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Shaw® Shaw Environmental, Inc.

August 5, 2004

835423-SHAWCHO-0245

DEPARTMENT OF THE ARMY
Mr. Karl Blankinship
US Army Corps of Engineers
Attn: CESAM-PM-ME
Building 4488, Room A317A, Martin Road
Redstone Arsenal, Alabama 35898

Contract: Total Environmental Restoration Contract
Contract DACA21-96-D-0018, Delivery Order 0018

Subject: Submittal of Final Continuous Surface Water Monitoring Report 2000 - 2002, Redstone Arsenal, Madison County, Alabama

Dear Mr. Blankinship:

The Final *Continuous Surface Water Monitoring Report 2000 - 2002,* Redstone Arsenal, Madison County, Alabama (Shaw, July 2004) is published for your reference.

The document has been published on ActiveProjects for electronic viewing to subscribers as listed on the attached distribution list and in accordance with the *Document Submission Requirements and Distribution Procedures (Revision XXIV).* This document has been forwarded to the recipients listed on the attached distribution list and in accordance with the revised distribution list, quantities as indicated.

Please note that the Army's response to EPA's comments resulted in the following changes to the Draft report.

1) added text to Sections 2 and 3 (response to general comment #'s 2 & 3 and specific comment #2)
2) Figure 3-37 (response to general comment #2)

If you have any questions or need additional information regarding this submittal, please do not hesitate to call me at 865-694-7433.

Respectfully submitted,

Kim Amast for

Don C. Burton
Project Manager
Shaw Environmental, Inc.

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DEPARTMENT OF THE ARMY
UNITED STATES ARMY GARRISON – REDSTONE
4488 MARTIN ROAD
REDSTONE ARSENAL, ALABAMA 35898-5000

REPLY TO
ATTENTION OF

AUG - 4 2004

AMSAM-RA-DES-IR

MEMORANDUM FOR Federal Facilities Branch (Ms. Julie Corkran), US Environmental Protection Agency, Waste Management Branch, 61 Forsyth Street, SW, Mail code 4WD-FFB-10th Floor, Atlanta, GA 30303-34013

Government Facilities Section (Mr. Tom Birks), Hazardous Waste Branch, Land Division, Alabama Department of Environmental Management, P.O. Box 301463, Montgomery, AL 36130-1463

SUBJECT: Final Continuous Surface Water Monitoring Report 2000 - 2002, Redstone Arsenal, Madison County, Alabama

1. Reference the Installation Restoration Program at Redstone Arsenal, Alabama (EPA ID AL7 210 020 742).

2. This letter transmits one hard copy of subject document. An approval letter has been received from the Environmental Protection Agency and is included with the document. Please note that the Army's response to EPA's comments resulted in the following changes to the Draft report:

a. Added text to Sections 2 and 3 (response to general comment #s 2 & 3 and specific comment #2)

b. Figure 3-37 (response to general comment #2)

3. Any questions or concerns regarding this report may be directed to Ms. Terry de la Paz, Installation Restoration Division (AMSAM-RA-DES-IR), e-mail terry.delapaz@redstone.army.mil, 256-955-6968.

Encl

TERRY W. HAZLE
Director, Directorate of Environment
and Safety

CF:
Gannett Fleming, Inc (Mr. J.E. "Ben" Bentkowski), Suite 700, Peachtree Center Tower, 230 Peachtree St, N, Atlanta, GA 30303 (2 hardcopies & 1 CD)
US Army Environmental Center, Installation Restoration Division, (SFIM-AEC-IRP, Mr. Michael Kelly), Bldg #E4480, Aberdeen Proving Ground, MD 21010-5401 (1 CD)

CF (continued):

US Army Center for Health Promotion and Preventative Medicine, (MCHB-TS-THR), Bldg #E1675, Aberdeen Proving Ground, MD 21010-5401 (1 CD)

Environmental Compliance Group (Mr. Jack Milligan), Tennessee Valley Authority, 1101 Market St, CST 17B, Chattanooga, TN 37402-2801 (1 CD)

Wheeler National Wildlife Refuge (Mr. Dwight Cooley), US Fish and Wildlife Service, 2700 Refuge HQ Road, Decatur, AL 35603 (1 CD)

Alabama Department of Public Health (Mr. Kenneth Calhoun), 201 Monroe St, Suite 1450 Montgomery, AL 36104 (1 CD)

Marshall Space Flight Center, Mr. Farley Davis, Bldg 4200, Mail Code AD-10, Marshall Space Flight Center, AL 35812 (1 CD)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4

61 Forsyth Street SW
Atlanta, Georgia 30303-3104

September 25, 2003

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

4WD-FFB

Mr. Terry Hazle
Department of the Army
Directorate of Environmental Management
(AMSAM-RA-DEM, Mr. Terry Hazle)
U.S. Army Aviation and Missile Command
Redstone Arsenal Support Activity, Building 4488
Redstone Arsenal, AL 35898

SUBJ: Redstone Army Arsenal, AL
AL7 210 020 742
Comments: *Continuous Surface Water Monitoring Report 2000-2002, Draft, (August 2003)*

Dear Mr. Hazle:

EPA has reviewed the subject document and is offering the enclosed comments for consideration and team discussion. EPA views the Army's surface water monitoring program as foundational to implementation of the Integrator Operable Unit approach to investigation and mitigation of contaminants from multiple Redstone and NASA Marshall Space Flight Center (MSFC) sources at this National Priorities List facility. Accordingly, I have copied Mr. Farley Davis of the NASA MSFC on this letter.

Please do not hesitate to contact me at 404/562-8547 or at corkran.julie@epa.gov if you have any questions about this correspondence.

Sincerely,

Julie L. Corkran

Julie L. Corkran
Senior Remedial Project Manager
Waste Management Division
Federal Facilities Branch

Enclosure

cc: Terry de la Paz, Redstone
Farley Davis, NASA MSFC
Tom Birks, ADEM
Nelly Smith, ADEM
David Lovoy, ADEM
Ben Bentkowski, Gannett-Fleming

U.S. Environmental Protection Agency (EPA) Region 4
Comments on:
Continuous Surface Water Monitoring Report 2000 – 2002,
Draft, dated August 2003
Redstone Arsenal, Madison County, Alabama,

GENERAL COMMENTS:

1. This report documents data collection efforts and provides recommendations for future surface water monitoring activities. EPA views the surface water monitoring effort by Redstone as foundational to implementation of the Integrator Operable Unit approach to investigation and mitigation of contaminants from multiple Army and NASA sources at this National Priorities List facility. Further, EPA views the report as a secondary-type document under the draft Federal Facility Agreement for the CERCLA cleanup at this facility. This Agency generated limited comments as a result of our review and the report is appreciated for its contribution to the overall understanding of the hydrology of Redstone Arsenal and NASA Marshall Space Flight Center.

2. This report is full of the hydrographs and flow data that make up the basic data of surface water hydrology. The water freely interchanges between the groundwater and the surface water and thereby potentially discharging contaminants to the surface water and allowing dilution of plumes in the subsurface. It would be useful if there were a map which depicted the gaining and losing reaches of the major surface water bodies across the facility. This map would aid in the holistic understanding of the hydrology of Redstone Arsenal and the specific impacts from the individual sites. Perhaps the map should be presented as a pair of maps depicting high pool/low pool stages or wet season/dry season conditions.

3. This report covers three years worth of data. Please provide an opinion as to the representativeness of this data set. Three years is a relatively short length of time to document 'natural' site conditions but may be sufficient given project specific constraints.

4. Many of the figures include a graphical representation or typed notation of the rating limits for the data or the data collection device. There are several instances where the rating limits exceed the data displayed. Please provide an explanation of rating limits and how they are used in evaluating the data collected.

Specific Comments

1. Page 17, Section 4.0. Please provide a justification for the recommendation of the cessation of the collection of the stream flow data. It appears from earlier text that the recommendation to discontinue the gathering of flow data is because (i) it is an expense that is not tied to any specific waste unit, and (ii) it is expensive to perform accurately, since the stream cross section changes through time and these changes require recalibration of the parameters that feed into the Manning Equation evaluations (see Appendix A). If these are the reasons for ceasing the collection of stream flow data, then please state them in the text. If there are additional reasons, please provide them in the text as well and provide feedback to the agencies on how cessation of stream flow data collection may impact Integrator Operable Unit efforts for Redstone and NASA MSFC.

2. Introduction. In the *Introduction*, the report notes that all available surface water monitoring data on or adjacent to RSA have been integrated into this report. Please clarify whether surface water monitoring data gathered by NASA MSFC have been included in this report. For example, it is EPA's understanding that NASA MSFC has collected continuous surface water monitoring data at a tributary to Indian Creek near Martin Road.

Final

Continuous Surface Water Monitoring Report 2000 - 2002

Redstone Arsenal
Madison County, Alabama
U.S. EPA ID No. AL7 210 020 742

July 2004

Delivery Order 0018
Contract No. DACA21-96-D-0018
Project No. 835423

Alabama Department
of Environmental
Management

Continuous Surface Water Monitoring Report 2000 - 2002,
Redstone Arsenal, Madison County, Alabama, U.S. EPA ID No. AL7 210 020 742

Final
July 2004

Final
Continuous Surface Water Monitoring Report
2000 - 2002
Redstone Arsenal
Madison County, Alabama
EPA ID No. A17 210 020 742

Prepared for:

U.S. Army Corps of Engineers, Savannah District
Post Office Box 889
Savannah, Georgia 31402-0889

Prepared by:

Shaw Environmental, Inc.
312 Directors Drive
Knoxville, Tennessee 37923

Contract No. DACA21-96-D-0018
Delivery Order 0018
Project No. 835423

July 2004

Final
Continuous Surface Water Monitoring Report
2000 - 2002
Redstone Arsenal
Madison County, Alabama

Certification

I certify under penalty of law that this document was prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

T.F. Zondlo, Alabama PG No. 993
Principal Investigator

7/26/04
Date

THOMAS F. ZONDLO
LIC. 993
ALABAMA LICENSED PROFESSIONAL GEOLOGIST

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List of Acronyms

amsl	above mean sea level
cfs	cubic feet per second
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
DDT	dichlorodiphenyltrichloroethane
HSDR	Huntsville Spring Branch at Dodd Road
HSMN	Huntsville Spring Branch at mile 4.85
HSMR	Huntsville Spring Branch at Martin Road
ICCR	Indian Creek at Centerline Road
ICMR	Indian Creek at Martin Road
ICTR	Indian Creek at Triana
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
OU	Operable Unit
PVC	polyvinyl chloride
ROF	Report of Findings
RSA	Redstone Arsenal
Shaw	Shaw Environmental, Inc.
TVA	Tennessee Valley Authority
USGS	U.S. Geological Survey
ICMR	Indian Creek at Martin Road
MSFC	Marshall Space Flight Center

1.0 Introduction

This report documents the work performed, presents the surface water monitoring data for the period 2000 to 2002, and provides summary description and analysis of the data. It is expected that the interpretation contained will further document the climatic and surface water hydrologic conditions under which other project work was completed.

The overall objectives of the sitewide surface water monitoring are to synthesize available and newly acquired data to develop a sitewide understanding of surface water flow and discharge. The surface water investigation included the following activities:

- Acquiring and integrating available surface water stage and discharge data
- Instrumenting and continuously monitoring select surface water features to evaluate the dynamics of the karst aquifer system and interactions with surface water bodies.

Gauged surface water flow data often provide considerable insight regarding the karst aquifer. Depending on the gauging network, it may be possible to determine the overall size of a karst watershed based upon hydrographs for the surface water bodies draining the area. Further, by comparing the discharge measured at upstream and downstream stations on a particular stream or series of tributaries, it may be possible to identify gaining and losing reaches of a stream. Many aquifers display seasonal patterns of flow that are linked to rainfall. Analysis of hydrographs developed from stage and discharge data reveal the base flow, storm response, and groundwater discharge (either directly or via discrete springs or spring systems) components of flow. Additionally, in settings such as Redstone Arsenal (RSA), where the bounding surface water bodies are impoundments subject to considerable stage variability due to reservoir operations, surface water may dramatically impact groundwater discharge and contaminant transport. For this reason, Shaw Environmental, Inc. (Shaw), formerly IT Corporation, has identified, acquired, and integrated all available surface water monitoring data on or adjacent to RSA as part of this investigation.

2.0 Summary of Work Performed

In the previous surface water monitoring program, there were ten active long-term surface water gauging stations at RSA. These were operated by three separate entities, the U.S. Geological Survey (USGS), Tennessee Valley Authority (TVA) (for the Olin Corporation), and Shaw. In

August 2000, as recommended in the Sitewide Karst Phase I Report of Findings (ROF) (Shaw, 2003), Shaw installed six additional surface water gauges throughout RSA, for a total of 16 gauges. In March 2002, TVA terminated monitoring the six TVA-Olin gauges; and in August 2002, Shaw took over monitoring five of the six gauges. Additionally, there are a number of other stations that are no longer in service. This includes low-flow measurement (i.e., providing synoptic "snapshots" of flow conditions on a sporadic basis) and other stations, such as the TVA and USGS gauges on Huntsville Spring Branch at Patton Road. The 2000-2002 surface water gauging network is shown on **Figure 2-1**. **Table 2-1** summarizes the available surface water monitoring data for RSA.

The USGS operates four gauges as follows: Indian Creek at I-565 (03575830); McDonald Creek at Patton Road (03575980); Huntsville Spring Branch at Johnson Road (03575950), which is located off site, immediately east of RSA; and Tennessee River at Whitesburg (03575500). All four provide hourly stage and discharge data. The latter three stations are real-time monitoring locations accessible via the Internet and also provide rainfall data. The USGS gauges provide upstream streamflow information for the three primary streams where they enter RSA and for the Tennessee River along the southern boundary of RSA. Digital data from October 1994 through December 2002 have been provided to Shaw in provisional form in response to periodic written requests. In addition, from 1943 through 1989, the USGS has recorded low-flow measurements taken at seven other locations along these water bodies. This unpublished data have been provided to Shaw in hardcopy form.

TVA maintained six gauging locations on behalf of the Olin Corporation from 1992 to March 2002. These six gauges include three gauges on lower Huntsville Spring Branch and three gauges on lower Indian Creek. The Huntsville Spring Branch gauges are located at mile 2.4 (Dodd Road bridge, station Huntsville Spring Branch at Dodd Road [HSDR]), at mile 4.85 adjacent to Operable Unit (OU)-6 in the dichlorodiphenyltrichloroethane (DDT) abatement area (station Huntsville Spring Branch at mile 4.85 [HSMN]), and at Huntsville Spring Branch at Martin Road (station HSMR). Indian Creek gauges are located at mile 4.6 (Centerline Road, station ICCR) below the confluence with Huntsville Spring Branch, at Martin Road (station ICMR), and at mile 0.36 at Triana (station ICTR). All of these provided continuous stage data on an hourly basis; stations ICMR and HSMR also recorded streamflow discharge information. An additional gauge was maintained on Huntsville Spring Branch at Patton Road, but monitoring was discontinued at this station when the Patton Road bridge was replaced in 1997. Through arrangements with Olin and TVA, Shaw received this data automatically on a monthly basis, typically within one month of downloading the gauges. Shaw has acquired data from January 1992 through April 2001 for use in this evaluation. Data from May 2001 through March 2002 (when TVA terminated monitoring) was reported in a different format, and the hourly continuous stage data were not available for our use. In August 2002 Shaw took over monitoring at five of the six former TVA-Olin gauges; monitoring at station ICTR was discontinued at this time. After Shaw took over monitoring at these gauges, all loggers were synchronized to collect data at even 30-minute increments instead of hourly.

A stage gauge was established by Shaw on the Tennessee River at river mile 321, off Shields Road, as part of the Phase I continuous water level monitoring scope. This gauge has been operational since July 1999 and records river stage and water temperature at 30-minute increments.

Based upon analysis of available data from the previous surface water monitoring network (1992 to 2000) presented in the Sitewide Karst Phase I ROF (Shaw, 2003) and the results of the base-wide spring identification and characterization tasks completed in Phase I, there were specific areas where either a) the surface water discharge data indicated losing or gaining reaches between the existing gauging locations or b) a large number of springs were identified along or draining to specific stream reaches. In most cases, the previous monitoring network was insufficient to quantify groundwater discharge or recharge components due to the distance between stations or due to the location of existing gauges relative to observed or suspected groundwater discharge zones. Specific data gaps in surface water monitoring were identified for each of the three major surface water features which drain RSA, Indian Creek, McDonald Creek, and Hunstville Spring Branch. To provide the necessary control to achieve the objectives stated above, six additional surface water gauging stations were recommended in the Karst Phase I ROF (Shaw, 2003), and in August 2000 Shaw added the following gauges to the monitoring network.

- McDonald Creek at Martin Road (P1)
- McDonald Creek at confluence with Huntsville Spring Branch (P2)
- Unnamed drain paralleling Patton Road, at Huntsville Spring Branch (P3)
- Culvert at OU-6 (Mother Lode) swamp (P4)
- National Aeronautics and Space Administration (NASA) spring channel near confluence with Indian Creek (P5)
- Huntsville Spring Branch at Patton Road (P7).

A seventh gauge (P6) was proposed for construction on an unnamed stream tributary to Indian Creek. However, further reconnaissance failed to identify a viable, discrete location to establish a gauging station. The six gauges installed provide continuous stage data at even 30-minute increments. Five of the six gauges were rated by TVA and provide streamflow discharge information as well as stage. TVA did not rate the gauge at OU-6 (Mother Lode) swamp (P4); however, the Manning equation was used to calculate a discharge rating table for this circular culvert. **Appendix A** contains rating tables for gauges P1 through P7 as well as the methodology and calculations used to develop a rating table for the circular culvert gauge (P4) using the Manning equation.

At each continuous surface water monitoring location, a gauge was constructed using an 8- to 10-foot section of 3-inch-diameter polyvinyl chloride (PVC) attached by an elbow connector to a 5-foot section of slotted PVC screen. A commercial staff gauge was connected to the vertical casing to allow manual measurements of stage over time. The gauge was braced with rebar stakes and driven rods to stabilize the station. The top of casing and "gauge zero" staff gauge reference elevations were surveyed to provide stage elevation data **(Table 2-2)**. **Figure 2-2** diagrams surface water gauge construction.

An In Situ Troll 8000 downhole probe was used to collect continuous head, temperature and specific conductance data at the five former TVA stations. At the Tennessee River a Troll 4000 probe was used (unlike the Troll 8000, these probes are only designed to record head and temperature). In each of these cases, existing continuous monitoring equipment was utilized. In-Situ miniTrolls (smaller in diameter than the 8000 and 4000 models and designed to record only head) were procured and deployed at each Shaw surface water gauge (P1 to P7), since only head readings were required. Head (and stage) data were collected to determine if rainfall or stage was an influence on water levels. All loggers were synchronized to collect data at 30-minute increments.

To ensure data security, all locations were downloaded in the field on a monthly basis. As part of each download event, manual staff gauge readings were recorded along with manual depth to water measurements from inside the PVC riser. The references were reset to match the measured water level elevation at the gauge, and the Troll internal clocks were re-synchronized at that time.

Monitoring continued through December 2002 at all of the locations. The data obtained via continuous monitoring were integrated with rainfall data. Local precipitation data were obtained from a number of sources and integrated monthly with the recorded stage and discharge data from each gauge. Daily total rainfall was obtained for the Huntsville Airport meteorological station via the Internet. These data proved most consistent and are shown on the hydrographs included in this report. The USGS maintains two continuous recording rain gauges linked to surface water gauging stations on Huntsville Spring Branch at Johnson Road and McDonald Creek at Patton Road. Data are recorded on an hourly basis and available in real-time mode via the Internet. Shaw obtained periodic distributions of this data in raw digital directly from the USGS. However, the records contained many gaps and periods with apparently erroneous data and were considered less reliable for use in this application. The Redstone Technical Testing Center maintains monthly total rainfall records. Data for the period of 1983-1999 were obtained but were not used in conjunction with the past continuous monitoring due to the long time interval involved (monthly).

Hourly discharge data at five of the Shaw surface water gauges and two of the former TVA gauges were determined by correlating recorded stage elevations with elevations corresponding to various discharge values from rating tables provided by TVA. TVA developed the rating tables based upon streamflow measurements obtained at each gauge over a period of one year. The Manning equation was used to calculate a discharge rating table for P4, the circular culvert at OU-6 (Mother Lode) swamp.

As part of the surface water monitoring program, Shaw acquired all available data from the USGS and TVA sources, which have been merged with climatic data and continuous surface water monitoring data acquired by Shaw, in order to evaluate the surface water hydrology and to identify gaining or losing reaches of streams to the extent possible. The data obtained in this effort are presented in Section 3.0 as a series of annual hydrographs and statistical histograms. These are used to highlight pertinent points about surface water hydrology at RSA.

3.0 Results

RSA is bounded on the south by the Tennessee River, the master drain within the Tennessee River Valley watershed. Three tributary streams to the Tennessee River transect RSA: Indian Creek, McDonald Creek, and Huntsville Spring Branch. A number of smaller tributaries and drains serve to convey runoff to the larger streams. As outlined in the report, surface water flow conditions at RSA are related to precipitation and river stage. River stage as controlled by TVA remained consistent (in terms of daily or seasonal patterns of stage fluctuation) over the three-year period in comparison to previous years. Annual total rainfall serves as a robust indicator of the prevailing hydrologic conditions. Monthly and annual rainfall from 1983 to 1999 are reported in the RSA karst report of findings. Extending this evaluation to include data through 2003, the 20-year average annual rainfall (1983 to 2003) is 51.88 inches ranging up to a maximum of 67.73 inches in 1989. Over the three-year monitoring period reported, the lowest total rainfall was reported in 2000 (37.17 inches), while the rainfall for 2001 through 2003 was 64.11, 50.68, and 54.50 inches per year, respectively. Consequently, the range of rainfall and thus surface water flow conditions observed reflects the full range of conditions (minimum, average, and near highest recorded rainfall) observed within the 20-year period.

Pertinent descriptive information and surface water monitoring results are provided below for each of the principal surface water bodies.

Indian Creek. Indian Creek originates in a headwater catchment area well upstream of RSA. The creek enters RSA in the northwest part of the site at an average stage elevation of 605 ft above mean sea level (amsl) and flows for nearly 11 miles in a southerly direction before reaching the Tennessee River. The creek channel consists of dense clay and alluvium; no exposures of bedrock have been observed in the creek bed. In the northern half of the site, above Martin Road, the creek is up to 20 ft wide and up to 6 ft deep, flowing due south. Below Martin Road, the relief diminishes greatly and the stream is impacted by backwater stage effects of the Tennessee River. Additionally, a number of large-volume springs discharge to Indian Creek in the low, swampy wetland areas below Martin Road. Stream profiles for lower Indian Creek show the channel to be mostly U-shaped and shallow, with the channel bottom occurring at elevations above 548 ft amsl.

As shown in **Figure 2-1** and summarized in **Table 2-1**, there are a total of five continuously recording gauging stations along Indian Creek. Stage is recorded at each of these at 30-minute increments; but, due to the backwater effects, discharge is available for only the three upper gauges: at the northern RSA boundary adjacent to I-565 (drainage area = 49 square miles), Martin Road (drainage area = 62.7 square miles), and NASA spring (P5), which contributes to the flow of Indian creek between these two gauging stations. Another gauge (P6) was proposed for construction on an unnamed stream tributary to Indian Creek. However, further reconnaissance failed to identify a viable, discrete location to establish a gauging station. The locations of this proposed gauge (P6) and NASA spring (P5) relative to Martin Road are shown in detail in **Figure 3-1**.

As shown in **Figure 3-2b**, the streamflow discharge from 2000 to 2002 within Indian Creek at I-565 (station 03575830) ranges from 0.54 to 5,885.14 cubic feet per second (cfs), with a median flow rate of 28.71 cfs. For reference, the stream rating completed in 1999 by the USGS extends from a low flow of 0.50 to 19,000 cfs **(Table 3-1)**. At the downstream gauge at Martin Road (station ICMR), the flow ranges from 3.3 to 3,205 cfs, with a median discharge rate of 24 cfs **(Figure 3-3b)**. This gauge was rated by TVA in 1991; as shown in **Table 3-1**, the limits of the rating extend from a minimum of 2.5 to 4,000 cfs. Consequently, comparisons between the flow observed at these two gauges is limited to the lesser rating range (0.5 to 4,000 cfs).

The observed flow range at ICMR for this reporting period is lower than what has been seen historically at this station. However, there was an extended period (May 2001 to August 2002) for which no data were available for this station, and it is likely that the data ranges would be similar if this data were available. Historically, TVA has reported a flow range from 4 to 4,410 cfs, with a median flow rate of 49 cfs.

It is expected that flow measured at the ICMR station should be greater than that measured at the upstream USGS station, since the drainage area of this downstream gauge is larger than that of Indian Creek at I-565 (station 03575830). Further, between the two gauges there are two major contributors to surface water flow. One of these latter sources of surface water flow is a large spring-fed swamp at the lower reach of the unnamed tributary to Indian Creek immediately northwest of NASA-MSFC. The discharge from this swamp was estimated to be on the order of 10 cfs during the dry season in July 1999. Additionally, at NASA spring (P5), located immediately upstream of Martin Road, discharge ranges from 3.18 to 10 cfs with a median discharge rate of 4.84 cfs **(Figure 3-4b)**. For reference, low-flow measurements performed in the 1970s by the USGS reported NASA spring discharge between 6 and 10 cfs. As shown in **Table 3-1**, the stream rating completed for the NASA spring gauge in 2002 spans a range of discharge from 2.05 to 10 cfs; the upper bound of the rating (10 cfs) represents the highest measurable flow before flooding and backflow conditions result in overflow of the spring channel. **Figures 3-2a** to **3-6a** are histograms that show the 2000 to 2002 mean annual discharge and stage elevations for all five gauges along Indian Creek. The histograms represent the frequency distribution at which the discharge and stage values occurred within the monitoring period. The discharge histogram is set up on a logarithmic scale to display the wide range of discharge values for three of the gauges along Indian Creek. **Appendix B** contains 2000 to 2002 mean monthly discharge and stage elevations for the five gauges along Indian Creek, as well as average monthly precipitation over the three-year period.

Figures 3-7, 3-8 and **3-9** are composite hydrographs for each water year from 2000 through 2002. On these hydrographs, stage elevation and discharge are shown in relation to precipitation and river stage. **Figure 3-10** is a detailed hydrograph showing stage and discharge fluctuations over a two-week period in November 2002. It shows that flow at NASA Spring (P5) increased concurrently with the upstream gauge Indian Creek at I-565 (station 03575830) and the downstream gauge on Martin Road (station ICMR). **Figure 3-11** is a hydrograph illustrating the differential discharge over time between the upstream gauges Indian Creek at I-565 (station 03575830) and NASA Spring (P5) and the lower gauge on Martin Road (station ICMR). The differential discharge was determined by subtracting the summed flow for the I-565 and NASA Spring gauges from the Martin Road discharge. A positive value was expected, reflecting increasing cumulative flow in a downstream direction. However, after viewing the hydrographs, and assuming the discharge at Martin Road includes the approximate 4 cfs flow from nearby NASA Spring, it appears there are significant losing reaches along Indian Creek, upstream of NASA Spring. The discrete locations of these losing reaches cannot be determined given the distance between the existing monitoring gauges.

McDonald Creek. McDonald Creek originates off site and encompasses a drainage area of nearly 8 square miles to the north of RSA before entering the site on the east side of Madkin Mountain in OU-1. It flows south to ultimately discharge into Huntsville Spring Branch. From pre-impoundment mapping (TVA, 1934) and historic aerial photos, this stream was considerably smaller in the past and followed a meandering course. The stream has been subsequently straightened and channelized, with the excavated streambed materials piled along the banks. McDonald Creek is now between 15 and 20 ft wide and typically less than 2 ft deep, although some deeper pools exist in places.

Currently, there are three continuously recording gauging stations on McDonald Creek, as shown in **Figure 2-1** and summarized in **Table 2-1**. The farthest upstream gauge is operated by the USGS, at the intersection with Patton Road (station 03575980); this gauge provides documentation of the streamflow component entering RSA from the northern boundary. The other two gauges (P1 and P2) are operated by Shaw and are located farther downstream to gauge the spring discharge contributions to flow from a number of large springs that have been identified. Both stage and discharge are recorded at each of the three gauges. **Figures 3-12a** to **3-14b** show the 2000 to 2002 mean annual discharge and stage elevations for all three gauges along McDonald Creek. The histograms represent the frequency distribution at which the discharge and stage values occurred within the monitoring period. The discharge histogram is set up on a logarithmic scale to display the wide range of discharge values present for the three gauges along McDonald Creek. As shown on **Figure 3-12b**, the streamflow discharge at the Patton Road gauge (station 03575980) ranges from 0.07 to 3,318 cfs, with a median flow of 1.06 cfs. Note that the maximum discharge of 3,318 cfs was recorded in April 2000, prior to the installation of the two downstream gauges at Martin Road (P1) and at the confluence with

Huntsville Spring Branch (P2). The stream rating for the USGS gauge was completed in 1999 and allows documentation of streamflow between 0.02 and 8,400 cfs **(Table 3-1)**.

From field observations, it was expected that the groundwater springs along McDonald Creek south of the Hansen Road bridge would constitute a considerable percentage of the streamflow from this point onward in the creek. From field reconnaissance in 1999 and 2000, the spring discharge from the Hansen Road Spring alone appeared to constitute at least half of the streamflow from that point onward. Low-flow measurements performed by the USGS in the 1970s documented an increase in discharge of between 6 and 10 cfs in the reach between Patton Road and Martin Road. The two gauges on McDonald Creek (P1 at Martin Road and, to a lesser extent, P2 at McDonald Creek at the confluence with Huntsville Spring Branch) were intended to document the groundwater flux component.

At the downstream gauge at Martin Road (P1), the flow during the monitoring period was observed to range from 4.2 to 122 cfs with a median discharge rate of 14.4 cfs **(Figure 3-13b)**. As shown in **Table 3-1**, this observed range mimics rating limits and highlights the limitations in the ability to document streamflow at this station or compare results to the upstream USGS gauge. Given the upper bound rating limit of 122 cfs at Martin Road (P1) and the maximum observed flow at the USGS gauge of 3,318 cfs, station P1 is not suitable for assessing stream discharge (or spring contributions to streamflow) when the flow exceeds 122 cfs.

Based upon the data collected to date, the flow at the P2 gauge ranges from 1.8 to 67 cfs, with a median discharge rate of 18.2 cfs **(Figure 3-14b)**. As shown in **Table 3-1**, the stream rating completed in 2002 allows documentation of flow ranging from 1.8 to 67 cfs, which also represents the range of observed flow. Clearly, the limitations of the rating restrict the ability to document flows outside this range and, more importantly, limit the ability to evaluate the results from the upstream gauges, since this is the smallest range of the three rated gauges. An upper bound flow rating of 67 cfs is too low, considering that maximum flow observed at the upstream gauges at Patton and Martin Road has been 3,318 and 122 cfs, respectively. The upper bound is due to the fact that under higher flows (in response to storms, for example) the flow in Huntsville Spring Branch swells and results in backwater conditions for a short distance upstream in McDonald Creek. **Appendix B** contains 2000 to 2002 mean monthly discharge and stage elevations for the three gauges along McDonald Creek, as well as average monthly precipitation over the three-year period.

During this recent monitoring period (2000-2002), measurements were recorded between Martin Road (P1) and the confluence with Huntsville Spring Branch (P2) to attempt to quantify potential gaining and losing reaches along this stream; a detailed map showing these gauges and Hansen Road Spring is presented in **Figure 3-15**. **Figures 3-16, 3-17,** and **3-18** are composite hydrographs for each water year from 2000 through 2002; stage elevation and discharge are shown in relation to precipitation and river stage. **Figure 3-19** is a hydrograph illustrating the differential discharge over time between upstream gauges on McDonald Creek, Patton Road gauge (station 03575980), Martin Road (P1), and the lower gauge at the confluence with Huntsville Spring Branch (P2). The differential discharge was determined by subtracting the summed flow for the Patton Road and Martin Road gauges from the confluence with Huntsville Spring Branch discharge. A positive value was expected, reflecting increasing cumulative flow in a downstream direction as the drainage area increases, but also due to contributions from Hansen Road spring and other springs along McDonald Creek. A net increase in median discharge of approximately 12 cfs occurs between the Patton Road (station 03575980) and Martin Road gauge (P1). This increase is interpreted as due to spring discharge contributions and direct seepage discharge of groundwater to surface water.

Comparing the median discharge from the P2 and P1 gauges, a net increase of 4 cfs is observed. It was expected that the difference would have been greater, to account for the 12 cfs increase observed between the Patton Road and P1 gauges plus additional flow due to the increased drainage area. Further, the reach of stream between P2 and P1 is bounded by swamps and wetlands, so that it was expected that a significant gaining reach would have been documented. However, the data suggest a losing reach on the order of 8 cfs based upon the median flow recorded. This analysis is constrained by the limits of the most conservative gauging station rating, which in this case is unfortunately the most downstream gauge at P2.

As noted on the hydrographs, a disturbing trend has been observed in the data recorded at the Martin Road gauge (P1). There is a constantly increasing "drift" of the baseline stage and discharge between storm events. The storm events still appear to reflect typical storm pulses and recessions, but the baseline hydrograph between these events continues to rise. No changes have been observed in the stations themselves, and the equipment (loggers, transducers) is functioning appropriately. This suggests a significant change in the channel character that is impacting the gauges. A number of downed trees have been observed along McDonald Creek between the upper gauge at Martin Road (P1) and the lower gauge at the confluence with Huntsville Spring Branch (P2). Large amounts of debris collect at these dammed areas along the creek, causing a visible head difference and elevated stage readings at the upper gauge at Martin Road (P1). These dammed areas tend to flatten the gradient in the vicinity of the P1 gauge, thus yielding false discharge data. The rating curve is not valid during these periods; therefore, the questionable stage and discharge data were eliminated from the histograms and differential discharge analysis. The rapid changes in the stream channel and flow regime render the previous stream rating invalid. Because this change occurred in less than a year's time since the gauge was installed and rated, this raises concerns about the validity of the rating performed on other older gauges, such as Indian Creek at Martin Road and Huntsville Spring Branch at Martin Road. These gauges were rated by TVA in 1991 and have not been revisited since then.

Huntsville Spring Branch. Huntsville Spring Branch originates as discharge from Big Spring in the center of Huntsville and flows in a south-southwesterly direction before discharging into lower Indian Creek at mile 4.7 on RSA. The drainage area for Huntsville Spring Branch encompasses 46.9 square miles, and this stream receives considerable runoff and other discharges from the industrialized and developed parts of southwest Huntsville before entering RSA on the east side at mile 9.75 near Martin Road. Huntsville Spring Branch has been channelized and in some places lined along the reach upstream of RSA. When flowing through RSA, the channel ranges up to 80 ft wide and is incised into dense mud and clay. Bedrock outcrops have been observed in the creek bed at Patton Road and just below the confluence with McDonald Creek. Stream profiles show the stream to be shallow, with the deepest point of the channel (elevation 550.8 ft amsl) occurring near the Dodd Road bridge. Similar to Indian Creek, backflow conditions prevail to just above Patton Road. It should be noted that the course of Huntsville Spring Branch between miles 2.4 and 4.85 had been diverted as part of the DDT abatement completed in the 1980s. Previously, Huntsville Spring Branch followed a northward meander loop along the north side of the DDT abatement dike and road.

As shown on **Figure 2-1** and summarized in **Table 2-1**, there are six active continuously recording surface water gauging stations along or draining into Huntsville Spring Branch on RSA. A seventh gauge, operated by the USGS as a real-time monitoring station, is located off site at the Johnson Road bridge. Due to the backflow on the lower reaches of the creek, discharge is available only at Martin Road (station HSMR), Patton Road (P7), and Johnson Road (03575950) stations along the Huntsville Spring Branch and at the two stations draining into the Huntsville Spring Branch (P3 and P4). The P3 gauging station is located along an unnamed drain paralleling Patton Road; this gauge monitors flow from all of OU-6 in central Redstone, including stream discharge along the stream itself. The P4 gauging station is located on a culvert at OU-6; it was intended to document flow from the drainage ditch between RSA-10 and RSA-55 as well as considerable spring discharge in Mother Lode swamp. **Figures 3-20** and **3-21** show a detailed view of the gauges along and discharging into the Huntsville Spring Branch. **Figures 3-22a** to **3-26a** show the 2000 to 2002 mean annual discharge and stage elevations for all five gauges along Huntsville Spring Branch. The histograms represent the frequency distribution at which the discharge and stage values occurred within the 2000 to 2002 monitoring period. The discharge histogram is set up on a logarithmic scale to display the wide range of discharge values present for three of the gauges along Huntsville Spring Branch.

As shown in **Figure 3-22b**, streamflow discharge along Huntsville Spring Branch at Johnson Road ranges from 263.5 to 9,738 cfs, with a median flow of 465 cfs. The stream rating completed by the USGS in 1999 can document flows ranging from 8 to 16,000 cfs **(Table 3-1)**. Streamflow discharge along Huntsville Spring Branch at Martin Road during the reporting period ranged from 9.3 to 4,661 cfs, with a median flow of 53.4 cfs **(Figure 3-23b)**. As shown in **Table 3-1**, this station was rated by TVA in 1991 and is capable of documenting streamflow from 9.3 to 8,000 cfs. Further downstream at Patton Road (P7), the flow recorded during the reporting period ranged from 20 to 905 cfs, with a median discharge rate of 156.9 cfs **(Figure 3-24b)**. As shown in **Table 3-1**, the stream rating for this station was completed in 2002 and contains rating limits of 20 and 905 cfs. This gauge is impacted by backflow conditions during high pool stage periods and peak storm events; flow reversals have been observed to extend a short distance upstream of the Patton Road bridge. Consequently, the differential discharge analysis and statistical histograms include only periods of normal downstreamflow; data impacted by backflow have been excluded from the analysis.

Figures 3-27a to **3-28b** show the 2000 to 2002 mean annual discharge and stage elevations for the two gauges established on surface water features draining into Huntsville Spring Branch. As shown in **Figure 3-27b** the streamflow discharge at the unnamed drain paralleling Patton Road (P3) ranges from 0.2 to 8.2 cfs, with a median discharge rate of 0.99 cfs. As shown in **Table 3-1**, the stream rating completed in 2002 contains rating limits of 0.2 and 8.2 cfs. The upper bound to the rating is limited by the channel geometry such that, above the equivalent stage elevation, the stream would overflow the banks. **Figure 3-28b** shows that flow at the culvert at OU-6 draining Mother Lode swamp ranges from 0.11 to 21.97 cfs, with a median flow of 6.31cfs. The calculated stream rating contains discharge limits of 0.0 and 21.97 cfs. **Appendix B** contains 2000 to 2002 mean monthly discharge and stage elevations for all gauges along Huntsville Spring Branch as well as average monthly precipitation over the three-year period. **Figures 3-29, 3-30,** and **3-31** are composite hydrographs for each water year from 2000 through 2002; stage elevation and discharge are shown relative to precipitation and river stage.

Previous low-flow discharge measurements performed by the USGS in Huntsville Spring Branch and McDonald Creek in the 1970s indicated that a major losing reach might exist along Huntsville Spring Branch between the confluence with McDonald Creek (P2) and the P7 gauge at Patton Road. This is an area where limestone bedrock is exposed in the stream bed as well as along the banks. Since this also represents the point where the Huntsville Spring Branch turns to flow westerly rather than due south to the river and the distance between the creek and the river is actually less than the distance the stream follows before intersecting Indian Creek and ultimately discharging to the river near Triana, it is possible that a hydraulic cutoff could exist. Under the right bounding stage conditions, it is possible that surface water flow could be lost to groundwater and more efficiently discharge to the river along southerly groundwater flow paths. Such conditions could occur when the hydraulic gradient from this point to the river is greater than the normal surface water gradient to the river, notably, when the stage at P7 exceeds that in the river near the Redstone park/boat ramp at mile 321.

In order to evaluate whether a losing reach exists upstream of gauge P7 at Patton Road, an attempt was made to measure the difference between the P7 gauge discharge and the summed discharge from McDonald Creek (measured at gauge P2) and Huntsville Spring Branch (measured at the Martin Road gauge, HSMR). While these represent the major sources of surface water flow, the total discharge at P7 also reflects inputs from Byrd Spring, the OU-10 swamps south of Huntsville Spring Branch, and the discharge from the OU-10 groundwater treatment plant effluent line. These latter sources of surface water flow are not gauged or, in some cases, amenable to gauging. The OU-10 groundwater treatment plant effluent (~ 0.7 cfs) is discharged directly to Huntsville Spring Branch at a point several hundred feet downstream of the confluence with McDonald Creek. Byrd Spring, located east of RSA, is a large spring emanating at the base of a bluff, which ultimately discharges into Huntsville Spring Branch downstream of Martin Road. Discharge from Byrd Spring was recorded by the USGS in the 1970s to range from 5.5 to 17.3 cfs (a median flow of 7.5 cfs was assumed in this report for the differential discharge calculations). Consequently, it is not possible to accurately document the discharge difference with full accuracy. This is further complicated by the fact that discharge at P7 is impacted by backflow conditions in Huntsville Spring Branch that persist during Tennessee River high pool stage conditions and following large storm events. Consequently, this assessment is only possible during low pool stage conditions between November and March each year.

Additionally, comparing the discharge measurements on Huntsville Spring Branch at the Martin Road gauge (HSMR) and the upstream USGS gauge at Johnson Road, the upstream gauge records significantly more flow than the Martin Road gauge. Using the Martin Road data, the downstream reach demonstrates both gaining and losing periods (i.e., gaining when the summed discharge is less than the P7 gauge and losing when the summed discharge exceeds the P7 gauge flow). Using the USGS gauging data, because the flow is nearly an order of magnitude greater than the Martin Road gauge flow, the reach is always losing. It is not clear which of these gauges is correct. In the case of the HSMR gauge, the rating was performed in 1991 and has not been updated since. Based upon the rapid degradation of the rating seen in the McDonald Creek gage at Martin Road, it is possible that this results in erroneous flow values (although it would be expected they would have increased). In the case of the USGS gauge, the rating was performed in 1999, but the reach between this gauge and the downstream Martin Road gauge is a lined channel with almost no tributaries entering in. Therefore, it is quite unexpected to see a difference in flow of the magnitude indicated by the data.

Figure 3-32 illustrates the differential discharge over time between the upper gauges along Huntsville Spring Branch (HSMR), McDonald Creek (P2) and spring discharge (Byrd Spring) with the downstream Patton Road gauge (P7). As shown in the hydrograph, discharge seems to increase at the Patton Road gauge (P7) in response to rain events. This increase in discharge may be due to an increase in spring flow from Byrd Spring or a number of springs in the northern part of OU-10, which flow into the Huntsville Spring Branch upstream from Patton Road. During dry periods, when spring flow is not a large contributor, losing reaches seem to be evident. This suggests possible flow along karst conduits to the river, possibly extending through OU-10.

Given the inherent sources of error discussed above, a simple assessment was performed to determine if there is any relationship between apparent gaining or losing periods (using the HSMR data) and river stage. A plot of the differential flow (P7 gauge minus all others) versus the difference in stage between the P7 gauge and the Tennessee River was constructed and is shown as **Figure 3-33**. It was expected that the reach of stream would be losing when the Huntsville Spring Branch stage exceeded the river stage and a higher hydraulic gradient existed to facilitate more efficient bypass of the normal streamflow route. Conversely, when the river stage is higher than the P7 stage height, the hydraulic gradient is reversed and no longer allows this hydraulic cutoff to function. In fact, it would appear from **Figure 3-33** that under these conditions normal groundwater discharge is also backed up, resulting in a gaining reach in this part of the stream. Although there is some question about exactly how much flow is either being lost or gained in this reach, the data allow for an order-of-magnitude estimate. It appears that, when the difference between the Huntsville Spring Branch and the river is greatest, the stream may be either losing on the order of 88 to 112 cfs or gaining as much as 288 to 312 cfs (assuming plus or minus 12 cfs reflecting variance expected for Byrd Spring and other ungauged inputs).

Tennessee River/Wheeler Reservoir. The reach of the Tennessee River adjacent to RSA is a run-of-the-river impoundment, part of Wheeler Reservoir. Stage and flow conditions within the river are controlled by reservoir operations at the TVA Guntersville and Wheeler dams, located 23 miles upstream and 46 miles downstream of RSA, respectively. Therefore, the construction of these two dams and the impoundment of the river have dramatically altered the geometry and flow conditions of the original Tennessee River and first order tributary streams to it, as well as impacting groundwater flow. As a result of the impoundment of the river, the stage has increased somewhere between 2 and 19 ft. The river width did not change appreciably over most of the reach adjacent to RSA although the stage level increased. However, the increase in stage dramatically impacted the profile of the lower reaches of the tributary channels and inundated large areas within the lower-relief parts of RSA. As the master drain, the river still represents the lowest possible head and serves as the regional base level for surface water and groundwater discharge on either side of the river.

The long-term median headwater stage at Wheeler dam is 553.78 ft amsl. The long-term median tailwater stage elevation at Guntersville is 557.33 ft amsl. Consequently, although the gradient along the river between the two structures is low (between 1 and 3.6 feet over a 74-mile distance), flow does exist in the vicinity of RSA. Stage heights in the river adjacent to RSA (measured at the Whitesburg Bridge from 1993 to 1999) range from a minimum of 550.15 ft to a maximum of 566.32 ft during flood stage. The median stage elevation in the river is 555.72 ft amsl. As shown on **Figure 3-34a**, during the 2000 to 2002 monitoring period the range of stage height at Whitesburg Bridge was a minimum of 550.08 ft to a maximum of 568.09 ft during flood stage. The median stage elevation was 555.32 ft amsl. At mile 321 stage height was recorded at a minimum of 550.61 ft to a maximum of 562.29 ft during flood stage. The median stage elevation was 554.93 ft amsl. It should be noted that, under the maximum flood stage, most of the southern half of RSA and much of OU-7, and OU-2 along McDonald Creek would be inundated. The 100-year flood elevation in this area is 570 ft amsl.

