more varied but appear to be best at times when the floodplain along the river is slightly inundated, to allow long-legged wading birds ample foraging areas and eco-tourists access to viewing them by boat or from the trail or hiking paths. Because bird viewing activities are based on multiple factors (habitat, time of year, temperatures, wind conditions, as well as water levels), optimal conditions for birding are less easily quantified.

Wading birds such as the little blue heron, Great blue heron, and the Wood stork (a group that represents the most visible group of birds for eco-tourists) are abundant within this area of the river (DNR 1991). For scenic and aesthetic considerations, the two factors of importance are: (1) that the riparian zone is inundated at least to an elevation where wading birds can stand and hunt; and (2) that there is sufficient water within the riparian zone so that the eco-tourism boats can access the congregation spots for the birds.

Wading birds find abundant food sources along the riparian zones where it is inundated at relatively shallow depths (less than six inches for all but the largest wading bird species). Also, at these shallow floodplain inundation depths, food resources would tend to be concentrated in pool areas, making foraging more efficient. Such shallow water depths are adequate for the eco-tourism boats to access the foraging sites where the wading birds would congregate. At 0.5 ft above the top of the bank elevations, the portion of the floodplain easily accessible to eco-tourists would have water inundation depths that approximate an optimal viewing condition for wading birds.

It needs to be stressed here that the baseline variations in water levels in the Rainbow River are slight (less than 1 foot annual variation and only 2.6 feet all time minimum to all-time maximum). In the 42-year period of record, there have been no events reported that altered the aesthetic appeal of this river system. Hence, withdrawals of 2% will be unnoticeable at high water levels/flows and at low water flows/levels. Table D-1 (HEC-RAS model results) provides this information. To provide an example from that table, at transect River Mile (RM) 4.93, throughout the entire range of flows modeled, a 2% reduction in flow results, at most, in approximately a 0.1 foot reduction in water depth. A similar level of small declines are evident at all transect locations at all baseline flows. Performing a similar analysis for a 15% withdrawal, at RM 4.93, regardless of baseline flow, the resultant decline in water levels is about 0.5 feet. At RM 0.01, a 15% rate of withdrawal results in less than 0.5 foot water level reductions regardless of starting stage. A 0.5 foot reduction in water level can be noticeable on the Rainbow River. The extent to which such a potential reduction in water levels could be considered significantly harmful to the aesthetic and scenic resources will likely depend as much upon indirect effects such as possible reductions in use of the river by wading birds if their floodplain food resources are negatively affected (this subject is discussed in WRV-2) than on any direct visual observations of water levels. Results from WRV-2 suggest that water level reductions that reduce floodplain inundation events should be limited to no more than a 5% of baseline flow. Such a withdrawal scenario would clearly also be protective of aesthetic and scenic attributes, both from a direct visual observation of water levels and from continued presence of wading birds that are important to the success of the eco-tourism industry.

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4.7 WRV-7: Filtration and Absorption of Nutrients and Other Pollutants

This WRV is **defined** as the reduction in concentration of nutrients and other pollutants through the processes of filtration and absorption; i.e., the removal of suspended and dissolved materials as these substances move through the water column, soil, or substrate and associated organisms. The **criteria** for protection are the processes of filtration and absorption. The **representative function** used to assess protection is the ability of water to promote nutrient removal in the river and adjacent wetlands. The **general indicators** of protection are the depth and duration of floodplain and residence time. The **specific indicators** of protection are the return intervals of stages associated with selected duration sufficient to maintain contact with riparian vegetation and residence time similar to baseline conditions.

Filtration and absorption of nutrients and other pollutants are natural system processes associated with aquatic and wetland ecology and are protected under FAC 62-40.470 (Natural Systems Protection and Management) and 60-40.473 (Minimum Flows and Levels). Filtration consists of physical, chemical and biological processes that occur as water flows through media such as soil and sediment. Absorption is a chemical process that occurs during filtration. In natural environments, filtration and absorption can take place at many points throughout the hydrologic cycle. Therefore, understanding where these processes occur is important in evaluating the protection of this WRV in terms of minimum flows and levels. A thorough description of filtration and absorption of nutrients can be found in HSW (2006) and HSW (2008).

Filtration and absorption processes are identified to occur within water column through contact with submerged aquatic vegetation and in riparian zones where major medium such as vegetation, sediments, and soils, exist. The rates of these processes are functions of residence time, or contact time, with these medium. The longer nutrient and pollutant particles exist within a water body, the more likely they will be filtered, absorbed, or assimilated. It is recognized that the processes associated with filtration and absorption of nutrients will affect the water quality of Rainbow River. However, water quality is explicitly defined as the chemical and physical properties of the aqueous phase evaluated in Chapter 4.9.

As corroborated by HEC-RAS results, water withdrawals will reduce the water stage, discharge, and velocity, which would allow more contact time for nutrients and pollutants within water column. The extended retention time would allow more time for the nutrients and pollutants to be filtrated, absorbed, or otherwise assimilated by submerged aquatic vegetation (SAV), bottom sediments and organisms in water columns. Therefore, it may be reasonable to conclude that that changes on water retention time associated with the MFL scenarios would benefit the filtration and absorption functional capacities of the SAV which is abundant throughout the Rainbow River (PBSJ 2008).

The major factor that would be affected by the MFL would be the physical contact of water with riparian vegetation. The degree of nutrient release and assimilation in the wetlands, as well as the decomposition of the vegetation communities, depends to a large extent on the frequency and duration of inundation, because the process of filtration and absorption requires both wet and dry periods. If the selected threshold stages will not occur substantially less frequent under the MFLs condition than under baseline conditions, it can be inferred that the process of filtration and absorption in wetland soils, sediments, and vegetative communities, littoral vegetation, bottom sediments, and water column organisms would be protected. As such, this WRV is also protected by maintaining contact with the floodplain as was done in WRV-4 Detrital Transfer with the results from that section applying to this WRV analysis.

As was documented in Chapter 4.4 (Detrital Transfer), the adjacent cypress swamp is the only vegetation class that is permanently or semi-permanently inundated and represents an important vegetation class to protect to insure proper filtration (PBSJ 2008). Vegetation transects VEG 3 and VEG 2 contain cypress swamp vegetation at median elevations of 29.4 and 28.4 ft-NGVD respectively (Table 4.7-1) are inundated 30.6% and 49.9% of the time respectively (Table 4.7-2). To protect connectivity between the river and cypress swamps, the mean cypress swamp elevation for each transect is selected for WRV protection analysis (Table 4.7-2). To insure long-term inundation of the cypress swamps, which rely on permanent or semi-permanent inundation, a duration of 120 days is chosen for evaluation.

Table 4.7-1. Median elevation (NGVD) of vegetation classes and wetted perimeter breakpoint along the Rainbow River transects

Transect	HEC-RAS Station (river mile)	Cypress Swamp	Maple Hardwood Hammock	Ironwood Hardwood Hammock	Wetted Perimeter Breakpoint
VEG 3	1.98	29.4	-*	31.6	30.1
VEG 2	1.11	28.4	29.4	-	28.7

* - indicated vegetation classification not present

Table 4.7-2. Critical stage and discharge values for nutrient filtration

Transect	HEC-RAS Station	Stage	Discharge at Station	Discharge @ SR484	% Time Exceeded
VEG 3	1.98	29.4	677	735	30.6
VEG 2	1.11	28.4	649	675	49.9

Table 4.7-3. Frequency and duration parameters for WRV-7 under baseline and MFL scenarios

Transect	Discharge (cfs)		Baseline	Historical	Percent flow reduction from Baseline 2%	5%	7%	10%	15%
120 Day Duration									
VEG 3	735	Events[1]	38.2	38.2	33.1	25.6	21.1	15.0	7.4
		Difference[2]		0.0	5.2	12.6	17.2	23.2	30.8
		RPD[3]		0.1	13.6	32.9	44.9	60.7	80.6
VEG 2	675	Events	60.8	60.4	55.5	47.1	41.4	32.9	20.0
		Difference		0.4	5.3	13.6	19.4	27.9	40.8
		RPD		0.6	8.7	22.4	31.8	45.8	67.1

1. Number of events per 100 years
2. Difference between number of events for flow scenario and baseline
3. Relative percent difference defined as the change in the number of events per 100 years divided by the baseline number of events times 100

The change in the number of events ranges from near 0 to 0.4 events per 100 years for the two transects when the historical is compared to the baseline (Table 4.7-3). This represents a relative percent difference (RPD) of less than 1. The most commonly occurring event in Table occurs at the VEG 2 Transect with about 61 out of every 100 years having a 120 day event that meets or exceeds the median cypress swamp elevation (28.4 ft-NGVD). For this event, a 5% reduction in flow is required before the RPD exceeds 15%.

References:

HSW Engineering, Inc. (HSW). 2006. Evaluation of the Effects of the Proposed Minimum Flows and Levels Regime on Water Resource Values on the St. Johns River Between SR 528 and SR 46.

HSW Engineering, Inc. (HSW). 2008. Evaluation of the Effects of the Proposed Minimum Flows and Levels Regime on Water Resources Values on Lake Poinsett.

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4.8 WRV-8: Sediment Loads

The **criterion** for protection that will be the focus of the analyses is the “transport of inorganic materials.” The analyses focus on the effect of changing the return frequency of events on the transport, erosion, and deposition of sediment. The **representative function** used to assess the protection of sediment loads is to maintain the transport of sediment in the Rainbow River. The **general indicators** of protection for high water and low water conditions are variations in stage, velocity, and bed shear stress between the baseline and the MFLs conditions for each situation. The **specific indicators** of protection are the minimum current velocities and bed shear stress required for adequate sediment transport derived from the literature, and the extent to which the number of events per 100 years for which intervals of these minimum velocities will change under the proposed withdrawal scenario.

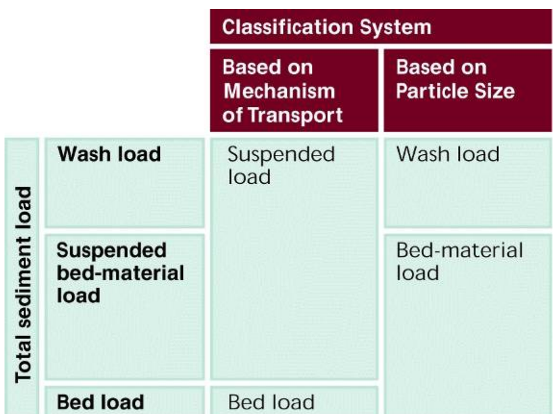

Figure 4.8-1. Sediment load classification categories (FISRWG 1998)

The movement, or transport, of sediment is a function of flow condition, sediment material composition, and supply (i.e., source of particulate matter) where Figure 1 depicts the classification categories (Mehta, 2004; Vanoni, 1977). Sediment transport amount, or “sediment load,” is then conveyed as a mass or weight per unit time (e.g., tons/day or kg/sec). A more thorough discussion of sediment transport can be found in HSW (2006) and HSW (2008).

To protect this WRV, consideration must be given to the effect of water withdrawals on suspended load, in addition to bed material load (as defined in Figure 4.8-1). The key variable with regard to total suspended solids (TSS) is mean flow velocity, which transports the suspended particles (both organic and inorganic). If the number of mean flow velocity events per 100 years is not substantially changed under MFLs conditions, it can be inferred that TSS will be protected. A more thorough discussion of TSS and its protection can be found in Chapter 4.4 (evaluation of organic transport and protection of WRV-4).

The Rainbow River is a swift flowing spring run that is dominated by well to moderately well sorted medium to fine sand (Ellis et al. 2007) over a majority of its length. According to the Rainbow River Sediment Study (Ellis et al 2007), "clear quartz sand" and "clear quartz sand mixed with woody detritus" are overwhelming the most common occurring sediment types found in the core samples. Detritus in the samples was from adjacent riverine swamps, seasonal floodplain inundation, and overhanging vegetation. This is supported by a 1991 sediment study (SWFWMD 2004) that indicated that 94% of sediment upstream of SR484 is sand with 6% being clay and silt. Finer sediments begin to dominate bed composition below SR484 and near the confluence with Withlacoochee (SWFMWD 2004; Ellis et al. 2007).

Based on the Unified Soil Classification System (USCS), fine to medium sand would a median grain size diameter (D_{50}) of approximately 0.5 mm with most particles being less than 2.0 mm in size. As such, for sediment transport purposes, the bed material can be analyzed as non-cohesive inorganic fine sediment which a median grain size diameter (D_{50}) of 0.50 mm. The initiation of motion of these particles is primarily a function of bed shear stress and particle size (Vanoni, 1977; Yang, 1996). Bed shear stress (τ) is computed as:

$$\tau = \gamma R S$$

where γ is specific weight of water, R is the hydraulic radius (cross-sectional flow area over wetted perimeter), and S is the slope of the energy grade line (which can be approximated by the bottom slope of the channel for uniform or gradually varied flow conditions).

A commonly accepted measure of the initiation of motion for uniform non-cohesive sediments can be determined using the Shields diagram (Shields 1936). The Shields curve divides a region of motion from a region of no motion. By determining the dimensionless Shields parameter and dimensionless grain Reynolds number, a prediction of sediment motion may be obtained. For D_{50} sediment grain sizes of approximately 0.50 mm, the critical shear for motion is about 0.006 lb/ft^2.

The District's HEC-RAS results can be utilized to evaluate this section of river under the proposed MFLs regime (Appendix D). Table D-2 in Appendix D includes HEC-RAS results from the calibrated model for spring discharges that vary from 239.2 cfs to 367.1 cfs which equate to 520 cfs to 798 cfs at the downstream boundary of SR484 (EAS 2008). Based on the critical shear of 0.006 lb/ft^2, the bed is mobilized and sediment transported across the entire range of flow events and on a vast majority of cross-sections (all but two - stations 3.88 and 4.76). As such, further evaluation of sediment transport initiation is unnecessary.

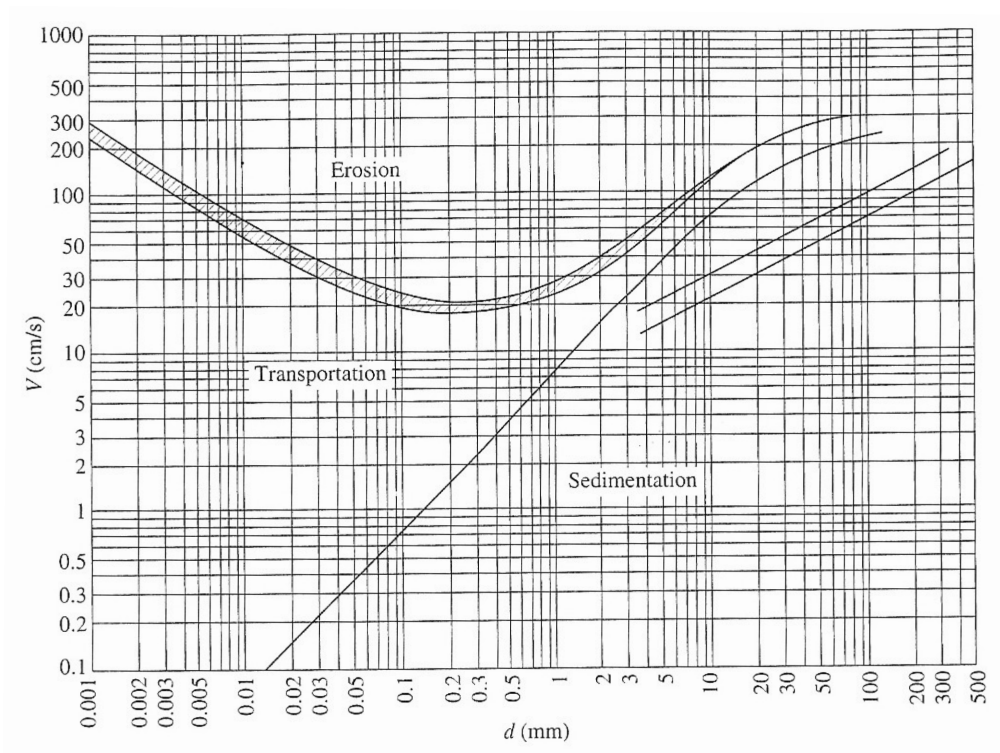

Figure 4.8-2. Hjulstrom's chart of sediment zones

A key protection metric is whether the overall transport of sediment will be influenced by withdrawals. Significant changes in the sediment transport regime could cause net erosion or deposition of sediment in the channel thereby changing the natural sediment regime. A simplified approach for this analysis is based on the work of Hjulstrom. Hjulstrom (1935) considered a wide range of uniform sediment size and flow conditions and developed a chart that indicates the regions of erosion, transport, and deposition (or sedimentation) (Figure 4.8-2). Therefore, sediment of a diameter of 0.5 mm would remain transported at a rate of between 4 cm/sec and 20 cm/sec. With regard to the proposed MFLs regime, the important consideration is not necessarily the condition (erosion versus transport), but rather that the proposed water withdrawals would not cause a significant shift in occurrence of those conditions. If, for example, the flow condition is erosive under current water levels, then it should remain erosive under the MFLs conditions in order to maintain the natural morphology of the river. Therefore, for the ranges of bed material sediment size present in this stretch of river, the key velocity is approximately 20 cm/sec, or 0.6 ft/sec. A significant shift in the occurrence of this velocity could cause morphological changes in the river.

Based on HEC-RAS results, there are eight cross-sections for which modeled velocities of 0.6 ft/sec depend on flow conditions with the remaining cross-section either being consistently above or below 0.6 ft/sec. A representative sample of four of those cross-sections were analyzed including the farthest upstream (3.02), the farthest downstream (0.56), and two in the middle reaches of the river (1.32 and 2.46) including one located at a PHABSIM cross-section (2.46). Table 4.8-1 has the stage and discharge for the critical conditions for these four cross-sections along with the representative discharge at SR484 Bridge. The discharge range being considered is from 562 cfs to 774 cfs so this analysis includes a majority of the flow regime.

An alternative approach is to calculate (or measure) sediment load for current conditions and verify that the overall sediment load would not be significantly altered under MFLs conditions. There are numerous sediment load equations that have been developed for the prediction of bed load transport, suspended load transport, and total load transport (U.S. Army Corps of Engineers 1995; Yang 1996). These equations are used to predict sediment load based on numerous variables that could include mean flow velocity, discharge, stream power, shear stress, particle size, water depth, and water temperature. The Engelund-Hansen method (Engelund and Hansen 1972), which predicts total sediment load, is particularly well suited for Florida streams. The Engelund-Hansen method is based on a stream power approach where stream power is the product of shear stress and mean flow velocity (τ V). Since the above approach is protective of shear stress and mean flow velocity, by default it is also protective of stream power.

The critical value of mean flow velocity is 0.6 ft/sec and the critical value of shear stress is 0.006 lb/ft^2. There are four cross-sections for which corresponding critical discharge and stage values for the USGS Rainbow River at Dunellon Gauge can be determined (Table 4.8-1).

Finally, the durations of interest are 7 and 30 days to consider a range durations associated with the wide range of flow conditions.

Table 4.8-1. Critical stage and discharge values for sediment load

HEC-RAS Station	Stage	Discharge	Discharge @ SR484	% Time Exceeded
0.56	27.75	555	562	91.2
1.32	28.61	656	690	44.0
2.46	30.00	696	774	22.9
3.02	29.16	442	550	94.5

Table 4.8-2. Frequency and duration parameters for WRV-8 under baseline and MFL scenarios

HEC-RAS Station	Discharge (cfs)		Baseline	Historical	Percent flow reduction from Baseline				
					2%	5%	7%	10%	15%
7- Day Duration									
		Events[1]	96.6	96.3	95.7	94.0	92.6	89.9	83.4
0.56	562	Difference[2]		0.3	0.9	2.5	4.0	6.7	13.2
		RPD[3]		0.3	0.9	2.6	4.1	6.9	13.6
		Events	77.3	76.6	73.9	68.0	63.7	56.6	43.6
1.32	690	Difference		0.7	3.5	9.3	13.7	20.7	33.7
		RPD		0.9	4.5	12.1	17.7	26.8	43.5
		Events	54.4	53.8	49.8	42.8	38.0	31.0	20.2
2.46	774	Difference		0.6	4.6	11.6	16.4	23.4	31.2
		RPD		1.1	8.4	21.4	30.1	43.0	62.8
		Events	97.4	97.1	96.7	95.3	94.1	91.8	86.2
3.02	550	Difference		0.2	0.7	2.1	3.2	5.5	11.1
		RPD		0.2	0.7	2.1	3.3	5.7	11.4
30- Day Duration									
		Events[1]	96.0	95.6	95.0	93.1	91.4	88.3	80.9
0.56	562	Difference[2]		0.4	1.0	3.0	4.6	7.7	15.1
		RPD[3]		0.4	1.0	3.1	4.8	8.1	15.7
		Events	74.1	73.1	70.3	63.9	59.2	51.7	38.5
1.32	690	Difference		0.9	3.8	10.2	14.9	22.4	35.6
		RPD		1.3	5.2	13.8	20.1	30.2	48.0
		Events	49.5	48.6	44.8	37.6	32.9	26.1	16.1
2.46	774	Difference		0.8	4.7	11.8	16.5	23.3	33.3
		RPD		1.7	9.5	23.9	33.5	47.2	67.4
		Events	96.9	96.6	96.1	94.5	93.1	90.5	84.1
3.02	550	Difference		0.3	0.8	2.4	3.8	6.4	12.8
		RPD		0.3	0.8	2.5	3.9	6.6	13.2

1. Number of events per 100 years
2. Difference between number of events for flow scenario and baseline
3. Relative percent difference defined as the change in the number of events per 100 years divided by the baseline number of events times 100

Annual high-flow events of a magnitude and duration identified as critical for maintaining baseline sediment transport occur quite frequently on the rainbow river and the absolute and relative decrease in the number of events is small. This is particularly true for baseline events that occur more than about 95 percent of the time. For less frequent events associated with transects at RM 1.32 and RM 2.46, flow reduction on the order of 2 to 7 % do not appreciably change the frequency of these events.

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4.9 WRV-9: Water Quality

For this analysis, water quality is **defined** as the chemical and physical properties of the aqueous phase within Rainbow River. The **criteria** for protection are "the chemical and physical properties of the water" that affect the health of the aquatic community. The **representative function** used to assess protection is the ability of water to assimilate chemical constituents which directly or indirectly affect community health. The **general indicators** of protection are key water quality characteristics influenced by lake stage that affect the health of the aquatic community. The **specific indicator(s)** of protection are the return intervals of minimum stages associated with select durations sufficient to maintain key water quality characteristics similar to baseline conditions.

This WRV is evaluated by focusing on those chemical and physical parameters most likely to negatively impact the ecological structure and function of the river because of an altered hydrologic regime. Numerous water quality parameters have been measured by the District to characterize the water quality of the Rainbow River as is consistent with FDEP surface water criteria established for Class III waters of the state. In addition to analyzing existing physical and chemical parameters, the Water Quality Index (WQI) was calculated by HSW Engineering, Inc. for three sites in the study reach using the Florida modified method as described in Hand et al. (2000) and SJRWMD Technical Publication SJ2004-3 (SJRWMD 2004).

The Water Quality Index is a composite index evaluation of water quality based on individual constituents. For this analysis, the constituent water quality parameters provided by the District that were used to calculate WQI included turbidity, total suspended solids (TSS), dissolved oxygen (DO), total organic carbon (TOC), total nitrogen (TN), total phosphorus (TP), total coliform, and fecal coliform. Understanding the relationship between WQI and its constituent parameters with stage or discharge is the key in evaluating the protection of this WRV with respect to the proposed withdrawal scenarios which would reduce the occurrence of specific stage events. In the case of a stream or spring (as the Rainbow River is classified), a WQI value less than 45 is considered good water quality, between 45 and 60 is fair, and above 60 is poor.

Appendix B includes tabular values of all water quality variables considered for the three locations (Rainbow Headsprings, Devil's Elbow, and CR484) along with well stage at USGS Gauge at Dunnellon. The well stage correlates to stage and discharge along the Rainbow River so it can be used to evaluate whether water withdrawals will impact water quality. These values were used to generate scatter plots of WQI and the constituent components versus stage which are also included in Appendix B.

From the plots and tables, it can be seen that WQI for the headsprings and the upper reaches of the river is always below 30 indicating very good water quality. Near the SR484 bridge, the water quality is occasionally classified as “fair” but more commonly is categorized as good. In all three locations, there is no significant WQI trend with stage with a reduction in stage. The strongest correlation is at the headsprings where a decrease in stage is associated with an increase in WQI, but not to a level that would change the classification.

In addition to evaluating WQI, two base constituents, water clarity and total nitrogen, are important issues in Rainbow River system (SWFWMD 2004). Water clarity, as measured by a horizontal Secchi disk depth, has been as high as 80 meters at the Rainbow River headspring but tends to range between 50 m and 75 m since 2002. Figure 4.9-1 is a plot of Secchi disk depths versus time for nine water quality locations along the Rainbow River sampled by the District from 2002 to 2008 where RR1 is the headsprings and RR9 is the SR484 Bridge (Figure 2-9). From this figure it is clear there are no apparent long term trends with regards to water clarity along the Rainbow River. However, as evidenced in Figure 4.9-1, water clarity decreases from the headspring rapidly with Secchi depths averaging around 35 m less than 0.5 miles downstream at sampling location RR2 and less than 10 m closer to the CR484 Bridge (RR9). Anastasiou’s study (2006) also reveals the similar pattern of spatial variability in water clarity of Rainbow River, and also indicates that the water clarity was great during the fall and winter months and poorest during the spring and summer months. However, this seasonal and spatial variability in water clarity, or the reasons causing the decline (a natural phenomena, a result of anthropogenic impacts, or a combination of both) are well understood (SWFWMD 2004). In addition, Figure 4.9-2 and 4.9-3 are plots of Secchi depth versus stage for the same District data set at the headsprings (RR1) and CR484 (RR9) and the relationship between water clarity and stage is weak.

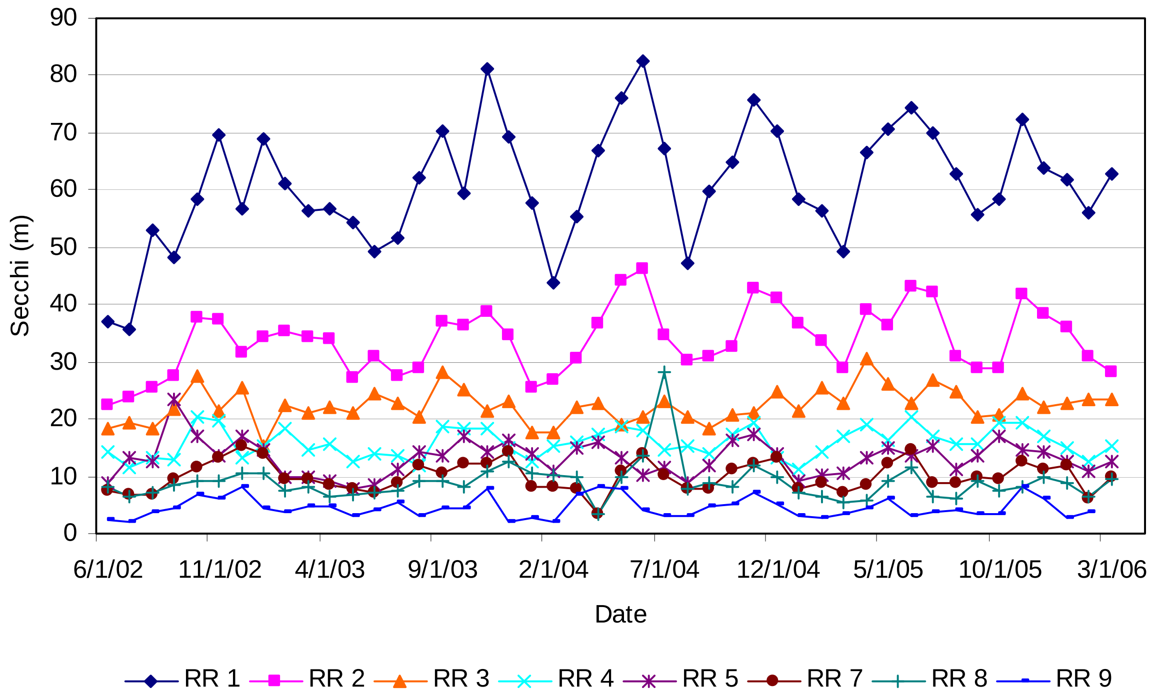

Figure 4.9-1. Secchi depth versus time (2002-2008) at the Rainbow River Head Springs

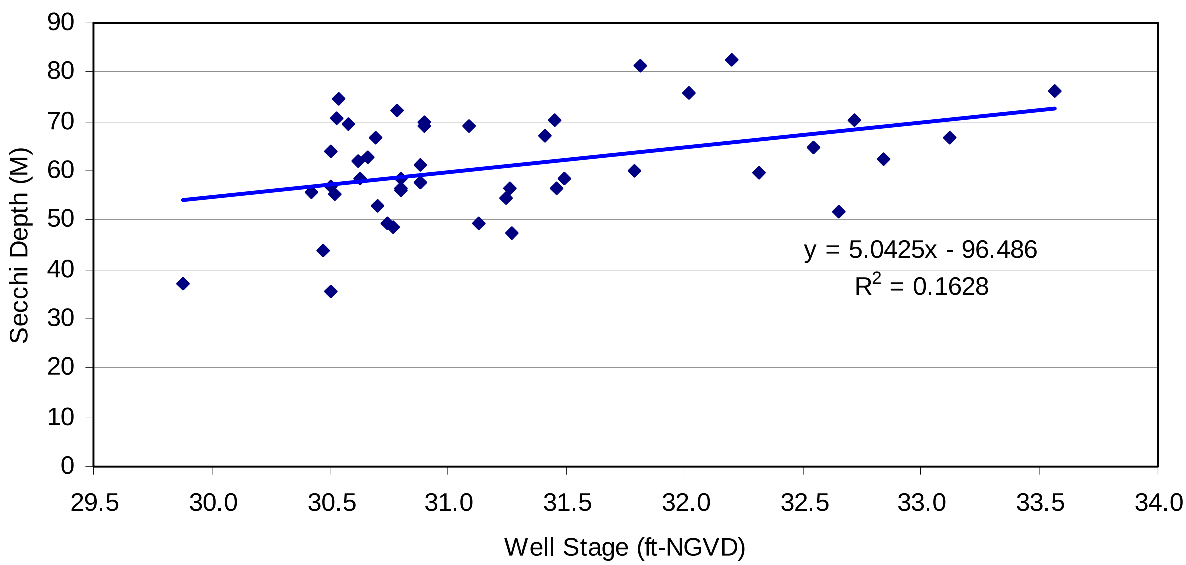

Figure 4.9-2. Secchi depth at water quality station RR1 on the Rainbow River versus well stage (2002-2008) at USGS 290514082270701 Rainbow Springs Well near Dunnellon, FL

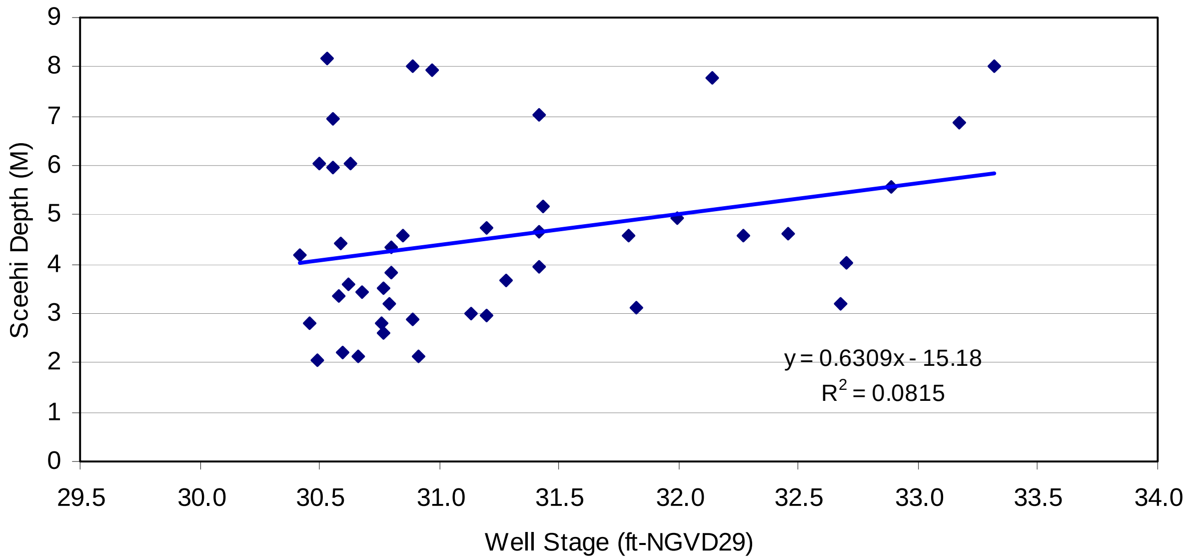

Figure 4.9-3. Secchi depth at water quality station RR9 on the Rainbow River versus well stage (2002-2008) at USGS 290514082270701 Rainbow Springs Well near Dunnellon, FL

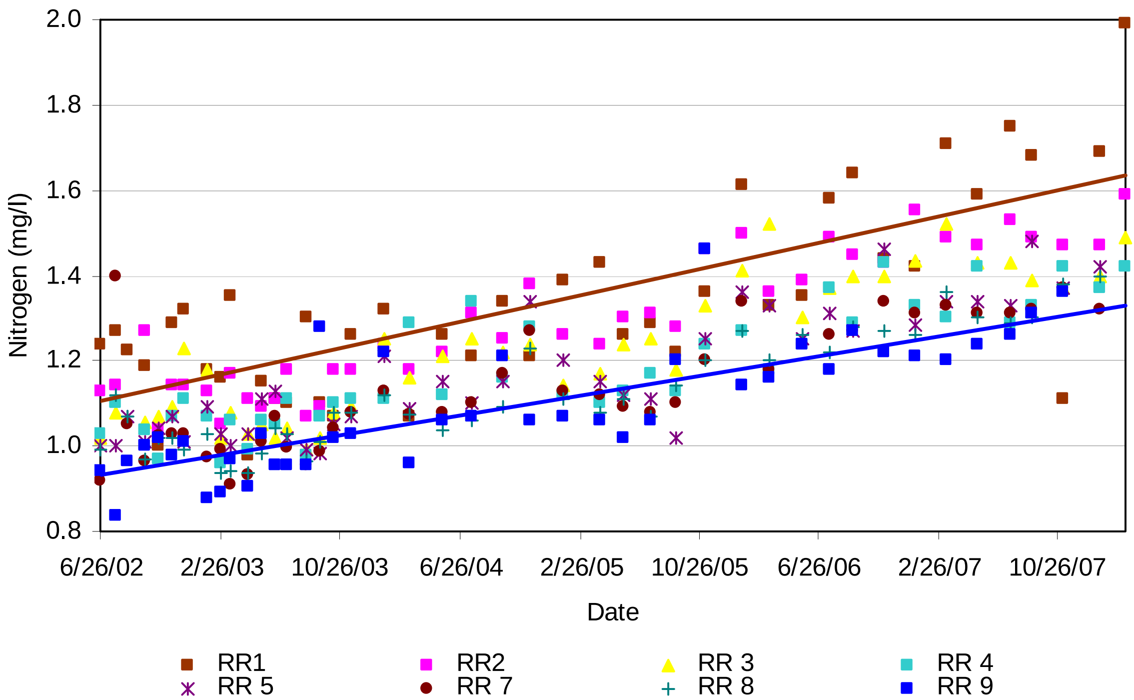

Figure 4.9-4. Total nitrogen versus time for 9 sampling locations on the Rainbow River

Although the overall water quality is considered good, nitrates in Rainbow Springs have steadily increased over the past fifty years from less than 0.1 mg/L in the 1940’s and 1950’s (Odom 1957; Jones et al. 1996) to about 1.0 mg/L in 2002 (SWFWMD 2004). This trend has continued by 2008 when nitrogen levels in the river had increased by about 50% over the past six years (Figure 5.9-4). As described in the Rainbow River SWIM Report (SWFWMD 2004), the total annual nitrate loading into Rainbow Springs is 70 times greater at a concentration of 1.0 mg/L than it was when nitrates were at background concentration (0.1 mg/L) which given the increasing trend is cause for concern. However, it is uncertain that this increase in nitrate and total nitrogen has impacted the river system to date and what effect future increases in the river’s water quality, water clarity, and biological communities (SWFWMD 2004). The principle source of nitrate entering Rainbow Springs is inorganic nitrogen (Jones et al. 1996), which is primarily from fertilizer used in agriculture applications, although it may be also from residential and golf course turf fertilization. Jones et al. (1996) reported that N inputs from septic tank effluent and sewage effluent disposal do not appear to be significantly contributing to the nitrate entering the springs.

