DEVELOPMENT OF BANKFULL DISCHARGE AND CHANNEL GEOMETRY REGRESSIONS FOR PENINSULAR FLORIDA STREAMS

By

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To my Mom, Dad, and Eric

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DEVELOPMENT OF BANKFULL DISCHARGE AND CHANNEL GEOMETRY
REGRESSIONS FOR PENINSULAR FLORIDA STREAMS

By

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Regional curves, which relate bankfull discharge and channel geometry (cross-sectional area, width, and mean depth) to drainage area in regions of similar climate, geology, and vegetation, have greatly aided in creating target natural channel designs for stream restoration efforts. Regional curves were developed for peninsular Florida based on cross-sectional and longitudinal survey data collected at 17 gaged and 28 ungaged as near-to-natural streams, ranging in drainage area from 0.2 to 311 square miles and valley slope from 0.02 to 2.27%. Based on an analysis of prevalence among sites, slopes, and hydrologic data, the elevation of the flat floodplain was determined to be the most reliable bankfull indicator at sites with a wetland floodplain, while the elevation of the inflection on the bank was the most reliable indicator at sites with an upland floodplain. Analysis of bankfull indicator slopes further revealed that a water slope threshold of approximately 0.5% exists, above which bankfull indicators appear to more reliable, suggesting that slope-area techniques for calculating the bankfull discharge may be unreliable in peninsular Florida streams with a water slope less than 0.5%.

The dataset was further divided based on physiography (flatwoods versus highlands), geography (northern versus southern peninsula), and floodplain types (wetland versus upland and cypress-

dominated versus non-cypress-dominated) to determine if significant differences exist in the bankfull regressions and/or various dimensionless ratios (sinuosity, width-to-depth, maximum depth-to-mean depth, valley slope, and maximum discharge-to-mean annual discharge) among various peninsular Florida stream subsets. Streams with wetland floodplains were found to have a significantly greater bankfull area and bankfull width than streams with an upland floodplain. Also, streams with cypress-dominated floodplains had a greater width-to-depth ratio than streams with non-cypress-dominated floodplains. Further, streams draining flatwoods physiographies were found to be flashier. These differences may be important considerations when designing natural channels in peninsular Florida.

Annual peak flow data for the gaged sites were analyzed to estimate the bankfull discharge return interval using Log Pearson Type III distributions. The bankfull discharge ranged from less than one year to 1.44 years, which is more frequent than the average 1.5-year return interval often cited in the literature. Based on analysis of the flow duration at gaged sites, bankfull discharge for peninsular Florida streams is equaled or exceeded approximately 21% of the time on average, or about 77 days per year. On average, the bankfull discharge is roughly four times that of the mean annual discharge and is 35% of the 1.5-year discharge.

Lastly, the regional curves developed for peninsular Florida were compared to regional curves previously developed for other regions of the southeastern United States Coastal Plain. Peninsular Florida bankfull channels were found to have a lower bankfull discharge and smaller bankfull channel (narrower and shallower) than northwest Florida streams, which receives more mean annual precipitation and runoff. These differences indicate that the regional curves developed in the present work are more applicable to peninsular Florida streams than are regional curves developed for other regions of the southeastern Coastal Plain.

CHAPTER 1
INTRODUCTION

Land use changes (i.e., deforestation, agriculture, mining, and residential and urban development) and channel and floodplain alterations (i.e., levees, dams, channelization, and dredging) have negatively impacted large numbers of streams across the United States by affecting the amount, location, and timing of water movement through a watershed. These watershed alterations can introduce hydraulic instability to a system by altering flow and sediment transport rates, and may ultimately lead to increased deposition (aggradation), increased erosion (degradation), or abandonment of existing channels for new ones (Dunne and Leopold, 1978). Because the physical environment largely controls species composition and abundance of stream-dependent fauna (Allan, 1995; Gordon *et al.,* 2004), restoring streams to a more stable and biologically productive state has become a priority for many government agencies and private organizations, and approximately $10 billion has been spent on 30,000 river restoration projects in the United States to date (Malakoff, 2004).

While traditional stream stabilization practices have relied on hardening reaches with rip-rap or concrete, natural channel designs that take a stream's natural tendencies into account have recently gained popularity and are now commonly practiced in many areas. Regional curves, which relate bankfull discharge and channel geometry (cross-sectional area, width, and mean depth) to drainage area in regions of similar climate, geology, and vegetation, have greatly aided in creating target natural channel designs. Bankfull discharge, or flow that fills a stable alluvial channel to the elevation of the active floodplain, is a useful parameter in developing regional curves because its stage is reasonably identifiable in the field, and it is the flow most often used to estimate the channel-forming discharge. Dunne and Leopold (1978) describe bankfull discharge as "the most effective streamflow for moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphological characteristics of channels." While regional curves provide important information for natural channel structure, they also aid in estimating bankfull discharge and channel geometry in ungaged watersheds where drainage area is known, help confirm field identifications of bankfull stage, and allow for comparisons between regions (Leopold, 1994)

Because many Florida streams have been degraded due to land use changes and channel and floodplain alterations, development of regional curves for peninsular Florida will provide the necessary data to implement natural channel designs as a stream restoration technique in Florida. These data will be useful to public agencies such as Department of Environmental Protection (DEP), United States Geological Survey (USGS), and Department of Transportation (DOT), as well as to private industries such as the phosphate mining industry. Metcalf (2004) published regional curves for "Florida streams," yet his study sites were confined to extreme north Florida and the Panhandle and even included sites in Georgia and Alabama (Figure 1-1). Thus these relationships may not be applicable to streams in peninsular Florida, as it is quite different in physiography, geological context, and rainfall patterns.

To develop regional curves for peninsular Florida, forty-five as near-to-natural peninsular Florida streams were surveyed, ranging in drainage area from 0.2 to 311 square miles and in valley slope from 0.02% to 2.27% (Table, 1-1, Figure 1-2). Seventeen of the study sites are or historically have been gaged by the U.S. Geological Survey (USGS), while 29 are ungaged. The sites were further divided into subsets based on their physiography, geography, and floodplain types. Twenty-five sites drain a flatwoods physiography (generally with an abundance of wetlands, poorly-drained D-type soils, high water tables, flat topography, and many streams), while 21 drain a highlands physiography (generally with an abundance lakes, relict sand dunes, well-drained A-type soils, low water tables, rolling topography, and few streams). Twenty of the sites are located in the northern portion of the peninsula (above the 28.5 degrees north latitude line), while 26 are located in the southern portion of the peninsula (below the 28.5 degrees north latitude). Twenty-three sites had a wetland floodplain (dominated by hydrophytic vegetation and hydric soils) and twenty-two had an upland floodplain (dominated by hydrophobic vegetation and non-hydric soils). Of the twenty-three sites with a wetland floodplain, 11 were dominated by cypress (*Taxodium spp*.)

Research objectives were to 1) determine the most reliable bankfull indicator for peninsular Florida streams; 2) develop bankfull discharge and channel geometry relationships (regional curves) for peninsular Florida streams; 3) compare bankfull discharge and channel geometry relationships between streams draining different physiographies (flatwoods versus highlands), geographies (northern versus southern peninsula), and floodplain types (wetland versus upland and cypress-dominated versus non-cyrpess-dominated); 4) estimate the recurrence interval associated with the bankfull discharge for peninsular Florida streams; and 5) compare regional curves developed for peninsular Florida to those previously developed for other regions of the southeastern United States Coastal Plain.

Hypotheses were 1) when present, the level of a flat depositional floodplain will be the best bankfull indicator for peninsular Florida streams; 2) bankfull discharge and channel geometry relationships will vary in peninsular Florida by physiography and floodplain type, but not by geography; 3) bankfull discharge occurs more frequently in peninsular Florida than the often cited 1.5-year return interval for bankfull discharge; and 4) regional curves developed for peninsular Florida will be significantly different than regional curves developed for other regions of the southeastern United States Coastal Plain.

Table 1-1. Summary of study sites

	Location				Data Subsets			Independent Variables		Managed Lands	
Site name	County	Latitude	Longitude	USGS station ID	Physio-graphy	Geo-graphy	Flood-plain type	Drainage area (sq mi)	Valley slope (%)	Managed lands	Managed lands owner
Alexander Springs Creek tributary 2	Lake	29.100	-81.576	--	HL	N	UP	1.6	1.042	Ocala National Forest	US Forest Service
Blackwater Creek near Cassia	Lake	28.874	-81.490	02235200	HL	N	WFC	126	0.020	Seminole State Forest	Division of Forestry
Blues Creek near Gainesville	Alachua	29.728	-82.431	02322016	FW	N	UP	2.6	0.206	San Felasco Hammock SP	FDEP
Bowlegs Creek near Ft Meade	Polk	27.700	-81.695	02295013	FW	S	WF	47.2	0.050	--	--
Carter Creek near Sebring	Highlands	27.532	-81.388	02270000	HL	S	UP	38.8	0.237	Lake Wales Ridge WMA	FWC
Catfish Creek near Lake Wales	Polk	27.961	-81.496	02267000	HL	S	WFC	58.9	0.050	Catfish Creek Preserve SP	FDEP
Coons Bay Branch	Hardee	27.594	-81.857	--	FW	S	WF	0.5	0.348	--	--
Cow Creek	Levy	29.231	-82.649	--	FW	N	WFC	5.3	0.080	Goethe State Forest	Division of Forestry
Cypress Slash tributary	Highlands	27.597	-81.267	--	HL	S	UP	0.5	1.042	Avon Park Air Force Range	US Air Force
East Fork Manatee River tributary	Manatee	27.523	-82.106	--	FW	S	UP	0.2	0.313	Duette Preserve	Manatee County
Fisheating Creek at Palmdale	Glades	26.933	-81.315	02256500	FW	S	WFC	311	0.029	Fisheating Creek WMA	FWC
Gold Head Branch	Clay	29.836	-81.951	--	HL	N	UP	1.8	1.316	Gold Head Branch SP	FDEP
Hammock Branch	Putnam	29.540	-81.610	--	HL	N	WF	3.0	0.167	Dunns Creek SP	FDEP
Hickory Creek near Ona	Hardee	27.482	-81.880	02295755	FW	S	WF	3.75	0.116	--	--
Hillsborough River tributary	Pasco	28.216	-82.118	--	FW	S	WFC	0.7	0.260	Upper Hillsborough	SWFWMD
Horse Creek near Arcadia	De Soto	27.199	-81.988	02297310	FW	S	WF	218	0.043	--	--
Jack Creek	Highlands	27.364	-81.426	--	HL	S	WF	5.2	0.286	Lake Wales Ridge WMA	FWC
Jumping Gully	Lake	29.171	-81.598	--	HL	N	UP	4.6	1.111	Ocala National Forest	US Forest Service
Lake June-In-Winter tributary	Highlands	27.287	-81.414	--	FW	S	UP	0.4	0.781	Lake June-In-Winter SP	FDEP
Little Haw Creek near Seville	Flagler	29.322	-81.385	02244420	FW	N	WFC	93	0.061	--	--
Livingston Creek near Frostproof	Polk	27.709	-81.446	02269520	HL	S	UP	120	0.064	Lake Wales Ridge SF	Division of Forestry
Livingston Creek tributary	Polk	27.684	-81.459	--	HL	S	UP	0.4	0.250	Lake Wales Ridge SF	Division of Forestry
Lochloosa Creek at Grove Park	Alachua	29.600	-82.145	02241900	FW	N	WFC	7.4	0.116	--	--
Lowry Lake tributary	Clay	29.863	-81.982	--	HL	N	UP	0.25	0.625	Camp Blanding	FL Dept. of Military Affairs
Manatee River near Myakka Head	Manatee	27.474	-82.211	02299950	FW	S	UP	65.3	0.116	Duette Preserve	Manatee County
Manatee River tributary	Manatee	27.483	-82.197	--	FW	S	UP	0.3	1.163	Duette Preserve	Manatee County
Morgan Hole Creek	Polk	27.661	-81.303	--	FW	S	UP	9.4	0.091	Avon Park Air Force Range	US Air Force
Moses Creek near Moultrie	St. Johns	29.775	-81.316	02247027	FW	N	WFC	7.4	0.159	--	--
Myakka River tributary 1	Sarasota	27.239	-82.281	--	FW	S	UP	2.6	0.091	Myakka River SP	FDEP
Myakka River tributary 2	Sarasota	27.196	-82.309	--	FW	S	UP	1.7	0.129	Myakka River SP	FDEP
Nine Mile Creek	Lake	29.093	-81.610	--	HL	N	WF	16	0.488	Goethe State Forest	Division of Forestry
Rice Creek near Springside	Putnam	29.688	-81.742	02244473	FW	N	WFC	43.2	0.041	Rice Creek Cons. Area	SJRWMD
Santa Fe River near Graham	Alachua	29.846	-82.220	02320700	FW	N	UP	94.9	0.058	--	--
Shiloh Run near Alachua	Alachua	29.819	-82.472	02322050	FW	N	UP	0.32	2.000	--	--
Snell Creek	Polk	28.142	-81.572	--	HL	S	WF	1.7	0.167	--	--
South Fork Black Creek	Clay	29.930	-81.942	--	HL	N	WF	25.5	0.110	Camp Blanding	FL Dept. of Military Affairs
Spoil Bank tributary (Highlands)	Highlands	27.068	-81.276	--	FW	S	UP	8.6	0.313	Smoak Groves Cons. Ease.	FDEP
Ten Mile Creek	Levy	29.144	-82.617	--	FW	N	WFC	25	0.130	Goethe State Forest	Division of Forestry
Tiger Creek near Babson Park	Polk	27.811	-81.444	02268390	HL	S	UP	52.8	0.081	Lake Wales Ridge SF	Division of Forestry
Tiger Creek tributary	Polk	27.858	-81.487	--	HL	S	WF	0.9	0.139	Tiger Creek Preserve	TNC
Triple Creek unnamed tributary 1	Hillsborough	27.791	-82.252	--	HL	S	WF	1.7	0.532	Balm Boyette; Triple Creek	Hillsborough County
Triple Creek unnamed tributary 2	Hillsborough	27.797	-82.254	--	FW	S	UP	0.2	0.885	Balm Boyette; Triple Creek	Hillsborough County
Tuscawilla Lake tributary	Marion	29.467	-82.285	--	HL	N	UP	0.3	2.273	Price's Scrub	FDEP
Tyson Creek	Osceola	27.940	-81.006	--	FW	S	WFC	20.5	0.054	Three Lakes WMA	FWC
Unnamed Lower Wekiva tributary	Lake	28.919	-81.405	--	HL	N	WF	0.4	0.769	Lower Wekiva River SP	FDEP

Notes: -- = Ungaged site or site located on private lands; FW = Flatwoods physiography; HL = Highlands physiography; N = Northern peninsula geography; S = Southern peninsula geography; WF = Wetland floodplain; WFC = Wetland floodplain dominated by cypress; UP = Upland floodplain; SP = State Park; FDEP = Florida Department of Environmental Protection; SF = State Forest; WMA = Wildlife Management Area; FWC = Florida Fish and Wildlife Conservation Commission; TNC = The Nature Conservancy; Cons. Ease. = Conservation Easement

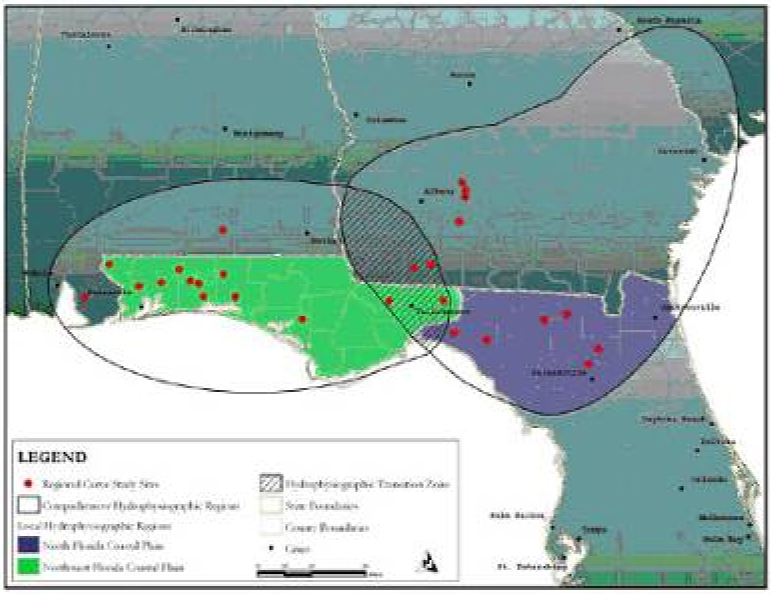


Figure 1-1. North and northwest Florida regional curve study sites. Source: Metcalf, 2004

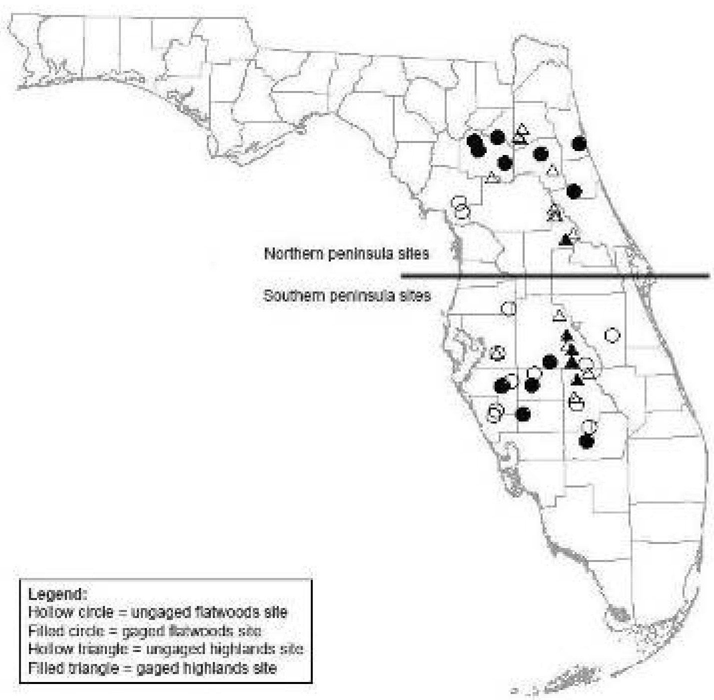


Figure 1-2. Peninsular Florida regional curve study sites

CHAPTER 2
LITERATURE REVIEW

Introduction

Metcalf (2004) published regional curves for "Florida streams," yet his study sites were confined to extreme north Florida and the Panhandle and even included sites in Georgia and Alabama (Figure 1-1). Thus, these relationships may not be applicable to streams in peninsular Florida, as it is quite different in physiography, geological context, and rainfall patterns. The following literature review begins by describing Florida's unique physiography, geological context, weather and climate, and water resources. A description of regional curves follows, which includes the history of regional curve development, the concept of channel-forming discharge, and methods for the identification of the bankfull stage.

Florida Background

Physiography/Geological Context

Florida is located within the Coastal Plain physiographic province of the United States, which is a region of low relief underlain by unconsolidated to poorly consolidated sediments and hardened carbonate rocks (Berndt *et al.,* 1998) (Figure 2-1). Florida's present configuration is largely a result of sea level fluctuations throughout the Cenozoic Era (the last 65 million years of geologic time). Sea level during the early Cenozoic was significantly higher than present, and carbonate rocks (limestone and dolomite) formed due to the deposition of marine life fossils. Little siliciclastic material from the eroding Appalachian Mountains reached the Florida Platform during this time due to a marine current running through the Gulf Trough (Figure 2-2A). However, in the mid-Cenozoic the Appalachians were uplifted, increasing erosional rates, and siliciclastic sediments eventually filled the Gulf Trough and covered Florida's carbonate foundation with sands, silts, and clays (Lane, 1994) (Figure 2-2B).

Most landforms characterizing Florida's modern topography, as well as the streams, lakes, springs, and wetlands dotting the state today, formed during the most recent period of geologic time, the Quaternary (1.8 million years ago to present) (Lane, 1994). The Quaternary Period, which is made up of two geologic epochs (the Pleistocene or "Ice Age" and the Holocene), has been a time of world-wide glaciations and widely fluctuating sea levels, with seas alternately flooding and retreating from Florida's land area. At peak interglacial stages, sea level rose to approximately 150 feet above the present level, and peninsular Florida likely consisted only of islands (Lane, 1994) (Figure 2-3). As seas retreated, waves and currents eroded a series of relict, coast-parallel scarps and constructed sand ridges spanning the state. Many of these features are found today stranded many miles inland, including the Cody Scarp, Trail Ridge, Brooksville Ridge, and Lake Wales Ridge (Lane, 1994). The development of Pleistocene landforms has also been influenced by the karst nature of Florida's foundation, as naturally acidic rain and groundwater have flowed through the limestone for millions of years dissolving conduits and caverns. Sometimes caverns collapse to create sinkholes, the largest of which can be seen today as lakes (Lane, 1994).

Two basic physiographies support peninsular Florida streams: 1) Flatwoods—generally with an abundance of wetlands, poorly-drained D-type soils, high water tables, flat topography, and many streams; and 2) Highlands—generally with an abundance lakes, relict sand dunes, well-drained A-type soils, low water tables, rolling topography, and few streams. One objective of the present work is to determine what, if any, differences exist between streams draining these two physiographies.

Weather and Climate

Although Florida is located at the same latitude as some of the world's major deserts, it is one of the wettest states in the nation, with an average annual rainfall of 53 inches (Henry, 1998).

Florida has two major climate types: humid subtropical in the northern three quarters of the state and tropical savanna in the southern portion of the peninsula and the Keys (Figure 2-4). In the tropical savanna climate, all months average over 64 degrees Fahrenheit, and there are distinct wet (June through September) and dry (winter) seasons. In the humid subtropical climate, some months have an average temperature less than 64 degrees Fahrenheit, and the dry season is not as pronounced (Henry, 1998).

Rainfall throughout Florida varies considerably from place to place, season to season, and year to year. It averages from 69 inches (Wewahitchka in the Panhandle) to 40 inches (Key West) annually (Henry, 1998). The wettest places in Florida are the Panhandle where rain falls abundantly throughout the year and the southeastern part of the state where the Gulf Stream enhances the likelihood of rainfall (Henry, 1998). The lowest amounts of rainfall occur in the Keys and in the central portion of the peninsula (Figure 2-5). Seasonally, the Panhandle receives proportionately more winter precipitation from large-scale frontal systems than any other part of the state. The southern portion of the state receives proportionately more summer precipitation, as Florida's peninsular shape, converging sea breezes of the Atlantic Ocean and the Gulf of Mexico, position relative to the Atlantic high pressure system, and tropical and subtropical location make it an ideal spawning ground for thunderstorms (Henry, 1998). Rainfall throughout the state also varies from year to year with cycles of drought, the occurrence of hurricanes that can yield 5 to 12 inches of rain, and the phenomena of El Niño and La Niña (Henry, 1998).

Nearly 70 percent of Florida's rain is returned to the atmosphere through evaporation and evapotranspiration. The remainder flows to its rivers and streams or seeps into the ground and recharges aquifers (Figure 2-6). Nearly all of Florida's groundwater originates from precipitation

(Berndt *et al.,* 1998). Rainfall contributes to stream-flow in Florida through several pathways, including overland flow, interflow, and baseflow (Mossa, 1998).

Water Resources

With approximately 10,000 miles of rivers and streams, 7,800 lakes, 33 first-magnitude springs (those that discharge water at a rate of 100 cubic feet per second or more), and millions of acres of wetlands, Florida has abundant surface water (Kautz *et al.,* 1998). Even more abundant is Florida's groundwater. With more than a quadrillion gallons flowing beneath the surface through the porous underlying limestone, groundwater comprises 30,000 times the daily flow to the sea of Florida's 13 major rivers (Conover, 1973). Regardless of amounts, Florida's unique karst landscape keeps surface water and groundwater well-connected through features such as sinkholes and springs. Well-developed karst features are also found in south-central Kentucky, Yucatan peninsula, parts of Cuba and Puerto Rico, southern China, and western Malaysia; however, Florida supports more rivers and streams than do these other karst areas due to its high water tables and flat terrain (Purdum, 2002).

Florida's karst terrain and flat topography can make determining watershed boundaries difficult. A watershed is defined as the land area that contributes runoff, or surface water flow to a water body. Local topography controls drainage direction and patterns, though drainage is also influenced by geology, soil, climate, and vegetation (Mossa, 1998). Networks of channel segments form drainage networks, most of which around the world are dendritic (tree-like). In Florida, however, many drainage networks are best described as either deranged, where numerous depressions (i.e., lakes or wetlands) are interspersed along the channel network, or "disjointed," where streams and rivers do not form continuous channels on the land surface and may disappear underground in sinks or depressions (Mossa, 1998). Other areas of Florida, such as the Everglades, are poorly drained with few or no streams and water flows across the surface through swamps and marshes as sheetflow. Florida's major rivers and watersheds are depicted in Figure 2-7 and Figure 2-8, respectively.

Several classification systems have been developed to categorize Florida's more than 1,700 rivers and streams (Nordlie, 1990). These were developed primarily by ecologists and are based mainly on faunal metrics, water quality, and sediment type. Beck (1965) developed the most commonly used classification of Florida waterways, which includes the following five categories:

- **Sand-bottomed streams:** slightly acidic with moderately high color; the most widely distributed and abundant stream type in Florida
- **Calcareous streams:** predominantly of spring origin with relatively cool, clear, and alkaline waters
- **Swamp-and-bog streams:** very acidic, highly colored, sluggish streams, which originate in swamps, sphagnum bogs, and marshes
- **Large rivers:** carry significant sediment loads and are always turbid; a "category of convenience"
- **Canals:** also a "category of convenience"

The Florida Natural Areas Inventory (FNAI, 1990) refined Beck's work by adding descriptions of landscape settings and water sources to their classification system, which includes four categories:

- **Alluvial streams:** originate in high uplands and are typically turbid due to high sediment loads; typically flood once to twice a year, providing an important pulse of nutrient-rich water to the floodplain, as well as sediment for natural levee development; sparsely distributed in Florida and primarily restricted to the Panhandle
- **Blackwater streams:** originate in sandy lowlands where wetlands slowly discharge tannic waters to the channel; generally acidic waters; most widely distributed and numerous stream type in Florida
- **Seepage streams:** originate from an unusual geologic process in which rainwater percolates through deep, sandy upland soils and encounters an impermeable layer causing the water to travel laterally until reaching a surface and producing a seepage face; clear to lightly colored water; generally small in magnitude

- **Spring-run streams:** derive most of their water from artesian vents in the underground aquifer; clear, slightly alkaline, cool water; generally have sandy bottoms or exposed limestone.

Many Florida rivers are actually a combination of stream types. For example, the Suwannee begins as a blackwater river draining the Okefenokee Swamp, but becomes a spring-fed river as it travels south where many springs contribute to its flow. As the Suwannee approaches the Gulf, it has a low-forested floodplain more characteristic of an alluvial river (Kautz *et al.,* 1998).

Though not specific to Florida streams, Rosgen (1994) developed what is currently the most comprehensive and commonly used stream classification system based on the principles of fluvial geomorphology. Rosgen (1994) first identified seven major stream types based on differences in geomorphic variables (i.e., entrenchment ratio, width/depth ratio, sinuosity, and channel slope) that can be seen when displayed in the following two-dimensional perspectives:

- **Longitudinal profile:** compares the elevation of the water or bed surface with distance downstream; bed features can be inferred from this perspective as these features have consistently been found to relate to channel slope

- **Cross-section:** compares the elevation with the width or distance across the channel; width to depth ratio, level of confinement (lateral containment), and level of entrenchment (vertical containment) can be inferred from this perspective

- **Plan form:** compares width across the channel with distance along the channel; sinuosity, meander width ratio (belt width/bankfull surface width), and radius of curvature can be inferred from this perspective. (Figure 2-9)

Rosgen (1994) then identified six additional stream types, which were delineated by dominant channel material ranging in particle size diameter from bedrock to silt/clay. When combined with the previous stream types, 42 major stream types emerged (Figure 2-10). Metcalf (2004) applied Rosgen's shape-based classification to streams in extreme north Florida and the Panhandle and identified two major physical classes of streams—C5, which are broad and shallow sand-bottomed streams, and E5, which are deep and narrow sand-bottomed streams.

Rosgen's classification system works on the assumption that streams are under alluvial control, meaning that their shape is strongly dictated as a function of sediment transport. Because of Florida's unique geology and climate, its fluvial forms are under variable degrees of alluvial control and may not lend themselves to this type of reach-scale, form-based classification that is now widely used throughout the United States (Kiefer, personal communication). For example, Florida's mild humid climate allows for a nearly year-round growing season, and vegetation probably exerts significant confinement on channel cross-section morphology and planform patterns in Florida compared to other regions (Kiefer, personal communication).

Regional Curves

Fluvial geomorphology is often the most fundamentally important scientific discipline for managing riparian corridors or planning ecological restoration of damaged stream ecosystems. Stream pattern is directly influenced by eight major variables: channel width, depth, velocity, discharge, channel slope, roughness of channel materials, sediment load, and sediment size (Leopold *et al.,* 1964). Change in any one of these variables sets up a series of channel adjustments that can lead to change in the others, resulting in channel pattern alteration (Rosgen, 1994). Land use changes (i.e., deforestation, agriculture, mining, and residential and urban development) and channel and floodplain alterations (i.e., levees, dams, channelization, and dredging) have impacted large numbers of streams across the United States by affecting the amount, location, and timing of water movement through a watershed. These watershed alterations can introduce hydraulic instability to a system by altering flow and sediment transport rates, and may ultimately lead to increased deposition (aggradation), increased erosion (degradation), or the abandonment of existing channels for new ones (Dune and Leopold, 1978). Because the physical environment largely controls species composition and abundance of stream-dependent fauna (Allan, 1995; Gordon *et al.,* 2004), restoring streams to a more stable and biologically productive state has become a priority for many government agencies and private organizations.

While traditional stream stabilization practices have relied on hardening reaches with rip-rap or concrete, natural channel designs that take a stream's natural tendencies of adjustment into account have recently gained popularity and are now commonly practiced in many areas. Regional curves, which relate bankfull discharge and channel geometry (cross-sectional area, width, and mean depth) to drainage area in regions of similar climate, geology, and vegetation, have greatly aided in creating target natural channel designs. Bankfull discharge, or flow that fills a stable alluvial channel to the elevation of the active floodplain, is a useful parameter in developing regional curves because its stage is reasonably identifiable in the field, and it is the flow most often used to estimate the channel-forming discharge. Dunne and Leopold (1978) describe bankfull discharge as "the most effective stream-flow for moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphological characteristics of channels." While regional curves provide important information for natural channel structure, they also aid in estimating bankfull discharge and channel geometry in ungaged watersheds when drainage area is known, help confirm field identifications of bankfull stage, and allow for comparisons between regions (Leopold, 1994).

History of Regional Curve Development

Dunne and Leopold (1978) are often credited as the pioneers of regional curves. They found that strong correlations exist between bankfull discharge and drainage area, as well as between bankfull channel geometry (cross-sectional area, width, and mean depth) and drainage area, in regions of similar climate, geology, and vegetation. Dunne and Leopold (1978) developed regional curves for four regions of the United States (Figure 2-11), including the San

Francisco Bay region, the eastern United States (more specifically, the Brandywine area of Pennsylvania), the Upper Green River in Wyoming, and the Upper Salmon River in Idaho (data for which were collected and published by Emmett, 1975). Their work revealed regional differences between the rainfall-runoff channels of the east and west coasts and the snowmelt-runoff channels of Idaho and Wyoming. Although Dunne and Leopold (1978) are often credited as the pioneers of the regional curve, older studies conducted by Nixon (1959) and Emmett (1975) developed similar curves for England and Wales and for the Upper Salmon River in Idaho, respectively.

Prior to these studies, Leopold and Maddock (1953) developed hydraulic geometry theory, in which channel geometry characteristics such as width, depth, and velocity vary directly with discharge as simple power functions, as shown in Figure 2-12 and Equations 2-1, 2-2, and 2-3.

$$w = aQ^b \tag{2-1}$$
$$d = cQ^f \tag{2-2}$$
$$v = kQ^m \tag{2-3}$$

In Equations 2-1 to 2-3, w is the width [L], d is the mean depth [L], v is the mean velocity [LT^{-1}], and Q is the water discharge [L^3T^{-1}]. The constants b, f, and m are empirical and represent slopes of the three lines, the sum of which should equal 1.0. The constants a, c, and k are also empirical and represent the intercepts of the three lines, the product of which should equal 1.0. Leopold and Maddock (1953) also postulated that discharge is dependent upon drainage area characteristics, which dictate runoff and sediment production.

Channel-forming Discharge

Several terms are used throughout the literature to describe channel-forming discharge, including dominant discharge, effective discharge, and bankfull discharge. Although these are often used interchangeably, they have distinct definitions and a brief description of each is thus useful in understanding the concept of channel-forming discharge.