Discharge at Guntersville dam is typically cyclic, ranging up to 56,060 cfs, with a median flow of 47,960 cfs (Pinkston, 2000). Typically in December through early May, the discharge is continuous though variable. The remainder of the year, discharge is cyclic, with periods of ramped flow lasting from 4 to 24 hours and periods of no flow lasting up to 14 hours. At downstream Wheeler dam, discharge ranges up to a maximum of 126,426 cfs with a median flow of 50,625 cfs (Pinkston, 2000). The median discharge at Whitesburg from 1993 to 1999 was 48,510 cfs. As shown on **Figure 3-34b**, during the 2000 to 2002 monitoring period the range of discharge at Whitesburg Bridge was a minimum of 355.2 cfs to a maximum of 206,422.8 cfs, and the median discharge was 33,864.68 cfs. Discharge patterns are similar to Guntersville, except they are not always synchronous. This results from the compound operations at the two dams which create variable flow conditions in the river and the lower reaches of the principal tributary streams at RSA. There are periods of null flow in the river and short periods of backflow that amount to about 0.2 percent of the flow conditions on an annual basis. **Figure 3-35a** shows the 2000 to 2002 mean annual stage elevations for the Tennessee River at mile 321. The histogram represents the frequency distribution at which the stage values occurred during the monitoring period. **Appendix B** contains 2000 to 2002 mean monthly discharge and stage elevations for the two gauges along the Tennessee River as well as average monthly precipitation over the three-year period.

The river stage fluctuates both seasonally and daily in response to reservoir operations as well as in response to rainfall. **Figure 3-36** is a hydrograph showing stage elevation and discharge from 2000 to 2002 for the Tennessee River adjacent to RSA (Whitesburg) and the Tennessee River at mile 321. As can be seen, the stage follows a cyclic pattern that is a function of reservoir operations at the two dams. TVA maintains the reservoir at low pool stage during the rainy season from late December to early April as a flood control measure. Then, with late winter storms, the reservoir is allowed to fill and by end of April, the reservoir returns to full pool stage and is maintained at that level for power generation through much of the summer. In early to mid-August, TVA begins to draw the reservoir down, creating a transitional, declining stage condition that lasts until low pool stage conditions are once again attained in late December.

In addition to the seasonal fluctuations, the hydrograph also shows shorter term variability in river stage. These include daily and weekly cycles of stage fluctuation that can be directly attributed to daily reservoir operations at both the upstream and downstream dams. These fluctuations occur throughout the year but are most noticeable on hydrographs during high pool and transitional pool stage conditions.

On **Figures 3-29** to **3-31**, it can be seen that the stage effects in the Tennessee River extend upstream to impact the stage gauges along the lower reaches of Huntsville Spring Branch and Indian Creek. The stage effect extends to just upstream of the Patton Road bridge. There is an actual backflow of water that occurs in Huntsville Spring Branch associated with the stage changes. This backflow condition impacts the assessment of flow at the Patton Road gauge (P7) as gaining vs. losing reaches are calculated. Normal streamflow conditions prevail at the remainder of the gauges on the upper reaches of Indian Creek, McDonald Creek, and Huntsville Spring Branch. It appears that, as the river stage declines during the transition to low pool, the backflow effect is not seen as far upstream. At low pool stage, the backflow effect is not apparent at Patton Road or at the next downstream gauge at mile 4.85. Normal streamflow conditions extend farther downstream during this period.

Based on review of the available surface water data and as described above, there is some indication that a losings and/or gaining reaches may occur along the principal surface water features monitored. These areas are indicated on Figure 3-37, and summarized as follows:

- A losing reach indicated along Indian Creek upstream of the Martin Road gage (and NASA spring). Hydrographs indicate that summed flow from Indian Creek at I-565 and NASA spring exceed that recorded at the downstream gage on Indian Creek at Martin Road. The exact locations of loss along the upstream segment of Indian Creek is not known. Further, given the low gradient, bradied, meandering nature of Indian Creek in the northwest quadrant of the Arsenal, it is unlikely that additional gagging stations could be constructed in this area to constrain this further. Reconnaissance aimed at siting and constructing the proposed P-6 gage in this area were unsuccessful.

- A gaining reach is indicated along McDonald Creek upstream of Martin Road and downstream of Hansen Road. It is readily observable that the flow upstream of Hansen Road is increased dramatically downstream of the bridge where several large springs discharge to the creek. The springflow discharge is not gagged and, given the multiple discharge points and channels, would prove difficult to quantify. Additionally, gaining reaches are believed to occur downstream of the springs as a diffuse seepage; no discrete springs or seeps were confirmed in this reach. Unfortunately, stream rating limitations at the downstream gage at Martin Road (P1) do not allow for a full assessment of the overall contribution of the springs and seepage area to McDonald Creek flow. Available data indicates a 12 cfs increase in flow in the reach of McDonald Creek at Patton Road to the downstream gage at Martin Road. The gaining reach shown on Figure 3-37 is shown to extend from Hansen Road to Martin Road.

- A losing reach is indicated downstream of Martin Road along McDonald Creek, based upon gaged flow differences at the P1 and P2 stations. While the flow at P2 remained greater than at P1, considering the increased drainage area and that swamps border the creek along this reach, it was expected that the net flow would have been much higher. Consequently, a losing reach may exist somewhere along this stream segment.

- A significant losing reach is indicated along Huntsville Spring Branch in the reach downstream of the confluence with McDonald Creek and upstream of Patton Road. This is also a reach where bedrock is exposed in the stream channel. As described previously, the stream in this reach appears to be losing during periods when the creek stage elevation exceeds the river stage elevation and either gaining or static during other times (resulting in no net loss in flow at the Patton Road gage).

- A gaining reach is indicated along the unnamed tributary to Huntsville Spring Branch that flows parallel to Patton Road. Springs observed upstream of the P-3 gage and weathered limestone bedrock along much of the channel indicate gaining conditions may occur.

It should be noted that gaining and losing reaches cannot be identified on the basis of flow in those lower reaches of Huntsville Spring Branch (downstream of Patton Road, P-7) and Indian Creek (downstream of Martin Road, ICMR). Backflow conditions related to reservoir operations along the Tennessee River preclude establishing standard surface water flow gaging stations. In order to evaluate flow in the lower portions of these bodies, Doppler stations such as used by the USGS would be required, if at all feasible.

4.0 Recommendations

Previous sections have presented the 2000 to 2002 surface water monitoring data in graphical and summary descriptive form. This section provides recommendations for future surface water monitoring at RSA.

At the end of the 2000 to 2002 monitoring period, there were fifteen active surface water gauging stations on or adjacent to RSA that are operated and maintained by two separate entities, the U.S. Geological Survey and Shaw. In January 2003, monitoring at two of the Shaw gauges was discontinued due to location problems and inadequate findings. The gauge at NASA spring (P5) upstream from Martin Road on Indian Creek was discontinued in January 2003 due to continuous beaver dam problems in that area. Frequently, data recorded at this gauge were questionable due to the backed up conditions causing elevated stage and discharge readings; the data were corrected if possible. The gauge at the culvert draining Mother Lode swamp into the Huntsville Spring Branch (P4) was also discontinued in January 2003. This gauge had been operational since September 2000, with the intent to attempt a rough water balance summary of all flow discharge to Motherlode swamp as well as runoff. It was intended that flow from known surface water features, including the drainage ditch between RSA-10 and RSA-55, could be used in conjunction with the P4 flow data to arrive at this estimate. However, the RSA-10 ditch is not equipped to gauge flow and, further, the recent dye tracing has indicated springs on the downgradient side of the dike road reflect discharge of groundwater from sources north of Motherlode swamp. Clearly, underflow is present that cannot be gauged; therefore, the P4 gauge was taken out of service and there is no need to continue monitoring at this location.

Although approval was granted in early 2003 to continue monitoring all surface water locations, after reviewing this report of findings for the 2000 to 2002 monitoring period, several changes to the existing surface water monitoring program are recommended. In general, it is recommended that attempts to document streamflow in order to support water balance estimates be terminated. Specific recommendations for the remaining gauges are as follows:

Indian Creek at I-565 (03575830). Comparing discharge values from Indian Creek at I-565 (03575830) to the downstream gauge at Martin Road (ICMR), the data suggest extensive losing reaches along Indian Creek. While these losing reaches do exist, the many beaver dams along Indian Creek prevent us from monitoring other areas to determine discrete locations of the losing reaches. In addition, outdated stream ratings at either Indian Creek at I-565 (03575830) or Martin Road (ICMR) could also be contributing to the lower-than-expected discharge values downstream. Conversations with the USGS about discharge data collected at the I-565 location have indicated the possibility for error in the rating at this site, particularly at low flows. In the near future the USGS plans to terminate the discharge gauging operation at I-565. Therefore, at this time it is recommended that RSA continue to acquire the stage data from the USGS Indian Creek at I-565 station (03575830), since it is a free service and provides hydraulic boundary information for the northwest area of the Arsenal.

Indian Creek at Martin Road (ICMR). Since the stream rating at Martin Road was completed in 1991, the cross section of the channel has changed considerably; it is doubtful that the rating is still accurate. Since streamflow rating is relatively expensive, time consuming, and apparently subject to errors as the channel form changes over time, it is recommended that re-rating this station is not required or appropriate. At the Martin Road gauge (ICMR) on Indian Creek, it is recommended that continuous stage monitoring be continued, but only to acquire stage data that would prove useful to ongoing Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) projects in and around the NASA-MSFC facility. This information is useful for documenting the hydraulic boundary conditions along Indian Creek throughout the year and in response to rainfall events. The data document the conditions under which other site characterization data are acquired.

There is a significant "dent" in the stilling well established at this site. Rather than investing to correct this, it is recommended that this station be used "as is"; the data collected via the pressure transducers are unaffected by this physical defect.

Indian Creek at Centerline Road (ICCR). A review of the data collected from Indian Creek at Centerline Road (ICCR) shows little difference between ICCR and the Tennessee River. The ICCR gauge is always in the zone of backflow; knowing this and having twelve years of monitoring data at this location, it will save both time and money to discontinue monitoring this location.

McDonald Creek at Patton Road (03575980). Unlike the Indian Creek gauge at I-565, the USGS maintains confidence in the data recorded at McDonald Creek at Patton Road. The discharge data from this gauge are necessary to determine flow entering the Arsenal. This information is especially necessary during our surface water and sediment background study, which will run through February or March 2004. This gauge is one of three USGS gauges with real-time display via the Internet, and it is relied upon to coordinate and implement effective sampling at RSA. It is recommended that RSA continue to acquire this information from the USGS and integrate it with other surface water monitoring data acquired to document the conditions under which sampling is conducted.

McDonald Creek at Martin Road (P1). The Martin Road gauge (P1) has been proven to be problematic and to provide questionable data. Dammed areas caused by downed trees and debris along the creek and beaver dam activity in the swampy areas tend to flatten the gradient in the vicinity of the P1 gauge, thus yielding elevated stage and discharge data. Unless constant stream maintenance is performed along McDonald Creek to prevent damming, it is not beneficial to continue monitoring this gauge for flow or stage. It is recommended that monitoring of this station be terminated immediately and the electronic equipment deployed elsewhere as required.

McDonald Creek at Huntsville Spring Branch (P2). The lower gauge on McDonald Creek at the confluence with Huntsville Spring Branch (P2) will no longer be useful to determine the spring and swamp contributions downstream of Martin Road without the Martin Road gauge (P1) functioning. In addition, this gauge is only rated to document flow up to 67 cfs. This limit is easily exceeded since the upstream gauge recorded maximum flow at 3,318 cfs and the Martin Road gauge recorded maximum flow at 122 cfs. This low rating makes discharge readings at this station of little or no use; however, monitoring stage at this gauge should continue to support remedial investigation work being performed in the area. The stage data can be used to show the effects of flooding at OU-7 sites (frequency, highs, duration) and provide useful data for the nature and extent investigations at these sites.

Huntsville Spring Branch at Johnson Road (03575950). The Huntsville Spring Branch at Johnson Road gauge (03575950) is a real-time gauging station operated and maintained by the USGS. Data from this gauge can be used to monitor flow entering the Arsenal. However, as discussed previously, there appear to be some issues regarding the accuracy of the measured flow, since it remains significantly higher than the gauge at Martin Road. It is expected that the lower gauge on Martin Road (HSMR) would have a higher discharge than this upstream gauge at Johnson Road; however, the opposite is true.

The stage values collected at the gauge at Martin Road seem valid, so we suspect the existing stream rating is no longer valid. The rating at Martin Road was completed in 1991, so it is most likely outdated and discharge data invalid. As well, the discharge readings at Johnson Road seem too high compared to surrounding gauges; since the gauge was rated in 1998, the discharge values at this location may also be out of date. Few small tributaries enter the Huntsville Spring Branch between Johnson Road and Martin Road, so the discharge is expected to be similar at both gauges. It is recommended that stage and discharge continue to be integrated from the USGS gauge on Johnson Road until it is proven inaccurate. The USGS will be contacted to identify the potential problem with the discharge data observed.

Huntsville Spring Branch at Martin Road (HSMR). As discussed above, the rating for this station is out of date (1991) and it is likely incapable of providing accurate discharge measurement data. However, the stage data are still valid. If the discharge measurements at the USGS Johnson Road gauge are proven valid, there will be no need to maintain the gauge at Martin Road. We have no sites nearby and could rely on the USGS gauge for information. The determination of this is pending. Rather than expend funding to update the rating at this gauge, it is recommended that, in the interim, monitoring be continued but only to acquire stage data. This data can later be translated into discharge, should it be required. Further, this gauge is useful to document the extent of flooding and its impacts on the hydrologic system.

Huntsville Spring Branch at Patton Road (P7). The gauge at Patton Road (P7) provides good stage data, which are very useful in evaluating other data acquired at adjacent CERCLA sites. The gauge is impacted by backflow conditions during high pool stage periods (early April to mid August) and peak storm events, so it documents backflow limits and impacts of flood conditions. This gauge provides hydrologic boundary control for sites on either side of the creek. Discharge data at this gauge are of marginal value, since measurable and reliable flow conditions, free of backflow, occur only on average 180 days a year. Given the short window when flow is measurable, it is not possible to evaluate gaining or losing reaches throughout the water year. Given the issues at McDonald Creek at the confluence with Huntsville Spring Branch (P2), Huntsville Spring Branch at Martin Road (HSMR), and the lack of discharge data from Byrd Spring and other springs at OU-10, it is recommended that stage only be monitored at the Patton Road (P7) location.

Unnamed Tributary to Huntsville Spring Branch (P3). The P3 gauging station is located downstream along an unnamed drain parallel to Patton Road. This gauge monitors flow from all of OU-6 in central Redstone. The gauge is most useful to measure contaminant flux coming out of OU-6B and the sites above this operable unit. Given the proposed CERCLA characterization activities within OU-6B, and specifically along this drainage, continued documentation of discharge and stage is warranted. This gauge collects useful data, since it is not impacted by backflow on the Huntsville Spring Branch and, although it does not fully capture discharge to the Huntsville Spring Branch because of contributing downstream springs, it is necessary to continue monitoring to measure contaminant fluctuations.

Huntsville Spring Branch downstream of Patton Road (HSMN, HSDR). Due to the backflow on the lower reaches of the Huntsville Spring Branch, discharge monitoring is not possible at the HSMN and HSDR gauges. However, stage data collected at both gauges are very important, since the data document boundary conditions between the hydrologic regime to the north and the Tennessee River. For this reason, it is recommended that monitoring stage at both locations continue.

Tennessee River at Mile 321. Continued monitoring at the Tennessee River gauges is crucial for many reasons. The gauge at mile 321 is the perhaps the most important gauge used to document hydrologic boundary conditions that impact all groundwater and surface water regimes at RSA and is applicable to all CERCLA investigations conducted at RSA. It is recommended that stage monitoring continue at this station. Due to flooding of the Tennessee River, this gauge has been under water several times and the equipment has been damaged. In the future, it will be necessary to relocate this gauge nearby to a higher elevation where the equipment will be protected from flood damage.

Tennessee River at Whitesburg. The USGS gauge at the Whitesburg bridge, immediately upstream of the RSA boundary, is our only measurement of discharge on the Tennessee River. Considering that the bulk of the surface water features at RSA ultimately discharge via Indian Creek downstream of the RSA boundary, this is the best (and only) source of flow in the river adjacent to RSA. In addition, the Tennessee River gauge at Whitesburg is a real-time station, so it is used often to plan sampling events at the Arsenal. Presently there is a discrepancy in elevation between the gauge at mile 321 and the Whitesburg gauge. We are assuming our gauge at mile 321 is correct, since we recently had it resurveyed and the new elevation was very similar to the original survey; therefore, the USGS gauge at Whitesburg elevation is a half-foot too low.

The recommendations can be summarized as follows:

- All monitoring to be discontinued at P1 and ICCR stations. Monitoring already terminated at NASA spring (P5) and P4 gauges.

- Continued monitoring at the following gauges maintained by Shaw: ICMR, P2, P7, P3, HSMN, HSDR, and the Tennessee River, but for stage only (no discharge).
- Continued monitoring at the HSMR gauge until such time as the discharge questions regarding the USGS Johnson Road gauge are answered (stage only).
- Continued acquisition and integration of data available for the four USGS gauges on Indian Creek, McDonald Creek, Huntsville Branch, and the Tennessee River. The discharge data for the Indian Creek station will soon be no longer available from the USGS due to issues with the present rating data.

The recommended surface water monitoring network serves to document hydrologic conditions under which current and proposed site characterizations and sampling are conducted. The recommended network is shown on **Figure 4-1**. To minimize cost, all surface water locations will be downloaded in the field once every two months. The data obtained will continue to be integrated with USGS stage and discharge data as well as daily rainfall data.

In addition to the recommendations above, there is a definite need to establish a continuous recording rain gauge capable of recording rainfall events to a resolution of 0.01 inches of rain at 30-minute increments at RSA. Currently, rainfall data are principally available from two sources: the Huntsville airport station, and the USGS. The Huntsville airport station provides only daily total rainfall. The USGS records rainfall data on an hourly basis at two surface water gauging stations, McDonald Creek at Patton Road (station 03575980) and Huntsville Spring Branch at Johnson Road (station 03575950). Unfortunately, these USGS stations have not proven to be a reliable source. Setting up and monitoring a rain gauge on RSA would provide valuable data to incorporate into our long-term surface water record.

5.0 References

Shaw Environmental, Inc. (Shaw), 2003, ***Sitewide Karst Hydrogeologic Investigation, Phase I Report of Findings, Draft Final, Volume I and II, Redstone Arsenal, Madison County, Alabama***, May.

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United States Geological Survey (USGS), 1999, Rating Tables for Monitoring Stations on or near Redstone Arsenal.

Pinkston, J., 2000, Personal communication from Janice Pinkston, Tennessee Valley Authority to T. F. Zondlo, Shaw, E-Mail transmission of Digital Headwater and Tailwater Stage and Discharge Data for Wheeler and Guntersville Dams.

TABLES

Table 2-1

Summary of Available Surface Water Stage and Discharge Data
Redstone Arsenal, Madison County, Alabama

Station ID	Location Description	Source	DA (sq mi)	Data Type	Record in hand	Period of Record	Format	Rating Curve
03575500	Tenn R. @ Whitesburg	USGS	25,610	real time, continuous (HR) stage, Q, precip	10/01/94 - 9/30/97 1/01/00 - present	10/94 - 9/97 (discontinued 1997), 1/99 - present	digital	Yes
03575830	Indian Ck. @ Interstate 565	USGS	49	continuous (HR) stage, Q	10/01/94 - 1/31/03	10/59 - 9/66, 10/66 - 9/72 (peak Q only); 10/72 - 9/75 flood stage only); 10/75 - present (Q + stage)	digital	Yes
03575849	Indian Ck 400 ft US of Martin Rd	USGS	62.5	low flow measurement station	10/23/69, 10/21/70, 10/13/71, 10/25/71, 10/31/71, 4/19/72, 9/27/73, 11/5/79, 5/6/80, 11/13/80, 5/5/81, 4/21/82, 11/2/82	same	hard copy	
03575850	Indian Ck @ Martin Rd	USGS	62.7	low flow measurement station	12/6/43, 11/17/52, 11/10/53, 9/10/54, 10/23/69, 10/21/70, 12/11/70, 8/27/71, 9/17/71, 10/13/71, 9/18/73. 9/27/73	same	hard copy	Yes
03575950	HSB @ Johnson Rd	USGS	41.8	real time, continuous (HR) stage, Q, precip	10/01/94 - 1/31/03	1/67 - 9/68 (TVA); 3/71 - 9/74 (stage only); 9/84 to present	digital	Yes
03575960	HSB @ Martin Rd	USGS	46.9	low flow measurement station	6/5/48, 6/7/48, 10/22/70, 6/9/71, 9/18/71, 10/14/71, 2/2/72, 3/16/72, 4/14/72, 5/25/72, 6/22/72, 7/27/72, 8/9/72, 9/28/72, 11/2/72, 9/27/73, 5/20/73, 7/1/75, 9/11/75, 12/3/75, 11/16/76, 9/19/78, 8/31/83	same	hard copy	
03575970	HSB @ Byrd Spring	USGS	5.6	low flow measurement station	10/23/70, 10/14/71, 4/19/72	same	hard copy	
03575980	McDonald Ck @ Patton Rd	USGS	8.93	low flow measurement station	10/24/69, 10/21/70, 10/14/71, 4/20/72, 9/18/73, 10/22/84, 7/22/86, 12/9/86, 6/22/89	same	hard copy	
				real time, continuous (HR) stage, Q, precip	10/01/94 - 1/31/03	ongoing	digital	Yes
03575994	McDonald Ck @ Martin Rd	USGS	14.5	low flow measurement station	10/22/70, 10/14/71, 4/20/72, 9/18/73, 11/7/74, 7/22/86	same	hard copy	
03576000	HSB @ Patton Rd	USGS	72.9	sporadic data	10/22/70, 12/11/70, 6/11/71, 9/18/71, 10/14/71, 4/20/72, 9/18/73	same	hard copy	
03576020	HSB @ Dodd Rd (Mile 2.4)	USGS	83.9	low flow measurement station	10/22/70, 10/14/71, 9/23/73	same	hard copy	
ICTR	Indian Ck @ Mile 0.38	TVA-OLIN		continuous (HR) stage	1/01/92 - 4/30/01	same	digital	
ICCR	Indian Ck @ Mile 4.6	TVA-OLIN		continuous (HR) stage	1/01/92 - 4/30/01, 8/1/02 - present	same, ongoing	digital	

Table 2-1

Summary of Available Surface Water Stage and Discharge Data
Redstone Arsenal, Madison County, Alabama

Station ID	Location Description	Source	DA (sq mi)	Data Type	Record in hand	Period of Record	Format	Rating Curve
ICMR	Indian Ck @ Mile 8.2 (Martin Rd)	TVA-OLIN	62.7	continuous (HR) stage, Q	1/01/92 - 4/30/01, 8/1/02 - present	same, ongoing	digital	Yes
HSDR	HSB @ Mile 2.4 (Dodd Rd)	TVA-OLIN	83.9	continuous (HR) stage	1/01/92 - 4/30/01, 8/1/02 - present	same, ongoing	digital	
HSMN	HSB @ Mile 4.85 (RSA-60)	TVA-OLIN		continuous (HR) stage	1/01/92 - 4/30/01, 8/20/02 - present	same, ongoing	digital	
HSPR	HSB @ Mile 5.9 (Patton Rd)	TVA-OLIN	72.9	continuous (HR) stage	1/01/92 - 4/17/99	same	digital	
HSMR	HSB @ Mile 9.75 (Martin Rd)	TVA-OLIN	46.9	continuous (HR) stage, Q	1/01/92 - 4/30/01, 8/20/02 - present	same, ongoing	digital	Yes
Guntersville	Guntersville Dam	TVA		hourly discharge, HW/TW stage	1/01/92 - 9/01/99	ongoing	digital	
Wheeler	Wheeler Dam	TVA		hourly discharge, HW/TW stage	1/01/92 - 9/01/99	ongoing	digital	
TennR	Tenn R. @ Mile 321	Shaw E&I		continuous (30 min) stage	7/99 - present	same, ongoing	digital	
P1	McDonald Creek @ Martin Road	Shaw E&I		continuous (30 min) stage	8/00 - present	same, ongoing	digital	Yes
P2	McDonald Creek @ HSB	Shaw E&I		continuous (30 min) stage	8/00 - present	same, ongoing	digital	Yes
P3	West of Patton Road Creek	Shaw E&I		continuous (30 min) stage	8/00 - present	same, ongoing	digital	Yes
P4	Culvert @ DDT abatement area	Shaw E&I		continuous (30 min) stage	8/00 - 1/29/03	same	digital	
P5	Nasa Spring	Shaw E&I		continuous (30 min) stage	8/00 - 1/29/03	same	digital	Yes
P7	HSB @ Patton Road	Shaw E&I		continuous (30 min) stage	8/00 - present	same, ongoing	digital	Yes

Table 2-2

Surface Water Gauge Survey Summary
Redstone Arsenal, Madison County, Alabama

STATION	COMPANY	LOCATION	EASTING	NORTHING	STATUS	GAUGE TYPE	TOC ELEVATION	GAUGE ZERO ELEVATION	COMMENTS
P1	Shaw	McDonald Ck @ Martin Rd	421764.27	1511886.21	Active	Continuous	568.94	558.89	
P2	Shaw	McDonald Ck @ confluence w/ HSB	421469.91	1507120.20	Active	Continuous	565.17	557.48	
P3	Shaw	Unnamed drain paralleling Patton R	416395.65	1503944.87	Active	Continuous	565.35	559.29	*TVA survey shows gauge 1.5ft lower in elevation
P4	Shaw	OU-6 (Mother Lode) swamp drain	409625.01	1498978.25	Active	Continuous	564.97	554.85	
P5	Shaw	NASA Spring channel	399721.20	1509850.83	Active	Continuous	568.26	559.61	*TVA survey shows gauge 2.4 ft higher in elevation
P7	Shaw	HSB @ Patton Rd	416657.77	1501911.76	Active	Continuous	564.71	553.46	
TennR	Shaw	Tennessee River @ Mile 321	399347.15	1488390.01	Active	Continuous	559.99	551.35	
03575830	USGS	Indian Creek @ I-565	395787.00	1528167.00	Active	Continuous	-	601.32	
03575950	USGS	Huntsville Spr Br @ Johnson Rd	426781.00	1525314.00	Active	Continuous, real time	-	565.34	
03575980	USGS	McDonald Creek @ Patton Rd	417368.00	1526239.00	Active	Continuous, real time	-	579.34	
3575500	USGS	Tennessee River @ Whitesburg	437996.00	1482162.47	Active	Continuous, real time	-	549.00	
HSDR	TVA-Olin	Huntsville Spr Br @ Dodd Rd	405894.49	1499644.05	Active	Continuous	574.47	-	
HSMN	TVA-Olin	Huntsville Spr Br @ Mile 4.85	413823.79	1498684.06	Active	Continuous	565.30	-	
HSMR	TVA-Olin	Huntsville Spr Br @ Martin Rd	424301.05	1514014.92	Active	Continuous	578.17	-	
ICCR	TVA-Olin	Indian Creek @ Mile 4.6	395867.39	1498398.16	Active	Continuous	571.34	-	
ICMR	TVA-Olin	Indian Creek @ Martin Rd	400385.26	1509447.00	Active	Continuous	571.12	-	
ICTR	TVA-Olin	Indian Creek @ Triana	386170.75	1486401.35	Inactive	Continuous	-	-	

Table 3-1

Redstone Arsenal Surface Water Gauge Rating Limits
Redstone Arsenal, Madison County, Alabama

Surface Water Gauge	Mean Annual Minimum (2000-2002)	Mean Annual Maximum (2000-2002)	Minimum Discharge Rating Limit	Maximum Discharge Rating Limit	Minimum Stage Rating Limit	Maximum Stage Rating Limit
Indian Creek at I-565 (USGS 03575830)	0.54	5885.14	0.50	19000	601.37	614.62
Nasa Spring (P5)	3.18	10 *	2.05	10 *	560.21	560.76
Indian Creek at Martin Road (ICMR)	3.30	3205	2.50	4000	557.90	565.40
McDonald Creek at Patton Road (USGS 03575980)	0.07	3318	0.02	8400	579.84	591.34
McDonald Creek at Martin Road (P1)	4.2 *	122 *	4.2 *	122 *	560.89	563.89
McDonald Creek at confluence with HSB (P2)	1.8 *	67 *	1.8 *	67 *	558.18	560.28
HSB at Johnson Road (USGS 03575950)	263.50	9738	8	16000	568.94	581.34
HSB at Martin Road (HSMR)	9.3 *	4661	9.3 *	8000	558.80	573.00
HSB at Patton Road (P7)	20 *	905 *	20 *	905 *	554.77	559.46
Drain parallel to HSB (P3)	0.2 *	8.2 *	0.2 *	8.2 *	559.79	560.49
Motherlode Swamp draining to HSB (P4)	0.11	21.97 *	0.00	21.97 *	554.85	558.23
Tennessee River at Whitesburg (USGS 03575500)	355.20	206422.80	Not Available			

* Minimum or Maximum recorded value over the three year monitoring period cutoff at rating limit

FIGURES

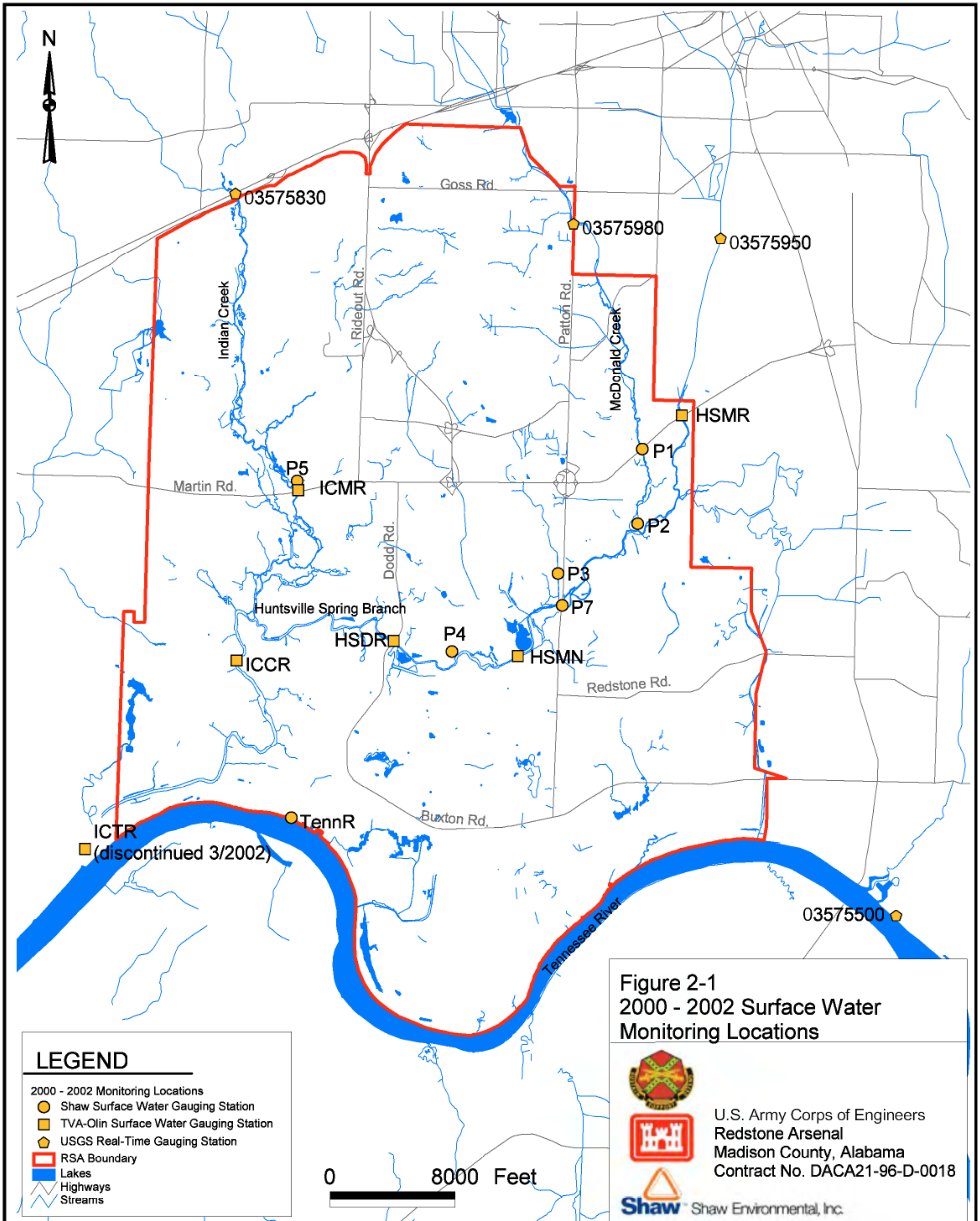

Figure 2-1
2000 - 2002 Surface Water Monitoring Locations

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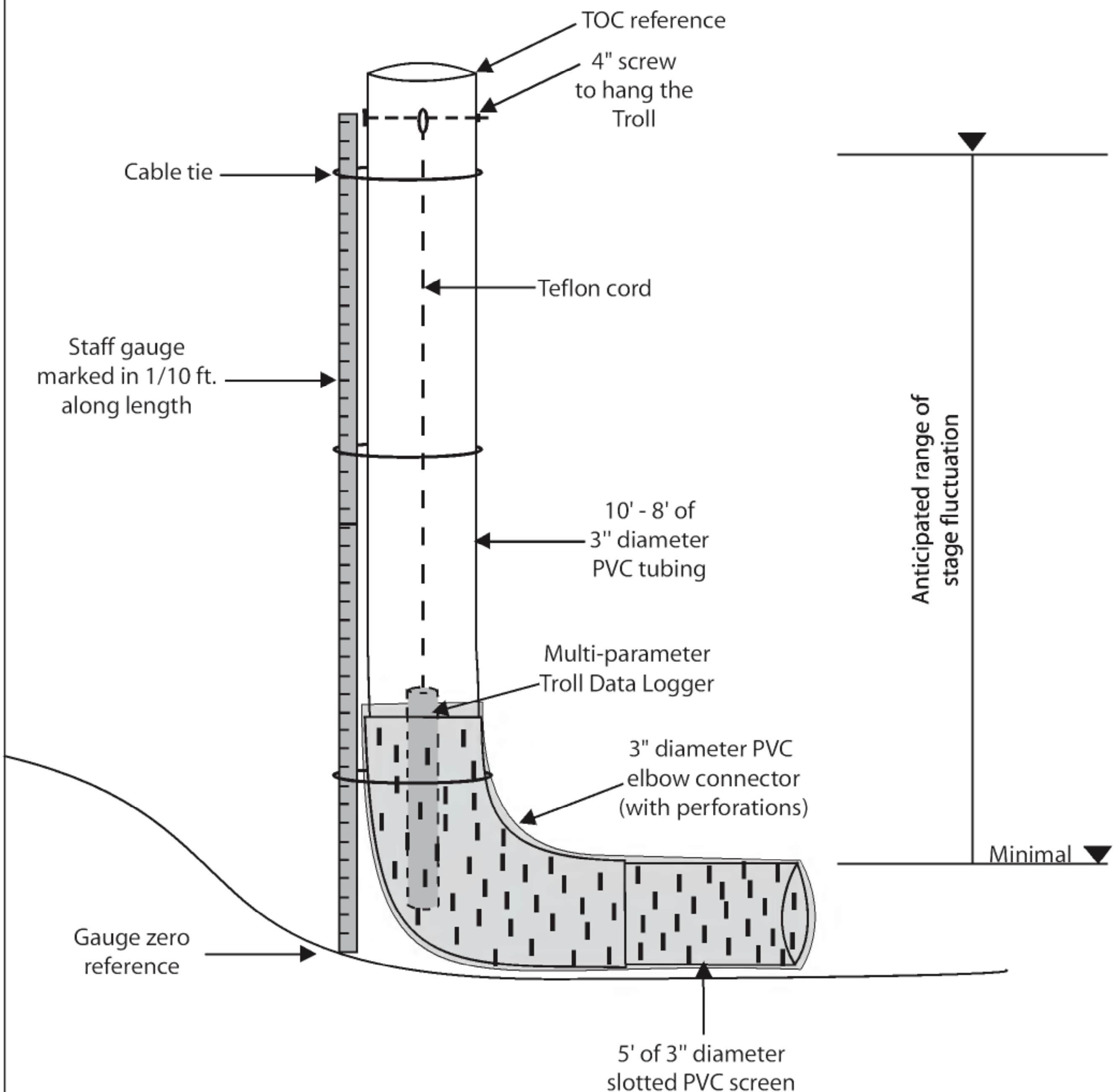

Figure 2-2
Surface Water Gauge Construction Diagram

U.S. Army Corps of Engineers
Redstone Arsenal
Madison County, Alabama
Contract No. DACA21-96-D-0018

Shaw Environmental, Inc.

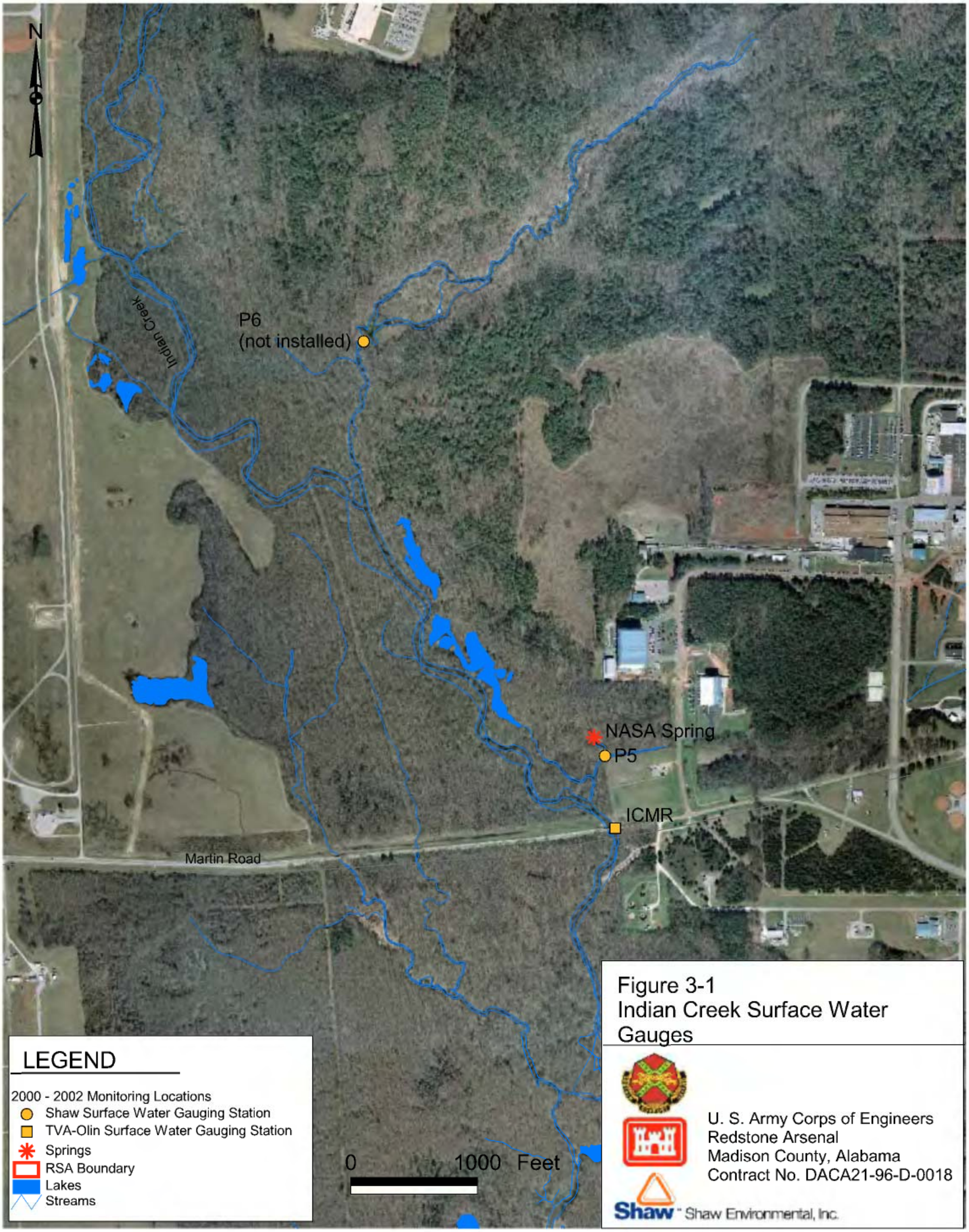

Figure 3-1
Indian Creek Surface Water Gauges

U. S. Army Corps of Engineers
Redstone Arsenal
Madison County, Alabama
Contract No. DACA21-96-D-0018

Shaw Environmental, Inc.