This WRV assessment is focused on whether or not the altered hydrologic regimes due to water withdrawals will cause appreciable changes in the WQI, water clarity and total nitrogen from the baseline condition using selected metrics. There is no compelling evidence that spring discharge impacts these water quality metrics and therefore this WRV would be protected under all water withdrawal scenarios under consideration (less than 15% total withdrawal of discharge).

References:

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4.10 WRV-10: Navigation

HSW (2007) observed no commercial vessels on the Rainbow River and based on interviews, no commercial vessel are used in the Rainbow Springs and along the spring run. However, commercial guide and fishing boats are not excluded and can be included in the analysis for recreational boat traffic as discussed in Section 5.1 (WRV-1, Recreation In and On the Water). Therefore, no evaluation is provided for this WRV.

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5.0 SUMMARY

The frequency analysis approach used to evaluate each WRV consists of identifying key parameters, structures or functions for each WRV, appropriate hydraulic metrics associated with these key functions, and then key events in terms of the magnitude, duration and frequency of occurrence. The relevant analysis for evaluating WRVs is the change and or relative change in the number of events per 100 years as a result of a reduction in flow from the baseline condition.

WRV-3 **Estuarine Resources** was not analyzed because it is not applicable to this water body. WRV-10 **Navigation** was not directly evaluated because there is no commercial boat traffic on the river; however, **recreational boating** is covered under **recreation in and on the water** (WRV-1). The WRVs **aesthetic and scenic attributes** and **water quality** are important WRVs for the Rainbow River, but metrics that could be associated with hydraulic parameters in a quantitative manner could not be identified within the range of flows that have historically been observed. For example, it is reasonable to posit that water quality is a function of flow, particularly at low flow, but a relationship between water quality and stage/discharge are not be evident from the data. The conclusion in this case is that an event (i.e., low flow event) has not been observed or occurs very infrequently, and is not expected to occur under the withdrawal scenarios examined in this report. As such, the water quality WRV will be protected under a maximum discharge withdrawal scenario of 15%.

The WRV **recreation in and on the water** was examined with swimming, tubing and recreational boating defined as key functions, and stage as the appropriate metric for the latter two. Swimming was examined qualitatively and the water circulation rate is well in excess of health requirements at all times. Similarly, the depth requirement for safe boat operation has always been well exceeded so no frequency evaluation was performed. For recreational tubing, the dominant use of this river system by people, a critical depth of 5 feet was determined to be appropriate for the protection of aquatic vegetation from swimmer/tuber contact. This is interesting metric was chosen as a surrogate for protecting recreational use of the river; the logic being that if people begin to destroy aquatic vegetation, river access would be restricted.

Several functions were examined for the WRV **fish and wildlife habitats and the passage of fish** including floodplain inundation for habitat and fish passage. Floodplain inundation (i.e., high flow event) was examined quantitatively because, like other functions, low flow events that would impact potential habitat functions have not been observed. Floodplain inundation is an important function for the habitat health for various classes of flora and fauna, and withdrawals on the order of 5 % would be protective of floodplain habitat. Floodplain inundation and or connectivity to the river channel also were used as a key function for WRVs **transfer of detrital material** and **filtration and absorption of nutrients and other pollutants.** Similarly, withdrawals on the order of 2 to 5 % were determined to be protective of these WRVs.

The WRV **sediment load** was examined using velocity and shear stress in the channel as the key function and discharge as the metric. Velocity and shear stress are associated with the initiation and transport of motion of bed sediment. Events associated with the movement of sediment occur quite frequently in the Rainbow River and withdrawals of 2 to 7 % were determined to be protective of the WRV.

With the exception of the low flow associated with tubing, all of the other metrics were associated with high flow events. This is because the river has a very narrow range of flows and low flow events that might be associated with adverse impacts have not been observed. Because the other WRVs that were examined quantitatively have metrics associated with high flows and, in particular, floodplain inundation and connectivity, it is not surprising that the results are similar for these WRVs.

Finally, while we sometimes examined the change in the number of very infrequent events associated with withdrawals, we caution against placing much confidence in these results. Even small changes in the occurrence of very infrequent events will result in large relative changes. Other than perhaps a catastrophic event, it is not clear that small changes in the number of events that occur less than about one year in ten, for example, have much impact on the WRVs examined in this report. Also recognize that very infrequent events such as 1 event in 100 years are not known with much confidence when the period of record is only 42 years.

Appendix A

Rainbow River Frequency Analysis Figures

Figure A-1
SWFWMD - Rainbow River Minimum Flows and Levels
Low Frequency Continuously Not Exceeded
1-Day Duration

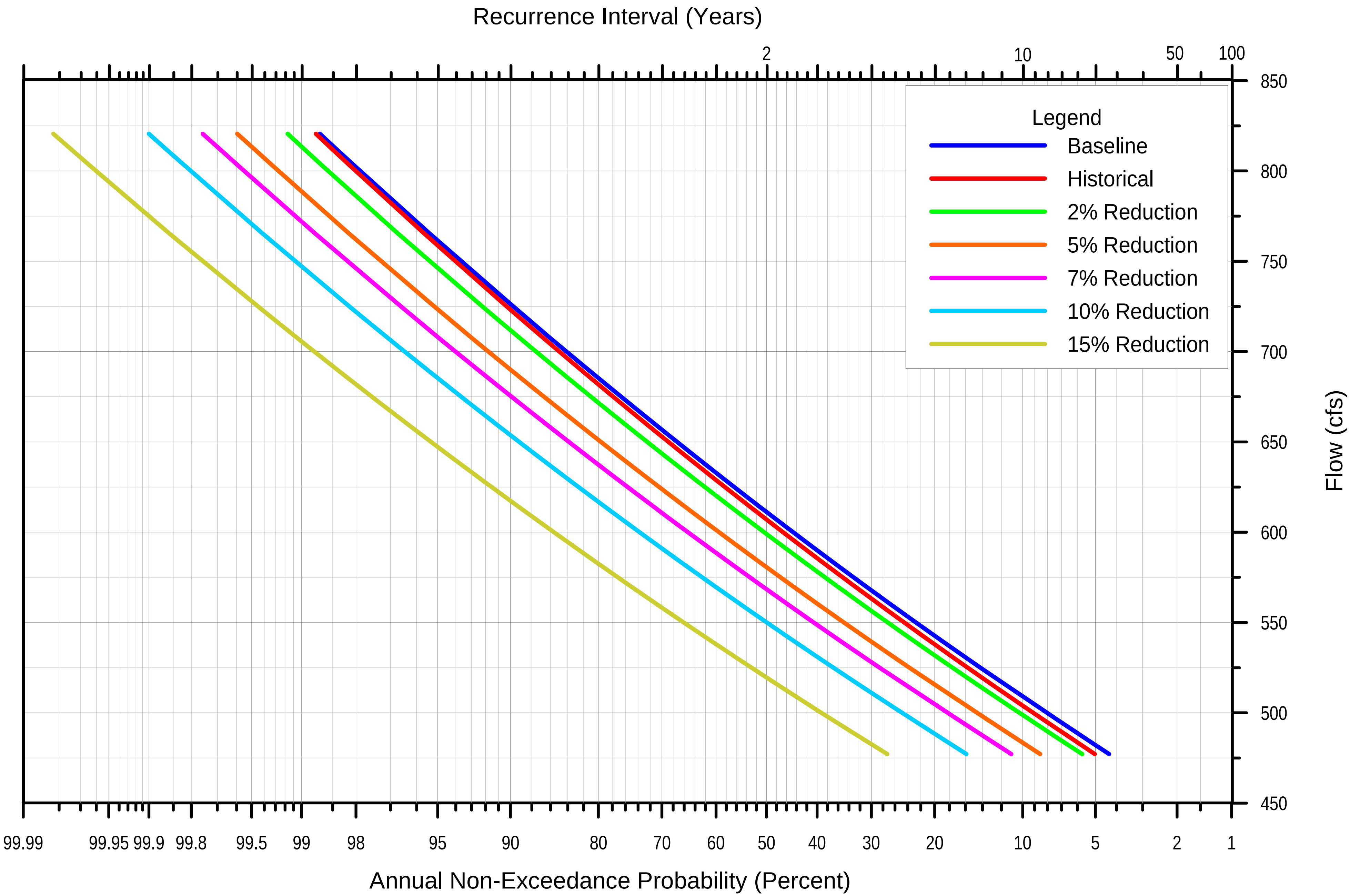


Figure A-2
SWFWMD - Rainbow River Minimum Flows and Levels
Low Frequency Continuously Not Exceeded
7-Day Duration

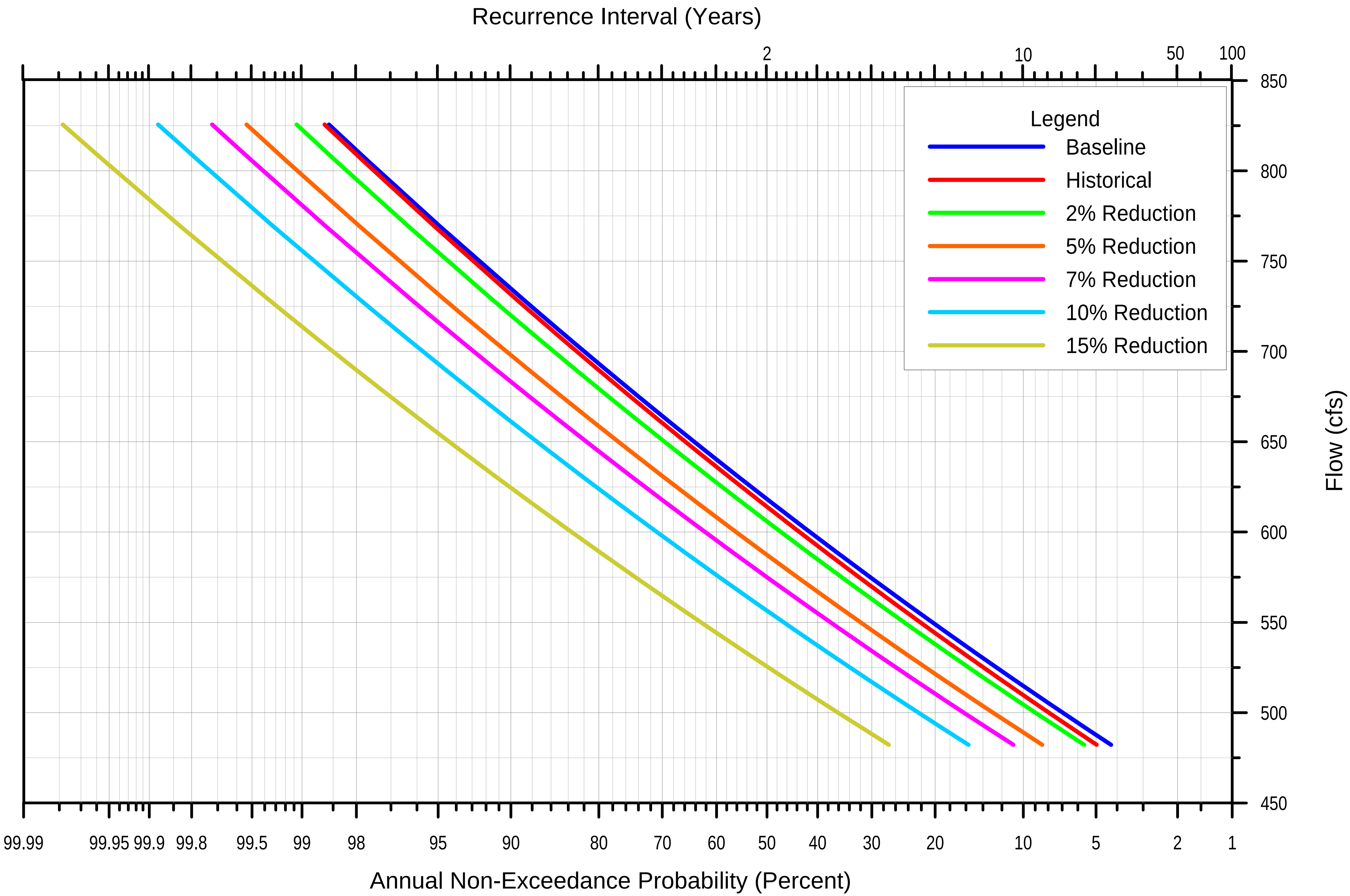


Figure A-3
SWFWMD - Rainbow River Minimum Flows and Levels
Low Frequency Continuously Not Exceeded
14-Day Duration

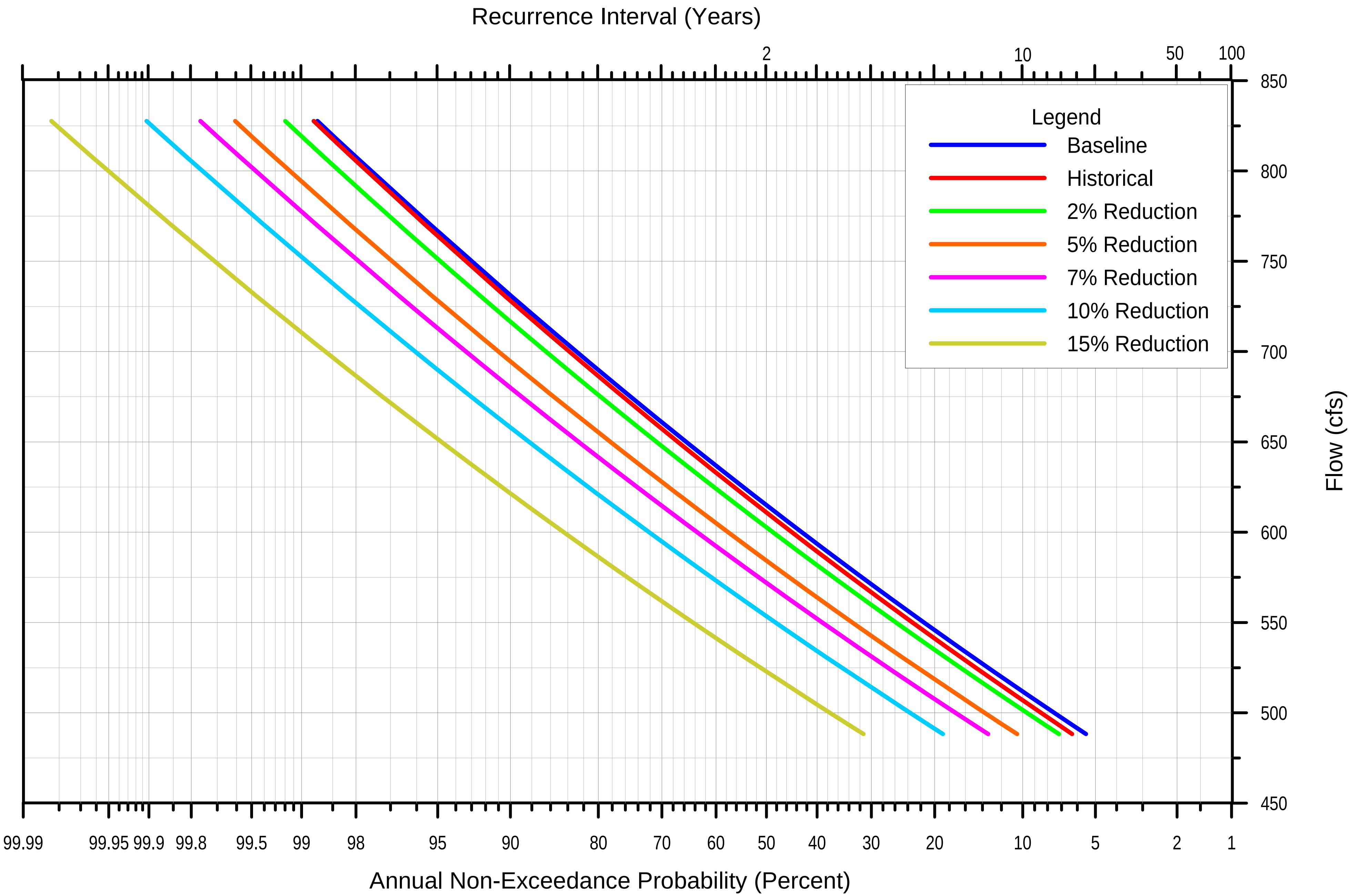


Figure A-4
SWFWMD - Rainbow River Minimum Flows and Levels
Low Frequency Continuously Not Exceeded
30-Day Duration

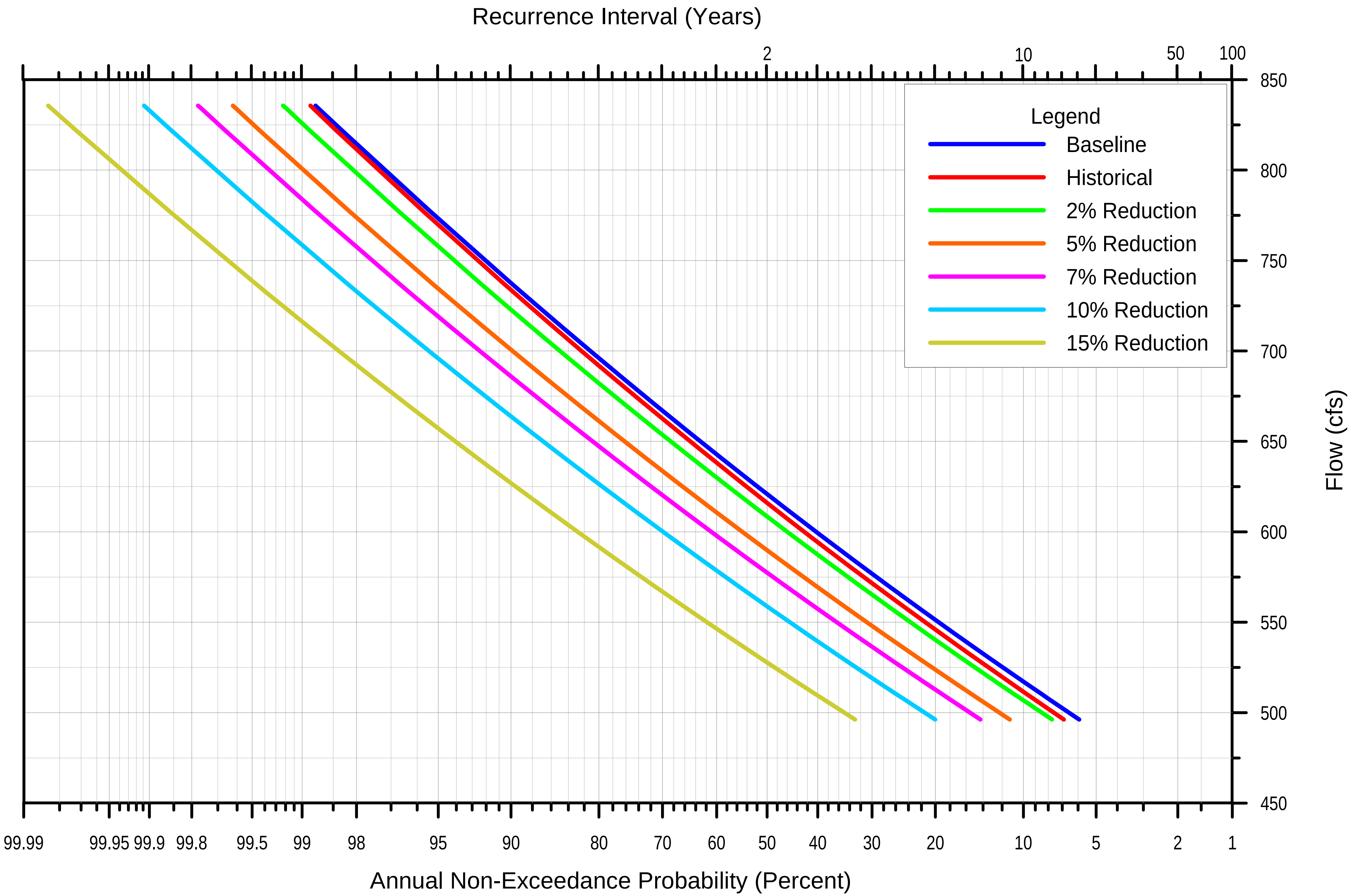


Figure A-5
SWFWMD - Rainbow River Minimum Flows and Levels
Low Frequency Continuously Not Exceeded
60-Day Duration

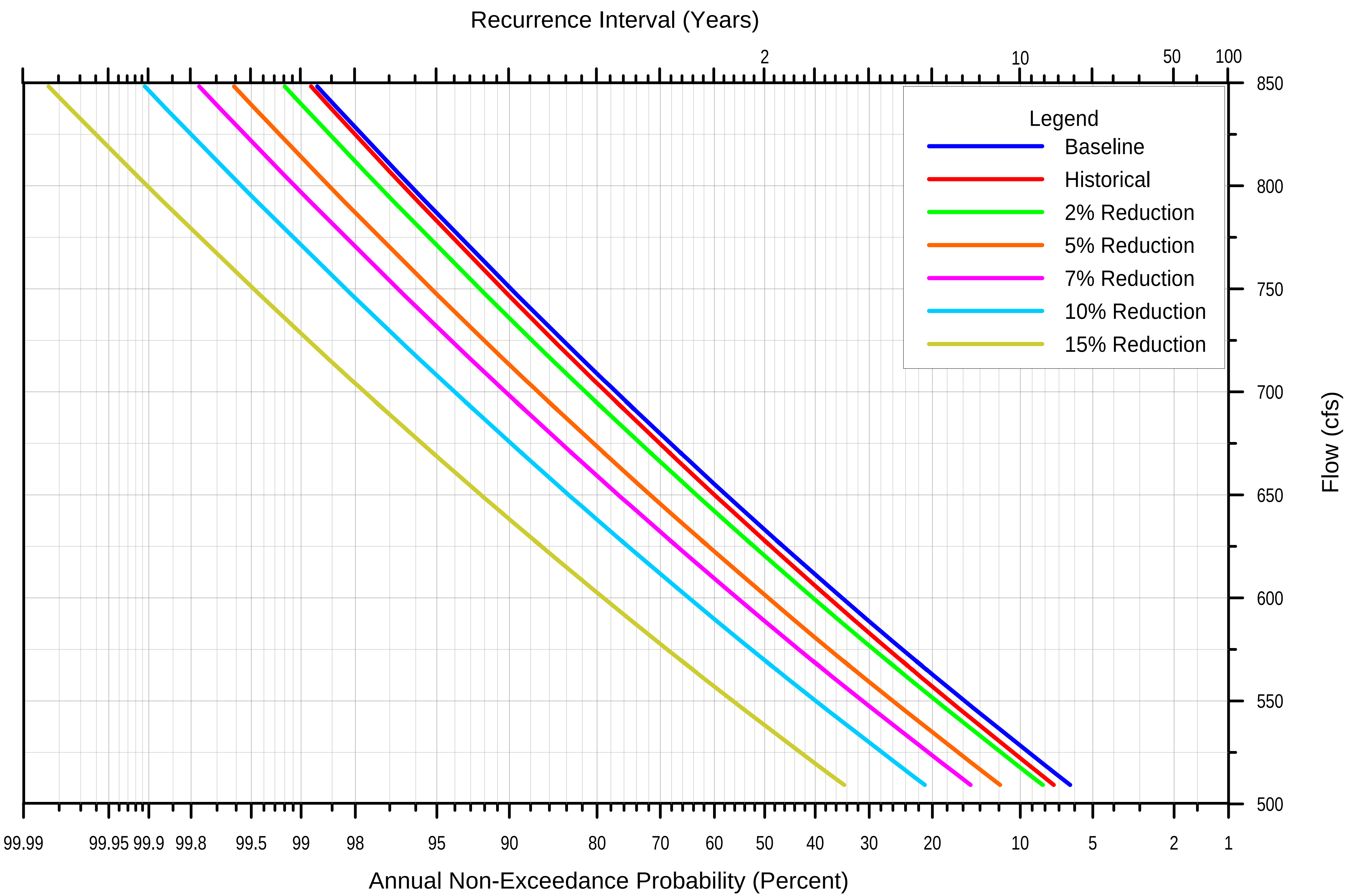


Figure A-6
SWFWMD - Rainbow River Minimum Flows and Levels
High Frequency Continuously Exceeded
1-Day Duration

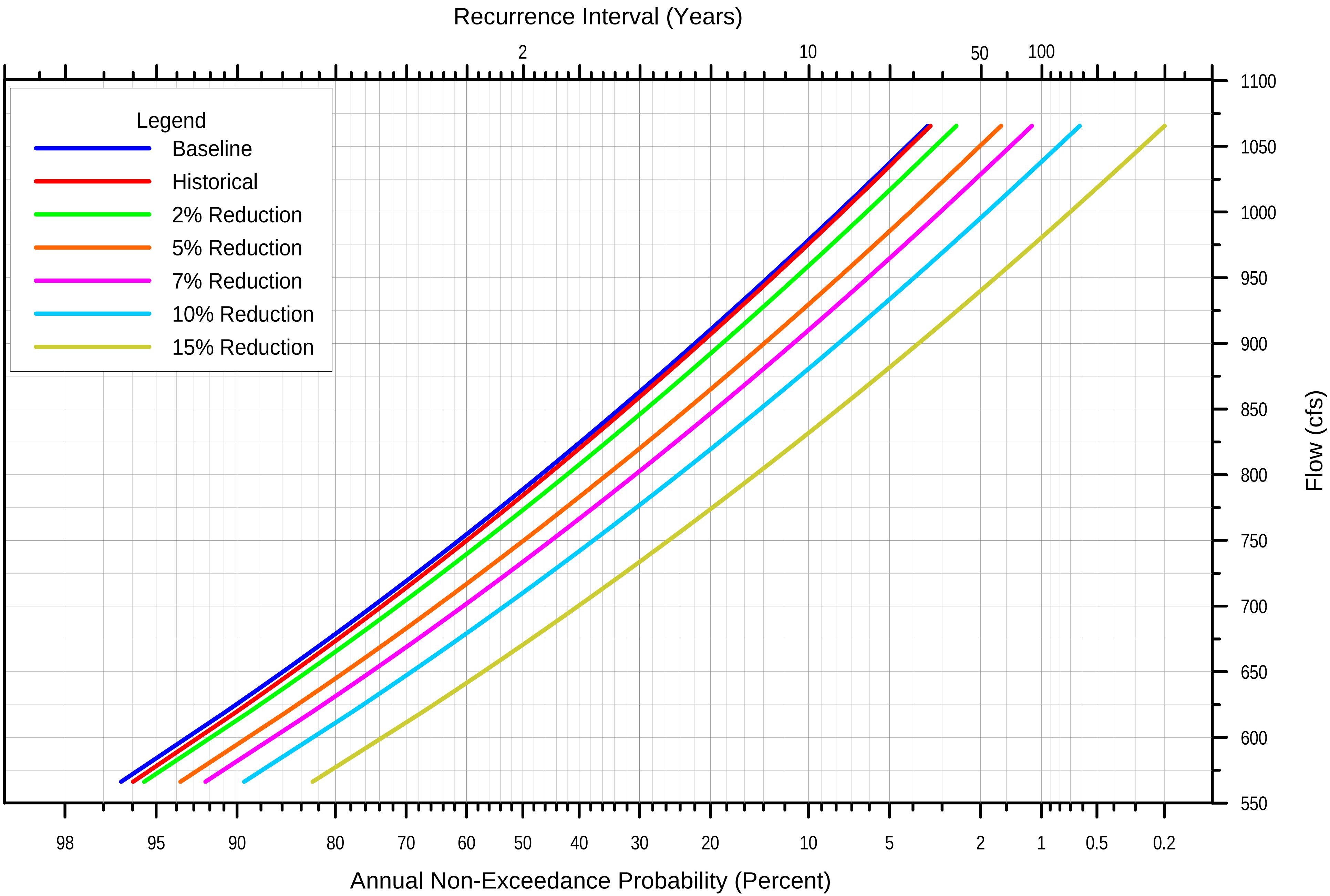


Figure A-7
SWFWMD - Rainbow River Minimum Flows and Levels
High Frequency Continuously Exceeded
7-Day Duration