Dominant discharge is defined as the "theoretical discharge that if maintained indefinitely in an alluvial stream would produce the same channel geometry as the natural long-term hydrograph (Copeland *et al.,* 2000)." Effective discharge, on the other hand, can be derived mathematically and is defined as the discharge that transports the largest fraction of the average annual bed-material load (Copeland *et al.,* 2000). Effective discharge incorporates the principle prescribed by Wolman and Miller (1960) that channel-forming discharge is a function of both the magnitude of the event and the frequency of occurrence. Wolman and Miller found that low-magnitude, relatively high-frequency events (occurring at least once each year or two), rather than rare catastrophic floods (occurring once in fifty or a hundred years), are the most effective in transporting sediment and performing "work." As shown in Figure 2-13, the effective discharge occurs at the peak of the curve obtained by multiplying the flood frequency curve and the sediment discharge rating curve. Development of a sediment discharge rating curve is difficult; however, because it requires collecting field data of bedload and total suspended sediment coupled with discharge over a wide range of flows (Metcalf, 2004). Effective discharge is thus not often used to develop regional curves.

Bankfull discharge is the most commonly used channel-forming discharge in the development of regional curves because it may be reasonably identified in the field by physical indicators (which will be described below). It is defined as flow that fills a stable alluvial channel to the elevation of the active floodplain (Figure 2-14). Leopold (1994) defines the active floodplain as the "flat area adjacent to the river channel, constructed by the present river in the present climate and frequently subjected to overflow." Bankfull discharge is thus morphologically significant because it represents the breakpoint between the processes of channel formation (erosion) and floodplain formation (deposition) (Copeland *et al.,* 2000). Gage station analysis throughout the United States has shown that bankfull discharge has average recurrence interval of 1.5 years, or a 66.7% annual exceedance probability (Dunne and Leopold, 1978; Leopold, 1994) (Figure 2-15). However, this widely reported assertion that bankfull discharge occurs on average once every one to two years is now seen as oversimplification (Thorne *et al.,* 1997), with several recent studies (particularly in the southeastern United States Coastal Plain) reporting much lower bankfull discharge recurrence intervals (Table 4-12). One objective of the present work is to estimate the recurrence interval of bankfull discharge in peninsular Florida streams.

Although many hydrologists and river engineers work under the assumption that dominant, effective, and bankfull discharges are approximately equal, this is controversial—while some have found effective and bankfull discharges to be in agreement, others have found that the former occurs more frequently than the latter (Knighton, 1998). It is thus important to understand that a channel is formed by a range of flows, and that bankfull discharge is but a surrogate of these flows (Knighton, 1998; Emmett, 2004).

Indicators of Bankfull Stage

Proper identification of bankfull stage, or the elevation at which the stream just begins to overtop its floodplain, is critical to both development of regional curves and calculation of bankfull discharge (Emmett, 2004). Field identification of bankfull stage is the method most often used to estimate channel-forming flow, though its correct identification in the field can be difficult and subjective (Knighton, 1998). U.S. Forest Service has published a field guide for both determining bankfull stage and conducting a stream channel survey (Harrelson *et al.,* 1994). Videos demonstrating how to identify bankfull stage in the Western and Eastern United States are also available from the U.S.D.A. Forest Service (1995, 2003). Some common field indicators of bankfull stage include:

- Top of bank for non-incised channels
- Height of depositional features—especially the top of the pointbar
- Position on the bank where the slope first becomes level—this feature can be identified by facing the stream and dragging your foot until it flattens
- Change in vegetation—especially the lower limit of perennial species
- Slope or topographic breaks along the bank
- Change in the particle size of bank material—such as the boundary between coarse cobble or gravel with fine-grained sand or silt
- Undercuts in the bank—which usually reach an interior elevation slightly below bankfull stage
- Stain lines or the lower extent of lichens on boulders or trees. (Harrelson *et al.,* 1994; Leopold, 1994; U.S.D.A. Forest Service, 1995 and 2003)

Several analytical, non-field based techniques can also be used to determine bankfull stage, including:

- Stage-discharge rating curves— the inflection point on the rating curve that corresponds to the point at which the stream overtops its bank and the stage consequently levels off (Figure 2-16)
- Elevation at which the width-to-depth ratio is at a minimum (Figure 2-17)
- Flood frequency analysis of available stream gage data—bankfull discharge has an average recurrence interval of 1.5 years (Dunne and Leopold, 1978; Leopold, 1994)
- Regional curves—although the present work focuses on using bankfull indicators to develop regional curves, regional curves, in turn, can be used to confirm field identification of bankfull stage (FISRWG, 1998; Wolman, 1955; Leopold, 1994).

Reliable indicators have not been verified for peninsular Florida, though Metcalf (2004) found that bankfull indicators in extreme north Florida and the Panhandle were most often the top of bank or sometimes a lower bench/bar feature. Studies conducted on North Carolina streams found that the top of bank or lowest scour or bench was rarely an indicator of bankfull and determined that the highest scour line or the back of the point bar was the most consistent bankfull indicator (Harman, 1999). One objective of the present work is to determine the most reliable bankfull indicator for peninsular Florida (Chapter 3).

Once bankfull stage has been determined, bankfull cross-sectional area, width (width of water surface at bankfull stage), mean depth (quotient of bankfull cross-sectional area and bankfull width), and discharge can be determined. In gaged streams, bankfull discharge can be determined from a stage-discharge (Stage-Q) rating curve. In ungaged streams, Manning's equation (Equation 2-4) can be used to calculate bankfull discharge.

$$v = k_m/n * R^{2/3} * S^{1/2} \qquad (2\text{-}4)$$

In Equation 2-4, v is the velocity, km is a numerical constant (1.49 for units of feet and seconds and 1.0 for units of meters and seconds), n is the roughness coefficient (Manning's), R is the hydraulic radius (quotient of cross-sectional area and wetted perimeter) [L], and S is the water slope. Bankfull discharge and channel geometry (cross-sectional area, width, and mean depth) can then be plotted against drainage area for a population of streams, and a regression can be fit to develop a regional curve (Leopold, 1994).

Conclusions

There has been a recent surge in regional curve development throughout the United States, which can be attributed to the increased popularity of natural channel design as a stream restoration technique. While traditional stream stabilization practices have relied on hardening reaches with rip-rap or concrete, natural channel designs that take a stream's natural tendencies of adjustment into account have recently gained popularity and are now commonly practiced in many areas. Regional curves, which relate bankfull discharge and channel geometry to drainage area in regions of similar climate, geology, and vegetation, have greatly aided in design of stable stream channels. Regional curves also aid in estimating bankfull discharge and channel geometry in ungaged watersheds where the drainage area is known, help confirm field identifications of bankfull stage, and allow for comparisons between regions (Leopold, 1994).

Metcalf (2004) published regional curves for "Florida streams," yet his sites were confined to extreme north Florida and the Panhandle, and even included sites in Georgia and Alabama (Figure 1-1). Peninsular Florida, however, is quite different in physiography, geological context, and rainfall patterns. For example, the Panhandle receives abundant rain throughout the year and proportionately more winter precipitation due to large frontal-based storms coming off the mainland, while the peninsula receives less rain throughout the year and proportionately more summer precipitation due to convective storms occurring from the convergence of Gulf of Mexico and Atlantic Ocean sea breezes (Henry, 1998). As a result, streams draining these regions likely have significant differences in their bankfull discharge and channel geometry for a given drainage area. Development of regional curves for peninsular Florida is thus justified, and one objective of the present work is to determine what, if any, differences exist between peninsular Florida streams and those of other regions of the southeastern United States Coastal Plain.

Figure 2-1. Physiographic provinces of the United States. Source: Fenneman, 1946.

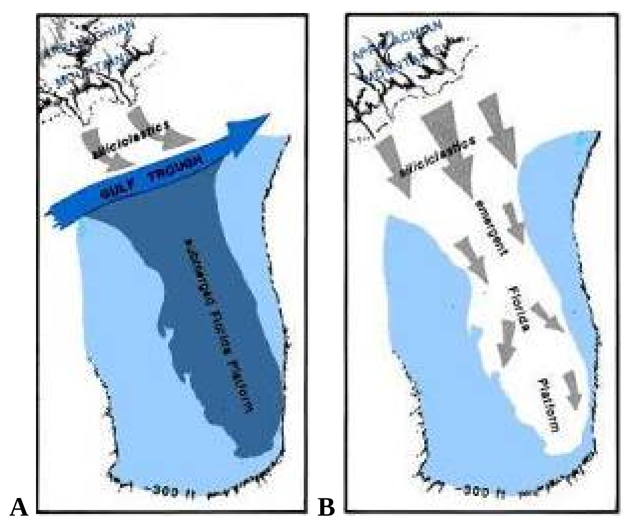


Figure 2-2. Geologic history of Florida. A) Through Oligocene time the Florida Platform was a shallow, marine limestone bank environment. Currents through the Gulf Trough diverted sands, silts, and clays that were eroding off the Appalachian Mountains to the north. B) Siliciclastic sediments had filled the Gulf Trough by Miocene time and encroached down the peninsula, covering the limestone environments. Source: Lane, 1994.

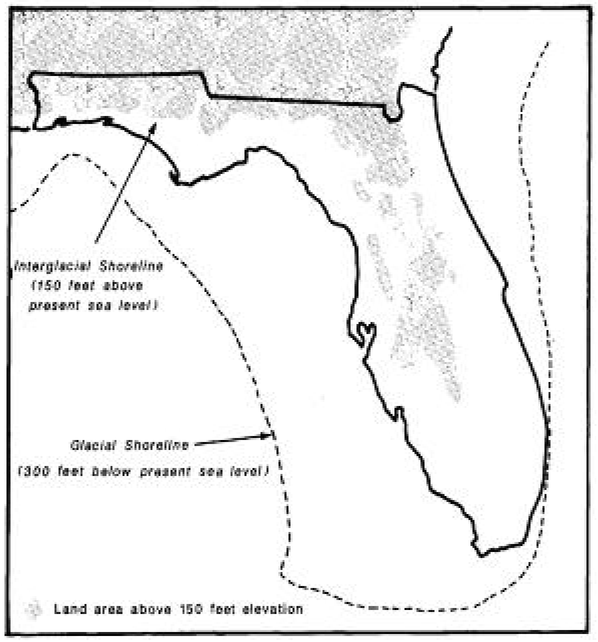


Figure 2-3. Pleistocene shorelines in Florida. Source: Lane, 1994.

Figure 2-4. Climate zones in Florida. Source: Henry, 1998.

Figure 2-5. Florida precipitation map. Source: Henry, 1998.

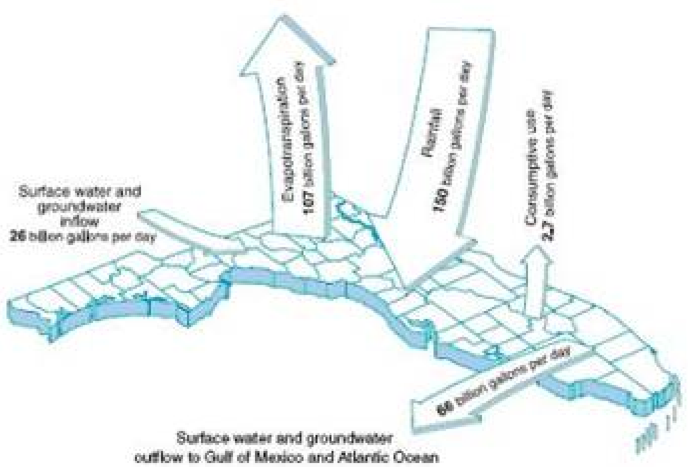


Figure 2-6. Florida's water cycle. Source: Purdum, 1998.

Figure 2-7. Florida's surface water drainage. Source: Mossa, 1998.

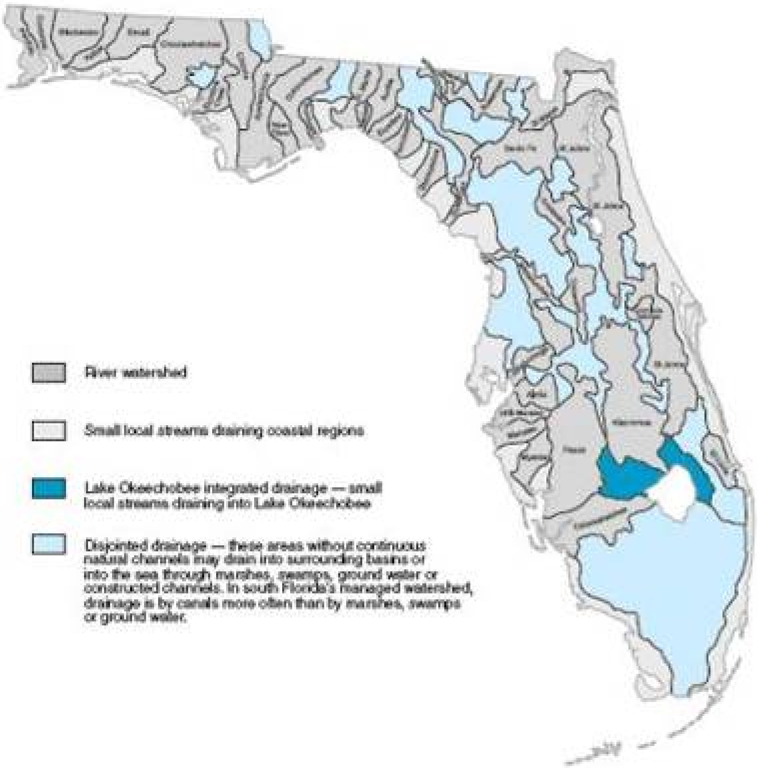


Figure 2-8. Florida's watersheds. Source: Mossa, 1998.

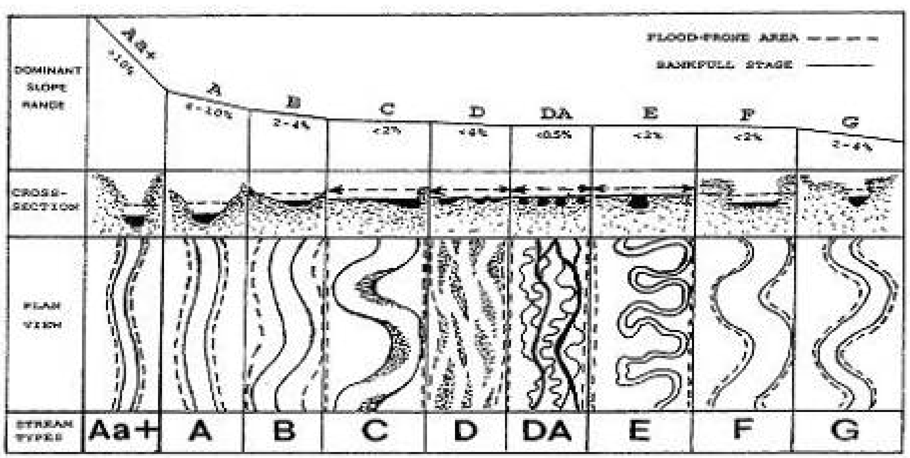


Figure 2-9. Longitudinal, cross-sectional, and plan views of major stream types. Source: Rosgen, 1994.

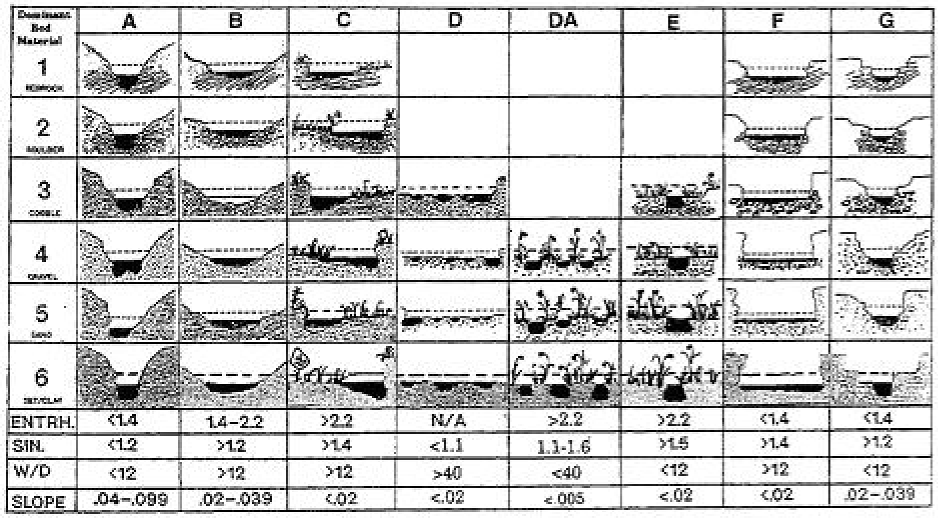
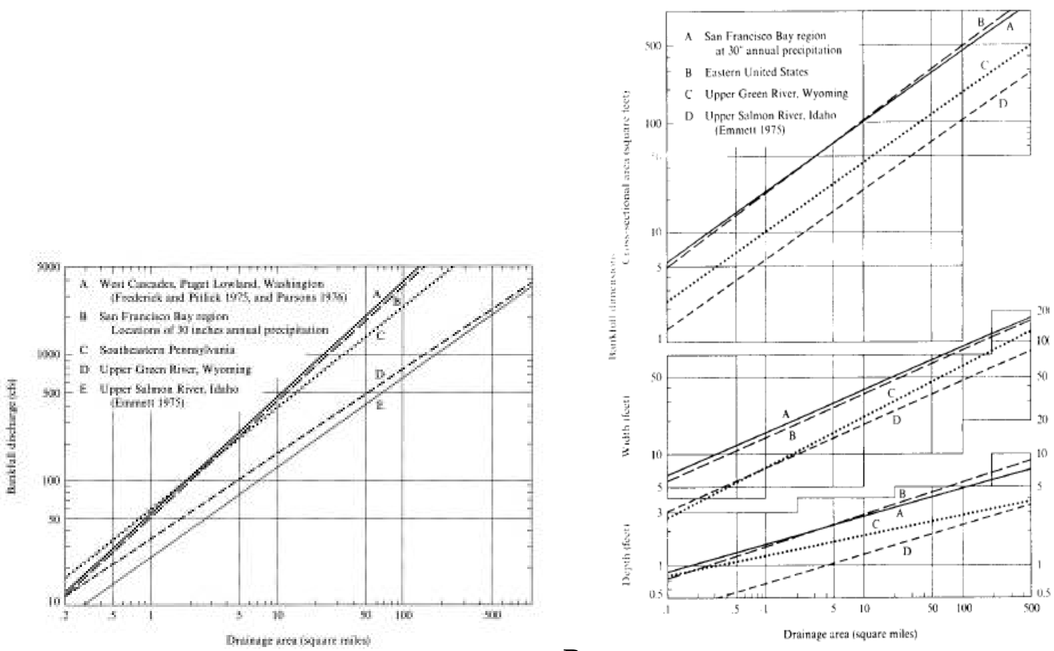


Figure 2-10. Cross-sectional configuration, composition, and delineative criteria of major stream types. Source: Rosgen, 1994.



A

B

Figure 2-11. Regional curves for four US regions. A) Bankfull discharge against drainage area. B) Bankfull channel geometry against drainage area. Source: Dunne and Leopold, 1978.

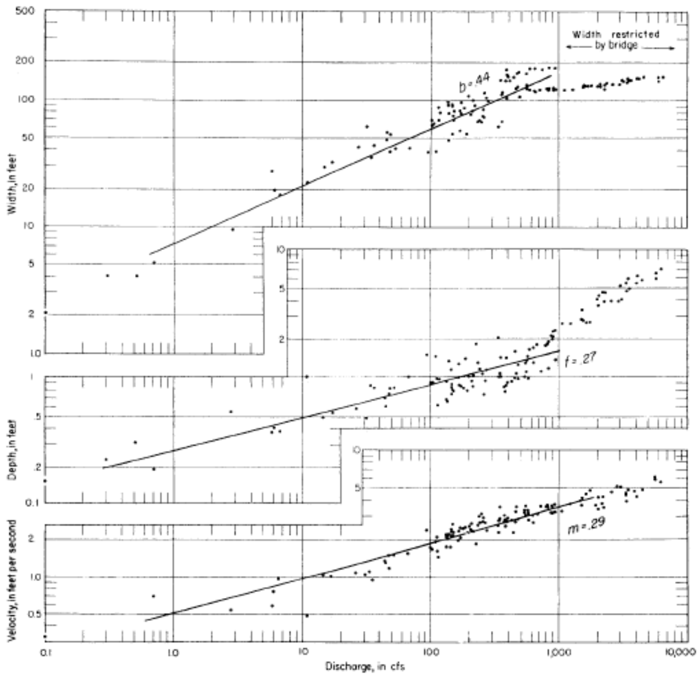


Figure 2-12. Relation of width, depth, and velocity to discharge, Powder River at Arvada, Wyoming. Source: Leopold and Maddock, 1953.

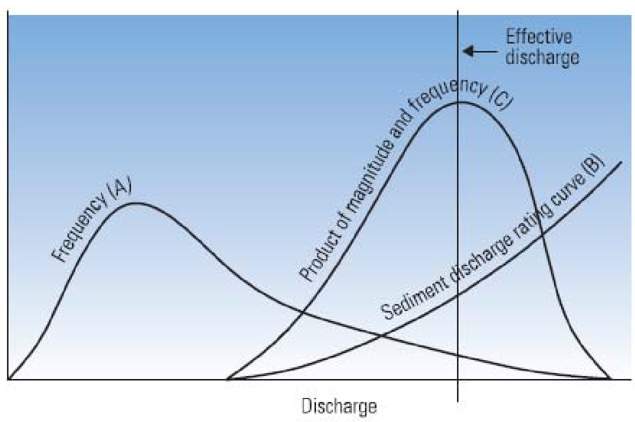


Figure 2-13. Effective discharge determination from sediment rating and flow duration curves. The peak of curve C marks the discharge that is most effective in transporting sediment. Source: FISWRG, 1998 adaptation of Wolman and Miller, 1960.

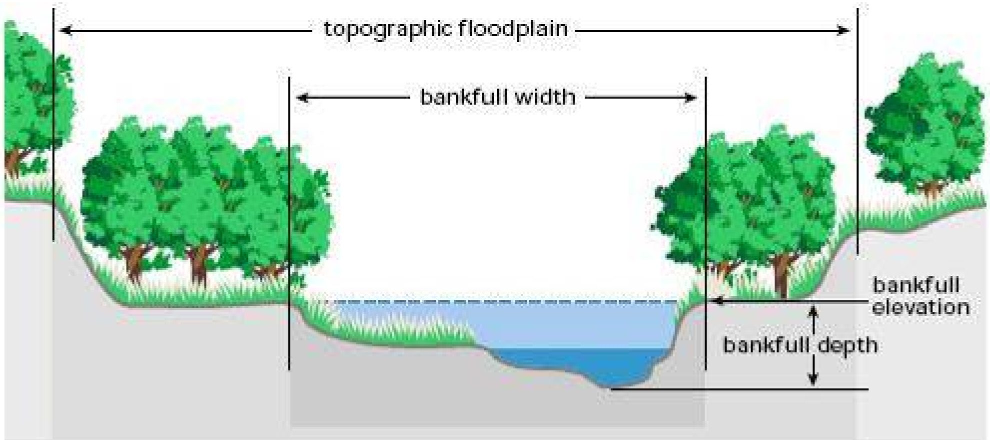


Figure 2-14. Channel cross section identifying bankfull parameters. Source: FISRWG, 1998.

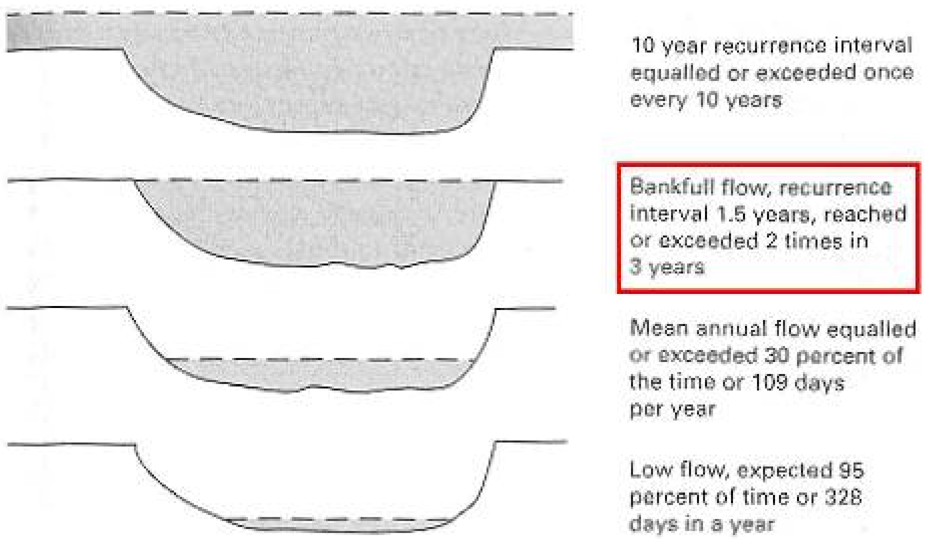


Figure 2-15. Amount of water in a river channel and frequency with which such an amount occurs. Source: Leopold, 1994.

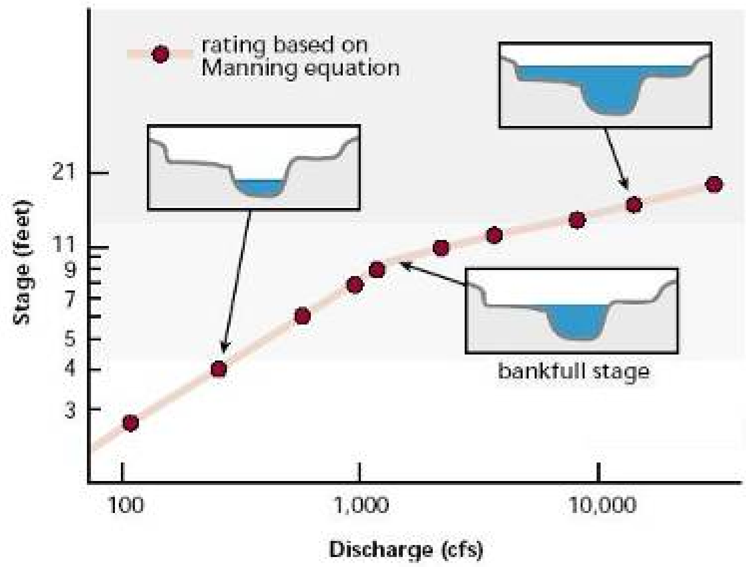


Figure 2-16. Determination of bankfull stage from a stage-discharge rating curve. The inflection point on the rating curve corresponds to the point at which the stream overtops its bank and the stage consequently levels off. Source: FISRWG, 1998.

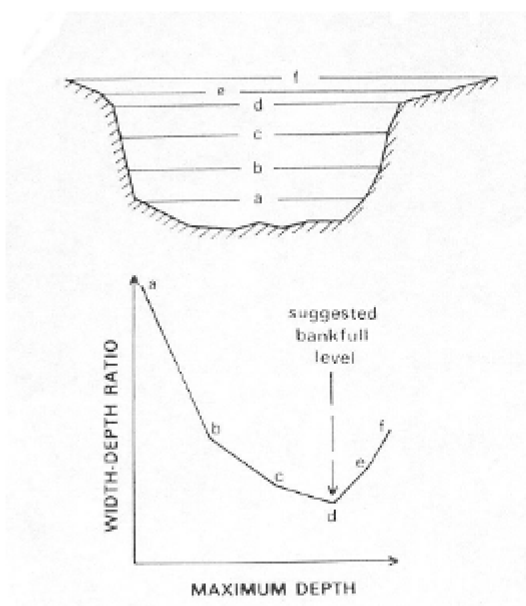


Figure 2-17. Determination of bankfull stage from a plot of width-to-depth ratio against maximum depth. The elevation at which the width-to-depth ratio is at a minimum is the suggested bankfull level. Source: Copeland *et al.,* 2000 citing Knighton, 1984 P.163.

CHAPTER 3
DETERMINING THE MOST RELIABLE BANKFULL INDICATOR FOR PENINSULAR FLORIDA STREAMS

Introduction

Proper identification of bankfull stage, or the elevation at which the stream just begins to overflow onto its floodplain, is critical to both development of regional curves and calculation of bankfull discharge (Emmett, 2004). The floodplain is defined as the relatively flat, depositional surface adjacent to the stream that is being built and rebuilt by a stream in the present hydrologic regime (Emmett, 2004). Bankfull discharge is morphologically significant because it represents the breakpoint between processes of channel formation (erosion) and floodplain formation (deposition) (Copeland *et al.,* 2000). Field identification of bankfull stage is the method most often used to estimate the channel-forming flow, though its correct identification in the field can be difficult and subjective (Johnson and Teil, 1996; Knighton, 1998). U.S. Forest Service has published a field guide for both determining bankfull stage and conducting a stream channel survey (Harrelson *et al.,* 1994). Videos demonstrating how to identify bankfull stage in the Western and Eastern United States are also available from the U.S.D.A. Forest Service (1995, 2003). Some common field indicators of bankfull stage include:

- Top of bank for non-incised channels
- Height of depositional features—especially the top of the pointbar
- Position on the bank where the slope first becomes level—this feature can be identified by facing the stream and dragging your foot until it flattens
- Slope or topographic breaks along the bank
- Change in vegetation—especially the lower limit of perennial species
- Undercuts in the bank—which usually reach an interior elevation slightly below bankfull stage

- Change in the particle size of bank material—such as the boundary between coarse cobble or gravel with fine-grained sand or silt

- Stain lines or the lower extent of lichens on boulders or trees (Harrelson *et al.,* 1994; Leopold, 1994; U.S.D.A. Forest Service, 1995 and 2003).

Several analytical, non-field based techniques can also be used to determine bankfull stage, including:

- Stage-discharge (Stage-Q) rating curves— inflection point on the rating curve corresponds to the point at which the stream overtops its bank and stage consequently levels off (Figure 2-16)

- Elevation at which the width-to-depth ratio is at a minimum (Figure 2-17)

- Flood frequency analysis of available stream gage data—gage station analysis throughout the United States has shown that bankfull discharge has an average recurrence interval of 1.5 years, or a 66.7% annual exceedance probability (Dunne and Leopold, 1978; Leopold, 1994)

- Regional curves—although the current work focuses on using bankfull indicators to develop regional curves, regional curves, in turn, can be used to confirm field identification of bankfull stage (FISRWG, 1998; Wolman, 1955; Leopold, 1994).

Reliable indicators have not been verified for peninsular Florida, though Metcalf (2004) found that bankfull indicators in extreme north Florida and the Panhandle were most often the top of bank or sometimes a lower bench/bar feature. Studies conducted in other regions of the Coastal Plain, such as North Carolina, found the top of bank or lowest scour or bench to rarely be an indicator of bankfull and determined the highest scour line or the back of the point bar to be the most consistent bankfull indicator (Harman, 1999).

One objective of the present work is to determine the most reliable bankfull indicator for as near-to-natural peninsular Florida streams. To accomplish this objective, various indicators of bankfull stage were identified, surveyed, and analyzed individually to determine if there is a single most reliable bankfull indicator for peninsular Florida streams. The following factors were examined: prevalence of each bankfull indicator among study sites; how closely the slope of each bankfull indicator matches the slope of the water; and how frequently and for how long discharge and stage associated with each bankfull indicator occur. This chapter outlines the methods used to reach the objective, including selection of study sites, completion of reference reaches surveys, and analysis of both field data collected during reference reach surveys and long-term hydrologic data obtained from the United States Geological Survey (USGS). The methods are followed by the study results; a discussion of the potential errors, trends, and anomalies associated with the data collection and analyses; and conclusions.

Methods

Tasks completed to determine the most reliable bankfull indicator for peninsular Florida streams included: 1) selecting between 40 and 50 gaged and ungaged stream sites that span a variety of physiographies and geographies; 2) conducting reference reach surveys to measure the plan form, longitudinal profile, and cross-sections of the bankfull channel; and 3) analyzing both field data collected during the reference reach surveys and long-term hydrologic data obtained from the USGS.

Site Selection

Site selections were limited to streams located roughly between the Santa Fe River watershed and Lake Okeechobee to assure that the stream population was peninsular rather than continental. Only sites with base levels two feet higher than mean high tide were included to assure that systems were palustrine rather than estuarine. The USGS site inventory (http://fl.waterdata.usgs.gov/nwis/) was used to select gaged sites that met the initial inclusionary criteria, which included:

- at least ten years of continuous or peak discharge measurements (though a two year record was accepted for basin areas between zero and ten square miles)
- no reaches and/or basins with water control structures, ditches, or canals

- less than 20% of basin is impervious cover
- less than 20% of basin is ditched or has induced discharge (i.e., agricultural tail water)
- less than 10% of basin is mined
- no major roads
- no significant land use changes during or since the gaging period, which was determined by examining historical aerial photographs at the University of Florida's Map and Imagery Library.