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Figure 3-2a Indian Creek at I-565 (USGS 03575830) Mean Annual Stage 2000 - 2002

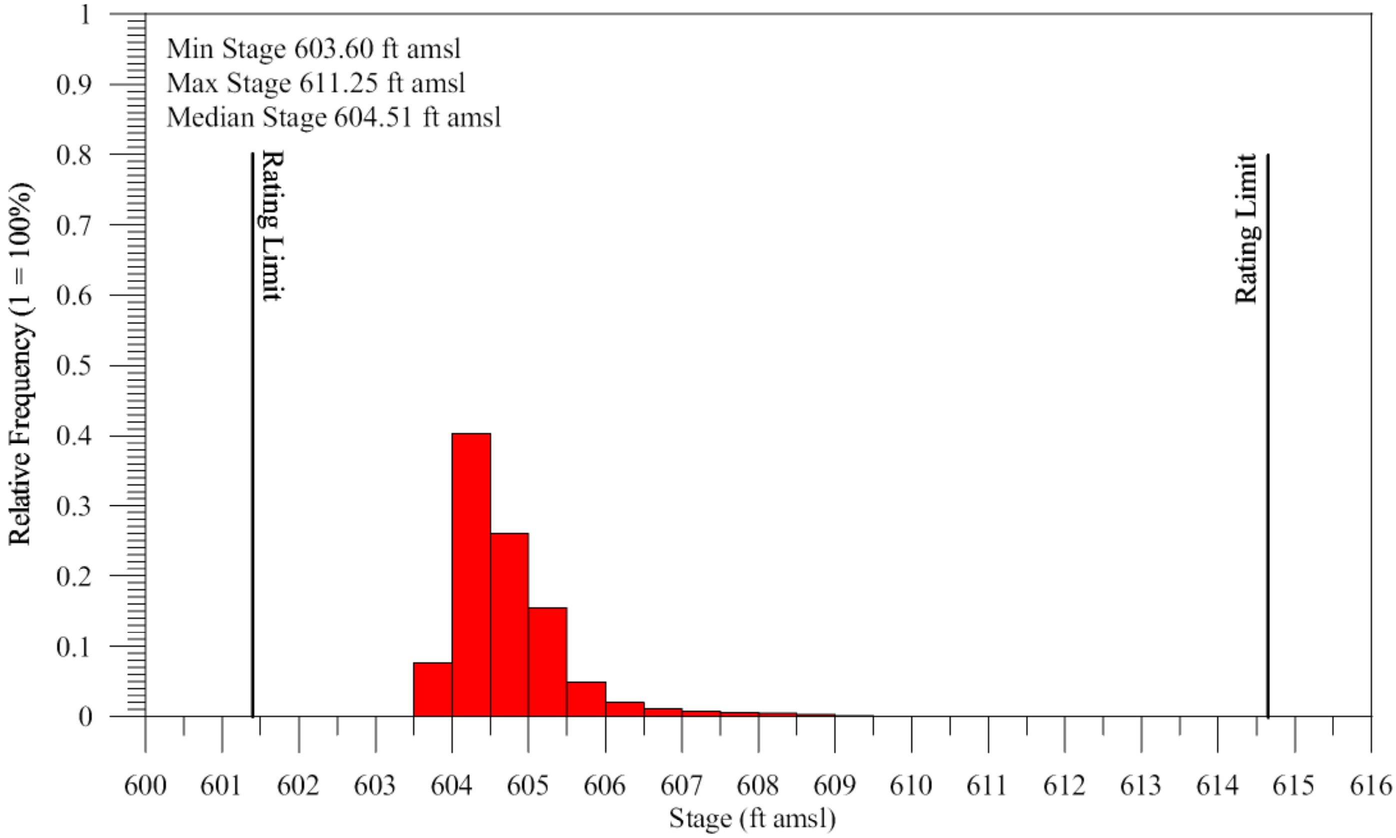
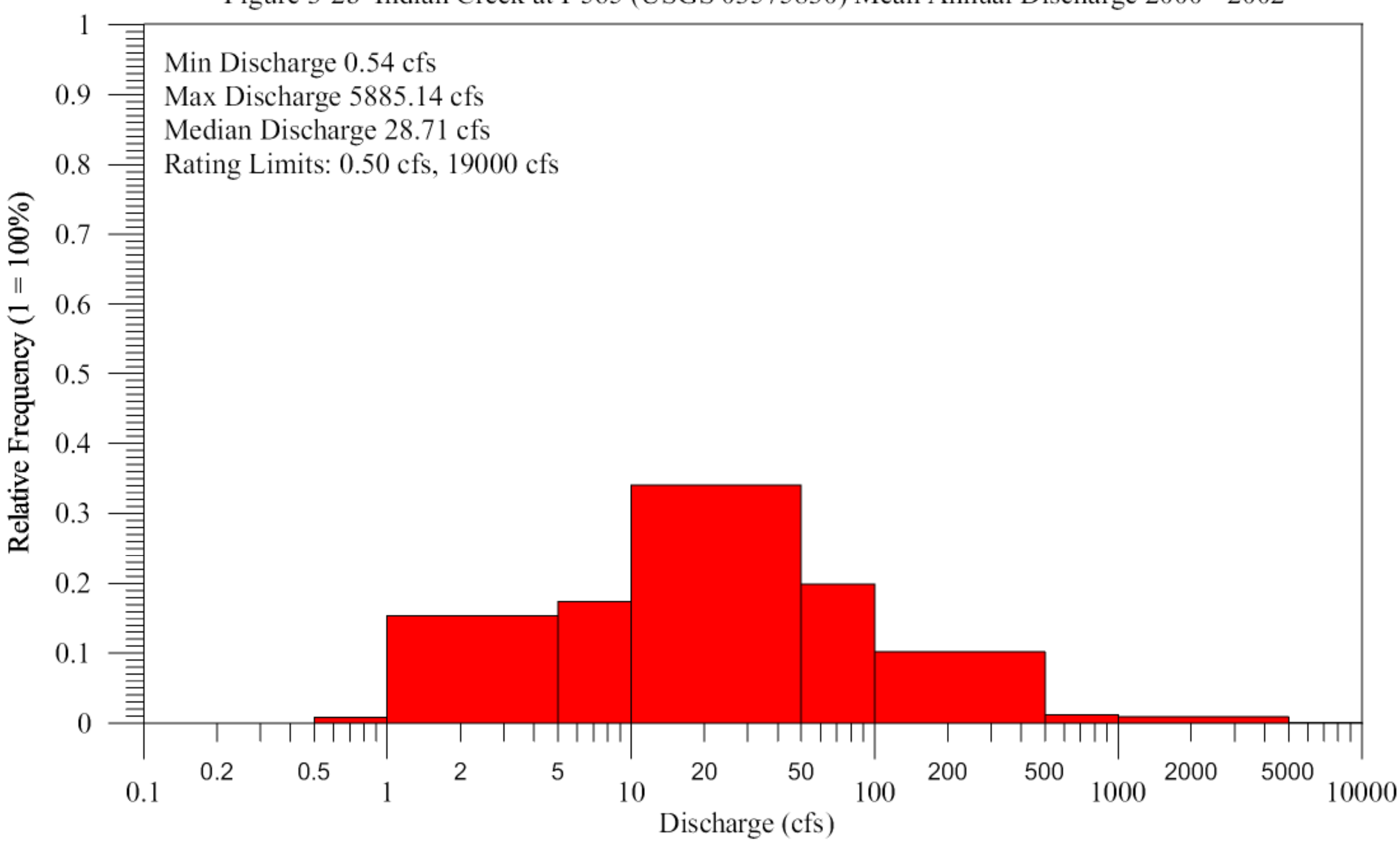


Figure 3-2b Indian Creek at I-565 (USGS 03575830) Mean Annual Discharge 2000 - 2002



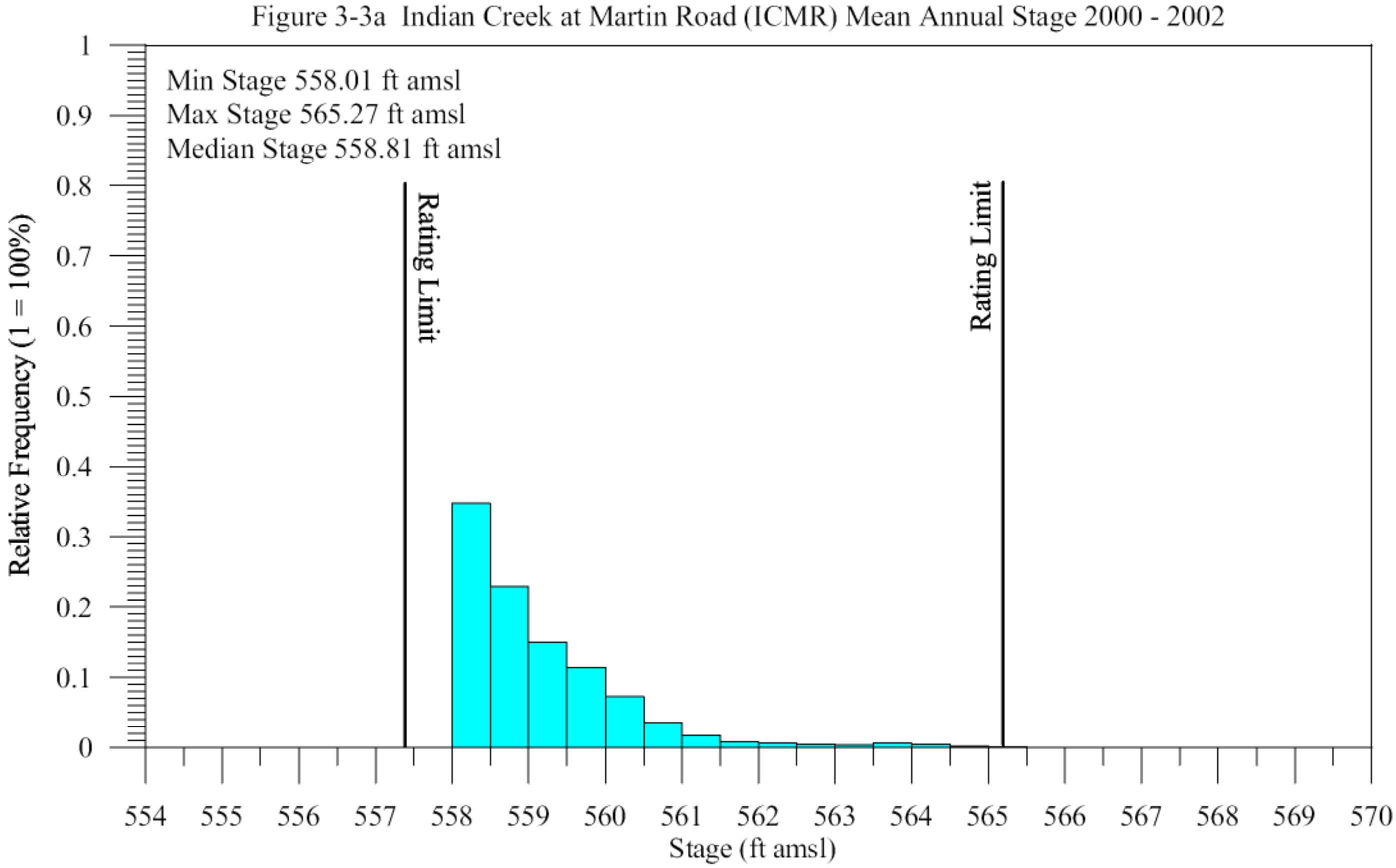


Figure 3-3a Indian Creek at Martin Road (ICMR) Mean Annual Stage 2000 - 2002
Min Stage 558.01 ft amsl
Max Stage 565.27 ft amsl
Median Stage 558.81 ft amsl
Rating Limit
Rating Limit
Relative Frequency (1 = 100%)
Stage (ft amsl)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570

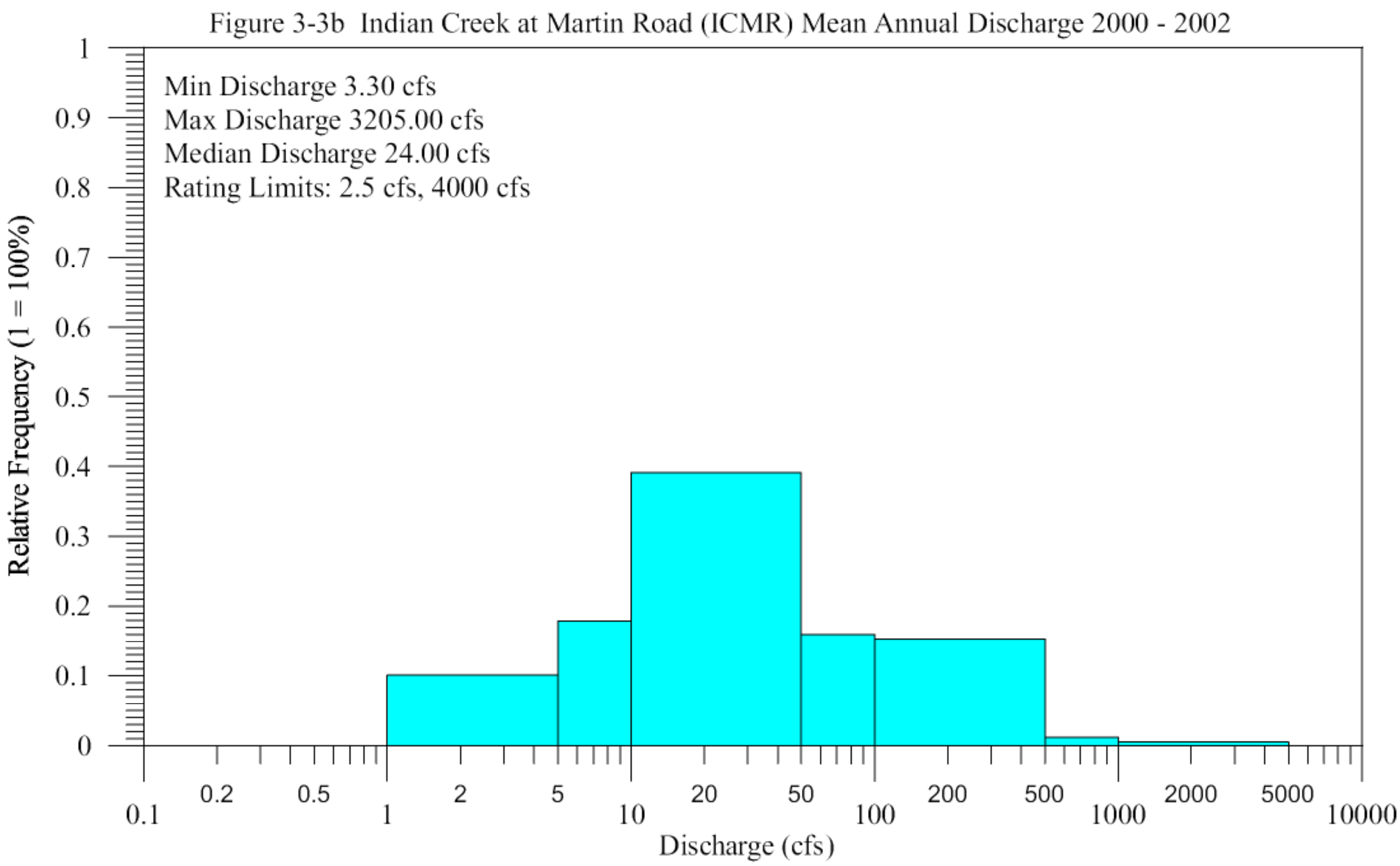


Figure 3-3b Indian Creek at Martin Road (ICMR) Mean Annual Discharge 2000 - 2002
Min Discharge 3.30 cfs
Max Discharge 3205.00 cfs
Median Discharge 24.00 cfs
Rating Limits: 2.5 cfs, 4000 cfs
Relative Frequency (1 = 100%)
Discharge (cfs)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.1
0.2
0.5
1
2
5
10
20
50
100
200
500
1000
2000
5000
10000

Figure 3-4a Indian Creek Nasa Spring (P5) Mean Annual Stage 2000 - 2002

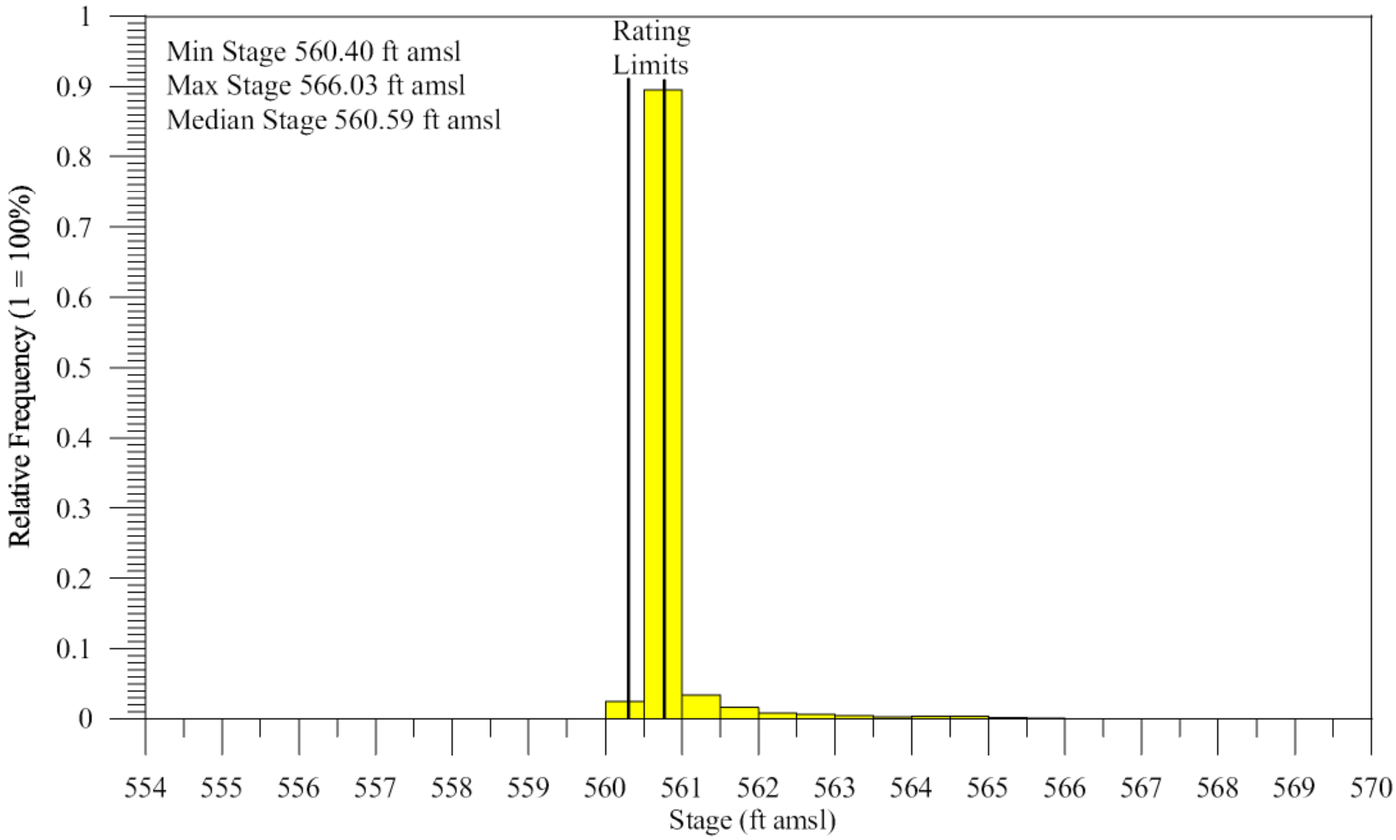


Figure 3-4b Indian Creek Nasa Spring (P5) Mean Annual Discharge 2000 - 2002

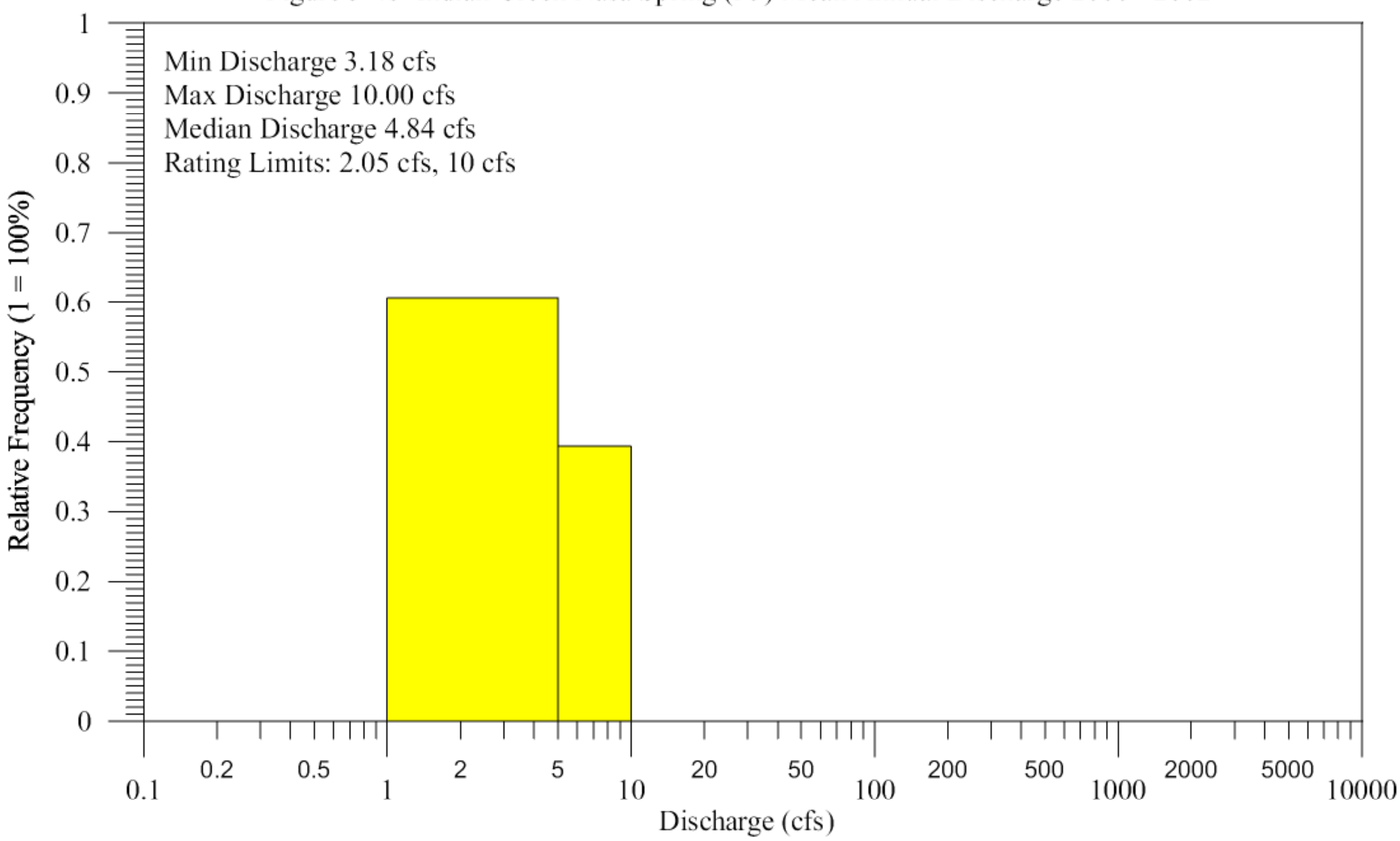
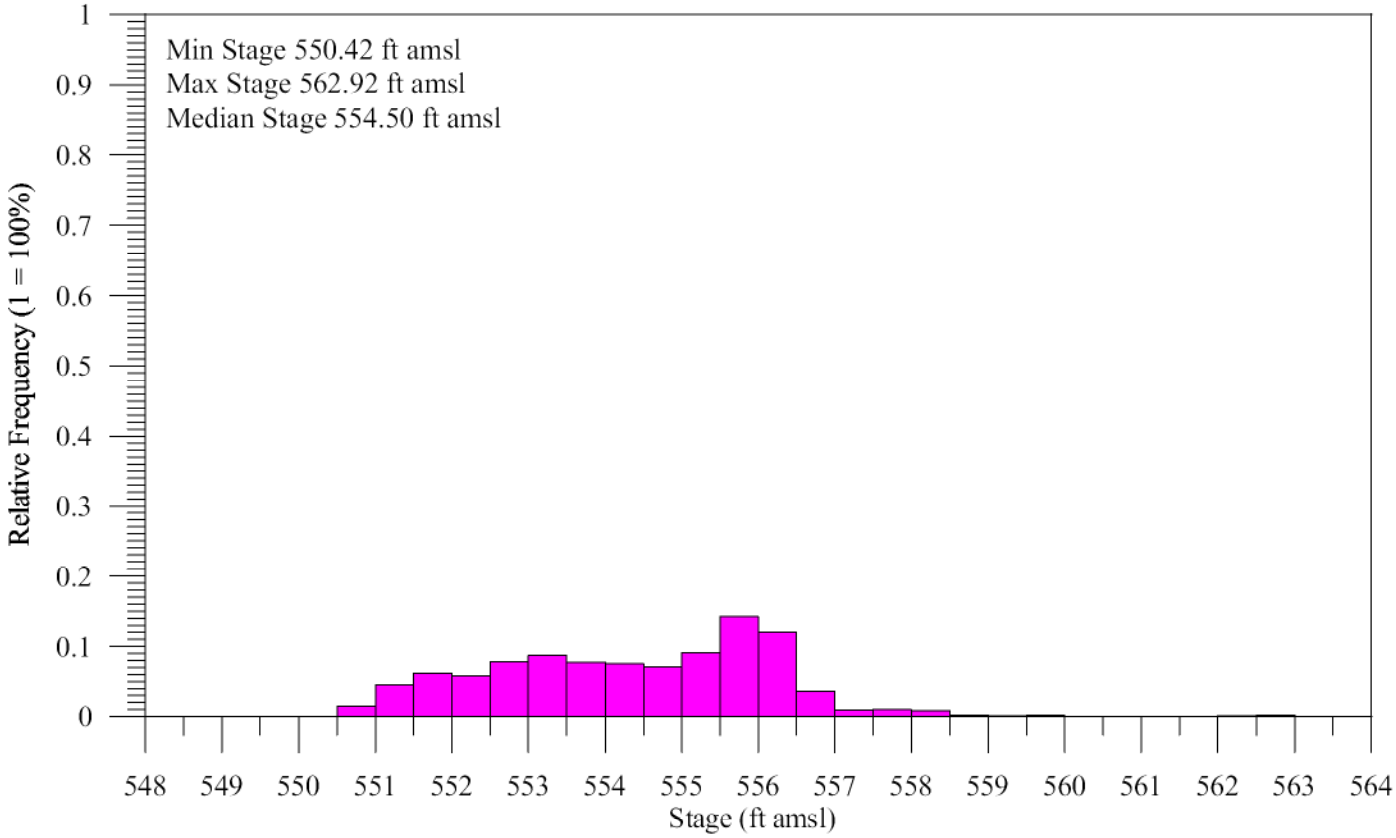


Figure 3-5 Indian Creek at Centerline Road (ICCR) Mean Annual Stage 2000 - 2002



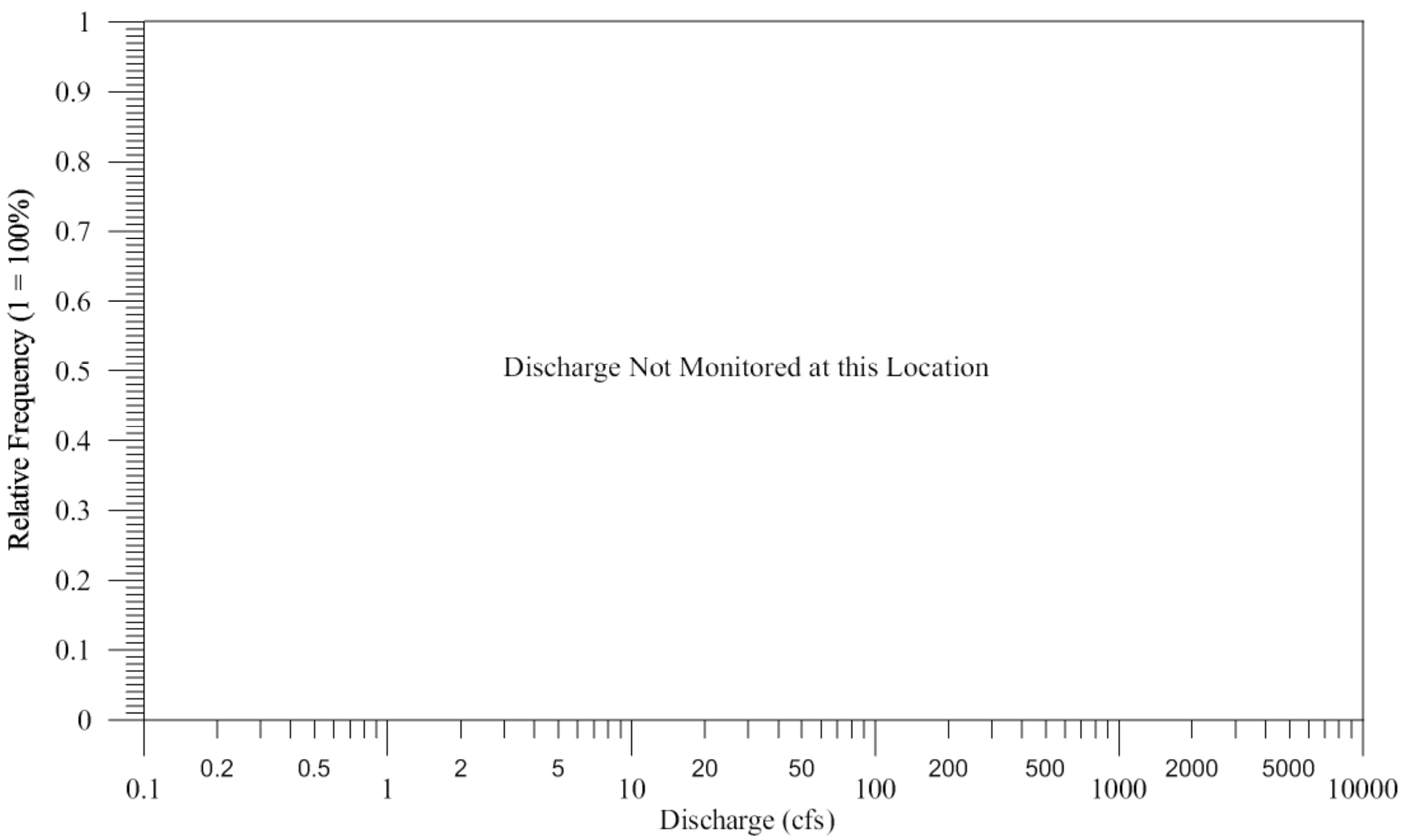
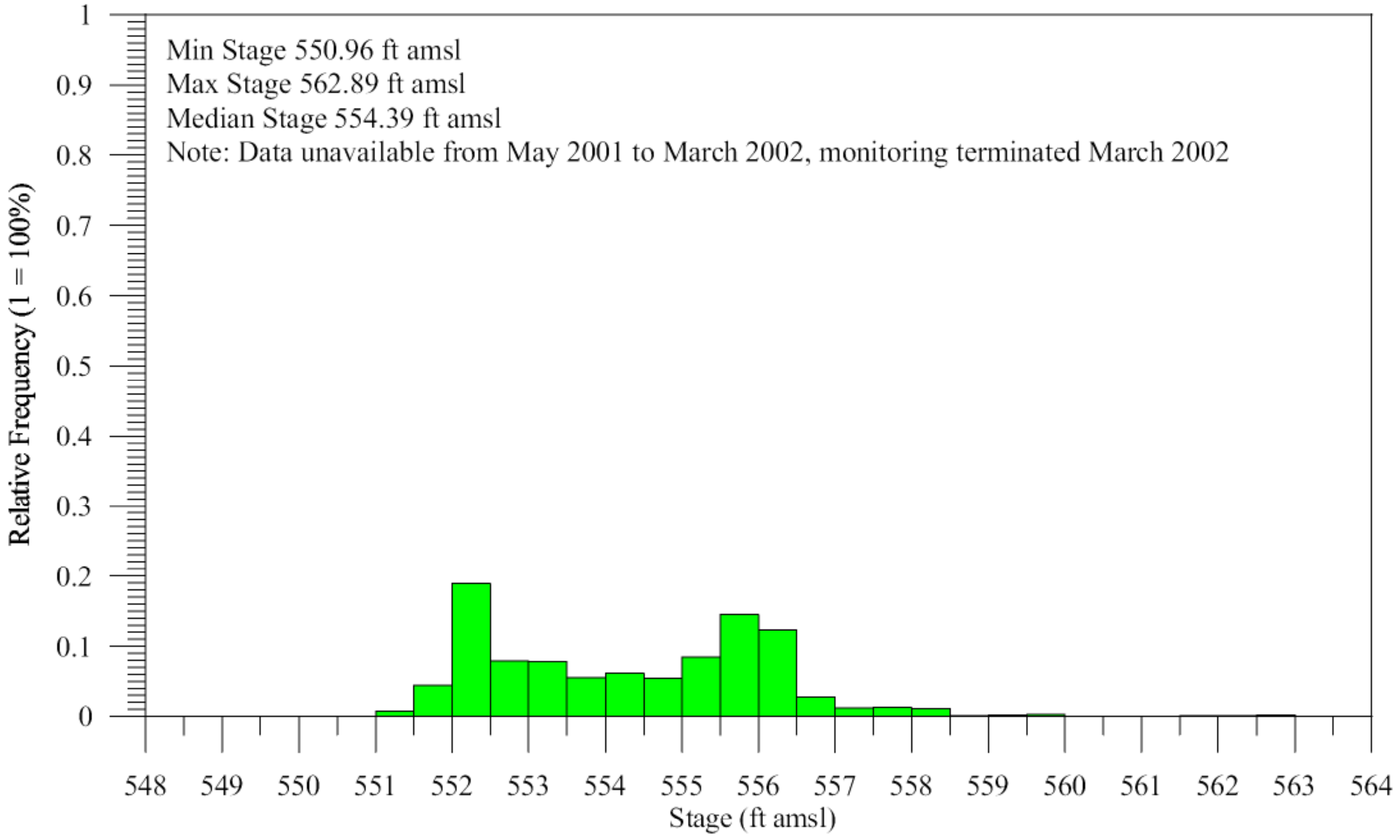


Figure 3-6 Indian Creek at Triana - Mile 0.38 (ICTR) Mean Annual Stage 2000 - 2002



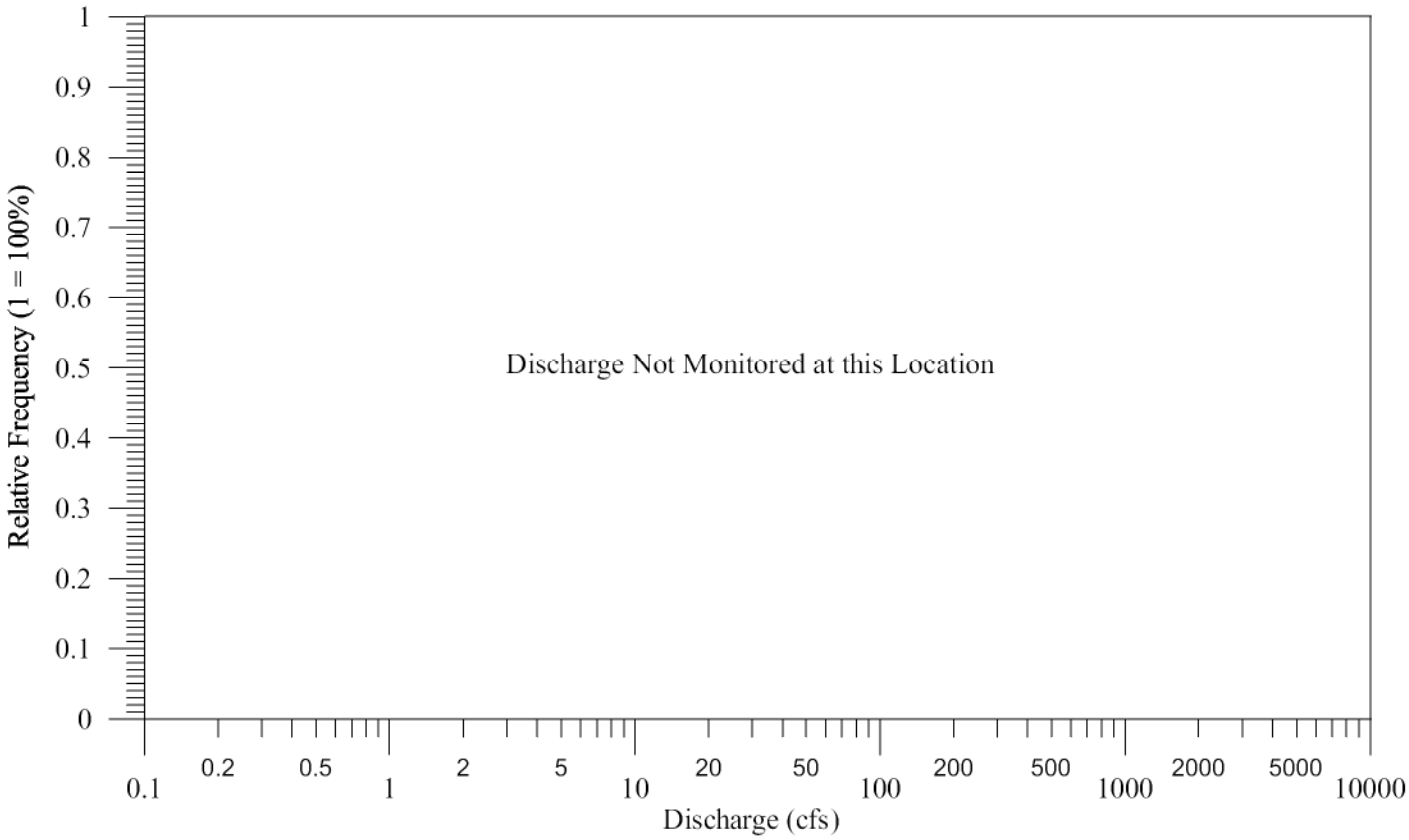
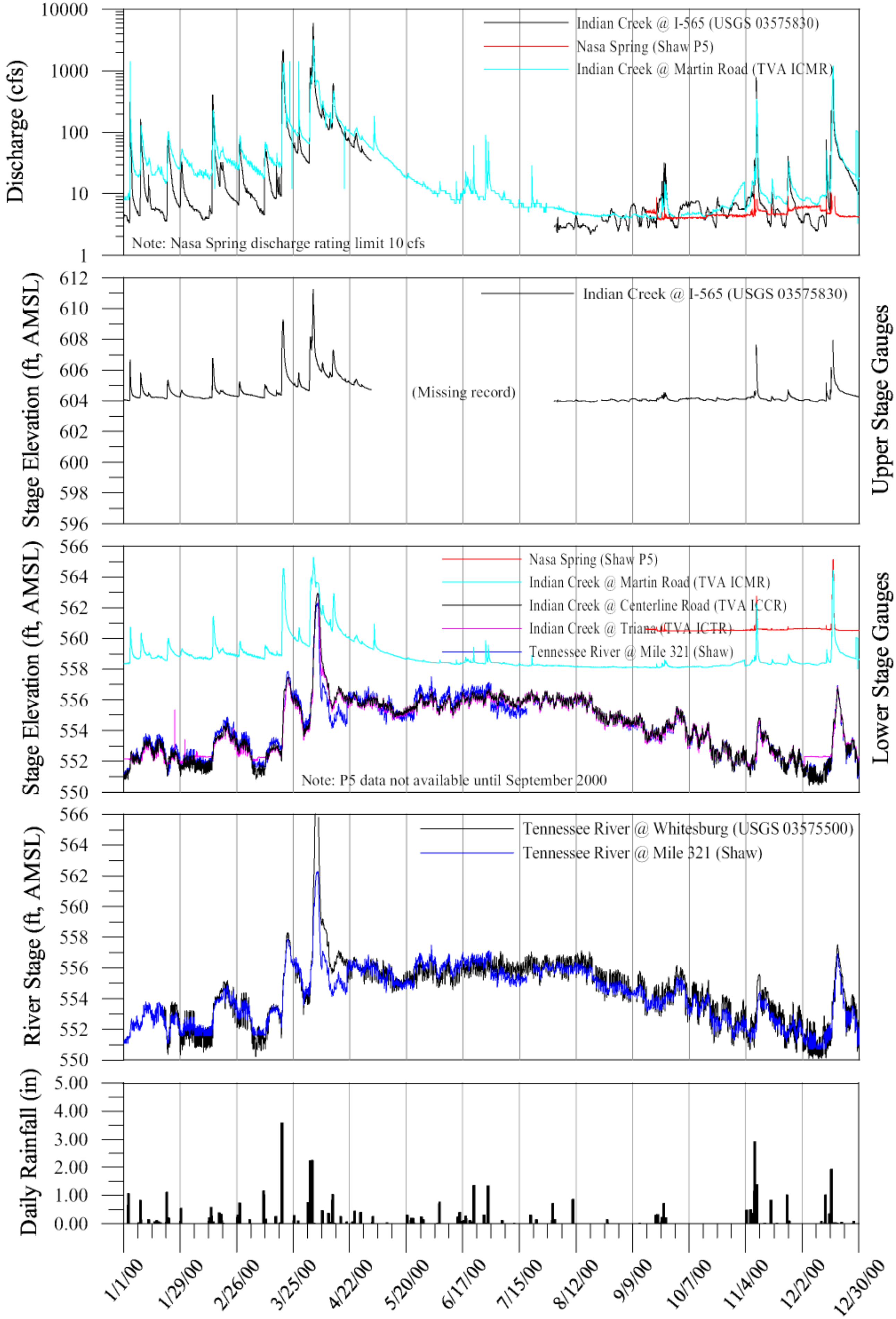


Figure 3-7 Indian Creek Hydrologic Data for Water Year 2000



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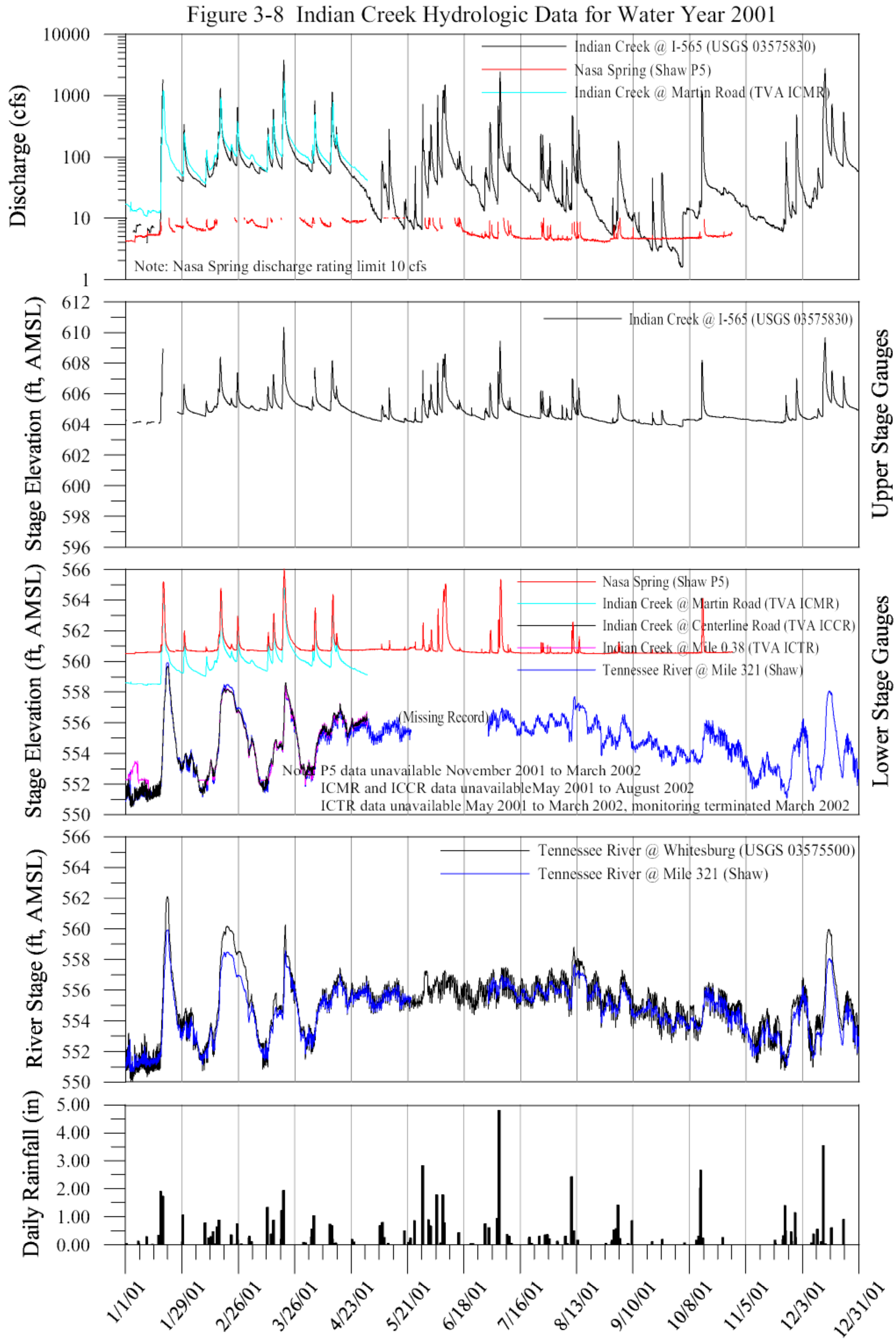

fig3-8_final sw2001indcrk.grf

Figure 3-9 Indian Creek Hydrologic Data for Water Year 2002

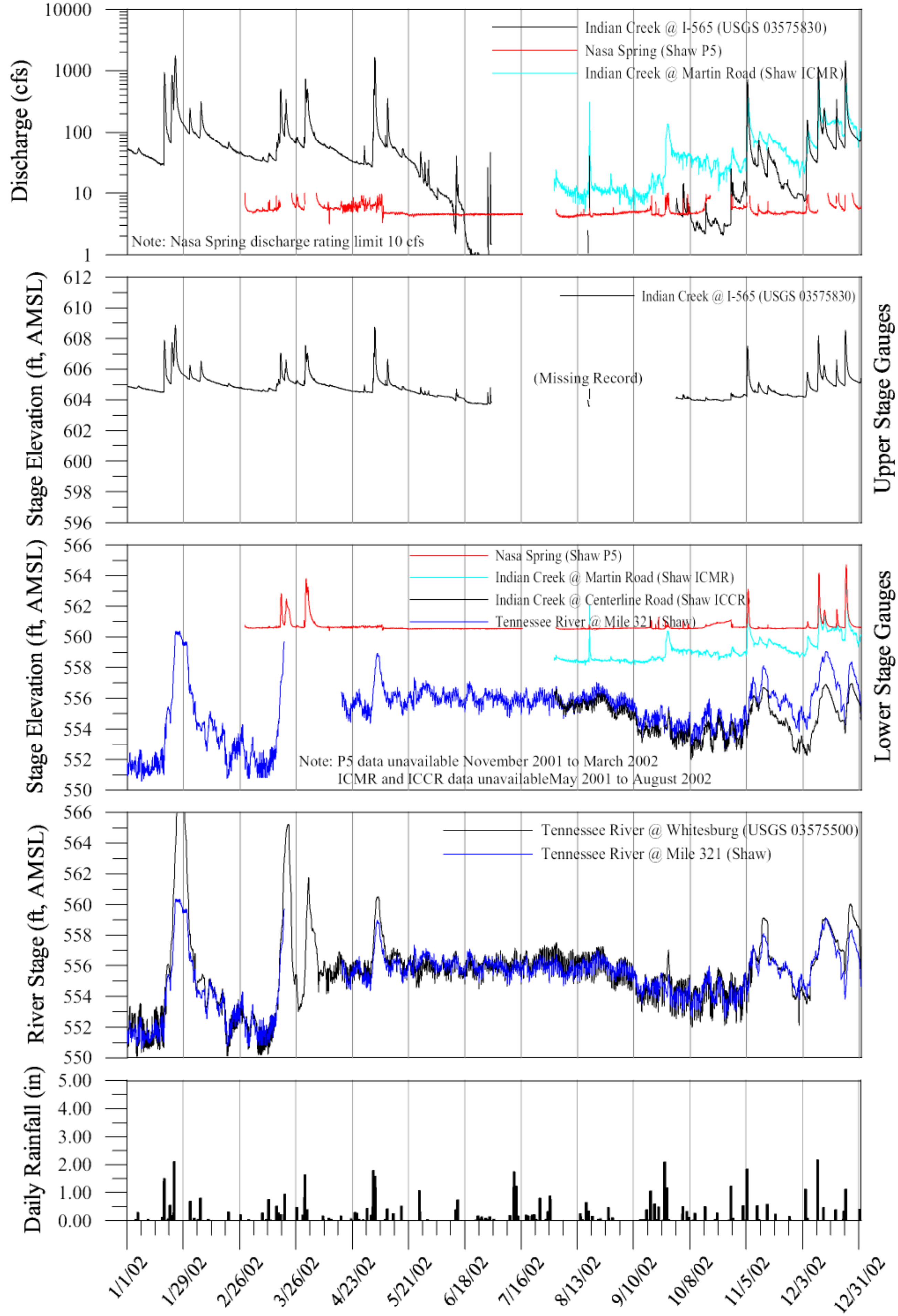

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Figure 3-10 Indian Creek Hydrologic Data - November 1 through November 15, 2002