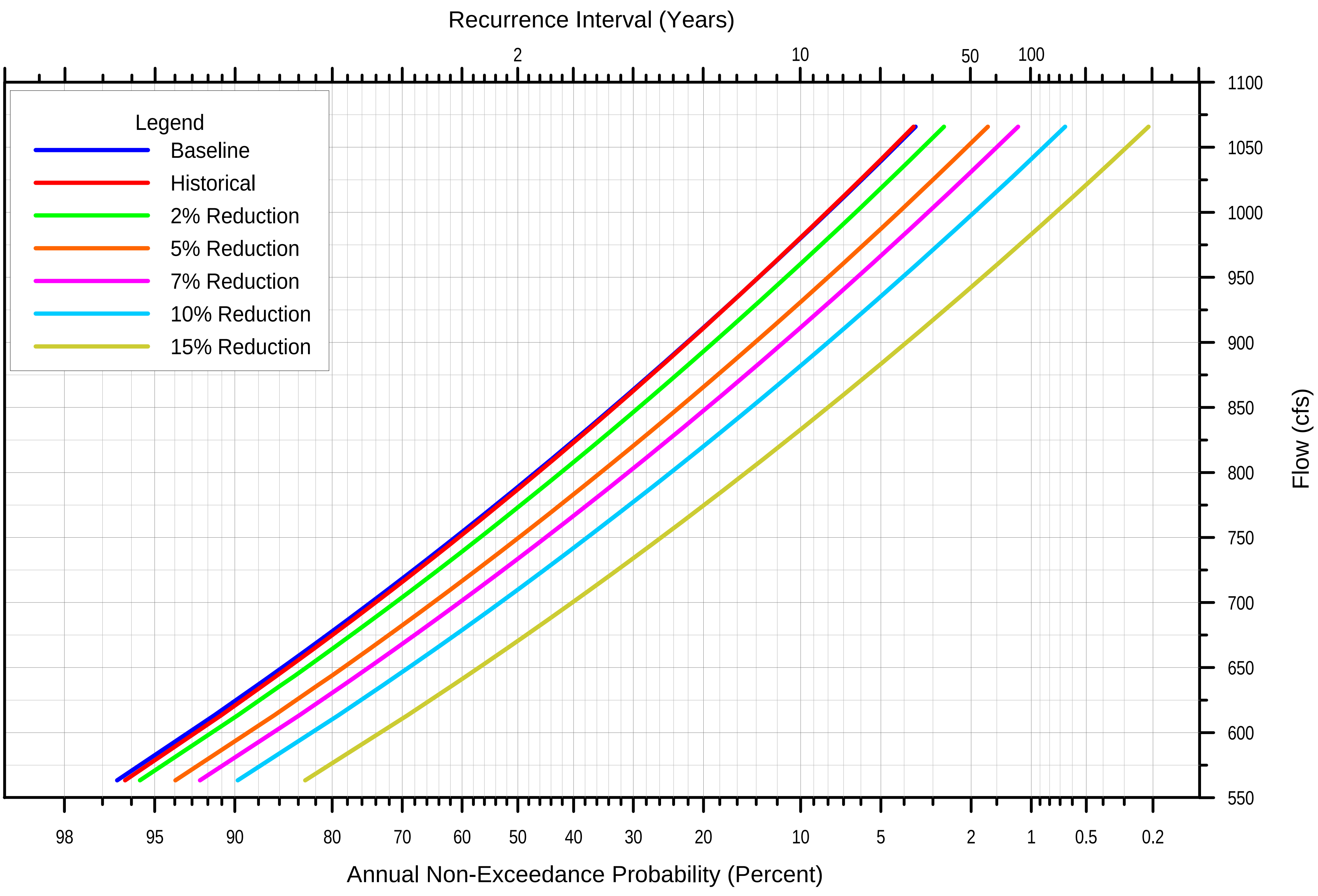


Figure A-8
SWFWMD - Rainbow River Minimum Flows and Levels
High Frequency Continuously Exceeded
14-Day Duration

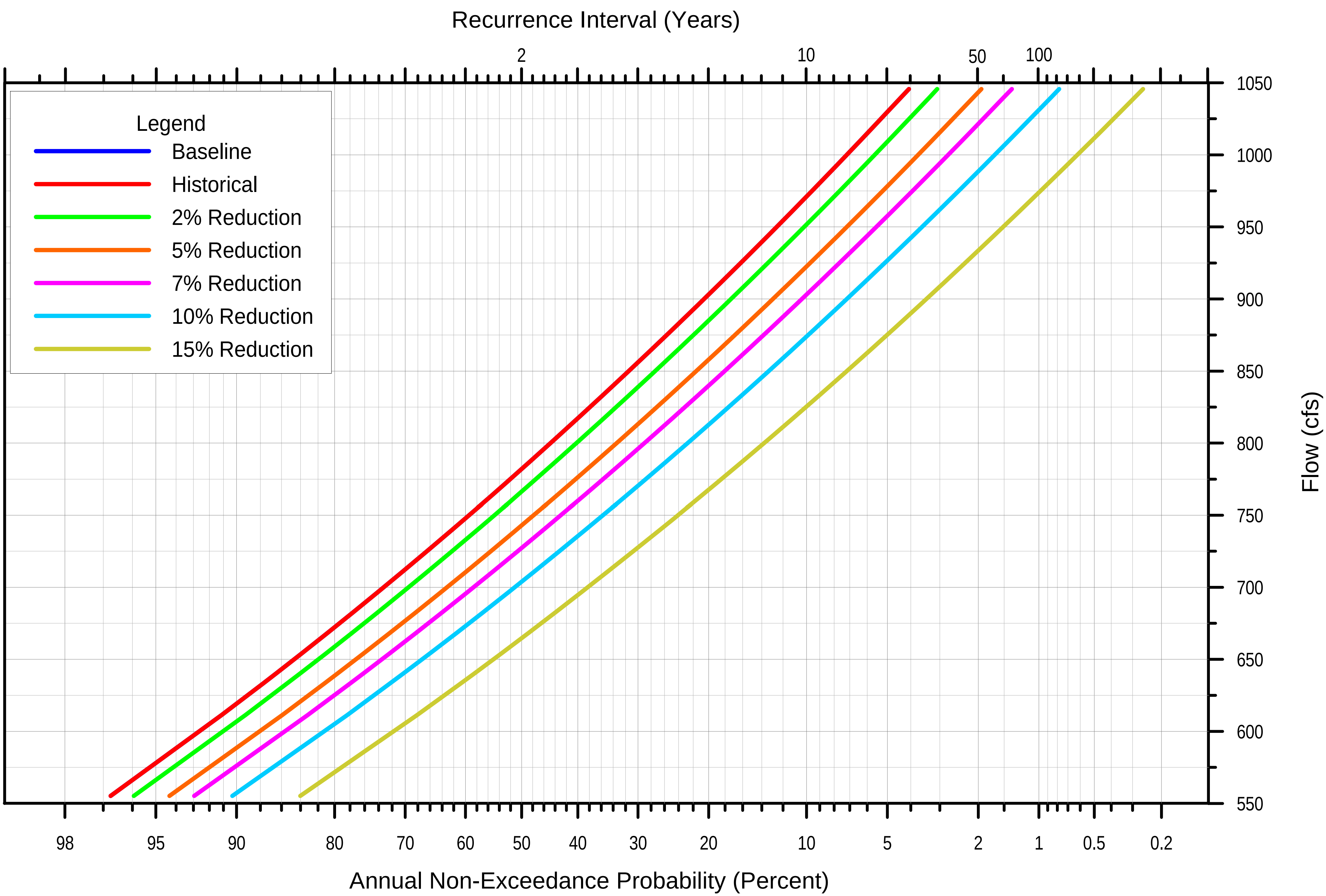


Figure A-9
SWFWMD - Rainbow River Minimum Flows and Levels
High Frequency Continuously Exceeded
30-Day Duration

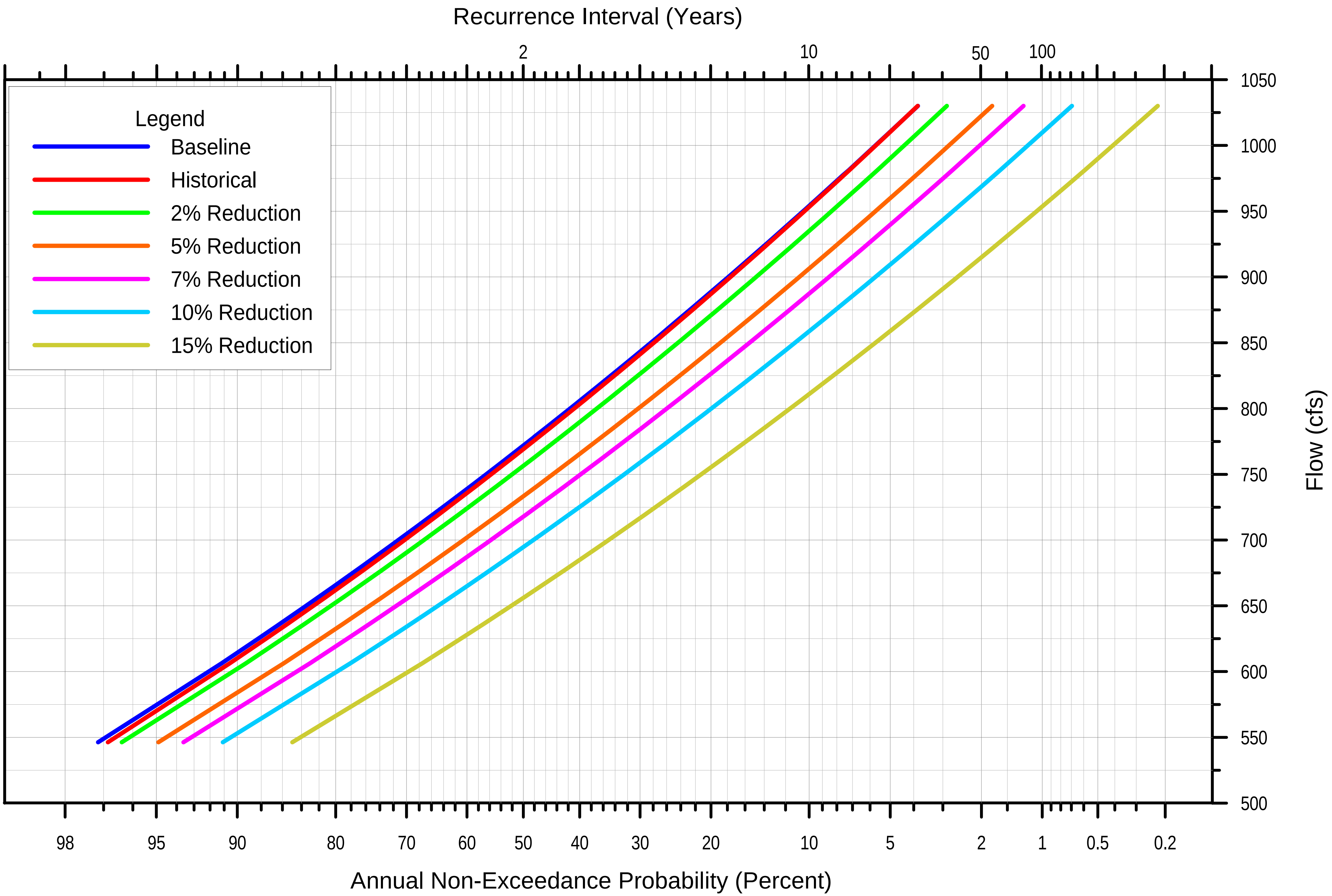
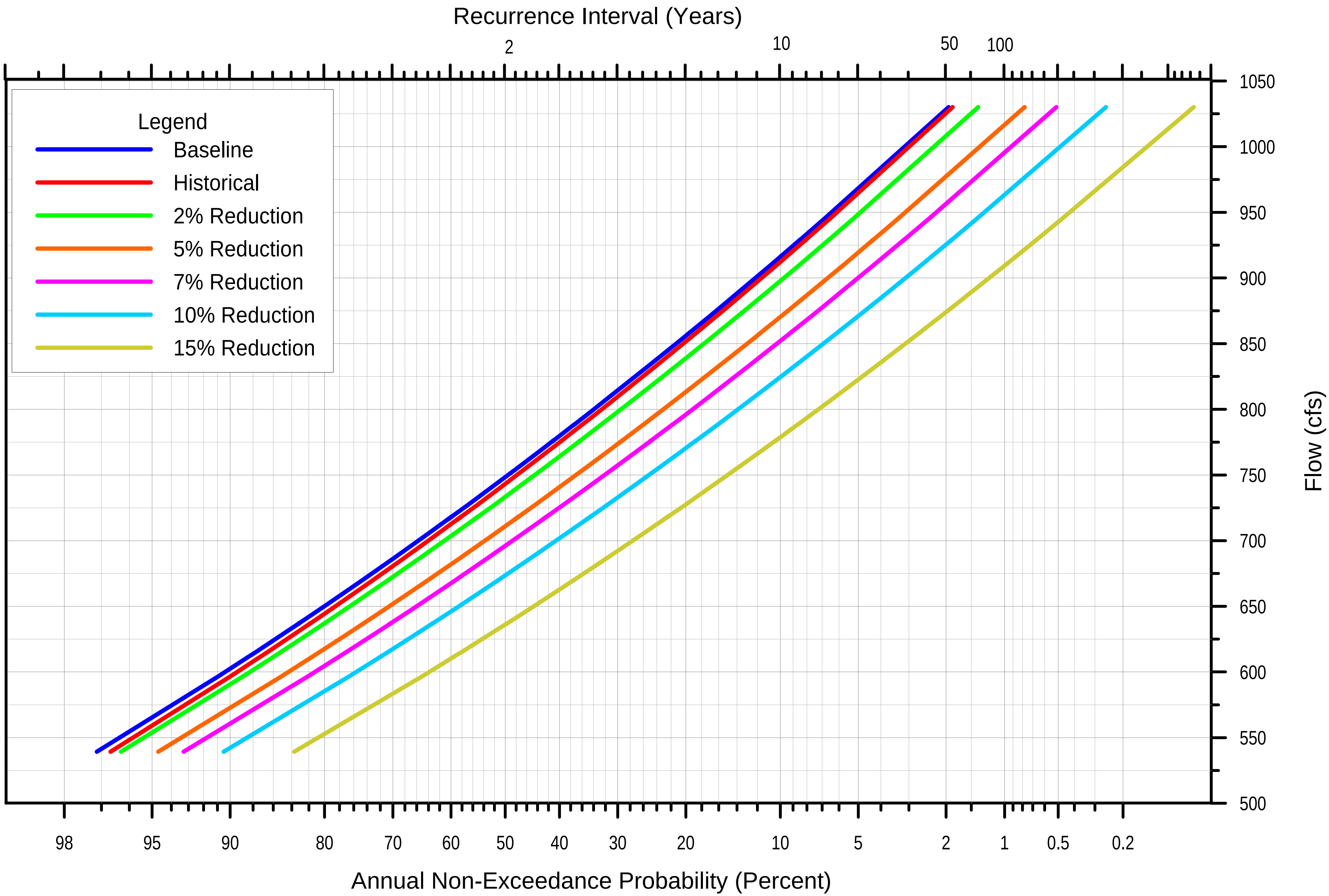


Figure A-10
SWFWMD - Rainbow River Minimum Flows and Levels
High Frequency Continuously Exceeded
60-Day Duration



Appendix B

Water Quality Index Tables & Figures

Table B-1. Water Quality and Water Quality Index near Rainbow River Headsprings

Date	Base Flow cfs	Well Stage ft	WQI	DO mg/L	TSS mg/L	TN mg/L	TP mg/L	TOC mg/L	Total Coliform #/100ml	Fecal Coliform #/100ml	Turbility NTU
6/26/02	500	29.88	19.22	7.24	--	1.24	0.03	--	--	--	0.06
7/29/02	563	30.50	19.91	7.1	0	1.27	0.03	--	--	--	0.03
8/20/02	583	30.70	20.05	6.99	0	1.23	0.03	--	--	--	0.2
9/24/02	590	30.77	17.47	7.32	0	1.19	0.03	--	--	--	0
10/22/02	597	30.80	21.35	6.67	0.1	1	0.04	--	--	--	0
11/19/02	575	30.58	28.89	5.73	0.01	1.29	0.03	--	--	--	0
12/12/02	567	30.50	17.82	7.4	0	1.32	0.02	--	--	--	0.12
1/28/03	607	30.90	16.88	7.49	0.03	1.18	0.03	--	--	--	0.1
2/25/03	605	30.88	17.54	7.26	0.05	1.16	0.03	--	--	--	0.09
3/18/03	643	31.26	18.30	7.47	0.03	1.35	0.03	--	--	--	0.11
4/22/03	663	31.46	15.87	7.3	0	0.98	0.03	--	--	--	0.15
5/19/03	641	31.24	16.80	7.48	0.06	1.15	0.03	--	--	--	0.14
6/18/03	630	31.13	15.68	7.51	0.16	1.11	0.03	--	--	--	0.13
7/10/03	782	32.65	14.41	7.74	0.09	1.1	0.03	--	--	--	0.14
8/19/03	801	32.84	14.09	8.11	0.08	1.3	0.02	--	--	--	0.1
9/15/03	789	32.72	14.13	8.02	0.05	1.1	0.03	--	--	--	0.19
10/13/03	748	32.31	17.01	7.33	0.05	1.07	0.03	--	--	--	0.28
11/17/03	698	31.81	18.30	7.36	0.03	1.26	0.03	--	--	--	0.18
1/26/04	626	31.09	13.60	8.5	0.1	1.32	0.03	--	--	--	0.2
3/15/04	605	30.88	22.65	6.35	0.05	1.07	0.03	--	--	--	0.12
5/24/04	564	30.47	19.30	7.06	0.11	1.26	0.02	--	--	--	0.06
7/20/04	569	30.52	25.47	6.19	0.09	1.21	0.03	--	--	--	0.058
9/21/04	720	33.12	15.70	7.92	0.06	1.34	0.03	--	--	--	0.02
11/16/04	816	33.56	18.03	7.38	0.68	1.21	0.03	--	--	--	0.04
1/24/05	737	32.20	21.18	6.93	0.03	1.39	0.02	--	--	--	0.03
4/6/05	658	31.41	15.76	8.27	0.1	1.43	0.03	--	--	--	0.08
5/24/05	644	31.27	18.30	7.41	0.07	1.26	0.03	--	--	--	0.18
7/19/05	696	31.79	17.60	7.48	0.1	1.29	0.03	--	--	--	0.04
9/8/05	771	32.54	15.48	7.93	0.08	1.22	0.03	--	--	--	0.03
11/7/05	719	32.02	17.45	7.59	0.06	1.36	0.03	--	--	--	0.03
1/23/06	662	31.45	20.31	7.4	0.04	1.61	0.03	--	--	--	0.03
3/20/06	666	31.49	16.66	7.6	0.11	1.33	0.02	--	--	--	0.06
5/25/06	597	30.80	19.25	7.35	0.1	1.35	0.03	--	--	--	0.04
7/17/06	591	30.74	22.50	7.09	0.09	1.58	0.03	--	--	--	0.03
9/5/06	586	30.69	22.59	7.07	0.13	1.64	0.03	--	--	--	0.03
11/6/06	570	30.53	18.71	7.47	0.18	1.44	0.03	--	--	--	0.07
1/9/07	571	30.54	19.00	7.46	0.22	1.42	0.03	--	--	--	0.08
3/13/07	607	30.90	21.74	7.26	0.07	1.71	0.03	--	--	--	0.05
5/15/07	583	30.66	24.89	6.7	0.11	1.59	0.03	--	--	--	0.05
7/23/07	559	30.42	22.99	7.21	0.06	1.75	0.03	--	--	--	0.02
9/4/07	580	30.63	21.43	7.36	0.18	1.68	0.03	--	--	--	0.06
11/6/07	595	30.78	15.47	7.49	0.08	1.11	0.02	--	--	--	0.05
1/22/08	587	30.50	20.25	7.35	--	1.69	0.02	--	--	--	--
3/11/08	609	30.62	26.11	6.81	0.23	1.99	0.03	--	--	--	0.32
5/5/08	604	30.80	--	7.28	--	--	--	--	--	--	--

WQI Overall Florida water quality index, which is a mean of eqalluy weighted constituent class WQIs when more than one constituent class is available

DO Dissolved oxygen

TSS Total suspended solids

TN Total nitrogen estimated as a sum of Total Kjeldahl Nitrogen (TKN) and Nitrate and Nitrite (NOx)

TP Total phosphorus

TOC Total organic carbon

When multiple data values exist for the same constituents, the average value for that constituent on a given day is provided

Stage is the mean daily well water elevation, ft-NGVD recorded at gage 29051408220701 Rainbow Springs Well near Dunnellon, FL

Flow is the daily discharge, cubic feet per second, collected at USGS gage 02313100, Rainbow Springs near Dunnellon, FL

Water quality data from station #1 collected by SWFWMD are used.

-- No data available

Table B-2. Water Quality and Water Quality Index at Rainbow River near Devil's Elbow

Date	Base Flow cfs	Well Stage ft	WQI	DO mg/L	TSS mg/L	TN mg/L	TP mg/L	TOC mg/L	Total Coliform #/100ml	Fecal Coliform #/100ml	Turbidity NTU
8/30/94	647	31.06	9.07	8	1	--	0.023	--	140	10	0.1
3/15/95	652	30.95	10.02	8	1	--	0.031	--	20	20	0.5
10/17/95	691	31.80	12.49	7.78	1	--	0.041	--	60	20	0.2
1/17/96	701	31.43	21.97	6.63	1	--	0.031	--	160	80	0.1
4/8/96	706	0.00	22.25	6.33	1	--	0.037	--	152	36	0.1
2/26/97	664	31.07	9.26	8.3	1	--	0.034	--	44	16	0.01
6/3/97	633	30.39	10.84	8.51	1	--	0.039	--	80	20	0.2
7/29/97	651	30.28	12.86	7.48	1	--	0.032	--	108	14	0.5
6/26/02	500	29.88	13.48	8.67	2.4	1.02	0.031	--	--	--	0.04
7/29/02	563	30.50	12.73	8.23	0.2	1.08	0.03	--	--	--	0
8/20/02	583	30.70	6.87	8.6	0.3	--	0.027	--	--	--	0
9/24/02	590	30.77	12.18	8.24	0.2	1.055	0.028	--	--	--	0
10/22/02	597	30.80	19.00	7.17	0.193	1.07	0.04	--	--	--	0
11/19/02	575	30.58	22.58	6.39	0.252	1.09	0.027	--	--	--	0
12/19/02	573	30.56	16.56	7.65	1.47	1.23	0.024	--	--	--	0.21
1/28/03	607	30.90	12.22	8.85	0.364	1.18	0.031	--	--	--	0.2
2/25/03	605	30.88	11.13	8.41	0.285	1.02	0.027	--	--	--	0.55
3/18/03	643	31.26	11.45	8.62	0.254	1.08	0.029	--	--	--	0.28
4/22/03	663	31.46	12.57	8.07	0.188	1.03	0.028	--	--	--	0.2
5/19/03	641	31.24	14.13	7.99	0.301	1.05	0.036	--	--	--	0.11
6/18/03	630	31.13	13.04	8.13	0.14	1.02	0.034	--	--	--	0.35
7/10/03	782	32.65	10.66	8.6	0.282	1.04	0.026	--	--	--	0.26
8/19/03	801	32.84	14.35	7.57	0.186	0.99	0.027	--	--	--	0.22
9/15/03	789	32.72	10.86	8.92	0.264	1.02	0.033	--	--	--	0.2
10/13/03	748	32.31	16.96	7.53	0.174	1.08	0.039	--	--	--	0.18
11/17/03	698	31.81	11.50	8.64	0.229	1.09	0.029	--	--	--	0.08
1/26/04	626	31.09	13.28	8.56	0.187	1.25	0.03	--	--	--	0.08
3/15/04	605	30.88	14.55	7.96	0.3289	1.16	0.03	--	--	--	0.14
5/24/04	564	30.47	16.02	7.59	0.2789	1.21	0.025	--	--	--	0.07
7/20/04	569	30.52	18.12	7.45	0.33599	1.25	0.032	--	--	--	0.105
9/21/04	720	33.12	14.23	8.1	0.1609	1.22	0.028	--	--	--	0.02
11/16/04	816	33.56	15.69	7.98	0.169	1.24	0.034	--	--	--	0.2
1/24/05	737	32.20	11.12	8.86	0.1014	1.14	0.026	--	--	--	0.03
4/6/05	658	31.41	11.58	11	0.2969	1.17	0.03	--	--	--	0.05
5/24/05	644	31.27	13.73	8.37	0.3559	1.24	0.03	--	--	--	0.31
7/19/05	696	31.79	13.36	8.38	0.3933	1.25	0.027	--	--	--	0.03
9/8/05	771	32.54	14.59	8.09	0.299	1.18	0.033	--	--	--	0.03
11/7/05	719	32.02	14.23	8.41	0.105	1.33	0.029	--	--	--	0.03
1/23/06	662	31.45	18.89	7.45	0.249	1.41	0.028	--	--	--	0.04
3/20/06	666	31.49	14.85	8.76	0.251	1.52	0.029	--	--	--	0.04
5/25/06	597	30.80	14.77	8.33	0.186	1.3	0.033	--	--	--	0.04
7/17/06	591	30.74	28.93	5.94	0.192	1.37	0.033	--	--	--	0.04
9/5/06	586	30.69	17.27	7.75	0.254	1.4	0.028	--	--	--	0.03
11/6/06	570	30.53	16.40	7.94	0.461	1.4	0.028	--	--	--	0.06
1/9/07	571	30.54	16.60	8.2	0.342	1.4341	0.0355	--	--	--	0.04
3/13/07	607	30.90	17.54	7.98	0.323	1.52	0.031	--	--	--	0.06
5/15/07	583	30.66	17.99	7.79	0.49	1.43	0.033	--	--	--	0.07
7/23/07	559	30.42	15.22	8.44	0.668	1.43	0.031	--	--	--	0.04
9/4/07	580	30.63	21.71	6.99	0.515	1.39	0.03	--	--	--	0.05
11/6/07	595	30.78	15.19	8.14	0.376	1.37	0.027	--	--	--	0.15
1/22/08	587	30.50	18.35	7.45	0.234	1.4	0.025	--	--	--	0.301
3/11/08	609	30.62	21.68	7.12	0.33	1.49	0.03	--	--	--	0.3
5/5/08	604	30.80	--	7.59	--	--	--	--	--	--	--
7/7/08	585	30.55	--	8.51	--	--	--	--	--	--	--

WQI Overall Florida water quality index, which is a mean of eqalluy weighted constituent class WQIs when more than one constituent class is available

DO Dissolved oxygen

TSS Total suspended solids

TN Total nitrogen estimated as a sum of Total Kjeldahl Nitrogen (TKN) and Nitrate and Nitrite (NOx)

TP Total phosphorus

TOC Total organic carbon

When multiple data values exist for the same constituents, the average value for that constituent on a given day is provided

Stage is the mean daily well water elevation, ft-NGVD recorded at gage 29051408220701 Rainbow Springs Well near Dunnellon, FL

Flow is the daily discharge, cubic feet per second, collected at USGS gage 02313100, Rainbow Springs near Dunnellon, FL

Water quality data from station #3 collected by SWFWMD and site 23010409 by FDEP are combined for this analysis.

-- No data available

Table B-3. Water Quality and Water Quality Index at Rainbow Springs near the Bridge at SR484

Date	Base Flow cfs	Well Stage ft	WQI	DO mg/L	TSS mg/L	TN mg/L	TP mg/L	TOC mg/L	Total Coliform #/100ml	Fecal Coliform #/100ml	Turbidity NTU
5/17/67	714	31.64	--	7.9	--	--	--	--	--	--	--
7/29/68	752	31.51	--	--	--	--	0.013	--	--	--	--
9/19/68	857	32.56	3.27	--	--	0.41	0.023	3	--	--	--
5/2/69	763	31.72	6.17	7.8	--	--	0.01	--	--	--	--
5/16/69	754	31.63	23.30	6.5	--	0.4	0.029	--	200	--	--
9/22/69	824	32.33	34.54	6.2	--	0.24	0.036	--	640	--	--
5/2/70	918	33.97	24.32	5.8	--	0.27	0.033	--	110	--	--
5/25/70	932	33.56	--	--	--	--	0.036	--	--	--	--
6/30/70	896	33.05	--	--	--	--	0.095	--	--	--	--
9/17/70	989	33.98	18.87	6.6	--	0.23	0.033	--	110	--	--
11/18/70	843	33.02	--	--	--	--	--	--	180	19	--
1/6/71	762	32.21	--	--	--	--	--	--	400	31	--
1/18/71	750	32.09	--	--	--	--	--	0	--	--	--
2/2/71	722	31.81	--	--	--	--	--	--	430	32	--
4/20/71	681	31.49	--	--	--	--	--	--	200	40	--
5/18/71	688	31.13	18.31	6.7	--	0.34	0.033	1	260	--	--
6/3/71	682	31.01	--	--	--	--	--	--	1900	17	--
7/21/71	677	30.96	--	--	--	--	--	1	--	--	--
9/17/71	799	32.18	46.63	6.1	--	0.63	0.029	31	420	--	--
5/16/72	671	31.09	20.58	6	--	0.48	0.028	0	210	--	--
6/27/72	658	0.00	--	--	2	--	--	--	--	--	--
8/29/72	680	31.18	26.19	6.7	--	0.5	0.035	10	--	--	--
9/19/72	735	31.03	16.02	6.5	--	0.4	0.03	0	150	--	--
5/21/73	709	31.52	23.23	5.6	--	0.6	0.026	3	200	--	--
9/18/73	743	32.11	24.13	4.6	--	0.26	0.02	0	150	--	--
9/25/73	744	32.12	--	--	1	--	--	--	--	--	--
5/14/74	582	30.30	13.81	6	--	0.32	0.03	0	30	--	--
9/17/74	733	31.97	11.90	6.9	--	0.37	0.03	0	100	--	--
1/17/75	635	30.83	10.64	6.7	--	0.26	0.03	1	10	0	--
3/26/75	608	30.36	10.64	6.7	--	0.26	0.03	0	13	0	--
5/27/75	568	30.05	16.51		2	--	0.06		20	0	--
5/28/75	566	30.05	9.80	6.7	--	0.41	0.02	1	--	0	--
7/22/75	567	29.90	9.14	7.5	--	0.46	0.03	0	--	--	--
8/13/75	581	30.05	12.65	6.3	--	0.33	0.03	0	25	0	--
9/19/75	593	30.35	19.59	5.1	--	0.28	0.04	0	60	0	--
11/18/75	643	30.91	11.63	6.5	--	0.43	0.03	0	25	0	--
5/20/76	542	30.29	8.82	7.2	--	0.19	0.04	0	10	--	--
7/26/76	688	31.75	--	6.2	--	--	--	--	--	--	--
9/21/76	685	31.72	16.77	6.6	--	0.26	0.04	3	160	--	--
5/20/77	611	30.83	7.17	7.4	--	0.45	0.03	2	50	--	--
6/2/78	728	31.98	48.02	6.4	--	--	0.03	33	--	--	--
6/14/78	720	31.85	4.88		--	0.39	0.03	0	--	--	--
5/17/79	639	30.86	4.88		--	0.25	0.03	0	--	--	--
9/11/79	671	31.18	23.64	7.1	--	0.34	0.03	11	--	--	--
5/6/80	666	31.12	15.73	7.7	--	0.48	0.05	--	--	--	--
8/28/80	737	31.83	15.85	7.2	--	0.26	0.03	--	--	--	--
5/29/81	580	30.26	17.79	6.9	--	0.41	0.11	0	--	--	--
6/29/82	787	32.33	29.54	4.2	--	0.37	0.03	2.7	--	--	--
4/19/83	872	32.48	10.58	7.6	--	0.47	0.04	3.6	--	--	--
8/10/83	798	32.04	9.42	7.4	--	0.38	0.03	1.8	--	--	--
6/14/84	828	32.03	10.86	7.5	--	0.6	0.03		--	--	--
8/22/84	872	32.48	15.33	7.3	--	0.9	0.03	0.1	--	--	--
12/5/84	749	31.59	--	7.7	--	--	--	--	--	--	--
1/17/85	710	31.20	19.88	7.2	--	0.66	0.03	--	--	--	--
2/1/85	698	31.08	--	7.6	--	--	--	--	--	--	--
3/29/85	649	30.59	--	8.2	--	--	--	--	--	--	--
5/24/85	603	30.34	6.47	8	--	0.43	0.03	0.5	--	--	--
7/18/85	622	30.67	17.69	7.8	--	--	0.07	--	--	--	--
11/14/85	845	32.49	--	8.4	--	--	--	--	--	--	--
3/11/86	765	31.70	--	7.8	--	--	--	--	--	--	--
5/21/86	746	31.51	16.80	7.1	--	--	0.04	--	--	--	--

Table B-3. Water Quality and Water Quality Index at Rainbow Springs near the Bridge at SR484