Twenty-seven gaged sites were selected using this method. To supplement the gaged sites, areas defined by the Cadastral Sectional grid were randomly selected to fill the roster with ungaged sites. If the selected Section contained more than one stream segment, it was successively quartered, and one of the quarters was then randomly selected until the selected polygon contained just one stream. A stream was then rejected if it did not meet the above inclusionary criteria (minus the minimum gage record criterion). Of the first 100 unaged sites selected in this fashion, 75 streams were rejected. To select sites more efficiently, Cadastral Sections were restricted to public landholdings, such as state parks, state and national forests, water management district lands, state wildlife lands, military bases, and county preserves, and to large private landholdings not subject to future development, such as those owned by the Nature Conservancy and those under conservation easement. Once 70% of the sites had been selected, these were graphically plotted based on their drainage area and valley slope to ensure that the sample was not skewed towards a clustered regression. Sites continued to be selected randomly, but were rejected if they fit a redundant drainage area to valley slope bin. Fifty-two unaged sites were selected in this manner.

Following initial site selection, landowners identified using county property appraisal maps were contacted to obtain access to the study sites. They were sent a formal letter requesting permission to access the stream from their property, as well as a permission form that was to be filled out and mailed back (Appendix A). This method had a surprisingly high response rate, and only 3 landowners denied access to the study site from their property. For sites located on publicly managed lands, the appropriate permits were obtained.

Once appropriate permission was obtained to access selected sites, initial field investigations were conducted. Sites were ultimately excluded from the study if they had negative local effects (i.e., cattle grazing, ditching, evidence of logging, bridge or road effects), were not single-threaded channels (i.e., braided or anastomosed stream types), did not have a defined channel (i.e., sloughs), had unsafe working conditions (i.e., non-wadeable, presence of large alligators), and/or had uncooperative landowners. Forty-five of the originally selected sites were ultimately surveyed, 17 of which were gaged, and 28 of which were ungaged (Table 1-1, Figure 1-2).

Reference Reach Surveys

A reference reach survey was conducted at each selected stream site according to Harrelson et al. (1994). Cross-sectional and longitudinal surveys were completed along a minimum reach length of 20 times the channel width (top of bank to top of bank) to determine bankfull width, mean bankfull depth, maximum bankfull depth, bankfull cross-sectional area, slope, and sinuosity of the channel. A Leica Total Station and a handheld data collector running Carlson SurvCE (Carlson) were used to record measurements to 1000th of a foot, as per accuracy of the equipment. Depth of water at the thalweg was recorded to the nearest 10th of a foot. Plan, longitudinal, and cross-section profiles are provided in Appendix B. Photographs taken in the upstream, downstream, right bank, and left bank directions at many sites are provided in Appendix C.

The survey crew, which generally consisted of two individuals, followed these step-by-step methods to conduct the reference reach surveys:

Step 1: Explore the stream by walking along or in it. Find a representative reach that does not cross any obvious breaks in valley slope and does not span the entry of a tributary. Note indicators of bankfull stage and look for a representative riffle at which to establish the classification riffle cross-section.

Step 2: Set a pin flag at a downstream riffle (XS-1). Measure the distance from one bank to the other and extend the survey upstream 20 times this distance, setting flags every channel width distance apart. Upon completion of flagging, there should be 21 flags/longitudinal stations along the reach, each located one channel width distance apart. For example, a ten-foot wide stream requires a 200-foot long reach, with flags set every ten feet apart along the reach. Distances are measured along the thalweg of the channel. In smaller streams, this should be done by running a 300-foot long measuring tape, while in larger streams this can be done by pacing.

Step 3: Flag various indicators of bankfull stage at six cross-sections along the reach, generally at every other odd-numbered flag (XS-1, XS-5, XS-9, XS-13, XS-17, XS-21). Choose one of these cross-sections (generally the shallowest riffle) to be the classification riffle. Bankfull indicators include the following:

- **Position on the bank where slope first becomes level (BKF-F):** This feature can be identified by facing the stream and dragging your foot along the bank until it flattens.
- **Inflection or break in slope of the bank (BKF-I):** This feature can be identified by finding the first break in the bank's slope as you look or feel from the streambed up the side of the bank.
- **Top of point bar (BKF-TOPB):** Bankfull stage is the boundary between zones of routine sediment transport versus deposition. The top of the point bar represents the height of a depositional feature.
- **Top of scour or undercuts in the bank (BKF-S):** This feature usually reaches an interior elevation slightly below bankfull stage and may be found around plant roots.

- **Bottom of moss collars (BKF-M):** This feature should only be recorded if moss is at least one inch thick.
- **Alluvial break (BKF-A):** This feature can be identified by finding the break between more easily transported streambed material and less easily transported bank material. This break may be found where roots become denser and prevent movement of sediment from the banks, where sediment texture changes (i.e., bank material may consist of more organics), or where sediment color changes (i.e., bank material may be darker in color due to the presence of organics) (Figure 3-1).

Step Four: Establish two temporary benchmarks (TBM-1 and TBM-2) near the reach by driving plastic-capped metal rods into the ground near a feature unlikely to change position or elevation within a few years (i.e., base of large live oak tree, upland terrace near edge of stable floodplain). Set the tripod up over TBM-1, mount the Total Station onto the tripod, and level it using knobs on the unit. Establish a reference datum for the site by assigning a reference elevation of 100 feet to TBM-1. Elevations do not need to be tied to actual elevations, as all data will be relative to the datum. Elevations may, however, be tied to a known elevation if desired. When using a total station, also assign a reference northing (5000 feet) and easting (2000 feet) to TBM-1. Backsight to TBM-2 to establish a zero angle. If a USGS or other permanent benchmark is available near the site, this can serve as TBM-2.

Step 5: Sketch a detailed plan form site map showing any distinctive features (such as secondary channels or backwater areas), TBM-1 and TBM-2 locations, cross-section locations, a direction of flow arrow, a north direction arrow, and gage station location (if present).

Step 6: Begin the survey. Collect longitudinal survey measurements, including the thalweg, water surface, and two streambed points, at each of the 21 cross-sections. At each thalweg and streambed point, qualitatively classify dominate substrate/habitat as sand (SAND), mud (MUD), leaf packs (LEAF), fine woody debris (FWD), or large woody debris (LWD). At the six-cross sections along the reach where bankfull indicators were flagged, collect additional cross-sectional measurements, including top of bank (TOB) and various bankfull indicators

(BKF). Record the ecosystem type at each top of bank point according to its determined Florida Land Use, Cover and Forms Classification System (FLUCCS) (1999) code. At the cross-section selected to be the classification riffle, extend the survey into the floodplain by at least two channel widths on either side of the channel, making the cross-section at least five channel widths long. Capture unique floodplain features, such as natural levees and oxbows, and record any changes in FLUCCS. Sketch a detailed cross-sectional view of the classification riffle. Keep the survey error to less than 0.03 feet throughout the survey traverse, which is the minimum amount of error preferred for the typical distances involved.

Step 7: Upon completion of the survey, the following various field tasks remain:

- Record locations of TBM-1, TBM-2, and the downstream and upstream ends of the reach using a sub-meter GPS.
- Take four photographs at the classification riffle, one pointing upstream, downstream, to the right bank, and to the left bank.
- Estimate percent canopy using a densitometer.
- Estimate base level of the stream by finding the depth at which a penetrometer reaches refusal at the thalweg, on the right bank, and on the left bank.
- Note dominant bed and bank material.
- Remove flags.

Step 8: Upon returning to the office, download data from the Carlson into a computer and enter it into RIVERMorph 4.0.1 Stream Restoration Software (RIVERMorph), a program developed by Wildland Hydrology.

This summarizes the field methods utilized to perform the 45 reference reach surveys conducted in this study. Additional information on conducting reference reach surveys is provided by Rosgen (1996) and the USDA Forest Service (Harrelson, *et al.,* 1994). It is important to note that for reference reach surveys conducted at gaged sites, the longitudinal survey was carried through the gage plate when possible. However, in instances where the gage plate was located at a bridge that had obvious effects on the hydraulics of the stream (as was often the case) or where permissions could not be obtained, the survey was conducted at a sufficient distance upstream or downstream of the bridge (Table 3-1).

Data obtained from the reference reach surveys were then used to determine the size (bankfull cross-sectional area, bankfull width, and bankfull mean depth), shape (width-to-depth ratio and maximum depth-to-mean depth ratio), pattern (sinuosity), and slope of each stream. RIVERMorph was used to calculate many of these parameters. When calculating the various bankfull parameters, RIVERMorph used the average of the left and right bank indicators to determine bankfull elevation at each cross-section. Sinuosity, which is a parameter that describes the meander pattern of a stream, was determined by dividing channel length surveyed in the longitudinal survey by valley length, which was calculated from the survey points using Equation 3-1. Pertinent data for each site were then entered into Microsoft Excel for further data analysis, graphing, and regional curve development, which are discussed in later sections.

$$=\sqrt{(\text{XS-1 Easting} - \text{XS-21 Easting})^2 + (\text{XS-1 Northing} - \text{XS-21 Northing})^2} \quad (3\text{-}1)$$

Data Analysis

Slopes of field indicators

For each site, RIVERMorph was used to plot a best fit line both through the survey points of each individual field bankfull indicator (BKF-F, BKF-I, BKF-S, BKF-A) and through the top of bank survey points (TOB). Each slope was then compared to the slope of a line best fit through the water surface survey points[1]. Leopold (1994) used this technique to verify the feature as bankfull if the two lines were generally parallel and consistent over a long reach. To

[1] For sites that did not have flowing water on the day of the survey, each bankfull indicator slope was compared to the slope of a line best fit through the channel bed (thalweg) survey points.

determine how parallel the lines were, water slope was divided by slope of each bankfull indicator to determine a water slope to bankfull indicator slope ratio. Theoretically, the closer the ratio is to one, the more parallel the indicator is to the water and thus the more reliable it is. Bankfull indicator slopes within 25% of the water slope, or those with a water slope to bankfull indicator ratio between 0.75 and 1.25, were thus deemed reliable candidate field indicators.

Gage analysis

Hydrologic data for the 17 surveyed gaged sites were obtained from the USGS and used to analyze the various bankfull indicators. Specifically, daily streamflow (discharge) and gage height (stage) measurements, field measurements, annual peak flow measurements, and drainage area were downloaded off the Internet from the USGS's online National Water Information System (NWIS), while current stage-discharge (stage-Q) rating tables were obtained from USGS personnel.

USGS data were used in conjunction with the reference reach survey data to determine stage, discharge, return interval, and duration associated with both top of bank and with the various bankfull indicators (BKF-F, BKF-I, BKF-S, BKF-A) at each gaged site. Stream stage and discharge measurements for the specific day the reference reach survey was conducted were downloaded from NWIS (Table 3-1). The stage of each bankfull indicator was then determined by adding the average difference between elevation of the bankfull indicator and that of the water surface at the time of the reference reach survey to the stage recorded by the USGS on the day of the survey. The most current stage-Q rating table was then used to find discharges associated with various determined stages. The discharges and stages associated with both top of bank and various bankfull indicators were then plotted graphically onto each gaged site's stage-Q rating curve (Appendix D). Stage-Q rating curves were developed by plotting the dimensionless discharge (daily mean discharge divided by mean annual discharge, Q/Q_{ma})

against the adjusted stage (daily mean stage minus the mean annual stage). Dimensionless discharge and adjusted stage were used to facilitate comparisons among gaged sites.

Gage station analysis throughout the United States has shown that bankfull discharge has an average recurrence interval of 1.5 years, which corresponds to a 66.7% annual exceedance probability (Dunne and Leopold, 1978; Leopold, 1994) (Figure 2-15). However, this widely reported assertion that bankfull discharge occurs on average once every one to two years is now seen as an oversimplification, with several recent studies reporting much lower bankfull discharge recurrence intervals (Thorne *et al.,* 1997) (Table 4-12). One objective of the present work is to estimate the recurrence interval associated with the bankfull discharge in peninsular Florida streams. Annual peak flow data for the gaged sites were thus analyzed to determine the return intervals associated with the discharges and stages associated with top of bank and various bankfull indicators using Log Pearson Type III distributions (skew coefficient of -0.1) in RIVERMorph (USGS, 1982). Discharges and stages associated with the following set return intervals (in years) were also determined for each gaged site using RIVERMorph: 1.0101, 1.25, 1.5, 2, 5, 10, 25, 50, and 100. All determined discharges and stages were plotted graphically onto each gaged site's stage-Q rating curve (Appendix D).

Long-term continuous discharge data were used to develop flow and stage duration curves for each gaged site. These show the percentage of time a given discharge or stage is equaled or exceeded, by representing the cumulative frequency of daily mean discharges or daily mean stages. Flow and stage duration curves were used to determine the percentage of time that discharges and stages associated with top of bank and various bankfull indicators were equaled or exceeded at each gaged site. Discharges and stages associated with both top of bank and various bankfull indicators were plotted graphically onto the flow and stage duration curves for visual comparison (Appendix D).

Lastly, the USGS data were used to analyze several analytical, non-field based techniques to determine or confirm bankfull stage, including:

- Stage-discharge (stage-Q) rating curves. Theoretically, the inflection point on the rating curve corresponds to the point at which the stream overtops its bank and stage consequently levels off (Figure 2-16). Stage-Q rating curves were developed for each gaged site from the long-term record. The infection point on each gaged site's stage-Q rating curve was then visually compared to field bankfull indicators, which were plotted onto the state-Q rating curve (Appendix D).

- Elevation at which the width-to-depth ratio is minimal (BKF-W/D) (Figure 2-17). Using the survey data for each site's classification riffle (which extended into the floodplain), the elevation of the minimum width-to-mean depth ratio was determined. The corresponding stage and discharge were then plotted graphically onto each gaged site's stage-Q rating curve and compared visually with other bankfull indicators (Appendix D).

- Flood frequency analysis of available stream gage data. Gage station analysis throughout the United States, has shown that bankfull discharge has an average recurrence interval of 1.5 years, which corresponds to a 66.7% annual exceedance probability (Dunne and Leopold, 1978; Leopold, 1994) (Figure 2-15). Peak flow data for the gaged sites were analyzed to determine the discharge and stage that occurs on average every 1.5 years. The corresponding stage and discharge were then plotted graphically onto each gaged site's stage-Q rating curve and compared visually with other bankfull indicators (Appendix D).

- Historical cross-sectional channel geometry data collected during routine USGS streamflow measurements. Stage measurements were plotted against width measurements (stage-w graph), as one would expect width to rapidly increase with small changes in stage as the stream overtops its banks. The stage of various bankfull indicators (BKF-F and BKF-I), as well as the stage of the 1.5 year flood, were plotted onto each gaged site's stage-w graph for visual comparison (Appendix E).

Results

The results of the study are presented below, beginning with a description of the selected study sites and followed by both results of the reference reach surveys and data analyses conducted on both field data collected during the reference reach surveys and long-term hydrologic data obtained from the USGS.

Site Selection

Forty-five peninsular Florida streams were surveyed, ranging in drainage area from 0.2 to 311 square miles and in valley slope from 44 to 5,000 feet/feet. Seventeen sites are or historically have been gaged by the USGS, while 28 sites are ungaged. Twenty-five sites drain a flatwoods physiography (generally with abundant wetlands, poorly-drained D-type soils, high water tables, flat topography, and many streams), while 20 sites drain a highlands physiography (generally with abundant lakes, relict sand dunes, well-drained A-type soils, low water tables, rolling topography, and few streams). Nineteen sites are located in the northern portion of the peninsula (above the 28.5 degrees north latitude line), while 26 are in the southern portion of the peninsula (below the 28.5 degrees north latitude line). Twenty-three had a wetland floodplain (dominated by hydrophytic vegetation and hydric soils), and twenty-two had an upland floodplain (dominated by hydrophobic vegetation and non-hydric soils). Of the twenty-three sites with a wetland floodplain, 11 were dominated by cypress (*Taxodium spp*.). The sites were classified by physiography, geography, and floodplain types to determine what, if any, differences exist among and between various stream sets. Table 1-1 lists the sites and pertinent details such as location (county, latitude/longitude), reference number (if gaged), drainage area, valley slope, physiography, geography, and floodplain type.

Sites are located on both private and publicly owned lands in the following counties: Alachua, Bradford, Clay, DeSoto, Flagler, Glades, Hardee, Highlands, Hillsborough, Lake, Levy, Manatee, Marion, Osceola, Pasco, Polk, Putnam, Volusia, Sarasota, and St. Johns counties. Figure 1-2 provides a map of the study site locations.

Reference Reach Surveys

The following bankfull indicators were surveyed during reference reach surveys: position on the bank where slope first becomes level (BKF-F), inflection or break in slope of the bank

(BKF-I), top of point bar (BKF-TOPB), top of scour or undercuts in the bank (BKF-S), bottom of moss collars (BKF-M), and the alluvial break (BKF-A). BKF-F was present at 87% of the sites, BKF-I at 100%, BKF-TOPB at 13%, BKF-S at 84%, BKF-M at18%, and BKF-A at 78% of the sites (Table 3-2). Detailed cross-sections that depict the locations of the various bankfull indicators at each site are found in Appendix B. Because of the low number of sites exhibiting BKF-TOPB and BKF-M indicators, these two bankfull indicators were excluded from further analyses.

In general, bankfull indicators were located in the following order along the bank: BKF-F (highest in elevation), BKF-I, BKF-S, and BKF-A (lowest in elevation) (Figure 3-1). In streams with a wetland floodplain, the BKF-F indicator appeared to be correlated strongly with the top of bank, while in streams without a wetland floodplain (which were often incised), BKF-F was often absent. In streams with flowing water on the day of the survey, the BKF-S and BKF-A indicators appeared closely associated with water surface elevation. It was often difficult to find a distinct alluvial break (BKF-A) as the stream bed and the stream banks at most of the sites were both composed of sand. For streams with high banks (i.e., Manatee River near Myakka Head, Horse Creek near Arcadia, and Livingston Creek near Frostproof), there were often two sets of inflection points (BKF-I), a high and a low, as well as two sets of scour lines (BKF-S), also a high and a low. The lower sets of these indicators were used in the data analysis.

Data Analysis

Field data collected during the reference reach surveys and long-term hydrologic data obtained from the USGS were analyzed to determine the following: 1) how closely slope of each bankfull indicator matches that of the water, and 2) how frequently/what percentage of time discharge and stage associated with each bankfull indicator occur.

Slopes of field indicators

Water slopes ranged from -0.026% at Blackwater Creek near Cassia to 1.610% at Gold Head Branch, with an average slope of 0.219% (± 0.336%) and a median slope of 0.097%. Channel bed slopes ranged from -0.349 to 16.100%, with an average slope of 0.605% (± 2.393%) and a median slope of 0.164%. Top of bank (TOB) slopes ranged from -0.227 to 1.796%, with an average slope of 0.346% (± 0.482%) and a median slope of 0.176%. BKF-F slopes ranged from -0.325 to 1.607%, with an average slope of 0.282% (± 0.443%) and a median slope of 0.122%. BKF-I slopes ranged from -0.268 to 1.518%, with an average slope of 0.300% (± 0.420%) and a median slope of 0.109%. BKF-S slopes ranged from -0.060 to 1.336%, with an average slope of 0.323% (± 0.368%) and a median slope of 0.183%. BKF-A slopes ranged from -0.062 to 1.54o%, with an average slope of 0.291% (± 0.369%) and a median slope of 0.121%. (Table 3-3) Appendix B provides the longitudinal profile, which includes slopes of the various bankfull indicators, for each study site.

A surprising number of sites had negative water, bed channel, top of bank, or bankfull indicator slopes, meaning that the best fit line through the surveyed points sloped in an upstream direction rather than in a downstream direction as one would expect. More specifically, 7% of sites had a negative water slope, 20% had a negative channel bed slope, 22% had a negative top of bank slope, 21% of sites exhibiting the BKF-F indicator had a negative BKF-F slope, 16% of sites exhibiting the BKF-I indicator had a negative BKF-I slope, 16% of sites exhibiting the BKF-S indicator had a negative BKF-S slope, and 17% of the sites exhibiting the BKF-A indicator had a negative BKF-A slope (Table 3-3).

Water slope to bankfull indicator slope ratios were calculated to analyze reliability of various bankfull indicators, as ratios close to one suggest that bankfull indicator slope runs parallel to water slope over the surveyed reach. Water slope to bankfull indicator ratios ranged from -2.86 to 7.58 (mean ratio of 0.65 ± 1.36) for the TOB indicator, from -15 to 3.46 (mean ratio 0.24 ± 2.82) for the BKF-F indicator, from -8.00 to 14.57 (mean ratio 1.01 ± 3.01) for the BKF-I indicator, from -7.43 to 3.82 (mean ratio 0.24 ± 2.20) for the BKF-S indicator, and from -9.36 to 3.69 (mean ratio 0.35 ± 2.24) for the BKF-A indicator. (Table 3-3)

When water slope to bankfull indicator slope ratios were plotted against water slope, a distinct break was seen at a water slope of approximately 0.5% for all bankfull indicators (Figures 3-2A-E). The variability of water slope to bankfull indicator slope ratios among sites with a water slope less than 0.5% (less than a 6-inch rise over 100-foot run) appeared to be much greater than that among sites with a water slope greater than 0.5% (more than a 6-inch rise over a 100-foot run) for both top of bank and all bankfull indicators except BKF-I. Assuming unequal variances, t-tests showed that water slope to bankfull indicator slope ratios between sites with a water slope greater than 0.5% and sites with a water slope less than 0.5% were indeed significantly different for all bankfull indicators except BKF-I (Table 3-4). Further, sites with water slopes greater than 0.5% were more likely to have bankfull indicator slopes within 25% of the water slope (or a water slope to bankfull indicator slope ratio between 0.75 and 1.25). More specifically, for sites with a water slope greater than 0.5%, 75% of sites had a TOB slope within 25% of the water slope, 75% exhibiting the BKF-F indicator had a BKF-F slope within 25% of the water slope, 88% exhibiting the BKF-I indicator had a BKF-I slope within 25% of the water slope, 88% exhibiting the BKF-S indicator had a BKF-S slope within 25% of the water slope, and 71% exhibiting the BKF-A indicator had a BKF-A slope within 25% of the water slope (Table 3-4). In comparison, for sites with a water slope less than 0.5%, only 17% of sites had a TOB slope within 25% of the water slope, 18% of the sites exhibiting the BKF-F indicator had a slope within 25% of the water slope, 19% of the sites exhibiting the BKF-I indicator had a BKF-I slope within 25% of the water slope, 23% of the sites exhibiting the BKF-S indicator had a BKF-S slope within 25% of the water slope, and 29% of the sites exhibiting the BKF-A indicator had a BKF-A slope within 25% of the water slope (Table 3-4). Additionally, no sites with a water slope greater than 0.5% had negative bankfull indicator slopes (Table 3-4).

Gage analysis

Drainage areas for gaged sites ranged from 0.32 square miles (sq mi) at Shiloh Run near Alachua to 311 sq mi at Fisheating Creek at Palmdale, with mean and median values of 75.9 sq mi and 52.8 sq mi, respectively (Table 3-1). Mean annual discharges ranged from 0.29 cubic feet per second (cfs) at Shiloh Run near Alachua to 256 cfs at Fisheating Creek at Palmdale, with mean and median values of 59 cfs and 42 cfs, respectively (Table 4-1). The discharges and stages associated with the top of bank (TOB) and various bankfull indicators (BKF-F, BKF-I, BKF-S, BKF-A), as well as their associated return intervals and duration (or percentage of time equaled or exceeded), are provided in Tables 3-5 and 3-6 and are detailed below[2]. The discharges and stages associated with various set return intervals (1.0101-, 1.25-, 1.5-, 2-, 5-, 10-, 25-, 50-, and 100-year), as well as their durations, are provided in Tables 3-7 and 3-8. The 1.5-year event is further detailed below, because it is the recurrence interval often cited with the bankfull event.

- Q_{TOB} ranged from 25 cubic feet per second (cfs) to 595 cfs, with mean and median values of 156 cfs and 90 cfs, respectively. The return interval associated with Q_{TOB} ranged from less than one year to 3.10 years. The percentage of time that Q_{TOB} was equaled or exceeded ranged from 0.21% to 41% of the time (or from 0.75 to 150 days per year), with mean and median values of 15% and 8.3% of the time (or 56 and 30 days per year), respectively (Table 3-5). The top of bank stage ranged from 0.36 feet above mean annual stage to 7.53 feet above mean annual stage, with mean and median values of 2.13 feet and

[2] Note that the results from Hickory Creek near Ona, Lochloosa Creek at Grove Park, Moses Creek near Moultrie, and Shiloh Run near Alachua were excluded from the summary statistics, as their period of record was insufficient (less than ten years) for proper peak flow analysis and/or flow duration curve development. However, rough estimates of the return intervals and the durations associated with the top of bank and with the various bankfull indicators can be found in Tables 3-5 and 3-6 and the stage-Q rating curves can be found in Appendix D.

1.42 feet above mean annual stage, respectively. The return interval associated with the top of bank stage ranged from less than one year to 1.98 years. The percentage of time that the top of bank stage was equaled or exceeded ranged from 0.06% to 43% of the time (or from 0.24 to 156 days per year), with mean and median values of 15% and 13% of the time (or 55 and 49 days per year), respectively (Table 3-6). TOB durations were not significantly different between stage and discharge measurements, but durations were significantly higher in streams with a wetland floodplain than in streams with an upland floodplain for both discharge ($p<0.01$) and stage ($p<0.01$) (Table 3-9).

- Q_{BKF-F} ranged from 25 cubic feet per second (cfs) to 402 cfs, with mean and median values of 111 cfs and 67 cfs, respectively. The return interval associated with Q_{BKF-F} ranged from less than one year to 1.12 years. The percentage of time that Q_{BKF-F} was equaled or exceeded ranged from 4.0% to 50% of the time (or from 15 to 181 days per year), with mean and median values of 26% and 24% of the time (or 94 and 87 days per year), respectively (Table 3-5). The BKF-F stage ranged from 0.42 feet below mean annual stage to 5.90 feet above mean annual stage, with mean and median values of 1.22 feet and 0.47 feet above mean annual stage, respectively. The return interval associated with the BKF-F stage ranged from less than one year to 1.13 years. The percentage of time that the BKF-F stage was equaled or exceeded ranged from 3.4% to 78% of the time (or from 12 to 283 days per year), with mean and median values of 28% and 24% of the time (or 101 and 89 days per year), respectively (Table 3-6). BKF-F durations were not significantly different between stage and discharge measurements or between sites with a wetland floodplain and those with an upland floodplain (Table 3-9).

- Q_{BKF-I} ranged from 18 cfs to 118 cfs, with mean and median values of 64 cfs and 56 cfs, respectively. The return interval associated with Q_{BKF-I} ranged from less than one year to 3.70 years. The percentage of time that Q_{BKF-I} was equaled or exceeded ranged from 0.77% to 50% of the time (or from 2.8 to 184 days per year), with mean and median values of 25% and 18% of the time (or 89 and 66 days per year), respectively (Table 3-5). The BKF-I stage ranged from 0.46 feet below mean annual stage to 2.39 feet above mean annual stage, with mean and median values of 0.76 feet and 0.64 feet above mean annual stage, respectively. The return interval associated with the BKF-I stage ranged from less than one year to 1.50 years. The percentage of time that the BKF-I stage was equaled or exceeded ranged from 0.82% to 52% of the time (or from 3.0 to 191 days per year), with mean and median values of 24% and 25% of the time (or 88 and 91 days per year), respectively (Table 3-6). BKF-I durations were not significantly different between stage and discharge measurements, but BKF-I durations were found to be significantly higher in streams with a wetland floodplain than in streams with an upland floodplain for both discharge ($p<0.01$) and stage (0.03) (Table 3-9).

- Q_{BKF-S} ranged from 9.9 cfs to 75 cfs, with mean and median values of 32 cfs and 29 cfs, respectively. The return interval associated with Q_{BKF-S} ranged from less than one year to 1.95 years. The percentage of time that Q_{BKF-S} discharge was equaled or exceeded ranged from 6.6% to 71% of the time (or from 24 to 260 days per year), with mean and median values of 43% and 51% of the time (or 157 and 186 days per year), respectively (Table 3-5). The BKF-S stage ranged from 1.18 feet below mean annual stage to 0.74 feet above mean annual stage, with mean and median values of 0.25 feet and 0.22 feet below mean annual stage, respectively. The return interval associated with the BKF-S stage ranged from less than one year to 1.20 years. The percentage of time that the BKF-S stage was equaled or exceeded ranged from 8.5% to 70% of the time (or from 31 to 257 days per year), with mean and median values of 45% and 48% of the time (or 164 and 175 days per year), respectively (Table 3-6). BKF-S durations were not significantly different between stage and discharge measurements or between sites with a wetland floodplain and those with an upland floodplain.

- Q_{BKF-A} ranged from 5.0 cfs to 38 cfs, with mean and median values of 16 cfs and 13 cfs, respectively. The return interval associated with Q_{BKF-A} ranged from less than one year to 1.08 years. The percentage of time that Q_{BKF-A} was equaled or exceeded ranged from 14% to 93% of the time (or from 51 to 338 days per year), with mean and median values of 60% and 57% of the time (or 219 and 208 days per year), respectively (Table 3-5). The BKF-A stage ranged from 1.90 feet below mean annual stage to 0.31 feet above mean annual stage, with mean and median values of 0.69 feet and 0.79 feet below mean annual stage, respectively. The return interval associated with the BKF-A stage was less than one year. The percentage of time that the BKF-A stage was equaled or exceeded ranged from 18% to 96% of the time (or from 64 to 350 days per year), with mean and median values of 62% and 67% of the time (or 226 and 246 days per year), respectively (Table 3-6). BKF-A durations were not significantly different between stage and discharge measurements or between sites with a wetland floodplain and those with an upland floodplain.

- $Q_{1.5}$ is a flow event with a 1.5-year return interval that has a 66.7% probability of occurring in a given year. $Q_{1.5}$ ranged from 60 cfs to 1,934 cfs, with mean and median values of 523 cfs and 288 cfs, respectively. The percentage of time that $Q_{1.5}$ was equaled or exceeded ranged from 0.18% to 17% of the time (or from 0.65 to 63 days per year), with mean and median values of 4.0% and 2.3% of the time (or 15 and 8.2 days per year), respectively (Table 3-7). The stage associated with the 1.5-year return interval ranged from 0.64 feet to 9.66 feet above mean annual stage, with mean and median values of 3.71 feet and 3.18 feet above mean annual stage, respectively. The percentage of time that the stage associated with the 1.5-year return interval was equaled or exceeded ranged from 0.15% to 12% of the time (or from 0.55 to 45 days per year), with mean and median values of 3.8% and 3.0% of the time (or 14 and 11 days per year), respectively (Table 3-8).

All previously mentioned discharge and stage values were plotted onto the stage-Q rating curves developed for each gaged site so that the top of bank and the various bankfull indicators could be compared visually to the set return intervals (Appendix D), resulting in the following:

- Top of bank points plotted below the 1.0101-year return interval points at 29% of the sites, between the 1.0101-year and 1.25-year return interval points at 35% of the sites, between the 1.25-year and 1.5-year return interval points at 24% of the sites, between the 1.5-year and 2-year interval points at 0% of the sites, and between the 2-year and 5-year interval points at 12% of the sites (Catfish Creek near Lake Wales and Shiloh Run near Alachua).

- BKF-F points plotted below the 1.0101-year return interval points at 38% of the sites exhibiting the BKF-F indicator, between the 1.0101-year and 1.25-year return interval points at 65% of the sites, and above the 1.25-year interval points at 0% of the sites.

- BKF-I points plotted below the 1.0101-year return interval points at 59% of the sites exhibiting the BKF-I indicator, between the 1.0101-year and 1.25-year return interval points at 29% of the sites, between the 1.25-year and 1.5-year return interval points at 0% of the sites, between the 1.5-year and 2-year return interval points at 6% of the sites, and between the 2-year and 5-year return interval points at 6% of the sites (Catfish Creek near Lake Wales).

- BKF-S points plotted below the 1.0101-year return interval points at 84% of the sites exhibiting the BKF-S indicator, between the 1.0101-year and 1.25-year return interval points at 8% of the sites, between the 1.25-year and 1.5-year return interval points at 0% of the sites, between the 1.5-year and 2-year return interval points at 8% of the sites, and above the 2-year return interval points at 0% of the sites.

- BKF-A points plotted below the 1.0101-year return interval at 93% of the sites exhibiting the BKF-A indicator, between the 1.0101-year and 1.25-year return interval points at 7% of the sites, and above the 1.25-year return interval at 0% of the sites.

The USGS gage data were also used to analyze several analytical, non-field based techniques of determining or confirming the bankfull stage, resulting in the following:

- The inflection point of the Stage-Q rating curves was found at a point on the stage-Q rating curve well above the field-based bankfull indicators at many of the sites (Appendix D), suggesting that bankfull flow occurs more frequently than the flow at which the stage levels out on the stage-Q rating curve. However, due to the variation found in stage-Q relationships, this method was difficult and likely unreliable.