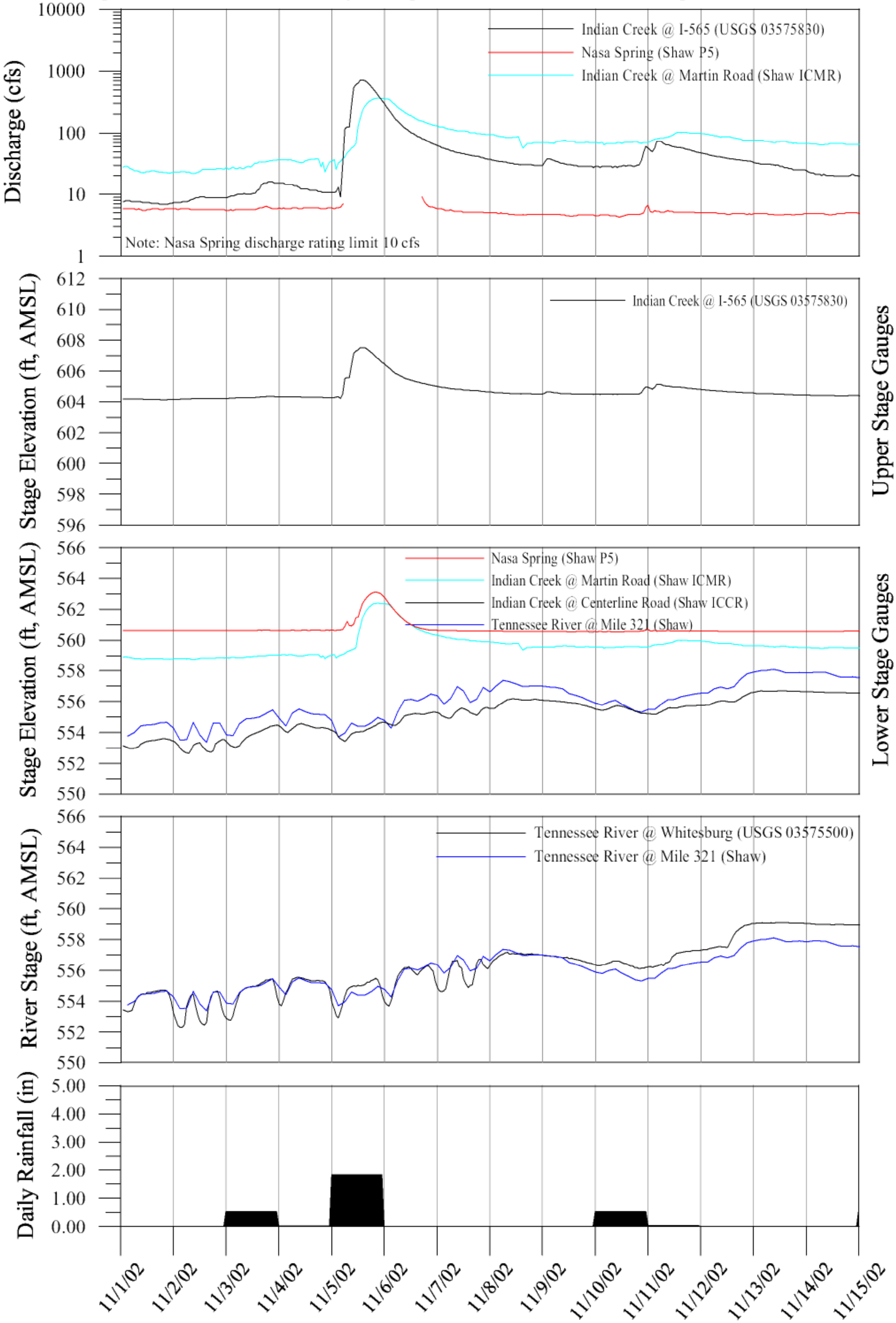

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Figure 3-11 Differential Discharge along Indian Creek (August 2000 through December 2002)

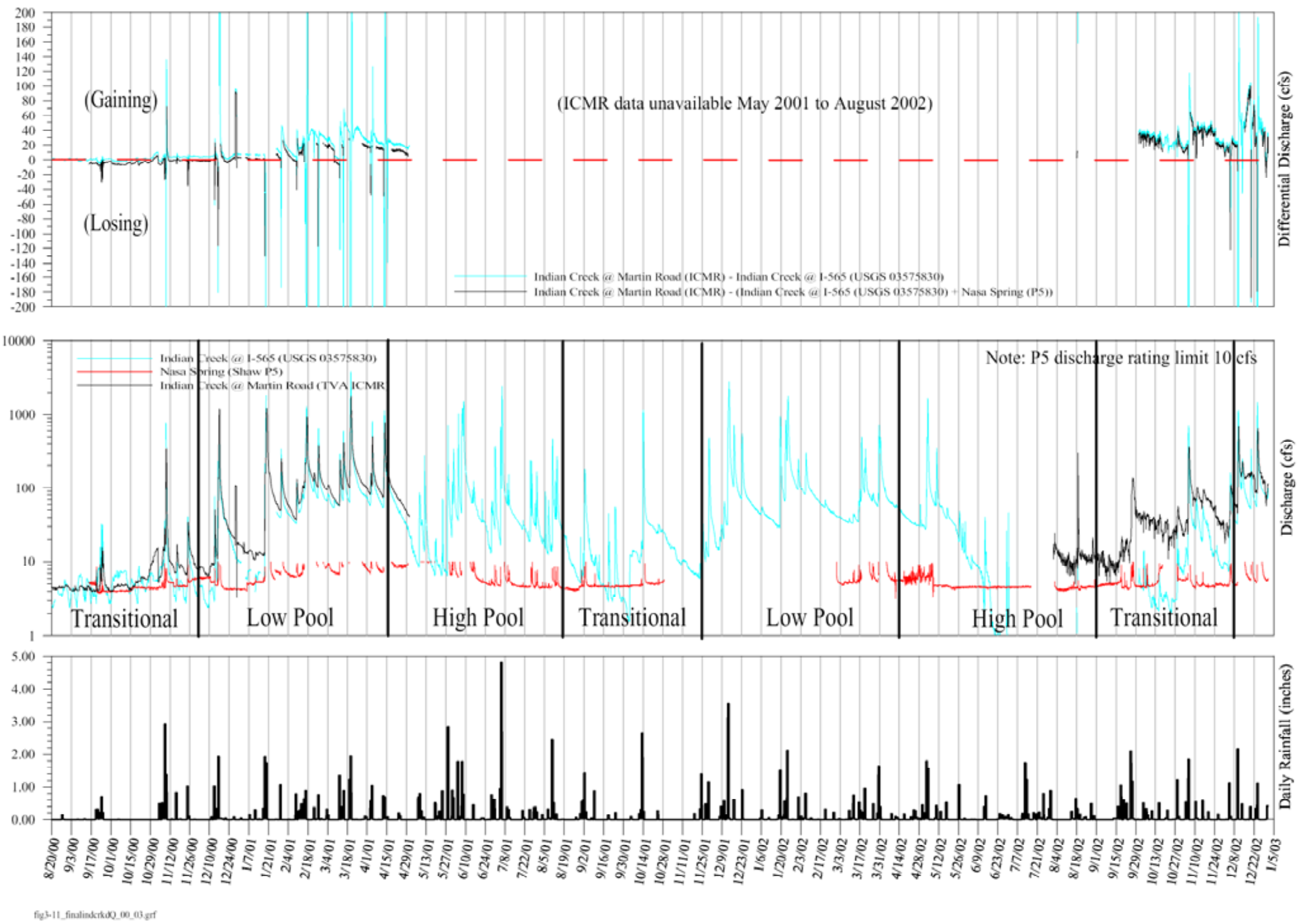


fig3-11_finalindcrkdQ_00_03.grf

Figure 3-12a McDonald Creek at Patton Road (USGS 03575980) Mean Annual Stage 2000 - 2002

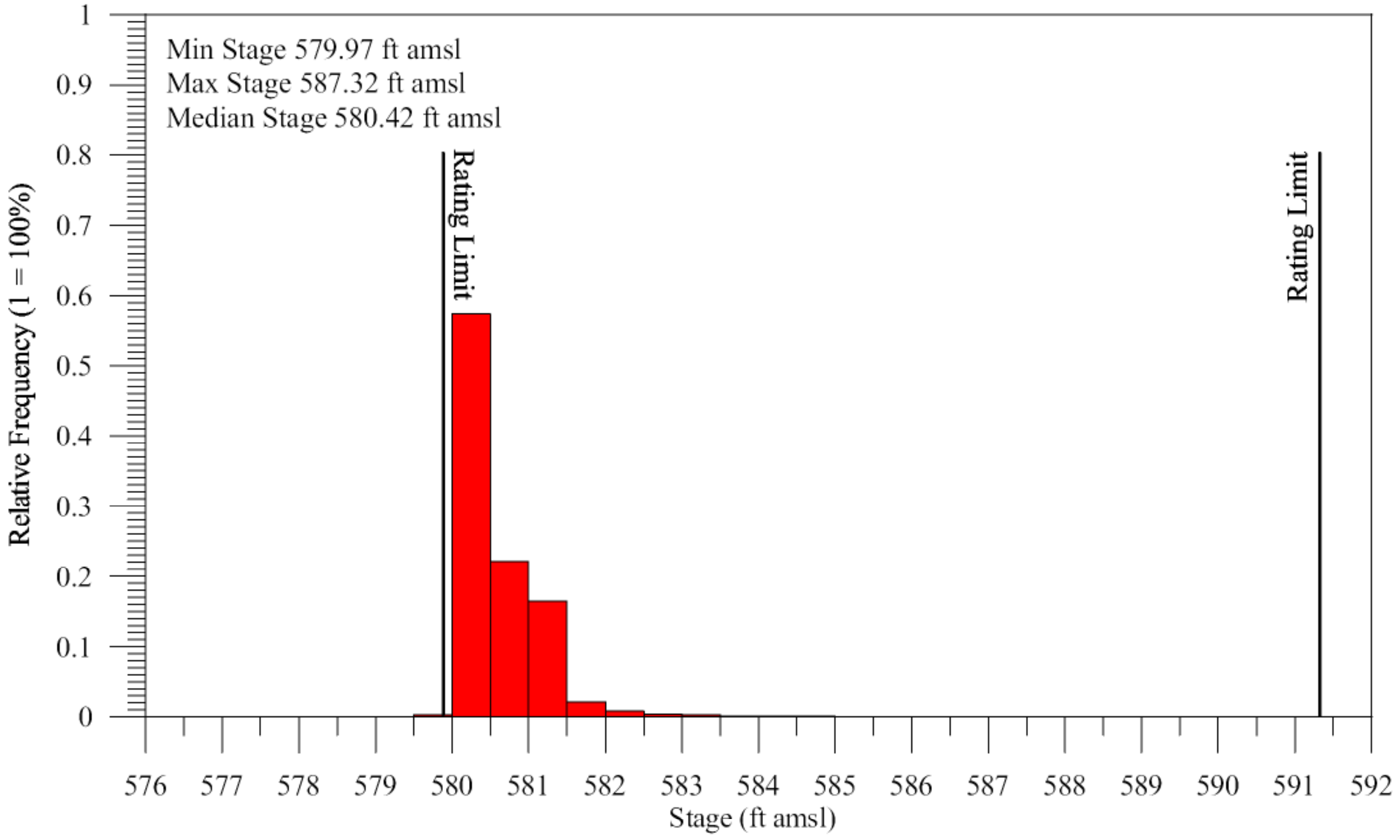


Figure 3-12b McDonald Creek at Patton Road (USGS 03575980) Mean Annual Discharge 2000 - 2002

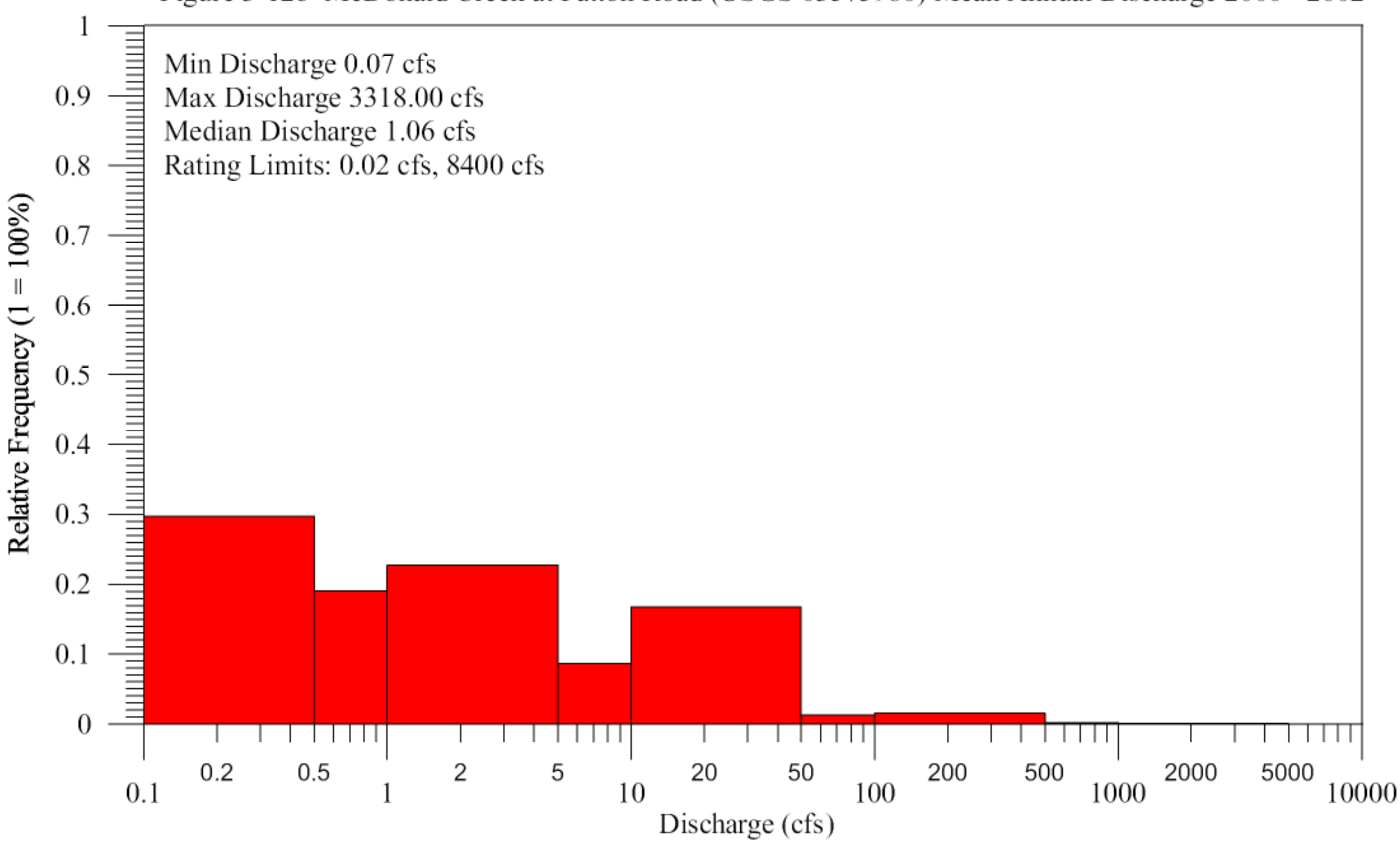


Figure 3-13a McDonald Creek at Martin Road (P1) Mean Annual Stage 2000 - 2002

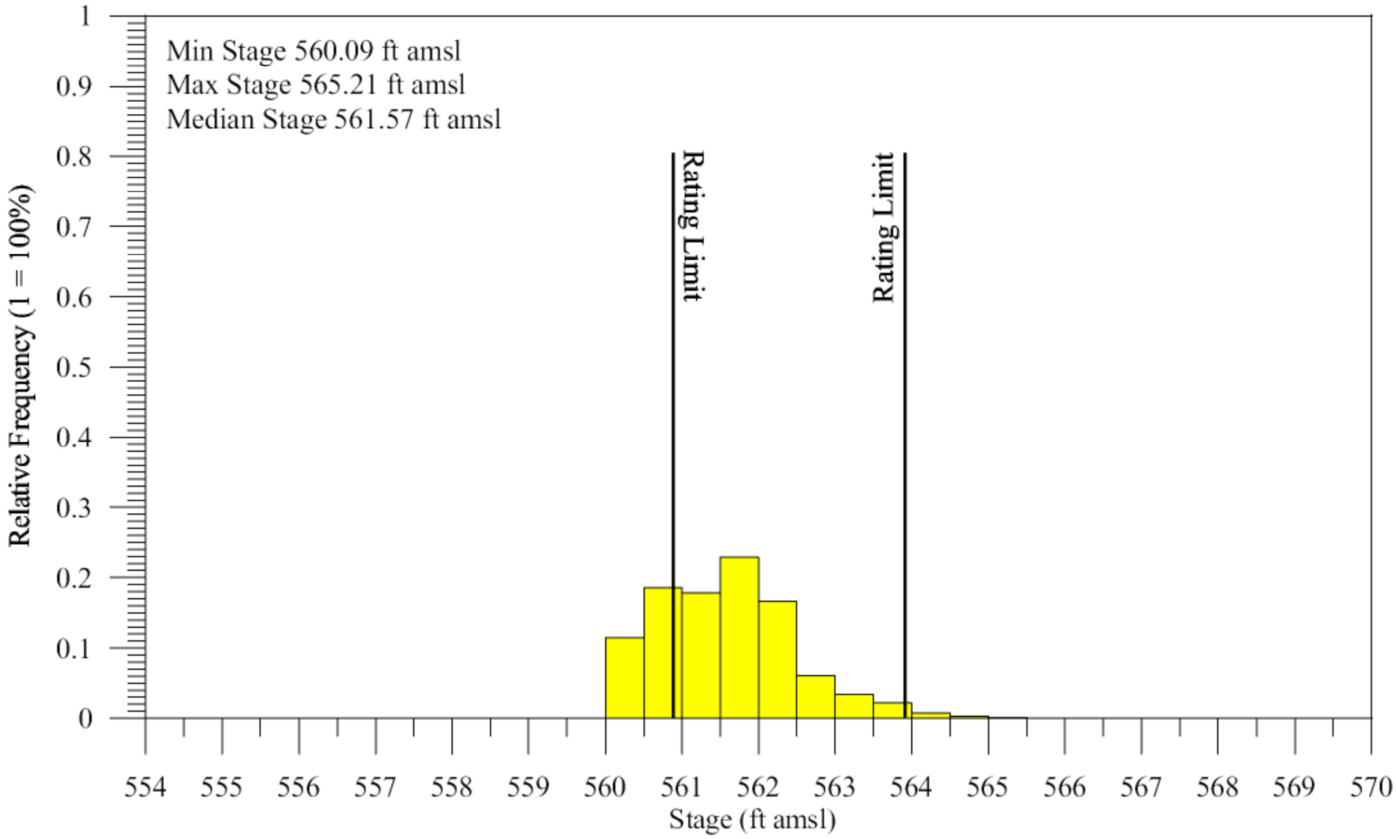


Figure 3-13b McDonald Creek at Martin Road (P1) Mean Annual Discharge 2000 - 2002

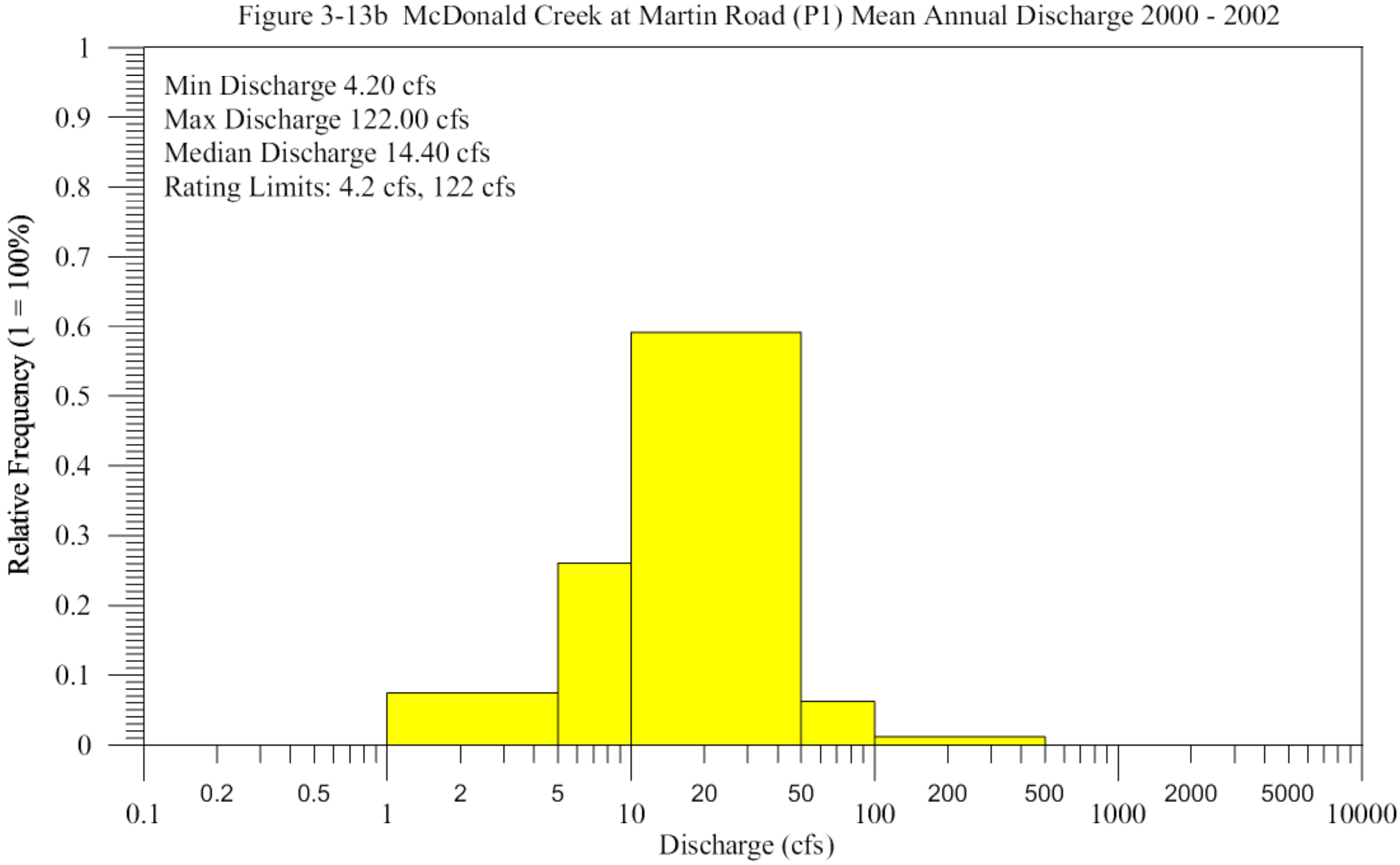


Figure 3-14a McDonald Creek at Huntsville Spring Branch (P2) Mean Annual Stage 2000 - 2002

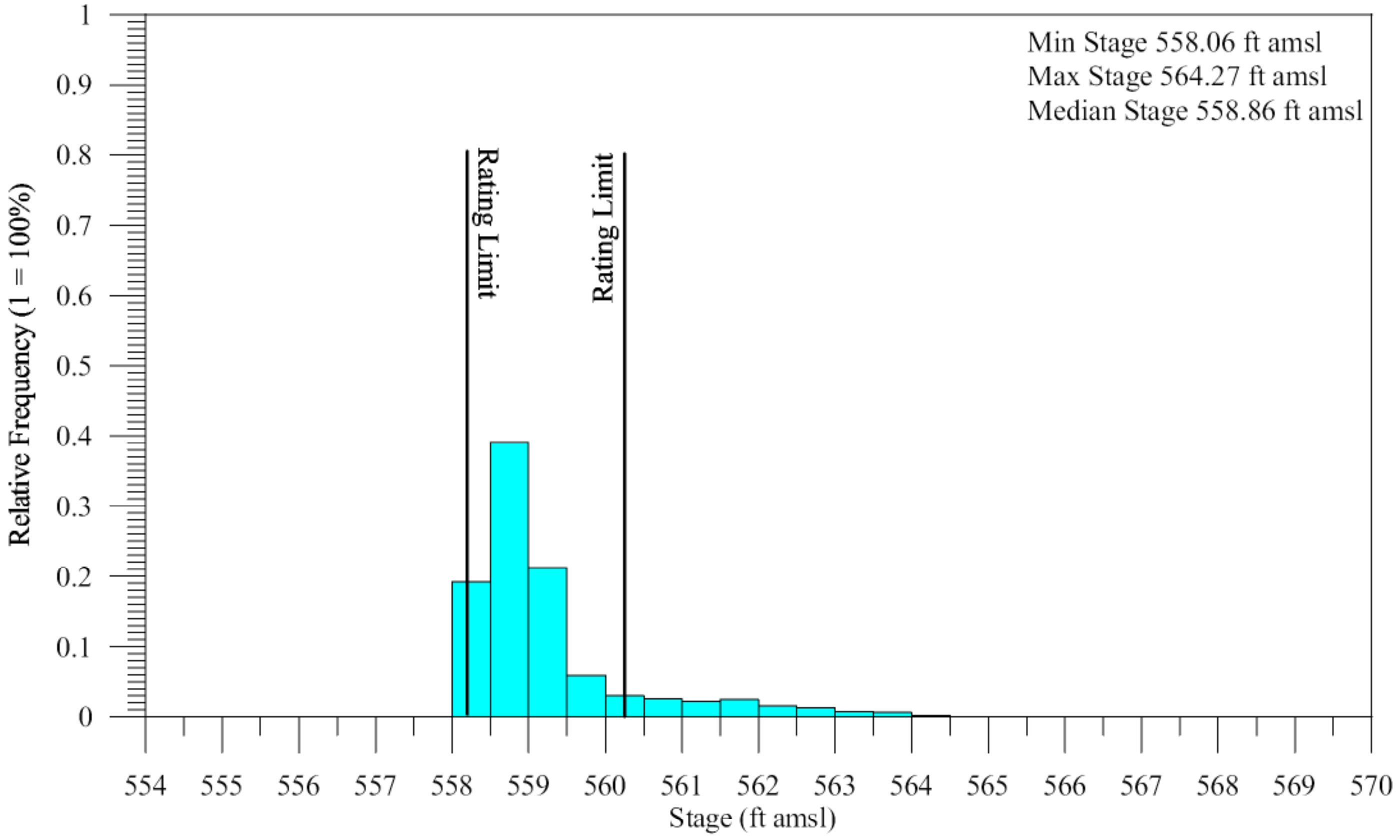
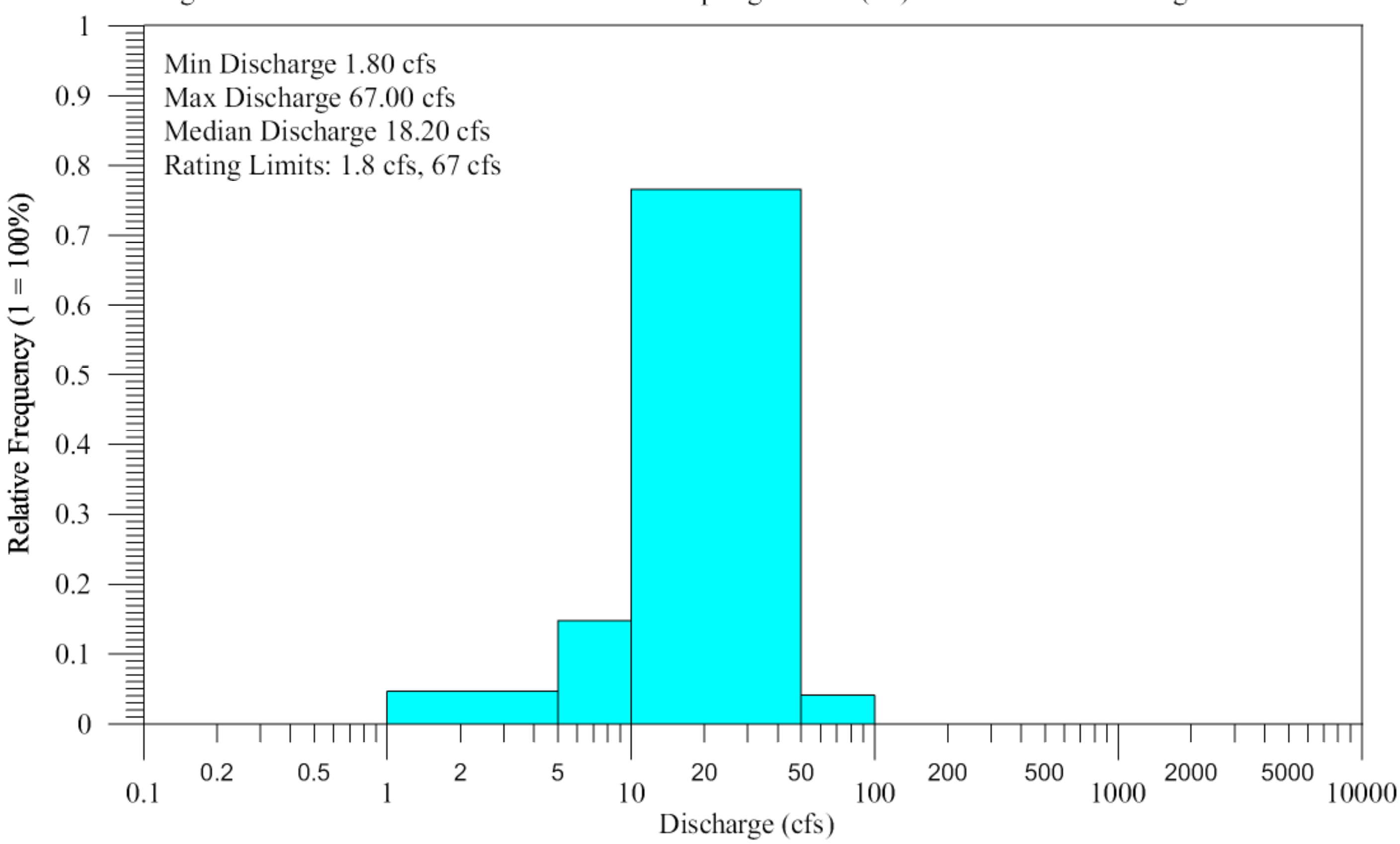


Figure 3-14b McDonald Creek at Huntsville Spring Branch (P2) Mean Annual Discharge 2000 - 2002



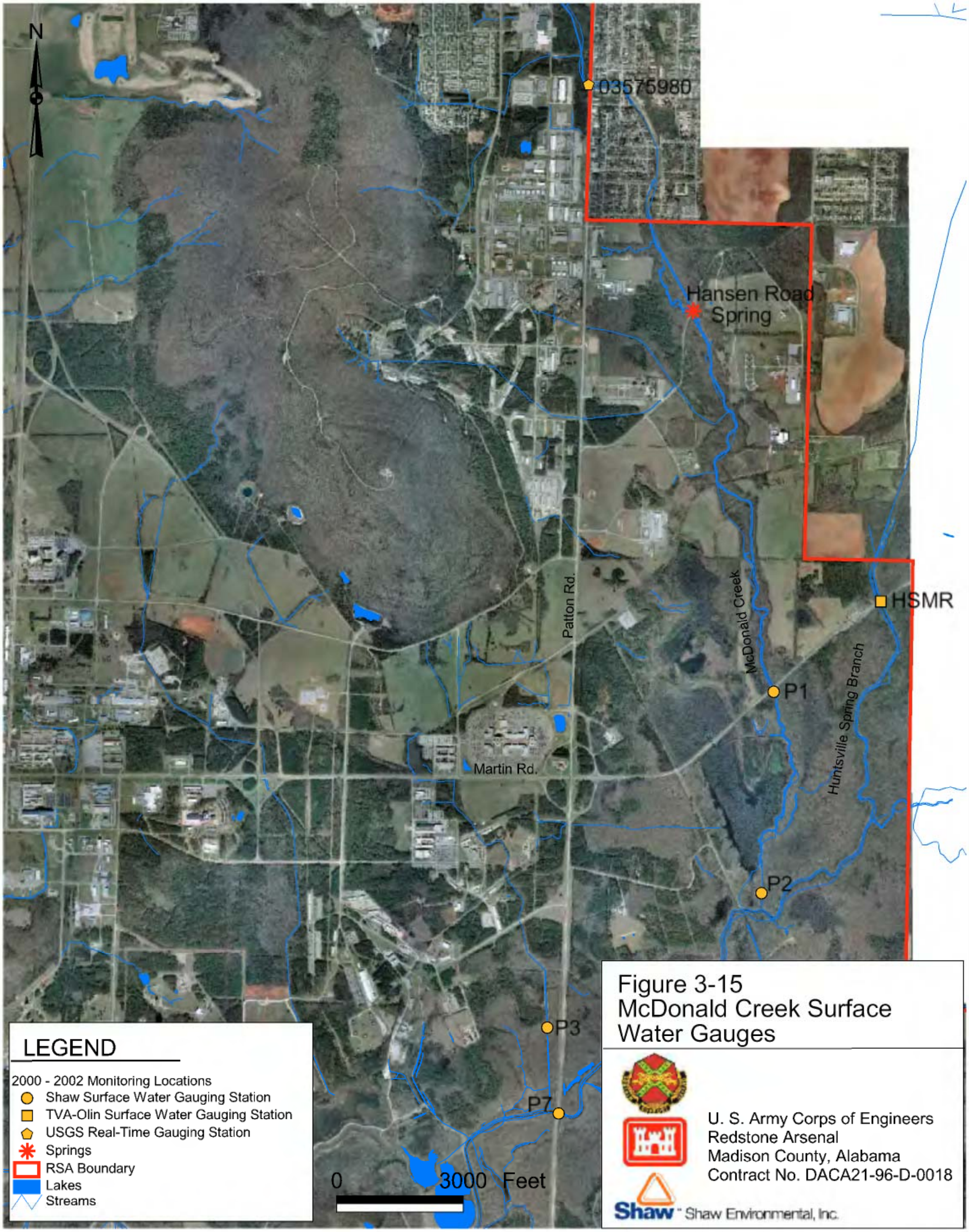


Figure 3-15
McDonald Creek Surface Water Gauges

U. S. Army Corps of Engineers
Redstone Arsenal
Madison County, Alabama
Contract No. DACA21-96-D-0018

Shaw Shaw Environmental, Inc.

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Figure 3-16 McDonald Creek Hydrologic Data for Water Year 2000

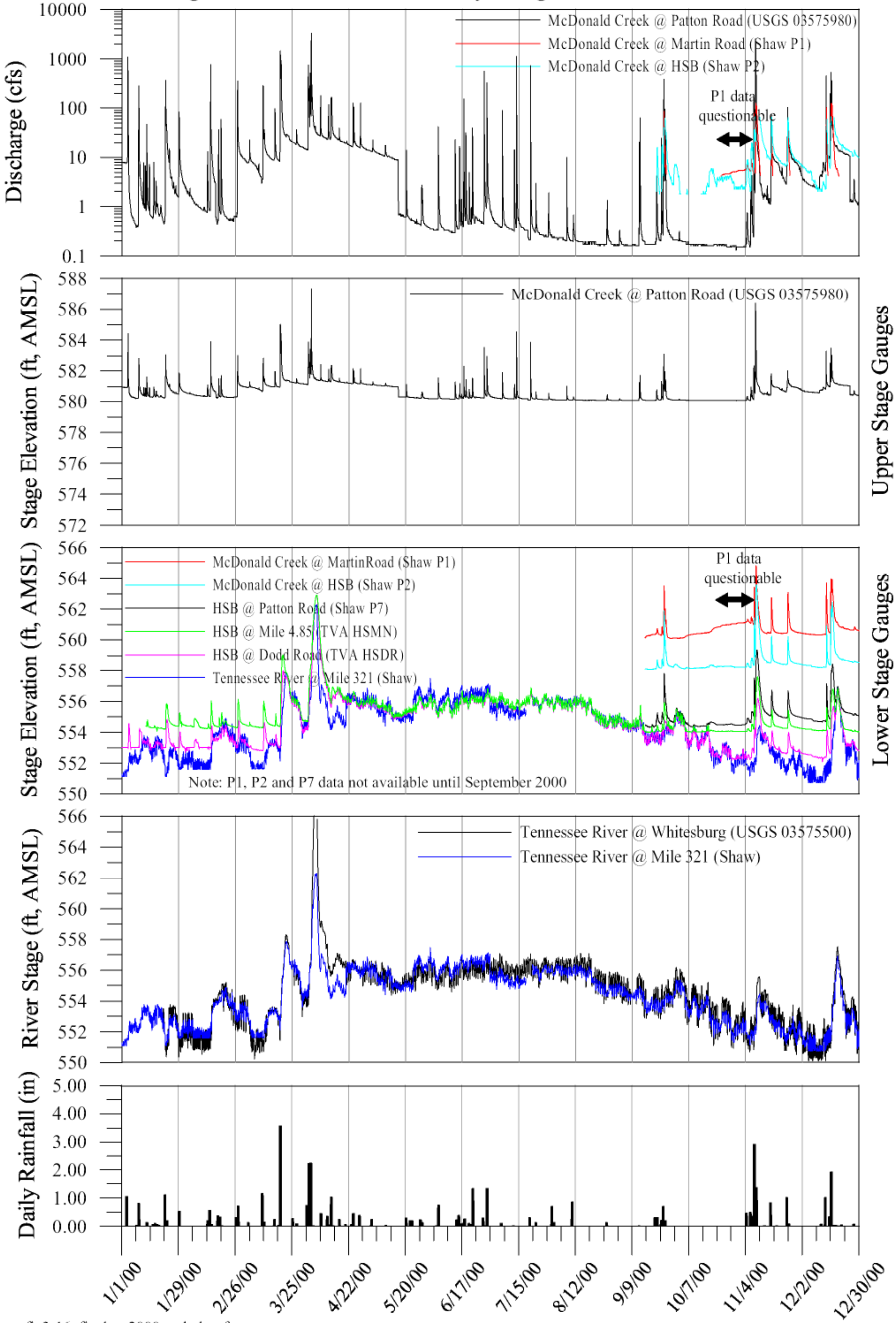

fig3-16_final sw2000mcdcrk.grf

Figure 3-17 McDonald Creek Hydrologic Data for Water Year 2001

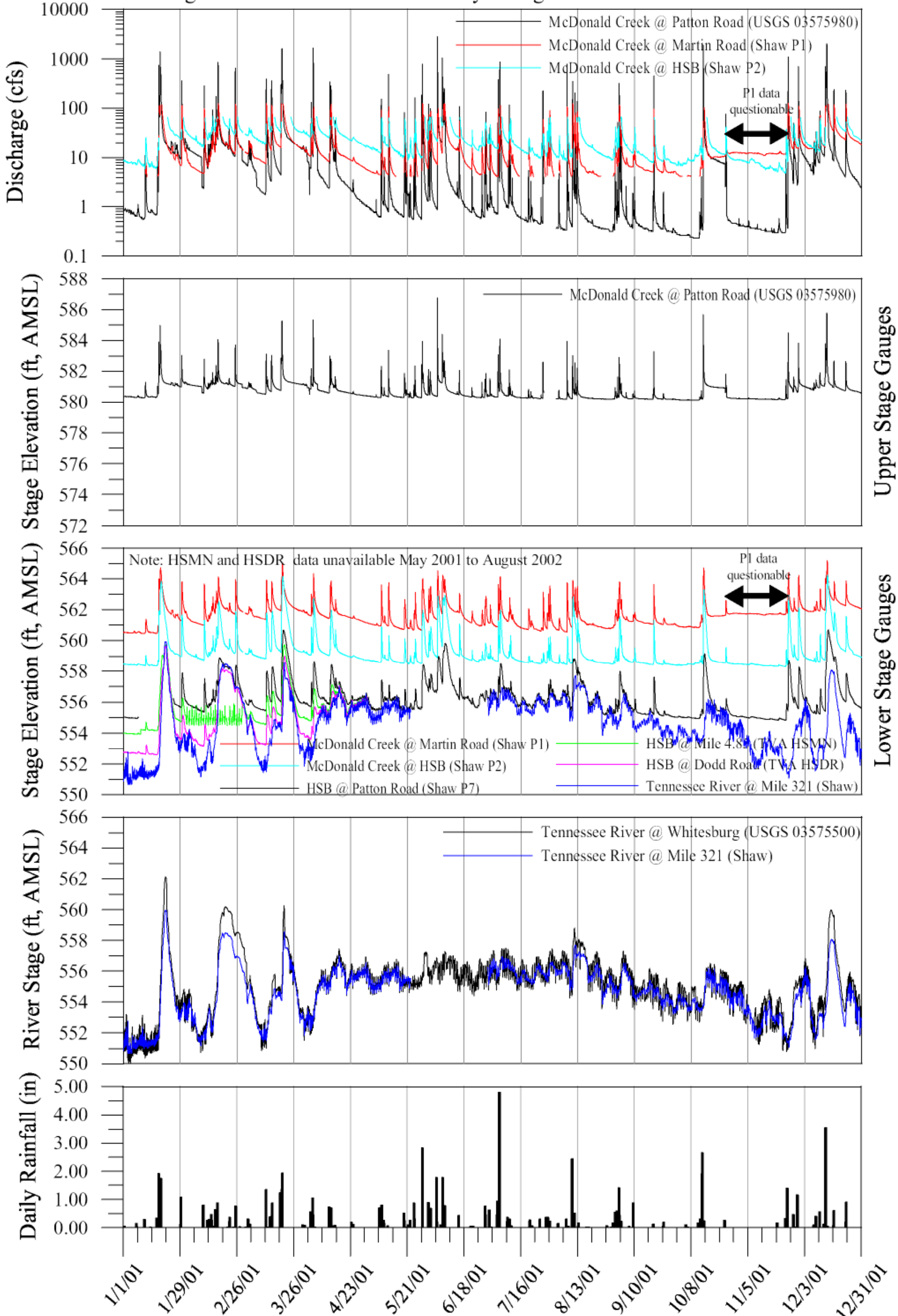

fig3-17_final sw2001mcdcrk.grf

Figure 3-18 McDonald Creek Hydrologic Data for Water Year 2002

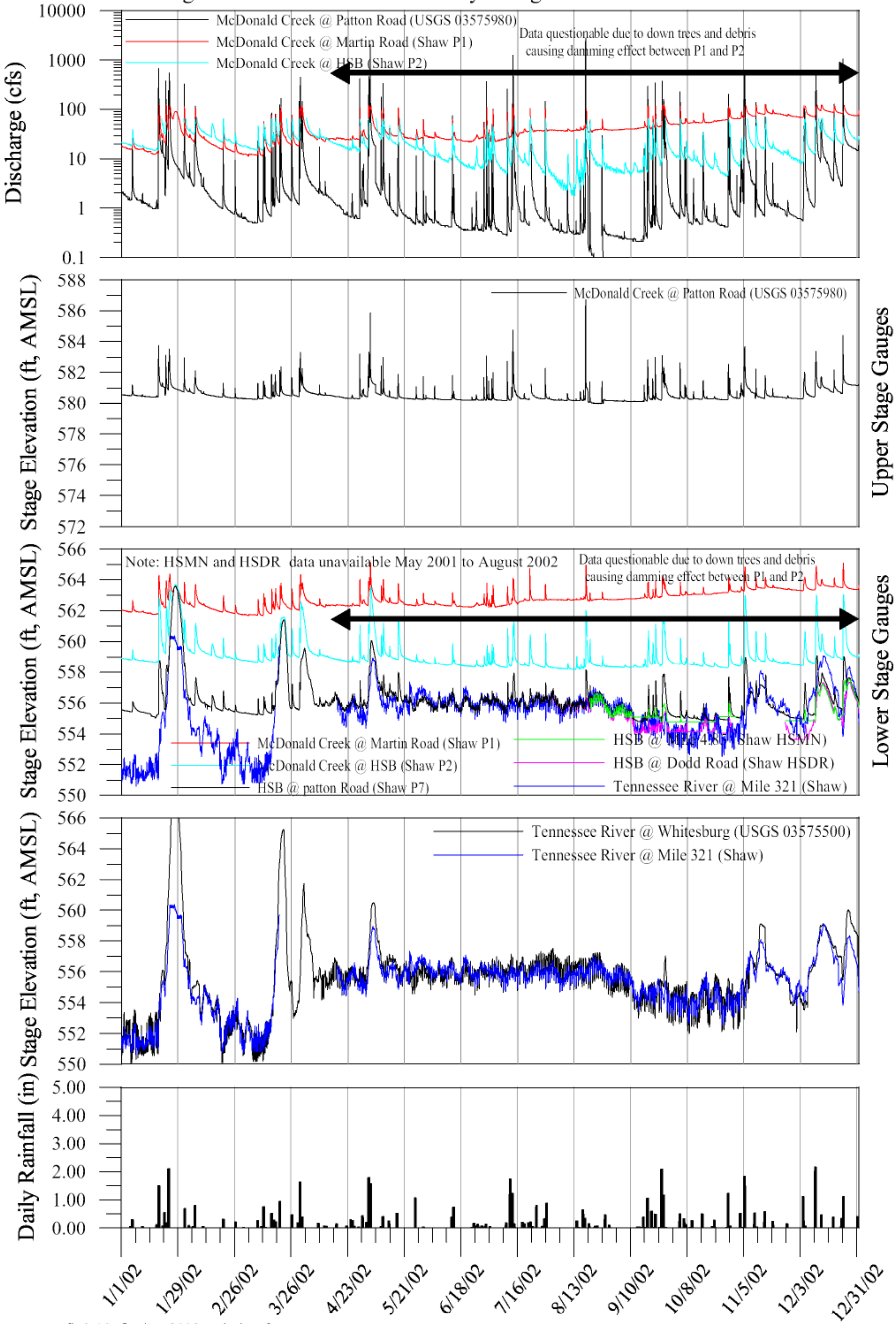

fig3-18_final sw2002mcdcrk.grf

Figure 3-19 Differential Discharge along McDonald Creek (August 2000 through December 2002)

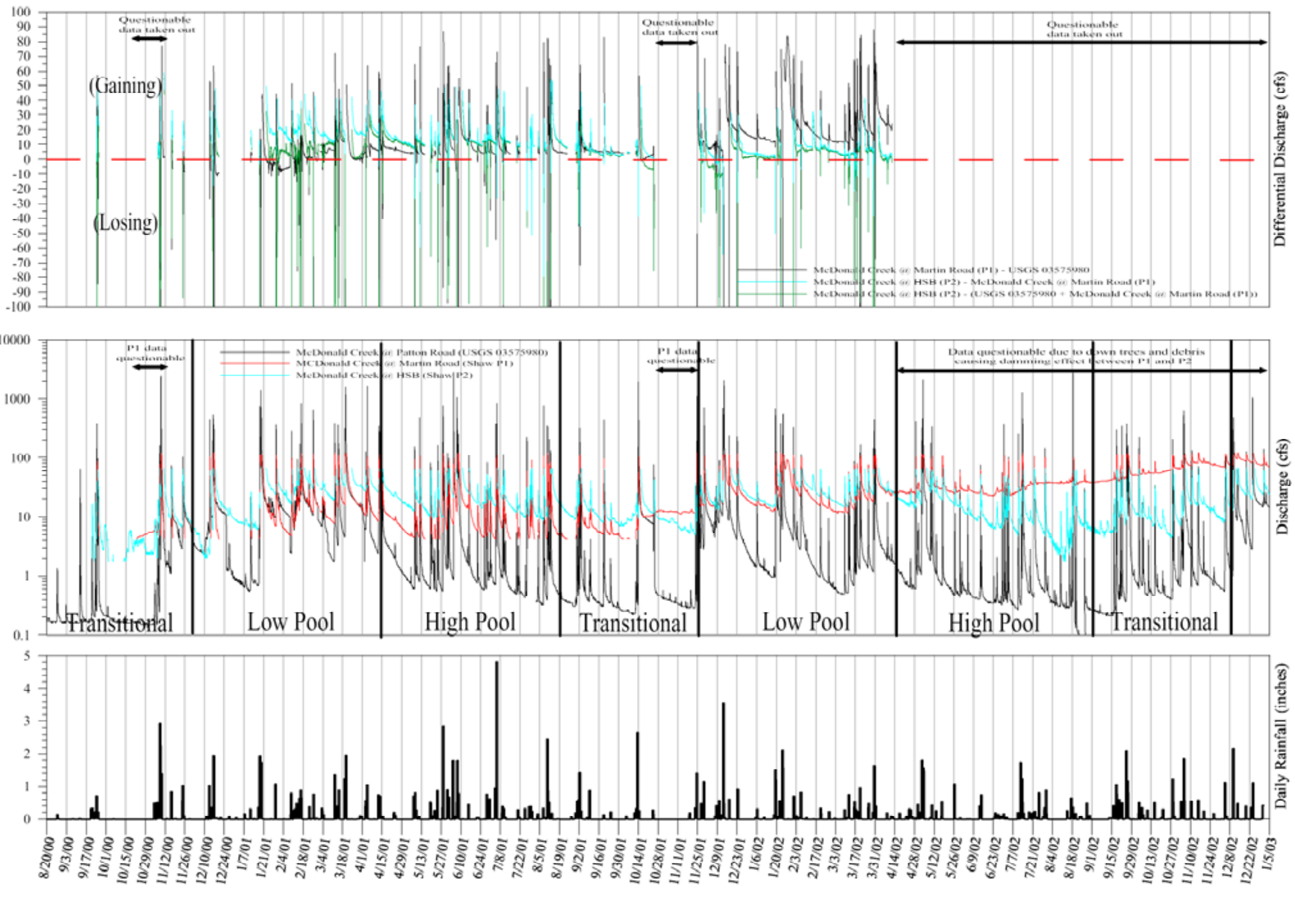

fig3-19_final mcdcrkdQ_00_03.grf

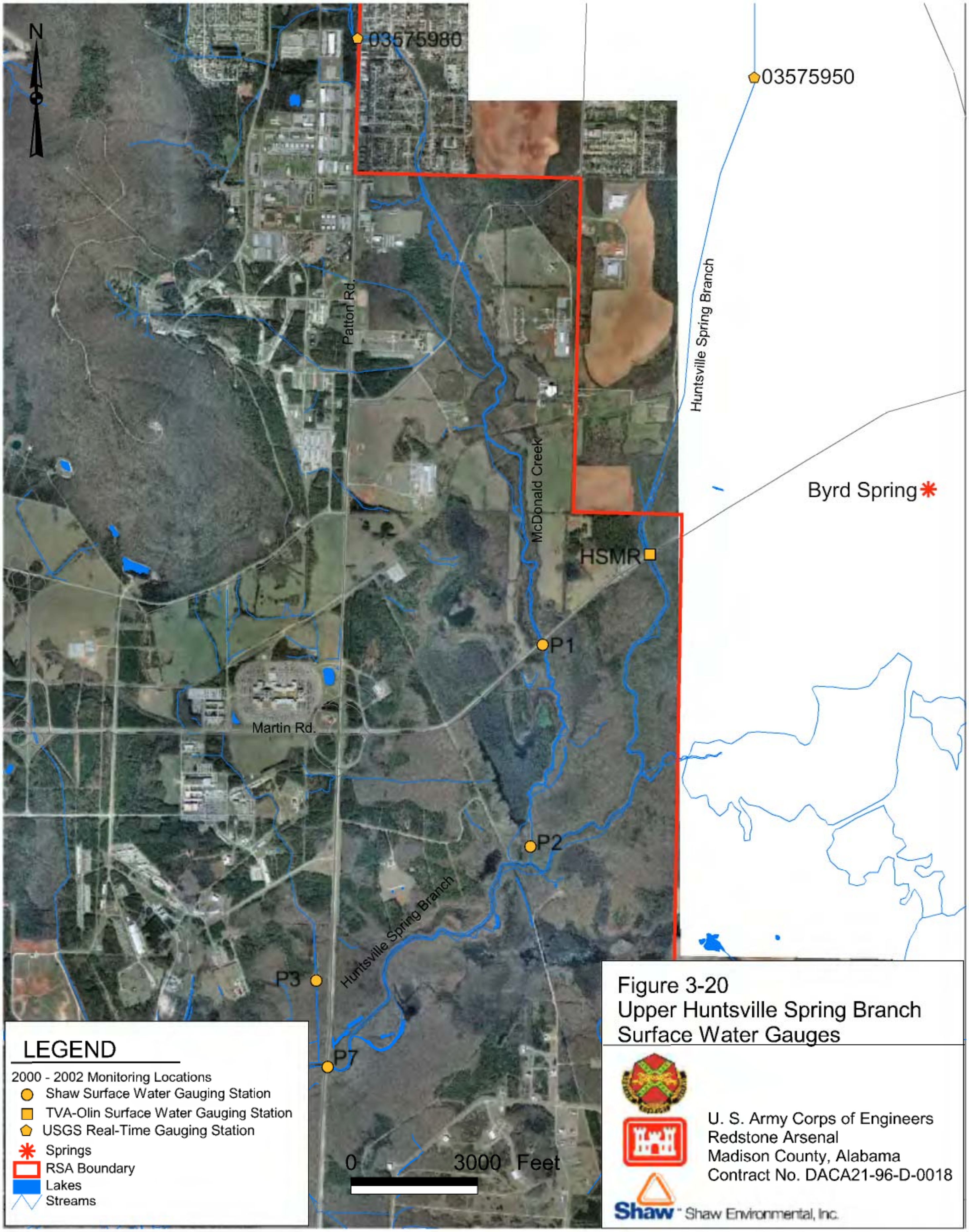

Figure 3-20
Upper Huntsville Spring Branch
Surface Water Gauges

U. S. Army Corps of Engineers
Redstone Arsenal
Madison County, Alabama
Contract No. DACA21-96-D-0018

Shaw Environmental, Inc.