Date	Base Flow cfs	Well Stage ft	WQI	DO mg/L	TSS mg/L	TN mg/L	TP mg/L	TOC mg/L	Total Coliform #/100ml	Fecal Coliform #/100ml	Turbidity NTU
6/19/86	725	31.30	--	5.7	--	--	--	--	--	--	--
8/15/86	703	31.08	27.37	6.2	--	--	0.07	--	--	--	--
10/16/86	762	31.67	--	7	--	--	--	--	--	--	--
12/5/86	726	31.31	--	7.4	--	--	--	--	--	--	--
2/13/87	711	31.16	--	7	--	--	--	--	--	--	--
4/7/87	829	32.34	--	7.2	--	--	--	--	--	--	--
6/11/87	810	32.15	16.21	7.2	--	--	0.04	--	--	--	--
7/31/87	773	31.78	10.16	7.9	--	--	0.03	--	--	--	--
4/28/88	775	31.79	21.20	6.7	--	--	0.05	0.7	--	--	--
8/26/88	731	31.35	22.08	6.8	--	--	0.06	0.8	--	--	--
4/13/89	674	31.18	22.36	5.9	--	--	0.03	0.2	--	--	--
9/27/89	644	30.88	9.76	--	--	--	0.03	1.2	--	--	--
5/4/90	564	30.36	--	--	--	--	--	10	--	--	--
8/29/90	627	30.91	22.73	--	--	1.5	0.04	0.3	--	--	--
6/13/91	669	31.13	28.83	5.8	--	--	0.06	0.2	--	--	--
9/26/91	672	31.92	13.34	--	--	--	0.04	1.4	--	--	--
5/1/92	581	30.34	28.14	5.9	--	--	0.06	--	--	--	--
8/21/92	583	30.60	20.37	--	--	--	0.07	0.4	--	--	--
2/23/93	636	30.89	21.42	8.27	1	--	0.071	--	284	56	1
5/19/93	651	30.78	23.71	5.95	1	--	0.072	--	40	12	1
5/27/93	645	30.68	18.84	7		0.95	0.04	--	--	--	--
7/13/93	614	30.57	12.99	8.41	1	--	0.043	--	84	30	1
9/9/93	636	30.59	21.27	7		1	--	1	--	--	--
11/10/93	623	30.66	31.76	5.66	1	--	0.055	--	220	92	0.2
1/4/94	637	30.80	26.26	6.89	1	--	0.061	--	150	138	0.3
4/26/94	678	31.21	15.93	7.5		0.79	0.06	2.2	--	--	--
5/11/94	661	31.04	23.53	6.52	1	--	0.053	--	220	24	0.7
7/5/94	628	30.71	30.39	5.7	1	--	0.067	--	180	46	0.9
8/17/94	647	30.90	6.53	8.3		--	0.02	3.9	--	--	
10/12/94	695	31.75	36.92	5	1	--	0.089	--	220	62	0.4
1/17/95	687	31.30	23.77	7.4	1	--	0.095	--	160	44	0.7
4/12/95	647	30.90	29.54	--	2	--	0.066	--	440	68	0.3
5/25/95	618	30.61	--	--	--	--	0.05	--	--	--	--
7/5/95	609	30.52	15.63	--	1	--	0.048	--	--	--	0.8
8/11/95	640	30.83	7.84	7.7	--	--	0.02	0.3	--	--	--
2/15/96	693	31.36	--	7.4	--	--	--	--	--	--	--
4/11/96	708	0.00	--	6.8	--	--	--	--	--	--	--
4/12/96	709	31.52	--	5.5	--	--	--	--	--	--	--
5/31/96	701	31.44	19.67	6.3	--	--	--	1.6	--	--	--
10/7/96	776	32.19	--	--	--	--	--	11	--	--	--
12/2/96	721	31.64	--	6.1	--	--	--	--	--	--	--
3/18/97	646	30.89	--	7.2	--	--	--	--	--	--	--
5/1/97	643	30.66	11.16	7.1	--	--	0.02	2.1	--	--	--
7/10/97	643	30.29	--	7	--	--	--	--	--	--	--
10/21/97	713	30.45	6.89	7.7	--	--	--	--	--	--	--
1/21/98	945	33.76	--	7.2	--	--	--	--	--	--	--
4/6/98	997	34.40	--	7	--	--	--	--	--	--	--
6/9/98	866	32.57	0.50	12.3	--	--	--	--	--	--	--
8/4/98	770	32.13	--	7.4	--	--	--	--	--	--	--
10/13/98	895	32.27	17.60	6.6	--	--	0.03		--	--	--
11/17/98	894	32.20	--	6.6	--	--	--	--	--	--	--
1/21/99	784	31.60	--	7.8	--	--	--	--	--	--	--
5/17/99	625	30.68	20.65	6.5	--	--	0.04	--	--	--	--
7/1/99	625	30.68	--	7.4	--	--	--	--	--	--	--
9/2/99	629	30.72	8.43	7.5	--	--	--	--	--	--	--
6/27/02	498	29.86	24.10	7.91	11	0.92	0.034	--	--	--	0.38
8/8/02	572	30.60	13.40	9.35	0.6	1.4	0.029	--	--	--	0.23
8/27/02	578	30.66	18.09	7.02	0.4	1.05	0.027	--	--	--	0.19
10/3/02	597	30.80	12.71	8.1	0.751	0.964	0.035	--	--	--	0.21
10/24/02	597	30.80	12.62	8.22	0.633	1.024	0.033	--	--	--	0.2
11/21/02	573	30.56	10.89	9.21	0.722	1.03	0.035	--	--	--	0.33

Table B-3. Water Quality and Water Quality Index at Rainbow Springs near the Bridge at SR484

Date	Base Flow cfs	Well Stage ft	WQI	DO mg/L	TSS mg/L	TN mg/L	TP mg/L	TOC mg/L	Total Coliform #/100ml	Fecal Coliform #/100ml	Turbidity NTU
12/17/02	573	30.56	11.85	8.39	0.406	1.03	0.031	--	--	--	0.3
1/30/03	606	30.89	9.97	9.7	0.603	0.975	0.032	--	--	--	0.62
2/27/03	602	30.85	19.76	7.06	1.81	0.99	0.035	--	--	--	0.44
3/20/03	645	31.28	14.01	7.66	1.18	0.91	0.031	--	--	--	0.9
4/24/03	661	31.44	10.53	8.58	1.12	0.932	0.031	--	--	--	0.34
5/21/03	637	31.20	14.69	8.17	1.76	1.01	0.035	--	--	--	1.06
6/16/03	630	31.13	12.68	8.43	0.962	1.07	0.035	--	--	--	0.89
7/14/03	787	32.70	16.28	7.7	1.52	0.994	0.04	--	--	--	0.51
8/21/03	806	32.89	15.99	7.42	0.76	0.956	0.036	--	--	--	0.4
9/17/03	785	32.68	13.83	7.94	0.608	0.986	0.037	--	--	--	0.34
10/15/03	744	32.27	17.84	7.39	0.943	1.04	0.044	--	--	--	0.7
11/19/03	698	31.81	15.04	7.85	0.883	1.08	0.036	--	--	--	0.4
1/28/04	614	30.97	21.03	6.88	0.62	1.13	0.037	--	--	--	0.29
3/22/04	608	30.91	11.57	9.74	0.675	1.076	0.037	--	--	--	0.36
5/26/04	563	30.46	11.63	9.1	1.34	1.08	0.031	--	--	--	0.11
7/22/04	566	30.49	11.07	10		1.1	0.031	--	--	--	--
9/23/04	711	33.17	17.00	7.62	0.4549	1.17	0.036	--	--	--	0.02
11/23/04	811	33.32	14.25	9.05	0.44	1.27	0.044	--	--	--	0.02
1/26/05	731	32.14	11.88	9.13	0.4969	1.13	0.034	--	--	--	0.34
4/12/05	659	31.42	14.05	11.4	2.04	1.12	0.039	--	--	--	0.03
5/26/05	637	31.20	13.51	8.42	0.817	1.09	0.041	--	--	--	0.74
7/21/05	699	31.82	12.33	8.52	1.08	1.08	0.033	--	--	--	0.05
9/15/05	763	32.46	11.75	8.76	0.843	1.1	0.032	--	--	--	0.07
11/9/05	716	31.99	12.37	9.32	0.31375	1.2	0.034	--	--	--	0.04
1/25/06	659	31.42	15.81	8.26	0.815	1.34	0.037	--	--	--	0.06
3/23/06	660	31.43	18.87	7.43	1.2	1.18	0.04	--	--	--	0.04
5/30/06	596	30.79	17.61	7.6	0.557	1.24	0.035	--	--	--	0.03
7/19/06	594	30.77	18.65	7.54	0.327	1.26	0.04	--	--	--	0.05
9/7/06	585	30.68	23.60	6.65	1.12	1.27	0.034	--	--	--	0.07
11/8/06	576	30.59	18.11	7.74	1.03	1.34	0.038	--	--	--	0.06
1/11/07	567	30.50	13.50	10.15	0.824	1.3129	0.0353	--	--	--	0.04
3/15/07	606	30.89	17.91	7.68	1.12	1.33	0.033	--	--	--	0.05
5/17/07	579	30.62	22.03	7.02	1.43	1.31	0.033	--	--	--	0.04
7/25/07	559	30.42	14.01	9	0.809	1.31	0.038	--	--	--	0.05
9/6/07	575	30.58	19.14	7.44	0.644	1.32	0.035	--	--	--	0.106
11/8/07	594	30.77	17.73	7.87	1.08	1.37	0.037	--	--	--	0.05
1/24/08	591	30.53	24.18	6.74	1.05	1.32	0.042	--	--	--	0.58
3/13/08	610	30.63	--	7.66	--	--	--	--	--	--	--
5/7/08	598	30.76	--	8.7	--	--	--	--	--	--	--
7/7/08	585	30.55	--	6.73	--	--	--	--	--	--	--

WQI Overall Florida water quality index, which is a mean of eqalluy weighted constituent class WQIs when more than one constituent class is available

DO Dissolved oxygen

TSS Total suspended solids

TN Total nitrogen estimated as a sum of Total Kjeldahl Nitrogen (TKN) and Nitrate and Nitrite (NOx)

TP Total phosphorus

TOC Total organic carbon

When multiple data values exist for the same constituents, the average value for that constituent on a given day is provided

Stage is the mean daily well water elevation, ft-NGVD recorded at gage 29051408220701 Rainbow Springs Well near Dunnellon, FL

Flow is the daily discharge, cubic feet per second, collected at USGS gage 02313100, Rainbow Springs near Dunnellon, FL

Water quality data from station #7 collected by SWFWMD, sites 23010055 and 23010404 by FDEP, and site 02313100 by USGS are combined for this analysis.

-- No data available

Figure B-1
Water Quality Index near Rainbow River Headsprings versus Well Stage at Gage 29051408220701 Rainbow Springs Well near Dunnellon, FL

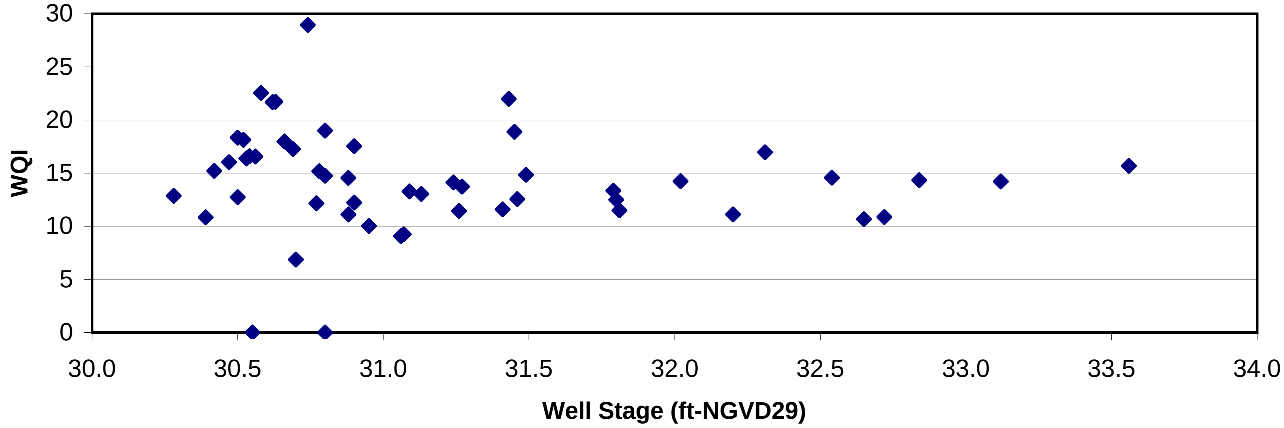


Figure B-2
Water Quality Index at Rainbow River near Devil's Elbow versus Well Stage at Gage 29051408220701 Rainbow Springs Well near Dunnellon, FL

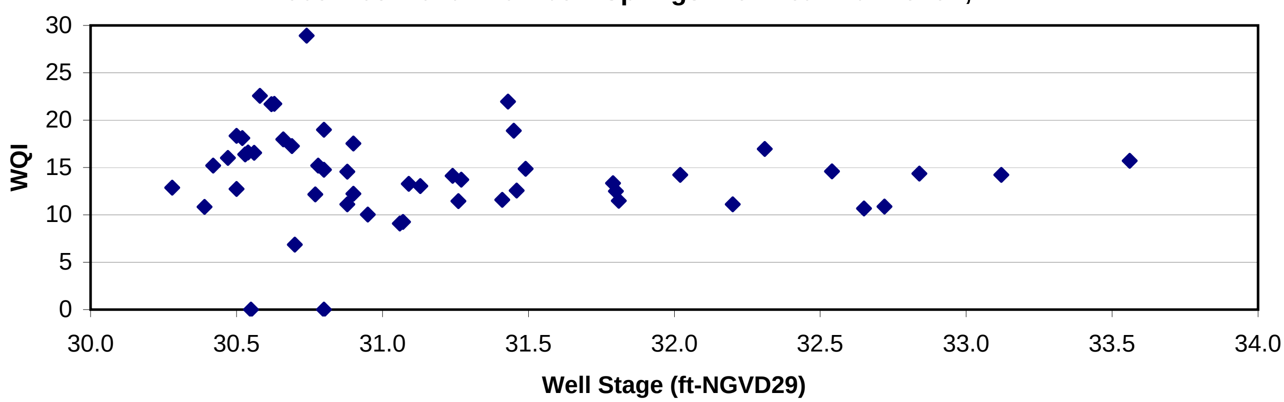
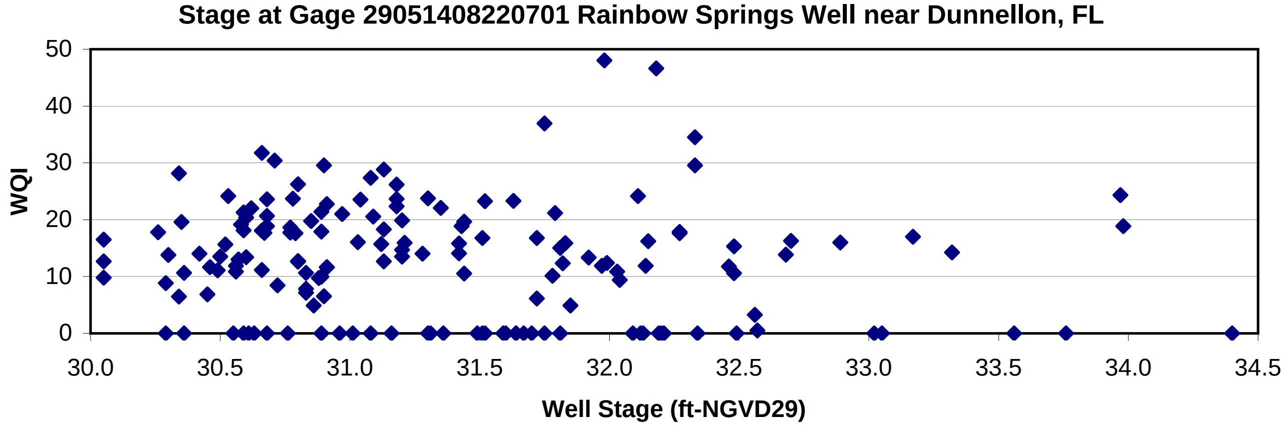


Figure B-3
Water Quality Index at Rainbow Springs near the Bridge at SR484 versus Well Stage at Gage 29051408220701 Rainbow Springs Well near Dunnellon, FL

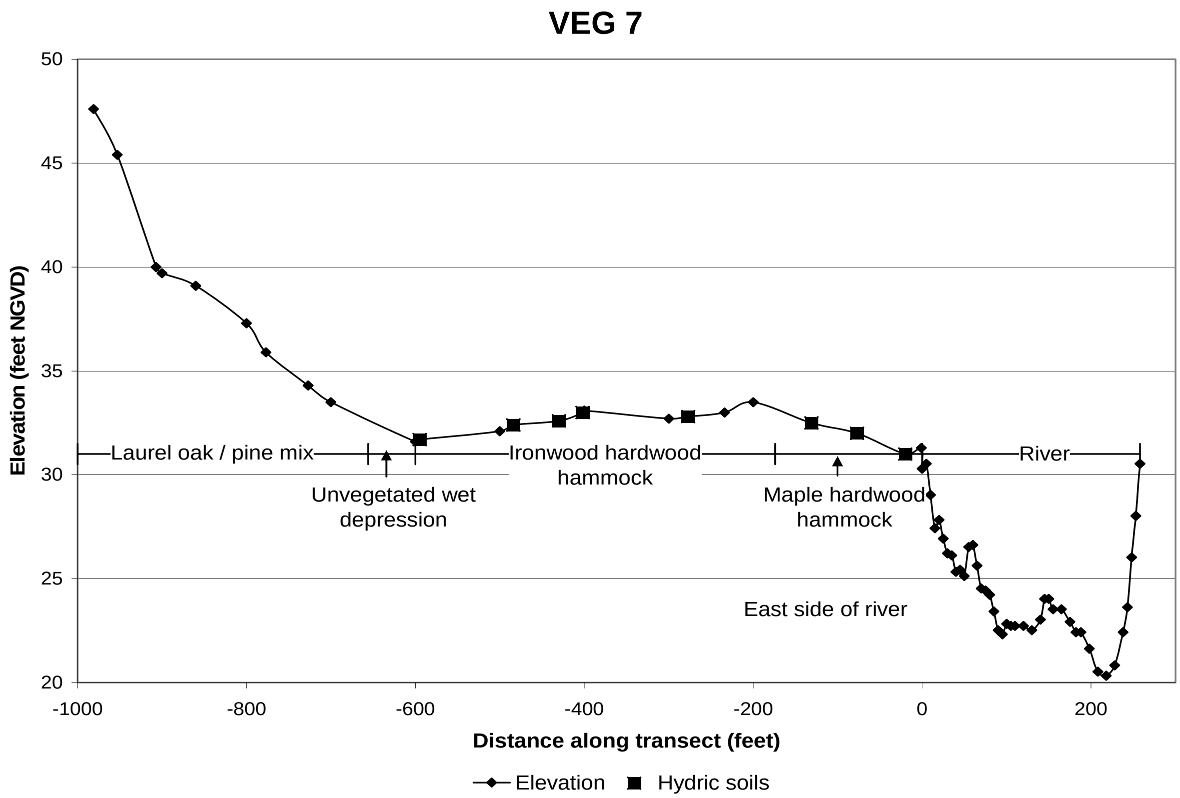


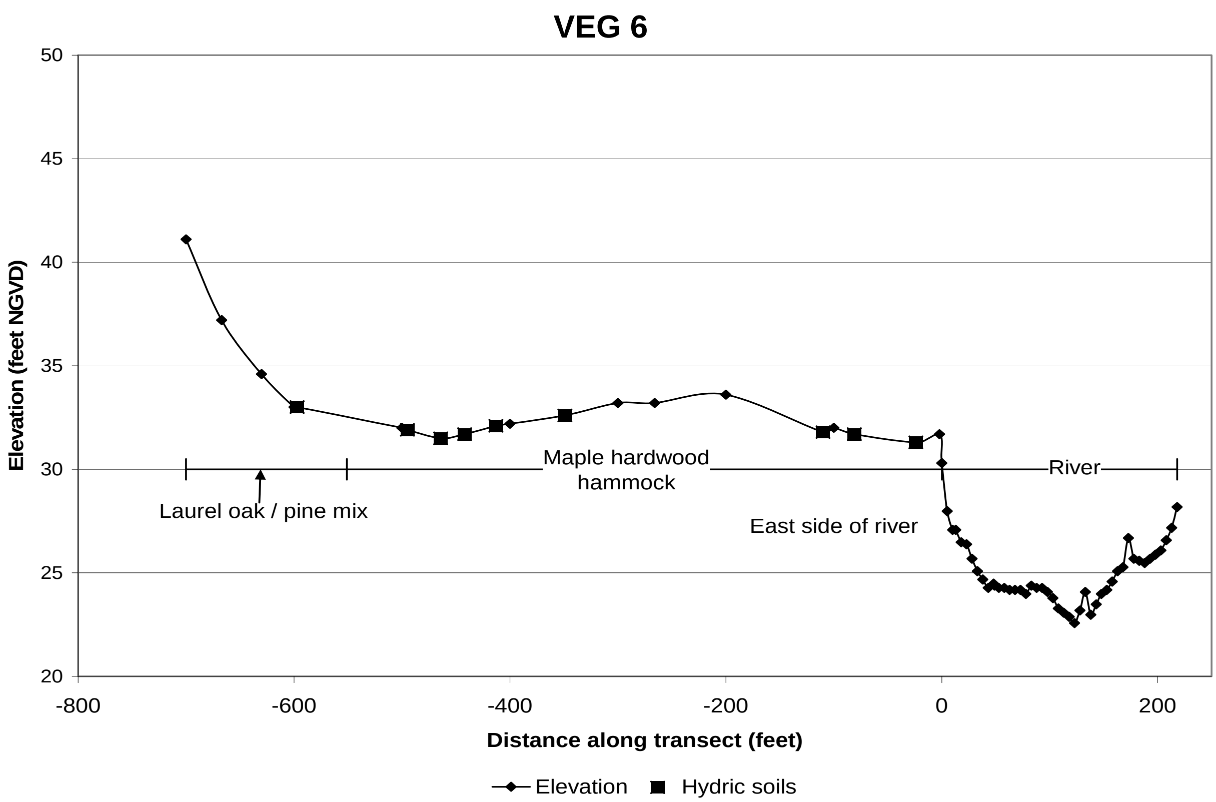
Appendix C

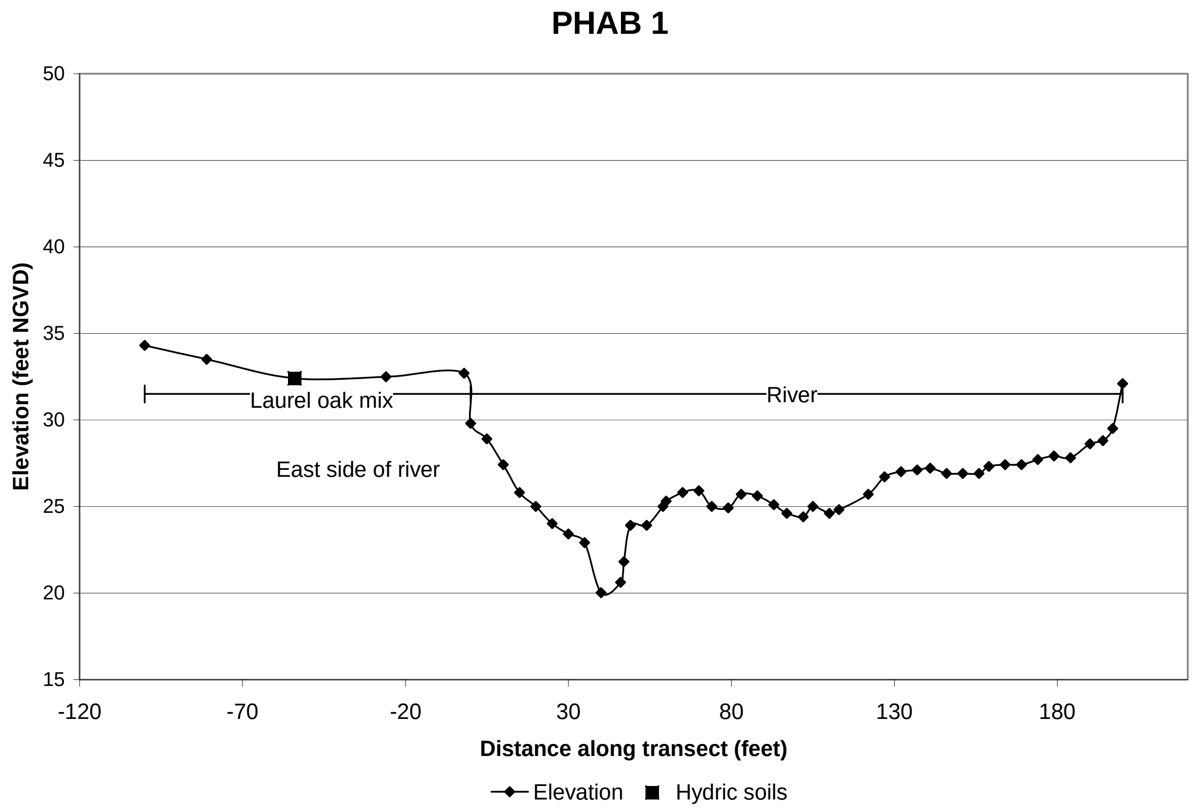
Referred Appendices in the PBSJ Report

Figure C-1

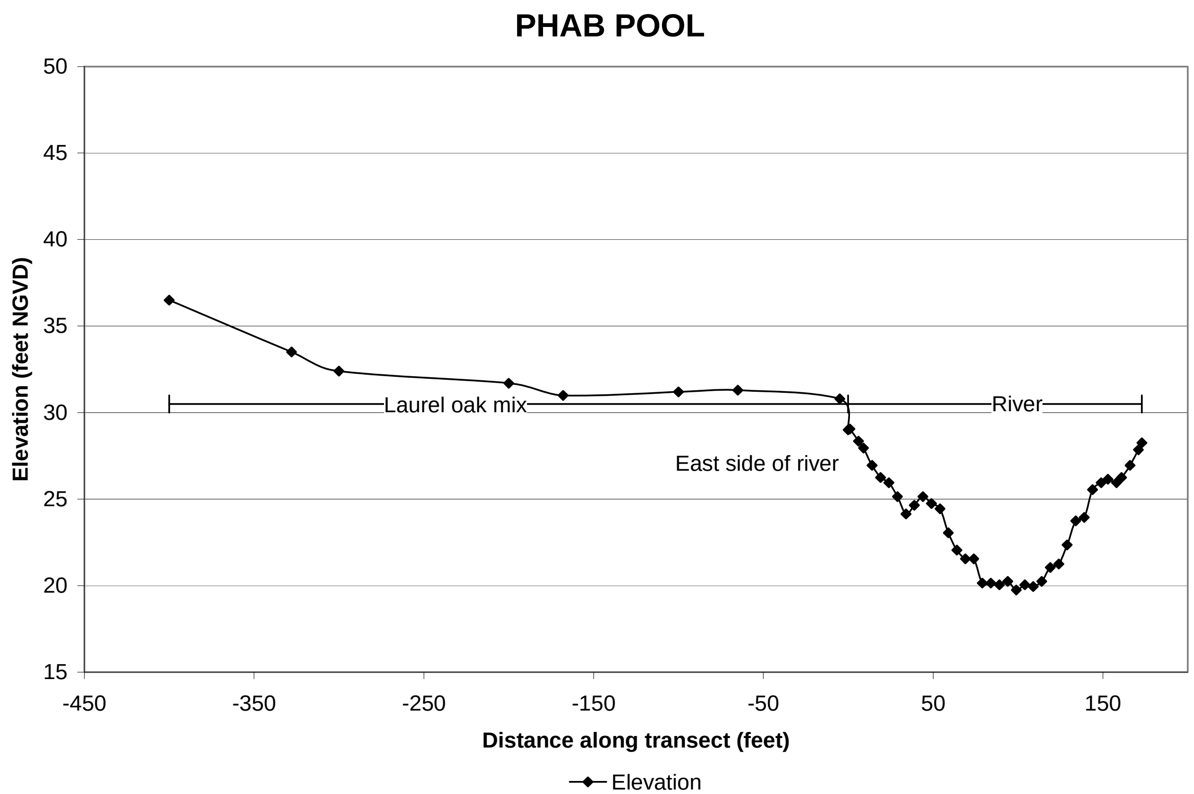
Elevation and Vegetation Profiles for the Rainbow River Study Corridor


VEG 7
Elevation (feet NGVD)
Distance along transect (feet)
Laurel oak / pine mix
Unvegetated wet depression
Ironwood hardwood hammock
Maple hardwood hammock
River
East side of river
Elevation
Hydric soils

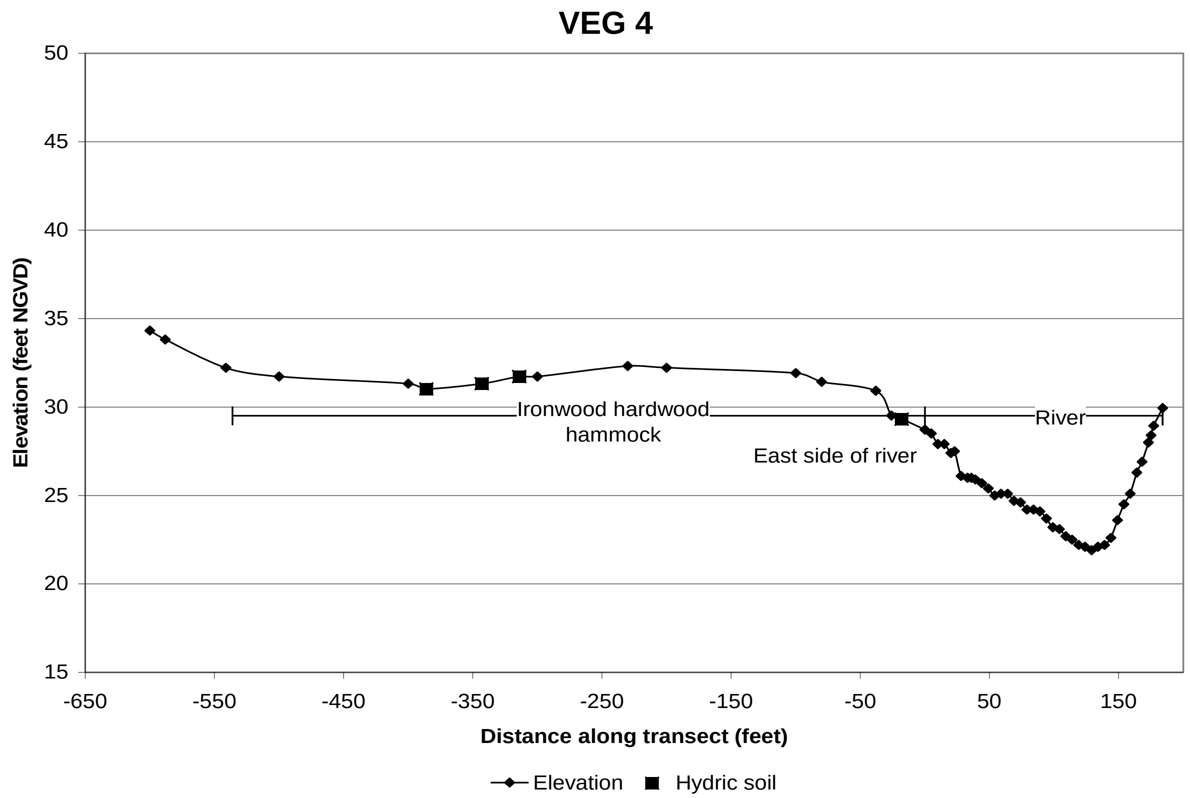

VEG 6
Elevation (feet NGVD)
Distance along transect (feet)
Laurel oak / pine mix
Maple hardwood hammock
River
East side of river
Elevation
Hydric soils



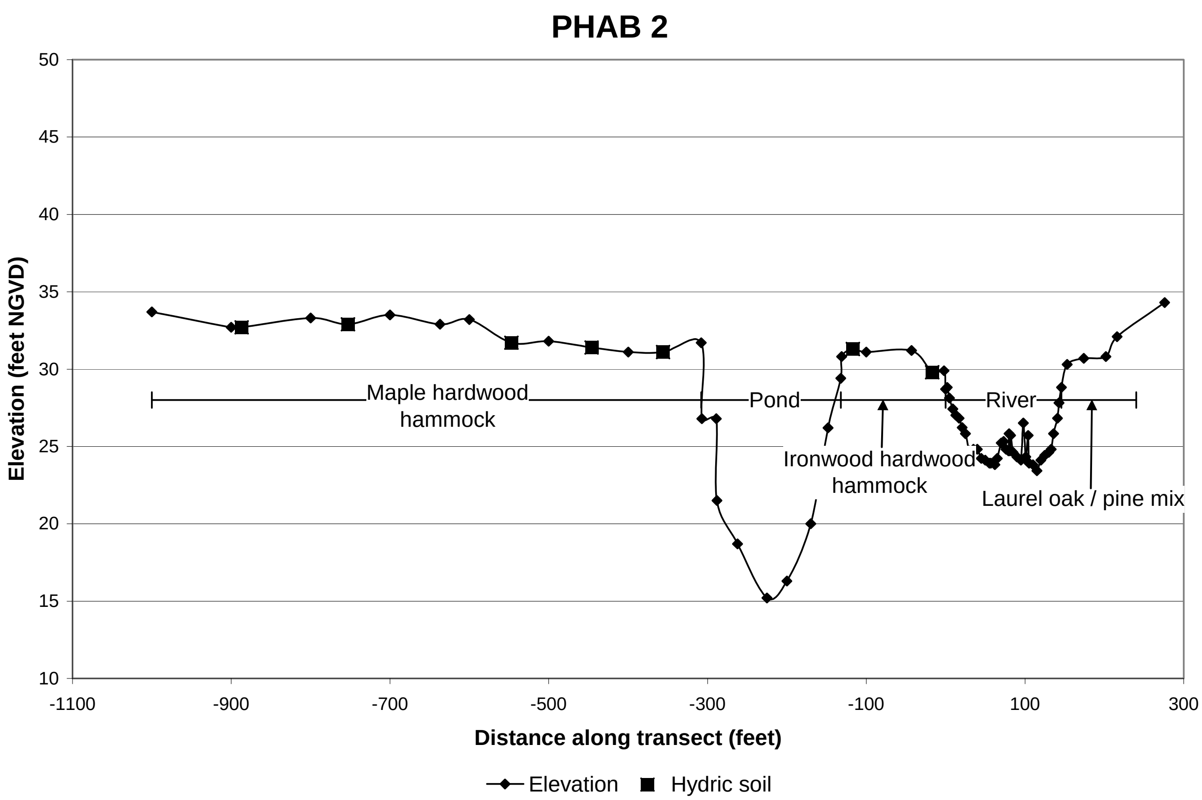
PHAB 1
Elevation (feet NGVD)
50
45
40
35
30
25
20
15
-120
-70
-20
30
80
130
180
Distance along transect (feet)
Laurel oak mix
River
East side of river
Elevation
Hydric soils