- The elevation and associated discharge at which the width-to-depth ratio was at a minimum (BKF-W/D) at the classification riffle were determined for each gaged site (Tables 3-5 and 3-6). $Q_{BKF\text{-}W/D}$ ranged from 8.3 cfs to 381 cfs. The return interval associated with $Q_{BKF\text{-}W/D}$ ranged from less than one year to 1.65 years, with mean and median values of 1.10 years and 1.02 years, respectively. The percentage of time that $Q_{BKF\text{-}W/D}$ was equaled or exceeded ranged from 0.33% to 82% of the time (or from 1.2 to 299 days per year), with mean and median values of 29% and 27% of the time (or 106 and 97 days per year), respectively (Table 3-5). The BKF-W/D stage ranged from 1.45 feet below mean annual stage to 5.40 feet above mean annual stage, with mean and median values of 1.20 feet and 0.28 feet above mean annual stage, respectively. The return interval associated with the BKF-W/D stage ranged from less than one year to 1.65 years. The percentage of time that the BKF-W/D stage was equaled or exceeded ranged from 0.31% to 85% of the time (or from 1.1 to 310 days per year) with mean and median values of 32% and 30% of the time (or 116 and 108 days per year), respectively (Table 3-6). When plotted on the stage-Q rating curve, BKF-W/D points plotted below the 1.0101-year return interval points at 41% of the sites, between the 1.0101-year and 1.25-year return interval points at 53% of the sites, between the 1.25-year and 1.5-year return interval points at 0% of the sites, between the 1.5-year and 2-year return interval points at 6% of the sites, and above the 2-year interval points at 0% of the sites (Appendix D). BKF-W/D durations were not significantly different between stage and discharge measurements or between sites with a wetland floodplain and those without a wetland floodplain. Most interestingly, though not surprising, BKF-W/D plotted between the BKF-F and BKF-I field indicators on the stage-Q rating curve at many of the sites. Although BKF-W/D is not an indicator found in the field, it is important to note that its determination does require field survey data.

- Because gage station analysis throughout the United States has shown that bankfull discharge has an average recurrence interval of 1.5 years (Dunne and Leopold, 1978; Leopold, 1994), discharges associated with the 1.5-year return interval were determined and plotted onto each gaged site's stage-Q rating curve (Appendix D). As previously mentioned, the majority of bankfull indicators (93%) plotted below the 1.5-year return interval on the stage-Q curve, suggesting that the bankfull event in peninsular Florida streams occurs more frequently than elsewhere in the United States.

- Historical cross-sectional channel geometry data collected during routine USGS streamflow measurements were used to plot stage against width. For non-incised streams, two distinct clusters were observed (an "in-the-banks" cluster and an "out-of-the-banks" cluster), separated by a large increase in width. This occurs because as the stream overtops its banks, its width increases rapidly with only small increases in stage; however, the water eventually reaches an upland terrace that confines the lateral extent (or width). When the BKF-F and BKF-I stages were plotted onto this graph, they generally corresponded well with the stage at which the jump in width occurs, while when the 1.5-year return interval stage was plotted onto the graph, it generally plotted well above the jump in width, again confirming that bankfull flow in peninsular Florida streams occurs more frequently than 1.5 years (Figure 3-3A, Appendix E). For incised streams, there were no distinct clusters because in incised streams the river valley is largely confined and width thus increases gradually as stage increases. When the BKF-F, BKF-I, and 1.5-year return interval stages were plotted onto these graphs, no real distinctions could be made (Figure 3-3B, Appendix E). For non-incised streams, plotting width against stage can be a good method for determination or confirmation of bankfull stage, while for incised streams it is not as useful.

Discussion

In this study, various indicators of bankfull stage were identified, surveyed, and analyzed individually to determine if there is a single most reliable bankfull indicator for peninsular Florida streams. The following factors were examined: how prevalent each bankfull indicator is among study sites; how closely the slope of each bankfull indicator matches that of the water;

and how frequently and for how long discharge and stage associated with each bankfull indicator occur. The discussion begins with an examination of the potential sources of error involved in conducting the reference reach surveys and implications this could have on interpretation of data. The discussion continues with an examination of analyses conducted on field data collected both during reference reach surveys and long-term hydrologic data obtained from the USGS. Observed trends and anomalies for each data set are discussed and potential explanations are presented. Interpretation of data is presented as it relates to achieving the objective of this chapter, which is to determine the most reliable bankfull indicator for peninsular Florida streams.

Reference Reach Surveys

Common sources of error associated with surveying, such as those in transcribing data and in entering data into the computer, were minimized by using a total station, which records all the survey points digitally. Rod height readings were taken carefully and double-checked if results were questionable. Extra care was taken in establishing turning points. When survey data were downloaded into RIVERMorph, they were analyzed for surveying errors, then corrected in Excel. Corrections were highlighted and explained in the notes section of each study site's spreadsheet so future users of the raw survey data may be aware of any survey errors.

Another potential source of error associated with reference reach surveys is the incorrect identification or surveying of bankfull stage. As previously described, bankfull stage is the elevation at which the stream just begins to overflow onto its floodplain, which is defined as the relatively flat, depositional surface adjacent to the stream that is being built and rebuilt by the stream in the present hydrologic regime (Emmett, 2004). Field identification of bankfull stage is the method most often used to estimate the channel-forming flow, though its correct identification in the field can be difficult and subjective (Johnson and Teil, 1996; Knighton, 1998). In this study, various indicators of bankfull stage (TOB, BKF-F, BKF-I, BKF-TOPB, BKF-S, BKF-M, and BKF-A) were surveyed at six cross-sections along a longitudinal profile. Because various indicators of bankfull stage were identified, surveyed, and analyzed separately and consistently, the potentially subjective nature of choosing the bankfull stage was minimized for the most part, with the exception of BKF-A (as explained below).

Methods of bankfull indicator identification were consistent throughout the study; however, several factors may have led to the inaccurate reading of a particular bankfull indicator. For example, the alluvial break (BKF-A) was particularly difficult to identify as the stream bed and stream banks at all sites were both predominantly composed of sand and therefore of uniform particle size. In larger rivers, such as the Manatee River near Myakka Head and the Santa Fe River near Graham, several distinct breaks in slope (BKF-I) and scour lines (BKF-S) were found. Though all inflections and scour lines were surveyed, only the lowest of each were used in data analysis. Further complicating identification of the active floodplain is Florida's recent drought conditions, which can lead to floodplain vegetation growing clearly within the channel. Regardless of drought, some floodplain tree species, such as cypress (*Taxodium spp.*), can actually grow in the middle of the channel and should be ignored when attempting to identify the active floodplain in peninsular Florida. Inaccurate readings could also be due to the rod not being placed exactly on the bankfull indicator, the rod sinking into the mud, surveying a relict indicator, surveying a root rather than an actual bank inflection, or surveying a local deposit resulting from local velocity controls such as vegetation. Inaccurate readings may affect slope (which will be discussed in further detail in the following section), width, and depth of the bankfull indicators and ultimately calculation of bankfull discharge.

Based on reference reach surveys, several conclusions can be drawn regarding the most reliable bankfull indicator for peninsular Florida. Break in slope (BKF-I) appears to be the most consistent bankfull indicator, as it was found at all of the sites surveyed. The flat floodplain (BKF-F) was a consistent indicator for sites with a relatively flat wetland floodplain (Table 3-2). The scour line (BKF-S) was consistent at most sites, but was generally absent at sites dominated by a cypress (*Taxodium spp*.) floodplain perhaps due to the presence of cypress knees or the low gradient nature of these systems not generating enough stream power to produce a scour line. As previously mentioned, the alluvial break (BKF-A) was difficult to identify and is thus not a reliable indicator for peninsular Florida streams. Furthermore, BKF-A and BKF-S were generally located at a lower elevation on the cross-section than BKF-I and BKF-F, and they appeared to be more closely associated with the water level on the day of the survey (for those sites with water). Because surveying was conducted during the dry season, the present water level on the day of the survey would not be expected to be flowing at bankfull stage, and thus these two indicators are likely not the best interpretation of the bankfull stage. Based solely on prevalence and elevation of various bankfull indicators during reference reach surveys, BKF-I and BKF-F (for streams with relatively flat wetland floodplains) appear to be the most reliable field indicators of bankfull stage for peninsular Florida streams.

Data Analysis

Slopes of field indicators

Slopes of a line best fit through survey points of each individual bankfull indicator (BKF-F, BKF-I, BKF-S, BKF-A) and through the top of bank survey points (TOB) were compared to the slope of a line best fit through the water surface survey points (or the channel bed surface points for those sites that had no flowing water on the day of the survey). Leopold (1994) used this technique to verify the feature as bankfull if the two lines were generally parallel and consistent over a long reach. To determine how parallel the lines were, water slope was divided by the slope of each bankfull indicator to determine a water slope to bankfull indicator slope ratio. Theoretically, the closer the ratio is to one, the more reliable the indicator. Bankfull indicator slopes within 25% of the water slope, or those with a water slope to bankfull indicator ratio between 0.75 and 1.25, were deemed candidate reliable field indicators (Table 3-3).

Slopes analysis results show that: 1) variability of water slope to bankfull indicator slope ratios among sites with a water slope less than 0.5% was significantly greater than that among sites with a water slope greater than 0.5% for all indicators except for BKF-I (Table 3-4, Figures 3-2); and 2) sites with a water slope greater than 0.5% were more likely to have bankfull indicator slopes within 25% of the water slope (Table 3-4). This suggests that slope-area techniques for calculating the bankfull discharge should not be used in peninsular Florida for sites with a water slope less than 0.5%, or vice versa, that calculating discharge using slope-area techniques is acceptable for sites with a water slope greater than 0.5%. Bankfull indicators may be more reliable for streams with a water slope greater than 0.5% because the steeper slope can generate more stream power and consequently perhaps the stream can build more consistent morphological features.

There may be several explanations why bankfull indicator slopes were unreliable at many of the sites (i.e., were not within 25% of the water slope or even had a negative slope/reverse gradient signature). First, there is a certain amount of inherent vertical variability in natural stream systems. A few inches of variability, however, can make a big difference when determining slopes for peninsular Florida's low-gradient stream systems. These low-gradient streams also leave little room for surveying errors that can occur from incorrectly identifying or surveying a particular bankfull indicator (as mentioned in the previous section). If a stream drops only a couple of inches in elevation over an entire reach, then any surveying errors may lead to an inaccurate bankfull slope. Solutions to these issues may be to survey a longer reference reach or to survey more points along the reach to make up for any potential surveying errors. Another solution may be to remove variability in bankfull indicator slope before actually surveying. This can be done by picking the best indicator at each cross-section along the reach and making sure that it is within a fixed, small amount of variability of the water, rather than by surveying a variety of bankfull indicators at each cross-section, then determining slopes of each indicator individually. This method was tested at Morgan Hole Creek, a site where every bankfull indicator's slope was negative. Although a more reliable bankfull slope was determined, this method seems to make bankfull stage determination more of an art than a science.

Second, the slope of the water encountered on the day of the survey may not be an accurate representation of the water slope at bankfull, which would render basing reliability of a bankfull indicator on water slope to bankfull indicator slope ratio useless. For example, two sites (Blackwater Creek near Cassia and Cow Creek) actually had negative water slopes on the day of the survey. These sites were extremely low-gradient, cypress-dominated systems with muddy streambeds, which may have led to inaccurate present water level readings due to the survey rod sinking into the mud. Solutions to this issue may be to survey water slope when the water is at or near bankfull stage.

Third, some sites did not have flowing water on the day of the survey so channel bed slope was used in place of the water slope to calculate water slope to bankfull indicator slope ratio. In these cases, the location of the survey's endpoints could have significant effects on the resulting channel bed slope and consequently the water slope to bankfull indicator slope ratio. For example, if one endpoint is at a pool and one is at a riffle, this could significantly affect overall slope and could even produce a negative slope. The solution to this issue is to be sure to begin and end the reference reach survey at a riffle. Another solution is to use another surrogate for water slope when there is no flowing water on the day of the survey, such as valley slope divided by sinuosity.

Lastly, perhaps peninsular Florida's unique climate, geology, and vegetation prevent its streams from fitting neatly within the concepts of bankfull that were developed in higher gradient piedmont and montane river systems. For example, in peninsular Florida, cyclonic storms (versus frontal low pressure systems) lead to patchy distributions of intense rainfall. Mid-order to high-order streams have a greater chance of rainfall variation along their lengths than do low-order headwater streams since their drainage areas are larger. This rainfall variation may affect water surface profiles, particularly if the downstream portion receives more rain and creates backwater effects. In other words, peninsular Florida streams likely do not exhibit a one to one ratio of rain to discharge as do other places in the United States, which may be why the bankfull indicators at many of the sites are smeared. Other hypotheses for reverse gradient bankfull signatures include: backwater effects (due to Florida's deranged network of wetlands and lakes), drought effects, animal effects (i.e., hogs), vegetative control, or bottom-up wetting (water infiltrating through Florida's sandy soils and entering the stream as groundwater, versus overland flow, and creating a gross movement of water that causes the channel to cut uphill).

Based on slope analysis, several conclusions can be drawn regarding the most reliable bankfull indicator for peninsular Florida. When comparing water slope to bankfull indicator slope ratios, BKF-I was the most reliable bankfull indicator, with an average ratio of 1.01. Further, variance in water slope to BKF-I slope ratio between streams with water slope less than 0.5% and those with a water slope greater than 0.5% was not significantly different ($p>0.05$) (Table 3-4). Perhaps more importantly, however, slopes analysis suggests that there is a water slope threshold of approximately 0.5%, above which bankfull indicators become more reliable. It is important to note, however, that the population of streams with water slopes greater than 0.5% was rather small (n=8), thus additional research is recommended. Findings further suggest that slope-area techniques for calculating the bankfull discharge should not be used in peninsular Florida for sites with a water slope less than 0.5%, or conversely, that calculating discharge using slope-area techniques is acceptable for sites with a water slope greater than 0.5%.

Gage analysis

Sites with long-term hydrologic data obtained from the USGS were analyzed to determine frequency and duration of stage and discharge associated with various bankfull indicators. As previously discussed, bankfull stage of each indicator was determined by adding the average difference between elevation of the bankfull indicator and that of the water surface at the time of the survey to the stage recorded by the USGS on the day of the survey. The most current stage-Q rating table was then used to determine bankfull discharges associated with the determined bankfull stages. Therefore, any issues associated with USGS data could have significant effects on bankfull discharge determination at the gaged sites. An important issue discovered upon analysis of USGS data was the extreme variability found in stage-Q relationships. For example, at Catfish Creek near Lake Wales (1947 to present), variation in stage was as much as 1.2 feet for a given discharge of 50 cfs and that in discharge was as much as 65 cfs for a given stage of 4.00 feet (Figure 3-4A). There also appeared to be several distinct rating curves within the data. To help discern the data, the daily discharge and stage measurements were separated by decade (Figure 3-4B). This exercise confirmed that stage-Q rating curves for peninsular Florida streams can change over time, sometimes quite drastically. Further, Figure 3-5 provides a visual comparison of variation within the long-term stage and discharge measurements among gaged sites through use of boxplots.

There may be several explanations for variation seen in the stage-Q relationships of peninsular Florida streams. First, USGS only directly measures discharge six to 12 times per year at a cross-section where the velocity can be measured most accurately; therefore, discharge measurements may not always be taken at the same location. Additionally, channel controls such as sand bars, topography, vegetation, and large woody debris can also have a significant effect on discharge measurements. For example, a single large storm can input large woody debris or cause channel bed adjustments (many of peninsular Florida's streams are sand-bottomed and can thus adjust relatively quickly), which can significantly affect discharge. Florida's deranged stream networks of wetlands and lakes may also affect discharge by creating backwater effects. Higher gradient streams systems, however, may be less affected by backwater so their stage-Q relationships may be less variable, which may explain why their bankfull indicators tend to be more reliable (as discussed in the previous section). Because discharge can be so variable, stage may be a more useful parameter for understanding the concept of bankfull in peninsular Florida streams. Stage may also be more useful because it is the parameter that the USGS actually measures. However, this study did not find any significant differences in durations between discharge and stage measurements associated with the top of bank and with each bankfull indicator (Table 3-9).

Gage station analysis throughout the United States has shown that bankfull discharge has an average recurrence interval of 1.5 years, which corresponds to a 66.7% annual exceedance probability (Dunne and Leopold, 1978; Leopold, 1994) (Figure 2-15). Frequency analyses of gaged sites found that stage and discharge associated with top of the bank and bankfull indicators occurred more frequently than 1.5 years. Frequency analyses of gaged sites found that the stage and discharge associated with BKF-A occurred the most frequently on average, while stage and discharge associated with top of bank and BKF-F generally occurred least frequently (Tables 3-5 and 3-6). Duration analyses found that stage and discharge associated with BKF-A were exceeded the most, while the stage and discharge associated with the top of bank and with BKF-F were generally exceeded the least. This intuitively makes sense based on observations made during the reference reach survey that BKF-A generally occurred the lowest in elevation on the cross-section, while BKF-F and top of bank were generally highest in elevation (Figure 3-1).

Based on gage analysis, it is safe to conclude that both BKF-A and BKF-S occur far too frequently and are exceeded far too often to be considered the best indicator of the bankfull discharge, or the most effective discharge in transporting sediment and performing "work." Significant differences were then found in durations of discharges and stages associated with top of bank ($p<0.01$) and the BKF-I indicator ($p<0.01$) between sites with a wetland floodplain and those without a wetland floodplain (Table 3-9). However, significant differences were not found in the durations of discharges and stages associated with BKF-F between sites with a wetland floodplain and those without a wetland floodplain. This is likely due to the nature of the BKF-F indicator itself—a flat floodplain, which is generally found at sites with a wetland floodplain and is generally absent from sites without one as these sites are more likely to be incised. Because BKF-I and top of bank were found at every site, the fact that significant differences exist between sites with a wetland floodplain and sites without one suggests that a different indicator should be used between these two site types. Because BKF-F is generally found at sites with a wetland floodplain, it is the most reliable bankfull indicator for peninsular streams Florida streams with a wetland floodplain. For streams without a wetland floodplain, BKF-I is the most reliable bankfull indicator.

Conclusions

In this study, various indicators of bankfull stage were identified, surveyed, and analyzed individually to determine if there is a single most reliable bankfull indicator for peninsular Florida streams. The following factors were examined: how prevalent each bankfull indicator among sites; how closely slope of each bankfull indicator matches that of the water; and how frequently and for how long the discharge and stage associated with each bankfull indicator occur. Based on these factors, there is not a single most reliable bankfull indicator for peninsular Florida streams, but rather, two: 1) BKF-F, or the position on the bank where the slope first becomes level, should be used for streams with a wetland floodplain or those with a broad valley; and 2) BKF-I, or the inflection in bank slope of the bank, should be used for streams without a wetland floodplain or those with a confined valley. Another important finding of the study is that bankfull indicators are more reliable for streams with a water slope greater than 0.5%, suggesting that slope-area techniques for calculating the bankfull discharge should not be used in peninsular Florida for sites with a water slope less than 0.5%, or vice versa, that calculating discharge using slope-area techniques is acceptable for sites with a water slope greater than 0.5%.

Table 3-1. Summary of gaged sites

Site name	USGS station ID	Period of record (WY)	County	Latitude	Longitude	Drainage area (sq mi)	Date surveyed	Reference reach survey location (in relation to gage)	Discharge reported on day of survey (cfs)	Adjusted stage reported / observed on day of survey (ft)
	Gage Information						Reference Reach Survey Information			
Blackwater Creek near Cassia	02235200	81-07	Lake	28.874	-81.490	126	3/3/08	Ended reach ~1800 feet US of gage	28	0.25
Blues Creek near Gainesville	02322016	85-94	Alachua	29.728	-82.431	2.62	1/10/08	Ended reach ~1 mile US of gage	0.37 [1]	-0.43
Bowlegs Creek near Fort Meade	02295013	65-68/92-07	Polk	27.700	-81.695	47.2	12/3/07	Ended reach ~1375 feet US of gage	3.7	0.12
Carter Creek near Sebring	02270000	55-67/92-07	Highlands	27.532	-81.388	38.8	12/7/07	Ended reach ~1.9 miles US of gage	3.2	-1.01
Catfish Creek near Lake Wales	02267000	48-07	Polk	27.961	-81.496	58.9	9/27/07	Began reach at gage	25	-0.64
Fisheating Creek at Palmdale	02256500	32-07	Glades	26.933	-81.315	311	3/20/08	Ended reach ~1.64 miles US of gage	11	-1.55
Hickory Creek near Ona	02295755	82-84*	Hardee	27.482	-81.880	3.75	8/9/07	Began reach ~550 feet DS of gage	13.66 [3]	0.94
Horse Creek near Arcadia	02297310	51-07	De Soto	27.199	-81.988	218	3/17/08	Began reach ~345 feet DS of gage	5.8	-1.92
Little Haw Creek near Seville	02244420	52-06	Flagler	29.322	-81.385	93	2/29/08	Surveyed through gage	9.3	-1.12
Livingston Creek near Frostproof	02269520	92-07	Polk	27.709	-81.446	120	12/4-5/07	Surveyed through gage	17.5 [4]	-0.56
Lochloosa Creek at Grove Park	02241900	96-05*	Alachua	29.600	-82.145	7.4	1/7/08	Began reach ~425 feet DS of gage	0.05 [3]	-0.40
Manatee River near Myakka Head	02299950	67-07	Manatee	27.474	-82.211	65.3	11/8-9/07	Ended reach ~1150 feet US of gage	22.5 [4]	-0.17
Moses Creek near Moultrie	02247027	00-02*	St. Johns	29.775	-81.316	7.4	1/18/08	Began reach ~364 DS of gage	1.3 [2,3]	-0.19
Rice Creek near Springside	02244473	74-04	Putnam	29.688	-81.742	43.2	1/11/08	Ended reach ~420 feet US of gage	10 [2]	-0.50
Santa Fe River near Graham	02320700	57-98	Bradford	29.846	-82.220	94.9	1/15-16/08	Ended reach ~550 feet US of gage	13.6 [2,4]	-1.36
Shiloh Run near Alachua	02322050	84-87*	Alachua	29.819	-82.472	0.32	1/8/08	Ended reach ~75 feet US of gage	0 [1,3]	--
Tiger Creek near Babson Park	02268390	92-07	Polk	27.811	-81.444	52.8	3/14/08	Ended reach ~1.4 miles US of gage	28	-0.18

Notes: WY = Water year; HL = Highlands physiography; FW = Flatwoods physiography; N = Northern peninsula; S = Southern peninsula; WF = Wetland floodplain; WFC = Wetland floodplain dominated by cypress; UP = Upland floodplain; US = upstream; DS = downstream; Adjusted stage = Reported or observed stage - Mean annual stage; -- = No stage data, [1] No discharge reported for the day of survey (gage inactive) and staff gage no longer at site or no longer accurate-- estimated discharge and then determined the associated stage from the stage-Q rating table; [2] No discharge reported for the day of survey (gage inactive)-- used gage height observed at the staff gage on the day of the survey and then determined the associated discharge from the stage-Q rating table; [3] Period of record for continuous data and/or annual peak data is less than 10 years-- gage analysis results are rough estimates and were not included in summary statistics; [4] Discharge averaged over two days; * Period of record less than 10 years-- data insufficient for proper gage analysis

Table 3-2. Prevalence of field bankfull indicators

Site Name	Physio-graphy	Geo-graphy	Flood-plain type	Flat floodplain (BKF-F)	Inflection (BKF-I)	Top of point bar (BKF-TOPB)	Scour (BKF-S)	Moss (BKF-M)	Alluvial break (BKF-A)
Alexander Springs Creek tributary 2	HL	N	UP	Present	Present	Not present	Present	Not present	Present
Blackwater Creek near Cassia	HL	N	WFC	Present	Present	Not present	Not present	Not present	Not present
Blues Creek near Gainesville	FW	N	UP	Not present	Present	Not present	Present	Present	Present
Bowlegs Creek near Ft Meade	FW	S	WF	Present	Present	Not present	Not present	Not present	Present
Carter Creek near Sebring	HL	S	UP	Present	Present	Not present	Present	Not present	Present
Catfish Creek near Lake Wales	HL	S	WFC	Present	Present	Not present	Present	Not present	Present
Coons Bay Branch	FW	S	WF	Present	Present	Not present	Present	Not present	Present
Cow Creek	FW	N	WFC	Present	Present	Not present	Present	Not present	Present
Cypress Slash tributary	HL	S	UP	Present	Present	Not present	Present	Not present	Present
East Fork Manatee River tributary	FW	S	UP	Present	Present	Not present	Present	Present	Not present
Fisheating Creek at Palmdale	FW	S	WFC	Present	Present	Present	Present	Not present	Not present
Gold Head Branch	HL	N	UP	Present	Present	Not present	Present	Not present	Present
Hammock Branch	HL	N	WF	Present	Present	Not present	Present	Not present	Present
Hickory Creek near Ona	FW	S	WF	Present	Present	Not present	Present	Not present	Present
Hillsborough River tributary	FW	S	WFC	Present	Present	Not present	Not present	Not present	Not present
Horse Creek near Arcadia	FW	S	WF	Present	Present	Not present	Present	Not present	Present
Jack Creek	HL	S	WF	Present	Present	Not present	Present	Not present	Present
Jumping Gully	HL	N	UP	Not present	Present	Not present	Present	Not present	Present
Lake June-In-Winter tributary	FW	S	UP	Not present	Present	Not present	Present	Not present	Present
Little Haw Creek near Seville	FW	N	WFC	Present	Present	Not present	Not present	Not present	Present
Livingston Creek near Frostproof	HL	S	UP	Present	Present	Not present	Present	Not present	Present
Livingston Creek tributary	HL	S	UP	Present	Present	Not present	Present	Not present	Not present
Lochloosa Creek at Grove Park	FW	N	WFC	Present	Present	Not present	Present	Not present	Present
Lowry Lake tributary	HL	N	UP	Present	Present	Not present	Present	Not present	Present
Manatee River near Myakka Head	FW	S	UP	Present	Present	Present	Present	Not present	Present
Manatee River tributary	FW	S	UP	Present	Present	Not present	Present	Present	Not present
Morgan Hole Creek	FW	S	UP	Present	Present	Not present	Present	Not present	Present
Moses Creek near Moultrie	FW	N	WFC	Present	Present	Not present	Present	Not present	Present
Myakka River tributary 1	FW	S	UP	Present	Present	Not present	Not present	Not present	Not present
Myakka River tributary 2	FW	S	UP	Present	Present	Present	Not present	Not present	Not present
Nine Mile Creek	HL	N	WF	Present	Present	Not present	Present	Not present	Present
Rice Creek near Springside	FW	N	WFC	Present	Present	Present	Present	Not present	Present
Santa Fe River near Graham	FW	N	UP	Not present	Present	Not present	Present	Not present	Present
Shiloh Run near Alachua	FW	N	UP	Not present	Present	Present	Present	Not present	Present
Snell Creek	HL	S	WF	Present	Present	Not present	Present	Not present	Present
South Fork Black Creek	HL	N	WF	Present	Present	Not present	Present	Not present	Present
Spoil Bank tributary (Highlands)	FW	S	UP	Present	Present	Present	Present	Present	Present
Ten Mile Creek	FW	N	WFC	Present	Present	Not present	Present	Not present	Present
Tiger Creek near Babson Park	HL	S	UP	Present	Present	Not present	Not present	Not present	Present
Tiger Creek tributary	HL	S	WF	Present	Present	Not present	Present	Not present	Present
Triple Creek unnamed tributary 1	HL	S	WF	Present	Present	Not present	Present	Not present	Not present
Triple Creek unnamed tributary 2	FW	S	UP	Present	Present	Not present	Present	Present	Not present
Tuscawilla Lake tributary	HL	N	UP	Not present	Present	Not present	Present	Present	Present
Tyson Creek	FW	S	WFC	Present	Present	Not present	Present	Present	Present
Unnamed Lower Wekiva tributary	HL	N	WF	Present	Present	Not present	Present	Present	Present
Percentage of sites at which bankfull indicator is present:				87%	100%	13%	84%	18%	78%

Notes: FW = Flatwoods physiography; HL = Highlands physiography; N = Northern peninsula geography; S = Southern peninsula geography; WF = Wetland floodplain; WFC = Wetland floodplain dominated by cypress; UP = Upland floodplain

Table 3-3. Summary of slopes data

			Top of bank (TOB)		Flat floodplain (BKF-F)		Inflection (BKF-I)		Scour (BKF-S)		Alluvial break (BKF-A)	
Site name	Water slope (%)	Channel bed slope (%)	Slope (%)	WS : TOB ratio	Slope (%)	WS : BKF-F ratio	Slope (%)	WS : BKF-I ratio	Slope (%)	WS : BKF-S ratio	Slope (%)	WS : BKF-A ratio
Alexander Springs Creek tributary 2	0.157	-0.347	0.691	0.23	0.701	0.22	0.502	0.31	0.280	0.56	0.108	1.45
Blackwater Creek near Cassia	-0.026	0.072	-0.145	0.18	-0.145	0.18	-0.090	0.29	--	--	--	--
Blues Creek near Gainesville [1]	No water	0.221	0.278	**0.79**	--	--	0.157	1.41	0.330	0.67	0.262	**0.84**
Bowlegs Creek near Ft Meade	0.104	0.027	0.115	**0.90**	0.115	**0.90**	0.094	**1.11**	--	--	0.117	**0.89**
Carter Creek near Sebring	0.173	0.224	0.719	0.24	0.631	0.27	0.418	0.41	0.560	0.31	0.136	1.27
Catfish Creek near Lake Wales	0.051	0.062	-0.050	-1.02	0.055	**0.93**	-0.069	-0.74	-0.054	-0.94	0.052	**0.98**
Coons Bay Branch [1]	No water	0.253	0.268	**0.94**	0.269	**0.94**	0.425	0.60	0.253	**1.00**	0.521	0.49
Cow Creek	-0.002	0.287	0.002	-1.00	0.049	-0.04	0.157	-0.01	0.072	-0.03	-0.018	0.11
Cypress Slash tributary [1, 2]	No water	1.140	1.018	**1.12**	1.027	**1.11**	0.921	**1.24**	1.003	**1.14**	1.096	**1.04**
East Fork Manatee River tributary [1]	No water	0.164	0.227	0.72	0.261	0.63	-0.085	-1.93	0.204	**0.80**	--	--
Fisheating Creek at Palmdale	0.020	-0.135	0.116	0.17	0.122	0.16	0.043	0.47	0.075	0.27	--	--
Gold Head Branch [2]	1.610	1.792	1.796	**0.90**	1.607	**1.00**	1.419	**1.13**	1.336	**1.21**	1.540	**1.05**
Hammock Branch	0.102	0.357	-0.226	-0.45	-0.102	-1.00	0.007	14.57	0.110	**0.93**	0.087	**1.17**
Hickory Creek near Ona	0.155	-0.051	-0.135	-1.15	--	--	0.084	1.85	0.054	2.87	0.121	1.28
Hillsborough River tributary [1]	No water	-0.118	0.481	-0.25	0.392	-0.30	0.271	-0.44	--	--	--	--
Horse Creek near Arcadia	0.008	0.062	-0.198	-0.04	-0.325	-0.02	0.009	**0.89**	0.013	0.62	-0.037	-0.22
Jack Creek	0.301	-0.349	0.159	1.89	-0.078	-3.86	0.028	10.75	0.268	**1.12**	0.518	0.58
Jumping Gully [2]	0.604	0.395	0.698	**0.87**	--	--	0.587	**1.03**	0.629	**0.96**	0.550	**1.10**
Lake June-In-Winter tributary [2]	0.845	0.872	0.708	**1.19**	--	--	0.779	**1.08**	0.884	**0.96**	0.742	**1.14**
Little Haw Creek near Seville	0.040	0.148	0.038	**1.05**	0.053	**0.75**	-0.005	-8.00	--	--	0.095	0.42
Livingston Creek near Frostproof	0.061	0.096	0.009	6.78	0.024	2.54	-0.077	-0.79	0.056	**1.09**	0.085	0.72
Livingston Creek tributary [1, 2]	No water	1.498	0.887	1.69	0.582	2.57	0.957	1.57	0.600	2.50	--	--
Lochloosa Creek at Grove Park	0.097	0.463	0.060	1.62	0.064	1.52	0.082	**1.18**	0.132	0.73	0.199	0.49
Lowry Lake tributary	0.351	0.470	1.178	0.30	1.046	0.34	0.637	0.55	0.537	0.65	0.567	0.62
Manatee River near Myakka Head	0.062	0.036	0.083	**0.75**	0.054	**1.15**	0.094	0.66	0.099	0.63	0.057	**1.09**
Manatee River tributary	0.042	0.816	0.846	0.05	0.846	0.05	0.474	0.09	0.223	0.19	--	--
Morgan Hole Creek [1]	No water	-0.229	-0.100	2.29	-0.106	2.16	-0.268	**0.85**	-0.060	3.82	-0.062	3.69
Moses Creek near Moultrie	0.096	0.164	0.036	2.67	0.039	2.46	0.076	1.26	0.124	**0.77**	0.092	**1.04**
Myakka River tributary 1 [1]	No water	0.045	-0.074	-0.61	0.013	3.46	0.078	0.58	--	--	--	--
Myakka River tributary 2 [1]	No water	0.375	-0.131	-2.86	-0.025	-15.00	0.000	**	--	--	--	--
Nine Mile Creek [2]	0.713	0.611	0.595	**1.20**	0.588	**1.21**	0.703	**1.01**	0.747	**0.95**	0.407	1.75
Rice Creek near Springside	0.017	-0.064	0.210	0.08	0.209	0.08	0.109	0.16	0.036	0.47	0.036	0.47
Santa Fe River near Graham	0.068	-0.006	-0.227	-0.30	--	--	-0.067	-1.01	-0.013	-5.23	0.057	**1.19**
Shiloh Run near Alachua [1, 2]	No water	1.128	1.048	**1.08**	--	--	1.169	**0.96**	1.132	**1.00**	1.033	**1.09**
Snell Creek	0.103	0.245	0.154	0.67	0.145	0.71	0.114	**0.90**	0.161	0.64	-0.011	-9.36
South Fork Black Creek	0.080	0.105	0.176	0.45	0.171	0.47	0.077	**1.04**	0.048	1.67	-0.013	-6.15
Spoil Bank tributary [1]	No water	0.144	0.019	7.58	-0.111	-1.30	0.066	2.18	-0.027	-5.33	-0.056	-2.57
Ten Mile Creek	0.097	-0.156	0.096	**1.01**	0.096	**1.01**	0.113	**0.86**	-0.022	-4.41	0.073	1.33
Tiger Creek near Babson Park	0.058	0.211	0.179	0.32	0.134	0.43	0.088	0.66	--	--	0.614	0.09
Tiger Creek tributary	0.213	0.095	0.464	0.46	0.426	0.50	0.497	0.43	0.325	0.66	0.221	**0.96**
Triple Creek unnamed tributary 1	0.419	0.448	0.252	1.66	0.259	1.62	0.273	1.53	0.726	0.58	--	--
Triple Creek unnamed tributary 2 [1]	No water	0.486	1.537	0.32	1.539	0.32	1.518	0.32	0.709	0.69	--	--
Tuscawilla Lake tributary [2]	0.844	0.731	1.222	0.69	--	--	1.015	**0.83**	0.738	**1.14**	0.584	1.45
Tyson Creek	0.008	0.088	-0.033	-0.24	-0.036	-0.22	0.006	1.33	0.010	**0.80**	0.150	0.05
Unnamed Lower Wekiva tributary	0.156	0.061	0.123	1.27	0.122	1.28	0.110	1.42	-0.021	-7.43	0.251	0.62
Mean	0.231	0.29	0.337	**0.80**	0.282	0.24	0.300	**1.01**	0.323	0.24	0.291	0.35
Standard deviation	0.343	0.45	0.488	1.70	0.443	2.82	0.420	3.01	0.368	2.20	0.369	2.24
Percentage of sites with negative slope	7%	20%	22%	N/A	21%	N/A	16%	N/A	16%	N/A	17%	N/A
Percentage of sites with BKF indicator slope within 25% of water slope [3]	N/A	N/A	N/A	27%	N/A	24%	N/A	31%	N/A	37%	N/A	37%