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Figure 3-21
Lower Huntsville Spring Branch
Surface Water Gauges

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Figure 3-22a Huntsville Spring Branch at Johnson Road (USGS 03575950) Mean Annual Stage 2000 - 2002

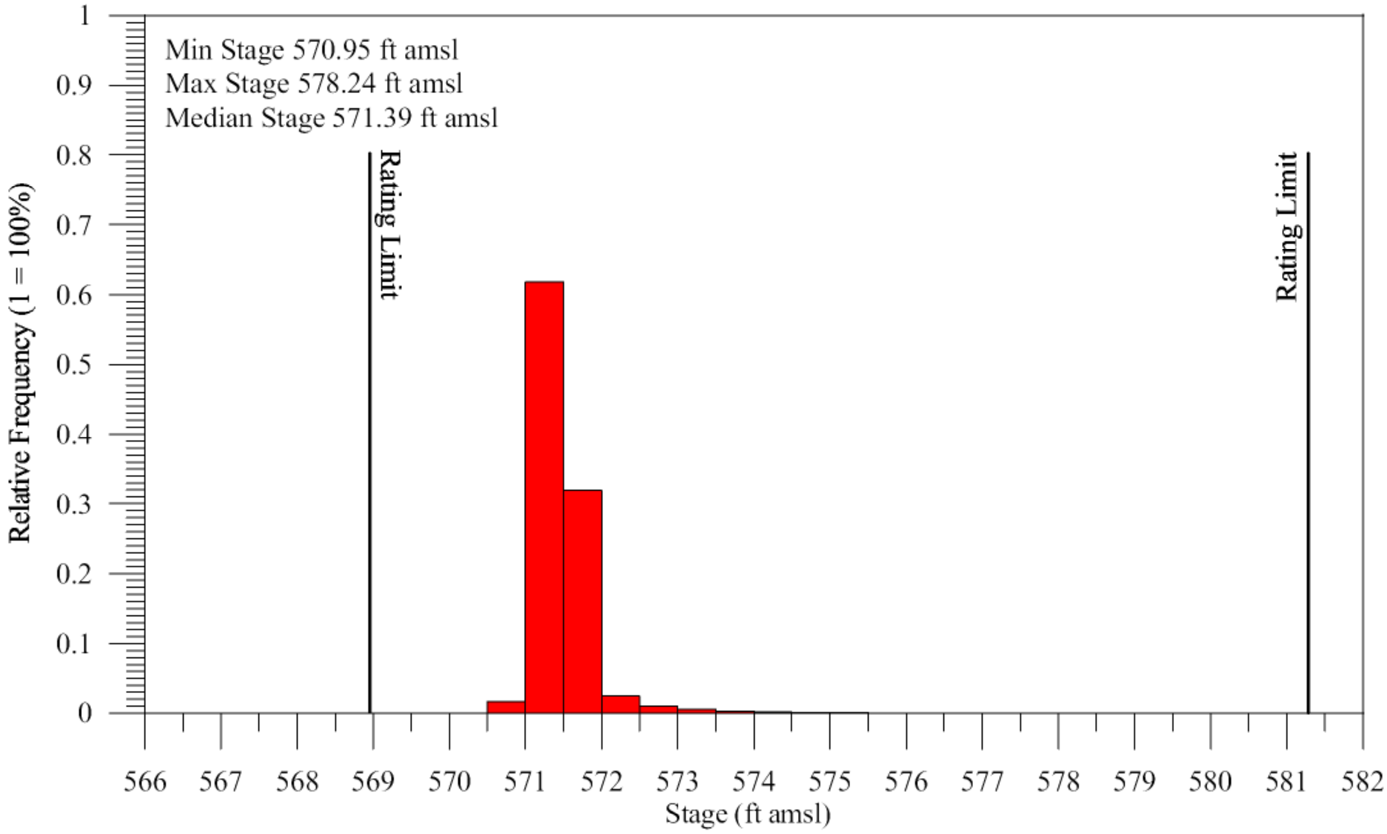


Figure 3-22b Huntsville Spring Branch at Johnson Road (USGS 03575950) Mean Annual Discharge 2000 - 2002

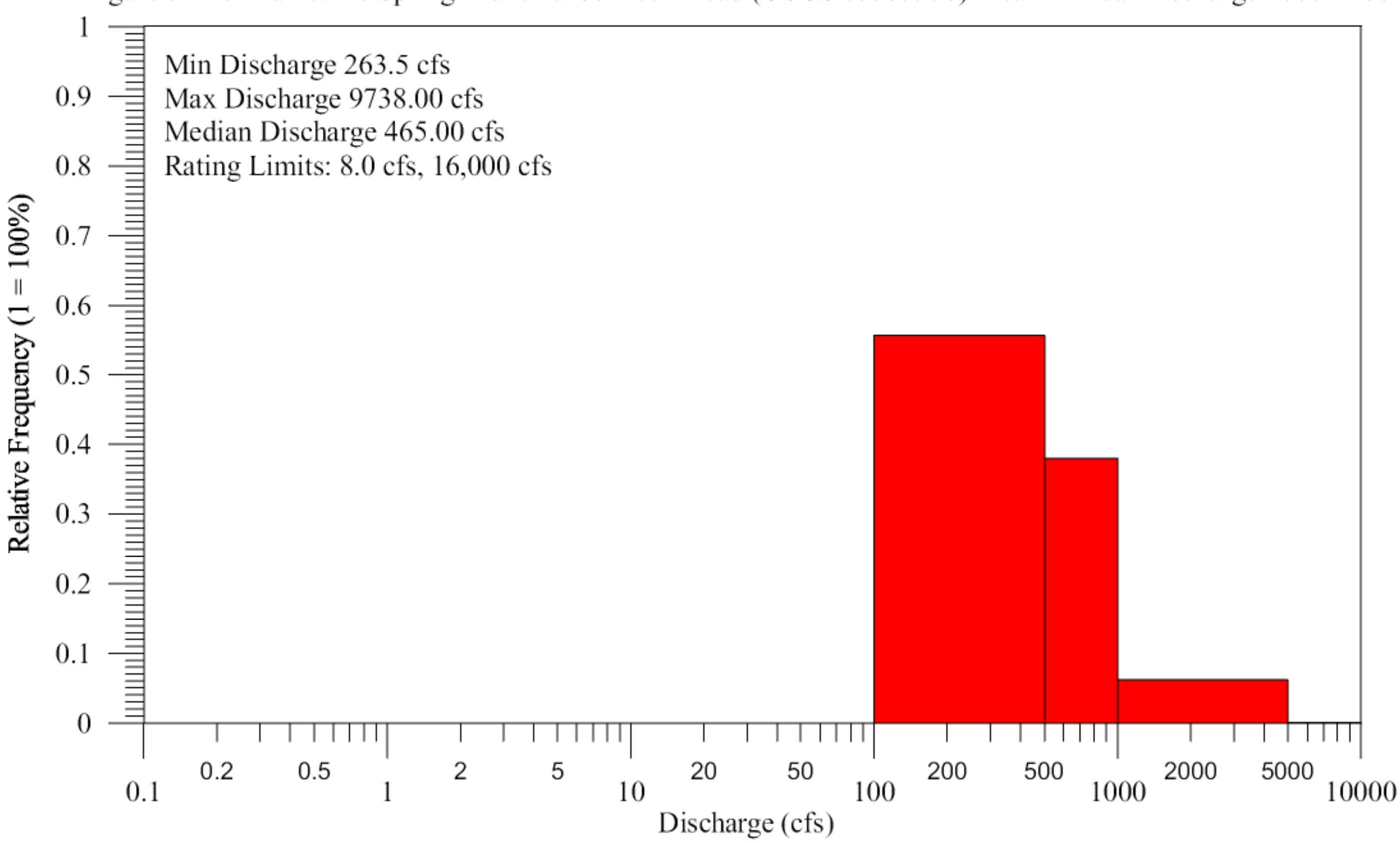


Figure 3-23a Huntsville Spring Branch at Martin Road (HSMR) Mean Annual Stage 2000 - 2002

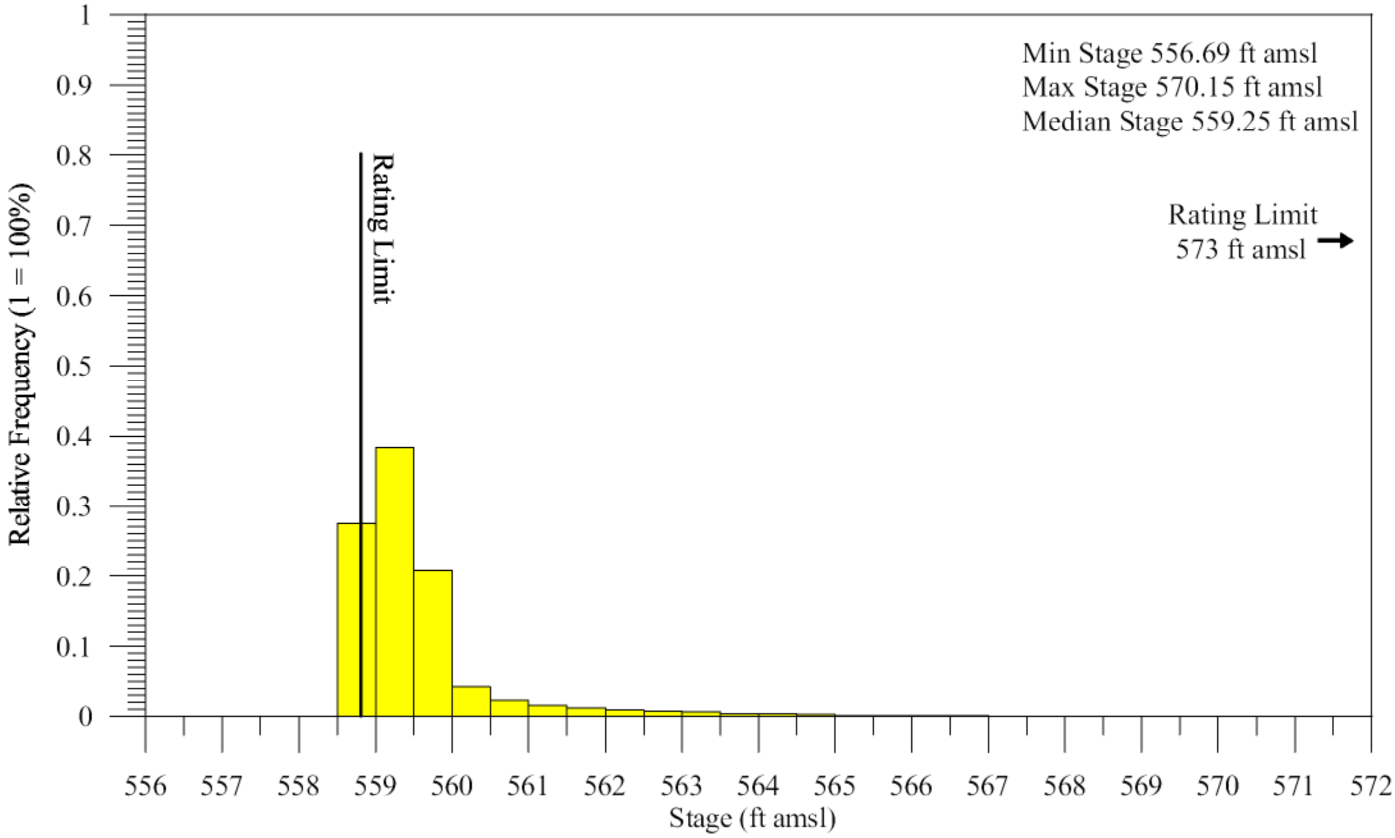


Figure 3-23b Huntsville Spring Branch at Martin Road (HSMR) Mean Annual Discharge 2000 - 2002

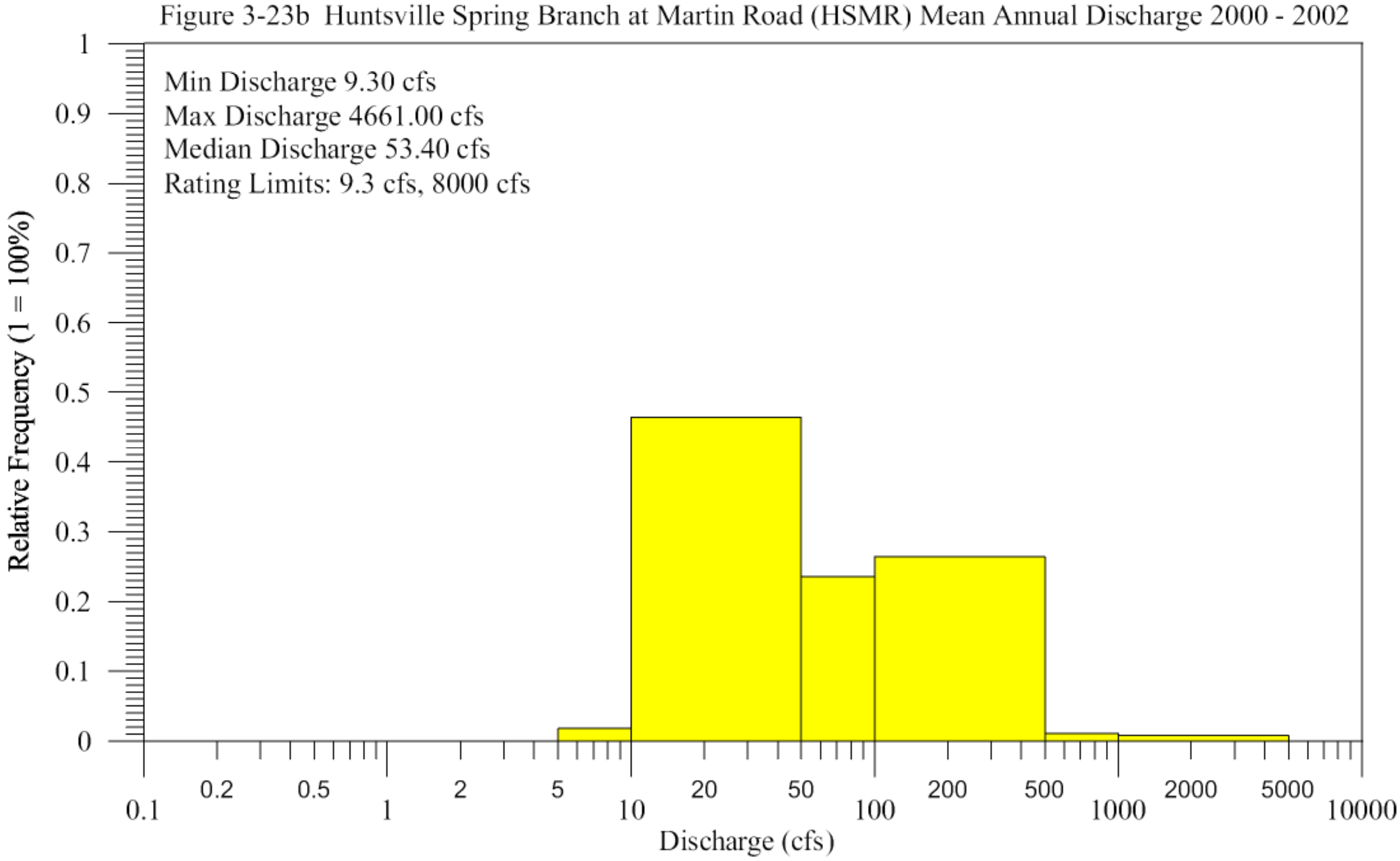


Figure 3-24a Huntsville Spring Branch at Patton Road (P7) Mean Annual Stage 2000 - 2002

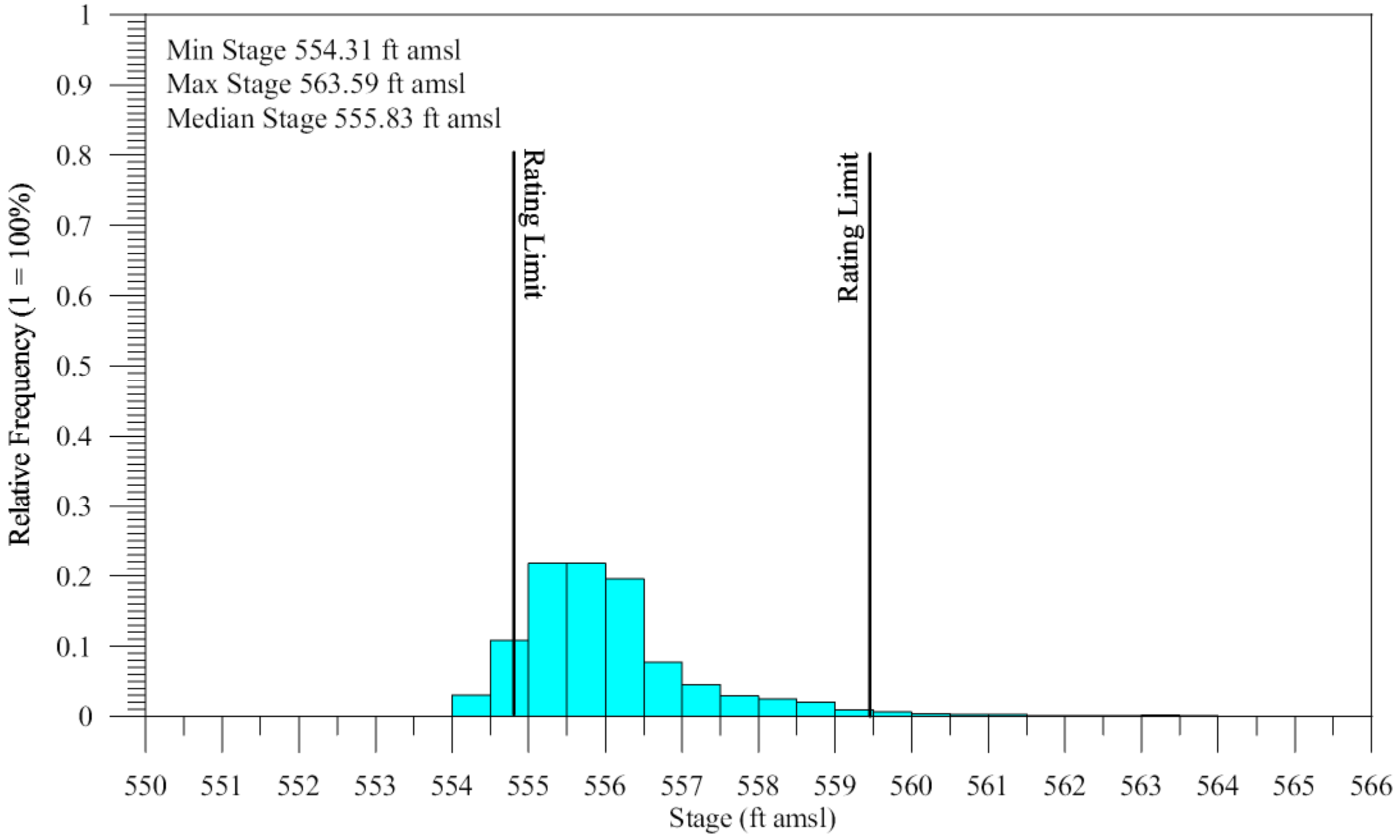


Figure 3-24b Huntsville Spring Branch at Patton Road (P7) Mean Annual Discharge 2000 - 2002

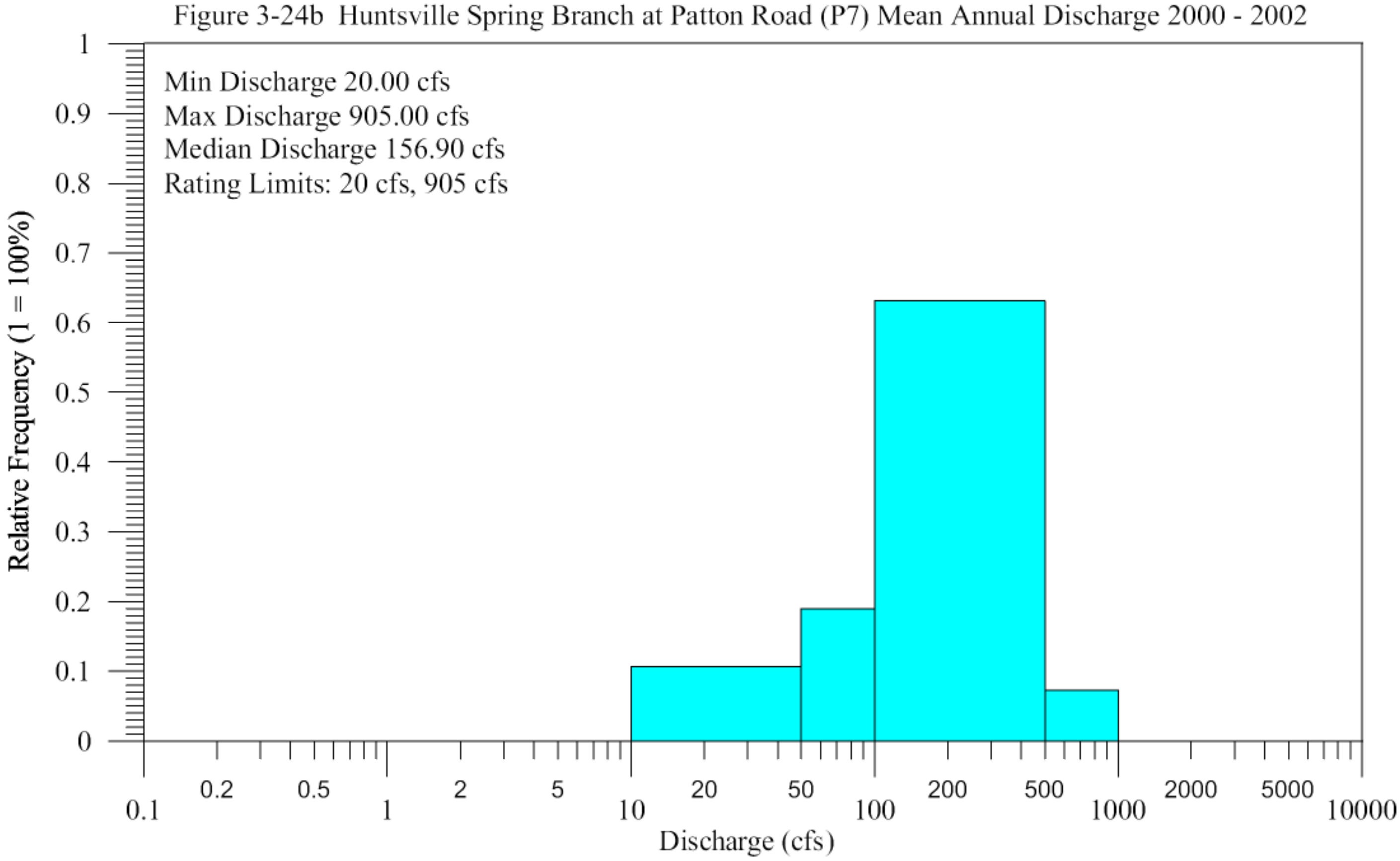
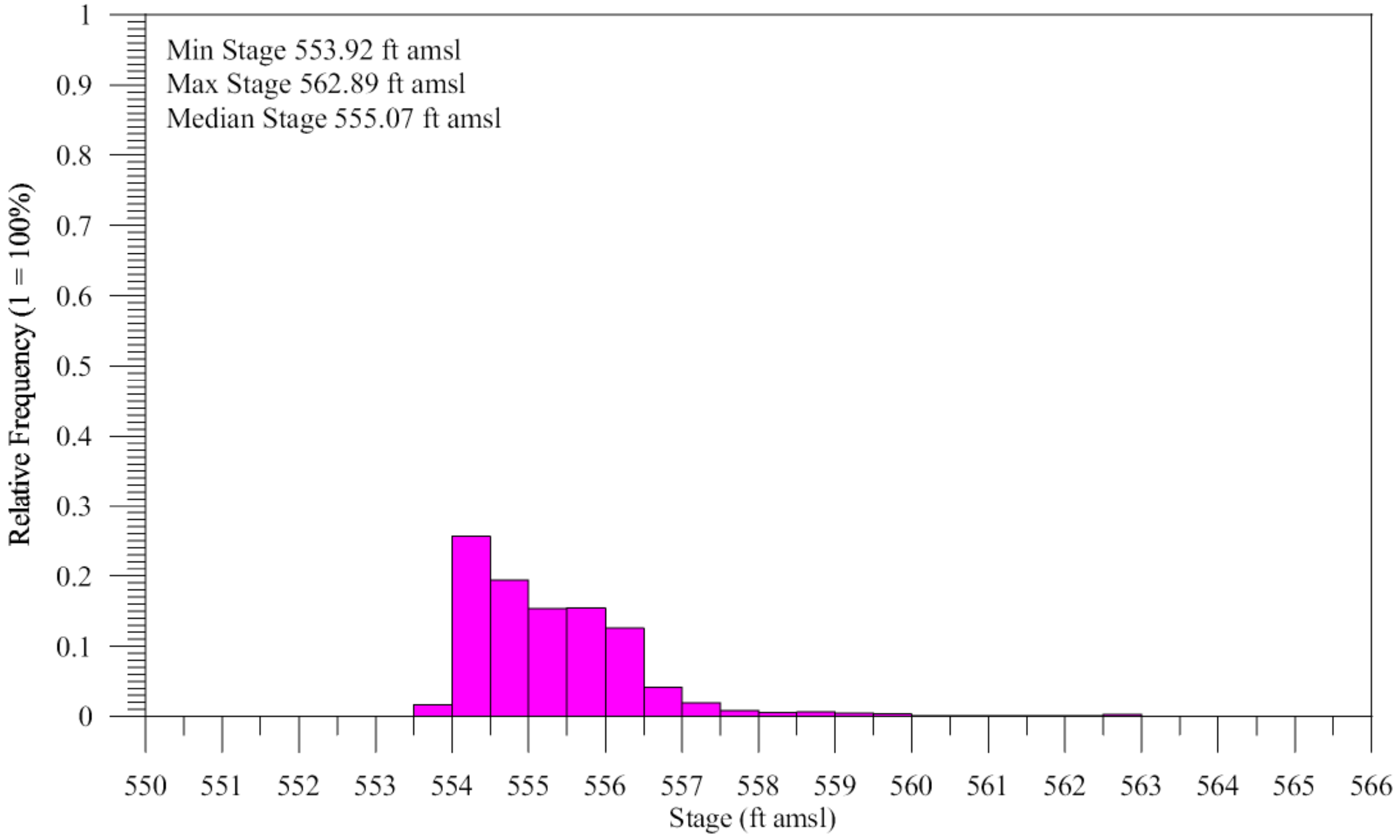


Figure 3-25 Huntsville Spring Branch at Mile 4.85 (HSMN) Mean Annual Stage 2000 - 2002



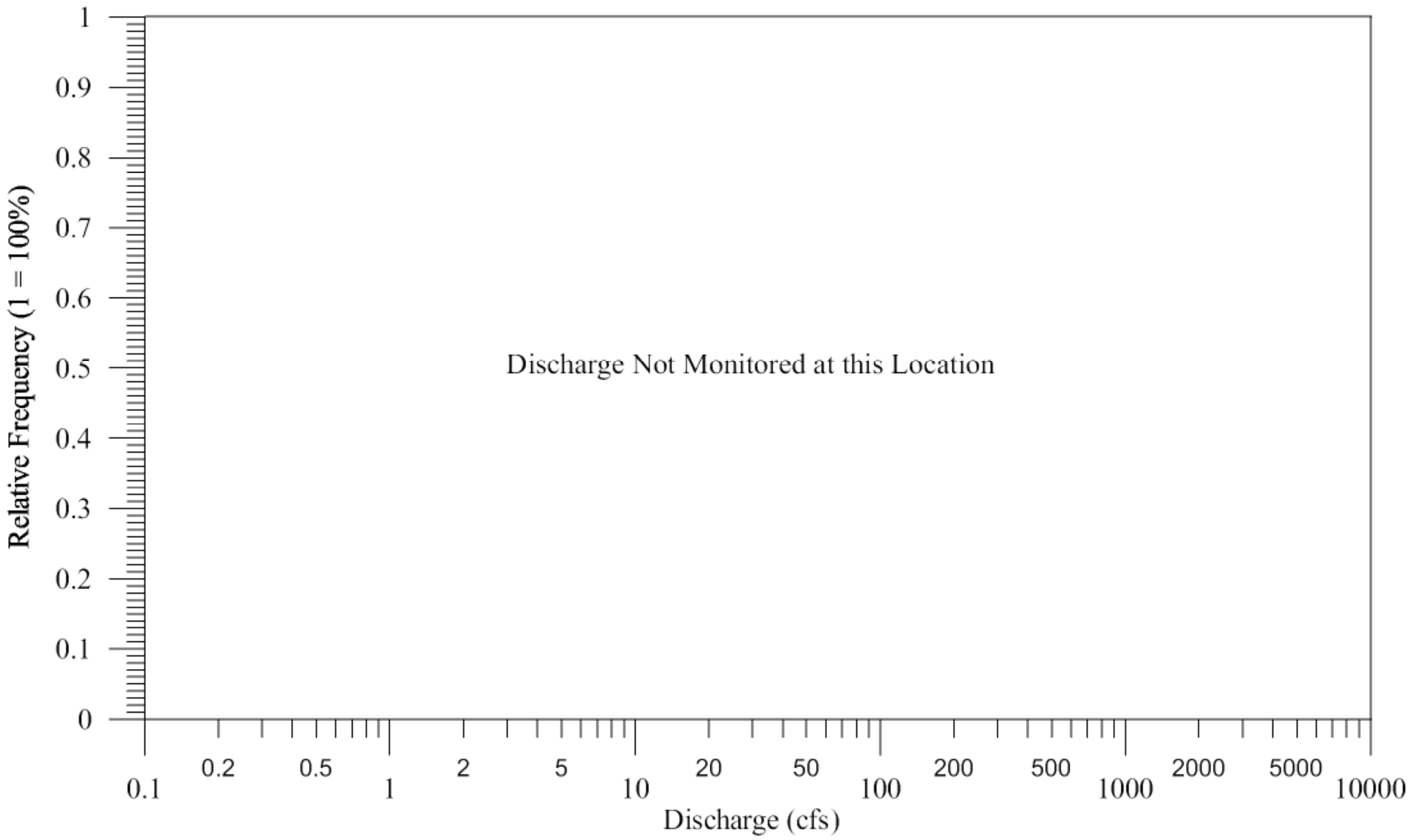
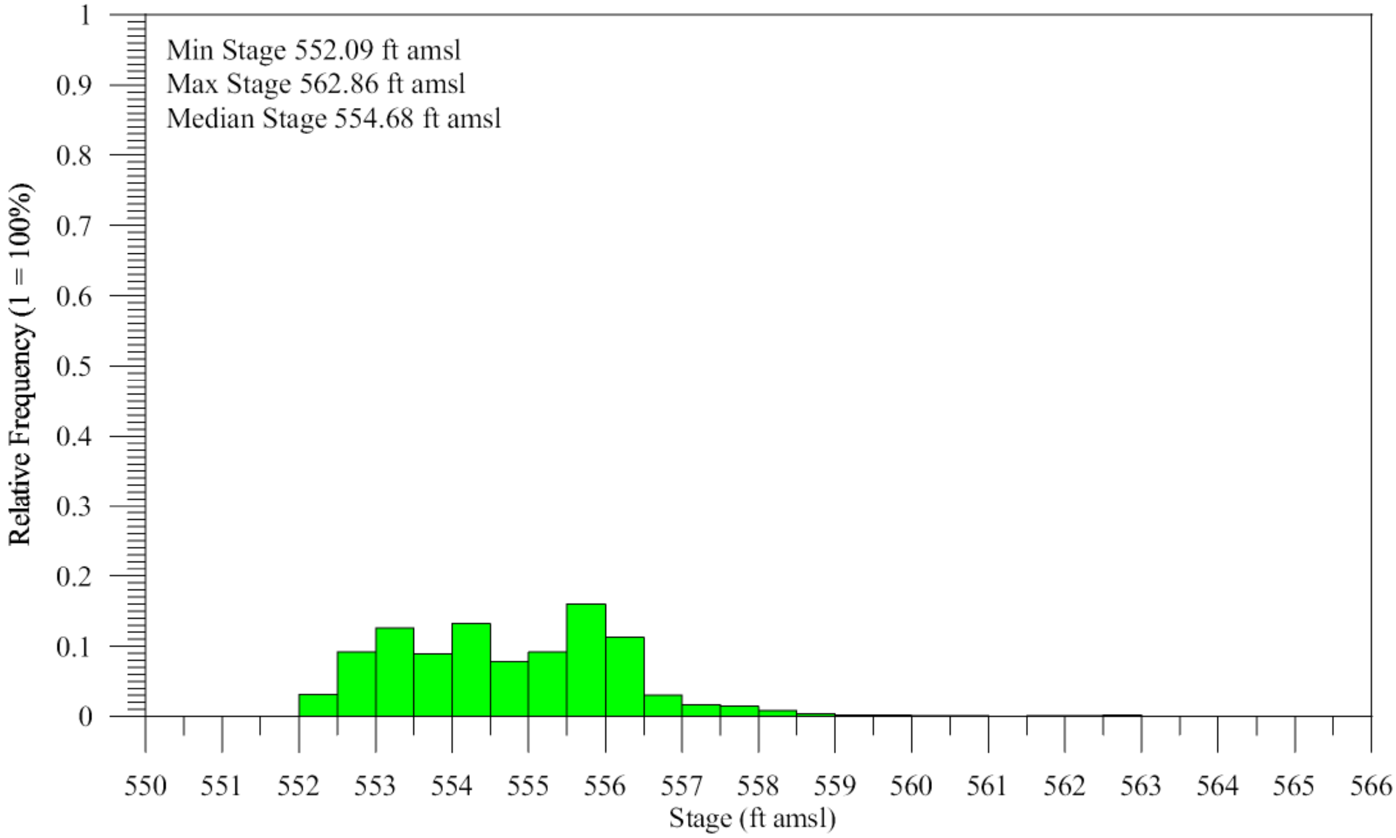


Figure 3-26 Huntsville Spring Branch at Dodd Road (HSDR) Mean Annual Stage 2000 - 2002



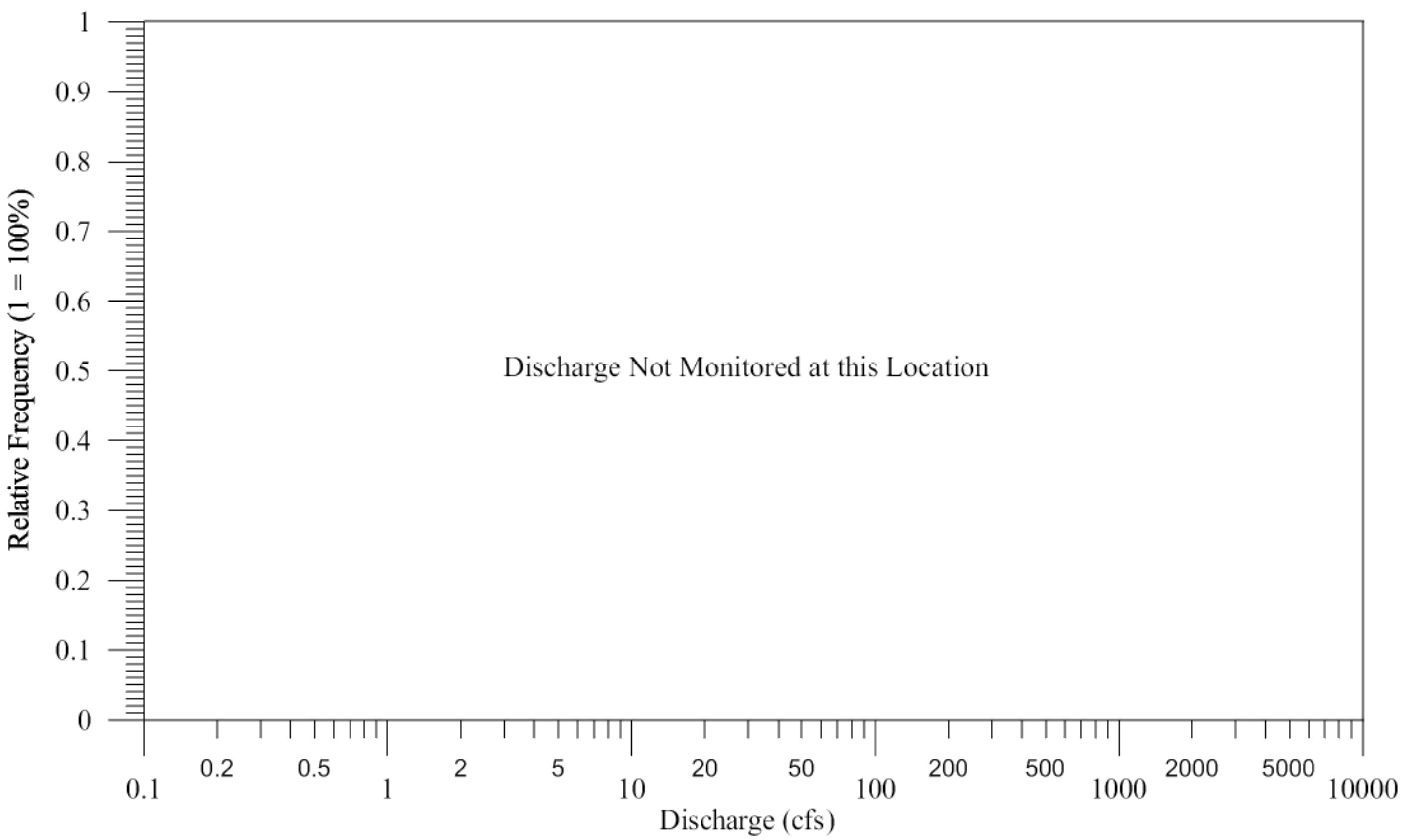


Figure 3-27a Drain Parallel to Huntsville Spring Branch (P3) Mean Annual Stage 2000 - 2002

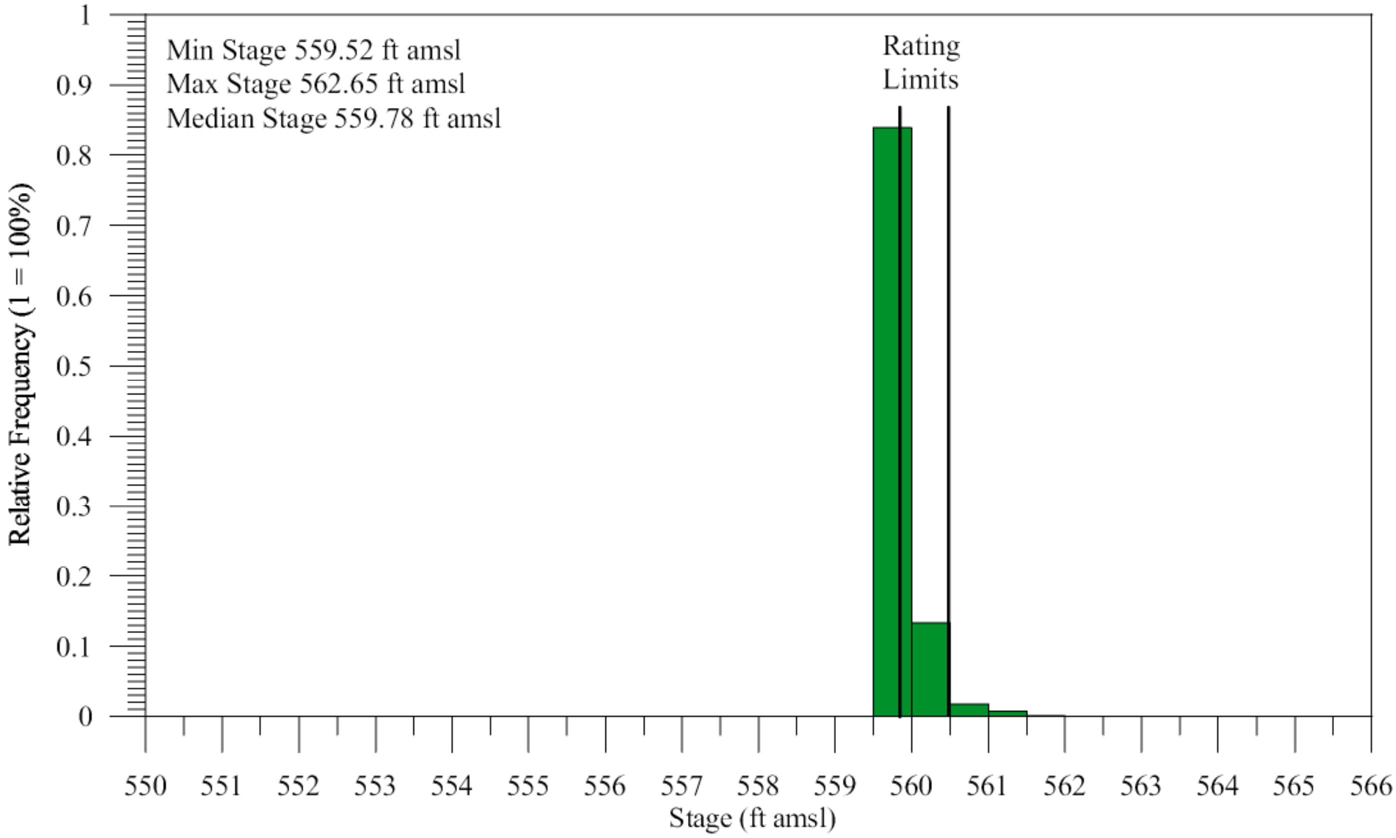


Figure 3-27b Drain Parallel to Huntsville Spring Branch (P3) Mean Annual Discharge 2000 - 2002