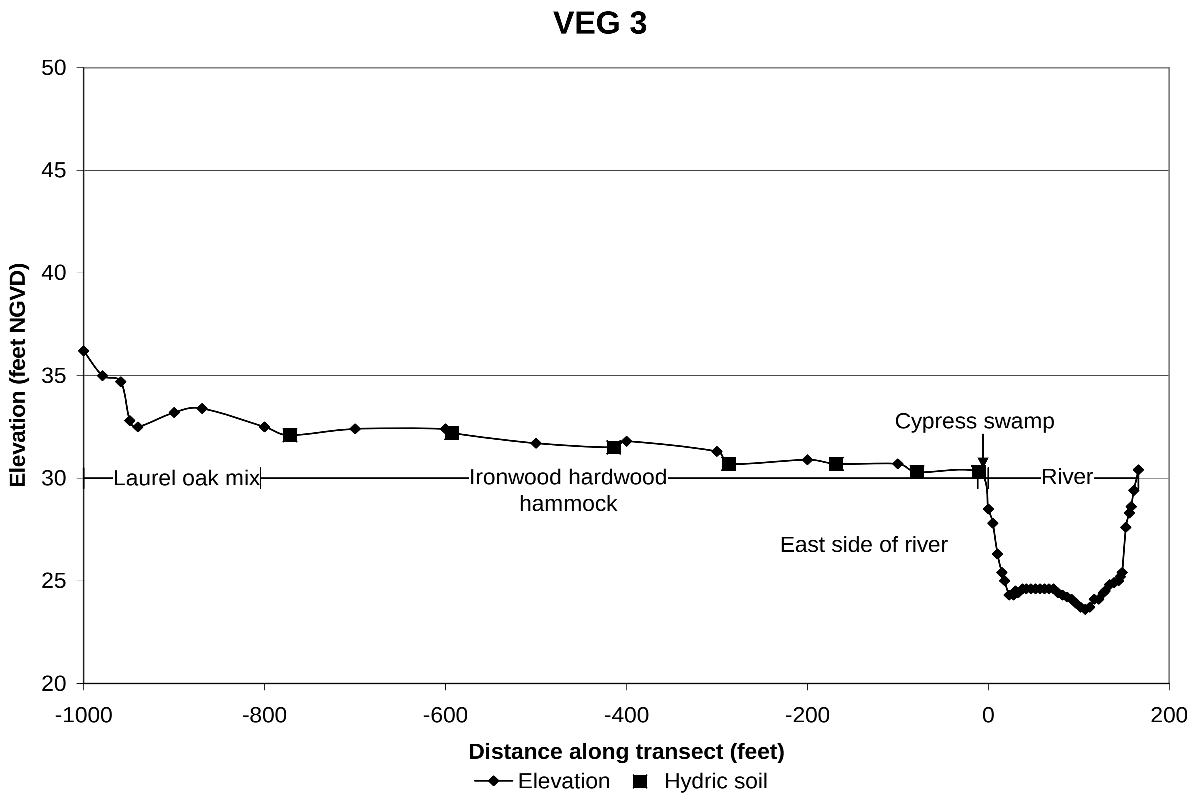
PHAB POOL
Elevation (feet NGVD)
50
45
40
35
30
25
20
15
-450
-350
-250
-150
-50
50
150
Distance along transect (feet)
Laurel oak mix
River
East side of river
Elevation

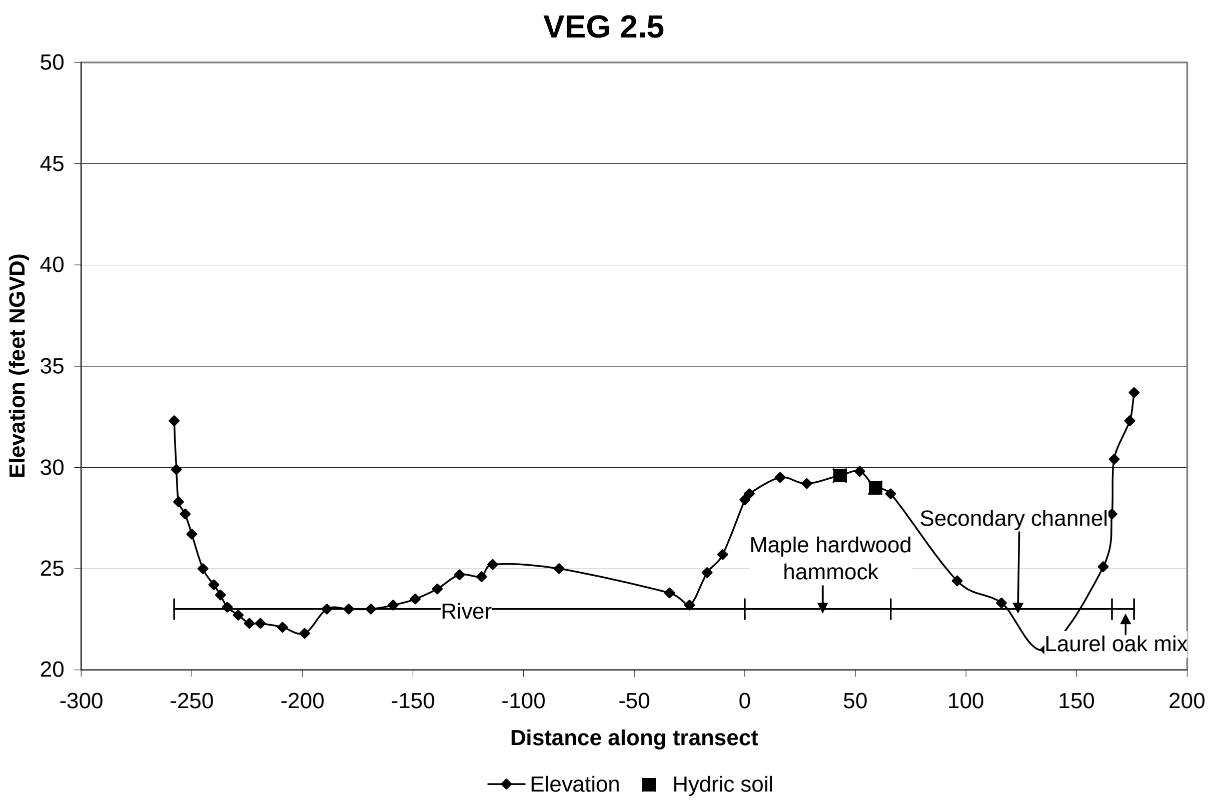


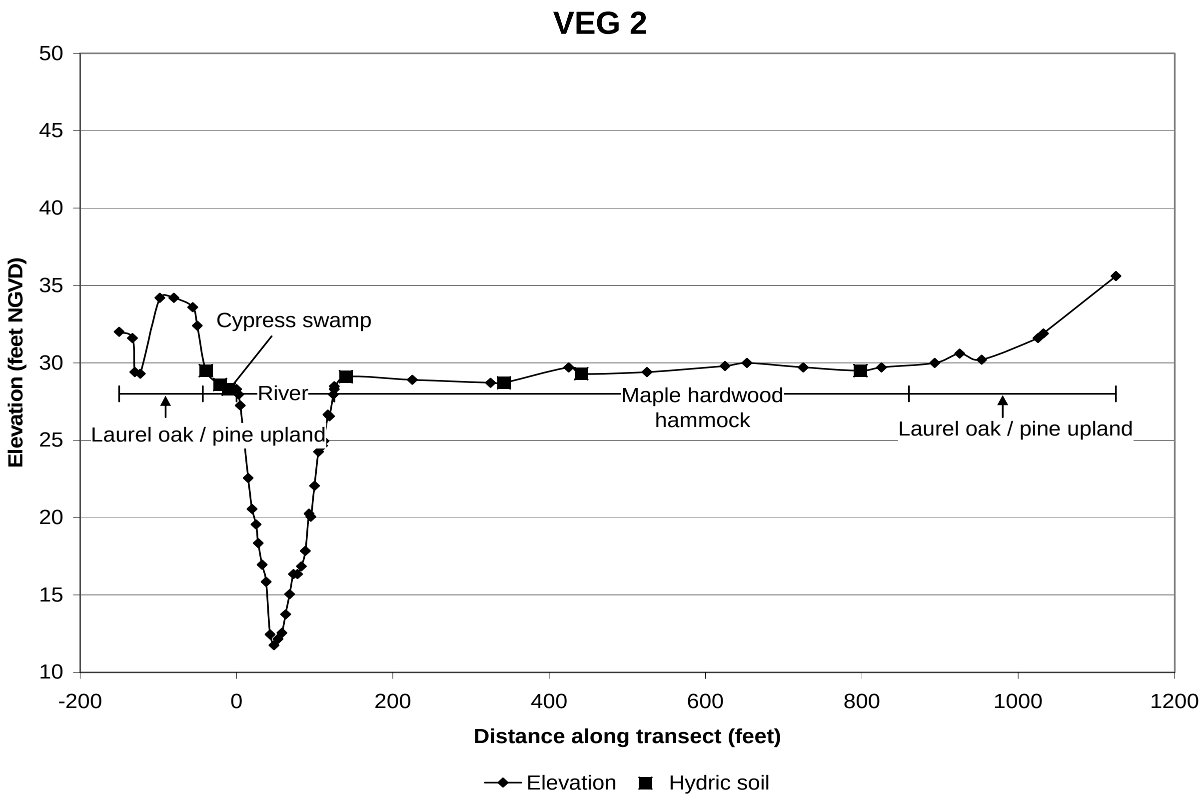
VEG 4
Elevation (feet NGVD)
50
45
40
35
30
25
20
15
-650
-550
-450
-350
-250
-150
-50
50
150
Distance along transect (feet)
Ironwood hardwood hammock
East side of river
River
Elevation
Hydric soil



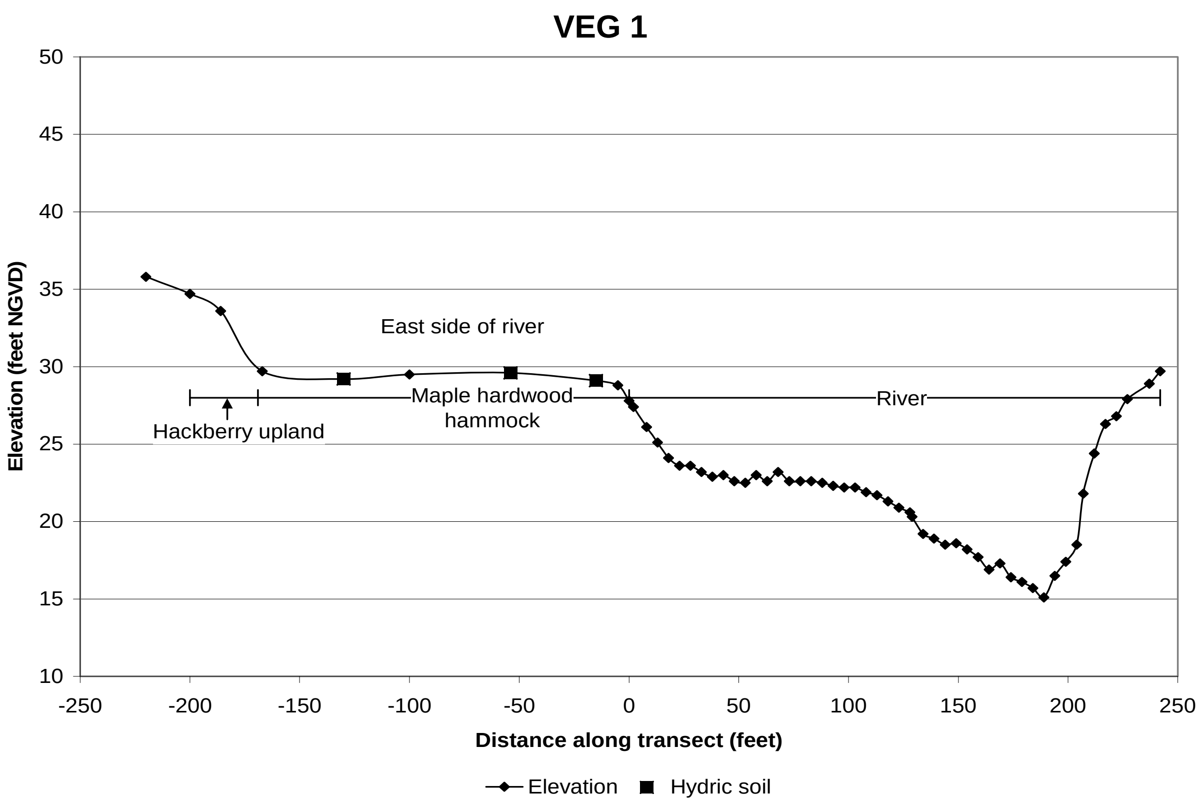
PHAB 2
Elevation (feet NGVD)
50
45
40
35
30
25
20
15
10
-1100
-900
-700
-500
-300
-100
100
300
Distance along transect (feet)
Maple hardwood hammock
Pond
River
Ironwood hardwood hammock
Laurel oak / pine mix
Elevation
Hydric soil


VEG 3
Elevation (feet NGVD)
50
45
40
35
30
25
20
-1000
-800
-600
-400
-200
0
200
Laurel oak mix
Ironwood hardwood hammock
Cypress swamp
River
East side of river
Distance along transect (feet)
Elevation
Hydric soil


VEG 2.5
Elevation (feet NGVD)
50
45
40
35
30
25
20
-300
-250
-200
-150
-100
-50
0
50
100
150
200
River
Maple hardwood hammock
Secondary channel
Laurel oak mix
Distance along transect
Elevation
Hydric soil



VEG 2
50
45
40
35
30
25
20
15
10
Elevation (feet NGVD)
Cypress swamp
River
Maple hardwood hammock
Laurel oak / pine upland
Laurel oak / pine upland
-200
0
200
400
600
800
1000
1200
Distance along transect (feet)
Elevation
Hydric soil



VEG 1
50
45
40
35
30
25
20
15
10
Elevation (feet NGVD)
East side of river
Maple hardwood hammock
River
Hackberry upland
-250
-200
-150
-100
-50
0
50
100
150
200
250
Distance along transect (feet)
Elevation
Hydric soil

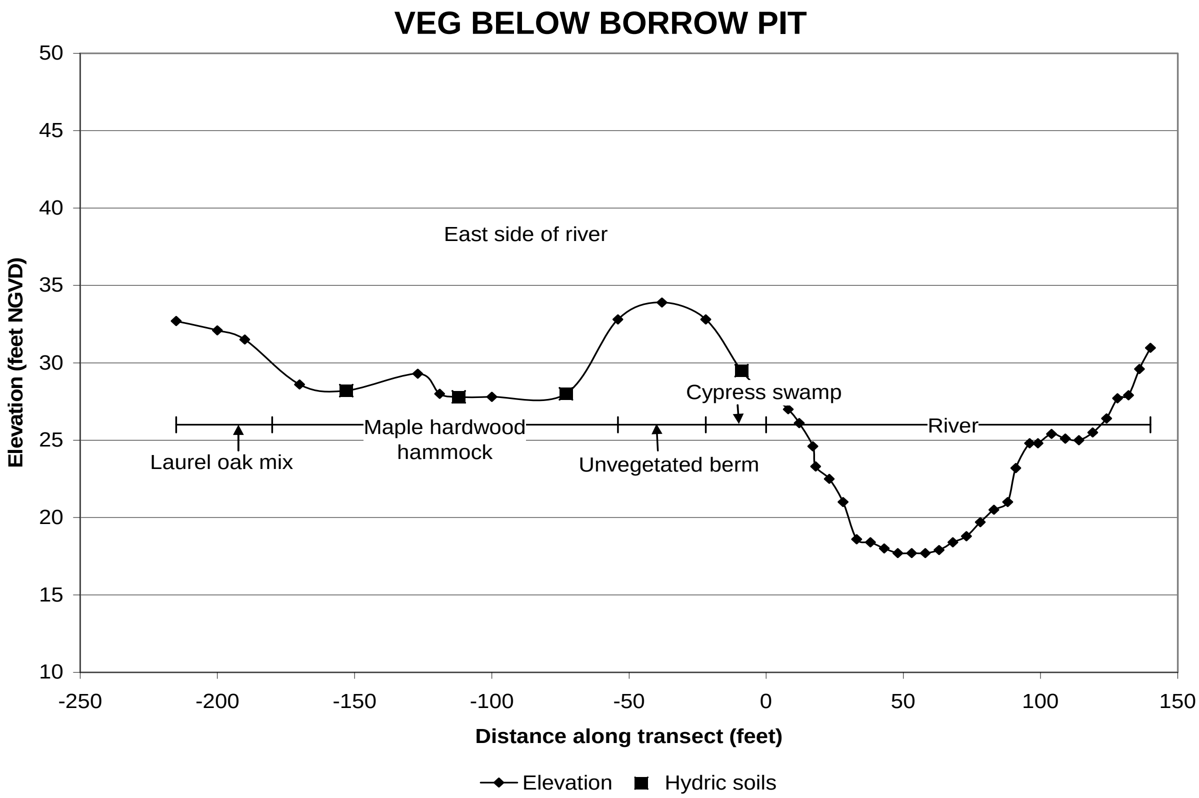
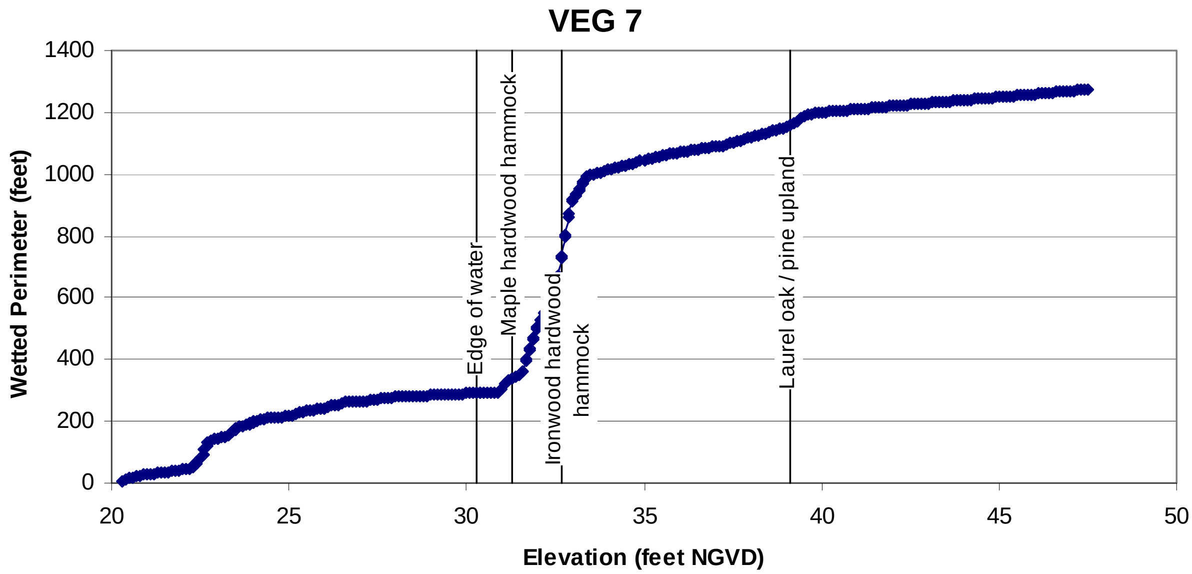
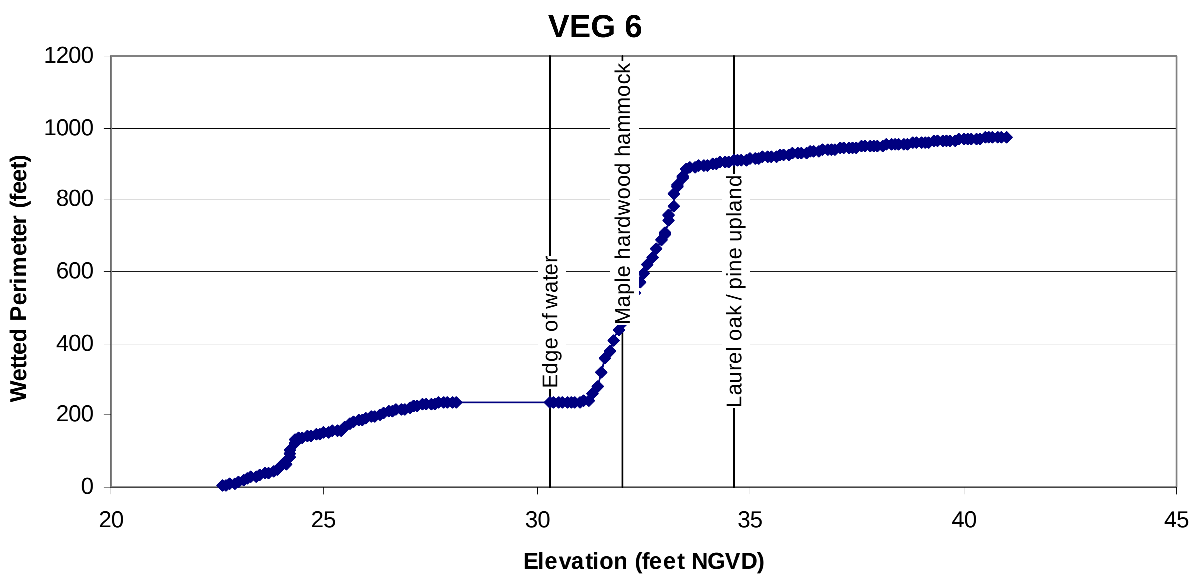
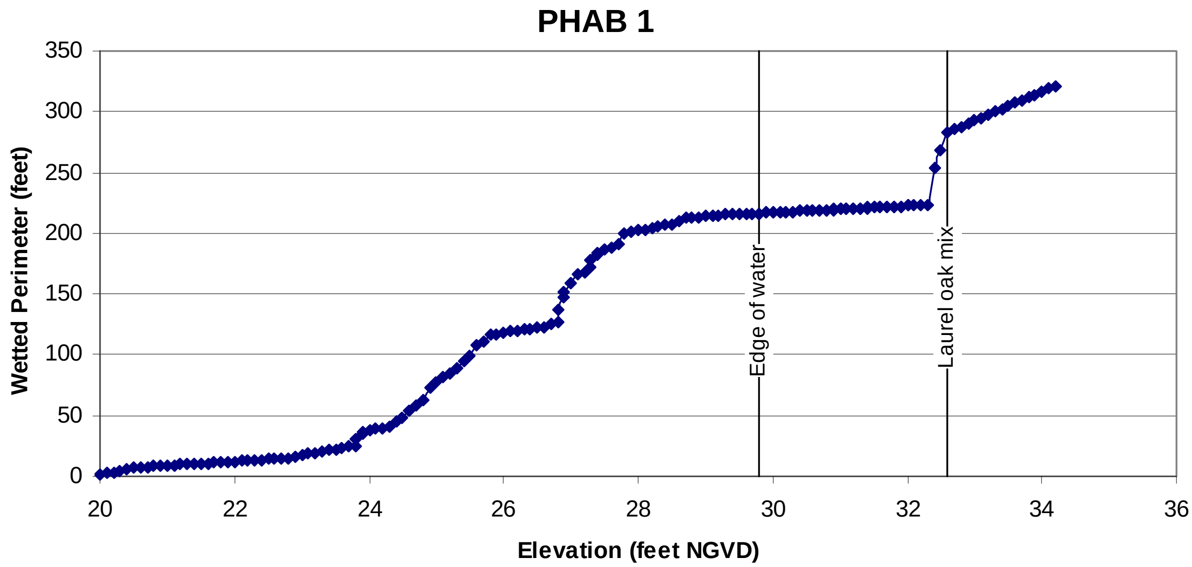

VEG BELOW BORROW PIT
Elevation (feet NGVD)
50
45
40
35
30
25
20
15
10
East side of river
Cypress swamp
Maple hardwood hammock
River
Laurel oak mix
Unvegetated berm
-250
-200
-150
-100
-50
0
50
100
150
Distance along transect (feet)
Elevation
Hydric soils

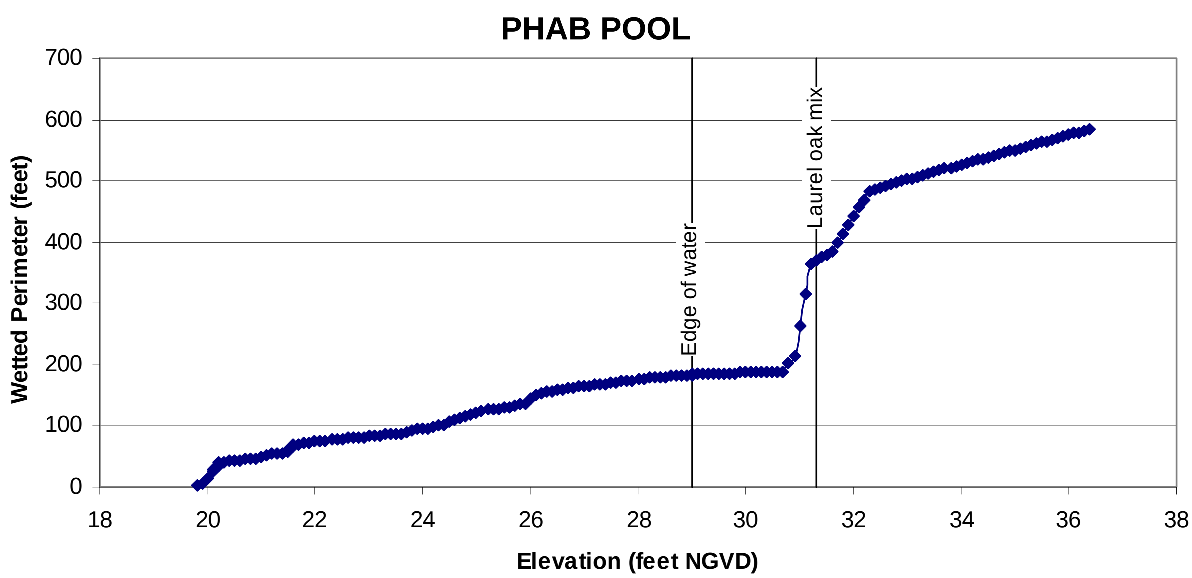
Figure C-2

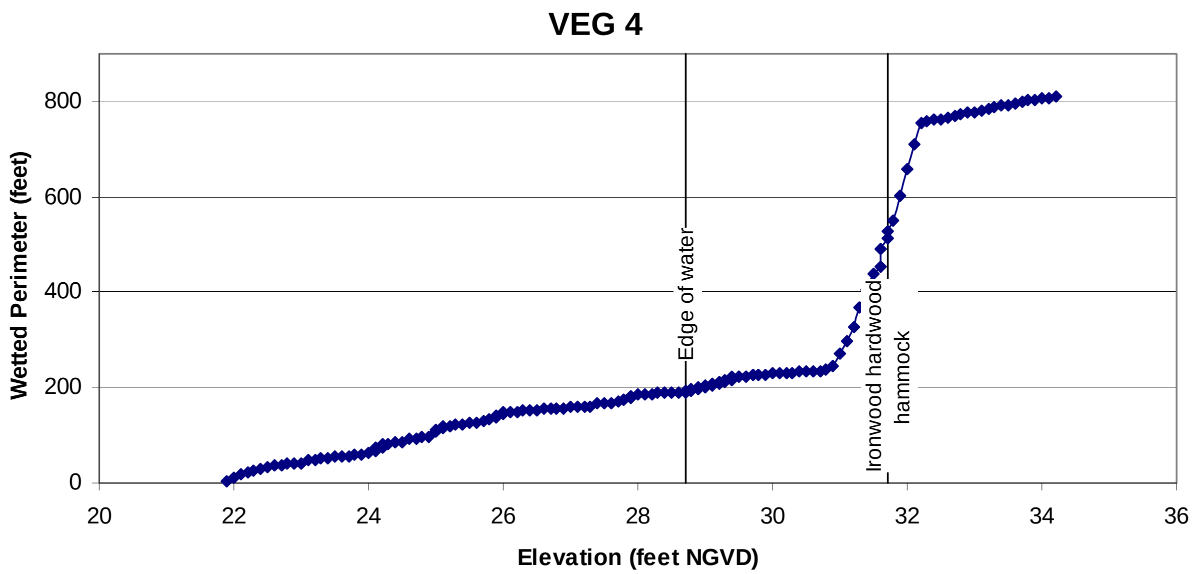
Wetted Perimeter Graphs for the Rainbow River Study Corridor (In upstream-to-downstream order)

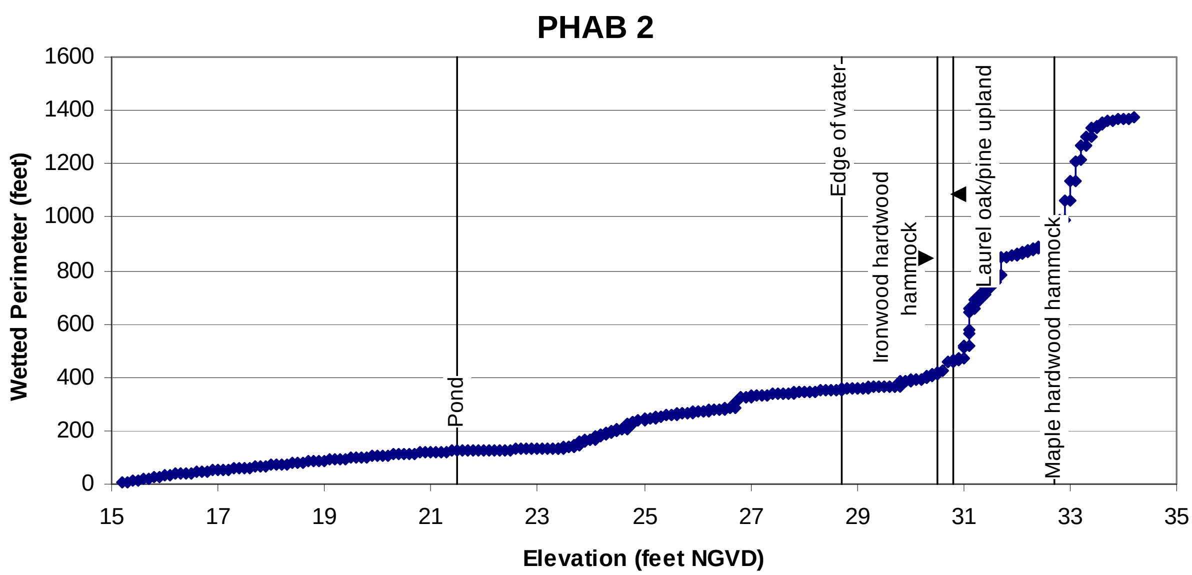

VEG 7
Wetted Perimeter (feet)
Elevation (feet NGVD)
0
200
400
600
800
1000
1200
1400
20
25
30
35
40
45
50
Edge of water
Maple hardwood hammock
Ironwood hardwood hammock
Laurel oak / pine upland