Notes: [1] Used channel bed slope in place of water slope in the calculation of the water slope to bankfull indicator slope ratio because there was no flowing water on the day of the survey; [2] Site has a water slope >0.5%; [3] Water slope to bankfull indicator ratio between 0.75 and 1.25; -- = Bankfull indicator not found at site; WS = Water slope; BKF = Bankfull; N/A = Not applicable; **Bold** = Water slope to bankfull indicator ratio within 25% of water slope (i.e. has a ratio between 0.75 and 1.25)

Table 3-4. Comparision of various water slope to bankfull indicator slope ratios by water slope

Effect	Average water slope to BKF-indicator slope ratio	Standard deviation	Percentage of sites with BKF indicator slope within 25% of water slope *	Percentage of sites with negative slope	P-value (t-Test assumming unequal variances)
Top of bank (TOB):					
WS <0.5%	0.55	1.48	17%	25%	0.03**
WS >0.5%	1.09	0.30	75%	0%	
Flat floodplain (BKF-F):					
WS <0.5%	0.10	2.94	15%	24%	0.02**
WS >0.5%	1.47	0.74	75%	0%	
Inflection (BKF-I):					
WS <0.5%	0.99	3.34	19%	19%	0.42
WS >0.5%	1.11	0.22	88%	0%	
Scour (BKF-S):					
WS <0.5%	-0.03	2.40	23%	20%	0.01**
WS >0.5%	1.23	0.52	88%	0%	
Alluvial break (BKF-A):					
WS <0.5%	0.13	2.46	29%	21%	0.01**
WS >0.5%	1.23	0.27	71%	0%	

Notes: WS = Water slope; BKF = Bankfull; * Water slope to bankfull indicator ratio between 0.75 and 1.25; ** Represents statistical significance ($p \leq 0.05$)

Table 3-5. Gaged sites discharge summary: Reference reach survey results

Site Name	Top of bank Discharge (cfs)	Top of bank RI (yrs)	Top of bank Duration (% of time)	Flat floodplain (BKF-F) Discharge (cfs)	Flat floodplain (BKF-F) RI (yrs)	Flat floodplain (BKF-F) Duration (% of time)	Inflection (BKF-I) Discharge (cfs)	Inflection (BKF-I) RI (yrs)	Inflection (BKF-I) Duration (% of time)	Scour (BKF-S) Discharge (cfs)	Scour (BKF-S) RI (yrs)	Scour (BKF-S) Duration (% of time)	Alluvial break (BKF-A) Discharge (cfs)	Alluvial break (BKF-A) RI (yrs)	Alluvial break (BKF-A) Duration (% of time)	Minimum W/D (BKF-W/D) Discharge (cfs)	Minimum W/D (BKF-W/D) RI (yrs)	Minimum W/D (BKF-W/D) Duration (% of time)
Blackwater Creek near Cassia	55	1.05	32	55	1.05	32	33	< 1.01	47	N/A	N/A	N/A	N/A	N/A	N/A	42.4	1.02	39
Blues Creek near Gainesville [1]	86	1.47	0.2	N/A	N/A	N/A	36	1.07	0.8	12	< 1.01	6.6	6.0	< 1.01	14	60.0	1.20	0.3
Bowlegs Creek near Fort Meade	36	< 1.01	21	35	< 1.01	21	25	< 1.01	26	N/A	N/A	N/A	12	< 1.01	42	30.6	< 1.01	23
Carter Creek near Sebring	59	1.10	6.9	30	< 1.01	26	42	< 1.01	14	11	< 1.01	71	5.5	< 1.01	93	8.3	< 1.01	82
Catfish Creek near Lake Wales	90	3.10	5.0	37	1.11	50	97	3.70	4.2	75	1.95	8.8	34	1.08	53	50	1.23	29
Fisheating Creek near Palmdale	75	< 1.01	41	75	< 1.01	41	39	< 1.01	50	53	< 1.01	46	N/A	N/A	N/A	13	< 1.01	65
Hickory Creek near Ona [1, 3]	21	< 1.01	6.5	N/A	N/A	N/A	4.7	< 1.01	13	5.8	< 1.01	11	1.1	< 1.01	25	22	< 1.01	4.0
Horse Creek near Arcadia	289	< 1.01	18	280	< 1.01	18	85	< 1.01	39	29	< 1.01	58	6.4	< 1.01	82	381	1.04	14
Little Haw Creek near Seville [2]	108	1.04	25	114	1.05	24	56	< 1.01	37	N/A	N/A	N/A	13	< 1.01	64	60	< 1.01	35
Livingston Creek near Frostproof [4]	171	1.42	8.3	100	1.12	19	106	1.14	18	38	< 1.01	51	38	< 1.01	51	77	1.06	27
Lochloosa Creek at Grove Park [2, 3]	13	< 1.01	23	13	< 1.01	23	6.3	< 1.01	34	3.6	< 1.01	44	0.1	< 1.01	73	1.9	< 1.01	53
Manatee River near Myakka Head [4]	595	1.09	2.1	402	1.03	4.0	116	< 1.01	14	16	< 1.01	56	18	< 1.01	52	201	< 1.01	8.7
Moses Creek near Moultrie [2, 3]	43	1.11	4.3	43	1.11	4.3	16	1.02	9.5	2.2	< 1.01	29	1.2	< 1.01	38	55	1.15	3.3
Rice Creek near Springside [2]	25	< 1.01	33	25	< 1.01	33	18	< 1.01	40	9.9	< 1.01	57	9.9	< 1.01	57	21	< 1.01	36
Santa Fe River near Graham [2, 4]	338	1.65	1.8	N/A	N/A	N/A	118	1.10	12	45	< 1.01	31	14	< 1.01	58	339	1.65	1.8
Shiloh Run near Alachua [1, 3]	16	3.50	IR	N/A	N/A	N/A	11	1.44	IR	5.5	1.04	0.1	0.2	< 1.01	39	7.0	1.13	IR
Tiger Creek near Babson Park	104	1.32	4.9	67	1.09	15	64	1.07	16	N/A	N/A	N/A	15	< 1.01	93	62	1.07	17
Mean	156	N/A	15	111	N/A	26	64	N/A	24	32	N/A	43	16	N/A	60	103	N/A	29
Standard deviation	162	N/A	14	120	N/A	13	36	N/A	16	23	N/A	23	11	N/A	23	124	N/A	24
Median	90	N/A	8.3	67	N/A	24	56	N/A	18	29	N/A	51	13	N/A	57	60	N/A	27

Notes: [1] No discharge reported for the day of survey (gage inactive) and staff gage no longer at site or no longer accurate-- estimated discharge and then determined the associated stage from the stage-Q rating table; [2] No discharge reported for the day of survey (gage inactive)-- used gage height observed at the staff gage on the day of the survey and then determined the associated discharge from the stage-Q rating table; [3] Period of record for continuous data and/or annual peak data is less than 10 years, thus gage analysis results are rough estimates-- did not include the results for these sites in summary statistics; [4] Discharge averaged over two days; cfs = cubic feet per second; RI = Return interval; yrs = years; W/D = Width-to-depth ratio; IR = Insufficient period of record for gage analysis; N/A = Not applicable (i.e. bankfull indicator not found at site and/or statistics could not be conducted because results are inconclusive)

Table 3-6. Gaged sites stage summary: Reference reach survey results

Site Name	Top of bank			Flat floodplain (BKF-F)			Inflection (BKF-I)			Scour (BKF-S)			Alluvial break (BKF-A)			Minimum W/D (BKF-W/D)		
	Adjusted stage (ft)	RI (yrs)	Duration (% of time)	Adjusted stage (ft)	RI (yrs)	Duration (% of time)	Adjusted stage (ft)	RI (yrs)	Duration (% of time)	Adjusted stage (ft)	RI (yrs)	Duration (% of time)	Adjusted stage (ft)	RI (yrs)	Duration (% of time)	Adjusted stage (ft)	RI (yrs)	Duration (% of time)
Blackwater Creek near Cassia	0.97	1.13	17	0.97	1.13	17	0.68	1.07	25	N/A	N/A	N/A	N/A	N/A	N/A	0.82	1.10	21
Blues Creek near Gainesville [1]	3.66	1.98	0.1	N/A	N/A	N/A	2.00	< 1.01	0.8	0.74	< 1.01	8.5	0.31	< 1.01	18	2.87	1.45	0.3
Bowlegs Creek near Fort Meade	1.42	< 1.01	13	1.41	< 1.01	14	0.98	< 1.01	17	N/A	N/A	N/A	0.28	< 1.01	27	1.23	< 1.01	15
Carter Creek near Sebring	1.50	< 1.01	4.6	0.47	< 1.01	21	0.94	< 1.01	11	-0.46	< 1.01	70	-0.92	< 1.01	95	-0.67	< 1.01	85
Catfish Creek near Lake Wales	0.55	1.33	16	-0.42	< 1.01	78	0.64	1.50	12	0.31	1.20	28	-0.48	< 1.01	81	-0.13	1.07	60
Fisheating Creek near Palmdale	0.37	< 1.01	43	0.37	< 1.01	43	-0.46	< 1.01	52	-0.09	< 1.01	48	N/A	N/A	N/A	-1.45	< 1.01	71
Hickory Creek near Ona [1, 3]	1.09	< 1.01	4.5	N/A	N/A	N/A	0.77	< 1.01	9.9	0.83	< 1.01	8.9	0.44	< 1.01	21	1.28	< 1.01	2.9
Horse Creek near Arcadia	2.33	1.04	17	2.25	1.04	17	-0.11	< 1.01	35	-1.18	< 1.01	53	-1.90	< 1.01	72	3.18	1.08	14
Little Haw Creek near Seville [2]	1.28	1.07	25	1.37	1.08	24	0.19	< 1.01	38	N/A	N/A	N/A	-1.20	< 1.01	66	0.28	< 1.01	37
Livingston Creek near Frostproof [4]	1.45	1.26	13	0.45	1.08	29	0.54	1.10	27	-0.78	< 1.01	67	-0.79	< 1.01	67	0.04	< 1.01	37
Lochloosa Creek at Grove Park [2, 3]	1.16	< 1.01	14	1.16	< 1.01	14	0.74	< 1.01	19	0.55	< 1.01	23	-0.17	< 1.01	44	0.40	< 1.01	26
Manatee River near Myakka Head [4]	7.53	1.15	1.6	5.90	1.04	3.4	2.39	< 1.01	11	-0.22	< 1.01	35	-0.11	< 1.01	33	3.63	< 1.01	7.6
Moses Creek near Moultrie [2, 3]	2.55	< 1.01	3.9	2.55	< 1.01	3.9	1.37	< 1.01	8.7	0.04	< 1.01	35	-0.20	< 1.01	44	2.91	< 1.01	2.8
Rice Creek near Springside [2]	0.36	< 1.01	31	0.36	< 1.01	31	0.03	< 1.01	38	-0.51	< 1.01	53	-0.51	< 1.01	53	0.20	< 1.01	34
Santa Fe River near Graham [2, 4]	5.38	1.65	2.3	N/A	N/A	N/A	1.74	1.10	15	-0.09	< 1.01	41	-1.35	< 1.01	74	5.40	1.65	2.3
Shiloh Run near Alachua [1, 3]	--	3.40	--	N/A	N/A	N/A	--	1.73	--	--	< 1.01	--	--	< 1.01	--	--	< 1.01	--
Tiger Creek near Babson Park	0.89	1.16	12.3	0.33	< 1.01	26	0.27	< 1.01	28	N/A	N/A	N/A	-0.94	< 1.01	96	0.23	< 1.01	30
Mean	2.13	N/A	15	1.22	N/A	28	0.76	N/A	24	-0.25	N/A	45	-0.69	N/A	62	1.20	N/A	32
Standard deviation	2.16	N/A	12	1.71	N/A	19	0.85	N/A	14	0.57	N/A	19	0.68	N/A	26	1.98	N/A	27
Median	1.42	N/A	13	0.47	N/A	24	0.64	N/A	25	-0.22	N/A	48	-0.79	N/A	67	0.28	N/A	30

Notes: [1] No stage reported for the day of survey (gage inactive) and staff gage no longer at site or no longer accurate-- estimated flow and then determined the associated stage from the stage-Q rating table; [2] No stage reported for the day of survey (gage inactive)-- used gage height observed at the staff gage on the day of the survey; [3] Period of record for continuous data and/or annual peak data is less than 10 years, thus gage analysis results are rough estimates-- did not include the results for these sites in summary statistics; [4] Stage averaged over two days; Adusted stage = Bankfull stage - Mean annual stage; ft = feet; -- = No stage data available for this site; N/A = Not applicable (i.e. bankfull indicator not found at site and/or statistics could not be conducted because results are inconclusive); W/D = Width-to-depth ratio

Table 3-7. Gaged sites discharge summary: Annual maximum series results

Site Name	1.01-year event (99% annual exceedance probability)		1.25-year event (80% annual exceedance probability)		1.5-year event (67% annual exceedance probability)		2-year event (50% annual exceedance probability)		5-year event (20% annual exceedance probability)		10-year event (10% annual exceedance probability)		25-year event (4% annual exceedance probability)		50-year event (2% annual exceedance probability)		100-year event (1% annual exceedance probability)	
	Discharge (cfs)	Duration (% of time)	Discharge (cfs)	Duration (% of time)	Discharge (cfs)	Duration (% of time)	Discharge (cfs)	Duration (% of time)	Discharge (cfs)	Duration (% of time)	Discharge (cfs)	Duration (% of time)	Discharge (cfs)	Duration (% of time)	Discharge (cfs)	Duration (% of time)	Discharge (cfs)	Duration (% of time)
Blackwater Creek near Cassia	38	42	131	12	173	6.9	256	2.8	493	0.4	689	0.1	979	IR	1225	IR	1493	IR
Blues Creek near Gainesville [1]	24	1.9	70	0.3	88	0.2	125	0.1	221	IR	296	IR	402	IR	489	IR	581	IR
Bowlegs Creek near Fort Meade	83	10	231	2.2	288	1.2	403	0.5	692	0.1	914	0.1	1222	0.0	1472	0.0	1738	IR
Carter Creek near Sebring	43	13	93	2.7	109	1.7	140	0.5	210	0.0	259	0.0	322	0.0	370	IR	418	IR
Catfish Creek near Lake Wales	26	69	52	25	60	17	77	8.1	113	2.3	136	1.1	167	0.3	191	0.2	214	0.1
Fisheating Creek near Palmdale	375	19	1426	3.7	1934	2.2	2951	0.9	5998	0.1	8610	0.0	12618	0.0	16069	0.0	19907	0.0
Hickory Creek near Ona [1, 3]	27	4.6	89	0.7	116	0.5	170	0.3	319	0.3	441	0.1	618	IR	766	IR	927	IR
Horse Creek near Arcadia	277	19	1016	3.7	1366	2.3	2065	0.9	4111	0.2	5848	0.1	8472	0.0	10740	0.0	13243	IR
Little Haw Creek near Seville [2]	87	29	266	8.8	341	5.5	490	2.3	887	0.4	1202	0.1	1656	0.0	2028	IR	2427	IR
Livingston Creek near Frostproof [4]	61	33	150	10	182	7.3	247	3.3	401	0.2	513	0.1	665	0.0	785	IR	910	IR
Lochloosa Creek at Grove Park [2, 3]	36	8.8	155	1.7	52	1.0	187	0.6	250	0.3	376	0.2	743	0.1	1052	0.1	1521	0.1
Manatee River near Myakka Head [4]	353	4.9	1054	0.6	1341	0.4	1914	0.1	3420	0.1	4603	0.0	6295	0.0	7674	IR	9162	IR
Moses Creek near Moultrie [2, 3]	13	11	83	1.8	132	1.0	229	0.6	611	0.1	1009	IR	1710	IR	2388	IR	3228	IR
Rice Creek near Springside [2]	113	9.6	389	1.0	513	0.6	762	0.3	1469	0.1	2056	IR	2924	IR	3656	IR	4457	IR
Santa Fe River near Graham [2, 4]	56	26	215	4.9	293	2.6	448	1.0	914	0.2	1318	0.1	1936	IR	2472	IR	3069	IR
Shiloh Run near Alachua [1, 3]	5.0	0.1	9.0	IR	10	IR	13	IR	19	IR	24	IR	29	IR	33	IR	37	IR
Tiger Creek near Babson Park	50	27	100	5.5	115	3.9	146	2.0	210	0.6	254	0.2	310	0.1	352	IR	394	IR
Mean	122	23	399	6.2	523	4.0	771	1.7	1472	0.4	2054	0.2	2921	0.1	3656	N/A	4463	N/A
Standard deviation	126	18	456	6.8	612	4.7	926	2.2	1853	0.6	2644	0.3	3852	0.1	4892	N/A	6046	N/A
Median	61	19	215	3.7	288	2.3	403	0.9	692	0.2	914	0.1	1222	0.0	1472	N/A	1738	N/A

Notes: [1] No discharge reported for the day of survey (gage inactive) and staff gage no longer at site or no longer accurate-- estimated discharge and then determined the associated stage from the stage-Q rating table; [2] No discharge reported for the day of survey (gage inactive)-- used gage height observed at the staff gage on the day of the survey and then determined the associated discharge from the stage-Q rating table; [3] Period of record for continuous data and/or annual peak data is less than 10 years, thus gage analysis results are rough estimates-- did not include the results for these sites in summary statistics; [4] Discharge averaged over two days; cfs = cubic feet per second; IR = Insufficient period of record for proper gage analysis; N/A = Not applicable -- insufficient period of record for proper gage analysis for the majority of sites

Table 3-8. Gaged sites stage summary: Annual maximum series results

Site Name	1.01-year event (99% annual exceedance probability) Adjusted stage (ft)	Duration (% of time)	1.25-year event (80% annual exceedance probability) Adjusted stage (ft)	Duration (% of time)	1.5-year event (67% annual exceedance probability) Adjusted stage (ft)	Duration (% of time)	2-year event (50% annual exceedance probability) Adjusted stage (ft)	Duration (% of time)	5-year event (20% annual exceedance probability) Adjusted stage (ft)	Duration (% of time)	10-year event (10% annual exceedance probability) Adjusted stage (ft)	Duration (% of time)	25-year event (4% annual exceedance probability) Adjusted stage (ft)	Duration (% of time)	50-year event (2% annual exceedance probability) Adjusted stage (ft)	Duration (% of time)	100-year event (1% annual exceedance probability) Adjusted stage (ft)	Duration (% of time)
Blackwater Creek near Cassia	-0.29	56	1.54	6.4	1.77	4.2	2.23	1.3	2.96	0.4	3.42	0.2	3.79	IR	4.03	IR	4.03	IR
Blues Creek near Gainesville [1]	2.29	0.5	2.57	0.3	2.94	0.3	3.69	0.1	4.41	IR	4.51	IR	4.53	IR	4.53	IR	4.53	IR
Bowlegs Creek near Fort Meade	2.37	8.0	3.13	4.2	3.43	2.8	4.03	1.0	4.85	0.2	5.39	0.0	6.11	IR	6.11	IR	6.11	IR
Carter Creek near Sebring	1.75	3.4	2.90	0.3	3.14	0.1	3.63	0.1	4.76	IR	5.24	IR	6.09	IR	6.20	IR	6.20	IR
Catfish Creek near Lake Wales	-0.36	74	0.49	19	0.64	12	0.94	5.1	1.30	1.7	1.64	0.7	2.23	0.1	2.40	0.02	2.44	0.005
Fisheating Creek near Palmdale	1.66	26	2.91	4.7	3.18	3.0	3.72	1.1	4.73	0.1	5.23	0.1	7.26	0.01	8.35	0.01	9.32	IR
Hickory Creek near Ona [1, 3]	1.20	3.8	1.66	0.8	1.78	0.6	2.03	0.3	2.60	0.2	2.60	0.2	2.60	0.2	2.60	0.2	2.60	0.16
Horse Creek near Arcadia	1.61	21	7.27	3.8	8.10	2.8	9.76	1.0	11.92	0.1	13.12	0.02	14.18	IR	14.31	IR	14.33	IR
Little Haw Creek near Seville [2]	0.68	32	3.09	7.4	3.40	5.1	4.01	2.2	5.19	0.4	5.56	0.2	6.28	0.02	6.53	0.01	6.56	IR
Livingston Creek near Frostproof [4]	0.04	37	1.43	14	2.06	8.2	3.32	2.2	4.57	0.3	5.45	0.1	6.57	IR	6.57	IR	6.57	IR
Lochloosa Creek at Grove Park [2, 3]	2.45	3.3	3.06	1.0	3.42	0.6	4.14	0.3	5.73	0.1	6.61	0.03	7.27	IR	7.28	IR	7.28	IR
Manatee River near Myakka Head [4]	5.38	4.1	9.11	0.6	9.66	0.5	10.76	0.3	13.06	0.04	14.59	0.02	15.80	IR	17.75	IR	17.75	IR
Moses Creek near Moultrie [2, 3]	2.96	2.7	2.96	2.7	3.24	1.8	3.79	0.9	6.41	IR	6.41	IR	6.41	IR	6.41	IR	6.41	IR
Rice Creek near Springside [2]	2.03	8.6	3.48	0.7	3.70	0.4	4.15	0.2	4.84	0.0	5.50	IR	5.91	IR	6.12	IR	6.12	IR
Santa Fe River near Graham [2, 4]	0.19	35	4.21	4.6	4.95	3.1	6.42	0.9	7.89	0.2	8.45	0.1	9.56	IR	9.92	IR	9.92	IR
Shiloh Run near Alachua [1, 3]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Tiger Creek near Babson Park	0.54	19	1.09	8.9	1.24	7.0	1.54	4.3	2.32	1.2	2.96	0.1	3.66	IR	3.66	IR	3.66	IR
Mean	1.38	25	3.33	5.7	3.71	3.8	4.48	1.5	5.60	0.4	6.24	0.1	7.08	N/A	7.42	N/A	7.50	N/A
Standard deviation	1.78	24	2.73	6.1	2.87	4.0	3.19	1.7	3.79	0.6	4.16	0.2	4.38	N/A	4.88	N/A	4.89	N/A
Median	1.61	21	2.91	4.6	3.18	3.0	3.72	1.0	4.76	0.2	5.39	0.1	6.11	N/A	6.20	N/A	6.20	N/A

Notes: [1] No stage reported for the day of survey (gage inactive) and staff gage no longer at site or no longer accurate-- estimated flow and then determined the associated stage from the stage-Q rating table; [2] No stage reported for the day of survey (gage inactive)-- used gage height observed at the staff gage on the day of the survey; [3] Period of record for continuous data and/or annual peak data is less than 10 years, thus gage analysis results are rough estimates-- did not include the results for these sites in summary statistics; [4] Stage averaged over two days; Adusted stage = Bankfull stage - Mean annual stage; ft = feet; -- = No stage data available for this site; IR = Insufficient period of record for gage analysis; N/A = Not applicable -- insufficient period of record for proper gage analysis for the majority of sites

Table 3-9. Comparison of various bankfull indicator discharge and stage durations by floodplain type

Effect	Discharge duration (% of time exceeded) Average	Discharge duration (% of time exceeded) P-value	Stage duration (% of time exceeded) Average	Stage duration (% of time exceeded) P-value
Top of bank (TOB):				
Wetland floodplain	25	<0.01*	23	<0.01*
Upland floodplain	4.0		5.7	
Flat floodplain (BKF-F):	31	0.14	32	0.24
Wetland floodplain	16		20	
Upland floodplain				
Inflection (BKF-I):				
Wetland floodplain	35	<0.01*	31	0.03*
Upland floodplain	13		16	
Scour (BKF-S):				
Wetland floodplain	43	0.97	45	0.95
Upland floodplain	43		44	
Alluvial break (BKF-A):				
Wetland floodplain	60	0.98	60	0.79
Upland floodplain	60		64	

* Represents statistical significance ($p \leq 0.05$)

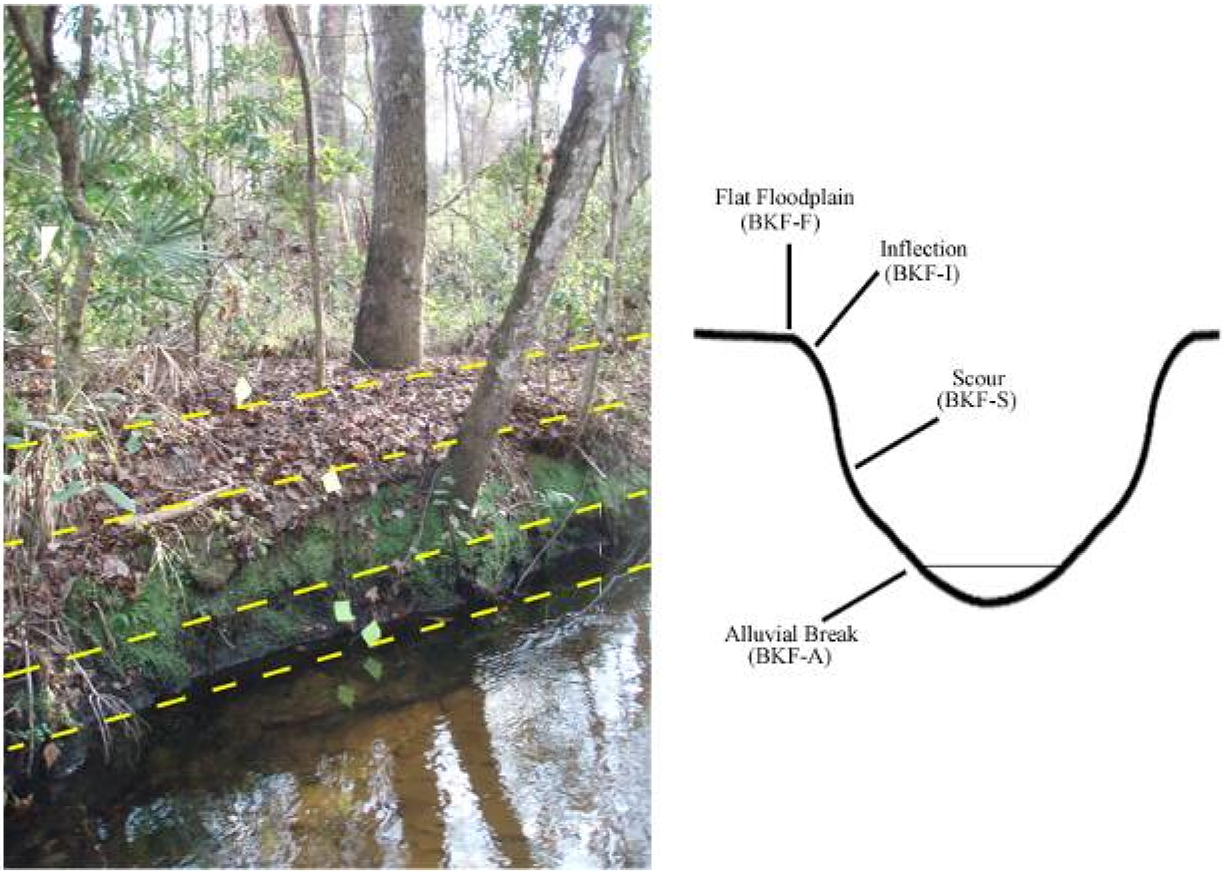


Figure 3-1. Various field indicators of bankfull stage: flat floodplain (BKF-F), inflection (BKF-I), scour (BKF-S), moss (BKF-M), and alluvial break (BKF-A).

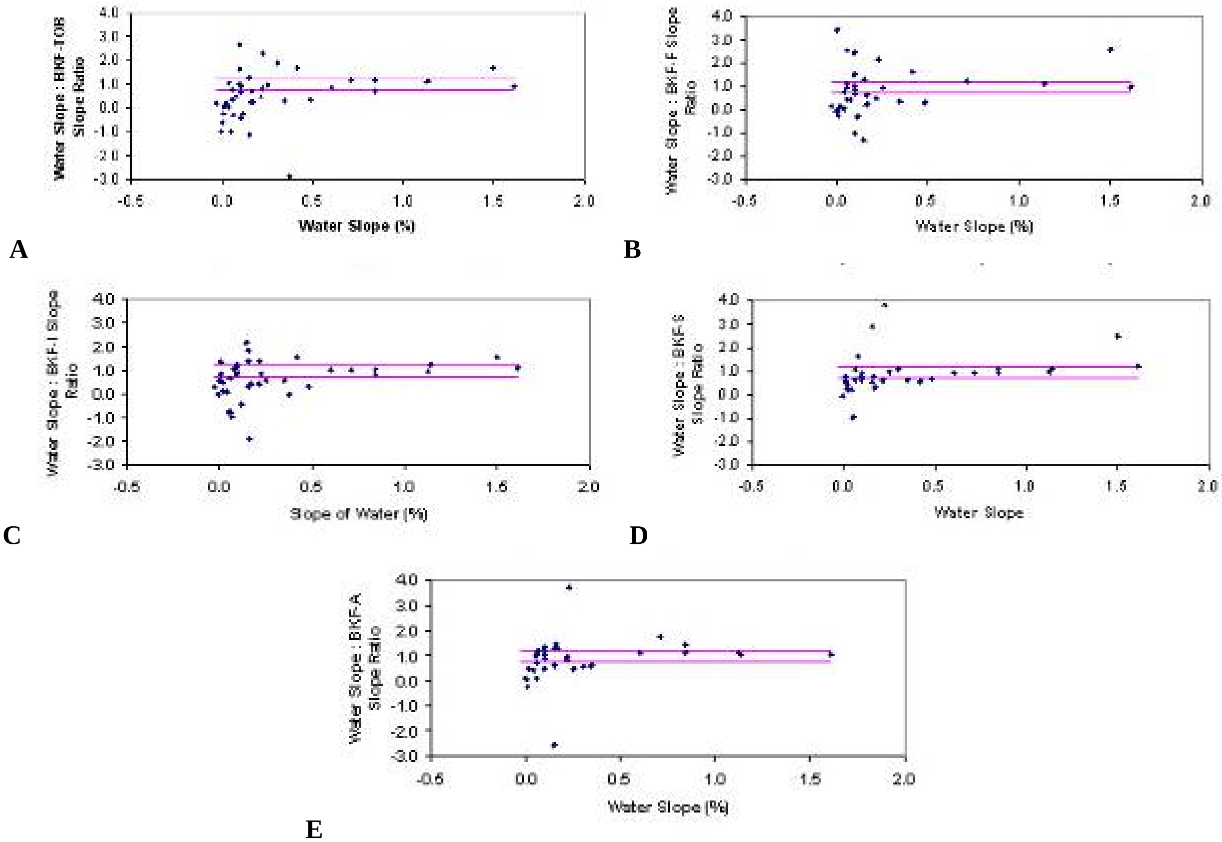


Figure 3-2. Water slope to various bankfull indicator slope ratios against water slope. A) Top of bank (TOB). B) Flat floodplain (BKF-F). C) Inflection (BKF-I). D) Scour (BKF-S). E) Alluvial break (BKF-A). Note: The pink parallel lines bracket the range of water slope to bankfull indicator slope ratios lying between 0.75 and 1.25 (i.e., the ratios for which bankfull indicator slope is within 25% of the water slope).