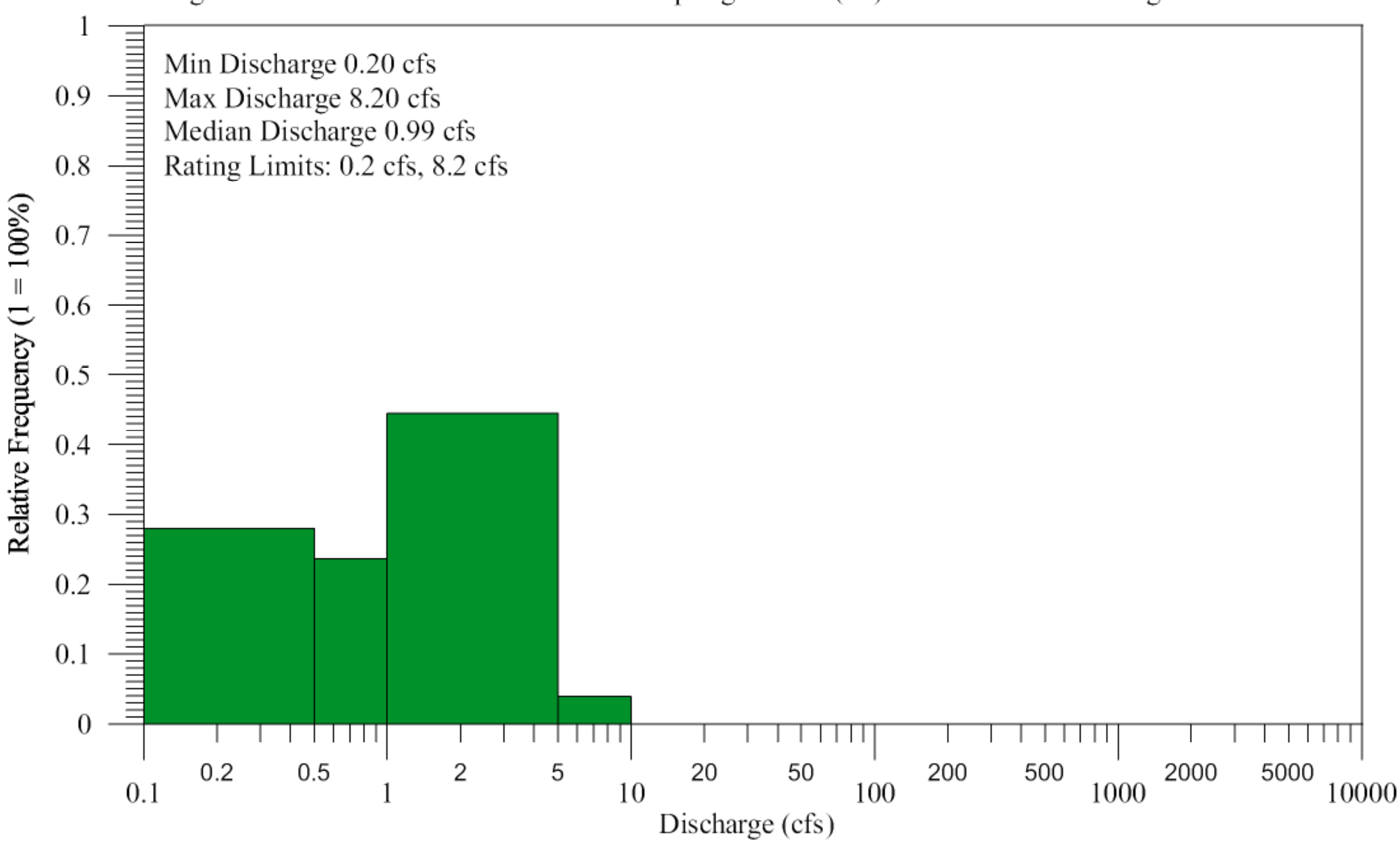


Figure 3-28a Motherlode Swamp Draining to Huntsville Spring Branch (P4) Mean Annual Stage 2000 - 2002

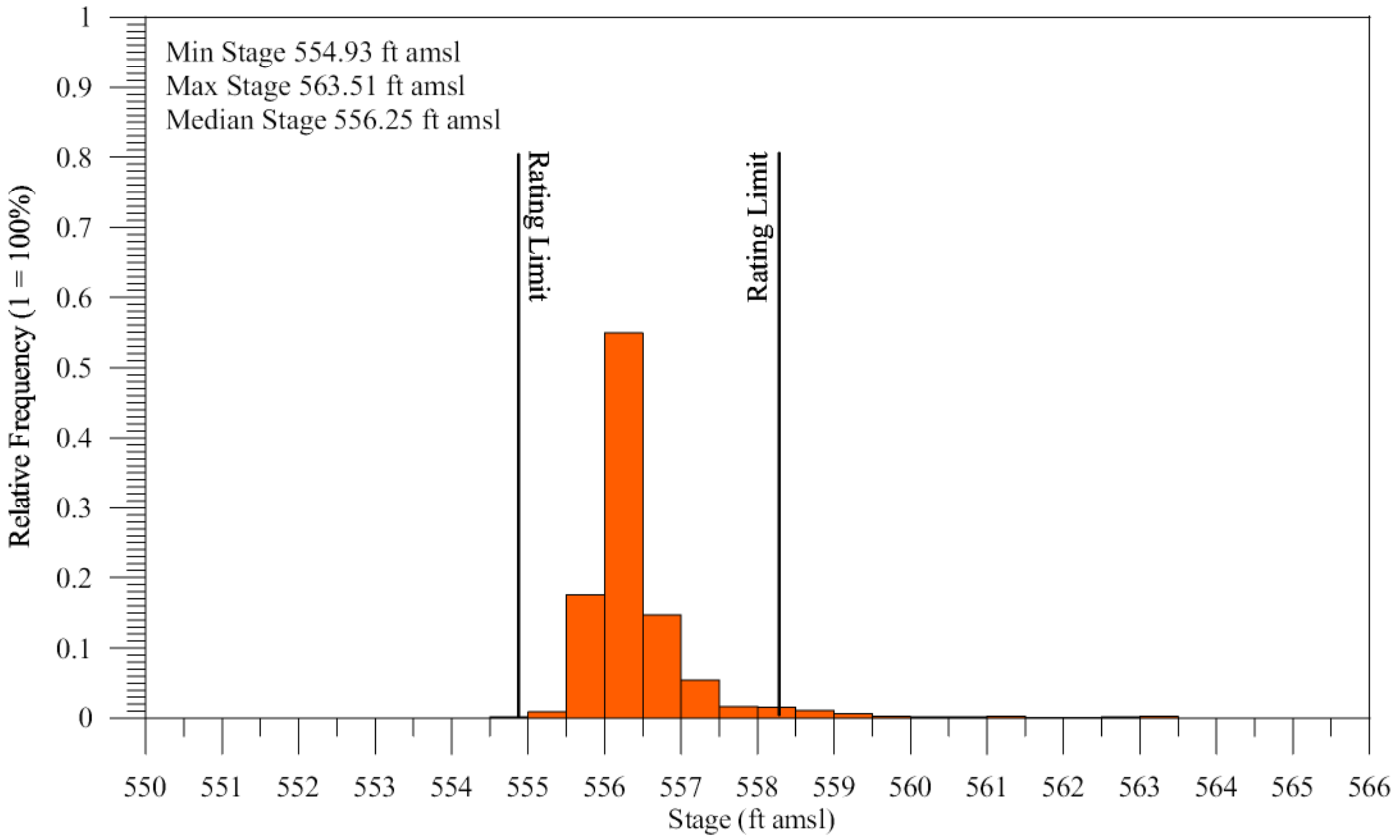


Figure 3-28b Motherlode Swamp Draining to Huntsville Spring Branch (P4) Mean Annual Discharge 2000 - 2002

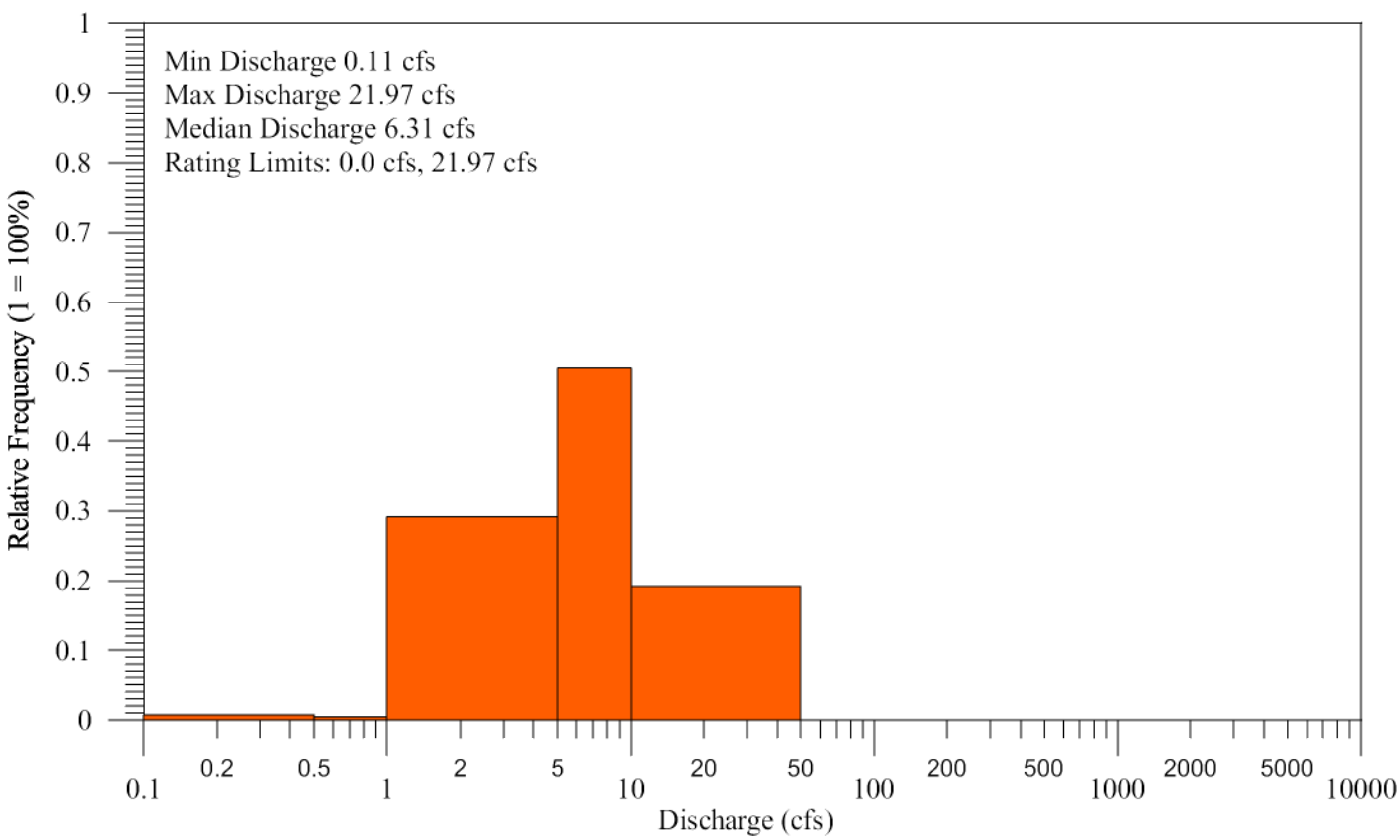


Figure 3-29 Huntsville Spring Branch Hydrologic Data for Water Year 2000

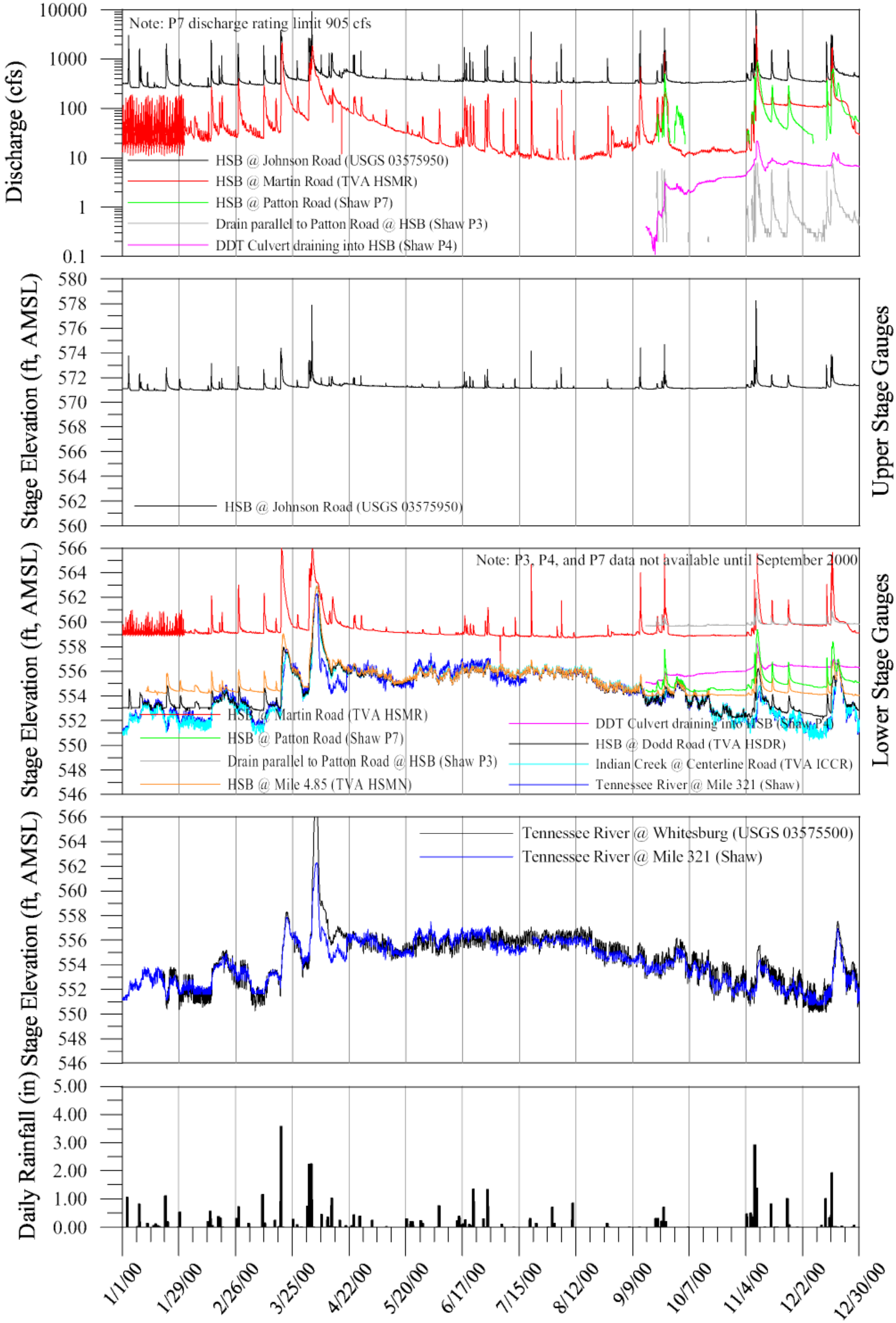


fig3-29_final sw2000hsb.grf

Figure 3-30 Huntsville Spring Branch Hydrologic Data for Water Year 2001

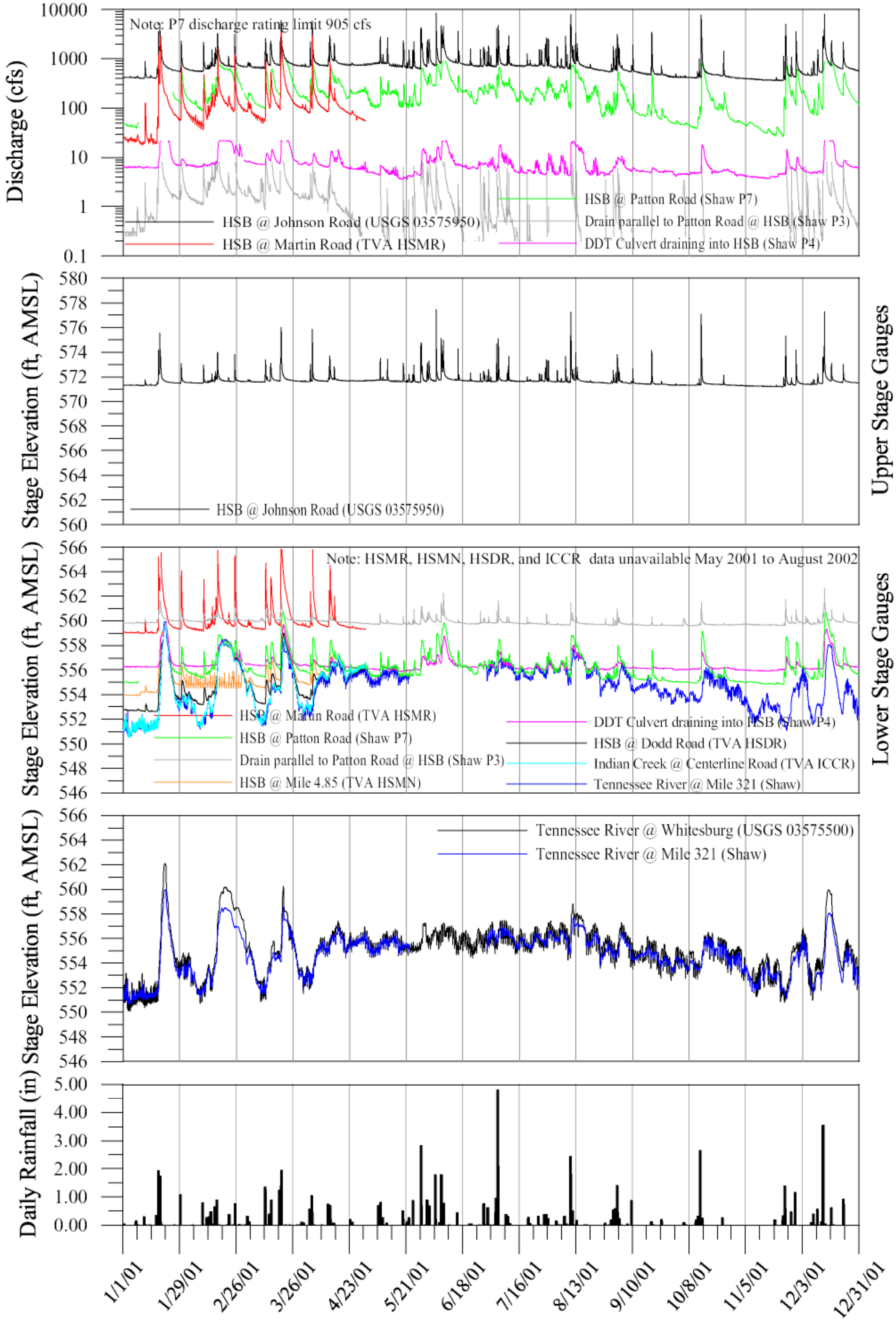


fig3-30_final sw2001hsb.grf

Figure 3-31 Huntsville Spring Branch Hydrologic Data for Water Year 2002

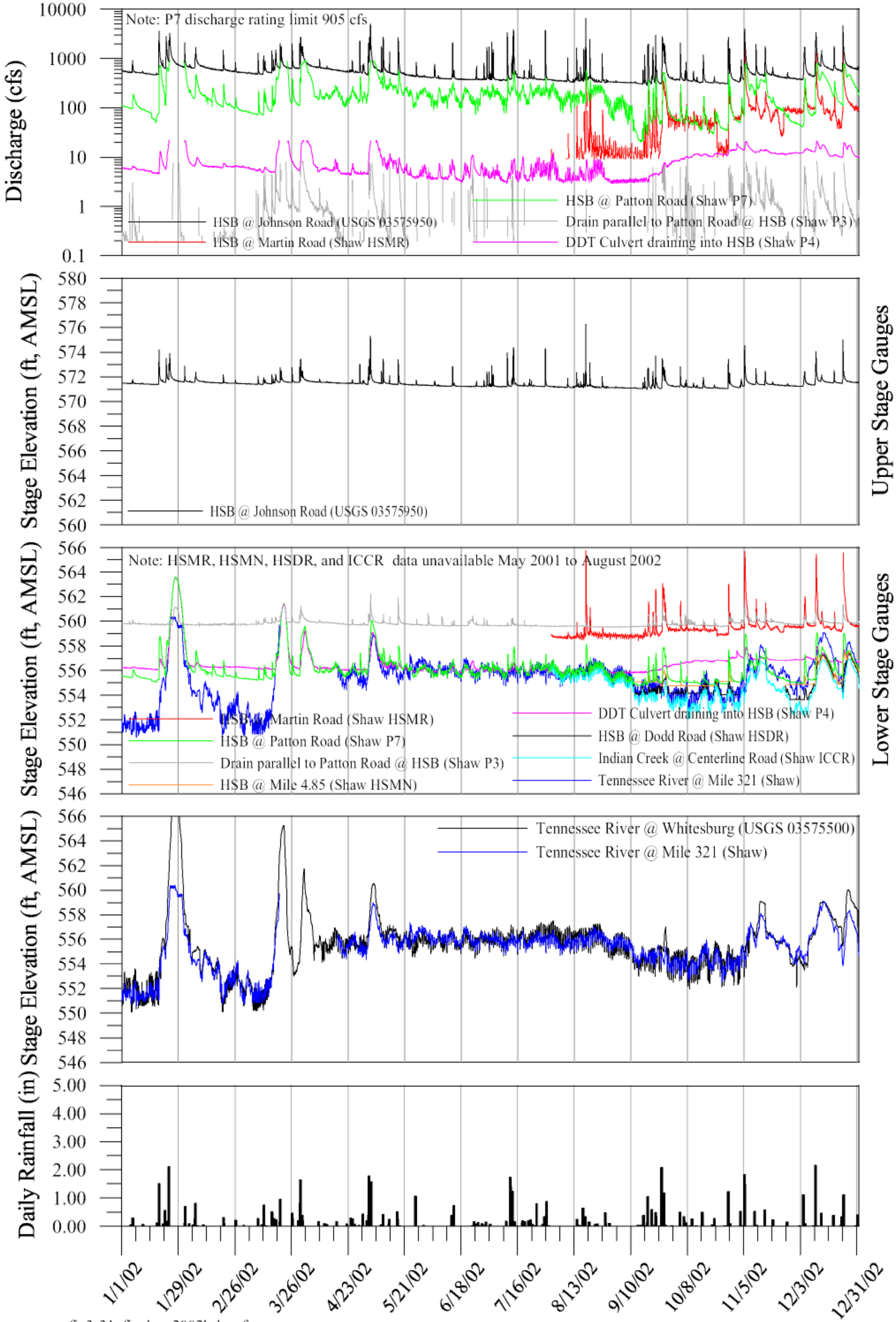


fig3-31_final sw2002hsb.grf

Figure 3-32 Differential Discharge along Huntsville Spring Branch (August 2000 through December 2002)

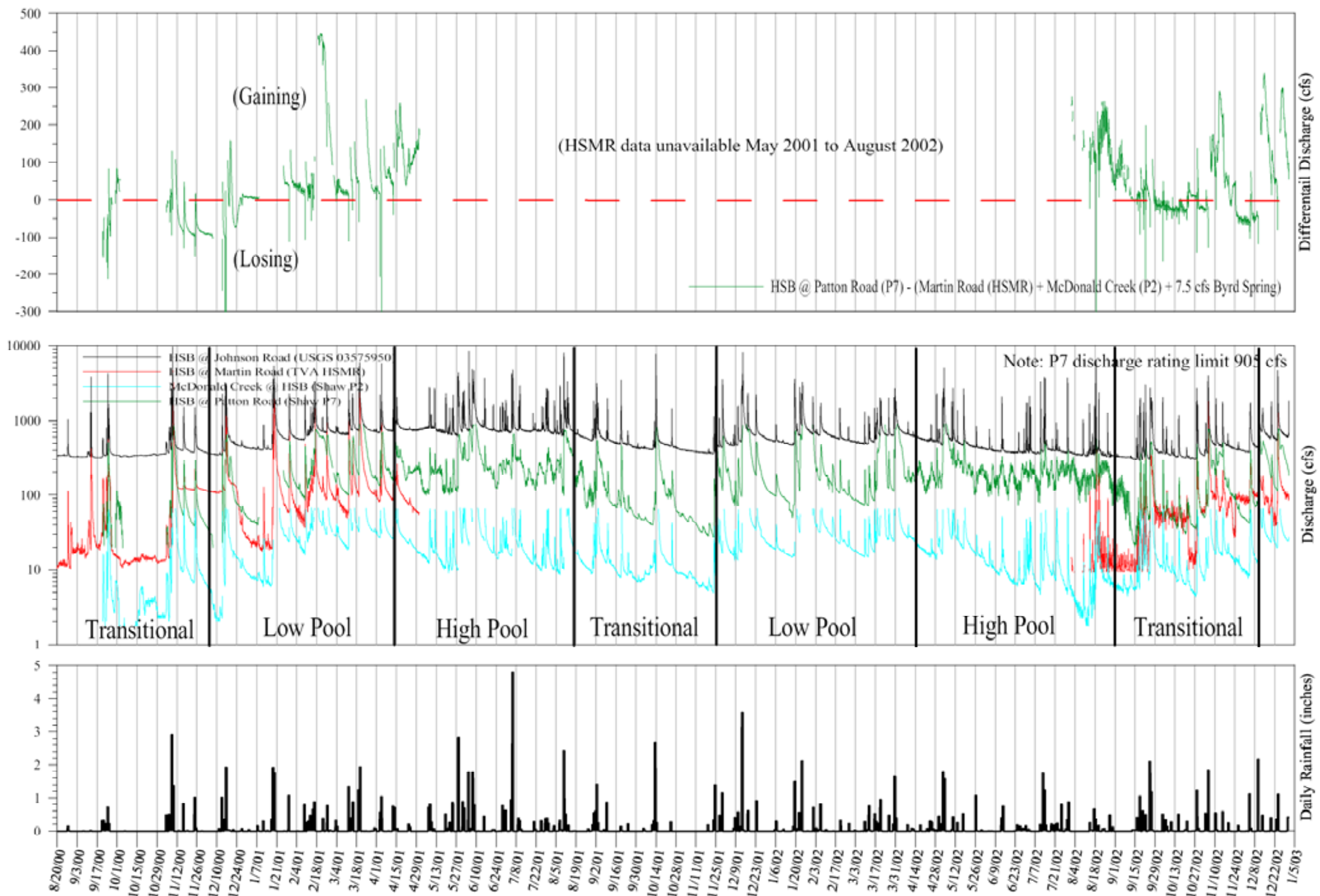


fig3-32_hsb1_dQ_00_03.grf

Figure 3-33 P7 Gauge Gaining vs. Losing in Relation to the Tennessee River

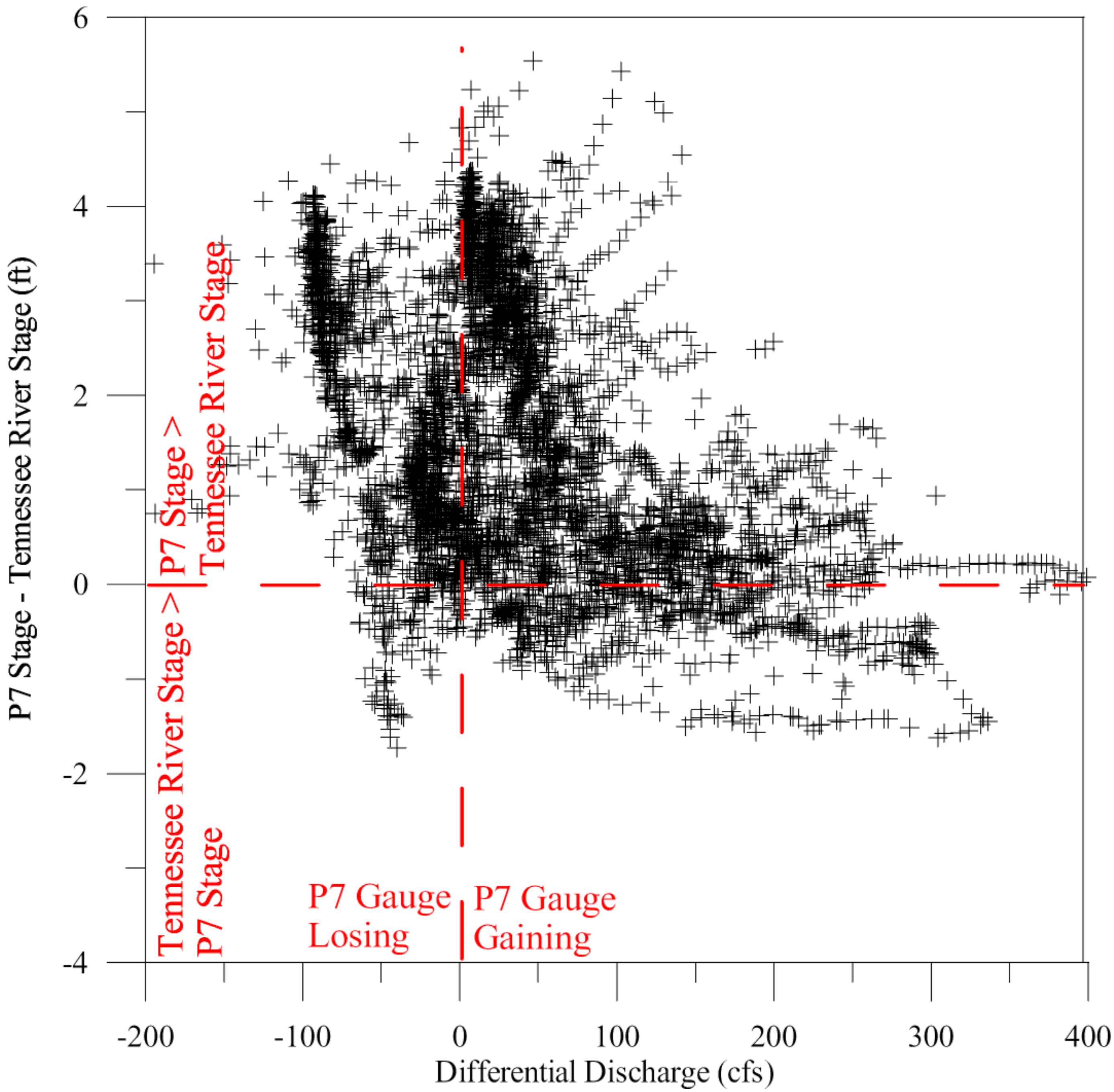


Figure 3-34a Tennessee River at Whitesburg (USGS 03575500) Mean Annual Stage 2000 - 2002

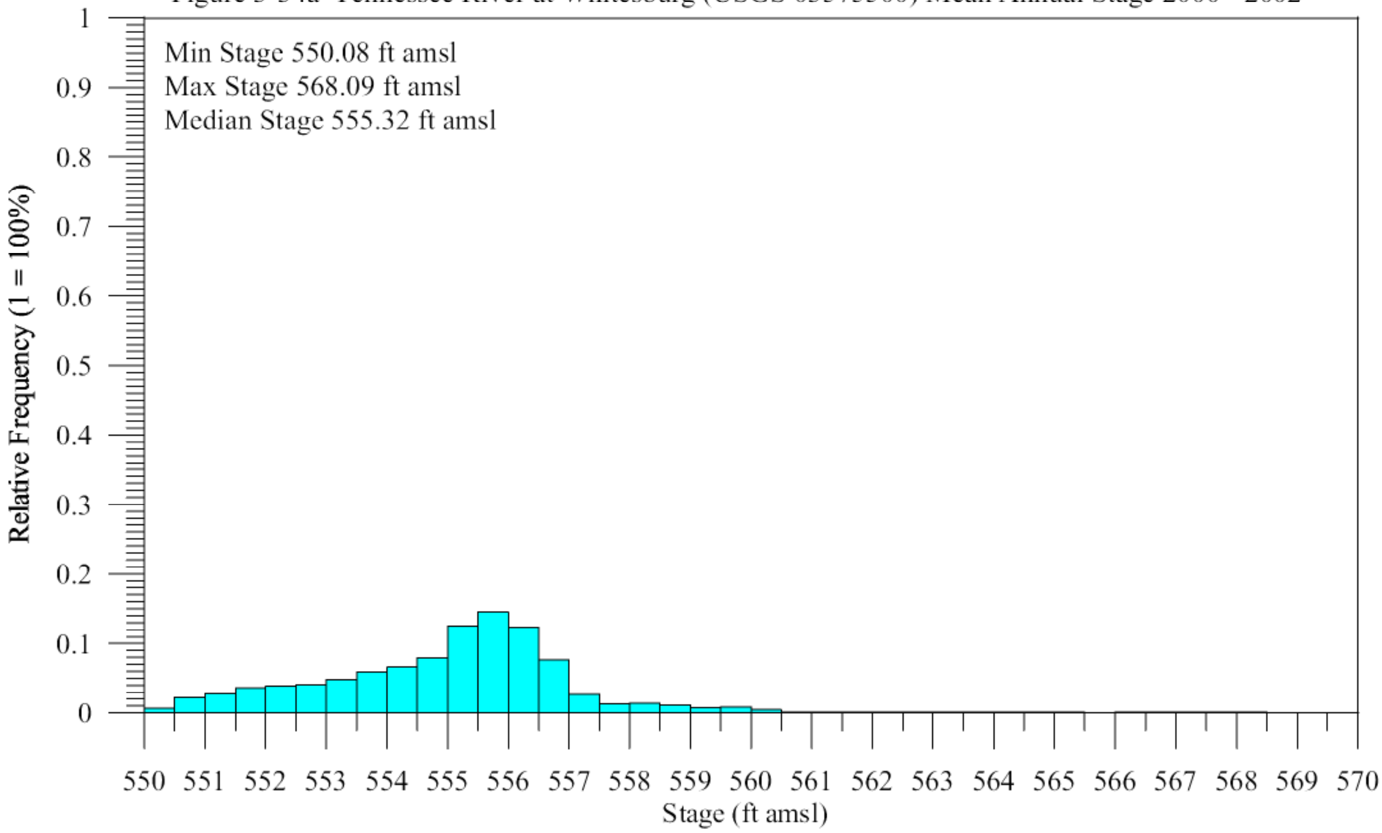


Figure 3-34b Tennessee River at Whitesburg (USGS 03575500) Mean Annual Discharge 2000 - 2002

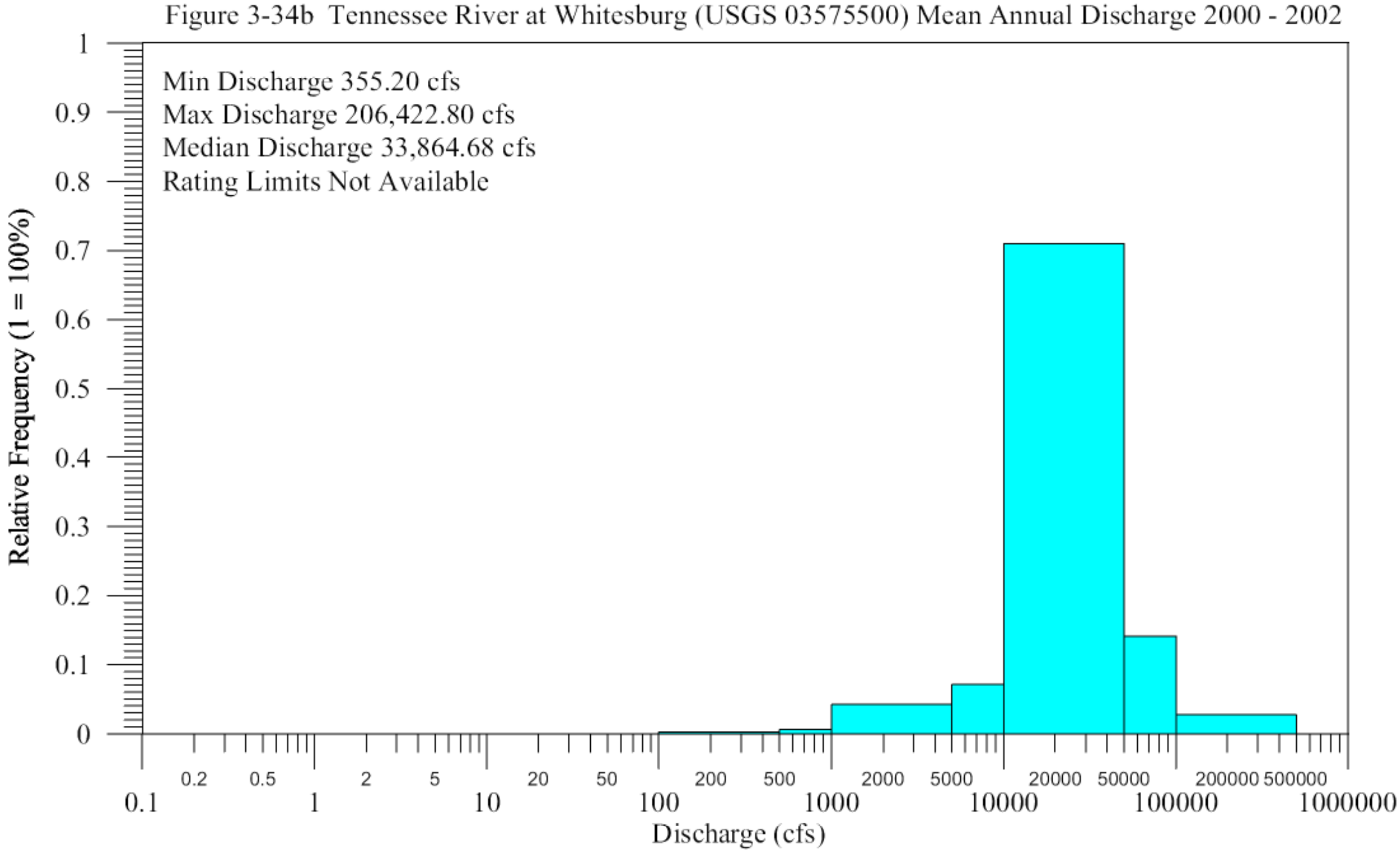
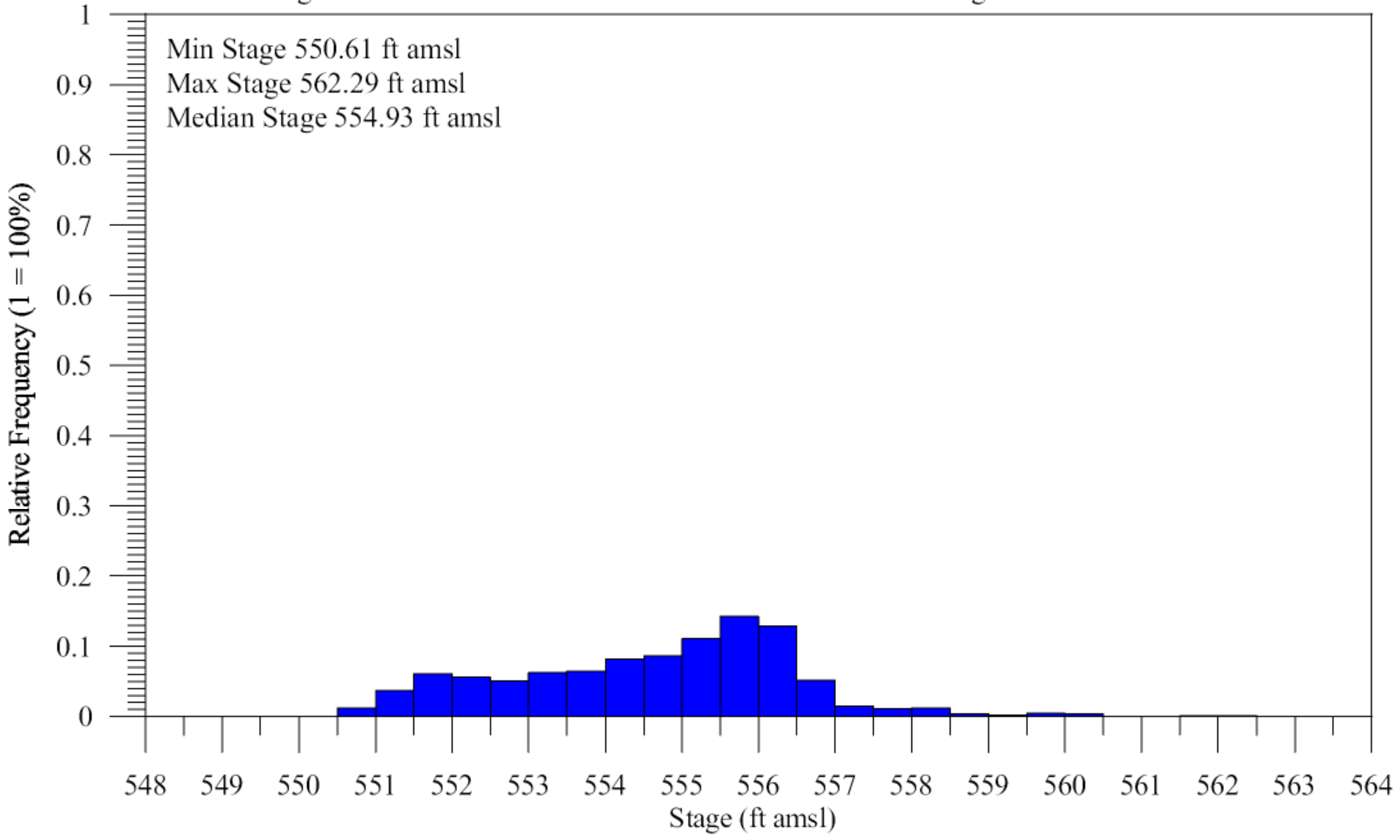


Figure 3-35 Tennessee River at Mile 321 Mean Annual Stage 2000 - 2002



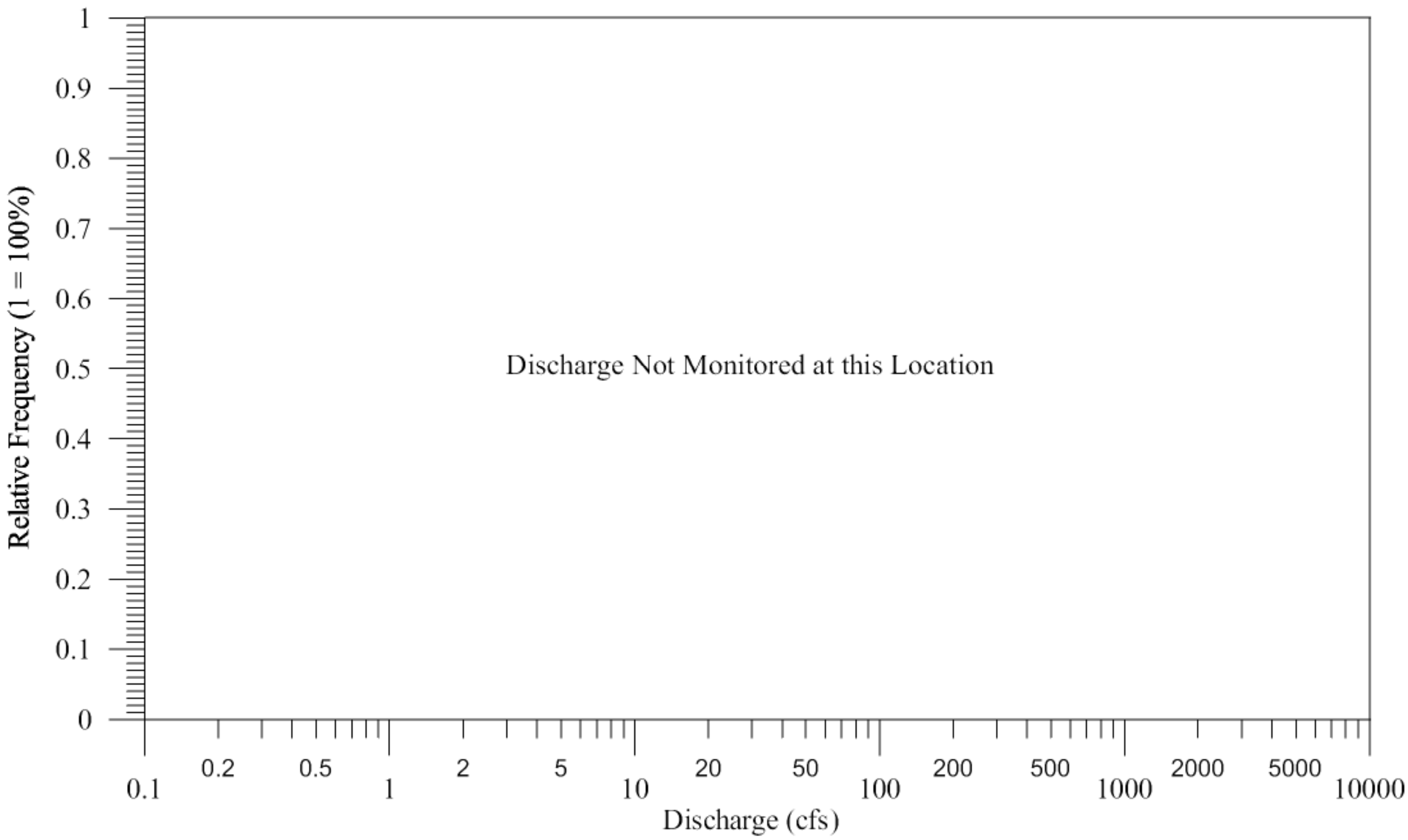


Figure 3-36 Tennessee River Stage and Discharge at Redstone Arsenal (August 2000 through December 2002)