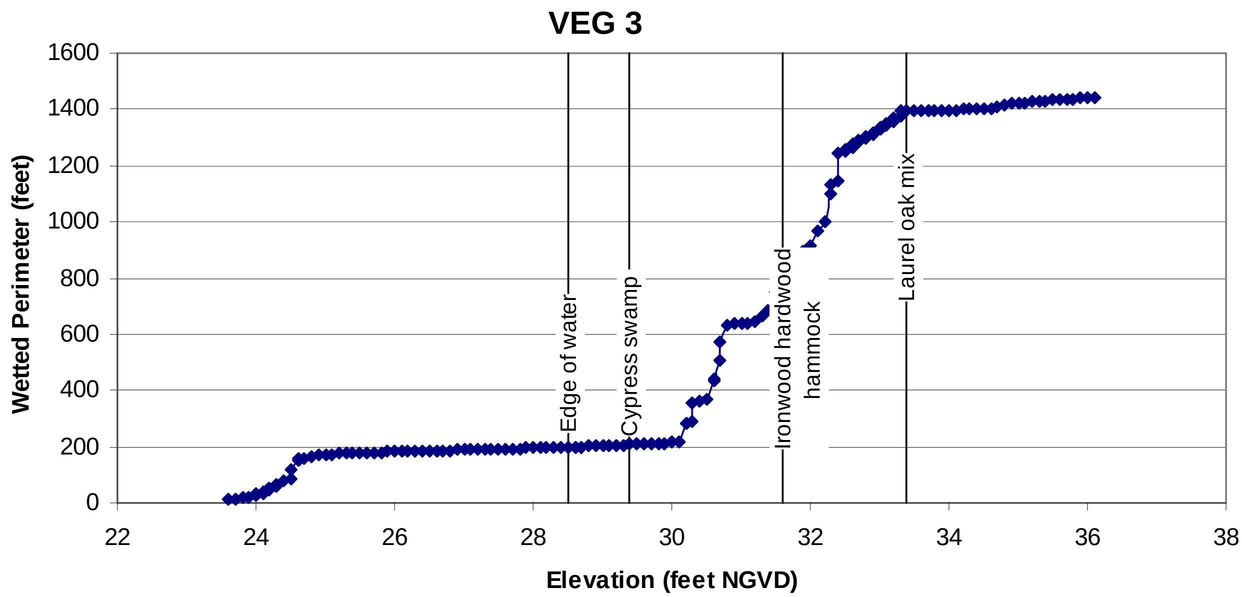

VEG 6
Wetted Perimeter (feet)
Elevation (feet NGVD)
0
200
400
600
800
1000
1200
20
25
30
35
40
45
Edge of water
Maple hardwood hammock
Laurel oak / pine upland

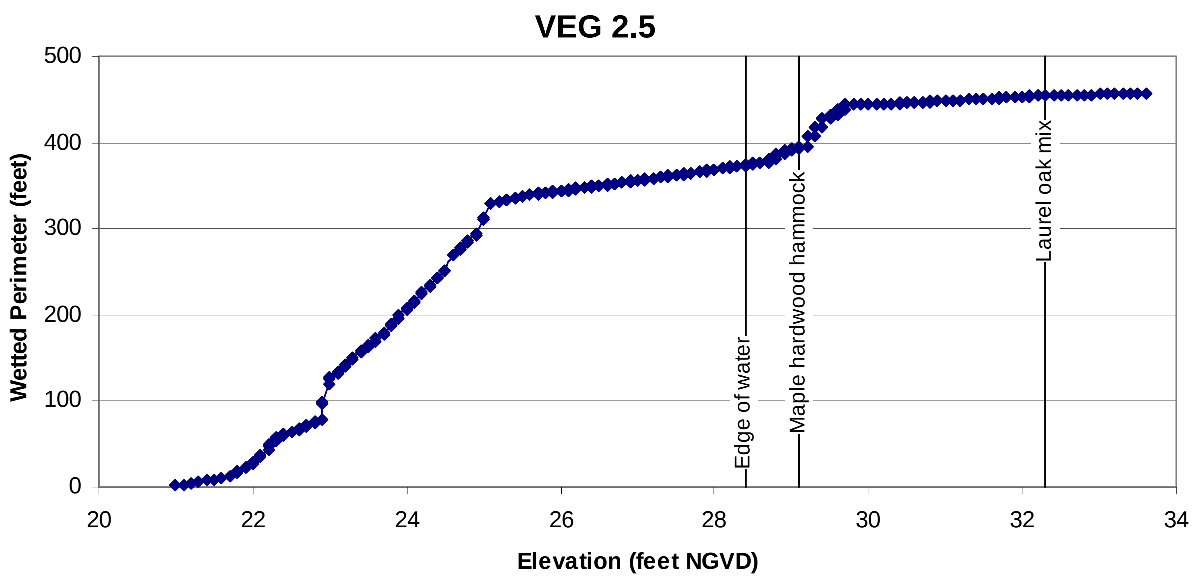

PHAB 1
Wetted Perimeter (feet)
350
300
250
200
150
100
50
0
20
22
24
26
28
30
32
34
36
Elevation (feet NGVD)
Edge of water
Laurel oak mix

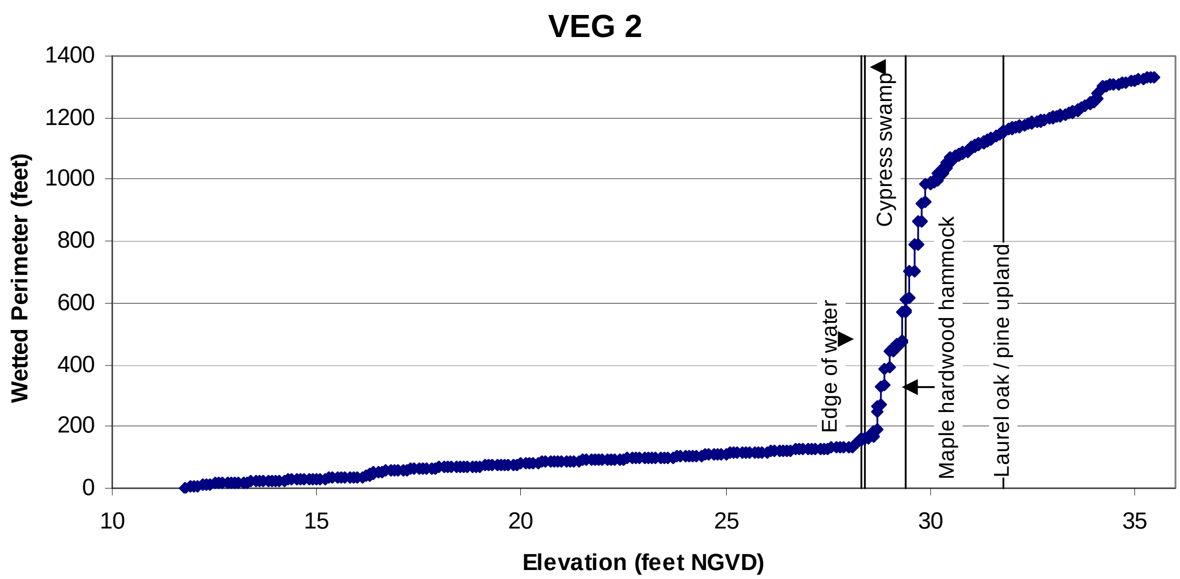

PHAB POOL
Wetted Perimeter (feet)
700
600
500
400
300
200
100
0
18
20
22
24
26
28
30
32
34
36
38
Elevation (feet NGVD)
Edge of water
Laurel oak mix

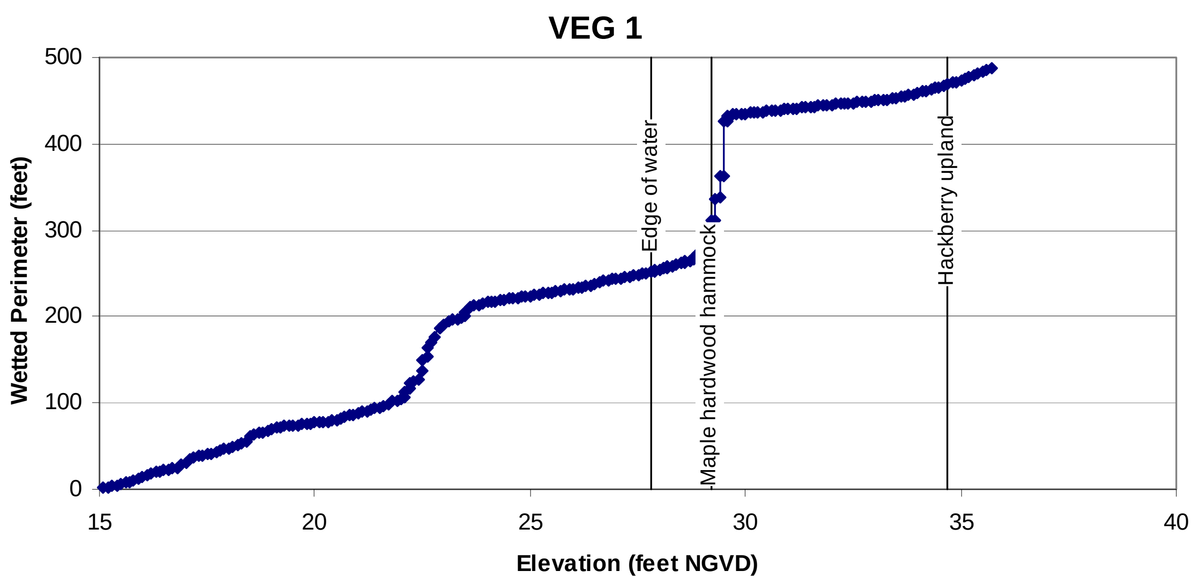

VEG 4
Wetted Perimeter (feet)
Elevation (feet NGVD)
Edge of water
Ironwood hardwood
hammock
0
200
400
600
800
20
22
24
26
28
30
32
34
36

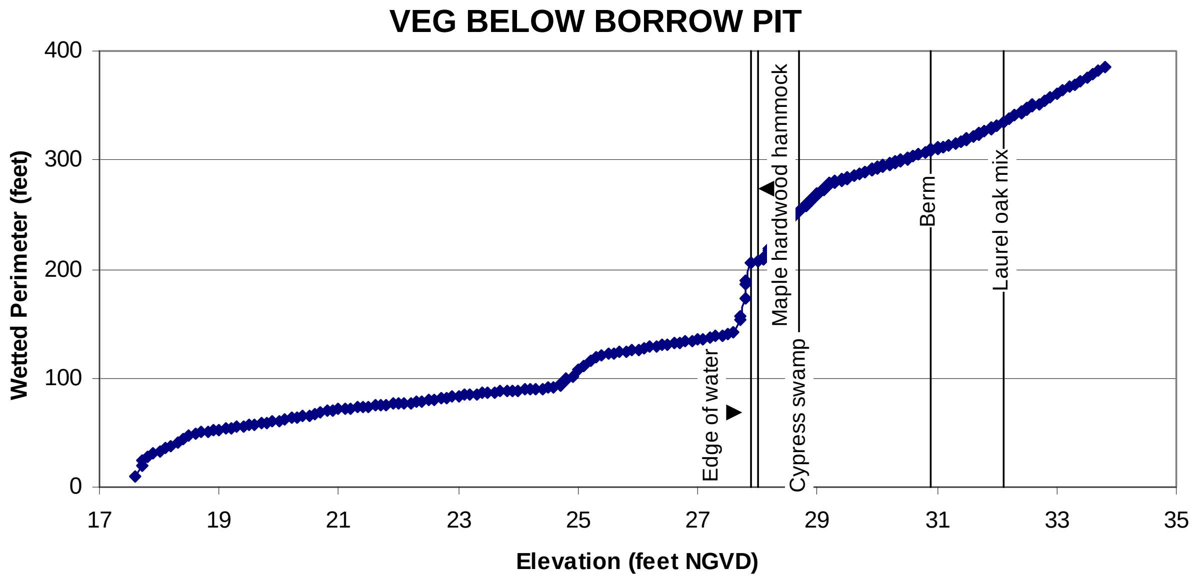

PHAB 2
Wetted Perimeter (feet)
Elevation (feet NGVD)
Pond
Edge of water
Ironwood hardwood
hammock
Laurel oak/pine upland
Maple hardwood hammock
0
200
400
600
800
1000
1200
1400
1600
15
17
19
21
23
25
27
29
31
33
35


VEG 3
Wetted Perimeter (feet)
Elevation (feet NGVD)
Edge of water
Cypress swamp
Ironwood hardwood hammock
Laurel oak mix
0
200
400
600
800
1000
1200
1400
1600
22
24
26
28
30
32
34
36
38


VEG 2.5
Wetted Perimeter (feet)
Elevation (feet NGVD)
Edge of water
Maple hardwood hammock
Laurel oak mix
0
100
200
300
400
500
20
22
24
26
28
30
32
34


VEG 2
1400
1200
1000
800
600
400
200
0
10
15
20
25
30
35
Wetted Perimeter (feet)
Elevation (feet NGVD)
Edge of water
Cypress swamp
Maple hardwood hammock
Laurel oak / pine upland


VEG 1
500
400
300
200
100
0
15
20
25
30
35
40
Wetted Perimeter (feet)
Elevation (feet NGVD)
Edge of water
Maple hardwood hammock
Hackberry upland


VEG BELOW BORROW PIT
Wetted Perimeter (feet)
Elevation (feet NGVD)
400
300
200
100
0
17
19
21
23
25
27
29
31
33
35
Edge of water
Maple hardwood hammock
Cypress swamp
Berm
Laurel oak mix

Appendix D

HEC-RAS Modeling Cross Sections and Outputs

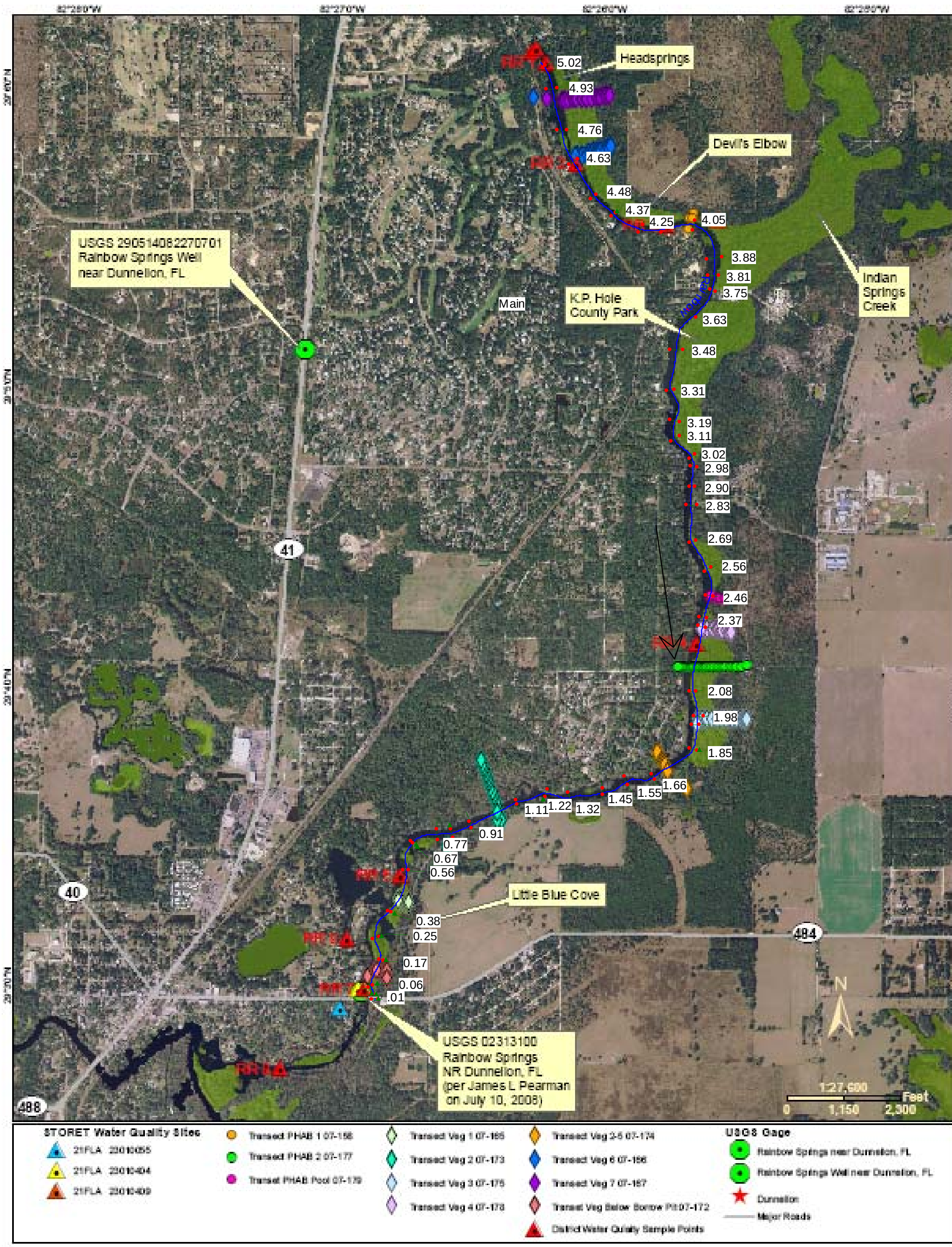


Figure D-1. HEC-RAS cross-sections along the Rainbow River Corridor

Table D-1. HEC-RAS results for discharge, elevation, depth, velocity, flow area, and width at 47 main channel cross-sections for Rainbow River, Florida

HEC-RAS	Q Total	Min Ch El	WS Elev	Max Chl Dpth	Hydr Depth	Vel Chnl	Vel Total	Flow Area	Top Width
mile	cfs	ft	ft	ft	ft	ft/sec	ft/sec	ft^2	ft
5.02	207	25.1	29.13	4.03	3.48	0.92	0.91	228.42	71.54
5.02	218.5	25.1	29.26	4.16	3.6	0.93	0.92	237.87	74.04
5.02	230	25.1	29.4	4.3	3.73	0.94	0.93	248.55	80.22
5.02	241.5	25.1	29.5	4.4	3.82	0.96	0.94	256.89	91.08
5.02	287.5	25.1	29.94	4.84	3.81	1.01	0.93	309.75	159.02
5.02	322	25.1	30.27	5.17	4.13	1.03	0.86	372.67	226.13
5.02	368	25.1	30.64	5.54	4.51	1.03	0.79	468.1	269.06
5.02	391	25.1	30.84	5.74	4.7	1.03	0.75	520.76	280.15
5.02	414	25.1	31.02	5.92	4.89	1.02	0.72	574.55	290.4
5.02	437	25.1	31.21	6.11	5.07	1.01	0.7	627.82	295.25
5.02	460	25.1	31.39	6.29	5.25	1	0.67	681.81	300.08
5.02	483	25.1	31.57	6.47	5.44	0.99	0.66	736.61	304.79
5.02	506	25.1	31.73	6.63	5.6	0.99	0.64	787.27	312.88
4.93	214.4	22	29.13	7.13	5.21	0.2	0.2	1053.62	204.2
4.93	226	22	29.26	7.26	5.29	0.21	0.21	1080.62	211.8
4.93	237.9	22	29.4	7.4	5.38	0.21	0.21	1110.37	216.4
4.93	249.8	22	29.5	7.5	5.45	0.22	0.22	1132.29	219.71
4.93	297.42	22	29.93	7.93	5.77	0.24	0.24	1235.14	266.41
4.93	333.1	22	30.26	8.26	6.07	0.26	0.25	1324.22	277.46
4.93	380.7	22	30.64	8.64	6.42	0.28	0.27	1433.71	300.99
4.93	404.5	22	30.83	8.83	6.6	0.28	0.27	1492.21	311.11
4.93	428.3	22	31.02	9.02	6.77	0.29	0.28	1551.91	320.28
4.93	452.1	22	31.2	9.2	6.94	0.3	0.28	1610.26	322.3
4.93	475.9	22	31.38	9.38	7.11	0.31	0.29	1668.81	324.32
4.93	499.7	22	31.56	9.56	7.27	0.31	0.29	1727.68	326.33
4.93	523.4	22	31.72	9.72	7.42	0.32	0.29	1781.25	328.15
4.76	226.9	13.8	29.12	15.32	8.95	0.11	0.11	2159.17	259.69
4.76	239.6	13.8	29.25	15.45	9.08	0.12	0.11	2192.9	262.85
4.76	252.2	13.8	29.39	15.59	9.22	0.12	0.11	2229.62	266.67
4.76	264.8	13.8	29.49	15.69	9.32	0.13	0.12	2257.09	269.76
4.76	315.22	13.8	29.93	16.13	9.76	0.14	0.13	2390.23	339.72
4.76	353	13.8	30.25	16.45	10.08	0.15	0.14	2502.71	352.86
4.76	403.5	13.8	30.63	16.83	10.46	0.17	0.15	2638.04	366.12
4.76	428.7	13.8	30.82	17.02	10.65	0.18	0.16	2708.25	371.48
4.76	453.9	13.8	31.01	17.21	10.84	0.18	0.16	2779.2	379.38
4.76	479.1	13.8	31.19	17.39	11.02	0.19	0.17	2848.41	384.12
4.76	504.3	13.8	31.37	17.57	11.2	0.2	0.17	2918.11	386.89
4.76	529.6	13.8	31.55	17.75	11.38	0.2	0.18	2988.46	394.74
4.76	554.7	13.8	31.71	17.91	11.55	0.21	0.18	3053.82	401.44
4.63	237.3	22.8	29.11	6.31	4.83	0.25	0.25	949.86	196.86
4.63	250.2	22.8	29.24	6.44	4.89	0.26	0.26	975.27	199.29
4.63	263.4	22.8	29.38	6.58	4.97	0.26	0.26	1003.03	201.91
4.63	276.6	22.8	29.49	6.69	5.03	0.27	0.27	1025.76	204.03
4.63	329.26	22.8	29.92	7.12	5.28	0.29	0.29	1123.23	240
4.63	368.7	22.8	30.25	7.45	5.57	0.31	0.31	1203.94	258.24
4.63	421.5	22.8	30.62	7.82	5.94	0.33	0.32	1308.24	291.5
4.63	447.8	22.8	30.81	8.01	6.13	0.34	0.33	1364.45	298.77
4.63	474.1	22.8	31	8.2	6.32	0.35	0.33	1420.96	305.84
4.63	500.5	22.8	31.18	8.38	6.5	0.36	0.34	1477.31	313.6
4.63	526.8	22.8	31.36	8.56	6.68	0.36	0.34	1534.06	315.08
4.63	553.2	22.8	31.54	8.74	6.86	0.37	0.35	1590.98	315.86
4.63	579.5	22.8	31.71	8.91	7.02	0.38	0.35	1642.55	316.54

Table D-1. HEC-RAS results for discharge, elevation, depth, velocity, flow area, and width at 47 main channel cross-sections for Rainbow River, Florida

HEC-RAS	Q Total	Min Ch El	WS Elev	Max Chl Dpth	Hydr Depth	Vel Chnl	Vel Total	Flow Area	Top Width
mile	cfs	ft	ft	ft	ft	ft/sec	ft/sec	ft^2	ft
4.48	249.1	20.8	29.07	8.27	5.11	0.41	0.41	603.84	124.72
4.48	262.9	20.8	29.2	8.4	5.22	0.43	0.42	619.69	126.54
4.48	276.8	20.8	29.34	8.54	5.33	0.44	0.43	637.43	131.12
4.48	290.6	20.8	29.45	8.65	5.11	0.45	0.45	652.53	146.23
4.48	345.92	20.8	29.88	9.08	4.92	0.49	0.47	733.66	216.69
4.48	387.4	20.8	30.2	9.4	5.22	0.51	0.48	810.76	252.86
4.48	442.8	20.8	30.58	9.78	5.56	0.54	0.49	909.67	271.58
4.48	470.4	20.8	30.77	9.97	5.74	0.55	0.49	961.77	276.04
4.48	498.1	20.8	30.95	10.15	5.91	0.56	0.49	1013.62	277.53
4.48	525.8	20.8	31.14	10.34	6.08	0.57	0.49	1063.84	278.96
4.48	553.4	20.8	31.32	10.52	6.24	0.58	0.5	1114.22	280.4
4.48	581.1	20.8	31.5	10.7	6.41	0.58	0.5	1164.87	281.83
4.48	608.8	20.8	31.66	10.86	6.55	0.59	0.5	1210.79	283.12
4.37	257.3	20.6	29.04	8.44	6.31	0.38	0.38	674.57	106.84
4.37	271.3	20.6	29.16	8.56	6.42	0.39	0.39	687.85	107.2
4.37	285.5	20.6	29.3	8.7	6.53	0.41	0.41	702.57	107.61
4.37	299.9	20.6	29.41	8.81	6.62	0.42	0.42	714.37	107.93
4.37	356.98	20.6	29.84	9.24	7	0.47	0.46	769.79	144.99
4.37	399.8	20.6	30.16	9.56	7.32	0.5	0.49	817.05	148.1
4.37	456.9	20.6	30.53	9.93	7.7	0.54	0.52	873.06	163.4
4.37	485.5	20.6	30.72	10.12	7.89	0.56	0.54	901.7	189.15
4.37	514.1	20.6	30.91	10.31	8.08	0.58	0.55	930.37	217.29
4.37	542.6	20.6	31.09	10.49	8.26	0.6	0.57	958.32	236.12
4.37	571.1	20.6	31.27	10.67	8.43	0.61	0.58	986.36	242.33
4.37	599.7	20.6	31.45	10.85	8.61	0.63	0.59	1014.54	244.73
4.37	628.2	20.6	31.61	11.01	8.78	0.65	0.6	1040.03	249.12
4.25	266.3	21.7	29	7.3	3.92	0.43	0.43	620.34	158.22
4.25	280.9	21.7	29.13	7.43	3.76	0.44	0.44	640.15	175.44
4.25	295.7	21.7	29.26	7.56	3.89	0.45	0.44	664.67	184.94
4.25	310.5	21.7	29.37	7.67	4	0.46	0.45	685.17	193.78
4.25	369.68	21.7	29.79	8.09	4.4	0.49	0.48	775.32	237.3
4.25	414	21.7	30.11	8.41	4.71	0.51	0.48	854.27	255.46
4.25	473.2	21.7	30.49	8.79	5.06	0.53	0.5	951.96	263.37
4.25	502.8	21.7	30.68	8.98	5.24	0.54	0.5	1001.76	265.55
4.25	532.3	21.7	30.86	9.16	5.41	0.55	0.51	1051.39	267.71
4.25	561.9	21.7	31.04	9.34	5.58	0.56	0.51	1099.59	269.78
4.25	591.5	21.7	31.22	9.52	5.75	0.57	0.52	1148.17	272.23
4.25	621.1	21.7	31.4	9.7	5.92	0.57	0.52	1197.5	275.28
4.25	650.6	21.7	31.56	9.86	6.07	0.58	0.52	1241.99	275.58
4.18	272.3	18.6	28.98	10.38	7.61	0.25	0.23	1186.99	231.35
4.18	287.3	18.6	29.1	10.5	7.73	0.26	0.24	1215.31	236.34
4.18	302.4	18.6	29.24	10.64	7.86	0.27	0.24	1247.8	241.56
4.18	317.5	18.6	29.35	10.75	7.97	0.28	0.25	1273.96	244.8
4.18	377.96	18.6	29.77	11.17	8.39	0.31	0.27	1379.7	255.98
4.18	423.3	18.6	30.09	11.49	8.71	0.34	0.29	1461.74	258.59
4.18	483.8	18.6	30.47	11.87	9.09	0.36	0.31	1560.59	261.7
4.18	514	18.6	30.66	12.06	9.28	0.38	0.32	1609.87	263.24
4.18	544.3	18.6	30.84	12.24	9.46	0.39	0.33	1659	267.63
4.18	574.5	18.6	31.02	12.42	9.64	0.4	0.34	1707.14	270.51
4.18	604.7	18.6	31.2	12.6	9.82	0.41	0.34	1755.81	273.4
4.18	635	18.6	31.38	12.78	10	0.42	0.35	1805.11	276.36
4.18	665.1	18.6	31.54	12.94	10.16	0.43	0.36	1849.87	279.23

Table D-1. HEC-RAS results for discharge, elevation, depth, velocity, flow area, and width at 47 main channel cross-sections for Rainbow River, Florida

HEC-RAS	Q Total	Min Ch El	WS Elev	Max Chl Dpth	Hydr Depth	Vel Chnl	Vel Total	Flow Area	Top Width
mile	cfs	ft	ft	ft	ft	ft/sec	ft/sec	ft^2	ft
4.05	282.3	20.31	28.96	8.65	3.55	0.4	0.4	706.57	201.4
4.05	297.9	20.31	29.08	8.77	3.64	0.41	0.41	731.06	205.6
4.05	313.6	20.31	29.22	8.91	3.77	0.41	0.41	759.82	222.77
4.05	329.3	20.31	29.32	9.01	3.87	0.42	0.42	784.01	228.45
4.05	392.03	20.31	29.74	9.43	4.29	0.45	0.44	886.68	261.57
4.05	439	20.31	30.06	9.75	4.61	0.47	0.45	975.5	306.28
4.05	501.8	20.31	30.44	10.13	4.99	0.49	0.46	1095.81	328.24
4.05	533.1	20.31	30.63	10.32	5.17	0.5	0.46	1159.84	354.9
4.05	564.5	20.31	30.81	10.5	5.36	0.51	0.46	1225.84	357.46
4.05	595.9	20.31	30.99	10.68	5.54	0.52	0.46	1289.76	359.12
4.05	627.2	20.31	31.17	10.86	5.72	0.52	0.46	1354.05	360.73
4.05	658.6	20.31	31.35	11.04	5.9	0.53	0.46	1419.18	369.93
4.05	689.9	20.31	31.51	11.2	6.06	0.53	0.47	1479.56	381.42
3.88	295.2	13.8	28.95	15.15	8.45	0.11	0.11	2808.76	373.45
3.88	311.4	13.8	29.07	15.27	8.57	0.11	0.11	2853.81	377.17
3.88	327.7	13.8	29.21	15.41	8.71	0.12	0.11	2905.03	382.13
3.88	344.2	13.8	29.32	15.52	8.81	0.12	0.12	2945.93	386.19
3.88	409.72	13.8	29.73	15.93	9.23	0.14	0.13	3110.03	399.27
3.88	458.8	13.8	30.05	16.25	9.55	0.15	0.14	3238.66	411.57
3.88	524.4	13.8	30.43	16.63	9.93	0.16	0.15	3400.4	433.44
3.88	557.2	13.8	30.61	16.81	10.11	0.17	0.16	3481.68	437.13
3.88	590	13.8	30.8	17	10.3	0.17	0.17	3563.19	442.16
3.88	622.8	13.8	30.98	17.18	10.48	0.18	0.17	3641.95	442.16
3.88	655.5	13.8	31.16	17.36	10.65	0.19	0.18	3720.82	442.16
3.88	688.3	13.8	31.33	17.53	10.83	0.19	0.18	3799.92	442.16
3.88	721.1	13.8	31.49	17.69	10.99	0.2	0.19	3870.84	442.16
3.81	300.3	9.5	28.95	19.45	6.69	0.2	0.2	1517.4	276.27
3.81	316.8	9.5	29.07	19.57	6.76	0.21	0.2	1551.02	284.57
3.81	333.4	9.5	29.2	19.7	6.9	0.21	0.21	1589.86	292.97
3.81	350.2	9.5	29.31	19.81	7.01	0.22	0.22	1621.37	300.79
3.81	416.85	9.5	29.72	20.22	7.42	0.25	0.24	1751.45	318.04
3.81	466.8	9.5	30.04	20.54	7.74	0.26	0.25	1852.89	323.1
3.81	533.6	9.5	30.42	20.92	8.12	0.29	0.27	1976.86	333.23
3.81	566.9	9.5	30.6	21.1	8.3	0.3	0.28	2039.22	335.63
3.81	600.3	9.5	30.79	21.29	8.49	0.31	0.29	2101.82	343.29
3.81	633.6	9.5	30.96	21.46	8.66	0.31	0.29	2163.51	350.23
3.81	666.9	9.5	31.14	21.64	8.84	0.32	0.3	2226.06	351.87
3.81	700.3	9.5	31.32	21.82	9.02	0.33	0.31	2289.44	355.24
3.81	733.7	9.5	31.48	21.98	9.18	0.34	0.31	2346.33	355.24
3.75	305.1	18	28.92	10.92	5.22	0.5	0.45	670.7	231.75
3.75	321.9	18	29.04	11.04	5.34	0.51	0.46	699.15	247.6
3.75	338.8	18	29.18	11.18	5.47	0.52	0.46	733.78	268.57
3.75	355.7	18	29.28	11.28	5.58	0.53	0.47	762.91	283.32
3.75	423.45	18	29.7	11.7	5.99	0.57	0.48	884.49	300.09
3.75	474.2	18	30.01	12.01	6.31	0.6	0.48	980.04	305.75
3.75	542	18	30.39	12.39	6.68	0.63	0.49	1096.37	312.42
3.75	575.9	18	30.57	12.57	6.87	0.64	0.5	1154.91	318.86
3.75	609.8	18	30.76	12.76	7.05	0.65	0.5	1214.44	327.5
3.75	643.6	18	30.94	12.94	7.23	0.66	0.51	1273.15	332.57
3.75	677.5	18	31.11	13.11	7.41	0.67	0.51	1332.43	333.93
3.75	711.4	18	31.29	13.29	7.59	0.68	0.51	1392.16	335.29
3.75	745.3	18	31.45	13.45	7.75	0.69	0.52	1445.83	336.48

Table D-1. HEC-RAS results for discharge, elevation, depth, velocity, flow area, and width at 47 main channel cross-sections for Rainbow River, Florida