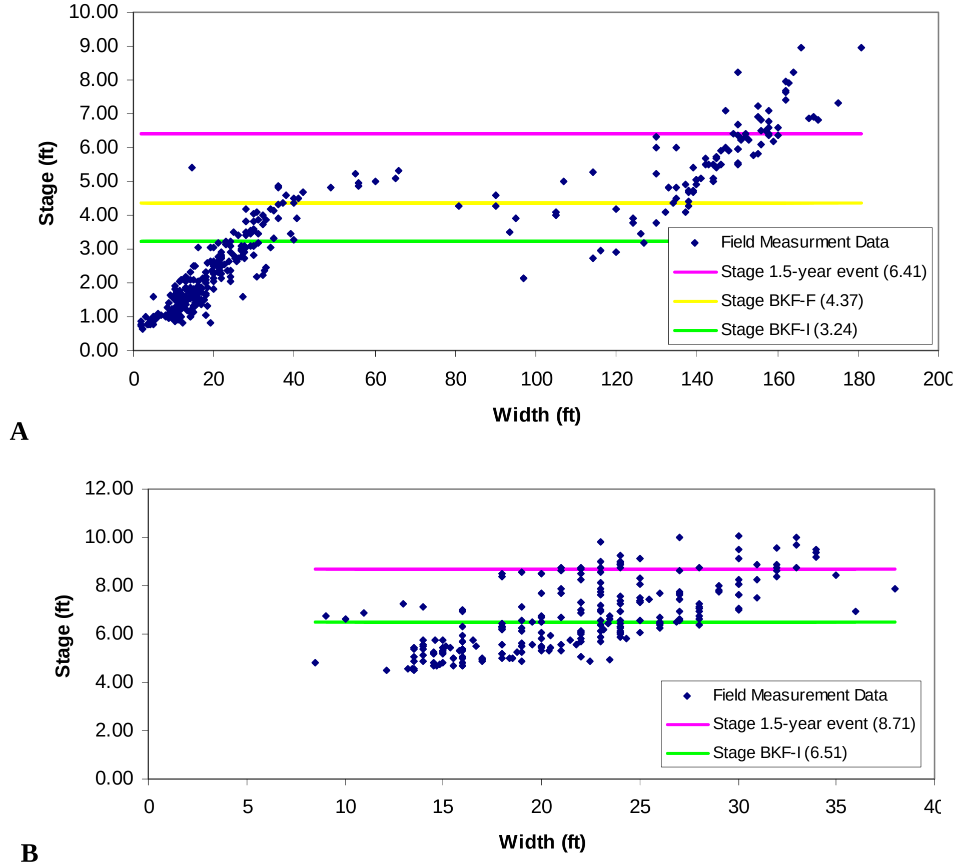
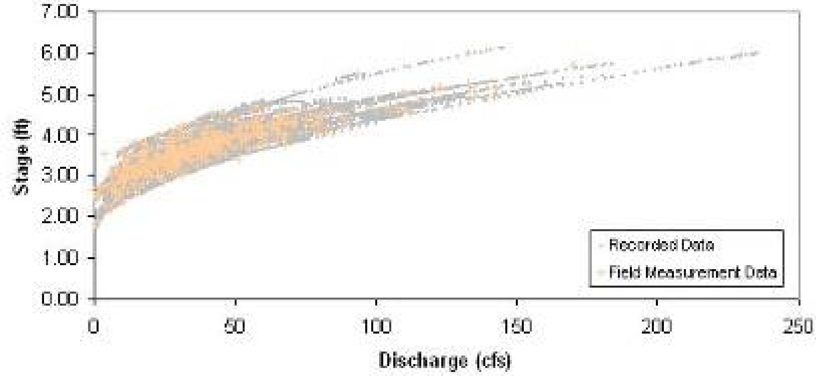
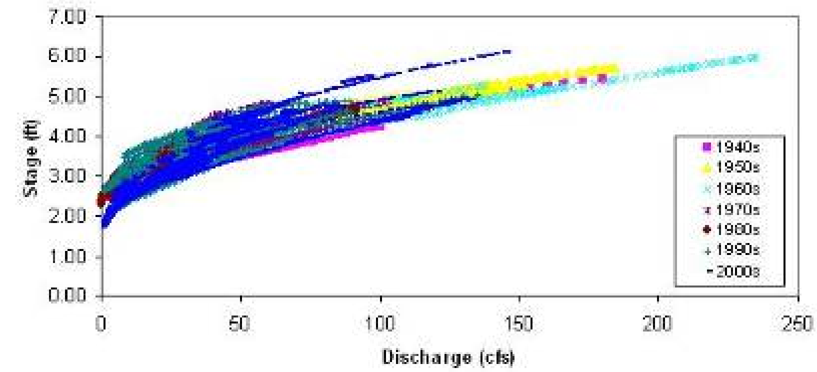


Figure 3-3. Width against stage field measurements. A) Little Haw Creek near Seville, a non-incised stream with a wetland floodplain. B) Carter Creek near Sebring, an incised stream with an upland floodplain.

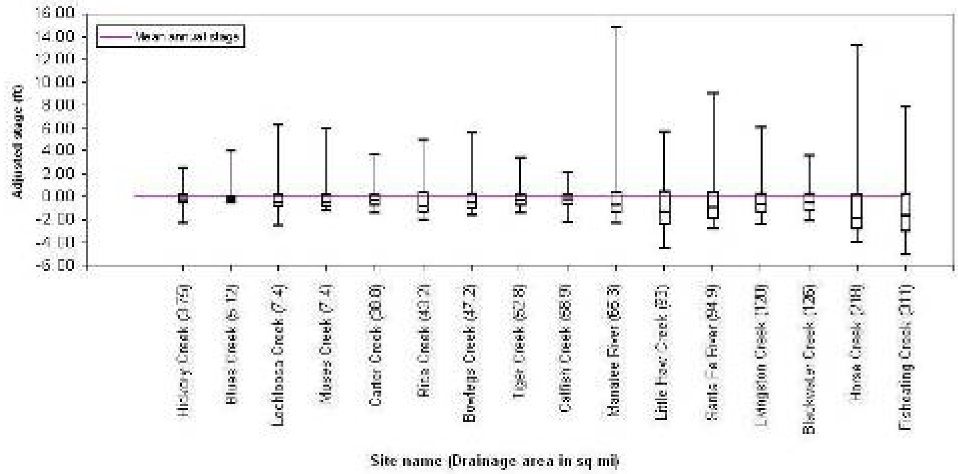


A

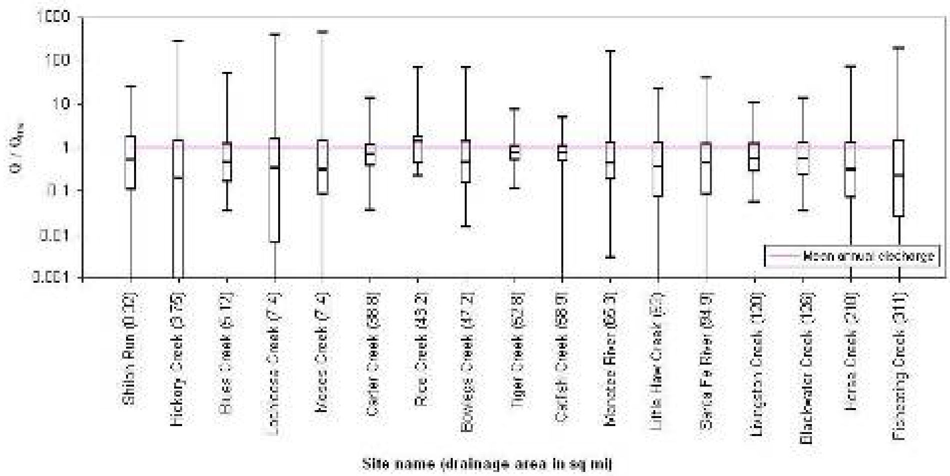


B

Figure 3-4. Example of variability in stage-Q rating curves. A) Catfish Creek near Lake Wales (WY 1947-2007) stage-Q rating curve. B) Catfish Creek near Lake Wales (WY 1947-2007) stage-Q rating curve split into decades.



A



B

Figure 3-5. Boxplots of stage and discharge data for gaged sites. A) Stage – Mean annual stage for all gaged sites, except Shiloh Run which had no stage data. B) Discharge/mean annual discharge for all gaged sites. Note: Because Q/Qma is plotted on a log scale there is no zero on the y-axis, and thus for sites with a minimum flow of zero, the boxplot line was extended down to the x-axis.

CHAPTER 4
DEVELOPING REGIONAL CURVES FOR PENINSULAR FLORIDA

Introduction

Regional curves, which relate bankfull discharge and channel geometry (cross-sectional area, width, and mean depth) to drainage area in regions of similar climate, geology, and vegetation, have greatly aided in creating target natural channel designs. Bankfull discharge, or flow that fills a stable alluvial channel to the elevation of the active floodplain, is a useful parameter in developing regional curves because its stage is reasonably identifiable in the field, and it is the flow most often used to estimate the channel-forming discharge. Dunne and Leopold (1978) describe bankfull discharge as “the most effective stream-flow for moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphological characteristics of channels.” While regional curves provide important information for natural channel structure, they also aid in estimating bankfull discharge and channel geometry in ungaged watersheds where drainage area is known, help confirm field identifications of bankfull stage, and allow for comparisons between regions (Leopold, 1994).

Metcalf (2004) published regional curves for “Florida streams,” yet his study sites were confined to extreme north Florida and the Panhandle, and even included sites in Georgia and Alabama (Figure 1-1). Peninsular Florida, however, is quite different in terms of its physiography, geological context, and rainfall patterns, as described in Chapter 2. It is an objective of the present work to develop regional curves for peninsular Florida. To accomplish this objective bankfull discharge and channel geometry (cross-sectional area, width, and mean depth) were plotted against drainage area, and coefficients of determination (R^2) were determined. Data were analyzed to determine whether significant differences exist between streams draining different physiographies (flatwoods versus highlands), geographies (northern versus southern peninsula), and floodplain types (wetland versus upland and cypress-dominated versus non-cypress-dominated), in terms of their bankfull parameters and various dimensionless ratios. The return interval associated with bankfull discharge was also estimated for peninsular Florida streams. The regional curves developed in this study were also compared to those developed for other regions of the southeastern United States Coastal Plain. This chapter describes the methods used to reach the objectives; the study results; a discussion of the potential errors, trends, and anomalies associated with data collection and analysis; and conclusions.

Methods

Tasks completed to develop regional curves for peninsular Florida included: 1) selecting between 40 and 50 gaged and ungaged stream sites that span a variety of drainage area sizes and valley slopes, as well as different physiographies (flatwoods versus highlands) and geographies (northern versus southern peninsula); 2) conducting reference reach surveys to determine bankfull channel geometry and discharge; 3) choosing the most reliable bankfull indicator for peninsular Florida streams; 4) delineating drainage basins and determining valley slopes; 5) developing and analyzing regional curves for peninsular Florida based on the entire data set as well as subsets of the data (physiography, geography, and floodplain types); 6) determining and analyzing various dimensionless ratios (sinuosity, width-to-depth, maximum depth-to-mean depth, and valley slope); 6) estimating bankfull return intervals; and 7) comparing regional curves developed for peninsular Florida to other southeastern United States Coastal Plain regional curve studies. The methods used to complete the first three tasks are reported in Chapter 3, while the remaining tasks are presented below.

Drainage Area Delineation and Valley Slope Determination

Drainage areas for each site were delineated by heads-up digitizing in ARCMap GIS using 5-foot contour USGS 1:24000 quads and refined using high-resolution aerials. Valley slopes were also determined in ARCMap GIS using 5-foot contour USGS 1:24000 quads by dividing the change in elevation by the straight line distance between the contour lines straddling the reference reach upstream and downstream.

Regional Curve Development

Data obtained from the reference reach surveys were used to determine bankfull discharge, bankfull cross-sectional area, bankfull width, and bankfull mean depth. Bankfull channel geometry parameters were based on the average value of the two smallest cross-sections (based on cross-sectional area) surveyed during the reference reach survey conducted at each study site, while bankfull discharge and stage were estimated for only gaged sites by using reference reach survey data of the field bankfull stage in conjunction with the most current USGS stage-discharge rating table. Regional curves were created in Microsoft Excel by plotting the various bankfull parameters against drainage area on a log-log scale. A power function regression was fit to the data, and the coefficient of determination (R^2) was determined. Due to the potential inaccuracies of determining bankfull discharge at gaged sites, mean annual discharge and 1.5-year discharge were also plotted against drainage area to see if these discharges were better correlated with drainage area than the bankfull discharge. More specifically, the 1.5-year return interval was chosen because it is the return interval most often associated with the bankfull flow (Leopold, 1994).

To determine whether peninsular Florida regional curves should be further split by physiography (flatwoods versus highlands), geography (northern versus southern peninsula), and/or floodplain type (wetland versus upland and cypress-dominated versus non-cypress-dominated), data were sorted by each of these subsets, and separate regional curves were created. Analysis of Covariance (ANCOVA) tests were then performed to determine whether significant differences exist in slopes and/or intercepts of bankfull discharge and channel geometry regressions for each data subset (JMP 7). It is important to note that the slope of the regression gives an indication of how sensitive a parameter is to changes in drainage area, and that if slopes are significantly different, this indicates that bankfull parameters in one set of streams change at a different rate with changes in drainage area than another set of streams. The intercept of the regression (determined by plotting the log values of the bankfull parameters and drainage area on a linear scale to obtain a linear regression) gives an indication of each bankfull parameter's "starting point," and if the intercepts are significantly different, this indicates that one set of streams starts out at a different bankfull parameter than another set of streams. Additionally, durations of various discharges were estimated and several ratios were calculated, including the peak discharge-to-mean annual discharge ratio (Q_p/Q_{ma}), which is an indication of the flashiness of a stream, the bankfull discharge-to-mean annual discharge ratio (Q_{bkf}/Q_{ma}), and the bankfull discharge-to-1.5-year discharge ratio ($Q_{bkf}/Q_{1.5}$).

Dimensionless Ratios

Data obtained from reference reach surveys were also used to determine various dimensionless ratios such as sinuosity, width-to-depth (w/d), maximum depth-to-mean depth (d_{max}/d), and valley slope. Sinuosity, which is found by dividing the channel length by the valley length, helps to define a stream's pattern. The width-to-depth ratio, found by dividing the bankfull width by the bankfull mean depth, and the maximum depth-to-mean depth both help to define a channel's shape. Valley slope, as previously mentioned, is found by dividing the change in elevation by the straight line distance between the contour lines straddling the reference reach upstream and downstream. Comparisons of means tests were performed using Excel Data

Analysis ANOVA: Single factor to determine if significant differences exist in the various dimensionless ratios by physiography (highlands versus flatwoods), geography (northern versus southern peninsula), and/or floodplain types (wetland versus upland and cypress- versus non-cypress-dominated).

Return Interval

Annual peak flow data for gaged sites were analyzed to determine return intervals associated with bankfull discharge using Log Pearson Type III distributions (skew coefficient of -0.1) in RIVERMorph (USGS, 1982).

Comparison to Other Southeastern United States Coastal Plain Regional Curves

Raw data from both the present work and previous regional curve studies conducted throughout the southeastern United States Coastal Plain were entered into Excel, and regional curves for each bankfull parameter were compiled into one graph for visual comparison. Analysis of Covariance (ANCOVA) tests were then performed to determine whether significant differences exist in slopes and/or intercepts of bankfull discharge and channel geometry regressions between peninsular Florida streams (the baseline regression) and other Coastal Plain regional curves (JMP 7).

Results

Results of the study are presented below, which include description of the drainage areas and valley slopes of the sites, presentation of bankfull discharge and channel geometry regressions developed for peninsular Florida along with analysis of the various data subsets (physiography, geography, and floodplain type), presentation of various dimensionless ratios along with analysis of the various data subsets, presentation of estimated return intervals associated with the bankfull discharge, and comparison of the regional curves developed for peninsular Florida to other regional curves studies conducted throughout the southeastern United States Coastal Plain.

Drainage Area Delineation and Valley Slope Determination

Drainage areas ranged from 0.2 sq mi at Triple Creek unnamed tributary 2 to 311 sq mi at Fisheating Creek at Palmdale, with mean and median values of 31.8 sq mi and 4.6 sq mi, respectively (Table 1-1). Valley slopes ranged from a very flat 0.02% at Blackwater Creek near Cassia to a high of 2.27% at Tuscawilla Lake tributary, one of the headwater streams, with mean and median values of 0.41% and 0.17%, respectively (Table 1-1). Generally, sites with smaller drainage areas had steeper slopes than those with larger areas, as expected (Figure 4-1).

Regional Curve Development

Bankfull discharge, mean annual discharge, and 1.5-year discharge were plotted against drainage area for the 17 gaged sites (Figures 4-2 though 4-6). Bankfull cross-sectional area, bankfull width, and bankfull mean depth were plotted against drainage area for all 45 sites (Figures 4-7 through 4-11). These relationships are presented and analyzed for the entire dataset and data subsets based on physiography (flatwoods versus highlands), geography (northern versus southern peninsula), and floodplain type (wetland versus upland and cypress-dominated versus non-cypress-dominated) in the following subsections. Table 4-1 summarizes discharge data used in peninsular Florida regional curve development, while Table 4-2 summaries channel geometry data used. Tables 4-3 and 4-4 summarize the power function regression equations, corresponding coefficients of determination, and sample sizes for discharge against drainage area and channel geometry against drainage area, respectively.

Discharge: bankfull, mean annual, 1.5-year

Relationships for bankfull discharge, mean annual discharge, and 1.5-year discharge as a function of drainage area for gaged sites are shown in Figures 4-2. Power function regression equations, corresponding coefficients of determination (R^2), and sample sizes are:

$Q_{bkf} = 14.26\ A_w^{0.36}$	$R^2 = 0.60$	n = 17	(4-1)
$Q_{ma} = 1.36\ A_w^{0.88}$	$R^2 = 0.95$	n = 17	(4-2)
$Q_{1.5} = 27.85\ A_w^{0.57}$	$R^2 = 0.60$	n = 17	(4-3)

where Q_{bkf} = bankfull discharge in cubic feet per second (cfs), Q_{ma} = mean annual discharge in cfs, $Q_{1.5}$ = 1.5-year discharge in cfs, and A_w = watershed drainage area in square miles (sq mi). Bankfull discharge, mean annual discharge, and 1.5-year discharge are all directly related to drainage area across the entire study area, with 60%, 95%, and 60% of the variability in discharges explained by drainage area, respectively.

On average, bankfull discharge is exceeded 21% of the time, while mean annual discharge is exceeded 26% of the time and the 1.5-year discharge is exceeded 3.4% of the time (note that the lower the % duration, the rarer or less frequent the event). On average, the largest flood or peak discharge (Q_p) is 52 times greater than mean annual discharge. Bankfull discharge is 35% of 1.5-year discharge and is 4.3 times greater than mean annual discharge on average. However, at six gaged sites, bankfull discharge is almost equal to or less than mean annual discharge, which is not expected as the bankfull discharge is generally higher than the mean annual discharge (Leopold, 1994 see Figure 2-15) (Table 4-1). Bankfull stage, on the other hand, is greater than mean annual stage at all but one gaged site (Catfish Creek near Lake Wales) (Appendix F).

Physiography (flatwoods versus highlands): Relationships for bankfull discharge, mean annual discharge, and 1.5-year discharge as a function of drainage area for the gaged sites for flatwoods (FW) and highlands (HL) physiographies are shown in Figure 4-3. The power function regression equations, corresponding coefficients of determination, and sample sizes are:

$Q_{bkf\text{-}FW} = 14.47\ A_w^{0.38}$	$R^2 = 0.64$	$n = 12$	(4-4)
$Q_{bkf\text{-}HL} = 6.97\ A_w^{0.49}$	$R^2 = 0.39$	$n = 5$	(4-5)
$Q_{ma\text{-}FW} = 1.35\ A_w^{0.92}$	$R^2 = 0.96$	$n = 12$	(4-6)
$Q_{ma\text{-}HL} = 2.55\ A_w^{0.67}$	$R^2 = 0.86$	$n = 5$	(4-7)
$Q_{1.5\text{-}FW} = 28.65\ A_w^{0.69}$	$R^2 = 0.86$	$n = 12$	(4-8)
$Q_{1.5\text{-}HL} = 10.20\ A_w^{0.58}$	$R^2 = 0.45$	$n = 5$	(4-9)

Bankfull discharge is directly related to drainage area, with 64% and 39% of the variability in discharge explained by drainage area for flatwoods and highlands physiographies, respectively. Mean annual discharge is directly related to drainage area, with 96% and 86% of the variability in discharge explained by drainage area for flatwoods and highland physiographies, respectively. Discharge associated with the 1.5-year event is directly related to drainage area, with 86% and 45% of variability in discharge explained by drainage area for flatwoods and highlands physiographies, respectively. For a given drainage area, bankfull discharge and 1.5-year discharge at the flatwoods sites appear to be higher than at the highlands sites, while there is not an obvious trend between physiographies for the mean annual discharge. Additionally, flatwoods streams "start out" (i.e., if drainage area were to equal zero) with a larger 1.5-year discharge than highlands streams ($p=0.02$), while their bankfull and mean annual discharges start out the same. ($p>0.05$) The various discharges increase at the same rate with an increase in drainage area for both physiographies ($p>0.05$) (Table 4-5).

No significant difference exists ($p>0.05$) in the duration of bankfull discharge based on physiography, which is equaled or exceeded on average 18% of the time at flatwoods sites and 26% at highlands sites. A significant difference exists ($p<0.1$) in duration of mean annual discharge, which is equaled or exceeded on average 23% of the time at flatwoods sites and 35%

at highlands sites. A significant difference exists ($p=0.01$) in duration of 1.5-year discharge, which is equaled or exceeded on average 1.6% and 7.4% of the time for flatwoods and highlands physiographies, respectively. On average, bankfull discharge is 29% of the 1.5-year discharge at flatwoods sites and 49% at highlands sites. Peak discharge is 69 and 11 times greater than mean annual discharge for flatwoods and highlands physiographies, respectively, which is significantly different ($p=0.01$) (Table 4-6).

Geography (northern versus southern peninsula): Relationships for bankfull discharge as a function of drainage area for gaged sites for northern (NP) and southern peninsula (SP) geographies are shown in Figure 4-4. Power function regression equations, corresponding coefficients of determination, and sample sizes are:

$Q_{bkf\text{-}NP} = 15.98\ A_w^{0.32}$	$R^2 = 0.58$	$n = 8$	(4-10)
$Q_{bkf\text{-}SP} = 9.42\ A_w^{0.47}$	$R^2 = 0.57$	$n = 9$	(4-11)
$Q_{ma\text{-}NP} = 1.37\ A_w^{0.88}$	$R^2 = 0.94$	$n = 8$	(4-12)
$Q_{ma\text{-}SP} = 1.30\ A_w^{0.88}$	$R^2 = 0.95$	$n = 9$	(4-13)
$Q_{1.5\text{-}NP} = 29.79\ A_w^{0.53}$	$R^2 = 0.78$	$n = 8$	(4-14)
$Q_{1.5\text{-}SP} = 22.27 A_w^{0.63}$	$R^2 = 0.37$	$n = 9$	(4-15)

Bankfull discharge is directly related to drainage area, with 58% and 57% of variability in discharge explained by drainage area for northern and southern peninsula geographies, respectively. Mean annual discharge is directly related to drainage area, with 94% and 95% of variability in discharge explained by drainage area for northern and southern peninsula geographies, respectively. Discharge associated with the 1.5-year event is directly related to drainage area, with 78% and 37% of variability in discharge explained by drainage area for northern and southern peninsula geographies, respectively. For a given drainage area, bankfull discharge, mean annual discharge, and 1.5-year discharge appear to be similar at northern and southern peninsula sites. Additionally, northern and southern peninsula streams start out with the same bankfull, mean annual, and 1.5-year discharges ($p>0.05$). The various discharges increase at the same rate with an increase in drainage area for both geographies ($p<0.05$) (Table 4-5).

No significant difference exists ($p>0.05$) in duration of bankfull discharge based on geography, which is equaled or exceeded on average 18% of the time at northern sites and 22% at southern sites. No significant difference exists ($p>0.05$) in duration of mean annual discharge, which is exceeded on average 25% of the time at northern sites and 28% at southern sites. No significant difference exists ($p>0.05$) in duration of 1.5-year discharge, which is equaled or exceeded on average 2.5% and 4.1% of the time for northern and southern peninsula geographies, respectively. On average, bankfull discharge is 40% of the 1.5-year discharge at northern sites and 31% at southern sites. Peak discharge is 55 and 49 times greater than mean annual discharge for northern and southern peninsula sites, respectively, which is not significantly different ($p>0.05$) (Table 4-6).

Floodplain type (wetland versus upland): Relationships for bankfull discharge as a function of drainage area for gaged sites for wetland (WF) and upland (UP) floodplain types are shown in Figure 4-5. Power function regression equations, corresponding coefficients of determination, and sample sizes are:

$$Q_{bkf\text{-}WF} = 9.13\ A_w^{0.44} \qquad R^2 = 0.55 \qquad n = 10 \qquad (4\text{-}16)$$
$$Q_{bkf\text{-}UP} = 18.64\ A_w^{0.36} \qquad R^2 = 0.88 \qquad n = 7 \qquad (4\text{-}17)$$

$$Q_{ma\text{-}WF} = 2.16\ A_w^{0.78} \qquad R^2 = 0.92 \qquad n = 10 \qquad (4\text{-}18)$$
$$Q_{ma\text{-}UP} = 1.04\ A_w^{0.91} \qquad R^2 = 0.98 \qquad n = 7 \qquad (4\text{-}19)$$

$$Q_{1.5\text{-}WF} = 28.49\ A_w^{0.58} \qquad R^2 = 0.52 \qquad n = 10 \qquad (4\text{-}20)$$
$$Q_{1.5\text{-}UP} = 27.24 A_w^{0.53} \qquad R^2 = 0.65 \qquad n = 7 \qquad (4\text{-}21)$$

Bankfull discharge is directly related to drainage area, with 55% and 88% of variability in discharge explained by drainage area for wetland and upland floodplains, respectively. Mean annual discharge is directly related to drainage area, with 92% and 98% of variability in discharge explained by drainage area for wetland and upland floodplains, respectively. Discharge associated with the 1.5-year event is directly related to drainage area, with 52% and 65% of variability in discharge explained by drainage area for wetland and upland floodplains, respectively. For a given drainage area, bankfull discharge at sites with an upland floodplain appears to be higher than at the sites with a wetland floodplain, while the opposite is true for mean annual discharge, and there is no obvious trend between floodplain types for the 1.5-year discharge. Additionally, streams with a wetland floodplain and those with an upland floodplain start out with the same bankfull, mean annual, and 1.5-year discharges ($p>0.05$). The various discharges increase at the same rate with an increase in drainage area for both floodplain types ($p<0.05$) (Table 4-5).

A nearly significant difference exists ($p=0.06$) in duration of bankfull discharge based on floodplain type, which is equaled or exceeded on average 25% of the time at sites with a wetland floodplain and 13% at sites with an upland floodplain. No significant difference exists ($p>0.05$) in duration of mean annual discharge, which is equaled or exceeded on average 25% of the time at sites with a wetland floodplain and 29% at sites with an upland floodplain. No significant difference exists ($p>0.05$) in duration of 1.5-year discharge, which is equaled or exceeded on average 3.8% and 2.7% of the time for wetland and upland floodplains, respectively. On average, bankfull discharge is 24% of 1.5-year discharge at sites with a wetland floodplain and 49% at sites with an upland floodplain. The largest flood is 66 and 31 times greater than the mean annual discharge for wetland and upland floodplains, respectively, which is not significantly different ($p>0.05$) (Table 4-6).

Floodplain type (cypress-dominated versus non-cypress-dominated): Relationships for bankfull discharge as a function of drainage area for gaged sites for cypress-dominated (CD) and non-cypress dominated (NC) floodplain types are shown in Figure 4-6. Power function regression equations, corresponding coefficients of determination, and sample sizes are:

$Q_{bkf\text{-}CD} = 10.94\ A_w^{0.35}$	$R^2 = 0.48$	n = 7	(4-22)
$Q_{bkf\text{-}NC} = 15.49\ A_w^{0.41}$	$R^2 = 0.79$	n = 10	(4-23)
$Q_{ma\text{-}CD} = 2.87\ A_w^{0.72}$	$R^2 = 0.87$	n = 7	(4-24)
$Q_{ma\text{-}NC} = 1.12\ A_w^{0.91}$	$R^2 = 0.98$	n = 10	(4-25)
$Q_{1.5\text{-}CD} = 19.88\ A_w^{0.62}$	$R^2 = 0.48$	n = 7	(4-26)
$Q_{1.5\text{-}NC} = 30.49 A_w^{0.56}$	$R^2 = 0.68$	n = 10	(4-27)

Bankfull discharge is directly related to drainage area, with 48% and 79% of variability in discharge explained by drainage area for cypress-dominated and non-cypress-dominated floodplains, respectively. Mean annual discharge is directly related to drainage area, with 87% and 98% of variability in discharge explained by drainage area for cypress-dominated and non-cypress-dominated floodplains, respectively. Discharge associated with the 1.5-year event is directly related to drainage area, with 48% and 68% of variability in discharge explained by drainage area for cypress-dominated and non-cypress-dominated floodplains, respectively. For a given drainage area, bankfull discharge and 1.5-year discharge at sites with a floodplain not dominated by cypress appear to be higher than at the sites with a cypress-dominated floodplain, while the opposite is true for the mean annual discharge. Additionally, streams with a cypress-dominated floodplain and those with a non-cypress-dominated floodplain start out with the same mean annual and 1.5-year discharges ($p>0.05$), but a significantly different bankfull discharge ($p=0.05$). The various discharges increase at the same rate with an increase in drainage area for both floodplain types. ($p<0.05$) (Table 4-5).

A significant difference exists ($p=0.01$) in duration of bankfull discharge based on floodplain type, which is equaled or exceeded on average 30% of the time at sites with a floodplain dominated by cypress and 13% at sites with a floodplain not dominated by cypress. No significant difference exists ($p>0.05$) in duration of mean annual discharge, which is equaled exceeded on average 26% of the time at sites with a floodplain dominated by cypress and 27% at sites with a floodplain not dominated by cyrpess. No significant difference exists ($p>0.05$) in duration of 1.5-year discharge, which is equaled or exceeded on average 4.9% and 2.2% of the time for cypress-dominated and non-cypress-dominated floodplains, respectively. On average, bankfull discharge is 28% of 1.5-year discharge at sites with a floodplain dominated by cypress and 40% at sites with a floodplain not dominated by cypress. The largest flood is 67 and 41 times greater than mean annual discharge for cypress-dominated and non-cypress-dominated floodplains, respectively, which is not significantly different ($p>0.05$) (Table 4-6).

Bankfull cross-sectional area

The relationship for bankfull cross-sectional area as a function of drainage area for the entire data set is shown in Figure 4-7A. Power function regression equation, corresponding coefficient of determination (R^2), and sample size are:

$$A_{bkf} = 6.05\ A_w^{0.47} \qquad R^2 = 0.78 \qquad n = 45 \qquad (4\text{-}28)$$

where A_{bkf} = bankfull cross-sectional area in square feet (sq ft) and A_w = watershed drainage area in square miles (sq mi). Bankfull cross-sectional area is directly related to drainage area, with 78% of variability in cross-sectional area across the entire study area explained by drainage area.