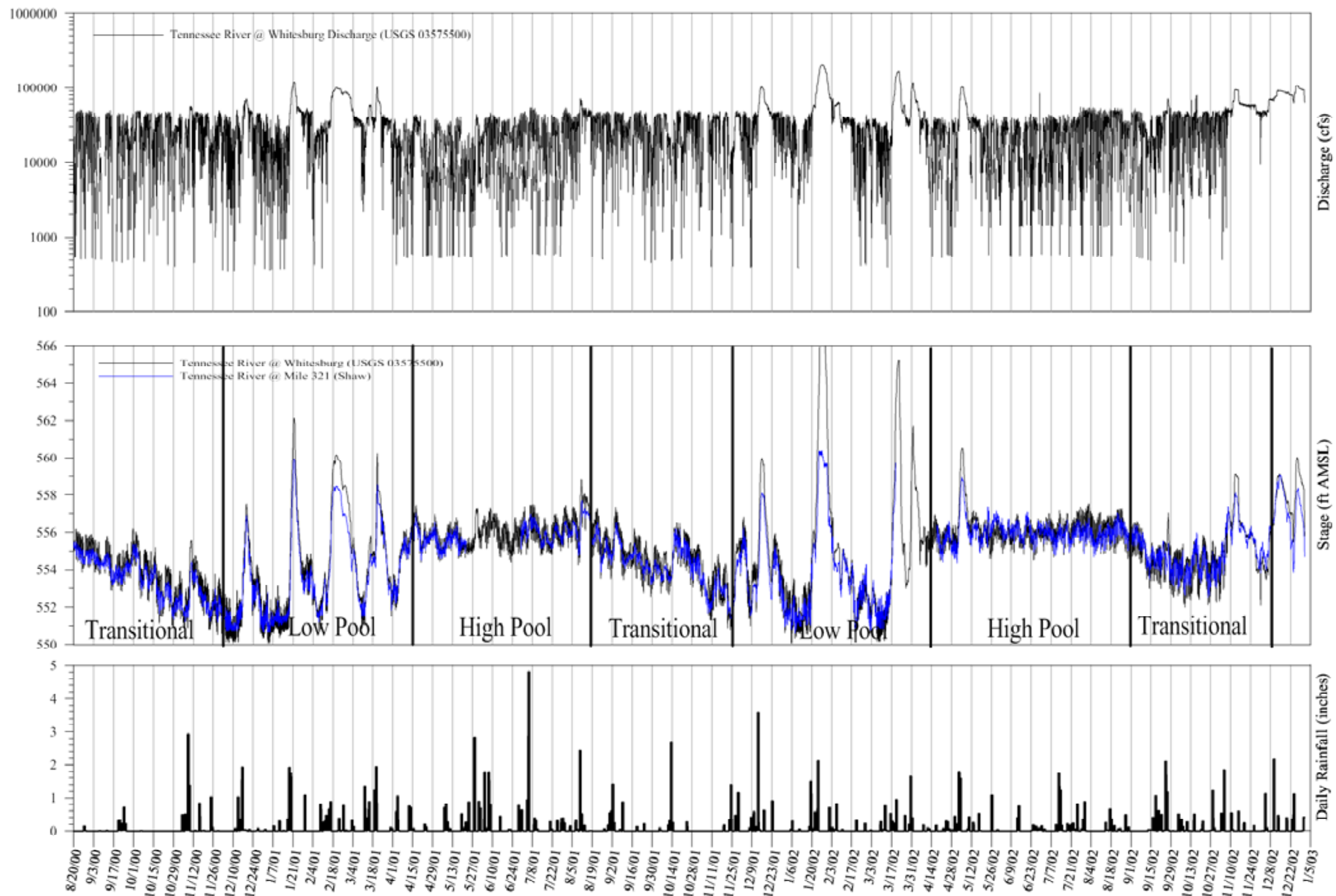


fig3-36_tennR_00_03.grf

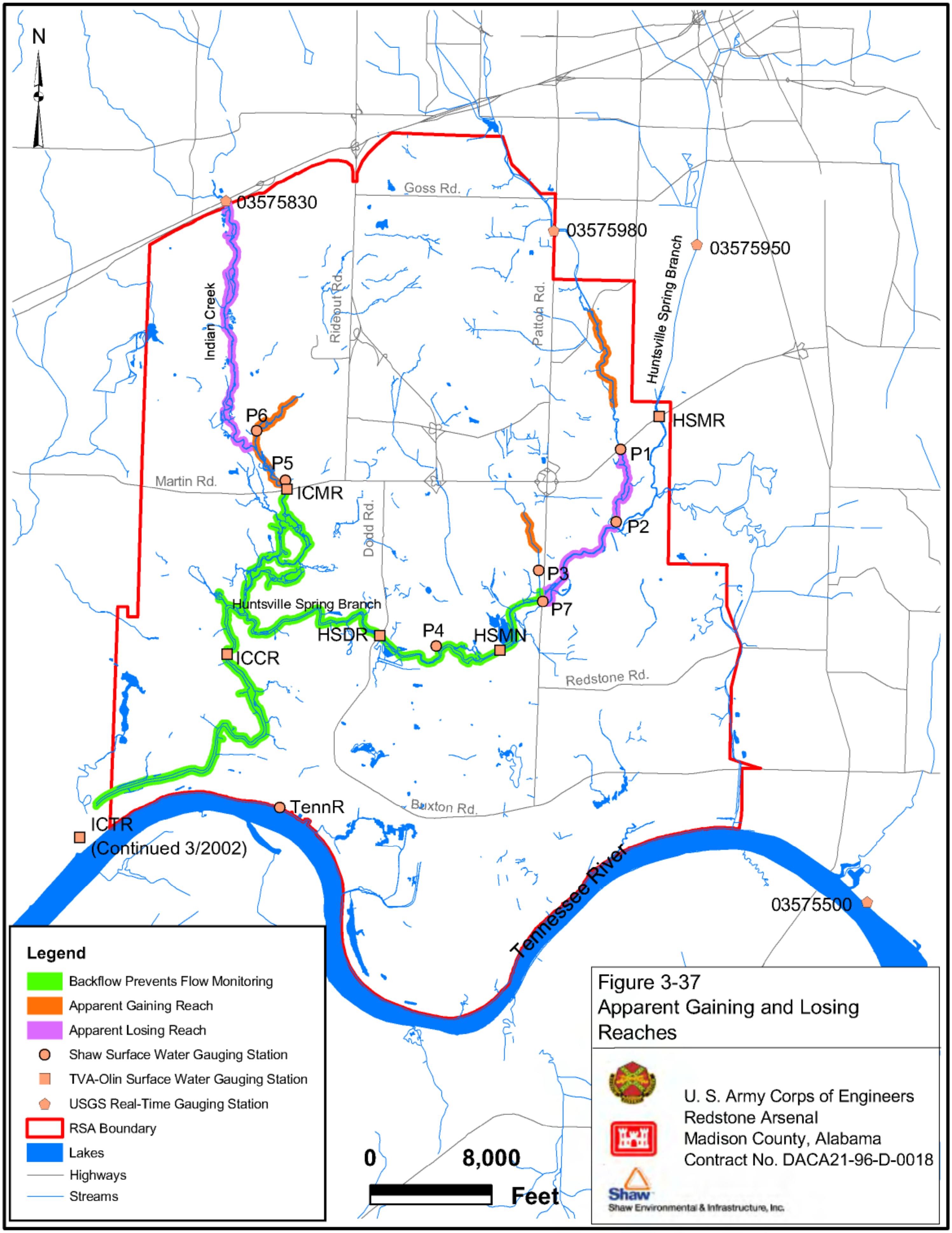


Figure 3-37
Apparent Gaining and Losing Reaches

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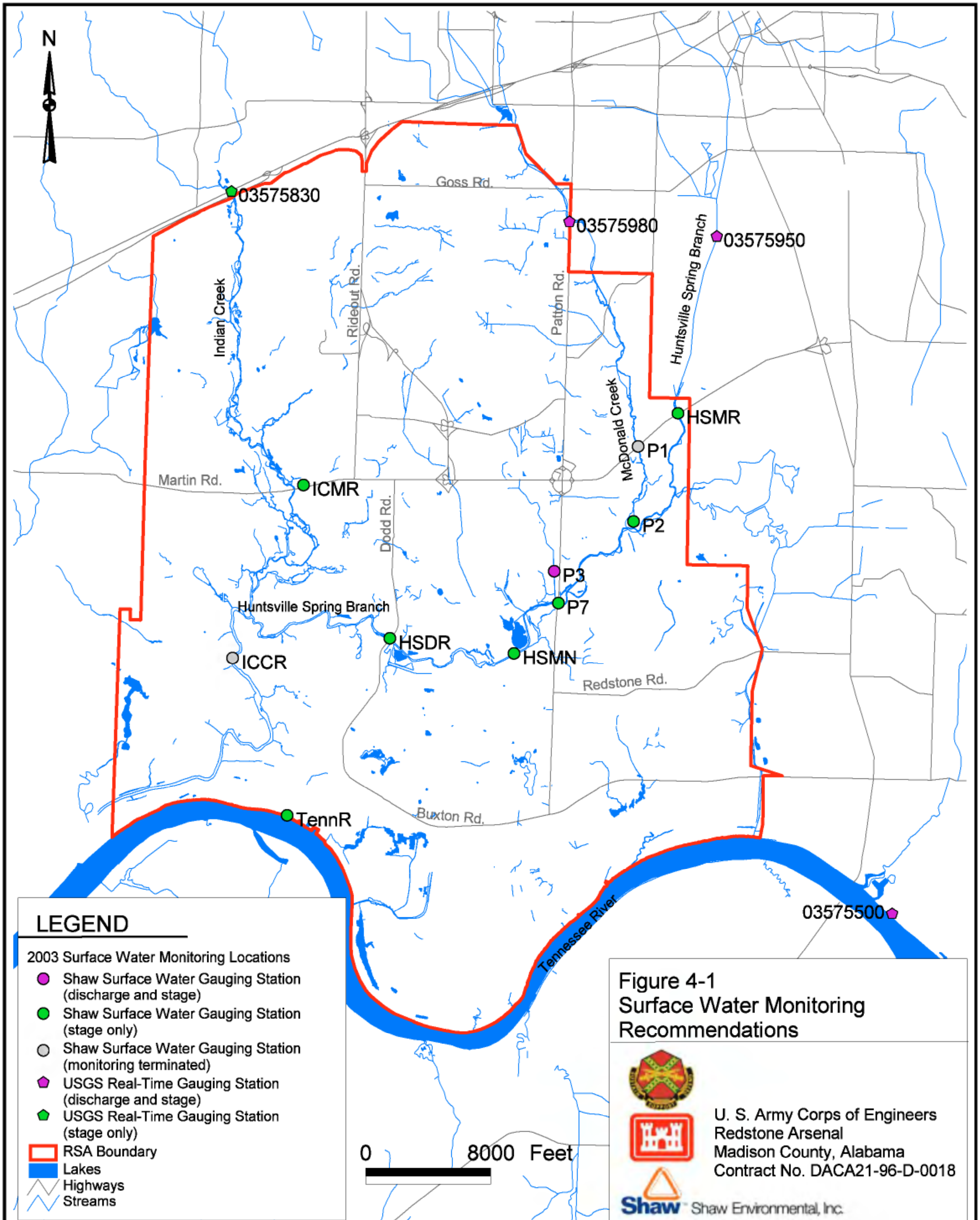

Figure 4-1
Surface Water Monitoring Recommendations

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APPENDIX A

TVA AND SHAW RATING TABLES

05/15/02 14:58

TENNESSEE VALLEY AUTHORITY

#P1 P1 McDonald Creek at Martin Road, AL 2001 WY

Rating Table 1 from 10/01/01 00:05 Scale Offset = -3.61

Provisional Rating

DISCHARGE IN CUBIC FEET PER SECOND

ght	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	1st diff	2nd diff
2.0	4.20*	4.25	4.31	4.36	4.42	4.48	4.53	4.59	4.65	4.71	.568	
2.1	4.77	4.83	4.89	4.95	5.01	5.08	5.14	5.20	5.27	5.33	.632	.065
2.2	5.40*	5.48	5.55	5.63	5.71	5.79	5.87	5.95	6.03	6.12	.800	.168
2.3	6.20*	6.28	6.35	6.43	6.51	6.59	6.67	6.75	6.83	6.92	.800	0
2.4	7.00*	7.09	7.17	7.26	7.35	7.44	7.53	7.62	7.71	7.81	.900	.100
2.5	7.90*	8.00	8.11	8.22	8.32	8.43	8.54	8.66	8.77	8.88	1.10	.200
2.6	9.00*	9.11	9.23	9.35	9.46	9.58	9.70	9.83	9.95	10.1	1.20	.100
2.7	10.2*	10.3	10.4	10.6	10.7	10.8	11.0	11.1	11.2	11.4	1.30	.100
2.8	11.5*	11.7	11.8	12.0	12.1	12.3	12.4	12.6	12.8	12.9	1.60	.300
2.9	13.1*	13.3	13.5	13.6	13.8	14.0	14.2	14.4	14.6	14.8	1.90	.300
3.0	15.0*	15.2	15.4	15.6	15.7	15.9	16.1	16.3	16.5	16.7	1.93	.030
3.1	16.9	17.1	17.3	17.5	17.8	18.0	18.2	18.4	18.6	18.8	2.14	.214
3.2	19.1	19.3	19.5	19.8	20.0	20.2	20.5	20.7	21.0	21.2	2.38	.234
3.3	21.5	21.7	22.0	22.2	22.5	22.7	23.0	23.3	23.5	23.8	2.63	.256
3.4	24.1	24.4	24.6	24.9	25.2	25.5	25.8	26.1	26.4	26.7	2.91	.279
3.5	27.0*	27.3	27.6	27.9	28.2	28.5	28.8	29.2	29.5	29.8	3.12	.211
3.6	30.1	30.5	30.8	31.1	31.5	31.8	32.1	32.5	32.8	33.2	3.44	.311
3.7	33.6	33.9	34.3	34.7	35.0	35.4	35.8	36.2	36.5	36.9	3.77	.337
3.8	37.3	37.7	38.1	38.5	38.9	39.4	39.8	40.2	40.6	41.0	4.14	.365
3.9	41.5	41.9	42.3	42.8	43.2	43.7	44.1	44.6	45.1	45.5	4.53	.394
4.0	46.0*	46.5	47.0	47.5	47.9	48.4	48.9	49.4	50.0	50.5	4.99	.460
4.1	51.0	51.5	52.0	52.6	53.1	53.7	54.2	54.8	55.3	55.9	5.46	.467
4.2	56.4	57.0	57.6	58.2	58.8	59.4	60.0	60.6	61.2	61.8	5.96	.503
4.3	62.4	63.0	63.7	64.3	64.9	65.6	66.2	66.9	67.6	68.2	6.50	.542
4.4	68.9	69.6	70.3	71.0	71.7	72.4	73.1	73.8	74.5	75.3	7.09	.584
4.5	76.0*	76.7	77.5	78.3	79.0	79.8	80.6	81.3	82.1	82.9	7.74	.650
4.6	83.7	84.5	85.4	86.2	87.0	87.9	88.7	89.6	90.4	91.3	8.42	.679
4.7	92.2	93.0	93.9	94.8	95.7	96.6	97.6	98.5	99.4	100.4	9.15	.730

Station P1
Rating #: 1
Page 2

ght	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	1st diff	2nd diff
4.8	101.3	102.3	103.2	104.2	105.2	106.2	107.2	108.2	109.2	110.2	9.93	.783
4.9	111.2	112.3	113.3	114.4	115.4	116.5	117.6	118.7	119.8	120.9	10.8	.840
5.0	122.0*											

* skeletal rating point

05/15/02 14:59

TENNESSEE VALLEY AUTHORITY

#P2 McDonald Creek near mouth at Huntsville Spring Branch 2001 WY

Rating Table 1 from 10/01/01 00:05 Scale Offset = 0.60

Provisional Rating

DISCHARGE IN CUBIC FEET PER SECOND

ght	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	1st diff	2nd diff
0.7	1.80*	2.02	2.25	2.48	2.72	2.95	3.20	3.44	3.69	3.94	2.40	
0.8	4.20*	4.44	4.69	4.93	5.18	5.43	5.68	5.93	6.19	6.44	2.50	.100
0.9	6.70*	6.96	7.21	7.47	7.73	7.99	8.25	8.51	8.77	9.04	2.60	.100
1.0	9.30*	9.57	9.83	10.1	10.4	10.6	10.9	11.2	11.5	11.7	2.70	.100
1.1	12.0*	12.3	12.6	12.9	13.2	13.5	13.8	14.1	14.4	14.7	3.00	.300
1.2	15.0*	15.3	15.6	15.9	16.2	16.4	16.7	17.0	17.3	17.6	2.90	-.100
1.3	17.9*	18.2	18.5	18.7	19.0	19.3	19.6	19.9	20.1	20.4	2.80	-.100
1.4	20.7*	21.0	21.3	21.6	21.9	22.2	22.6	22.9	23.2	23.5	3.10	.300
1.5	23.8*	24.1	24.4	24.7	25.0	25.3	25.7	26.0	26.3	26.6	3.10	-0
1.6	26.9*	27.2	27.5	27.8	28.1	28.4	28.8	29.1	29.4	29.7	3.10	0
1.7	30.0*	30.3	30.6	30.9	31.2	31.5	31.9	32.2	32.5	32.8	3.10	0
1.8	33.1*	33.4	33.8	34.1	34.5	34.8	35.1	35.5	35.8	36.2	3.40	.300
1.9	36.5*	36.8	37.1	37.5	37.8	38.1	38.4	38.7	39.1	39.4	3.20	-.200
2.0	39.7*	40.0	40.4	40.7	41.0	41.3	41.7	42.0	42.3	42.7	3.30	.100
2.1	43.0*	43.3	43.6	44.0	44.3	44.6	44.9	45.2	45.6	45.9	3.20	-.100
2.2	46.2*	46.5	46.8	47.1	47.4	47.7	48.0	48.3	48.6	48.9	3.00	-.200
2.3	49.2*	49.6	50.0	50.3	50.7	51.1	51.5	51.9	52.2	52.6	3.80	.800
2.4	53.0*	53.3	53.7	54.0	54.4	54.7	55.1	55.4	55.8	56.1	3.50	-.300
2.5	56.5*	56.8	57.2	57.5	57.9	58.2	58.6	58.9	59.3	59.6	3.50	0
2.6	60.0*	60.3	60.7	61.0	61.4	61.7	62.1	62.4	62.8	63.1	3.50	0
2.7	63.5*	63.8	64.2	64.5	64.9	65.2	65.6	65.9	66.3	66.6	3.50	0
2.8	67.0*											

* skeletal rating point

05/15/02 14:59

TENNESSEE VALLEY AUTHORITY

#P3 P3 Unnamed Tributary to Huntsville Spring Branch 2001 WY

Rating Table 1 from 10/01/01 00:05 Scale Offset = 0.43

Provisional Rating

DISCHARGE IN CUBIC FEET PER SECOND

ght	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	1st diff	2nd diff
0.5	.200*	.249	.301	.358	.418	.482	.549	.619	.693	.770	.650	
0.6	.850*	.919	.990	1.06	1.13	1.21	1.29	1.36	1.44	1.52	.750	.100
0.7	1.60*	1.69	1.78	1.87	1.96	2.06	2.15	2.25	2.35	2.45	.950	.200
0.8	2.55*	2.66	2.77	2.88	2.99	3.11	3.22	3.34	3.46	3.58	1.15	.200
0.9	3.70*	3.82	3.95	4.08	4.20	4.33	4.46	4.60	4.73	4.86	1.30	.150
1.0	5.00*	5.14	5.29	5.43	5.58	5.73	5.88	6.03	6.19	6.34	1.50	.200
1.1	6.50*	6.66	6.83	6.99	7.16	7.33	7.50	7.67	7.85	8.02	1.70	.200
1.2	8.20*											

* skeletal rating point

I. Purpose: To determine the discharge (Q) from a circular culvert south of the DDT Abatement Area.

II. Methodology:

The Manning Equation is the most commonly used equation to analyze open channel flows. It is a semi-emperical equation for simulating flows in channels and culverts where the water is open to the atmosphere. The units in the Manning equation appear to be inconsistent; however, the value k has hidden units in it to make the equation consistent. The Manning Equation was developed for uniform steady state flow. Uniform means that the channel is prismatic. Prismatic means the channel has constant dimensions along its length. Steady state means that flowrate, velocity, and everything elese are constant with time. In reality, no flow can be uniform and steady. However, for individual channel reaches the assumption may be fairly well achieved.

III. Background: An exit point for the motherload spring system is a circular culvert. This circular culvert is being monitored as part of the surface water monitoring program and is referred as station P4. The amount of discharge from the motherload spring system can be estimated from the Manning Equation along with the stage height (or gauge height).

IV. Calculation Methods: Manning Equation is:

V= (k/n)*R^(2/3)*S^(1/2)

Where V = Velocity
k = conversion factor (for english units it is 1.486)
R = Hydraulic radius of the flow cross-section
S = Slope of culvert or water surface
n = Manning coefficient. n is a function of the culvert material.

The hydraulic radius of a pipe flowing full is:

R = D/4

Where D = diameter of culvert.

Discharge is:

Q=V*A

Where Q = Discharge
V = Velocity
A = Area

Circular channel discharge ratios were determined from Table 1 to determine the discharge of the channel from its stage height.

V. Assumptions: The assumptions for the culvert at P4 are as follows:

1. The diameter of the culvert is symetric (no deformation). Therefore, the diameter is 3.6 feet.
2. The slope of culvert is 0.001.
3. A constant manning roughness coefficent for corregated steel pipe, one that does not vary with depth.

VI. Summary of Results:

R = 0.9 feet
n for corregated steel pipe = 0.022
S = 0.001
Velocity of the water when the culvert is full = 1.9911
Discharge of water when the culvert is full (Q_{full}) = 20.2660
Table 1 determined discharge Ratios
Discharge was determined from knowing Q_{full} and the ratio of Q/Q_{full} and is listed in Table 2.

VII. Attachments:

Table 1 - Circular Channel Ratios
Table 2 - Discharge data for P4

Table 1

Circular Channel Ratios

Experiments have shown that n varies slightly with depth. This figure gives velocity and flow rate ratios for varying n (solid line) and constant n (broken line) assumptions.

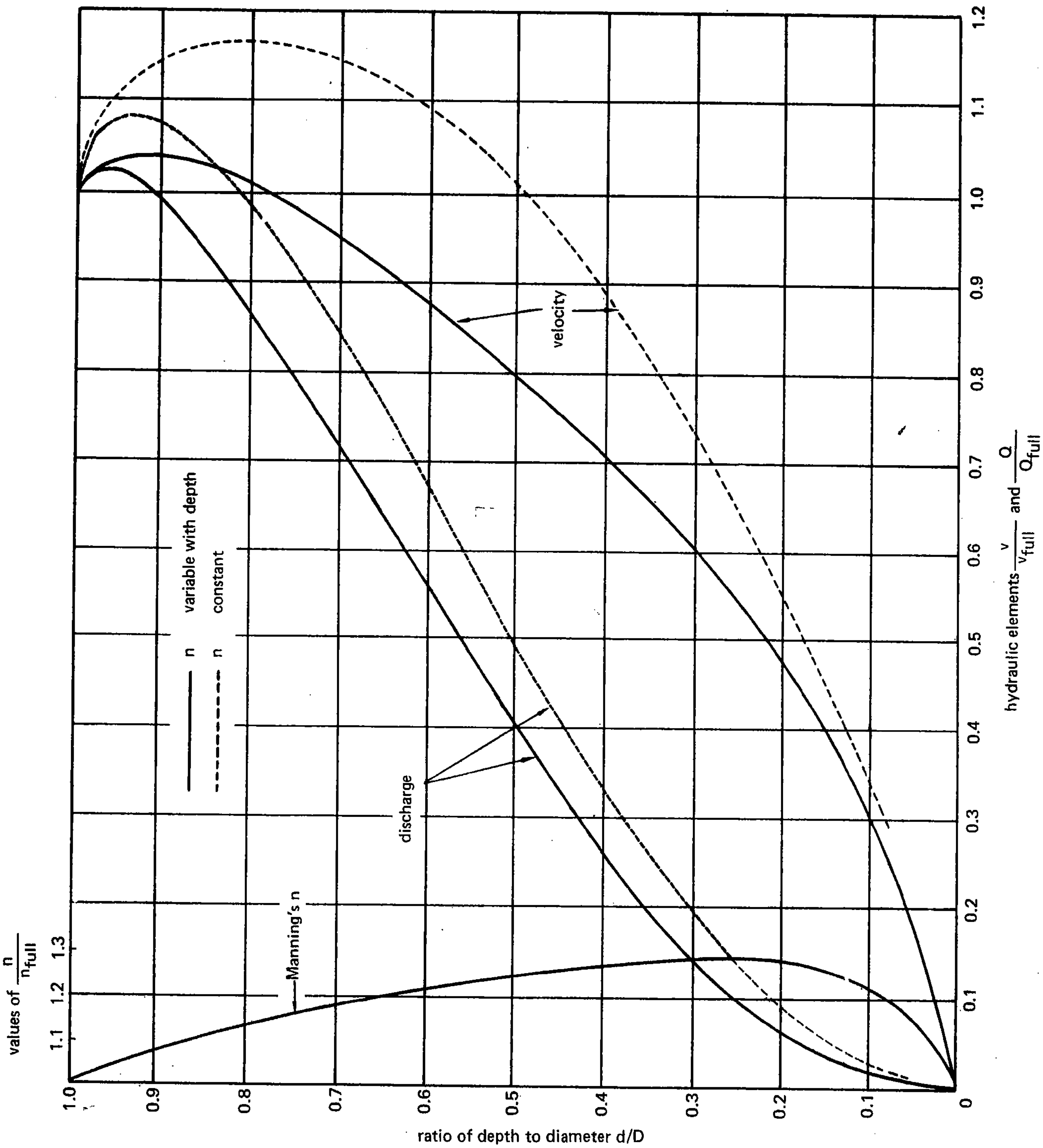

Table 2: Rating Table for Mother Lode Spring System (P4)

Stage (d)	Diameter (D)	Ratio of d/D	Qfull	Ratio Q/Qfull	Q
0	3.6	0.0000	20.267	0.0000	0.0000
0.01	3.6	0.0028	20.267	0.0007	0.0141
0.02	3.6	0.0056	20.267	0.0014	0.0281
0.03	3.6	0.0083	20.267	0.0021	0.0422
0.04	3.6	0.0111	20.267	0.0028	0.0563
0.05	3.6	0.0139	20.267	0.0035	0.0703
0.06	3.6	0.0167	20.267	0.0042	0.0844
0.07	3.6	0.0194	20.267	0.0049	0.0985
0.08	3.6	0.0222	20.267	0.0056	0.1125
0.09	3.6	0.0250	20.267	0.0062	0.1266
0.1	3.6	0.0278	20.267	0.0069	0.1407
0.11	3.6	0.0306	20.267	0.0076	0.1547
0.12	3.6	0.0333	20.267	0.0083	0.1688
0.13	3.6	0.0361	20.267	0.0090	0.1828
0.14	3.6	0.0389	20.267	0.0097	0.1969
0.15	3.6	0.0417	20.267	0.0104	0.2110
0.16	3.6	0.0444	20.267	0.0111	0.2250
0.17	3.6	0.0472	20.267	0.0118	0.2391
0.18	3.6	0.0500	20.267	0.0125	0.2533
0.19	3.6	0.0528	20.267	0.0134	0.2720
0.2	3.6	0.0556	20.267	0.0143	0.2907
0.21	3.6	0.0583	20.267	0.0153	0.3094
0.22	3.6	0.0611	20.267	0.0162	0.3281
0.23	3.6	0.0639	20.267	0.0171	0.3468
0.24	3.6	0.0667	20.267	0.0180	0.3655
0.25	3.6	0.0694	20.267	0.0190	0.3841
0.26	3.6	0.0722	20.267	0.0199	0.4028
0.27	3.6	0.0750	20.267	0.0208	0.4215
0.28	3.6	0.0778	20.267	0.0217	0.4402
0.29	3.6	0.0806	20.267	0.0226	0.4589
0.3	3.6	0.0833	20.267	0.0236	0.4776
0.31	3.6	0.0861	20.267	0.0245	0.4963
0.32	3.6	0.0889	20.267	0.0254	0.5149
0.33	3.6	0.0917	20.267	0.0263	0.5336
0.34	3.6	0.0944	20.267	0.0273	0.5523
0.35	3.6	0.0972	20.267	0.0282	0.5710
0.36	3.6	0.1000	20.267	0.0291	0.5898
0.37	3.6	0.1028	20.267	0.0305	0.6180
0.38	3.6	0.1056	20.267	0.0319	0.6463
0.39	3.6	0.1083	20.267	0.0333	0.6745
0.4	3.6	0.1111	20.267	0.0347	0.7028
0.41	3.6	0.1139	20.267	0.0361	0.7310
0.42	3.6	0.1167	20.267	0.0375	0.7593
0.43	3.6	0.1194	20.267	0.0389	0.7875
0.44	3.6	0.1222	20.267	0.0403	0.8158
0.45	3.6	0.1250	20.267	0.0416	0.8440
0.46	3.6	0.1278	20.267	0.0430	0.8723
0.47	3.6	0.1306	20.267	0.0444	0.9005

Table 2: Rating Table for Mother Lode Spring System (P4)

Stage (d)	Diameter (D)	Ratio of d/D	Qfull	Ratio Q/Qfull	Q
0.48	3.6	0.1333	20.267	0.0458	0.9288
0.49	3.6	0.1361	20.267	0.0472	0.9570
0.5	3.6	0.1389	20.267	0.0486	0.9853
0.51	3.6	0.1417	20.267	0.0500	1.0136
0.52	3.6	0.1444	20.267	0.0514	1.0418
0.53	3.6	0.1472	20.267	0.0528	1.0701
0.54	3.6	0.1500	20.267	0.0542	1.0985
0.55	3.6	0.1528	20.267	0.0561	1.1360
0.56	3.6	0.1556	20.267	0.0579	1.1735
0.57	3.6	0.1583	20.267	0.0598	1.2110
0.58	3.6	0.1611	20.267	0.0616	1.2484
0.59	3.6	0.1639	20.267	0.0635	1.2859
0.6	3.6	0.1667	20.267	0.0653	1.3234
0.61	3.6	0.1694	20.267	0.0672	1.3609
0.62	3.6	0.1722	20.267	0.0690	1.3984
0.63	3.6	0.1750	20.267	0.0709	1.4359
0.64	3.6	0.1778	20.267	0.0727	1.4734
0.65	3.6	0.1806	20.267	0.0746	1.5109
0.66	3.6	0.1833	20.267	0.0764	1.5484
0.67	3.6	0.1861	20.267	0.0783	1.5859
0.68	3.6	0.1889	20.267	0.0801	1.6234
0.69	3.6	0.1917	20.267	0.0820	1.6609
0.7	3.6	0.1944	20.267	0.0838	1.6984
0.71	3.6	0.1972	20.267	0.0857	1.7359
0.72	3.6	0.2000	20.267	0.0875	1.7734
0.73	3.6	0.2028	20.267	0.0903	1.8297
0.74	3.6	0.2056	20.267	0.0931	1.8860
0.75	3.6	0.2083	20.267	0.0958	1.9423
0.76	3.6	0.2111	20.267	0.0986	1.9986
0.77	3.6	0.2139	20.267	0.1014	2.0549
0.78	3.6	0.2167	20.267	0.1042	2.1112
0.79	3.6	0.2194	20.267	0.1069	2.1675
0.8	3.6	0.2222	20.267	0.1097	2.2238
0.81	3.6	0.2250	20.267	0.1125	2.2801
0.82	3.6	0.2278	20.267	0.1153	2.3364
0.83	3.6	0.2306	20.267	0.1181	2.3927
0.84	3.6	0.2333	20.267	0.1208	2.4490
0.85	3.6	0.2361	20.267	0.1236	2.5053
0.86	3.6	0.2389	20.267	0.1264	2.5616
0.87	3.6	0.2417	20.267	0.1292	2.6179
0.88	3.6	0.2444	20.267	0.1319	2.6742
0.89	3.6	0.2472	20.267	0.1347	2.7305
0.9	3.6	0.2500	20.267	0.1375	2.7867
0.91	3.6	0.2528	20.267	0.1405	2.8477
0.92	3.6	0.2556	20.267	0.1435	2.9088
0.93	3.6	0.2583	20.267	0.1465	2.9698
0.94	3.6	0.2611	20.267	0.1495	3.0308
0.95	3.6	0.2639	20.267	0.1526	3.0918

Table 2: Rating Table for Mother Lode Spring System (P4)

Stage (d)	Diameter (D)	Ratio of d/D	Qfull	Ratio Q/Qfull	Q
0.96	3.6	0.2667	20.267	0.1556	3.1529
0.97	3.6	0.2694	20.267	0.1586	3.2139
0.98	3.6	0.2722	20.267	0.1616	3.2749
0.99	3.6	0.2750	20.267	0.1646	3.3359
1	3.6	0.2778	20.267	0.1676	3.3970
1.01	3.6	0.2806	20.267	0.1706	3.4580
1.02	3.6	0.2833	20.267	0.1736	3.5190
1.03	3.6	0.2861	20.267	0.1766	3.5800
1.04	3.6	0.2889	20.267	0.1797	3.6410
1.05	3.6	0.2917	20.267	0.1827	3.7021
1.06	3.6	0.2944	20.267	0.1857	3.7631
1.07	3.6	0.2972	20.267	0.1887	3.8241
1.08	3.6	0.3000	20.267	0.1917	3.8852
1.09	3.6	0.3028	20.267	0.1952	3.9556
1.1	3.6	0.3056	20.267	0.1986	4.0259
1.11	3.6	0.3083	20.267	0.2021	4.0963
1.12	3.6	0.3111	20.267	0.2056	4.1667
1.13	3.6	0.3139	20.267	0.2091	4.2370
1.14	3.6	0.3167	20.267	0.2125	4.3074
1.15	3.6	0.3194	20.267	0.2160	4.3778
1.16	3.6	0.3222	20.267	0.2195	4.4481
1.17	3.6	0.3250	20.267	0.2229	4.5185
1.18	3.6	0.3278	20.267	0.2264	4.5889
1.19	3.6	0.3306	20.267	0.2299	4.6592
1.2	3.6	0.3333	20.267	0.2334	4.7296
1.21	3.6	0.3361	20.267	0.2368	4.8000
1.22	3.6	0.3389	20.267	0.2403	4.8703
1.23	3.6	0.3417	20.267	0.2438	4.9407
1.24	3.6	0.3444	20.267	0.2473	5.0111
1.25	3.6	0.3472	20.267	0.2507	5.0814
1.26	3.6	0.3500	20.267	0.2542	5.1519
1.27	3.6	0.3528	20.267	0.2586	5.2406
1.28	3.6	0.3556	20.267	0.2630	5.3293
1.29	3.6	0.3583	20.267	0.2673	5.4181
1.3	3.6	0.3611	20.267	0.2717	5.5068
1.31	3.6	0.3639	20.267	0.2761	5.5955
1.32	3.6	0.3667	20.267	0.2805	5.6842
1.33	3.6	0.3694	20.267	0.2848	5.7730
1.34	3.6	0.3722	20.267	0.2892	5.8617
1.35	3.6	0.3750	20.267	0.2936	5.9504
1.36	3.6	0.3778	20.267	0.2980	6.0392
1.37	3.6	0.3806	20.267	0.3024	6.1279
1.38	3.6	0.3833	20.267	0.3067	6.2166
1.39	3.6	0.3861	20.267	0.3111	6.3053
1.4	3.6	0.3889	20.267	0.3155	6.3941
1.41	3.6	0.3917	20.267	0.3199	6.4828
1.42	3.6	0.3944	20.267	0.3242	6.5715
1.43	3.6	0.3972	20.267	0.3286	6.6603

Table 2: Rating Table for Mother Lode Spring System (P4)

Stage (d)	Diameter (D)	Ratio of d/D	Qfull	Ratio Q/Qfull	Q
1.44	3.6	0.4000	20.267	0.3333	6.7550
1.45	3.6	0.4028	20.267	0.3377	6.8442
1.46	3.6	0.4056	20.267	0.3421	6.9333
1.47	3.6	0.4083	20.267	0.3465	7.0225
1.48	3.6	0.4111	20.267	0.3509	7.1117
1.49	3.6	0.4139	20.267	0.3553	7.2009
1.5	3.6	0.4167	20.267	0.3597	7.2900
1.51	3.6	0.4194	20.267	0.3641	7.3792
1.52	3.6	0.4222	20.267	0.3685	7.4684
1.53	3.6	0.4250	20.267	0.3729	7.5576
1.54	3.6	0.4278	20.267	0.3773	7.6467
1.55	3.6	0.4306	20.267	0.3817	7.7359
1.56	3.6	0.4333	20.267	0.3861	7.8251
1.57	3.6	0.4361	20.267	0.3905	7.9143
1.58	3.6	0.4389	20.267	0.3949	8.0034
1.59	3.6	0.4417	20.267	0.3993	8.0926
1.6	3.6	0.4444	20.267	0.4037	8.1818
1.61	3.6	0.4472	20.267	0.4081	8.2710
1.62	3.6	0.4500	20.267	0.4125	8.3601
1.63	3.6	0.4528	20.267	0.4168	8.4469
1.64	3.6	0.4556	20.267	0.4211	8.5337
1.65	3.6	0.4583	20.267	0.4253	8.6205
1.66	3.6	0.4611	20.267	0.4296	8.7074
1.67	3.6	0.4639	20.267	0.4339	8.7942
1.68	3.6	0.4667	20.267	0.4382	8.8810
1.69	3.6	0.4694	20.267	0.4425	8.9678
1.7	3.6	0.4722	20.267	0.4468	9.0546
1.71	3.6	0.4750	20.267	0.4510	9.1414
1.72	3.6	0.4778	20.267	0.4553	9.2282
1.73	3.6	0.4806	20.267	0.4596	9.3150
1.74	3.6	0.4833	20.267	0.4639	9.4018
1.75	3.6	0.4861	20.267	0.4682	9.4886
1.76	3.6	0.4889	20.267	0.4725	9.5754
1.77	3.6	0.4917	20.267	0.4767	9.6622
1.78	3.6	0.4944	20.267	0.4810	9.7490
1.79	3.6	0.4972	20.267	0.4853	9.8358
1.8	3.6	0.5000	20.267	0.4896	9.9227
1.81	3.6	0.5028	20.267	0.4943	10.0189
1.82	3.6	0.5056	20.267	0.4991	10.1150
1.83	3.6	0.5083	20.267	0.5038	10.2112
1.84	3.6	0.5111	20.267	0.5086	10.3073
1.85	3.6	0.5139	20.267	0.5133	10.4035
1.86	3.6	0.5167	20.267	0.5181	10.4996
1.87	3.6	0.5194	20.267	0.5228	10.5957
1.88	3.6	0.5222	20.267	0.5276	10.6919
1.89	3.6	0.5250	20.267	0.5323	10.7880
1.9	3.6	0.5278	20.267	0.5370	10.8842
1.91	3.6	0.5306	20.267	0.5418	10.9803

Table 2: Rating Table for Mother Lode Spring System (P4)

Stage (d)	Diameter (D)	Ratio of d/D	Qfull	Ratio Q/Qfull	Q
1.92	3.6	0.5333	20.267	0.5465	11.0765
1.93	3.6	0.5361	20.267	0.5513	11.1726
1.94	3.6	0.5389	20.267	0.5560	11.2688
1.95	3.6	0.5417	20.267	0.5608	11.3649
1.96	3.6	0.5444	20.267	0.5655	11.4611
1.97	3.6	0.5472	20.267	0.5702	11.5572
1.98	3.6	0.5500	20.267	0.5750	11.6535
1.99	3.6	0.5528	20.267	0.5801	11.7571
2	3.6	0.5556	20.267	0.5852	11.8607
2.01	3.6	0.5583	20.267	0.5903	11.9643
2.02	3.6	0.5611	20.267	0.5954	12.0679
2.03	3.6	0.5639	20.267	0.6006	12.1714
2.04	3.6	0.5667	20.267	0.6057	12.2750
2.05	3.6	0.5694	20.267	0.6108	12.3786
2.06	3.6	0.5722	20.267	0.6159	12.4822
2.07	3.6	0.5750	20.267	0.6210	12.5858
2.08	3.6	0.5778	20.267	0.6261	12.6894
2.09	3.6	0.5806	20.267	0.6312	12.7930
2.1	3.6	0.5833	20.267	0.6363	12.8965
2.11	3.6	0.5861	20.267	0.6414	13.0001
2.12	3.6	0.5889	20.267	0.6466	13.1037
2.13	3.6	0.5917	20.267	0.6517	13.2073
2.14	3.6	0.5944	20.267	0.6568	13.3109
2.15	3.6	0.5972	20.267	0.6619	13.4145
2.16	3.6	0.6000	20.267	0.6670	13.5181
2.17	3.6	0.6028	20.267	0.6721	13.6209
2.18	3.6	0.6056	20.267	0.6771	13.7237
2.19	3.6	0.6083	20.267	0.6822	13.8265
2.2	3.6	0.6111	20.267	0.6873	13.9293
2.21	3.6	0.6139	20.267	0.6924	14.0321
2.22	3.6	0.6167	20.267	0.6974	14.1349
2.23	3.6	0.6194	20.267	0.7025	14.2376
2.24	3.6	0.6222	20.267	0.7076	14.3404
2.25	3.6	0.6250	20.267	0.7126	14.4432
2.26	3.6	0.6278	20.267	0.7177	14.5460
2.27	3.6	0.6306	20.267	0.7228	14.6488
2.28	3.6	0.6333	20.267	0.7279	14.7516
2.29	3.6	0.6361	20.267	0.7329	14.8544
2.3	3.6	0.6389	20.267	0.7380	14.9572
2.31	3.6	0.6417	20.267	0.7431	15.0600
2.32	3.6	0.6444	20.267	0.7482	15.1628
2.33	3.6	0.6472	20.267	0.7532	15.2656
2.34	3.6	0.6500	20.267	0.7583	15.3685
2.35	3.6	0.6528	20.267	0.7629	15.4624
2.36	3.6	0.6556	20.267	0.7676	15.5563
2.37	3.6	0.6583	20.267	0.7722	15.6502
2.38	3.6	0.6611	20.267	0.7768	15.7441
2.39	3.6	0.6639	20.267	0.7815	15.8380

Table 2: Rating Table for Mother Lode Spring System (P4)

Stage (d)	Diameter (D)	Ratio of d/D	Qfull	Ratio Q/Qfull	Q
2.4	3.6	0.6667	20.267	0.7861	15.9318
2.41	3.6	0.6694	20.267	0.7907	16.0257
2.42	3.6	0.6722	20.267	0.7954	16.1196
2.43	3.6	0.6750	20.267	0.8000	16.2135
2.44	3.6	0.6778	20.267	0.8046	16.3074
2.45	3.6	0.6806	20.267	0.8093	16.4013
2.46	3.6	0.6833	20.267	0.8139	16.4952
2.47	3.6	0.6861	20.267	0.8185	16.5891
2.48	3.6	0.6889	20.267	0.8232	16.6830
2.49	3.6	0.6917	20.267	0.8278	16.7769
2.5	3.6	0.6944	20.267	0.8324	16.8708
2.51	3.6	0.6972	20.267	0.8371	16.9647
2.52	3.6	0.7000	20.267	0.8417	17.0587
2.53	3.6	0.7028	20.267	0.8459	17.1432
2.54	3.6	0.7056	20.267	0.8500	17.2276
2.55	3.6	0.7083	20.267	0.8542	17.3121
2.56	3.6	0.7111	20.267	0.8584	17.3965
2.57	3.6	0.7139	20.267	0.8625	17.4810
2.58	3.6	0.7167	20.267	0.8667	17.5654
2.59	3.6	0.7194	20.267	0.8709	17.6499
2.6	3.6	0.7222	20.267	0.8750	17.7344
2.61	3.6	0.7250	20.267	0.8792	17.8188
2.62	3.6	0.7278	20.267	0.8834	17.9033
2.63	3.6	0.7306	20.267	0.8875	17.9877
2.64	3.6	0.7333	20.267	0.8917	18.0722
2.65	3.6	0.7361	20.267	0.8959	18.1566
2.66	3.6	0.7389	20.267	0.9000	18.2411
2.67	3.6	0.7417	20.267	0.9042	18.3255
2.68	3.6	0.7444	20.267	0.9084	18.4100
2.69	3.6	0.7472	20.267	0.9125	18.4944
2.7	3.6	0.7500	20.267	0.9167	18.5788
2.71	3.6	0.7528	20.267	0.9204	18.6537
2.72	3.6	0.7556	20.267	0.9241	18.7287
2.73	3.6	0.7583	20.267	0.9278	18.8037
2.74	3.6	0.7611	20.267	0.9315	18.8787
2.75	3.6	0.7639	20.267	0.9352	18.9537
2.76	3.6	0.7667	20.267	0.9389	19.0287
2.77	3.6	0.7694	20.267	0.9426	19.1037
2.78	3.6	0.7722	20.267	0.9463	19.1787
2.79	3.6	0.7750	20.267	0.9500	19.2537
2.8	3.6	0.7778	20.267	0.9537	19.3286
2.81	3.6	0.7806	20.267	0.9574	19.4036
2.82	3.6	0.7833	20.267	0.9611	19.4786
2.83	3.6	0.7861	20.267	0.9648	19.5536
2.84	3.6	0.7889	20.267	0.9685	19.6286
2.85	3.6	0.7917	20.267	0.9722	19.7036
2.86	3.6	0.7944	20.267	0.9759	19.7786
2.87	3.6	0.7972	20.267	0.9796	19.8536