HEC-RAS	Q Total	Min Ch El	WS Elev	Max Chl Dpth	Hydr Depth	Vel Chnl	Vel Total	Flow Area	Top Width
mile	cfs	ft	ft	ft	ft	ft/sec	ft/sec	ft^2	ft
3.63	314.6	20.7	28.89	8.19	4.36	0.31	0.3	1038.43	258.99
3.63	331.8	20.7	29	8.3	4.48	0.32	0.31	1069.19	260.81
3.63	349.2	20.7	29.14	8.44	4.61	0.32	0.32	1103.52	262.83
3.63	366.7	20.7	29.24	8.54	4.72	0.33	0.32	1131.03	264.43
3.63	436.6	20.7	29.65	8.95	5.13	0.36	0.35	1241.03	270.76
3.63	489	20.7	29.97	9.27	5.44	0.38	0.37	1326.87	275.59
3.63	558.9	20.7	30.34	9.64	5.82	0.41	0.39	1433.5	290.47
3.63	593.8	20.7	30.53	9.83	6	0.42	0.4	1487.5	291.65
3.63	628.7	20.7	30.71	10.01	6.19	0.43	0.41	1541.19	292.82
3.63	663.6	20.7	30.89	10.19	6.36	0.44	0.42	1593.14	293.96
3.63	698.5	20.7	31.07	10.37	6.54	0.45	0.42	1645.48	295.11
3.63	733.5	20.7	31.24	10.54	6.72	0.46	0.43	1698.25	296.27
3.63	768.4	20.7	31.4	10.7	6.88	0.47	0.44	1745.55	297.31
3.48	326.4	21.2	28.86	7.66	4.76	0.24	0.24	1386.84	318.61
3.48	344.5	21.2	28.98	7.78	4.88	0.24	0.24	1424.42	319.49
3.48	362.6	21.2	29.1	7.9	4.99	0.25	0.25	1463.85	320.4
3.48	380.7	21.2	29.21	8.01	5.09	0.26	0.25	1496.95	321.17
3.48	453.22	21.2	29.61	8.41	5.47	0.28	0.28	1628.48	329.5
3.48	507.6	21.2	29.93	8.73	5.77	0.3	0.29	1733.82	340.59
3.48	580.1	21.2	30.31	9.11	6.15	0.32	0.31	1865.81	366.35
3.48	616.4	21.2	30.49	9.29	6.33	0.33	0.32	1934.66	378.67
3.48	652.6	21.2	30.67	9.47	6.52	0.34	0.33	2004.93	385.88
3.48	688.9	21.2	30.85	9.65	6.69	0.35	0.33	2073.04	385.88
3.48	725.1	21.2	31.03	9.83	6.87	0.36	0.34	2141.44	385.88
3.48	761.4	21.2	31.21	10.01	7.05	0.36	0.34	2210.18	385.88
3.48	797.6	21.2	31.37	10.17	7.21	0.37	0.35	2271.45	385.88
3.31	338.9	16.1	28.84	12.74	6.5	0.31	0.31	1086.94	190.41
3.31	357.5	16.1	28.96	12.86	6.61	0.33	0.32	1109.55	195.49
3.31	376.3	16.1	29.07	12.97	6.73	0.34	0.33	1132.39	200.49
3.31	395.2	16.1	29.17	13.07	6.83	0.35	0.34	1152.98	202.35
3.31	470.42	16.1	29.58	13.48	7.23	0.39	0.38	1234.74	203.44
3.31	526.8	16.1	29.89	13.79	7.54	0.42	0.41	1297.93	204.28
3.31	602.1	16.1	30.26	14.16	7.92	0.45	0.44	1375.45	205.31
3.31	639.8	16.1	30.45	14.35	8.1	0.47	0.45	1413.2	205.81
3.31	677.4	16.1	30.63	14.53	8.29	0.49	0.47	1450.72	206.3
3.31	715	16.1	30.81	14.71	8.46	0.5	0.48	1486.95	206.78
3.31	752.6	16.1	30.98	14.88	8.64	0.52	0.49	1523.48	207.26
3.31	790.3	16.1	31.16	15.06	8.82	0.53	0.51	1560.3	207.74
3.31	827.9	16.1	31.32	15.22	8.97	0.54	0.52	1593.12	208.17
3.19	348.8	19	28.81	9.81	4.51	0.42	0.42	839.69	202.19
3.19	368	19	28.93	9.93	4.63	0.43	0.43	863.38	204.16
3.19	387.4	19	29.04	10.04	4.74	0.44	0.44	885.42	205.98
3.19	406.8	19	29.14	10.14	4.84	0.45	0.45	906.26	207.68
3.19	484.29	19	29.54	10.54	5.24	0.5	0.49	990.47	215.68
3.19	542.4	19	29.85	10.85	5.54	0.53	0.51	1058.98	225.41
3.19	619.9	19	30.22	11.22	5.92	0.56	0.54	1147.51	245.88
3.19	658.6	19	30.4	11.4	6.1	0.58	0.55	1192.82	249.42
3.19	697.4	19	30.59	11.59	6.28	0.59	0.56	1238.66	257.5
3.19	736.1	19	30.76	11.76	6.46	0.61	0.57	1284.36	262.63
3.19	774.8	19	30.94	11.94	6.63	0.62	0.58	1330.49	262.63
3.19	813.6	19	31.11	12.11	6.81	0.63	0.59	1376.92	262.63
3.19	852.3	19	31.27	12.27	6.97	0.65	0.6	1418.11	262.63

Table D-1. HEC-RAS results for discharge, elevation, depth, velocity, flow area, and width at 47 main channel cross-sections for Rainbow River, Florida

HEC-RAS	Q Total	Min Ch El	WS Elev	Max Chl Dpth	Hydr Depth	Vel Chnl	Vel Total	Flow Area	Top Width
mile	cfs	ft	ft	ft	ft	ft/sec	ft/sec	ft^2	ft
3.11	354.3	19.7	28.79	9.09	4.69	0.34	0.33	1089.84	253.5
3.11	373.9	19.7	28.91	9.21	4.81	0.35	0.33	1119.35	255.32
3.11	393.5	19.7	29.01	9.31	4.91	0.36	0.34	1146.71	257
3.11	413.3	19.7	29.11	9.41	5.01	0.37	0.35	1172.54	261.66
3.11	491.97	19.7	29.51	9.81	5.41	0.4	0.38	1278.7	273.2
3.11	551	19.7	29.82	10.12	5.72	0.43	0.4	1363.46	277.77
3.11	629.7	19.7	30.19	10.49	6.09	0.46	0.43	1467.8	279.82
3.11	669.1	19.7	30.37	10.67	6.27	0.47	0.44	1518.77	280.81
3.11	708.4	19.7	30.55	10.85	6.45	0.48	0.45	1569.56	281.8
3.11	747.8	19.7	30.73	11.03	6.63	0.5	0.46	1618.64	282.75
3.11	787.1	19.7	30.9	11.2	6.8	0.51	0.47	1668.29	283.71
3.11	826.5	19.7	31.08	11.38	6.98	0.52	0.48	1718.47	284.68
3.11	865.8	19.7	31.24	11.54	7.14	0.53	0.49	1763.05	285.53
3.02	362	20.5	28.76	8.26	4.61	0.53	0.53	683.48	156.5
3.02	381.8	20.5	28.87	8.37	4.73	0.55	0.54	701.7	160.18
3.02	401.9	20.5	28.98	8.48	4.84	0.56	0.56	718.8	163.4
3.02	422	20.5	29.08	8.58	4.93	0.58	0.57	735.53	177.19
3.02	502.42	20.5	29.47	8.97	5.33	0.64	0.62	808.13	190.6
3.02	562.7	20.5	29.78	9.28	5.63	0.67	0.65	867.65	199.98
3.02	643.1	20.5	30.15	9.65	6	0.72	0.68	947.83	226.86
3.02	683.3	20.5	30.33	9.83	6.18	0.74	0.69	989.13	229.9
3.02	723.5	20.5	30.51	10.01	6.36	0.76	0.7	1030.73	232.93
3.02	763.7	20.5	30.68	10.18	6.54	0.77	0.71	1071.28	236.04
3.02	803.8	20.5	30.86	10.36	6.71	0.79	0.72	1112.63	236.75
3.02	844	20.5	31.03	10.53	6.89	0.8	0.73	1154.33	236.75
3.02	884.2	20.5	31.19	10.69	7.04	0.82	0.74	1191.15	236.75
2.98	365.1	17.6	28.74	11.14	6.35	0.42	0.41	882.21	174.22
2.98	385.1	17.6	28.86	11.26	6.46	0.44	0.43	902.42	179.17
2.98	405.4	17.6	28.96	11.36	6.57	0.46	0.44	921.46	183.71
2.98	425.7	17.6	29.06	11.46	6.67	0.47	0.45	939.68	187.67
2.98	506.78	17.6	29.45	11.85	7.06	0.53	0.5	1015.38	199.08
2.98	567.5	17.6	29.75	12.15	7.36	0.56	0.53	1077.01	205.83
2.98	648.7	17.6	30.12	12.52	7.73	0.61	0.56	1154.23	211.54
2.98	689.2	17.6	30.3	12.7	7.91	0.63	0.58	1192.58	214.62
2.98	729.8	17.6	30.48	12.88	8.09	0.65	0.59	1231.4	218.95
2.98	770.3	17.6	30.66	13.06	8.26	0.67	0.61	1270.1	230.35
2.98	810.8	17.6	30.83	13.23	8.44	0.69	0.62	1310.94	239.81
2.98	851.4	17.6	31.01	13.41	8.61	0.71	0.63	1353.53	244.9
2.98	891.8	17.6	31.16	13.56	8.77	0.73	0.64	1391.83	249.39
2.9	370.9	21	28.71	7.71	5.7	0.51	0.5	738.97	174.68
2.9	391.3	21	28.83	7.83	5.81	0.53	0.52	759.29	183.92
2.9	411.9	21	28.93	7.93	5.92	0.55	0.53	778.81	192.37
2.9	432.5	21	29.03	8.03	6.01	0.56	0.54	798.06	208.11
2.9	514.93	21	29.42	8.42	6.41	0.63	0.58	881.85	220.2
2.9	576.7	21	29.72	8.72	6.71	0.66	0.61	949.04	225.41
2.9	659.1	21	30.09	9.09	7.07	0.71	0.64	1034.13	245.27
2.9	700.3	21	30.27	9.27	7.25	0.73	0.65	1079.26	257.06
2.9	741.5	21	30.44	9.44	7.43	0.76	0.66	1128.38	287.13
2.9	782.7	21	30.62	9.62	7.6	0.78	0.66	1178.65	298.85
2.9	823.9	21	30.79	9.79	7.78	0.8	0.67	1230.49	298.85
2.9	865.1	21	30.96	9.96	7.95	0.81	0.67	1282.84	298.85
2.9	906.2	21	31.12	10.12	8.11	0.83	0.68	1328.91	298.85

Table D-1. HEC-RAS results for discharge, elevation, depth, velocity, flow area, and width at 47 main channel cross-sections for Rainbow River, Florida

HEC-RAS	Q Total	Min Ch El	WS Elev	Max Chl Dpth	Hydr Depth	Vel Chnl	Vel Total	Flow Area	Top Width
mile	cfs	ft	ft	ft	ft	ft/sec	ft/sec	ft^2	ft
2.83	376.7	20.5	28.69	8.19	5.57	0.31	0.31	1232.65	224.34
2.83	397.4	20.5	28.8	8.3	5.68	0.32	0.32	1257.9	225.66
2.83	418.3	20.5	28.9	8.4	5.77	0.33	0.33	1281.11	226.87
2.83	439.2	20.5	29	8.5	5.86	0.34	0.34	1302.85	228
2.83	522.88	20.5	29.4	8.9	6.22	0.38	0.37	1394.57	232.68
2.83	585.6	20.5	29.7	9.2	6.5	0.4	0.4	1464.97	238.77
2.83	669.3	20.5	30.06	9.56	6.87	0.43	0.43	1558.93	275.78
2.83	711.1	20.5	30.24	9.74	7.05	0.45	0.44	1609.13	288.04
2.83	753	20.5	30.42	9.92	7.22	0.46	0.45	1661.3	300.25
2.83	794.8	20.5	30.59	10.09	7.39	0.48	0.46	1713.36	310.95
2.83	836.6	20.5	30.76	10.26	7.57	0.49	0.47	1768	320.81
2.83	878.4	20.5	30.93	10.43	7.74	0.5	0.48	1824.95	330.78
2.83	920.2	20.5	31.09	10.59	7.9	0.51	0.49	1876.26	336.21
2.69	387.3	20.6	28.64	8.04	5.29	0.58	0.56	690.69	167.15
2.69	408.7	20.6	28.75	8.15	5.4	0.6	0.58	709.51	174.23
2.69	430.2	20.6	28.85	8.25	5.51	0.62	0.59	728.39	200.6
2.69	451.7	20.6	28.94	8.34	5.6	0.63	0.6	747.62	210.87
2.69	537.74	20.6	29.34	8.74	5.99	0.7	0.64	841.29	256.99
2.69	602.2	20.6	29.63	9.03	6.29	0.74	0.65	925.89	305.52
2.69	688.3	20.6	29.99	9.39	6.65	0.79	0.66	1038.9	315.16
2.69	731.3	20.6	30.17	9.57	6.82	0.81	0.67	1094.7	316.97
2.69	774.4	20.6	30.35	9.75	7	0.82	0.67	1150.7	318.79
2.69	817.4	20.6	30.52	9.92	7.17	0.84	0.68	1204.75	320.53
2.69	860.4	20.6	30.69	10.09	7.34	0.86	0.68	1260.06	321.85
2.69	903.4	20.6	30.86	10.26	7.52	0.87	0.69	1316.39	324.29
2.69	946.4	20.6	31.01	10.41	7.67	0.89	0.69	1365.98	326.43
2.56	397.3	20.4	28.59	8.19	5.62	0.45	0.43	914.4	219.98
2.56	419.1	20.4	28.7	8.3	5.73	0.46	0.45	938.7	227.97
2.56	441.2	20.4	28.8	8.4	5.83	0.48	0.46	961.6	238.33
2.56	463.2	20.4	28.89	8.49	5.92	0.49	0.47	983.77	247.27
2.56	551.47	20.4	29.28	8.88	6.31	0.55	0.51	1087.33	291.79
2.56	617.6	20.4	29.57	9.17	6.6	0.58	0.53	1173.95	297.16
2.56	705.9	20.4	29.93	9.53	6.96	0.62	0.55	1280.9	301.2
2.56	750	20.4	30.1	9.7	7.13	0.64	0.56	1333.78	303.18
2.56	794.1	20.4	30.28	9.88	7.31	0.66	0.57	1387.01	305.17
2.56	838.2	20.4	30.44	10.04	7.47	0.68	0.58	1438.41	307.07
2.56	882.3	20.4	30.62	10.22	7.65	0.69	0.59	1491.24	309.08
2.56	926.4	20.4	30.79	10.39	7.82	0.71	0.6	1545.35	313.4
2.56	970.5	20.4	30.94	10.54	7.97	0.72	0.61	1593.06	317.16
2.46	405.2	20.24	28.56	8.32	6.6	0.44	0.4	1018.44	209.98
2.46	427.5	20.24	28.67	8.43	6.71	0.45	0.41	1041.15	214.73
2.46	450	20.24	28.76	8.52	6.81	0.47	0.42	1062.24	219.57
2.46	472.5	20.24	28.85	8.61	6.9	0.49	0.44	1082.1	222.85
2.46	562.5	20.24	29.23	8.99	7.28	0.54	0.48	1170.3	251.21
2.46	629.9	20.24	29.52	9.28	7.57	0.58	0.5	1248.17	276.63
2.46	720	20.24	29.88	9.64	7.92	0.63	0.53	1347.7	291.98
2.46	765	20.24	30.05	9.81	8.1	0.66	0.55	1400.09	306.37
2.46	810	20.24	30.22	9.98	8.27	0.67	0.56	1453.51	307.43
2.46	855	20.24	30.39	10.15	8.44	0.69	0.57	1505.33	313.08
2.46	900	20.24	30.56	10.32	8.61	0.71	0.58	1559.26	317.45
2.46	945	20.24	30.74	10.5	8.78	0.73	0.59	1614.35	317.45
2.46	989.9	20.24	30.89	10.65	8.93	0.74	0.6	1662.14	317.45

Table D-1. HEC-RAS results for discharge, elevation, depth, velocity, flow area, and width at 47 main channel cross-sections for Rainbow River, Florida

HEC-RAS	Q Total	Min Ch El	WS Elev	Max Chl Dpth	Hydr Depth	Vel Chnl	Vel Total	Flow Area	Top Width
mile	cfs	ft	ft	ft	ft	ft/sec	ft/sec	ft^2	ft
2.37	406.9	21.1	28.52	7.42	4.29	0.57	0.55	733.9	215.3
2.37	429.4	21.1	28.63	7.53	4.4	0.58	0.57	756.81	217.19
2.37	451.9	21.1	28.73	7.63	4.49	0.6	0.58	777.64	218.89
2.37	474.6	21.1	28.81	7.71	4.58	0.62	0.6	797.02	220.46
2.37	564.95	21.1	29.19	8.09	4.96	0.68	0.64	882.13	236.25
2.37	632.7	21.1	29.48	8.38	5.24	0.71	0.66	952.48	251.98
2.37	723.1	21.1	29.83	8.73	5.6	0.76	0.69	1045.06	271.67
2.37	768.3	21.1	30	8.9	5.77	0.78	0.7	1092.21	278.21
2.37	813.5	21.1	30.17	9.07	5.94	0.79	0.71	1141.32	290.79
2.37	858.7	21.1	30.34	9.24	6.11	0.81	0.72	1190.85	301.68
2.37	903.9	21.1	30.51	9.41	6.28	0.83	0.73	1242.79	308.09
2.37	949.1	21.1	30.68	9.58	6.45	0.84	0.73	1296.72	314.62
2.37	994.2	21.1	30.83	9.73	6.6	0.86	0.74	1344.32	322.35
2.33	407.7	21	28.5	7.5	4.8	0.57	0.55	737.95	197.19
2.33	430.2	21	28.6	7.6	4.9	0.59	0.57	759.29	208.82
2.33	452.8	21	28.7	7.7	5	0.6	0.58	779.42	214.95
2.33	475.4	21	28.79	7.79	5.08	0.62	0.6	798.31	218.02
2.33	566.01	21	29.16	8.16	5.46	0.69	0.64	882.95	234.08
2.33	633.9	21	29.44	8.44	5.74	0.73	0.67	952.94	250.54
2.33	724.5	21	29.79	8.79	6.09	0.77	0.69	1043.47	271.54
2.33	769.7	21	29.97	8.97	6.27	0.8	0.71	1091.68	289.57
2.33	815.1	21	30.14	9.14	6.44	0.82	0.71	1143.06	305.19
2.33	860.3	21	30.3	9.3	6.6	0.84	0.72	1194.89	320.53
2.33	905.6	21	30.47	9.47	6.77	0.85	0.72	1250.86	334.24
2.33	950.9	21	30.65	9.65	6.95	0.87	0.73	1309.94	348.62
2.33	996.2	21	30.8	9.8	7.1	0.89	0.73	1363.06	362.33
2.08	412.9	22.6	28.26	5.66	3.94	0.73	0.69	595.42	220.65
2.08	435.6	22.6	28.36	5.76	4.04	0.75	0.71	617.29	223.08
2.08	458.5	22.6	28.45	5.85	4.13	0.77	0.72	636.73	225.23
2.08	481.5	22.6	28.53	5.93	4.21	0.79	0.74	654.49	227.16
2.08	573.16	22.6	28.88	6.28	4.56	0.86	0.78	735.68	235.82
2.08	641.9	22.6	29.16	6.56	4.84	0.9	0.8	802.24	242.69
2.08	733.6	22.6	29.49	6.89	5.17	0.95	0.82	893.18	295.04
2.08	779.5	22.6	29.66	7.06	5.34	0.97	0.83	943.73	305.31
2.08	825.4	22.6	29.83	7.23	5.51	0.99	0.83	996.49	311.98
2.08	871.2	22.6	30	7.4	5.68	1.01	0.83	1048.13	315.72
2.08	917	22.6	30.17	7.57	5.85	1.02	0.83	1102.36	316.83
2.08	962.9	22.6	30.34	7.74	6.03	1.03	0.83	1158.44	317.98
2.08	1008.8	22.6	30.49	7.89	6.17	1.04	0.84	1205.73	318.94
1.98	414.9	22.5	28.2	5.7	4.66	0.43	0.41	1006.29	244.28
1.98	437.8	22.5	28.3	5.8	4.76	0.44	0.43	1029.95	244.95
1.98	460.8	22.5	28.38	5.88	4.84	0.46	0.44	1050.64	245.54
1.98	483.8	22.5	28.46	5.96	4.92	0.47	0.45	1069.31	246.07
1.98	575.96	22.5	28.8	6.3	5.26	0.53	0.5	1154.43	249.91
1.98	645	22.5	29.08	6.58	5.54	0.56	0.53	1224.25	257.85
1.98	737.2	22.5	29.41	6.91	5.87	0.6	0.56	1313.86	288.83
1.98	783.3	22.5	29.58	7.08	6.04	0.62	0.57	1363.85	322.46
1.98	829.4	22.5	29.75	7.25	6.21	0.64	0.58	1421.54	341.99
1.98	875.4	22.5	29.91	7.41	6.37	0.65	0.59	1477.86	346.96
1.98	921.5	22.5	30.08	7.58	6.55	0.66	0.6	1538.09	355
1.98	967.6	22.5	30.26	7.76	6.72	0.68	0.6	1601.58	361.57
1.98	1013.6	22.5	30.41	7.91	6.87	0.69	0.61	1655.12	361.57

Table D-1. HEC-RAS results for discharge, elevation, depth, velocity, flow area, and width at 47 main channel cross-sections for Rainbow River, Florida

HEC-RAS	Q Total	Min Ch El	WS Elev	Max Chl Dpth	Hydr Depth	Vel Chnl	Vel Total	Flow Area	Top Width
mile	cfs	ft	ft	ft	ft	ft/sec	ft/sec	ft^2	ft
1.95	415.6	20.5	28.18	7.68	4.69	0.59	0.56	742.24	239.9
1.95	438.4	20.5	28.28	7.78	4.79	0.61	0.57	766.34	253.69
1.95	461.5	20.5	28.36	7.86	4.87	0.63	0.59	787.62	255.85
1.95	484.6	20.5	28.44	7.94	4.95	0.65	0.6	806.87	257.79
1.95	576.89	20.5	28.78	8.28	5.29	0.71	0.64	896.33	266.63
1.95	646.1	20.5	29.05	8.55	5.56	0.75	0.67	970.39	273.73
1.95	738.4	20.5	29.38	8.88	5.9	0.8	0.69	1062.94	287.1
1.95	784.5	20.5	29.55	9.05	6.06	0.83	0.7	1119.33	353.26
1.95	830.7	20.5	29.72	9.22	6.23	0.85	0.7	1179.39	354.65
1.95	876.9	20.5	29.88	9.38	6.39	0.86	0.71	1237.51	355.93
1.95	923	20.5	30.05	9.55	6.57	0.87	0.71	1298.73	357.27
1.95	969.2	20.5	30.23	9.73	6.74	0.88	0.71	1362.06	358.9
1.95	1015.3	20.5	30.38	9.88	6.89	0.9	0.72	1415.35	361.65
1.85	417.6	22.3	28.12	5.82	4.83	0.54	0.53	791.31	200.07
1.85	440.5	22.3	28.21	5.91	4.92	0.56	0.54	810.13	202.9
1.85	463.7	22.3	28.29	5.99	4.99	0.58	0.56	826.56	205.34
1.85	486.9	22.3	28.37	6.07	5.05	0.6	0.58	841.37	207.52
1.85	579.64	22.3	28.7	6.4	5.35	0.67	0.63	912.84	231.97
1.85	649.1	22.3	28.97	6.67	5.58	0.71	0.67	976.07	248.4
1.85	741.9	22.3	29.29	6.99	5.89	0.76	0.7	1057.24	268
1.85	788.3	22.3	29.46	7.16	6.05	0.78	0.72	1099.43	276.9
1.85	834.7	22.3	29.63	7.33	6.22	0.8	0.73	1143.37	302.3
1.85	881	22.3	29.79	7.49	6.39	0.82	0.74	1186.18	315.16
1.85	927.4	22.3	29.96	7.66	6.56	0.84	0.75	1233.44	344.45
1.85	973.8	22.3	30.14	7.84	6.73	0.86	0.76	1283.96	363.53
1.85	1020.1	22.3	30.28	7.98	6.88	0.87	0.77	1327.06	375.08
1.66	421.5	19.7	27.99	8.29	5.25	0.67	0.65	648.12	154.03
1.66	444.6	19.7	28.08	8.38	5.34	0.69	0.67	661.62	156.29
1.66	468	19.7	28.15	8.45	5.41	0.72	0.7	673.11	158.18
1.66	491.4	19.7	28.21	8.51	5.48	0.75	0.72	683.24	159.83
1.66	584.99	19.7	28.52	8.82	5.78	0.84	0.8	734.11	177.44
1.66	655.1	19.7	28.78	9.08	6.04	0.9	0.83	786.02	224
1.66	748.8	19.7	29.09	9.39	6.35	0.97	0.87	860	251.42
1.66	795.6	19.7	29.25	9.55	6.51	1	0.88	900.21	256.1
1.66	842.4	19.7	29.41	9.71	6.67	1.02	0.89	942.93	260.98
1.66	889.2	19.7	29.57	9.87	6.83	1.05	0.9	984.76	264.35
1.66	936	19.7	29.74	10.04	7	1.07	0.91	1029.66	267.93
1.66	982.8	19.7	29.92	10.22	7.18	1.09	0.91	1077.62	271.7
1.66	1029.5	19.7	30.06	10.36	7.32	1.11	0.92	1116.93	279.33
1.55	423.7	22.4	27.89	5.49	4.09	0.56	0.56	762.34	215.38
1.55	447	22.4	27.98	5.58	4.18	0.58	0.57	780.32	219.38
1.55	470.5	22.4	28.04	5.64	4.24	0.6	0.59	795.33	223.25
1.55	494	22.4	28.1	5.7	4.3	0.62	0.61	808.36	226.82
1.55	588.08	22.4	28.39	5.99	4.59	0.69	0.67	876.92	246.09
1.55	658.6	22.4	28.64	6.24	4.84	0.73	0.7	942.64	288.55
1.55	752.7	22.4	28.94	6.54	5.14	0.78	0.73	1035.55	318.42
1.55	799.8	22.4	29.1	6.7	5.3	0.8	0.74	1085.93	328.08
1.55	846.8	22.4	29.26	6.86	5.46	0.82	0.74	1140.58	337.73
1.55	893.9	22.4	29.42	7.02	5.62	0.84	0.75	1194.56	344.52
1.55	940.9	22.4	29.59	7.19	5.79	0.85	0.75	1253.4	350.47
1.55	988	22.4	29.77	7.37	5.97	0.86	0.75	1316.88	356.32
1.55	1035	22.4	29.91	7.51	6.11	0.87	0.76	1368	360.96

Table D-1. HEC-RAS results for discharge, elevation, depth, velocity, flow area, and width at 47 main channel cross-sections for Rainbow River, Florida

HEC-RAS	Q Total	Min Ch El	WS Elev	Max Chl Dpth	Hydr Depth	Vel Chnl	Vel Total	Flow Area	Top Width
mile	cfs	ft	ft	ft	ft	ft/sec	ft/sec	ft^2	ft
1.45	425.6	18.8	27.84	9.04	6.2	0.45	0.38	1107.18	244.07
1.45	449.2	18.8	27.92	9.12	6.28	0.47	0.4	1126.79	248.38
1.45	472.8	18.8	27.98	9.18	6.34	0.49	0.41	1142.88	253.04
1.45	496.4	18.8	28.04	9.24	6.4	0.5	0.43	1158.2	266.68
1.45	590.95	18.8	28.31	9.51	6.67	0.59	0.48	1234.4	290.17
1.45	661.8	18.8	28.56	9.76	6.92	0.62	0.51	1307.6	293.71
1.45	756.4	18.8	28.86	10.06	7.21	0.67	0.54	1394.1	297.92
1.45	803.7	18.8	29.01	10.21	7.36	0.7	0.56	1439.71	300.11
1.45	851	18.8	29.17	10.37	7.53	0.72	0.57	1488.38	302.44
1.45	898.2	18.8	29.33	10.53	7.68	0.73	0.58	1535.71	304.68
1.45	945.5	18.8	29.5	10.7	7.85	0.75	0.6	1587.04	307.1
1.45	992.8	18.8	29.67	10.87	8.03	0.76	0.6	1642.27	309.68
1.45	1040.1	18.8	29.81	11.01	8.17	0.78	0.62	1685.87	311.73
1.32	428.3	20.3	27.8	7.5	4.85	0.46	0.45	942.74	203.26
1.32	452	20.3	27.87	7.57	4.93	0.47	0.47	958.31	204.17
1.32	475.8	20.3	27.93	7.63	4.99	0.49	0.49	970.74	204.87
1.32	499.6	20.3	27.99	7.69	5.04	0.51	0.51	981.3	205.46
1.32	594.74	20.3	28.24	7.94	5.29	0.58	0.57	1034.77	213.87
1.32	666	20.3	28.49	8.19	5.54	0.62	0.61	1088.9	228.26
1.32	761.3	20.3	28.77	8.47	5.82	0.67	0.66	1156.08	244.94
1.32	808.8	20.3	28.92	8.62	5.97	0.7	0.68	1193.27	253.37
1.32	856.4	20.3	29.08	8.78	6.13	0.72	0.69	1234.12	259.43
1.32	904	20.3	29.23	8.93	6.29	0.74	0.71	1274.43	267.88
1.32	951.6	20.3	29.4	9.1	6.45	0.75	0.72	1320.09	280.91
1.32	999.1	20.3	29.58	9.28	6.63	0.77	0.73	1370.37	282.35
1.32	1046.7	20.3	29.72	9.42	6.77	0.79	0.74	1409.45	283.42
1.22	430.2	20.1	27.75	7.65	5.91	0.48	0.48	897.27	195.72
1.22	454	20.1	27.83	7.73	5.94	0.5	0.5	911.75	199.51
1.22	477.9	20.1	27.88	7.78	5.98	0.52	0.52	923.25	202.61
1.22	501.8	20.1	27.94	7.84	6.04	0.54	0.54	935.13	205.81
1.22	597.36	20.1	28.19	8.09	6.29	0.62	0.61	987.06	214.44
1.22	669	20.1	28.43	8.33	6.53	0.67	0.64	1039.26	223.6
1.22	764.6	20.1	28.71	8.61	6.8	0.73	0.69	1101.62	242.67
1.22	812.4	20.1	28.85	8.75	6.95	0.76	0.72	1135.86	251.24
1.22	860.2	20.1	29.01	8.91	7.11	0.78	0.73	1173.31	260.59
1.22	908	20.1	29.16	9.06	7.26	0.81	0.75	1210.45	275.55
1.22	955.7	20.1	29.33	9.23	7.42	0.83	0.76	1252.44	287.05
1.22	1003.6	20.1	29.5	9.4	7.6	0.85	0.77	1298.76	293.85
1.22	1051.3	20.1	29.64	9.54	7.74	0.87	0.79	1334.47	297.24
1.11	432.7	16.5	27.69	11.19	7.61	0.68	0.64	680.5	132.23
1.11	456.5	16.5	27.76	11.26	7.68	0.71	0.66	689.61	134.43
1.11	480.5	16.5	27.81	11.31	7.73	0.74	0.69	696.61	136.11
1.11	504.6	16.5	27.86	11.36	7.79	0.77	0.72	703.84	137.77
1.11	600.66	16.5	28.09	11.59	8.01	0.89	0.82	736.22	146.29
1.11	672.7	16.5	28.32	11.82	8.24	0.96	0.87	770.02	151.42
1.11	768.9	16.5	28.58	12.08	8.5	1.06	0.95	812.77	179.93
1.11	816.9	16.5	28.73	12.23	8.65	1.11	0.97	840.93	194.73
1.11	865	16.5	28.88	12.38	8.8	1.14	0.99	871.04	202.59
1.11	913	16.5	29.02	12.52	8.95	1.18	1.01	901.24	211.75
1.11	961	16.5	29.18	12.68	9.11	1.21	1.03	937	227.89
1.11	1009.1	16.5	29.36	12.86	9.28	1.25	1.03	977.51	233.04
1.11	1057.1	16.5	29.49	12.99	9.41	1.28	1.05	1008.34	235.07

Table D-1. HEC-RAS results for discharge, elevation, depth, velocity, flow area, and width at 47 main channel cross-sections for Rainbow River, Florida