Physiography (flatwoods versus highlands): Relationships for bankfull cross-sectional area as a function of drainage area for flatwoods and highlands physiographies are shown in Figure 4-8A. Power function regression equations, corresponding coefficients of determination, and sample sizes are:

$$A_{bkf\text{-}FW} = 6.27\ A_w^{0.46} \qquad R^2 = 0.82 \qquad n = 25 \qquad (4\text{-}29)$$
$$A_{bkf\text{-}HL} = 5.80\ A_w^{0.49} \qquad R^2 = 0.74 \qquad n = 20 \qquad (4\text{-}30)$$

Bankfull cross-sectional area is directly related to drainage area, with 82% and 74% of variability in cross-sectional area explained by drainage area for flatwoods and highlands physiographies, respectively. For a given drainage area, bankfull cross-sectional area is similar at flatwoods and highlands sites. Additionally, flatwoods and highlands streams start out with the same bankfull area ($p>0.05$), and bankfull area increases at the same rate with an increase in drainage area for both physiographies ($p<0.05$) (Table 4-7).

Geography (northern versus southern peninsula): Relationships for bankfull cross-sectional area as a function of drainage area for northern and southern geographies are shown in Figure 4-9A. Power function regression equations, corresponding coefficients of determination, and sample sizes are:

$$A_{bkf\text{-}NP} = 6.41\ A_w^{0.49} \qquad R^2 = 0.80 \qquad n = 19 \qquad (4\text{-}31)$$
$$A_{bkf\text{-}SP} = 5.78\ A_w^{0.46} \qquad R^2 = 0.78 \qquad n = 26 \qquad (4\text{-}32)$$

Bankfull cross-sectional area is directly related to drainage area, with 80% and 78% of variability in cross-sectional area explained by drainage area for northern and southern peninsula geographies, respectively. For a given drainage area, bankfull cross-sectional area appears to be similar at northern and southern peninsula sites. Additionally, northern and southern peninsula streams start out with the same bankfull area ($p>0.05$), and it increases at the same rate with an increase in drainage area for both geographies ($p<0.05$) (Table 4-7).

Floodplain type (wetland versus upland): Relationships for bankfull cross-sectional area as a function of drainage area for wetland and upland floodplain types are shown in Figure 4-10A. Power function regression equations, corresponding coefficients of determination, and sample sizes are:

$$A_{bkf\text{-}WF} = 8.11\ A_w^{0.41} \qquad R^2 = 0.79 \qquad n = 23 \qquad (4\text{-}33)$$
$$A_{bkf\text{-}UP} = 5.13\ A_w^{0.47} \qquad R^2 = 0.75 \qquad n = 22 \qquad (4\text{-}34)$$

Bankfull cross-sectional area is directly related to drainage area, with 79% and 75% of variability in cross-sectional area explained by drainage area for northern and southern peninsula geographies, respectively. For a given drainage area, bankfull cross-sectional area appears to be larger at sites with a wetland floodplain than at those without a wetland floodplain. Additionally, streams with a wetland floodplain start out larger than streams with an upland floodplain ($p=0.03$). Bankfull area increases at the same rate with an increase in drainage area for both ($p<0.05$) (Table 4-7). Note that a cluster of upland sites occurs between a drainage area of 0.1 and one square mile (Figure 4-10A).

Floodplain type (cypress-dominated versus non-cypress-dominated): Relationships for bankfull cross-sectional area as a function of drainage area for cypress-dominated and non-cypress-dominated floodplain types are shown in Figure 4-11A. Power function regression equations, corresponding coefficients of determination, and sample sizes are:

$$A_{bkf\text{-}CD} = 7.29\ A_w^{0.46} \qquad R^2 = 0.84 \qquad n = 11 \qquad (4\text{-}35)$$
$$A_{bkf\text{-}NC} = 5.90\ A_w^{0.45} \qquad R^2 = 0.73 \qquad n = 34 \qquad (4\text{-}36)$$

Bankfull cross-sectional area is directly related to drainage area, with 84% and 73% of the variability in cross-sectional area explained by drainage area for the northern and southern peninsula geographies, respectively. For a given drainage area, the bankfull cross-sectional area appears to be slightly larger at sites with a floodplain dominated by cypress than at those the floodplain is not dominated by cypress. Additionally, streams with a cypress-dominated floodplain and those with a non-cypress-dominated floodplain start out with the same bankfull area ($p>0.05$), and bankfull area increases at the same rate with an increase in drainage area for both floodplain types ($p<0.05$) (Table 4-7). Also note that a cluster of non-cypress-dominated floodplain sites occurs between a drainage area of 0.1 and one square mile (Figure 4-11A).

Bankfull width

The relationship for bankfull width as a function of drainage area for the entire data set is shown in Figure 4-7B. Power function regression equation, corresponding coefficient of determination (R^2), and sample size are:

$$W_{bkf} = 6.87\ A_w^{0.30} \qquad R^2 = 0.81 \qquad n = 45 \qquad (4\text{-}37)$$

where W_{bkf} = bankfull width in feet (ft), and A_w = watershed drainage area in square miles (sq mi). Bankfull width is directly related to drainage area, with 81% of variability in width across the entire study area explained by drainage area.

Physiography (flatwoods versus highlands): Relationships for bankfull width as a function of drainage area for flatwoods and highlands physiographies are shown in Figure 4-8B. Power function regression equations, corresponding coefficients of determination, and sample sizes are:

$$W_{bkf\text{-}FW} = 7.28\ A_w^{0.28} \qquad R^2 = 0.92 \qquad n = 25 \qquad (4\text{-}38)$$
$$W_{bkf\text{-}HL} = 6.43\ A_w^{0.33} \qquad R^2 = 0.72 \qquad n = 20 \qquad (4\text{-}39)$$

Bankfull width is directly related to drainage area, with 92% and 72% of variability in width explained by drainage area for flatwoods and highlands physiographies, respectively. For a given drainage area, bankfull width appears to be similar at flatwoods and highlands sites. Additionally, flatwood and highland streams start out with the same bankfull width ($p>0.05$), and bankfull width increases at the same rate with an increase in drainage area for both physiographies ($p<0.05$) (Table 4-8).

Geography (northern versus southern peninsula): Relationships for bankfull width as a function of watershed area for northern and southern peninsula geographies are shown in Figure 4-9B. Power function regression equations, corresponding coefficients of determination, and sample sizes are:

$$W_{bkf\text{-}NP} = 6.26\ A_w^{0.30} \qquad R^2 = 0.76 \qquad n = 19 \qquad (4\text{-}40)$$
$$W_{bkf\text{-}SP} = 7.32\ A_w^{0.30} \qquad R^2 = 0.85 \qquad n = 26 \qquad (4\text{-}41)$$

Bankfull width is directly related to drainage area, with 76% and 85% of variability in width explained by drainage area for northern and southern peninsula geographies, respectively. For a given drainage area, bankfull width appears to be slightly wider at northern peninsula sites than at southern ones. Additionally, northern and southern peninsula streams start out with the same bankfull width ($p>0.05$), and it increases at the same rate with an increase in drainage area for both geographies ($p<0.05$) (Table 4-8).

Floodplain type (wetland versus upland): Relationships for bankfull width as a function of watershed area for wetland and upland floodplain types are shown in Figure 4-10B. Power function regression equations, corresponding coefficients of determination, and sample sizes are:

$$W_{bkf\text{-}WF} = 8.61\ A_w^{0.26} \qquad R^2 = 0.77 \qquad n = 23 \qquad (4\text{-}42)$$
$$W_{bkf\text{-}UP} = 6.04\ A_w^{0.29} \qquad R^2 = 0.82 \qquad n = 22 \qquad (4\text{-}43)$$

Bankfull width is directly related to drainage area, with 77% and 82% of variability in width explained by drainage area for wetland and upland floodplain types, respectively. For a given drainage area, bankfull width appears to be wider at sites with a wetland floodplain than at those with an upland floodplain. Additionally, streams with a wetland floodplain and those with an upland floodplain start out with the same bankfull width ($p>0.05$), and bankfull width increases at the same rate with an increase in drainage area for both floodplain types ($p<0.05$) (Table 4-8). Note a cluster of sites with an upland floodplain occurs between a drainage area of 0.1 and one square mile (Figure 4-10B).

Floodplain type (cypress- versus non-cypress-dominated): Relationships for bankfull width as a function of drainage area for cypress-dominated and non-cypress-dominated floodplain types are shown in Figure 4-11B. Power function regression equations, corresponding coefficients of determination, and sample sizes are:

$$W_{bkf\text{-}CD} = 8.56\ A_w^{0.28} \qquad R^2 = 0.86 \qquad n = 11 \qquad (4\text{-}44)$$
$$W_{bkf\text{-}NC} = 6.67\ A_w^{0.27} \qquad R^2 = 0.75 \qquad n = 34 \qquad (4\text{-}45)$$

Bankfull width is directly related to drainage area, with 86% and 75% of variability in width explained by drainage area for cypress-dominated and non-cypress-dominated floodplain types, respectively. For a given drainage area, bankfull width appears to be wider at sites with a floodplain dominated by cypress than at sites with a non-cypress-dominated floodplain. Additionally, streams with a cypress-dominated floodplain and those with a non-cypress-dominated floodplain start out with the same bankfull width ($p>0.05$), and bankfull width increases at the same rate with an increase in drainage area for both floodplain types ($p<0.05$) (Table 4-8). Note a cluster of sites with a non-cypress-dominated floodplain occurs between a drainage area of 0.1 and one square mile (Figure 4-11B).

Bankfull depth

The relationship for bankfull depth as a function of drainage area for the entire data set is shown in Figure 4-7C. Power function regression equation, corresponding coefficient of determination (R^2), and sample size are:

$$D_{bkf} = 0.89\ A_w^{0.18} \qquad R^2 = 0.48 \qquad n = 45 \qquad (4\text{-}46)$$

where D_{bkf} = bankfull depth in feet (ft), and A_w = watershed drainage area in square miles (sq mi). Bankfull depth is directly related to drainage area, with 48% of variability in depth across the entire study area explained by drainage area. Regressions related to mean depth exhibit the lowest R^2 values of all regional curves developed in the present study.

Physiography (flatwoods versus highlands): Relationships for bankfull width as a function of drainage area for flatwoods and highlands physiographies are shown in Figure 4-8C.

Power function regression equations, corresponding coefficients of determination, and sample sizes are:

$$D_{bkf\text{-}FW} = 0.86\ A_w^{0.18} \qquad R^2 = 0.49 \qquad n = 25 \qquad (4\text{-}47)$$
$$D_{bkf\text{-}HL} = 0.91\ A_w^{0.17} \qquad R^2 = 0.48 \qquad n = 20 \qquad (4\text{-}48)$$

Bankfull depth is directly related to drainage area, with 49% and 48% of variability in depth explained by drainage area for flatwood and highland physiographies, respectively. For a given drainage area, bankfull mean depth appears to be similar at flatwoods and highlands sites. Additionally, flatwoods and highlands streams start out with the same bankfull depth ($p>0.05$), and bankfull depth increases at the same rate with an increase in drainage area for both physiographies ($p<0.05$) (Table 4-9).

Geography (northern versus southern peninsula): Relationships for bankfull depth as a function of drainage area for the northern and southern peninsula geographies are shown in Figure 4-9C. Power function regression equations, corresponding coefficients of determination, and sample sizes are:

$$D_{bkf\text{-}NP} = 1.03\ A_w^{0.19} \qquad R^2 = 0.67 \qquad n = 19 \qquad (4\text{-}49)$$
$$D_{bkf\text{-}SP} = 0.80\ A_w^{0.17} \qquad R^2 = 0.44 \qquad n = 26 \qquad (4\text{-}50)$$

Bankfull depth is directly related to drainage area, with 67% and 44% of variability in depth explained by drainage area for northern and southern peninsula geographies, respectively. For a given drainage area, bankfull mean depth appears to be deeper at northern peninsula sites than at the southern ones. Additionally, northern peninsula streams start out with a deeper bankfull depth than southern peninsula streams ($p>0.02$). Bankfull depth increases at the same rate with an increase in drainage area for both geographies ($p<0.05$) (Table 4-9).

Floodplain type (wetland versus upland): Relationships for bankfull depth as a function of drainage area for wetland and upland floodplain types are shown in Figure 4-10C. Power function regression equations, corresponding coefficients of determination, and sample sizes are:

$D_{bkf\text{-}WF} = 0.95\ A_w^{0.16}$	$R^2 = 0.52$	$n = 23$	(4-51)
$D_{bkf\text{-}UP} = 0.85\ A_w^{0.18}$	$R^2 = 0.41$	$n = 22$	(4-52)

Bankfull depth is directly related to drainage area, with 52% and 41% of variability in depth explained by drainage area for wetland and upland floodplain types, respectively. For a given drainage area, bankfull mean depth appears to be similar at sites with a wetland floodplain and those with an upland floodplain. Additionally, streams with a wetland floodplain and those with an upland floodplain start out with the same bankfull depth ($p>0.05$), and bankfull depth increases at the same rate with an increase in drainage area for both floodplain types ($p<0.05$) (Table 4-9). A cluster of sites with an upland floodplain occurs between a drainage area of 0.1 and one square mile (Figure 4-10C).

Floodplain type (cypress-dominated versus non-cypress dominated): Relationships for bankfull depth as a function of drainage area for northern and southern peninsula geographies are shown in Figure 4-11C. Power function regression equations, corresponding coefficients of determination, and sample sizes are:

$D_{bkf\text{-}CD} = 0.85\ A_w^{0.18}$	$R^2 = 0.47$	$n = 11$	(4-53)
$D_{bkf\text{-}NC} = 0.89\ A_w^{0.18}$	$R^2 = 0.45$	$n = 34$	(4-54)

Bankfull depth is directly related to drainage area, with 47% and 45% of variability in depth explained by drainage area for cypress-dominated and non-cypress-dominated floodplain types, respectively. For a given drainage area, bankfull mean depth appears to be similar at sites with a cypress-dominated floodplain and those with a non-cypress-dominated floodplain. Additionally, streams with a cypress-dominated floodplain and those with a non-cypress-dominated floodplain start out with the same bankfull depth ($p>0.05$), and bankfull depth increases at the same rate with an increase in drainage area for both floodplain types ($p<0.05$) (Table 4-9). A cluster of sites with an upland floodplain occurs between a drainage area of 0.1 and one square mile (Figure 4-11C).

Dimensionless Ratios

Dimensionless ratios including sinuosity, width-to-depth, maximum depth-to-mean depth, and valley slope were calculated for the 45 sites (Table 4-10). The results are presented and analyzed for both the entire dataset and data subsets based on physiography (flatwoods versus highlands), geography (northern versus southern peninsula), and floodplain type (wetland versus upland and cypress-dominated versus non-cypress-dominated). Boxplots for the various ratios are provided in Figures 4-12 through 4-15.

Sinuosity

Sinuosity averages 1.32 across all the sites. No significant differences exist ($p>0.05$) in sinuosity based on flatwoods versus physiography, northern versus southern peninsula geography, wetland versus upland floodplain type, or cypress-dominated versus non-cypress-dominated floodplain type (Table 4-11, Figure 4-12).

Width-to-depth

Width-to-depth ratio averages 11.11 across all the sites. No significant differences exist ($p>0.05$) in the width-to-depth ratio based on flatwoods versus highlands physiography or wetland versus upland floodplain type. However, southern sites and those with a cypress-dominated floodplain had significantly greater width-to-depth ratios than northern sites ($p=0.01$) and sites with a non-cypress-dominated floodplain ($p=0.01$), respectively (Table 4-11, Figure 4-13).

Maximum depth-to-mean depth

Maximum depth-to-mean depth ratio averages 1.62 across all sites. No significant differences exist ($p>0.05$) in the maximum depth-to-mean depth ratio based on flatwoods versus highlands physiography, northern versus southern peninsula geography, wetland versus upland floodplain, or cypress-dominated versus non-cypress-dominated floodplain (Table 4-11, Figure 4-14).

Valley slope

Valley slopes average 0.41% across all the sites. No significant differences exist ($p>0.05$) in valley slope based on flatwoods versus highlands physiography or northern versus southern peninsula geography. However, sites with an upland floodplain and those with a non-cypress-dominated floodplain had significantly greater valley slopes than sites with a wetland floodplain ($p<0.01$) and sites with a cypress-dominated floodplain ($p=0.02$), respectively (Table 4-11, Figure 4-15).

Return Intervals

Return intervals were estimated using Annual Maximum Series from a Log Pearson Type III distribution and ranged from less than one year to 1.44 years (Table 4-2), which is more frequent than the average 1.5-year return interval often reported in the literature (Dunne and Leopold, 1978; Leopold, 1994), but consistent with findings from other southeastern United States Coastal Plain studies (Sweet and Geratz, 2003) (Table 4-12). An average bankfull return interval could not be determined for the sites most gaged sites had a return interval of less than one year[3]. Bankfull discharge was equaled or exceeded on average 21% of the time, or 75 days per year, for gaged sites based on flow duration curve analysis.

[3] Note that return intervals less than one year cannot be determined when performing an Annual Maximum Series.

Comparison to Other Southeastern United States Coastal Plain Regional Curves

Regional curves have recently been developed to estimate bankfull discharge and channel geometry throughout the southeastern United States Costal Plain, including the Georgia Coastal Plain (Buck Engineering, 2004), Virginia and Maryland Coastal Plain (Krstolic and Chaplin, 2007), North Carolina Coastal Plain (Doll *et al.,* 2003; Sweet and Geratz, 2003), Northwest Florida and North Florida Coastal Plain (Metcalf, 2004), and Alabama Coastal Plain (Metcalf, 2005). Results of these studies as well as the present study are compiled in Table 4-12, and the regressions are compiled in Figures 4-16 through 4-19. The slope of peninsular Florida streams for all bankfull regressions tends to be less steep than the other slopes, indicating that bankfull parameters in peninsular Florida are less sensitive to changes in drainage area size, or in other words that the bankfull parameters in peninsular Florida streams increase at a slower rate with drainage area. When other Coastal Plain bankfull regressions were compared through ANCOVA testing to peninsular Florida bankfull regressions (the baseline regression), the following results were found:

- Georgia, North Carolina (Sweet and Geratz, 2003), and North Florida Coastal Plain streams start out with a significantly lower bankfull discharge than peninsular Florida streams ($p<0.01$, $p<0.01$, and $p<0.01$, respectively), while Alabama, North Carolina (Doll, 2003), Northwest Florida, and Virginia/Maryland Coastal Plain streams start out with a significantly higher bankfull discharge ($p=0.02$, $p=0.01$, $p<0.01$, and $p<0.01$, respectively). Bankfull discharge for all stream sets increases at the same rate with increasing drainage area as peninsular Florida streams ($p>0.05$) (Table 4-5, Figure 4-16).

- Georgia and North Florida Coastal Plain streams start out with a significantly smaller bankfull area than peninsular Florida streams ($p<0.01$ and $p=0.02$, respectively), while North Carolina (Doll, 2003), Northwest Florida, and Virginia/Maryland Coastal Plain streams start out with a significantly larger bankfull area ($p<0.01$, $p<0.01$, and $p=0.01$, respectively). Bankfull area in Alabama streams increased at a significantly faster rate with increasing drainage area than peninsular Florida streams ($p=0.01$), while the other regions increased at the same rate ($p>0.05$) (Table 4-7, Figure 4-17).

- Both North Carolina stream sets (Sweet and Geratz, 2003; Doll *et al.,* 2003), Northwest Florida, and Virginia/Maryland Coastal Plain streams start out significantly wider than peninsular Florida streams ($p=0.03$, $p<0.01$, $p=0.01$, and $p=0.01$, respectively). Alabama streams widened at a significantly faster rate with increasing drainage area than peninsular Florida streams ($p=0.03$), while North Florida streams widened at a significantly slower rate ($p=0.01$). Other Coastal Plain regions' streams widened at the same rate as peninsular Florida streams (Table 4-8, Figure 4-18).

- Georgia Coastal Plain streams start out significantly shallower than peninsular Florida streams ($p<0.01$), while North Carolina (Doll, 2003) and Northwest Florida streams started out significantly deeper ($p=0.01$ and $p<0.02$, respectively). North Florida streams deepened at a faster rate with increasing drainage area than peninsular Florida streams ($p=0.04$) (Table 4-9, Figure 4-19).

Discussion

In this study, regional curves relating bankfull discharge, bankfull cross-sectional area, bankfull width, and bankfull mean depth to drainage area were developed for peninsular Florida streams. Regional curve data, as well as various dimensionless ratios (sinuosity, width-to-depth, maximum depth-to-mean depth, valley slope), were analyzed to determine whether significant differences exist between streams draining different physiographies (flatwoods versus highlands), geographies (northern versus southern peninsula), and floodplain types (wetland versus upland and cypress-dominated versus non-cypress dominated). The return interval associated with bankfull discharge was also estimated for peninsular Florida streams. Lastly, regional curves developed in this study were compared to those developed for other regions of the southeastern United States Coastal Plain. The discussion begins with an examination of potential sources of error involved in developing regional curves and implications this could have on interpretation of data. An examination of the analyses conducted on each parameter and dimensionless ratio follows. Observed trends and anomalies are discussed, and potential explanations are presented. Interpretation of data is presented as it relates to achieving the objective of this chapter, which is to develop the most robust regional curves for peninsular Florida streams.

Regional Curve Development

As previously mentioned in the methods section, bankfull channel geometry parameters were based on the average value of the two smallest cross-sections (based on cross-sectional area) surveyed during the reference reach survey conducted at each study site. It is important to note, however, that six detailed cross-sections were surveyed for each stream, and as can be seen in Table 4-2, the range of variability within bankfull indicator parameters among cross-sections was highly variable. For example, the range of variability among cross-sections (maximum bankfull measurement minus minimum bankfull measurement) was as high as 187 square feet for bankfull area at Horse Creek near Arcadia, 50 feet for bankfull width at Tiger Creek near Babson Park, and approximately three feet in bankfull depth at Horse Creek near Arcadia. The average range of variability among all sites was 24 square feet for bankfull area, 11 feet for bankfull width, and eight tenths of a foot for bankfull mean depth. Further, Wolman (1955) recognized that local variations in cross-sectional form are a possible source of scatter in downstream hydraulic geometry relations. Clearly, the cross-section chosen for development of the regional curves can have a significant effect on the ultimate regression. The two-smallest cross-sections were thus ultimately chosen and their parameters averaged for use in development of peninsular Florida regional curves based on previous work by USGS and based on the notion that the smallest cross-section represents the stream's hydraulic control (Chaplin, 2005).

As previously mentioned in the methods section, bankfull discharge and stage were estimated for gaged sites by using reference reach survey data of field bankfull stage in conjunction with the most current USGS Stage-Q rating table. As discussed in Chapter 3, it is important to note that determinations of bankfull discharge and stage are rough estimates, as the reference reach survey was not always conducted exactly at the USGS gage station due to local effects of bridges on stream hydraulics. Table 3-1 gives the location of the gage compared to that of the reference reach survey.

Discharge: bankfull, mean annual, 1.5-year

Several important discussion topics arose when examining discharge data, each of which will be briefly discussed herein. First, mean annual discharge had noticeably high R^2 values across the board in comparison to R^2 values of bankfull discharge and 1.5-year discharge regressions, indicating that drainage area is a good predictor of mean annual yield but is not as robust a predictor of bankfull discharge (as defined by field indicators) or 1.5-year discharge. Perhaps the concept of return interval is not as important to Florida stream hydrology as to other regions of the United States.

Second, bankfull discharge was almost equal to or less than mean annual discharge at six of the gaged sites, which was unexpected as bankfull discharge is expected to be higher than mean annual discharge (Leopold, 1994 see Figure 2-15). A mean annual discharge above bankfull discharge indicates that on average the stream is over its banks. The bankfull stage, however, was greater than mean annual stage at all but one gaged sites (Catfish Creek near Lake Wales), indicating that on average the water surface elevation is below the banks. It is interesting to note that all six sites had a wetland floodplain, and so perhaps it is not unfathomable for mean annual discharge to, on average, actually be over the banks as these wetland systems can withstand flooding. It is also interesting to note that Catfish Creek near Lake Wales had a bankfull stage less than its mean annual stage because this stream drains a large lake, which may provide a constant source of water to the stream so it flows at or above the bankfull stage most of the time and is not as dependent on individual storm events. However, the discrepancy between stage and discharge data still remains, which may be due to issues with USGS gage data and estimates of bankfull stage and discharge (as discussed thoroughly in

Chapter 3). Perhaps stage trumps discharge, or vice versa, in peninsular Florida streams, and one or the other is more useful in understanding the concept of bankfull. These issues would be interesting to research further.

Third, general trends in bankfull discharge regional curves show that it is generally higher at: 1) flatwoods sites than at highlands sites, 2) sites with an upland floodplain than those with a wetland floodplain; and 3) sites with a non-cypress-dominated than cypress-dominated floodplain. Sites with an upland floodplain and sites with a non-cypress-dominated floodplain have a significantly higher valley slope (as presented in the Dimensionless Ratios: Valley slope results section) than do sites with a wetland floodplain and sites with a cypress-dominated floodplain, respectively. Perhaps these steeper slopes allow for higher velocities in these streams, and subsequently higher bankfull discharges. Because no significant differences were found in valley slopes of flatwoods versus highlands sites, perhaps other factors such as vegetation and soils are responsible for differences in bankfull discharge based on physiography. For example, highland soils are less cohesive, which perhaps leads to more erratic stream behavior that may help to explain why R^2 values for all highlands regional curves are lower than those for flatwoods curves.

Lastly, the peak discharge-to-mean annual discharge ratio was significantly higher at flatwoods than at highlands sites (p=0.01), which indicates that flatwoods streams are flashier (Table 4-6). However, it is important to note that sample size for highlands sites was relatively small (n=5). Boxplots of peak discharge-to-mean annual discharge ratios are provided in Figure 4-20.

Bankfull channel geometry

Several important discussion topics arose when examining bankfull channel geometry data (cross-sectional area, width, and mean depth), each of which will be briefly discussed herein. First, R^2 values of bankfull mean depth regressions were noticeably lower than those for bankfull area and bankfull width. This could be due to the fact that the streambed is highly variable, and one may survey a pool versus a riffle, which could significantly affect the results.

Second, when examining differences in floodplain types (wetland versus upland and cypress-dominated versus non-cypress-dominated), an obvious cluster of sites with an upland floodplain or a non-cypress-dominated floodplain occurs between a drainage area of 0.1 and one square mile. This is not surprising, as sites with smaller drainage areas (i.e., headwater streams) tend to have steeper valley slopes (Figure 4-1). Wetlands, however, tend to occur in areas with lower valley slopes.

Third, bankfull area and width appeared to be larger in streams with wetland floodplains and with cypress-dominated floodplains than in streams with upland floodplains and with non-cypress-dominated floodplains, respectively. Though not significantly different, peak discharge-to-mean annual discharge ratios were also higher in streams with wetland floodplains and with cypress-dominated floodplains, indicating that these streams are flashier than those with an upland floodplain or a non-cypress-dominated floodplain (Table 4-6, Figure 4-20). Flashiness of these streams may help explain why they are wider, as Osterkamp (1980) found that streams with a flashier regime and relatively high peak flows tend to develop wider channels.

Dimensionless Ratios

Several important discussion topics arose when examining dimensionless ratios (sinuosity, width-to-depth, maximum depth-to-mean depth, and valley slope), each of which will be briefly discussed herein. First, no significant differences were found in sinuosity based on physiography, geography, or floodplain type, indicating that stream pattern in peninsular Florida is similar for the stream types studied. Nor were there significant differences in maximum depth-to-mean depth ratios, indicating that channel shape, in terms of d_{max}/d, are similar for the stream types studied.

Second, southern peninsula sites and those with a cypress-dominated floodplain had significantly larger width-to-depth ratios, indicating that they are wider for a given depth than northern peninsula sites and sites with a non-cypress-dominated floodplain. Differences in southern versus northern peninsula streams may be due to land use practices or vegetation. Sites with a cypress-dominated floodplain may have a larger width-to-depth ratio due to the presence of cypress knees, which may prevent stream banks from becoming as well developed.

Third, sites with an upland floodplain and those with a non-cypress-dominated floodplain had significantly greater valley slopes than sites with a wetland floodplain and sites with a cypress-dominated floodplain. This is not surprising, as wetlands tend to develop where valley slope is flatter.

Return Intervals

Return intervals were estimated using Annual Maximum Series from a Log Pearson Type III distribution and ranged from less than one year to 1.44 years (Table 4-2), which is more frequent than the average 1.5-year return interval often reported in the literature (Dunne and Leopold, 1978; Leopold, 1994), but consistent with findings from other southeastern United States Coastal Plain studies (Sweet and Geratz, 2003) (Table 4-12). These findings have important implications for flood control, as they indicate that peninsular Florida streams are overtopping their banks more frequently than in other regions. Because Annual Maximum Series cannot determine return intervals less than one year, mean and median bankfull return interval values could not be determined for peninsular Florida streams. It is recommended that future work includes a partial duration series to refine return intervals less than one year.

Comparison to Other Southeastern United States Coastal Plain Studies

Several important discussion topics arose when comparing regional curves developed for peninsular Florida streams to regional curves developed for other regions of the southeastern United States Coastal Plain, each of which will be briefly discussed herein. First, peninsular Florida bankfull channels start out significantly narrower and shallower than North Carolina ($p<0.01$; $p=0.01$) and Northwest Florida ($p=0.01$; $p<0.01$) Coastal Plain streams (Table 4-8 and Table 4-9). Perhaps this indicates that peninsular Florida streams are more efficient at conducting water, as Peninsular Florida streams tend to be low gradient with sandy bottoms, which may enable them to conform and conduct water more easily than streams with steeper gradients and rocky streambeds. However, peninsular Florida streams also start out at a significantly lower bankfull discharge and area than North Carolina ($p=0.01$; $p<0.01$) and Northwest Florida ($p<0.01$; $p=0.02$) Coastal Plain streams, which could indicate that peninsular Florida streams receive less water overall (Tables 4-6 and 4-7). Peninsular Florida receives approximately ten inches less rain than Northwest Florida (Figure 2-5), and considerably less mean annual runoff (approximately 10 inches) than North Carolina (approximately 15 inches) and Northwest Florida (approximately 25 inches) (Figure 4-21) (Gerbert *et al.,* 1987). Peninsular Florida's low mean annual runoff values are likely attributable to its sandy soils, flat terrain, and deranged drainage networks. Peninsular Florida streams also deepen at a significantly faster rate with increasing drainage area than North Florida streams. Perhaps this is because North Florida streams have a steeper gradient and thus down-cut more. Overall, it is difficult to tweak out exactly why peninsular Florida streams are significantly different than other Coastal Plain streams without further research, as there are a variety of variables, including the amount of water these systems receives (which depends upon on various factors such as climate, rainfall patterns, runoff patterns, and baseflow), roughness of the streambed, gradient, level of alluvial control, and vegetation.

Conclusions

In this study, regional curves were developed for peninsular Florida streams. Bankfull discharge and channel geometry (cross-sectional area, width, and mean depth), which were determined from both USGS hydrologic data and reference reach surveys, mean annual discharge, and the 1.5-year discharge were plotted against drainage area, and coefficients of determination (R^2) were determined. Relationships for bankfull discharge, mean annual discharge, 1.5-year discharge, bankfull area, bankfull width, and bankfull mean depth are shown in Figures 4-2 through 4-11. Table 4-1 summarizes discharge data used in peninsular Florida regional curve development, while Table 4-2 summarizes channel geometry data. Table 4-3 and 4-4 summarize power function regression equations, corresponding coefficients of determination, and sample sizes for discharge against drainage area and channel geometry against drainage area, respectively.

Bankfull parameters and various discharges varied directly with drainage area. Bankfull mean depth had the lowest R^2 values, while mean annual discharge had the highest R^2 values. Data were further analyzed to determine whether significant differences exist between streams draining different physiographies (flatwoods versus highlands), geographies (northern versus southern peninsula), and floodplain types (wetland versus upland and cypress-dominated versus non-cypress-dominated), in terms of bankfull parameters and various dimensionless ratios (sinuosity, width-to-depth, maximum depth-to-mean depth, and valley slope). Bankfull discharge appears to be higher at flatwoods sites than highlands, at sites with upland floodplains than wetland floodplains, and at sites with non-cypress-dominated floodplains than cypress-dominated-floodplains (Figures 4-3, 4-5, and 4-6). Sites with a non-cypress-dominated floodplain "started out" with significantly higher bankfull discharge than those with a cypress-dominated floodplain (p=0.05) and have a significantly lower bankfull discharge duration (p=0.01) (Table 4-6). Flatwoods streams were flashier than highlands streams, based on having significantly higher maximum discharge to mean discharge ratios (p=0.01).

Sites with wetland floodplains and cypress-dominated floodplains appear to have a greater bankfull area and bankfull width than sites with upland floodplains and non-cypress-dominated floodplains, respectively (Figures 4-10 and 4-11). These sites with a wetland floodplain started out with a significantly higher bankfull area (p=0.03) and bankfull width (p<0.01) than sites with an upland floodplain (Tables 4-7 and 4-8). Bankfull mean depth started out significantly higher in northern peninsula streams than in southern peninsula streams (p=0.02) (Table 4-9).