Table 2: Rating Table for Mother Lode Spring System (P4)

Stage (d)	Diameter (D)	Ratio of d/D	Qfull	Ratio Q/Qfull	Q
2.88	3.6	0.8000	20.267	0.9833	19.9285
2.89	3.6	0.8028	20.267	0.9865	19.9924
2.9	3.6	0.8056	20.267	0.9896	20.0562
2.91	3.6	0.8083	20.267	0.9928	20.1201
2.92	3.6	0.8111	20.267	0.9959	20.1839
2.93	3.6	0.8139	20.267	0.9991	20.2477
2.94	3.6	0.8167	20.267	1.0022	20.3116
2.95	3.6	0.8194	20.267	1.0054	20.3754
2.96	3.6	0.8222	20.267	1.0085	20.4393
2.97	3.6	0.8250	20.267	1.0117	20.5031
2.98	3.6	0.8278	20.267	1.0148	20.5670
2.99	3.6	0.8306	20.267	1.0180	20.6308
3	3.6	0.8333	20.267	1.0211	20.6946
3.01	3.6	0.8361	20.267	1.0243	20.7585
3.02	3.6	0.8389	20.267	1.0274	20.8223
3.03	3.6	0.8417	20.267	1.0306	20.8862
3.04	3.6	0.8444	20.267	1.0337	20.9500
3.05	3.6	0.8472	20.267	1.0369	21.0138
3.06	3.6	0.8500	20.267	1.0400	21.0777
3.07	3.6	0.8528	20.267	1.0419	21.1162
3.08	3.6	0.8556	20.267	1.0438	21.1547
3.09	3.6	0.8583	20.267	1.0457	21.1932
3.1	3.6	0.8611	20.267	1.0476	21.2317
3.11	3.6	0.8639	20.267	1.0495	21.2702
3.12	3.6	0.8667	20.267	1.0514	21.3087
3.13	3.6	0.8694	20.267	1.0533	21.3472
3.14	3.6	0.8722	20.267	1.0552	21.3857
3.15	3.6	0.8750	20.267	1.0571	21.4242
3.16	3.6	0.8778	20.267	1.0590	21.4628
3.17	3.6	0.8806	20.267	1.0609	21.5013
3.18	3.6	0.8833	20.267	1.0628	21.5398
3.19	3.6	0.8861	20.267	1.0647	21.5783
3.2	3.6	0.8889	20.267	1.0666	21.6168
3.21	3.6	0.8917	20.267	1.0685	21.6553
3.22	3.6	0.8944	20.267	1.0704	21.6938
3.23	3.6	0.8972	20.267	1.0723	21.7323
3.24	3.6	0.9000	20.267	1.0740	21.7668
3.25	3.6	0.9028	20.267	1.0747	21.7809
3.26	3.6	0.9056	20.267	1.0754	21.7951
3.27	3.6	0.9083	20.267	1.0761	21.8093
3.28	3.6	0.9111	20.267	1.0768	21.8235
3.29	3.6	0.9139	20.267	1.0775	21.8377
3.3	3.6	0.9167	20.267	1.0782	21.8519
3.31	3.6	0.9194	20.267	1.0789	21.8661
3.32	3.6	0.9222	20.267	1.0796	21.8803
3.33	3.6	0.9250	20.267	1.0803	21.8944
3.34	3.6	0.9278	20.267	1.0810	21.9086
3.35	3.6	0.9306	20.267	1.0817	21.9228

Table 2: Rating Table for Mother Lode Spring System (P4)

Stage (d)	Diameter (D)	Ratio of d/D	Qfull	Ratio Q/Qfull	Q
3.36	3.6	0.9333	20.267	1.0824	21.9370
3.37	3.6	0.9361	20.267	1.0831	21.9512
3.38	3.6	0.9389	20.267	1.0840	21.9694
3.39	3.6	0.9417	20.267	1.0834	21.9573
3.4	3.6	0.9444	20.267	1.0831	21.9512
3.41	3.6	0.9472	20.267	1.0820	21.9289
3.42	3.6	0.9500	20.267	1.0800	21.8884
3.43	3.6	0.9528	20.267	1.0783	21.8539
3.44	3.6	0.9556	20.267	1.0766	21.8195
3.45	3.6	0.9583	20.267	1.0749	21.7850
3.46	3.6	0.9611	20.267	1.0732	21.7505
3.47	3.6	0.9639	20.267	1.0715	21.7161
3.48	3.6	0.9667	20.267	1.0698	21.6816
3.49	3.6	0.9694	20.267	1.0681	21.6472
3.5	3.6	0.9722	20.267	1.0664	21.6127
3.51	3.6	0.9750	20.267	1.0647	21.5783
3.52	3.6	0.9778	20.267	1.0630	21.5438
3.53	3.6	0.9806	20.267	1.0613	21.5094
3.54	3.6	0.9833	20.267	1.0600	21.4830
3.55	3.6	0.9861	20.267	1.0500	21.2804
3.56	3.6	0.9889	20.267	1.0400	21.0777
3.57	3.6	0.9917	20.267	1.0300	20.8750
3.58	3.6	0.9944	20.267	1.0200	20.6723
3.59	3.6	0.9972	20.267	1.0100	20.4697
3.6	3.6	1.0000	20.267	1.0000	20.2670

05/15/02 14:59

TENNESSEE VALLEY AUTHORITY

#P5 P5 Unnamed Tributary to Indian Creek 2001 WY

Rating Table 1 from 10/01/01 00:05 Scale Offset = 0.00

Provisional Rating

DISCHARGE IN CUBIC FEET PER SECOND

ght	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	1st diff	2nd diff
0.6	2.05*	2.10	2.15	2.20	2.25	2.30*	2.36	2.42	2.48	2.54	.550	
0.7	2.60*	2.66	2.72	2.78	2.84	2.90*	2.97	3.04	3.11	3.18	.650	.100
0.8	3.25*	3.33	3.41	3.49	3.57	3.65*	3.75	3.85	3.95	4.05	.900	.250
0.9	4.15*	4.26	4.37	4.48	4.59	4.70*	4.84	4.99	5.14	5.29	1.30	.400
1.0	5.45*	5.63	5.82	6.01	6.20	6.40*	6.65	6.90	7.16	7.43	2.25	.950
1.1	7.70*	8.12	8.56	9.02	9.50	10.0*						

* skeletal rating point

05/15/02 15:00

TENNESSEE VALLEY AUTHORITY

#P7 P7 Huntsville Spring Branch at Patton Road, AL 2001 WY

Rating Table 1 from 10/01/00 00:05 Scale Offset = 1.00

Provisional Rating - Gage in Backwater from Wheeler Reservoir □

DISCHARGE IN CUBIC FEET PER SECOND

ght	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	1st diff	2nd diff
1.3		20.0*	21.4	22.9	24.4	26.0*	27.1	28.2	29.3	30.4		
1.4	31.5*	32.6	33.7	34.8	35.9	37.0*	38.1	39.2	40.3	41.4	11.0	
1.5	42.5*	43.6	44.7	45.9	47.0	48.2	49.3	50.5	51.6	52.8	11.5	.500
1.6	54.0*	55.1	56.2	57.3	58.4	59.5	60.6	61.7	62.8	63.9	11.0	-.500
1.7	65.0*	66.2	67.4	68.6	69.7	70.9	72.1	73.4	74.6	75.8	12.0	1.00
1.8	77.0*	78.2	79.4	80.6	81.8	83.0	84.2	85.4	86.6	87.8	12.0	0
1.9	89.0*	90.3	91.6	92.9	94.2	95.4	96.8	98.1	99.4	100.7	13.0	1.00
2.0	102.0*	103.3	104.6	105.9	107.2	108.4	109.7	111.0	112.4	113.7	13.0	-.027
2.1	115.0	116.3	117.6	118.9	120.2	121.6	122.9	124.2	125.6	126.9	13.3	.306
2.2	128.3	129.6	130.9	132.3	133.6	135.0*	136.4	137.9	139.3	140.8	14.0	.690
2.3	142.2	143.7	145.1	146.6	148.1	149.5	151.0	152.5	154.0	155.4	14.7	.746
2.4	156.9	158.4	159.9	161.4	162.9	164.4	165.9	167.4	169.0	170.5	15.1	.350
2.5	172.0*	173.5	175.0	176.5	178.0	179.5	181.0	182.5	184.0	185.5	15.0	-.072
2.6	187.0	188.5	190.0	191.5	193.1	194.6	196.1	197.7	199.2	200.7	15.3	.279
2.7	202.3	203.8	205.4	206.9	208.4	210.0*	211.6	213.1	214.7	216.3	15.6	.334
2.8	217.9	219.5	221.0	222.6	224.2	225.8	227.4	229.0	230.6	232.2	15.9	.332
2.9	233.8	235.4	237.0	238.6	240.3	241.9	243.5	245.1	246.7	248.4	16.2	.259
3.0	250.0*	251.6	253.3	254.9	256.6	258.2	259.9	261.5	263.2	264.9	16.5	.326
3.1	266.5	268.2	269.9	271.5	273.2	274.9	276.6	278.2	279.9	281.6	16.8	.247
3.2	283.3	285.0	286.7	288.4	290.1	291.8	293.5	295.2	296.9	298.6	17.0	.239
3.3	300.3	302.0	303.7	305.4	307.2	308.9	310.6	312.3	314.1	315.8	17.2	.232
3.4	317.5	319.3	321.0	322.8	324.5	326.2	328.0	329.7	331.5	333.2	17.5	.225
3.5	335.0*	336.9	338.8	340.8	342.7	344.6	346.6	348.5	350.5	352.4	19.4	1.90
3.6	354.4	356.3	358.3	360.2	362.2	364.2	366.1	368.1	370.1	372.1	19.7	.325
3.7	374.1	376.0	378.0	380.0	382.0	384.0	386.0	388.0	390.0	392.0	20.0	.318
3.8	394.1	396.1	398.1	400.1	402.1	404.2	406.2	408.2	410.3	412.3	20.3	.312
3.9	414.4	416.4	418.5	420.5	422.6	424.7	426.7	428.8	430.9	432.9	20.6	.305
4.0	435.0*	437.1	439.1	441.2	443.3	445.4	447.4	449.5	451.6	453.7	20.8	.150

Station P7
Rating #: 1
Page 2

ght	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	1st diff	2nd diff
4.1	455.8	457.9	460.0	462.1	464.2	466.3	468.4	470.5	472.6	474.7	21.1	.285
4.2	476.8	479.0	481.1	483.2	485.3	487.5	489.6	491.7	493.9	496.0	21.3	.280
4.3	498.2	500.3	502.5	504.6	506.8	508.9	511.1	513.3	515.4	517.6	21.6	.275
4.4	519.8	522.0	524.1	526.3	528.5	530.7	532.9	535.1	537.3	539.5	21.9	.270
4.5	541.7	543.9	546.1	548.3	550.5	552.7	554.9	557.1	559.4	561.6	22.2	.266
4.6	563.8	566.1	568.3	570.5	572.8	575.0	577.2	579.5	581.7	584.0	22.4	.262
4.7	586.2	588.5	590.7	593.0	595.3	597.5	599.8	602.1	604.3	606.6	22.7	.258
4.8	608.9	611.2	613.5	615.8	618.0	620.3	622.6	624.9	627.2	629.5	22.9	.254
4.9	631.8	634.1	636.4	638.8	641.1	643.4	645.7	648.0	650.3	652.7	23.2	.250
5.0	655.0*	657.4	659.8	662.1	664.5	666.9	669.3	671.7	674.1	676.5	23.9	.684
5.1	678.9	681.3	683.7	686.1	688.5	690.9	693.3	695.7	698.1	700.6	24.1	.263
5.2	703.0	705.4	707.8	710.3	712.7	715.1	717.6	720.0	722.5	724.9	24.4	.259
5.3	727.4	729.8	732.3	734.7	737.2	739.6	742.1	744.6	747.0	749.5	24.6	.256
5.4	752.0	754.5	756.9	759.4	761.9	764.4	766.9	769.4	771.9	774.4	24.9	.253
5.5	776.9	779.4	781.9	784.4	786.9	789.4	791.9	794.4	797.0	799.5	25.1	.249
5.6	802.0	804.5	807.1	809.6	812.1	814.7	817.2	819.8	822.3	824.8	25.4	.246
5.7	827.4	830.0	832.5	835.1	837.6	840.2	842.7	845.3	847.9	850.5	25.6	.244
5.8	853.0	855.6	858.2	860.8	863.3	865.9	868.5	871.1	873.7	876.3	25.9	.241
5.9	878.9	881.5	884.1	886.7	889.3	891.9	894.5	897.1	899.8	902.4	26.1	.238
6.0	905.0*											

* skeletal rating point

APPENDIX B

MEAN MONTHLY DISCHARGE AND STAGE TABLES

Appendix B

Indian Creek Mean Monthly Discharge 2000-2002
Redstone Arsenal, Madison County, Alabama

(Page 1 of 2)

Mean Monthly Discharge 2000 - 2002												
SW Gauging Station	January (2000, 2001, 2002)				February (2000, 2001, 2002)				March (2000, 2001, 2002)			
	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q
Indian Creek @ I-565 (USGS 03575830)		3.38	1826	32.05		3.74	1301	50.86		4.55	3769	62.45
Nasa Spring (P5)	**4.93**	4.05	10	5.29	**3.13**	6.01	10	6.9	**5.60**	4.7	10	6.01
Indian Creek @ Martin Road (ICMR)		8	1412	25		12	926	50.1		12	1748	96.3

Mean Monthly Discharge 2000 - 2002												
SW Gauging Station	April (2000, 2001, 2002)				May (2000, 2001, 2002)				June (2000, 2001, 2002)			
	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q
Indian Creek @ I-565 (USGS 03575830)		22.35	5885.14	65.03		6.53	1637	29.9		0.62	1490	14.77
Nasa Spring (P5)	**3.45**	3.18	10	7.16	**4.85**	3.33	10	4.7	**4.27**	4.26	10	4.59
Indian Creek @ Martin Road (ICMR)		12	3205	107		11	184	25		7	91	10

Mean Monthly Discharge - Average Flow within the month of interest over the three year monitoring period (2000 - 2002)

Appendix B

Indian Creek Mean Monthly Discharge 2000-2002
Redstone Arsenal, Madison County, Alabama

(Page 2 of 2)

SW Gauging Station	Mean Monthly Discharge 2000 - 2002: July (2000, 2001, 2002) Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	August (2000, 2001, 2002) Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	September (2000, 2001, 2002) Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q
Indian Creek @ I-565 (USGS 03575830)		16.79	2411	39.42		0.54	473.7	5.73		2.44	178.8	4.77
Nasa Spring (P5)	**5.28**	4.37	10	4.59	**2.60**	3.95	8.56	4.48	**3.73**	3.75	10	4.7
Indian Creek @ Martin Road (ICMR)		5	29	7		4.2	306	6		4	136	7.4

SW Gauging Station	Mean Monthly Discharge 2000 - 2002: October (2000, 2001, 2002) Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	November (2000, 2001, 2002) Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	December (2000, 2001, 2002) Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q
Indian Creek @ I-565 (USGS 03575830)		1.56	1157	5.99		2.73	779.7	9.99		2.44	2767	49.42
Nasa Spring (P5)	**2.41**	3.85	9.5	4.7	**5.04**	4.15	9.5	4.84	**5.36**	4.15	10	5.29
Indian Creek @ Martin Road (ICMR)		4	56.2	11.8		5.2	363	25.8		3.3	1195	54.1

Mean Monthly Discharge - Average Flow within the month of interest over the three year monitoring period (2000 - 2002)

Appendix B

Indian Creek Mean Monthly Stage 2000 - 2002
Redstone Arsenal, Madison County, Alabama

Mean Monthly Stage 2000-2002												
	January (2000, 2001, 2002)				February (2000, 2001, 2002)				March (2000, 2001, 2002)			
SW Gauging Station	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage
Indian Creek @ I-565 (USGS 03575830)		604.01	608.92	604.58		604.16	608.38	604.87		604.2	610.33	605.03
Nasa Spring (P5)		560.5	565.23	560.61		560.64	564.79	560.73		560.56	566.03	560.72
Indian Creek @ Martin Road (ICMR)	4.93	558.32	564.46	558.84	3.13	558.64	564.1	559.28	5.60	558.66	564.85	559.91
Indian Creek @ Centerline Road (ICCR)		550.52	559.68	552.23		551.16	558.22	553.26		550.84	558.64	553.74
Indian Creek @ Triana (ICTR)		550.96	559.68	552.33		551.59	558.25	553.18		551.93	558.44	553.56

Mean Monthly Stage 2000-2002												
	April (2000, 2001, 2002)				May (2000, 2001, 2002)				June (2000, 2001, 2002)			
SW Gauging Station	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage
Indian Creek @ I-565 (USGS 03575830)		604.44	611.25	605.06		604.15	608.74	604.51		603.7	608.59	604.36
Nasa Spring (P5)		560.4	564.39	560.71		560.42	562.51	560.7		560.52	565.07	560.56
Indian Creek @ Martin Road (ICMR)	3.45	559.14	565.27	560.04	4.85	558.45	560.93	558.83	4.27	558.29	559.85	558.43
Indian Creek @ Centerline Road (ICCR)		552.55	562.92	556		554.88	556.44	555.63		554.99	556.7	556.01
Indian Creek @ Triana (ICTR)		552.25	562.89	555.94		554.68	556.43	555.57		554.83	556.67	555.97

Mean Monthly Stage - Average Stage within the month of interest over the three year monitoring period (2000 - 2002)

Appendix B

Indian Creek Mean Monthly Stage 2000 - 2002
Redstone Arsenal, Madison County, Alabama

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SW Gauging Station	Mean Monthly Stage 2000-2002											
	July (2000, 2001, 2002)				August (2000, 2001, 2002)				September (2000, 2001, 2002)			
	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage
Indian Creek @ I-565 (USGS 03575830)		604.38	609.41	604.68		603.6	606.99	604.12		603.95	605.92	604.08
Nasa Spring (P5)		560.53	565.36	560.55		560.49	562.58	560.54		560.465	561.263	560.558
Indian Creek @ Martin Road (ICMR)	5.28	558.18	558.91	558.26	2.60	558.1	562.04	558.23	3.73	558.08	560.38	558.305
Indian Creek @ Centerline Road (ICCR)		555.31	556.68	556.04		554.29	556.618	555.64		552.829	555.648	554.33
Indian Creek @ Triana (ICTR)		555.12	556.69	556.01		554.07	556.55	555.655		553.15	555.51	554.36

SW Gauging Station	Mean Monthly Stage 2000-2002											
	October (2000, 2001, 2002)				November (2000, 2001, 2002)				December (2000, 2001, 2002)			
	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage
Indian Creek @ I-565 (USGS 03575830)		603.86	608.20	604.13		603.97	607.63	604.27		603.95	609.68	604.84
Nasa Spring (P5)		560.482	564.089	560.561		560.51	563.11	560.57		560.509	565.151	560.631
Indian Creek @ Martin Road (ICMR)	2.41	558.08	559.37	558.48	5.04	558.18	562.4	558.85	5.36	558.01	564.44	559.34
Indian Creek @ Centerline Road (ICCR)		551.3	555.5	553.3985		550.98	556.687	553.45		550.42	556.953	553.518
Indian Creek @ Triana (ICTR)		551.67	555.41	553.245		551.67	554.67	552.31		551.7	556.87	552.31

Mean Monthly Stage - Average Stage within the month of interest over the three year monitoring period (2000 - 2002)

Appendix B

McDonald Creek Mean Monthly Discharge 2000-2002
Redstone Arsenal, Madison County, Alabama

(Page 1 of 2)

SW Gauging Station	Mean Monthly Discharge 2000-2002											
	January (2000, 2001, 2002)				February (2000, 2001, 2002)				March (2000, 2001, 2002)			
	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q
McDonald Creek @ Patton Road (USGS 03575980)	4.93	0.37	1419	1.75	3.13	0.44	754.1	2.86	5.60	0.49	1625	8.02
McDonald Creek @ Martin Road (P1)		4.25	122	16.3		4.77	119.8	17.5		7.62	122	17.8
McDonald Creek @ Confluence with HSB (P2)		5.93	66.3	16.7		15.6	67	30.9		14.7	66.6	27.2

SW Gauging Station	Mean Monthly Discharge 2000-2002											
	April (2000, 2001, 2002)				May (2000, 2001, 2002)				June (2000, 2001, 2002)			
	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q
McDonald Creek @ Patton Road (USGS 03575980)	3.45	0.61	3318	4.18	4.85	0.37	2082	0.96	4.27	0.29	561.2	0.58
McDonald Creek @ Martin Road (P1)		5.79	118.7	12.2		4.2	120.9	5.48		4.48	122	12
McDonald Creek @ Confluence with HSB (P2)		16.4	67	28.1		9.04	66.6	15		13.8	67	23.5

Mean Monthly Discharge - Average Flow within the month of interest over the three year monitoring period (2000-2002)

Appendix B

McDonald Creek Mean Monthly Discharge 2000-2002
Redstone Arsenal, Madison County, Alabama

SW Gauging Station	Mean Monthly Discharge 2000-2002											
	July (2000, 2001, 2002)				August (2000, 2001, 2002)				September (2000, 2001, 2002)			
	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q
McDonald Creek @ Patton Road (USGS 03575980)	5.28	0.21	1266	0.55	2.60	0.07	2766	0.31	3.73	0.16	382.6	0.31
McDonald Creek @ Martin Road (P1)		4.2	112.3	7.17		4.2	122	5.4		4.71	114.4	6.35
McDonald Creek @ Confluence with HSB (P2)		9.57	66.3	15.9		8.51	66.6	12.3		1.8	65.6	9.83

SW Gauging Station	Mean Monthly Discharge 2000-2002											
	October (2000, 2001, 2002)				November (2000, 2001, 2002)				December (2000, 2001, 2002)			
	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q
McDonald Creek @ Patton Road (USGS 03575980)	2.41	0.13	877.1	0.44	5.04	0.15	1096	1.11	5.36	0.55	2029	7.28
McDonald Creek @ Martin Road (P1)		4.2	101.3	10.3		4.36	122	16.7		4.2	122	22
McDonald Creek @ Confluence with HSB (P2)		1.8	65	8.51		4.93	66.6	11.6		2.02	66.6	16.2

Mean Monthly Discharge - Average Flow within the month of interest over the three year monitoring period (2000-2002)

Appendix B

McDonald Creek Mean Monthly Stage 2000-2002
Redstone Arsenal, Madison County, Alabama

	Mean Monthly Stage 2000-2002											
	January (2000, 2001, 2002)				February (2000, 2001, 2002)				March (2000, 2001, 2002)			
SW Gauging Station	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage
McDonald Creek @ Patton Road (USGS 03575980)		580.22	584.96	580.53		580.25	583.91	580.65		580.27	585.25	580.94
McDonald Creek @ Martin Road (P1)	**4.93**	560.46	564.75	561.9	**3.13**	560.99	564.13	562.02	**5.60**	561.36	565.03	562.04
McDonald Creek @ Confluence with HSB (P2)		558.35	563.82	558.86		558.7	562.53	559.26		558.67	564.16	559.22

	Mean Monthly Stage 2000-2002											
	April (2000, 2001, 2002)				May (2000, 2001, 2002)				June (2000, 2001, 2002)			
SW Gauging Station	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage
McDonald Creek @ Patton Road (USGS 03575980)		580.31	587.32	580.75		580.22	585.87	580.4		580.18	583.54	580.3
McDonald Creek @ Martin Road (P1)	**3.45**	561.14	564.35	561.74	**4.85**	560.66	564.01	561.02	**4.27**	560.94	564.55	561.76
McDonald Creek @ Confluence with HSB (P2)		558.73	562.72	559.15		558.47	561.97	558.69		558.64	562.94	559.09

Mean Monthly Stage - Average Stage within the month of interest over the three year monitoring period (2000-2002)

Appendix B

McDonald Creek Mean Monthly Stage 2000-2002
Redstone Arsenal, Madison County, Alabama

	Mean Monthly Stage 2000-2002											
	July (2000, 2001, 2002)				August (2000, 2001, 2002)				September (2000, 2001, 2002)			
SW Gauging Station	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage
McDonald Creek @ Patton Road (USGS 03575980)		580.13	584.73	580.29		579.97	586.71	580.19		580.09	583.11	580.19
McDonald Creek @ Martin Road (P1)	5.28	560.6	564.12	561.04	2.60	560.54	563.89	560.96	3.73	560.09	563.82	561.08
McDonald Creek @ Confluence with HSB (P2)		558.49	561.98	558.73		558.45	562.84	558.61		558.06	561.89	558.48

	Mean Monthly Stage 2000-2002											
	October (2000, 2001, 2002)				November (2000, 2001, 2002)				December (2000, 2001, 2002)			
SW Gauging Station	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage
McDonald Creek @ Patton Road (USGS 03575980)		580.06	584.12	580.25		580.08	584.47	580.43		580.29	585.8	580.91
McDonald Creek @ Martin Road (P1)	2.41	560.11	564.73	560.85	5.04	560.42	564.82	560.62	5.36	560.33	565.21	561.91
McDonald Creek @ Confluence with HSB (P2)		558.1	563.29	558.4		558.31	563.61	558.67		558.19	564.27	558.79

Mean Monthly Stage - Average Stage within the month of interest over the three year monitoring period (2000-2002)

Appendix B

Huntsville Spring Branch Mean Monthly Discharge 2000-2002
Redstone Arsenal, Madison County, Alabama

SW Gauging Station	Mean Monthly Discharge 2000 - 2002											
	January (2000, 2001, 2002)				February (2000, 2001, 2002)				March (2000, 2001, 2002)			
	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q
Huntsville Spring Branch @ Johnson Road (USGS 03575950)		263.5	5398	473		274.2	3327	582		300.2	6027	633
Huntsville Spring Branch @ Martin Road (HSMR)		11	3081	29.1		21	1686	58.25		24.8	3595	93.3
Huntsville Spring Branch @ Patton Road (P7)	4.93	39.2	891.9	99.4	3.13	85.4	756.9	168.2	5.60	70.9	899.8	159.9
Drain parallel to Patton Road (P3)		0.2	8.2	0.55		0.2	8.2	1.96		0.2	8.2	1.69
Culvert at Mother Lode swamp (P4)		4.59	21.97	6.31		6.04	21.96	7.02		4.87	21.97	7.47

SW Gauging Station	Mean Monthly Discharge 2000 - 2002											
	April (2000, 2001, 2002)				May (2000, 2001, 2002)				June (2000, 2001, 2002)			
	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q
Huntsville Spring Branch @ Johnson Road (USGS 03575950)		361.3	9115	654		370	4981	499		344.3	8374	392
Huntsville Spring Branch @ Martin Road (HSMR)		12	2984	104		21	94.6	36.6		13	197	19.3
Huntsville Spring Branch @ Patton Road (P7)	3.45	102	905	202.3	4.85	98.1	905	206.9	4.27	72.1	899.8	210
Drain parallel to Patton Road (P3)		0.2	7.16	0.99		0.2	8.2	0.62		0.2	8.2	1.06
Culvert at Mother Lode swamp (P4)		4.31	21.96	6.22		3.58	21.95	5.01		31.5	21.96	6.31

Mean Monthly Discharge - Average Flow within the month of interest over the three year monitoring period (2000 - 2002)

Appendix B

Huntsville Spring Branch Mean Monthly Discharge 2000-2002
Redstone Arsenal, Madison County, Alabama

SW Gauging Station	Mean Monthly Discharge 2000 - 2002											
	July (2000, 2001, 2002)				August (2000, 2001, 2002)				September (2000, 2001, 2002)			
	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q
Huntsville Spring Branch @ Johnson Road (USGS 03575950)	5.28	331.9	4703	397	2.60	324	7989	361	3.73	289	4194	366
Huntsville Spring Branch @ Martin Road (HSMR)		9.3	966	11.8		9.3	1479	12.2		9.3	1364	20.1
Huntsville Spring Branch @ Patton Road (P7)		78.2	662.1	210		62.8	742.1	191.5		20	548.3	78.2
Drain parallel to Patton Road (P3)		0.2	6.99	0.48		0.2	7.33	0.77		0.2	7.5	1.06
Culvert at Mother Lode swamp (P4)		2.97	18.24	5.24		2.91	21.58	4.94		0.11	10.79	4.59

SW Gauging Station	Mean Monthly Discharge 2000 - 2002											
	October (2000, 2001, 2002)				November (2000, 2001, 2002)				December (2000, 2001, 2002)			
	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q
Huntsville Spring Branch @ Johnson Road (USGS 03575950)	2.41	308	7709	357	5.04	336	9738	406	5.36	349	8089	563
Huntsville Spring Branch @ Martin Road (HSMR)		10	402	15		13	4661	99.5		25.8	2221	109
Huntsville Spring Branch @ Patton Road (P7)		20	824.8	56.2		20	878.9	66.2		20	899.8	159.9
Drain parallel to Patton Road (P3)		0.2	6.83	1.06		0.2	8.2	0.92		0.2	8.2	0.69
Culvert at Mother Lode swamp (P4)		1.77	18.24	4.94		3.7	21.97	7.91		4.73	21.97	7.56

Mean Monthly Discharge - Average Flow within the month of interest over the three year monitoring period (2000 - 2002)

Appendix B

Huntsville Spring Branch Mean Monthly Stage 2000-2002
Redstone Arsenal, Madison County, Alabama

	Mean Monthly Stage 2000 - 2002											
	January (2000, 2001, 2002)				February (2000, 2001, 2002)				March (2000, 2001, 2002)			
SW Gauging Station	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage
Huntsville Spring Branch @ Johnson Road (USGS 03575950)	4.93	570.95	575.57	571.4	3.13	570.98	574	571.52	5.60	571.05	575.99	571.57
Huntsville Spring Branch @ Martin Road (HSMR)		558.85	568	559.11		559.03	566.11	559.33		559.07	568.97	559.58
Huntsville Spring Branch @ Patton Road (P7)		554.93	563.6	555.51		555.33	558.88	555.94		555.21	561.4	555.96
Drain parallel to Patton Road (P3)		559.68	561.706	559.81		559.57	561.05	559.93		559.68	561.92	559.99
Huntsville Spring Branch @ Mile 4.85 (HSMN)		553.92	560	554.39		554.22	556.14	554.55		554.29	559.71	555.07
Culvert at Mother Lode swamp (P4)		556	563.51	556		556.21	558.69	556.32		556.07	561.34	556.4
Huntsville Spring Branch @ Dodd Road (HSDR)		552.6	559.64	553.06		552.68	558.17	553.67		552.8	559.01	554.3

Mean Monthly Stage - Average Stage within the month of interest over the three year monitoring period (2000 - 2002)

Appendix B

Huntsville Spring Branch Mean Monthly Stage 2000-2002
Redstone Arsenal, Madison County, Alabama

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SW Gauging Station	Mean Monthly Stage 2000 - 2002											
	April (2000, 2001, 2002)				May (2000, 2001, 2002)				June (2000, 2001, 2002)			
	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage
Huntsville Spring Branch @ Johnson Road (USGS 03575950)	3.45	571.2	577.89	571.59	4.85	571.22	575.28	571.43	4.27	571.16	577.46	571.27
Huntsville Spring Branch @ Martin Road (HSMR)		559.3	568.19	559.67		559.03	559.59	559.17		559	561	559
Huntsville Spring Branch @ Patton Road (P7)		555.46	559.57	556		555.43	560.05	556.2		555.22	559.83	556.23
Drain parallel to Patton Road (P3)		559.69	560.76	559.89		559.67	562.2	559.77		559.61	562.29	559.77
Huntsville Spring Branch @ Mile 4.85 (HSMN)		554.69	562.89	556.15		554.92	556.39	555.65		554.92	556.84	555.98
Culvert at Mother Lode swamp (P4)		555.99	559.25	556.24		555.88	559.09	556.1		555.81	558.76	556.24
Huntsville Spring Branch @ Dodd Road (HSDR)		553.59	562.86	555.99		554.83	556.33	555.58		554.88	556.64	555.92

Mean Monthly Stage - Average Stage within the month of interest over the three year monitoring period (2000 - 2002)

Appendix B

Huntsville Spring Branch Mean Monthly Stage 2000-2002
Redstone Arsenal, Madison County, Alabama

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SW Gauging Station	Mean Monthly Stage 2000 - 2002											
	July (2000, 2001, 2002)				August (2000, 2001, 2002)				September (2000, 2001, 2002)			
	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage
Huntsville Spring Branch @ Johnson Road (USGS 03575950)		571.13	575.08	571.28		571.11	577.23	571.2		571.02	574.7	571.21
Huntsville Spring Branch @ Martin Road (HSMR)		556.69	564.67	558.87		558.49	565.73	558.83		558.45	565.51	559
Huntsville Spring Branch @ Patton Road (P7)		555	558	556		555.14	558.82	556.09		554.31	557.99	555.22
Drain parallel to Patton Road (P3)	5.28	559.58	561.6	559.71	2.60	559.52	561.49	559.63	3.73	559.52	561.03	559.65
Huntsville Spring Branch @ Mile 4.85 (HSMN)		555.19	556.9	555.97		554.30	556.61	555.77		554.01	555.96	554.9
Culvert at Mother Lode swamp (P4)		555.78	557.51	556.12		555.77	558.04	556.08		554.93	556.74	556.03
Huntsville Spring Branch @ Dodd Road (HSDR)		555.18	556.58	555.93		554.22	556.92	555.8		553.15	555.90	554.39

Mean Monthly Stage - Average Stage within the month of interest over the three year monitoring period (2000 - 2002)

Appendix B

Huntsville Spring Branch Mean Monthly Stage 2000-2002
Redstone Arsenal, Madison County, Alabama

SW Gauging Station	Mean Monthly Stage 2000 - 2002											
	October (2000, 2001, 2002)				November (2000, 2001, 2002)				December (2000, 2001, 2002)			
	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage
Huntsville Spring Branch @ Johnson Road (USGS 03575950)		571.07	577.06	571.19		571.14	578.24	571.3		571.17	577.29	571.5
Huntsville Spring Branch @ Martin Road (HSMR)		558.76	563.01	558.94		558.90	570.15	559.63		559.08	567.06	559.71
Huntsville Spring Branch @ Patton Road (P7)		554	559	555		554.46	559.36	555.12		554.68	560.7	555.79
Drain parallel to Patton Road (P3)	2.41	559.53	561.52	559.69	5.04	559.62	562.40	559.83	5.36	559.67	562.65	559.86
Huntsville Spring Branch @ Mile 4.85 (HSMN)		554.02	556.03	554.75		554.05	557.61	554.4		553.99	557.52	554.85
Culvert at Mother Lode swamp (P4)		555.57	557.51	556.08		555.9	558.25	556.42		556.05	559.34	556.39
Huntsville Spring Branch @ Dodd Road (HSDR)		552.12	555.36	554.1		552.22	556.21	553.03		552.09	557.36	554.16

Mean Monthly Stage - Average Stage within the month of interest over the three year monitoring period (2000 - 2002)

Appendix B

Tennessee River at Whitesburg (USGS 03575500) Mean Monthly Discharge 2000-2002
Redstone Arsenal, Madison County, Alabama

January (2000, 2001, 2002)				February (2000, 2001, 2002)				March (2000, 2001, 2002)			
Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q
4.93	366.4	206422.8	39917.6	**3.13**	388.64	99788.8	34834.16	**5.60**	368.8	167043.8	35543.17
April (2000, 2001, 2002)				**May (2000, 2001, 2002)**				**June (2000, 2001, 2002)**			
Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q
3.45	428.5396	192576.8	32415.6	**4.85**	532.8183	102314	23155.2	**4.27**	552.019	84455.77	25223.03
July (2000, 2001, 2002)				**August (2000, 2001, 2002)**				**September (2000, 2001, 2002)**			
Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q
5.28	553.9062	54803.32	27853.945	**2.60**	516.0177	71479.23	37711.43	**3.73**	456.7487	71472.39	30278.76
October (2000, 2001, 2002)				**November (2000, 2001, 2002)**				**December (2000, 2001, 2002)**			
Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q	Average Total Monthly Rainfall	Average Min Q	Average Max Q	Average Median Q
2.41	413.8396	79486.24	35401.75	**5.04**	394.7596	94090.85	42281.775	**5.36**	355.1996	109184	47451.76

Mean Monthly Discharge - Average Flow within the month of interest over the three year monitoring period (2000 - 2002)

Appendix B

Tennessee River Mean Monthly Stage 2000-2002
Redstone Arsenal, Madison County, Alabama

Mean Monthly Stage 2000 - 2002												
	January (2000, 2001, 2002)				February (2000, 2001, 2002)				March (2000, 2001, 2002)			
SW Gauging Station	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage
Tennessee River @ Whitesburg (USGS 03575500)	4.93	550.08	568.09	552.49	3.13	550.12	560.17	553.59	5.60	550.18	565.25	553.69
Tennessee River @ Mile 321		550.61	560.38	552.3		550.77	558.49	553.45		550.77	559.67	553.23
	April (2000, 2001, 2002)				May (2000, 2001, 2002)				June (2000, 2001, 2002)			
SW Gauging Station	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage
Tennessee River @ Whitesburg (USGS 03575500)	3.45	551.86	567.17	555.94	4.85	554.37	560.51	555.72	4.27	554.41	557.28	555.96
Tennessee River @ Mile 321		552.17	562.29	555.64		554.37	558.95	555.76		554.93	557.49	556.2
	July (2000, 2001, 2002)				August (2000, 2001, 2002)				September (2000, 2001, 2002)			
SW Gauging Station	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage
Tennessee River @ Whitesburg (USGS 03575500)	5.28	554.66	557.49	556.03	2.60	553.55	558.81	556.11	3.73	552.56	557.32	554.73
Tennessee River @ Mile 321		554.74	556.99	555.84		553.86	557.7	555.85		553.17	556.55	554.52
	October (2000, 2001, 2002)				November (2000, 2001, 2002)				December (2000, 2001, 2002)			
SW Gauging Station	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage	Average Total Monthly Rainfall	Average Min Stage	Average Max Stage	Average Median Stage
Tennessee River @ Whitesburg (USGS 03575500)	2.41	550.96	556.52	554.22	5.04	550.52	559.11	553.85	5.36	550.11	560.03	554.5
Tennessee River @ Mile 321		551.32	556.18	553.99		551.07	558.11	552.81		550.67	559.07	553.69

Mean Monthly Stage - Average Stage within the month of interest over the three year monitoring period (2000 - 2002)

Response to U.S. Environmental Protection Agency (EPA) Region 4
Comments on
Continuous Surface Water Monitoring Report 2000-2002
Draft, dated August 2003
Redstone Arsenal, Alabama

Comments from Julie L. Corkran, Senior Remedial Project Manager, Waste Management Division, Federal Facilities Branch, dated, U.S. Environmental Protection Agency Region 4, dated September 25, 2003.

General Comments

Comment 1: **This report documents data collection efforts and provides recommendations for future surface water monitoring activities. EPA views the surface water monitoring effort by Redstone as foundational to implementation of the Integrator Operable Unit approach to investigation and mitigation of contaminants from multiple Army and NASA sources at this National Priorities List facility. Further, EPA views the report as a secondary-type document under the draft Federal Facility Agreement for the CERCLA cleanup at this facility. This Agency generated limited comments as a result of our review and the report is appreciated for its contribution to the overall understanding of the hydrology of Redstone Arsenal and NASA Marshall Space Flight Center.**

Response 1: Comment acknowledged.

Comment 2: **This report is full of the hydrographs and flow data that make up the basic data of surface water hydrology. The water freely interchanges between the groundwater and the surface water and thereby potentially discharging contaminants to the surface water and allowing dilution of plumes in the subsurface. It would be useful if there were a map which depicted the gaining and losing reaches of the major surface water bodies across the facility. This map would aid in the holistic understanding of the hydrology of Redstone Arsenal and the specific impacts from the individual sites. Perhaps the map should be presented as a pair of maps depicting high pool/low pool stages or wet season/dry season conditions.**

Response 2: With few exceptions, it is not possible to identify gaining or losing reaches for the monitored streams at Redstone. Such determinations are hindered by backflow conditions in the downstream reaches of Huntsville Spring Branch/Indian Creek, sparcity of monitoring stations along upper Indian Creek, and issues regarding rating changes over time in several other gaged locations. In the case of Indian Creek upstream of Martin Road, the low gradient, braided meandering channel is not conducive to establishing monitoring stations. Consequently, it is not possible to identify gaining or losing reaches between Martin Road and I-565. What is known is that there is a gaining reach along McDonald Creek downstream of the Hansen Road bridge, much of which can be attributed to discharge from several distinct springs. Additionally, and as described in the report, a losing reach exists along Huntsville Spring Branch between the confluence with McDonald Creek and the Patton Road bridge. Both of these conditions have been identified in the report. A single figure has been added to document the known reaches along Huntsville Spring Branch and McDonald Creek where gaining and/or losing conditions occur.

Comment 3: **This report covers three years worth of data. Please provide an opinion as to the representativeness of this data set. Three years is a relatively short length of time to document "natural" site conditions but may be sufficient given project specific constraints.**

Response 3: As outlined in the report, surface water flow is related to precipitation and river stage. River stage as controlled by TVA remained consistent (in terms of daily or seasonal patterns of stage fluctuation) over the three year period in comparison to previous years. Annual total rainfall serves as a robust indicator of the prevailing hydrologic conditions. Monthly and annual rainfall from1983-1999 are reported in the Redstone karst report of findings. Extending this evaluation to include data through 2003, the twenty-year average annual rainfall (1983-2003) is 51.88 inches ranging up to a maximum of 67.73 inches in 1989. Over the three year monitoring period reported, the lowest total rainfall was reported in 2000 (37.17 inches) while the rainfall for 2001 through 2003 was 64.11, 50.68, and 54.50 inches per year, respectively. Consequently, the range of rainfall and thus surface water flow conditions observed reflects the full range of conditions (minimum, average, and near highest recorded rainfall) observed within the 20-year period.

Comment 4: **Many of the figures include a graphical representation or typed notation of the rating limits for the data or the data collection device. There are several instances where the rating limits exceed the data displayed. Please provide an explanation of rating limits and how they are used in evaluating the data collected.**

Response 4: The rating limits reflect the range of conditions encountered during the rating period from which the flow-stage rating curves for each station were developed. The limits are only shown on figures which were rated (lower reaches of HSB and Indian Creek were not). The intent was to document the limitations imposed in capturing the full range of flow that might be encountered at a given station. Where the rating limits exceed the range of data observed during the monitoring period, this simply indicates that higher flow conditions were or could be encountered than were actually observed. In this condition, it is possible to document flow conditions over a broad range of stage conditions. In other gages, the range of stage conditions encountered during the rating period was limited and consequently, so is the ability to gage flow outside of that rated range. The lower rating limit is directly related to this limitation. The upper rating limit may also be constrained by the stream channel geometry: under flood conditions, the stream exceeds the channel boundary and is not ratable. Although stage levels are recorded for all conditions, flow cannot be determined for stage conditions outside the rated range (except to state they are greater than y or less than x, where x and y reflect the upper and lower rated flow rates, respectively). Figure 3-3a is an example of a rated station capable of documenting flow over a broad range of flow conditions (which were not exceeded during the monitoring period). Conversely, Figure 3-4a documents a very narrow range of rated stage/flow conditions, which were exceeded during certain periods or events over the monitored period. Conclusions and recommendations regarding the efficacy of various gaging stations was based on comparison of the rating limits and observed stage/flow conditions at locations along surface water features. Where an upstream station has a broader rated range than the downstream gage, the downstream gage defines the limits to which all surface water data for that stream can be used to evaluated with respect to gaining/losing reaches.

Specific Comments:

Comment 1: <u>Page 17, Section 4.0.</u> **Please provide a justification for the recommendation of the cessation of the collection of the stream flow data. It appears from earlier text that the recommendation to discontinue the gathering of flow data is because (i) it is an expense that is not tied to any specific waste unit, and (ii) it is expensive to perform accurately, since the stream cross section changes through time and these changes require recalibration of the parameters that feed into the Manning Equation evaluations (see Appendix A). If these are the reasons for ceasing the collection of stream flow data, then please state them in the text. If there are additional reasons, please provide them in the text as well and provide feedback to the agencies on how cessation of stream flow data collection may impact Integrator Operation Unit efforts for Redstone and NASA MSFC.**

Response 1: Rationale for the recommendations listed in bulleted form on page 21 are supported by previous text in Section 4.0. While funding is always a constraint, technical issues with respect to maintaining ratings or improving those completed to date dictate the decision to terminate the flow monitoring. It is felt that the evaluation completed to date has met the objectives of attempting to quantify gaining or losing reaches. The low gradient of the streams at Redstone, coupled with flooding conditions, siltation/deposition, and wildlife issues make effective surface water flow monitoring challenging. However, it should be noted that as of January 2004, all surface water monitoring activities performed by Shaw have been terminated due to budget constraints (funded scope completed, continued monitoring not funded). The only remaining monitoring stations are those maintained by the USGS (McDonald Creek at Patton Road, Huntsville Spring Branch at Johnson Road, and Indian Creek at I-565, Tennessee River at Whitesburg bridge).

Comment 2: **<u>Introduction.</u> In the *Introduction*, the report notes that all available surface water monitoring data on or adjacent to RSA have been integrated into this report. Please clarify whether surface water monitoring data generated by NASA MSFC have been included in this report. For example, it is EPA's understanding that NASA MSFC has collected continuous surface water monitoring data at a tributary to Indian Creek near Martin Road.**

Response 2: To clarify, the text refers to all TVA, USGS or Shaw/Army acquired data available for the Arsenal. We are unaware of any MSFC-NASA surface water gaging data having been acquired during this monitoring period. Text amended accordingly.