HEC-RAS	Q Total	Min Ch El	WS Elev	Max Chl Dpth	Hydr Depth	Vel Chnl	Vel Total	Flow Area	Top Width
mile	cfs	ft	ft	ft	ft	ft/sec	ft/sec	ft^2	ft
0.91	436.8	15.3	27.62	12.32	7.65	0.42	0.39	1108.29	220.52
0.91	460.7	15.3	27.68	12.38	7.71	0.44	0.41	1122.23	224.91
0.91	485.1	15.3	27.73	12.43	7.76	0.46	0.43	1132.6	232.09
0.91	509.3	15.3	27.77	12.47	7.81	0.48	0.45	1143.59	243.39
0.91	606.3	15.3	27.97	12.67	8.01	0.55	0.51	1195.66	273.61
0.91	679	15.3	28.19	12.89	8.22	0.6	0.54	1257.09	303.16
0.91	776.1	15.3	28.42	13.12	8.45	0.66	0.58	1332.19	332.14
0.91	824.5	15.3	28.56	13.26	8.6	0.69	0.6	1380.38	355.11
0.91	873.1	15.3	28.71	13.41	8.74	0.71	0.61	1432.33	365.62
0.91	921.6	15.3	28.85	13.55	8.88	0.74	0.62	1484.67	387.58
0.91	970	15.3	29	13.7	9.03	0.76	0.63	1546.28	401.13
0.91	1018.6	15.3	29.17	13.87	9.21	0.77	0.63	1615.82	412.66
0.91	1067	15.3	29.3	14	9.33	0.79	0.64	1667.91	417.76
0.83	438.5	17.4	27.6	10.2	5.93	0.39	0.38	1161.48	223.63
0.83	462.6	17.4	27.66	10.26	5.99	0.4	0.39	1175.19	224.4
0.83	486.9	17.4	27.71	10.31	6.04	0.42	0.41	1185	224.94
0.83	511.3	17.4	27.75	10.35	6.08	0.44	0.43	1195.03	225.5
0.83	608.64	17.4	27.94	10.54	6.28	0.51	0.49	1238.75	227.9
0.83	681.6	17.4	28.16	10.76	6.49	0.55	0.53	1288.28	231.72
0.83	779.1	17.4	28.38	10.98	6.72	0.6	0.58	1341.84	243.64
0.83	827.7	17.4	28.52	11.12	6.85	0.63	0.6	1375.9	248.78
0.83	876.4	17.4	28.67	11.27	7	0.65	0.62	1411.31	257.09
0.83	925.1	17.4	28.8	11.4	7.13	0.67	0.64	1445.81	267.51
0.83	973.8	17.4	28.96	11.56	7.29	0.69	0.66	1485.03	284.02
0.83	1022.5	17.4	29.13	11.73	7.46	0.71	0.67	1529.54	307.86
0.83	1071.1	17.4	29.25	11.85	7.58	0.73	0.69	1562.96	320.79
0.77	439.6	19.8	27.58	7.78	4.96	0.39	0.39	1130.02	248.81
0.77	463.7	19.8	27.64	7.84	5.01	0.41	0.41	1144.93	250.74
0.77	488.1	19.8	27.68	7.88	5.05	0.42	0.42	1155.48	252.1
0.77	512.5	19.8	27.73	7.93	5.09	0.44	0.44	1166.32	253.87
0.77	610.1	19.8	27.91	8.11	5.26	0.51	0.5	1214.47	263.92
0.77	683.2	19.8	28.13	8.33	5.48	0.55	0.54	1273.74	277.79
0.77	780.9	19.8	28.35	8.55	5.7	0.6	0.58	1337.6	301.58
0.77	829.7	19.8	28.49	8.69	5.84	0.62	0.6	1380.55	325.63
0.77	878.5	19.8	28.63	8.83	5.98	0.64	0.61	1428.88	363.63
0.77	927.3	19.8	28.77	8.97	6.11	0.66	0.63	1478.94	369.83
0.77	976.1	19.8	28.92	9.12	6.27	0.68	0.64	1535.8	371.9
0.77	1024.9	19.8	29.09	9.29	6.44	0.69	0.64	1599.41	374.2
0.77	1073.7	19.8	29.21	9.41	6.56	0.7	0.65	1645.23	375.85
0.67	441.7	18.1	27.57	9.47	7.83	0.3	0.2	2239.53	460.24
0.67	466	18.1	27.62	9.52	7.89	0.31	0.21	2266.36	461.16
0.67	490.5	18.1	27.66	9.56	7.93	0.32	0.21	2284.95	461.81
0.67	515	18.1	27.7	9.6	7.97	0.34	0.22	2303.97	462.46
0.67	613.07	18.1	27.88	9.78	8.15	0.39	0.26	2387.05	465.31
0.67	686.6	18.1	28.11	10.01	8.37	0.41	0.28	2491.07	467.6
0.67	784.7	18.1	28.32	10.22	8.59	0.45	0.3	2592.86	469.2
0.67	833.7	18.1	28.46	10.36	8.72	0.47	0.31	2656.43	470.79
0.67	882.8	18.1	28.6	10.5	8.86	0.49	0.32	2722.24	472.47
0.67	931.8	18.1	28.73	10.63	9	0.5	0.33	2785.87	473.4
0.67	980.9	18.1	28.89	10.79	9.15	0.51	0.34	2858.13	474.46
0.67	1029.9	18.1	29.06	10.96	9.32	0.52	0.35	2938.93	475.64
0.67	1078.9	18.1	29.18	11.08	9.44	0.54	0.36	2996.51	476.46

Table D-1. HEC-RAS results for discharge, elevation, depth, velocity, flow area, and width at 47 main channel cross-sections for Rainbow River, Florida

HEC-RAS	Q Total	Min Ch El	WS Elev	Max Chl Dpth	Hydr Depth	Vel Chnl	Vel Total	Flow Area	Top Width
mile	cfs	ft	ft	ft	ft	ft/sec	ft/sec	ft^2	ft
0.56	443.9	17.6	27.55	9.95	7.26	0.49	0.45	979.86	192.43
0.56	468.3	17.6	27.6	10	7.31	0.52	0.47	990.83	193.93
0.56	493	17.6	27.64	10.04	7.35	0.54	0.49	998.34	195.59
0.56	517.6	17.6	27.68	10.08	7.38	0.56	0.51	1006.12	198.64
0.56	616.21	17.6	27.85	10.25	7.54	0.65	0.59	1042.84	227.27
0.56	690.1	17.6	28.07	10.47	7.73	0.71	0.63	1093.91	240.35
0.56	788.7	17.6	28.28	10.68	7.93	0.78	0.69	1145.33	245.11
0.56	838	17.6	28.42	10.82	8.06	0.81	0.71	1178.08	247.65
0.56	887.4	17.6	28.56	10.96	8.2	0.84	0.73	1212.15	248.32
0.56	936.6	17.6	28.69	11.09	8.33	0.87	0.75	1245.11	248.94
0.56	985.9	17.6	28.84	11.24	8.48	0.89	0.77	1282.76	249.65
0.56	1035.2	17.6	29.01	11.41	8.65	0.91	0.78	1325.05	250.44
0.56	1084.4	17.6	29.13	11.53	8.77	0.94	0.8	1354.9	251
0.38	447.5	18.4	27.44	9.04	5.49	0.99	0.93	480.32	230.92
0.38	472.2	18.4	27.48	9.08	5.53	1.03	0.97	486.07	240.42
0.38	497.1	18.4	27.51	9.11	5.56	1.08	1.02	489.49	245.72
0.38	521.9	18.4	27.54	9.14	5.59	1.13	1.06	493.03	252.11
0.38	621.34	18.4	27.67	9.27	5.72	1.31	1.22	509.95	274.77
0.38	695.8	18.4	27.86	9.46	5.91	1.41	1.29	540.49	321.68
0.38	795.3	18.4	28.05	9.65	6.1	1.46	1.05	757.24	339.42
0.38	845	18.4	28.17	9.77	6.22	1.49	1.06	798.92	346.45
0.38	894.7	18.4	28.3	9.9	6.35	1.53	1.06	843.86	356.07
0.38	944.4	18.4	28.42	10.02	6.47	1.56	1.06	888.5	365.46
0.38	994.1	18.4	28.57	10.17	6.62	1.58	1.05	943.1	376.63
0.38	1043.8	18.4	28.74	10.34	6.79	1.59	1.04	1007.98	391.28
0.38	1093.5	18.4	28.85	10.45	6.9	1.61	1.04	1052.55	405.71
0.25	450	17.4	27.34	25.03	5.62	0.55	0.53	843.72	598.86
0.25	475	17.4	27.37	25.06	5.65	0.58	0.56	850.8	600.88
0.25	500	17.4	27.39	25.08	5.66	0.61	0.59	853.99	601.79
0.25	525	17.4	27.41	25.1	5.67	0.64	0.61	857.26	602.71
0.25	625	17.4	27.49	25.18	5.73	0.75	0.72	872.6	607.12
0.25	700	17.4	27.66	25.35	5.84	0.81	0.77	905.1	616.29
0.25	800	17.4	27.82	25.51	5.95	0.9	0.85	936.66	624.97
0.25	850	17.4	27.94	25.63	6.02	0.94	0.89	958.59	631.79
0.25	900	17.4	28.05	25.74	6.1	0.97	0.92	983.01	646.98
0.25	950	17.4	28.17	25.86	6.17	1	0.94	1007.74	661.76
0.25	1000	17.4	28.31	26	6.3	1.03	0.96	1040.23	673.6
0.25	1050	17.4	28.48	26.17	6.47	1.05	0.97	1079.84	685.4
0.25	1100	17.4	28.59	26.28	6.58	1.08	1	1105.17	691.83
0.17	450	18	27.29	9.29	6.69	0.64	0.62	723.69	179.93
0.17	475	18	27.32	9.32	6.73	0.67	0.65	728.23	186.38
0.17	500	18	27.33	9.33	6.74	0.7	0.69	729.79	188.6
0.17	525	18	27.34	9.34	6.75	0.74	0.72	731.39	190.47
0.17	625	18	27.4	9.4	6.81	0.87	0.85	739.14	196.71
0.17	700	18	27.57	9.57	6.98	0.95	0.92	762.04	218.34
0.17	800	18	27.71	9.71	7.12	1.06	1.02	782.23	242.23
0.17	850	18	27.82	9.82	7.22	1.11	1.07	797.14	260.35
0.17	900	18	27.93	9.93	7.33	1.16	1.11	813.94	284.01
0.17	950	18	28.03	10.03	7.44	1.2	1.14	830.84	304.81
0.17	1000	18	28.17	10.17	7.58	1.24	1.17	853.86	320.21
0.17	1050	18	28.34	10.34	7.75	1.27	1.19	882.97	326.46
0.17	1100	18	28.44	10.44	7.85	1.32	1.22	900.34	327.8

Table D-1. HEC-RAS results for discharge, elevation, depth, velocity, flow area, and width at 47 main channel cross-sections for Rainbow River, Florida

HEC-RAS	Q Total	Min Ch El	WS Elev	Max Chl Dpth	Hydr Depth	Vel Chnl	Vel Total	Flow Area	Top Width
mile	cfs	ft	ft	ft	ft	ft/sec	ft/sec	ft^2	ft
0.06	450	16.1	27.24	11.14	6.78	0.64	0.63	715.48	250.64
0.06	475	16.1	27.26	11.16	6.8	0.67	0.66	718.52	252.32
0.06	500	16.1	27.26	11.16	6.8	0.71	0.7	719.34	252.77
0.06	525	16.1	27.27	11.17	6.81	0.74	0.73	720.15	253.22
0.06	625	16.1	27.29	11.19	6.83	0.88	0.86	724.56	255.64
0.06	700	16.1	27.44	11.34	6.98	0.96	0.93	748.8	287.85
0.06	800	16.1	27.56	11.46	7.09	1.08	1.04	767.57	312.45
0.06	850	16.1	27.65	11.55	7.18	1.13	1.09	782.74	328.71
0.06	900	16.1	27.75	11.65	7.28	1.18	1.13	799.89	353.92
0.06	950	16.1	27.84	11.74	7.38	1.23	1.16	816.74	383.03
0.06	1000	16.1	27.98	11.88	7.51	1.27	1.19	841.23	418.1
0.06	1050	16.1	28.14	12.04	7.67	1.3	1.2	871.85	442.63
0.06	1100	16.1	28.23	12.13	7.76	1.34	1.24	888.6	450.64
0.02	450	17.5	27.21	9.71	5.54	0.86	0.85	529.65	163.53
0.02	475	17.5	27.23	9.73	5.56	0.9	0.89	531.22	164.11
0.02	500	17.5	27.23	9.73	5.56	0.95	0.94	531.43	164.18
0.02	525	17.5	27.23	9.73	5.56	1	0.99	531.61	164.25
0.02	625	17.5	27.23	9.73	5.56	1.19	1.18	531.75	164.3
0.02	700	17.5	27.37	9.87	5.7	1.3	1.28	545.55	169.34
0.02	800	17.5	27.47	9.97	5.8	1.46	1.44	555.03	172.79
0.02	850	17.5	27.55	10.05	5.88	1.53	1.51	563.18	175.77
0.02	900	17.5	27.64	10.14	5.97	1.59	1.57	572.4	179.14
0.02	950	17.5	27.73	10.23	6.06	1.65	1.63	581.24	182.36
0.02	1000	17.5	27.86	10.36	6.19	1.7	1.68	593.88	188.1
0.02	1050	17.5	28.02	10.52	6.35	1.74	1.72	609.91	197.27
0.02	1100	17.5	28.11	10.61	6.44	1.8	1.78	618.17	202.15
0.01	Bridge								
0	450	16.1	27.2	11.1	6.29	0.55	0.54	838.64	163.05
0	475	16.1	27.2	11.1	6.29	0.58	0.57	838.64	163.05
0	500	16.1	27.2	11.1	6.29	0.61	0.6	838.64	163.05
0	525	16.1	27.2	11.1	6.29	0.64	0.63	838.64	163.05
0	625	16.1	27.2	11.1	6.29	0.76	0.75	838.64	163.05
0	700	16.1	27.33	11.23	6.42	0.83	0.81	859.11	165.75
0	800	16.1	27.41	11.31	6.49	0.94	0.92	870.97	167.37
0	850	16.1	27.49	11.39	6.56	0.99	0.96	882.94	169
0	900	16.1	27.58	11.48	6.64	1.03	1	896.86	172.16
0	950	16.1	27.66	11.56	6.72	1.07	1.04	910.4	175.36
0	1000	16.1	27.79	11.69	6.83	1.11	1.07	930.56	180.05
0	1050	16.1	27.94	11.84	6.96	1.14	1.1	955.34	185.74
0	1100	16.1	28.02	11.92	7.03	1.18	1.14	968.66	188.74

River Sta	Cross sections measured from downstream boundary of the HEC-RAS Model (SR484 Bridge)
Q Total	Total channel discharge
Min ch El	Minimum channel bottom elevation
WS Elev	Water surface elevation
Max Chl Dpth	Maximum channel depth
Hydr Depth	Channel hydraulic depth
Vel Chnl	Channel velocity
Vel Total	Channel total velocity
Flow Area	Cross-section flow area
Top Width	Top width of water surface

Table D-2. HEC-RAS results for discharge, elevation, depth, velocity, and shear stress at 46 main channel cross-sections for Rainbow River, Florida

River Sta	Q	WS Elev	Top Width	Vel LOB	Vel ROB	Vel Chan	Shear Chan	Vel Total	Shear Total
mile	cfs	ft	ft	ft/sec	ft/sec	ft/sec	lb/ft^2	ft/sec	lb/ft^2
5.02	239.2	29.48	88.32	0.08	0.21	0.96	0.114	0.94	0.087
	287.5	29.94	159.08	0.13	0.2	1.01	0.126	0.93	0.065
	323.43	30.34	240.49	0.16	0.18	1.01	0.12	0.83	0.047
	367.08	30.82	279.47	0.2	0.18	0.97	0.108	0.71	0.043
4.93	247.45	29.47	218.82	0.02		0.22	0.005	0.22	0.005
	297.42	29.93	266.45	0.02		0.24	0.006	0.24	0.005
	334.58	30.33	284.74	0.03		0.26	0.007	0.25	0.005
	379.74	30.81	310.13	0.04		0.27	0.007	0.26	0.005
4.76	262.26	29.47	268.87	0.01	0.05	0.12	0.001	0.12	0.001
	315.22	29.93	339.75	0.01	0.06	0.14	0.002	0.13	0.001
	354.61	30.33	356.14	0.02	0.06	0.15	0.002	0.14	0.001
	402.48	30.81	369.71	0.02	0.06	0.17	0.002	0.15	0.002
4.63	273.95	29.46	203.52			0.27	0.008	0.27	0.008
	329.26	29.92	240.02	0.02	0.02	0.29	0.01	0.29	0.008
	370.41	30.32	267.78	0.04	0.04	0.31	0.01	0.3	0.008
	420.4	30.8	298.25	0.05	0.05	0.32	0.011	0.31	0.008
4.48	287.8	29.42	139.84	0.06		0.45	0.022	0.44	0.019
	345.92	29.88	216.72	0.06		0.49	0.027	0.47	0.018
	389.14	30.28	259.67	0.07		0.5	0.028	0.47	0.017
	441.67	30.76	275.95	0.1		0.52	0.028	0.46	0.017
4.37	297.01	29.38	107.85			0.42	0.018	0.42	0.018
	356.98	29.84	145.01	0.04	0.01	0.47	0.022	0.46	0.017
	401.59	30.24	148.66	0.06	0.05	0.5	0.024	0.48	0.019
	455.79	30.71	188.27	0.09	0.07	0.53	0.027	0.51	0.02
4.25	307.58	29.34	191.42	0.04		0.45	0.031	0.45	0.028
	369.68	29.79	237.34	0.07		0.49	0.035	0.48	0.026
	415.88	30.19	259.94	0.09		0.5	0.036	0.48	0.025
	472.01	30.67	265.5	0.12		0.51	0.036	0.47	0.026
4.18	314.46	29.32	243.99	0.07	0.07	0.28	0.009	0.25	0.006
	377.96	29.77	255.98	0.09	0.07	0.31	0.012	0.27	0.007
	425.19	30.17	259.24	0.1	0.09	0.33	0.013	0.29	0.008
	482.57	30.65	263.18	0.12	0.1	0.35	0.014	0.3	0.009
4.05	326.17	29.3	227.52	0.06	0.03	0.42	0.027	0.42	0.024
	392.03	29.74	261.58	0.09	0.06	0.45	0.03	0.44	0.024
	441.02	30.14	313.58	0.11	0.08	0.46	0.031	0.44	0.021
	500.55	30.62	353.92	0.13	0.1	0.47	0.031	0.43	0.02
3.88	340.89	29.29	385.18	0.03	0.02	0.12	0.002	0.12	0.002
	409.72	29.73	399.28	0.04	0.02	0.14	0.003	0.13	0.002
	460.92	30.13	426.71	0.04	0.02	0.15	0.003	0.14	0.002
	523.13	30.61	437.07	0.05	0.03	0.16	0.003	0.15	0.003

Table D-2. HEC-RAS results for discharge, elevation, depth, velocity, and shear stress at 46 main channel cross-sections for Rainbow River, Florida

River Sta	Q	WS Elev	Top Width	Vel LOB	Vel ROB	Vel Chan	Shear Chan	Vel Total	Shear Total
mile	cfs	ft	ft	ft/sec	ft/sec	ft/sec	lb/ft^2	ft/sec	lb/ft^2
3.81	346.82	29.28	298.84	0.02	0.03	0.22	0.007	0.21	0.006
	416.85	29.72	318.05	0.03	0.05	0.25	0.009	0.24	0.007
	468.94	30.12	324.42	0.05	0.06	0.26	0.01	0.25	0.008
	532.24	30.6	335.62	0.06	0.07	0.28	0.011	0.26	0.008
3.75	352.31	29.26	280.5	0.05	0.16	0.53	0.037	0.47	0.018
	423.45	29.7	300.09	0.08	0.18	0.57	0.042	0.48	0.021
	476.37	30.1	307.29	0.11	0.19	0.59	0.043	0.47	0.023
	540.66	30.58	319.04	0.13	0.21	0.6	0.044	0.47	0.024
3.63	363.25	29.21	264.03	0.1	0.05	0.33	0.016	0.32	0.014
	436.6	29.65	270.76	0.12	0.07	0.36	0.018	0.35	0.016
	491.16	30.06	277.04	0.12	0.08	0.38	0.019	0.36	0.017
	557.46	30.54	291.73	0.12	0.09	0.39	0.02	0.37	0.017
3.48	377.08	29.18	320.97	0.05		0.26	0.007	0.25	0.007
	453.22	29.61	329.53	0.06		0.28	0.009	0.28	0.008
	509.86	30.02	343.22	0.06	0.01	0.3	0.009	0.29	0.008
	578.67	30.5	379.31	0.08	0.02	0.31	0.01	0.3	0.008
3.31	391.39	29.15	202.28	0.04	0.04	0.35	0.015	0.34	0.013
	470.42	29.58	203.44	0.07	0.06	0.39	0.019	0.38	0.016
	529.2	29.98	204.55	0.09	0.07	0.41	0.021	0.4	0.018
	600.63	30.46	205.85	0.11	0.08	0.44	0.023	0.42	0.019
3.19	402.93	29.11	207.24	0.06	0.08	0.45	0.023	0.45	0.021
	484.29	29.54	215.72	0.08	0.11	0.5	0.027	0.49	0.024
	544.81	29.95	226.86	0.09	0.12	0.52	0.029	0.5	0.024
	618.35	30.43	249.58	0.09	0.13	0.54	0.03	0.52	0.024
3.11	409.32	29.09	258.88	0.05	0.14	0.37	0.015	0.35	0.013
	491.97	29.51	273.21	0.06	0.16	0.4	0.018	0.38	0.015
	553.44	29.92	278.32	0.08	0.16	0.42	0.019	0.4	0.016
	628.14	30.4	280.95	0.1	0.17	0.44	0.02	0.41	0.017
3.02	418.01	29.05	172.85	0.04	0.05	0.58	0.037	0.57	0.032
	502.42	29.47	190.61	0.07	0.08	0.64	0.044	0.62	0.035
	565.2	29.88	209.89	0.09	0.11	0.66	0.047	0.64	0.034
	641.49	30.36	230.42	0.1	0.13	0.69	0.049	0.64	0.034
2.98	421.64	29.03	186.83	0.08	0.07	0.47	0.022	0.45	0.017
	506.78	29.45	199.09	0.1	0.09	0.53	0.028	0.5	0.02
	570.1	29.86	207.43	0.11	0.11	0.56	0.03	0.52	0.022
	647.05	30.34	215.44	0.12	0.13	0.59	0.033	0.54	0.023
2.9	428.43	29	203.55	0.05	0.07	0.56	0.033	0.54	0.022
	514.93	29.42	220.21	0.09	0.1	0.63	0.04	0.58	0.025
	579.28	29.83	227.05	0.12	0.12	0.66	0.043	0.6	0.027
	657.47	30.31	265.8	0.15	0.14	0.69	0.046	0.6	0.026

Table D-2. HEC-RAS results for discharge, elevation, depth, velocity, and shear stress at 46 main channel cross-sections for Rainbow River, Florida

River Sta	Q	WS Elev	Top Width	Vel LOB	Vel ROB	Vel Chan	Shear Chan	Vel Total	Shear Total
mile	cfs	ft	ft	ft/sec	ft/sec	ft/sec	lb/ft^2	ft/sec	lb/ft^2
2.83	435.04	28.97	227.69		0.04	0.34	0.015	0.34	0.015
	522.88	29.4	232.69		0.05	0.38	0.018	0.37	0.018
	588.22	29.8	248.78	0.02	0.05	0.4	0.02	0.39	0.018
	667.62	30.28	290.99	0.03	0.07	0.42	0.022	0.41	0.017
2.69	447.4	28.92	208.08	0.09	0.1	0.63	0.043	0.6	0.028
	537.74	29.34	257.03	0.1	0.12	0.7	0.052	0.64	0.028
	604.94	29.74	312.57	0.11	0.14	0.73	0.054	0.63	0.026
	686.59	30.22	317.52	0.15	0.15	0.75	0.056	0.62	0.029
2.56	458.82	28.86	244.8	0.06	0.07	0.49	0.025	0.47	0.017
	551.47	29.28	291.84	0.08	0.09	0.55	0.031	0.51	0.018
	620.38	29.68	298.44	0.1	0.11	0.57	0.033	0.51	0.02
	704.11	30.16	303.9	0.13	0.12	0.6	0.035	0.52	0.022
2.46	468	28.83	221.93	0.12	0.13	0.48	0.023	0.43	0.017
	562.5	29.23	251.27	0.13	0.15	0.54	0.029	0.48	0.019
	632.79	29.64	279.07	0.11	0.17	0.58	0.032	0.49	0.019
	718.2	30.12	306.75	0.13	0.15	0.61	0.035	0.51	0.02
2.37	470.04	28.79	220.02	0.11	0.09	0.62	0.044	0.59	0.034
	564.95	29.19	236.28	0.14	0.12	0.68	0.051	0.64	0.039
	635.55	29.6	260.25	0.15	0.14	0.7	0.053	0.65	0.037
	721.33	30.08	282.21	0.16	0.16	0.72	0.055	0.65	0.037
2.33	470.92	28.76	217.14	0.12	0.07	0.62	0.043	0.59	0.031
	566.01	29.16	234.1	0.14	0.11	0.69	0.051	0.64	0.035
	636.73	29.57	254.69	0.14	0.14	0.71	0.053	0.65	0.035
	722.68	30.05	297.25	0.14	0.15	0.74	0.056	0.65	0.033
2.08	476.87	28.5	226.55	0.13	0.18	0.79	0.074	0.73	0.051
	573.16	28.88	235.84	0.18	0.21	0.86	0.085	0.78	0.058
	644.78	29.3	252.17	0.21	0.23	0.87	0.085	0.77	0.057
	731.81	29.8	311.06	0.21	0.19	0.89	0.085	0.74	0.049
1.98	479.2	28.43	245.89	0.08	0.15	0.47	0.025	0.45	0.022
	575.96	28.8	249.92	0.09	0.17	0.53	0.03	0.5	0.027
	647.94	29.23	263.46	0.09	0.17	0.55	0.032	0.51	0.027
	735.39	29.73	341.95	0.06	0.18	0.57	0.033	0.52	0.022
1.95	479.97	28.41	257.15	0.1	0.07	0.64	0.046	0.6	0.029
	576.89	28.78	266.65	0.14	0.09	0.71	0.055	0.64	0.035
	648.98	29.2	277.68	0.17	0.11	0.73	0.057	0.64	0.036
	736.57	29.71	354.58	0.16	0.14	0.75	0.058	0.63	0.031
1.85	482.26	28.34	206.77		0.1	0.6	0.04	0.58	0.032
	579.64	28.7	232.06	0.02	0.13	0.67	0.048	0.63	0.036
	652.07	29.13	262.7	0.06	0.16	0.69	0.05	0.64	0.036
	740.08	29.64	303.41	0.11	0.18	0.71	0.052	0.65	0.037

Table D-2. HEC-RAS results for discharge, elevation, depth, velocity, and shear stress at 46 main channel cross-sections for Rainbow River, Florida

River Sta	Q	WS Elev	Top Width	Vel LOB	Vel ROB	Vel Chan	Shear Chan	Vel Total	Shear Total
mile	cfs	ft	ft	ft/sec	ft/sec	ft/sec	lb/ft^2	ft/sec	lb/ft^2
1.66	486.72	28.19	159.2	0.14	0.12	0.74	0.06	0.72	0.047
	584.99	28.52	177.59	0.14	0.15	0.84	0.075	0.8	0.053
	658.1	28.95	240.68	0.14	0.13	0.87	0.079	0.8	0.044
	746.92	29.47	262.27	0.15	0.17	0.9	0.081	0.78	0.044
1.55	489.28	28.08	225.34	0.11	0.09	0.62	0.057	0.61	0.047
	588.08	28.39	246.18	0.14	0.11	0.69	0.069	0.67	0.054
	661.57	28.83	314.33	0.11	0.13	0.71	0.07	0.66	0.044
	750.86	29.36	341.91	0.15	0.16	0.71	0.069	0.64	0.042
1.45	491.67	28.02	262.86	0.07	0.22	0.5	0.033	0.43	0.023
	590.95	28.32	290.18	0.09	0.21	0.59	0.044	0.48	0.029
	664.79	28.76	296.56	0.11	0.23	0.6	0.046	0.49	0.03
	754.52	29.3	304.22	0.13	0.25	0.62	0.047	0.49	0.032
1.32	494.82	27.96	205.19	0.04	0.07	0.51	0.029	0.51	0.027
	594.74	28.24	213.92	0.06	0.09	0.58	0.037	0.57	0.033
	669.06	28.69	240.35	0.08	0.09	0.6	0.038	0.59	0.031
	759.36	29.23	267.51	0.1	0.1	0.62	0.04	0.6	0.03
1.22	497.01	27.92	204.53	0.04	0.03	0.54	0.031	0.53	0.023
	597.36	28.19	214.47	0.07	0.05	0.62	0.04	0.61	0.029
	672.01	28.64	238.71	0.1	0.07	0.65	0.043	0.62	0.03
	762.71	29.18	276.79	0.12	0.09	0.68	0.045	0.63	0.03
1.11	499.75	27.84	137.08	0.15	0.15	0.77	0.072	0.71	0.048
	600.66	28.09	146.3	0.18	0.17	0.89	0.096	0.82	0.061
	675.72	28.54	176.06	0.19	0.19	0.94	0.105	0.84	0.058
	766.93	29.07	220.59	0.23	0.19	0.99	0.113	0.84	0.053
0.91	504.44	27.75	237.62	0.1	0.08	0.47	0.027	0.44	0.017
	606.3	27.97	273.8	0.12	0.08	0.55	0.037	0.51	0.02
	682.06	28.42	331.71	0.12	0.09	0.58	0.04	0.51	0.019
	774.12	28.95	399.03	0.13	0.12	0.61	0.043	0.51	0.019
0.83	506.39	27.73	225.23	0.09	0.02	0.44	0.02	0.43	0.017
	608.64	27.94	227.92	0.12	0.03	0.51	0.027	0.49	0.023
	684.69	28.39	243.84	0.13	0.03	0.53	0.028	0.51	0.023
	777.11	28.93	281.24	0.15	0.06	0.55	0.03	0.53	0.024
0.77	507.6	27.71	252.79		0.06	0.44	0.022	0.44	0.02
	610.1	27.91	263.99	0.01	0.07	0.51	0.028	0.5	0.025
	686.33	28.36	302.26	0.04	0.08	0.53	0.03	0.51	0.023
	778.97	28.91	371.74	0.06	0.08	0.54	0.03	0.51	0.02
0.67	510.07	27.68	462.12	0.2	0.09	0.33	0.011	0.22	0.007
	613.07	27.89	465.33	0.23	0.11	0.39	0.014	0.26	0.009
	689.67	28.33	469.23	0.24	0.12	0.4	0.015	0.27	0.01
	782.76	28.89	474.47	0.25	0.13	0.41	0.015	0.27	0.01

Table D-2. HEC-RAS results for discharge, elevation, depth, velocity, and shear stress at 46 main channel cross-sections for Rainbow River, Florida

River Sta	Q	WS Elev	Top Width	Vel LOB	Vel ROB	Vel Chan	Shear Chan	Vel Total	Shear Total
mile	cfs	ft	ft	ft/sec	ft/sec	ft/sec	lb/ft^2	ft/sec	lb/ft^2
0.56	512.69	27.66	197.02	0.18		0.56	0.031	0.51	0.021
	616.21	27.86	227.35	0.21		0.65	0.042	0.59	0.025
	693.21	28.3	245.35	0.22	0.01	0.68	0.045	0.6	0.027
	786.78	28.86	249.73	0.24	0.05	0.71	0.047	0.61	0.029
0.38	516.95	27.52	247.22	0.22	0.23	1.12	0.135	1.05	0.096
	621.34	27.67	275.01	0.25	0.27	1.31	0.183	1.22	0.116
	698.98	28.12	343.46	0.24	0.28	1.25	0.164	0.89	0.061
	793.33	28.69	387.8	0.28	0.28	1.22	0.151	0.8	0.058
0.25	520	27.39	601.73		0.12	0.63	0.043	0.61	0.035
	625	27.49	607.19		0.15	0.75	0.059	0.72	0.048
	703.1	27.96	634.97	0.01	0.17	0.77	0.062	0.73	0.049
	798	28.55	689.8	0.07	0.19	0.79	0.064	0.73	0.045
0.17	520	27.33	187.48	0.11	0.13	0.73	0.054	0.71	0.045
	625	27.4	196.91	0.13	0.16	0.87	0.076	0.85	0.062
	703.1	27.87	271.33	0.14	0.17	0.91	0.082	0.87	0.06
	798	28.46	328.09	0.15	0.18	0.95	0.087	0.88	0.058
0.06	520	27.25	251.71	0.05		0.74	0.055	0.72	0.037
	625	27.3	255.78	0.07		0.88	0.079	0.86	0.053
	703.1	27.76	357.78	0.12	0.01	0.92	0.084	0.88	0.054
	798	28.36	456.01	0.17	0.04	0.96	0.088	0.88	0.056
0.02	520	27.21	163.66	0.24	0.28	0.99	0.106	0.98	0.103
	625	27.23	164.36	0.29	0.34	1.19	0.152	1.17	0.147
	703.1	27.7	181.13	0.35	0.39	1.23	0.159	1.22	0.154
	798	28.3	215.24	0.41	0.45	1.27	0.164	1.25	0.159

River Sta	Cross sections measured from downstream boundary of the HEC-RAS Model (SR484 Bridge)
Q	Total channel discharge
WS Elev	Water surface elevation
Top Width	Top width of water surface
Vel LOB	Velocity in left overbank section
Vel ROB	Velocity in right overbank section
Vel Chan	Velocity in main channel
Shear Chan	Shear stress in main channel
Vel Total	Total cross-section velocity
Shear total	Total cross-section shear stress