No significant differences were found in sinuosity or maximum depth-to-mean depth based on physiography, geography, or floodplain types. Sites with a cypress-dominated floodplain and sites located in the southern peninsula had significantly higher width-to-depth ratio than sites with either a non-cypress-dominated floodplain (p=0.01) or those located located in the northern peninsula (p=0.01) (Table 4-11). Sites with upland floodplains and non-cypress dominated floodplains had significantly steeper valley slopes than sites with wetland floodplains (p<0.01) and cypress-dominated floodplains (p=0.02), respectively.

The return interval associated with the bankfull discharge was also estimated for peninsular Florida streams using the Annual Maximum Series from a Log Pearson Type III distribution and ranged from less than one year to 1.44 years (Table 4-2), which is more frequent than the average 1.5-year return interval often reported in the literature (Dunne and Leopold, 1978; Leopold, 1994), but consistent with findings from other southeastern United States Coastal Plain studies to which regional curves developed in this study were compared. Bankfull discharge, area, width, and depth started out significantly smaller in peninsular Florida streams than in Northwest Florida streams and North Carolina streams, which receive considerably higher mean annual runoff (Figure 4-21). Further, the slope of peninsular Florida streams for all bankfull regressions tends to be less steep than the other slopes, indicating that bankfull parameters in peninsular Florida are less sensitive to changes in drainage area size, or in other words that the bankfull parameters in peninsular Florida streams increase at a slower rate with drainage area.

Table 4-1. Discharge data used in penisular Florida regional curve development and analysis

		Data Subsets			Discharge				Duration			Discharge Ratios		
Site name	Period of record (WY)	Physiography	Geography	Floodplain type	Q_{bkf} (cfs)	Q_{ma} (cfs)	$Q_{1.5}$ (cfs)	Q_p (cfs)	Q_{bkf} (% of time)	Q_{ma} (% of time)	$Q_{1.5}$ (% of time)	Q_{bkf}/Q_{ma}	$Q_{bkf}/Q_{1.5}$ (%)	Q_p/Q_{ma}
Blackwater Creek near Cassia	81-07	HL	N	WFC	55	58	173	808	32	31	6.9	1.0**	32	14
Blues Creek near Gainesville	85-94	FW	N	UP	36	3.5	88	147	0.8	25	0.2	10	41	42
Bowlegs Creek near Ft Meade	65-68/92-07	FW	S	WF	35	32	288	1450	21	23	1.2	1.1**	12	45
Carter Creek near Sebring	55-67/92-07	HL	S	UP	42	24.4	109	352	14	34	1.7	1.7	39	14
Catfish Creek near Lake Wales	48-07	HL	S	WFC	37	41	60	235	50	43	17	0.9**	62	5.8
Fisheating Creek at Palmdale	32-07	FW	S	WFC	75	256	1934	30500	41	24	2.2	0.3**	4	119
Hickory Creek near Ona	82-84*	FW	S	WF	21	5.3	116	490	6.5	17	0.5	4.0	18	93
Horse Creek near Arcadia	51-07	FW	S	WF	280	196	1366	10700	18	24	2.3	1.4	20	55
Little Haw Creek near Seville	52-06	FW	N	WFC	114	86	341	1810	24	29	5.5	1.3	33	21
Livingston Creek near Frostproof	92-07	HL	S	UP	106	64	182	700	18	32	7.3	1.7	58	11
Lochloosa Creek at Grove Park	96-05*	FW	N	WFC	13	21	52	3238	23	18	1.0	0.6**	25	157
Manatee River near Myakka Head	67-07	FW	S	UP	116	74	1341	6440	14	20	0.4	1.6	9	87
Moses Creek near Moultrie	00-02*	FW	N	WFC	43	8.3	132	861	4.3	14	1.0	5.2	33	103
Rice Creek near Springside	74-04	FW	N	WFC	25	42	513	2000	33	23	0.6	0.6**	5	47
Santa Fe River near Graham	57-98	FW	N	UP	118	52	293	1870	12	28	2.6	2.3	40	36
Shiloh Run near Alachua	84-87*	FW	N	UP	11	0.3	10	5.5	IR	28	IR	38	110	19
Tiger Creek near Babson Park	92-07	HL	S	UP	64	43	115	338	16	35	3.9	1.5	56	7.8
Minimum					11	0.3	10	5.5	0.8	14	0.2	0.3	3.9	5.8
Maximum					280	256	1934	30500	50	43	17	38	110	157
Mean					70	59	418	3644	21	26	3.4	4.3	35	52
Median					43	42	173	861	18	25	1.9	1.5	33	42

Notes: WY = Water year; cfs = cubic feet per second; Qbkf = Bankfull discharge; Qma = Mean annual discharge; Q1.5 = Discharge that occurs on average once every 1.5 years; Qp = Peak discharge; IR = Insufficient gage record; FW = Flatwoods physiography; HL = Highlands physiography; N = Northern peninsula geography; S = Southern peninsula geography; WF = Wetland floodplain; WFC = Wetland floodplain dominated by cypress; UP = Upland floodplain; * Period of gage record insufficient (less than 10 years) for proper gage analysis, but rough approximations are presented; ** Bankfull discharge approximately equal to or less the mean annual discharge (unexpected result)

Table 4-2. Reference reach survey data used in penisular Florida regional curve development and analysis

	Data Subsets			Independent Variables		Bankfull Discharge		Bankfull Channel Geometry			Range of variability within bankfull indicator among cross-sections			
Site name	Physio-graphy	Geo-graphy	Flood-plain type	Drainage area (sq mi)	Valley slope (%)	Bankfull discharge (cfs)	Return interval (yrs)	Bankfull area (sq ft)	Bankfull width (ft)	Bankfull mean depth (ft)	Bankfull indicator	Bankfull area (sq ft)	Bankfull width (ft)	Bankfull mean depth (ft)
Alexander Springs Creek tributary 2	HL	N	UP	1.6	1.042	--	--	6.82	6.63	1.06	I	5.08	3.55	1.08
Blackwater Creek near Cassia	HL	N	WFC	126	0.020	55	1.05	101.61	37.07	2.75	F	23.39	22.08	0.74
Blues Creek near Gainesville	FW	N	UP	2.6	0.206	36	1.07	12.77	7.67	1.67	I	4.24	3.73	0.69
Bowlegs Creek near Ft Meade	FW	S	WF	47.2	0.050	35	< 1.01	42.66	22.90	1.87	F	27.38	21.46	0.54
Carter Creek near Sebring	HL	S	UP	38.8	0.237	42	< 1.01	26.62	16.06	1.66	I	53.11	16.49	1.08
Catfish Creek near Lake Wales	HL	S	WFC	58.9	0.050	37	1.11	51.25	43.22	1.19	F	35.61	48.45	0.58
Coons Bay Branch	FW	S	WF	0.5	0.348	--	--	6.92	6.57	1.06	F	5.19	3.29	0.39
Cow Creek	FW	N	WFC	5.3	0.080	--	--	18.05	13.87	1.31	F	18.10	5.84	0.81
Cypress Slash tributary	HL	S	UP	0.5	1.042	--	--	1.25	4.54	0.27	I	2.03	1.61	0.30
East Fork Manatee River tributary	FW	S	UP	0.2	0.313	--	--	5.01	5.18	1.00	I	3.90	4.36	0.64
Fisheating Creek at Palmdale	FW	S	WFC	311	0.029	75	< 1.01	62.53	37.64	1.67	F	84.87	20.80	1.59
Gold Head Branch	HL	N	UP	1.8	1.316	--	--	8.04	5.81	1.40	I	3.55	5.22	0.45
Hammock Branch	HL	N	WF	3.0	0.167	--	--	15.91	10.95	1.46	F	25.74	7.11	1.75
Hickory Creek near Ona	FW	S	WF	3.75	0.116	21	< 1.01	8.92	10.33	0.85	F	19.13	22.84	0.42
Hillsborough River tributary	FW	S	WFC	0.7	0.260	--	--	5.10	8.11	0.63	F	13.53	6.53	0.70
Horse Creek near Arcadia	FW	S	WF	218	0.043	280	< 1.01	87.26	33.23	2.61	F	187.07	27.32	2.97
Jack Creek	HL	S	WF	5.2	0.286	--	--	7.00	7.88	0.89	F	8.90	3.00	0.60
Jumping Gully	HL	N	UP	4.6	1.111	--	--	3.58	4.19	0.87	I	4.37	1.63	0.66
Lake June-In-Winter tributary	FW	S	UP	0.4	0.781	--	--	3.69	5.32	0.66	I	5.23	3.69	0.61
Little Haw Creek near Seville	FW	N	WFC	93	0.061	114	1.05	83.85	31.34	2.69	F	36.75	10.79	1.29
Livingston Creek near Frostproof	HL	S	UP	120	0.064	106	1.14	44.69	27.51	1.73	I	69.90	19.78	1.53
Livingston Creek tributary	HL	S	UP	0.4	0.250	--	--	3.32	4.10	0.81	I	1.22	0.69	0.15
Lochloosa Creek at Grove Park	FW	N	WFC	7.4	0.116	13	< 1.01	15.73	15.58	1.02	F	14.14	4.78	0.62
Lowry Lake tributary	HL	N	UP	0.25	0.625	--	--	3.65	4.22	0.86	I	2.02	2.63	0.28
Manatee River near Myakka Head	FW	S	UP	65.3	0.116	116	< 1.01	60.05	24.52	2.45	I	59.25	15.02	0.92
Manatee River tributary	FW	S	UP	0.3	1.163	--	--	8.24	5.39	1.61	I	8.03	4.71	1.03
Morgan Hole Creek	FW	S	UP	9.4	0.091	--	--	14.21	9.61	1.50	I	10.82	7.29	0.56
Moses Creek near Moultrie	FW	N	WFC	7.4	0.159	43	1.11	31.50	14.59	2.16	F	37.85	6.13	1.77
Myakka River tributary 1	FW	S	UP	2.6	0.091	--	--	3.60	9.74	0.37	I	7.86	6.36	0.36
Myakka River tributary 2	FW	S	UP	1.7	0.129	--	--	1.88	4.93	0.39	I	2.63	3.39	0.17
Nine Mile Creek	HL	N	WF	16	0.488	--	--	10.28	9.19	1.12	F	6.27	4.59	0.41
Rice Creek near Springside	FW	N	WFC	43.2	0.041	25	< 1.01	31.97	20.47	1.60	F	30.79	8.98	1.15
Santa Fe River near Graham	FW	N	UP	94.9	0.058	118	1.10	51.98	17.64	3.02	I	35.43	11.22	1.13
Shiloh Run near Alachua	FW	N	UP	0.32	2.000	11	1.44	3.04	5.18	0.59	I	4.23	5.01	0.22
Snell Creek	HL	S	WF	1.7	0.167	--	--	22.69	17.80	1.38	F	14.76	13.61	0.61
South Fork Black Creek	HL	N	WF	25.5	0.110	--	--	45.09	17.41	2.59	F	23.81	11.10	0.61
Spoil Bank tributary (Highlands)	FW	S	UP	8.6	0.313	--	--	14.11	14.19	1.03	I	10.75	9.33	0.55
Ten Mile Creek	FW	N	WFC	25	0.130	--	--	26.40	15.51	1.71	F	23.27	8.33	0.51
Tiger Creek near Babson Park	HL	S	UP	52.8	0.081	64	1.07	65.89	33.91	1.92	I	74.41	49.99	0.68
Tiger Creek tributary	HL	S	WF	0.9	0.139	--	--	7.26	10.13	0.80	F	8.00	17.43	0.57
Triple Creek unnamed tributary 1	HL	S	WF	1.7	0.532	--	--	9.02	8.00	1.11	F	10.76	5.00	0.64
Triple Creek unnamed tributary 2	FW	S	UP	0.2	0.885	--	--	2.69	4.87	0.54	I	9.32	3.50	1.03
Tuscawilla Lake tributary	HL	N	UP	0.3	2.273	--	--	3.07	3.09	1.00	I	1.46	1.64	0.73
Tyson Creek	FW	S	WFC	20.5	0.054	--	--	20.23	19.02	1.06	F	32.92	14.01	0.63
Unnamed Lower Wekiva tributary	HL	N	WF	0.4	0.769	--	--	8.04	8.30	0.95	F	13.52	6.24	0.76

Notes: FW = Flatwoods physiography; HL = Highlands physiography; N = Northern peninsula geography; S = Southern peninsula geography; WF = Wetland floodplain; WFC = Wetland floodplain dominated by cypress; UP = Upland floodplain; cfs = cubic feet per second; ft = feet; sq ft = square feet; yrs = years; sq mi = square miles; -- = Ungaged site; IR = Insufficient gage record; F = Flat floodplain bankfull indicator; I = Inflection bankfull indicator; N/A = Not applicable

Table 4-3. Regression equations for various discharges against drainage area by entire data set and by subsets representing physiography, geography, and floodplain types

	Bankfull discharge (cfs)			Mean annual discharge (cfs)			1.5-year discharge (cfs)		
	Equation	R^2	n	Equation	R^2	n	Equation	R^2	n
Entire data set	$Q_{bkf} = 14.26\ A_w^{0.36}$	0.60	17	$Q_{ma} = 1.36\ A_w^{0.88}$	0.95	17	$Q_{1.5} = 27.85\ A_w^{0.57}$	0.60	17
Physiography:									
Flatwoods	$Q_{bkf\text{-}FW} = 14.47\ A_w^{0.38}$	0.64	12	$Q_{ma\text{-}FW} = 1.35\ A_w^{0.92}$	0.96	12	$Q_{1.5\text{-}FW} = 28.65\ A_w^{0.69}$	0.86	12
Highlands	$Q_{bkf\text{-}HL} = 6.97\ A_w^{0.49}$	0.39	5	$Q_{ma\text{-}HL} = 2.55\ A_w^{0.67}$	0.86	5	$Q_{1.5\text{-}HL} = 10.20\ A_w^{0.58}$	0.45	5
Geography:									
Northern peninsula	$Q_{bkf\text{-}NP} = 15.98\ A_w^{0.32}$	0.58	8	$Q_{ma\text{-}NP} = 1.37\ A_w^{0.88}$	0.94	8	$Q_{1.5\text{-}NP} = 29.79\ A_w^{0.53}$	0.78	8
Southern peninsula	$Q_{bkf\text{-}SP} = 9.42\ A_w^{0.47}$	0.57	9	$Q_{ma\text{-}SP} = 1.30\ A_w^{0.88}$	0.95	9	$Q_{1.5\text{-}SP} = 22.27\ A_w^{0.63}$	0.37	9
Floodplain Types:									
Wetland	$Q_{bkf\text{-}WF} = 9.13\ A_w^{0.44}$	0.55	10	$Q_{ma\text{-}WF} = 2.16\ A_w^{0.78}$	0.92	10	$Q_{1.5\text{-}WF} = 28.49\ A_w^{0.58}$	0.52	10
Upland	$Q_{bkf\text{-}UP} = 18.64\ A_w^{0.36}$	0.88	7	$Q_{ma\text{-}UP} = 1.04\ A_w^{0.91}$	0.98	7	$Q_{1.5\text{-}UP} = 27.24\ A_w^{0.53}$	0.65	7
Cypress-dominated	$Q_{bkf\text{-}CD} = 10.94\ A_w^{0.35}$	0.48	7	$Q_{ma\text{-}CD} = 2.87\ A_w^{0.72}$	0.87	7	$Q_{1.5\text{-}CD} = 19.88\ A_w^{0.62}$	0.48	7
Non-cypress-dominated	$Q_{bkf\text{-}NC} = 15.49\ A_w^{0.41}$	0.79	10	$Q_{ma\text{-}NC} = 1.12\ A_w^{0.91}$	0.98	10	$Q_{1.5\text{-}NC} = 30.49\ A_w^{0.56}$	0.68	10

Notes: Q_{bkf} = Bankfull discharge; Q_{ma} = Mean annual discharge; $Q_{1.5}$ = Discharge that occurs on average every 1.5 years; A_w = Watershed drainage area (sq mi); FW = Flatwoods physiography; HL = Highlands physiography; NP = Northern peninsula geography; SP = Southern peninsula geography; WF = Wetland floodplain; UP = Upland floodplain; CD = Cypress-dominated floodplain; NC = Non-cypress-dominated floodplain

Table 4-4. Regression equations for bankfull channel geometry against drainage area by entire data set and by subsets representing physiography, geography, and floodplain types

	Bankfull Area (sq ft)			Bankfull Width (ft)			Bankfull Mean Depth (ft)		
	Equation	R^2	n	Equation	R^2	n	Equation	R^2	n
Entire data set	$A_{bkf} = 6.05\ A_w^{0.47}$	0.78	45	$W_{bkf} = 6.87\ A_w^{0.30}$	0.81	45	$D_{bkf} = 0.89\ A_w^{0.18}$	0.48	45
Physiography:									
Flatwoods	$A_{bkf\text{-}FW} = 6.27\ A_w^{0.46}$	0.82	25	$W_{bkf\text{-}FW} = 7.28\ A_w^{0.28}$	0.92	25	$D_{bkf\text{-}FW} = 0.86\ A_w^{0.18}$	0.49	25
Highlands	$A_{bkf\text{-}HL} = 5.80\ A_w^{0.49}$	0.74	20	$W_{bkf\text{-}HL} = 6.43\ A_w^{0.33}$	0.72	20	$D_{bkf\text{-}HL} = 0.91\ A_w^{0.17}$	0.48	20
Geography:									
Northern peninsula	$A_{bkf\text{-}NP} = 6.41\ A_w^{0.49}$	0.80	19	$W_{bkf\text{-}NP} = 6.26\ A_w^{0.30}$	0.76	19	$D_{bkf\text{-}NP} = 1.03\ A_w^{0.19}$	0.67	19
Southern peninsula	$A_{bkf\text{-}SP} = 5.78\ A_w^{0.46}$	0.78	26	$W_{bkf\text{-}SP} = 7.32\ A_w^{0.30}$	0.85	26	$D_{bkf\text{-}SP} = 0.80\ A_w^{0.17}$	0.44	26
Floodplain Types:									
Wetland	$A_{bkf\text{-}WF} = 8.11\ A_w^{0.41}$	0.79	23	$W_{bkf\text{-}WF} = 8.61\ A_w^{0.26}$	0.77	23	$D_{bkf\text{-}WF} = 0.95\ A_w^{0.16}$	0.52	23
Upland	$A_{bkf\text{-}UP} = 5.13\ A_w^{0.47}$	0.75	22	$W_{bkf\text{-}UP} = 6.04\ A_w^{0.29}$	0.82	22	$D_{bkf\text{-}UP} = 0.85\ A_w^{0.18}$	0.41	22
Cypress-dominated	$A_{bkf\text{-}CD} = 7.29\ A_w^{0.46}$	0.84	11	$W_{bkf\text{-}CD} = 8.56\ A_w^{0.28}$	0.86	11	$D_{bkf\text{-}CD} = 0.85\ A_w^{0.18}$	0.47	11
Non-cypress-dominated	$A_{bkf\text{-}NC} = 5.90\ A_w^{0.45}$	0.73	34	$W_{bkf\text{-}NC} = 6.67\ A_w^{0.27}$	0.75	34	$D_{bkf\text{-}NC} = 0.89\ A_w^{0.18}$	0.45	34

Notes: A_{bkf} = Bankfull area; W_{bkf} = Bankfull width; D_{bkf} = Bankfull mean depth; A_w = Watershed drainage area; FW = Flatwoods physiography; HL = Highlands physiography; NP = Northern peninsula geography; SP = Southern peninsula geography; WF = Wetland floodplain; UP = Upland floodplain; CD = Cypress-dominated floodplain; NC = Non-cypress-dominated floodplain

Table 4-5. Comparison of bankfull discharge against drainage area regressions by physiography, geography, floodplain types, and Coastal Plain regions

	Slope			Intercept		
Effect	Estimate	R^2	P-value	Estimate (cfs)	R^2	P-value
Physiography:						
Flatwoods	0.38	0.64	0.85	14.47	0.64	0.52
Highlands	0.49	0.39		6.97	0.39	
Geography:						
Northern peninsula	0.32	0.58	0.46	15.98	0.58	0.95
Southern peninsula	0.47	0.57		9.42	0.57	
Floodplain Types:						
Wetland	0.44	0.55	0.40	9.13	0.55	0.55
Upland	0.36	0.88		18.63	0.88	
Cypress-dominated	0.35	0.48	0.74	10.94	0.48	0.05*
Non-cypress-dominated	0.41	0.79		15.49	0.79	
Coastal Plain Studies:						
Peninsular FL (Blanton, 2008)	0.36	0.60	Baseline	14.26	0.60	Baseline
North FL (Metcalf, 2004)	0.78	0.92	0.32	7.51	0.92	0.01*
Northwest FL (Metcalf, 2004)	0.71	0.95	0.88	27.48	0.95	<0.01*
AL (Metcalf, 2005)	0.94	0.93	0.08	10.95	0.93	0.02*
GA (Buck Engineering, 2004)	0.78	0.88	0.26	6.73	0.88	<0.01*
NC (Doll et al., 2003)	0.70	0.87	0.97	18.28	0.90	0.01*
NC (Sweet & Geratz, 2003)	0.71	0.85	0.89	9.32	0.92	<0.01*
VA & MD (Krstolic & Chaplin, 2007)	0.62	0.79	0.18	26.65	0.79	<0.01*

* Represents statistical significance ($p \leq 0.05$)

Table 4-6. Comparison of various discharge durations and ratios by physiography, geography, floodplain types, and Coastal Plain regions

	Q_{bkf} duration (% of time exceeded)		Q_{ma} duration (% of time exceeded)		$Q_{1.5}$ duration (% of time exceeded)		Q_p/Q_{ma}	
Effect	Average	P-value	Average	P-value	Average	P-value	Average	P-value
Physiography:								
Flatwoods	18	0.28	23	<0.01*	1.6	0.01*	69	0.01*
Highlands	26		35		7.4		11	
Geography:								
Northern peninsula	18	0.60	25	0.35	2.5	0.50	49	0.78
Southern peninsula	22		28		4.1		55	
Floodplain Types:								
Wetland	25	0.06	25	0.24	3.8	0.62	66	0.11
Upland	13		29		2.7		31	
Cypress-dominated	30	0.01*	26	0.86	4.9	0.23	67	0.25
Non-cypress-dominated	13		27		2.2		41	

Notes: Q_{bkf} = Bankfull discharge; Q_{ma} = Mean annual discharge; $Q_{1.5}$ = Discharge that occurs on average once every 1.5 years; Q_p = Peak discharge; * Represents statistical significance ($p \leq 0.05$)

Table 4-7. Comparison of bankfull area against drainage area regressions by physiography, geography, floodplain types, and Coastal Plain regions

	Slope			Intercept		
Effect	Estimate	R^2	P-value	Estimate (sq ft)	R^2	P-value
Physiography:						
Flatwoods	0.46	0.82	0.68	6.27	0.82	0.89
Highlands	0.48	0.74		5.80	0.74	
Geography:						
Northern peninsula	0.49	0.80	0.75	6.41	0.80	0.39
Southern peninsula	0.46	0.78		5.78	0.78	
Floodplain Types:						
Wetland	0.41	0.79	0.48	8.11	0.79	0.03*
Upland	0.47	0.75		5.13	0.75	
Cypress-dominated	0.46	0.84	0.99	7.29	0.84	0.39
Non-cypress-dominated	0.45	0.73		5.90	0.73	
Coastal Plain Studies:						
Peninsular FL (Blanton, 2008)	0.47	0.78	Baseline	6.05	0.78	Baseline
North FL (Metcalf, 2004)	0.70	0.98	0.96	6.40	0.98	0.02*
Northwest FL (Metcalf, 2004)	0.64	0.99	0.35	17.39	0.99	<0.01*
AL (Metcalf, 2005)	1.00	0.98	0.01*	4.36	0.98	0.88
GA (Buck Engineering, 2004)	0.72	0.96	0.63	5.92	0.96	<0.01*
NC (Doll et al., 2003)	0.66	0.88	0.47	14.33	0.88	<0.01*
NC (Sweet & Geratz, 2003)	0.71	0.96	0.79	9.57	0.96	0.08
VA & MD (Krstolic & Chaplin, 2007)	0.66	0.95	0.47	11.61	0.95	0.01*

* Represents statistical significance ($p \leq 0.05$)

Table 4-8. Comparision of bankfull width against drainage area regressions by physiography, geography, floodplain types, and Coastal Plain regions

	Slope			Intercept		
Effect	Estimate	R^2	P-value	Estimate (ft)	R^2	P-value
Physiography:						
Flatwoods	0.28	0.92	0.28	7.28	0.92	0.66
Highlands	0.33	0.72		6.43	0.72	
Geography:						
Northern peninsula	0.30	0.76	0.90	6.26	0.76	0.13
Southern peninsula	0.30	0.85		7.32	0.85	
Floodplain Types:						
Wetland	0.26	0.77	0.43	8.61	0.77	<0.01*
Upland	0.29	0.82		6.04	0.82	
Cypress-dominated	0.28	0.86	0.91	8.56	0.86	0.06
Non-cypress-dominated	0.27	0.75		6.67	0.75	
Coastal Plain Studies:						
Peninsular FL (Blanton, 2008)	0.30	0.81	Baseline	6.87	0.81	Baseline
North FL (Metcalf, 2004)	0.26	0.85	0.01*	9.82	0.85	0.06
Northwest FL (Metcalf, 2004)	0.38	0.96	0.77	10.81	0.96	0.01*
AL (Metcalf, 2005)	0.52	0.94	0.03*	5.64	0.94	0.39
GA (Buck Engineering, 2004)	0.35	0.84	0.55	8.58	0.84	0.15
NC (Doll et al., 2003)	0.36	0.87	0.89	10.97	0.87	<0.01*
NC (Sweet & Geratz, 2003)	0.39	0.95	0.40	9.39	0.95	0.03*
VA & MD (Krstolic & Chaplin, 2007)	0.38	0.89	0.74	10.55	0.89	<0.01*

* Represents statistical significance ($p \leq 0.05$)

Table 4-9. Comparison of bankfull mean depth against drainage area regressions by physiography, geography, floodplain types, and Coastal Plain regions

	Slope			Intercept		
Effect	Estimate	R^2	P-value	Estimate (ft)	R^2	P-value
Physiography:						
Flatwoods	0.18	0.49	0.77	0.86	0.49	0.83
Highlands	0.17	0.48		0.91	0.48	
Geography:						
Northern peninsula	0.19	0.67	0.69	1.03	0.67	0.02*
Southern peninsula	0.17	0.44		0.80	0.44	
Floodplain Types:						
Wetland	0.16	0.52	0.66	0.95	0.52	0.60
Upland	0.18	0.41		0.85	0.41	
Cypress-dominated	0.18	0.47	0.94	0.85	0.47	0.77
Non-cypress-dominated	0.18	0.45		0.89	0.45	
Coastal Plain Studies:						
Peninsular FL (Blanton, 2008)	0.18	0.48	Baseline	0.89	0.48	Baseline
North FL (Metcalf, 2004)	0.43	0.84	0.04*	0.66	0.84	0.16
Northwest FL (Metcalf, 2004)	0.26	0.86	0.16	1.61	0.86	<0.01*
AL (Metcalf, 2005)	0.48	0.96	0.10	0.77	0.96	0.40
GA (Buck Engineering, 2004)	0.38	0.83	0.25	0.68	0.83	<0.01*
NC (Doll et al., 2003)	0.30	0.74	0.46	1.29	0.74	0.01*
NC (Sweet & Geratz, 2003)	0.31	0.92	0.70	1.02	0.92	0.68
VA & MD (Krstolic & Chaplin, 2007)	0.28	0.87	0.26	1.10	0.87	0.65

* Represents statistical significance ($p \leq 0.05$)

Table 4-10. Summary of dimensionless ratios

	Data Subsets			Independent Variables		Dimensionless Ratios		
Site name	Physio-graphy	Geo-graphy	Flood-plain type	Drainage area (sq mi)	Valley slope (%)	Sinuosity	W/D	D_{max}/D
Alexander Springs Creek tributary 2	HL	N	UP	1.6	1.042	1.43	6.64	1.34
Blackwater Creek near Cassia	HL	N	WFC	126	0.020	1.07	13.50	1.60
Blues Creek near Gainesville	FW	N	UP	2.6	0.206	1.73	4.61	1.56
Bowlegs Creek near Ft Meade	FW	S	WF	47.2	0.050	1.44	12.28	1.94
Carter Creek near Sebring	HL	S	UP	38.8	0.237	1.57	9.70	1.62
Catfish Creek near Lake Wales	HL	S	WFC	58.9	0.050	1.47	36.49	1.63
Coons Bay Branch	FW	S	WF	0.5	0.348	1.25	6.22	1.45
Cow Creek	FW	N	WFC	5.3	0.080	1.33	10.63	1.60
Cypress Slash tributary	HL	S	UP	0.5	1.042	1.03	16.73	1.64
East Fork Manatee River tributary	FW	S	UP	0.2	0.313	1.23	5.53	1.60
Fisheating Creek at Palmdale	FW	S	WFC	311	0.029	1.42	22.63	1.73
Gold Head Branch	HL	N	UP	1.8	1.316	1.07	4.27	1.64
Hammock Branch	HL	N	WF	3.0	0.167	1.58	7.52	1.74
Hickory Creek near Ona	FW	S	WF	3.75	0.116	1.13	12.09	1.52
Hillsborough River tributary	FW	S	WFC	0.7	0.260	1.41	12.97	1.56
Horse Creek near Arcadia	FW	S	WF	218	0.043	1.09	12.82	1.58
Jack Creek	HL	S	WF	5.2	0.286	1.34	8.89	1.46
Jumping Gully	HL	N	UP	4.6	1.111	1.34	4.90	1.63
Lake June-In-Winter tributary	FW	S	UP	0.4	0.781	1.24	8.14	1.57
Little Haw Creek near Seville	FW	N	WFC	93	0.061	1.18	11.73	1.92
Livingston Creek near Frostproof	HL	S	UP	120	0.064	1.31	17.99	1.62
Livingston Creek tributary	HL	S	UP	0.4	0.250	1.01	5.07	1.74
Lochloosa Creek at Grove Park	FW	N	WFC	7.4	0.116	1.03	15.58	1.63
Lowry Lake tributary	HL	N	UP	0.25	0.625	1.09	4.89	1.83
Manatee River near Myakka Head	FW	S	UP	65.3	0.116	1.47	10.02	1.42
Manatee River tributary	FW	S	UP	0.3	1.163	1.29	3.73	1.79
Morgan Hole Creek	FW	S	UP	9.4	0.091	1.33	6.49	1.70
Moses Creek near Moultrie	FW	N	WFC	7.4	0.159	1.39	6.94	1.53
Myakka River tributary 1	FW	S	UP	2.6	0.091	1.03	26.31	1.54
Myakka River tributary 2	FW	S	UP	1.7	0.129	1.28	12.78	1.62
Nine Mile Creek	HL	N	WF	16	0.488	1.54	8.22	1.46
Rice Creek near Springside	FW	N	WFC	43.2	0.041	1.74	13.35	1.45
Santa Fe River near Graham	FW	N	UP	94.9	0.058	1.21	6.09	1.72
Shiloh Run near Alachua	FW	N	UP	0.32	2.000	1.10	9.08	1.72
Snell Creek	HL	S	WF	1.7	0.167	1.09	14.41	1.71
South Fork Black Creek	HL	N	WF	25.5	0.110	1.35	6.72	1.44
Spoil Bank tributary (Highlands)	FW	S	UP	8.6	0.313	2.08	14.88	2.00
Ten Mile Creek	FW	N	WFC	25	0.130	1.22	9.11	1.73
Tiger Creek near Babson Park	HL	S	UP	52.8	0.081	1.08	17.53	1.58
Tiger Creek tributary	HL	S	WF	0.9	0.139	1.37	15.32	1.76
Triple Creek unnamed tributary 1	HL	S	WF	1.7	0.532	1.47	7.57	1.39
Triple Creek unnamed tributary 2	FW	S	UP	0.2	0.885	1.77	9.28	1.53
Tuscawilla Lake tributary	HL	N	UP	0.3	2.273	1.20	3.11	1.56
Tyson Creek	FW	S	WFC	20.5	0.054	1.09	18.33	1.54
Unnamed Lower Wekiva tributary	HL	N	WF	0.4	0.769	1.58	8.72	1.58
Minimum				0.2	0.020	1.01	3.11	1.34
Maximum				311	2.273	2.08	36.49	2.00
Mean				31.8	0.409	1.32	11.11	1.62
Median				4.6	0.167	1.31	9.28	1.60

Notes: W/D = Width-to-depth ratio; D_{max}/D = Maximum depth-to-mean depth ratio; FW = Flatwoods physiography; HL = Highlands physiography; N = Northern peninsula geography; S = Southern peninsula geography; WF = Wetland floodplain; WFC = Wetland floodplain dominated by cypress; UP = Upland floodplain

Table 4-11. Comparison of various dimensionless ratios by physiography, geography, and floodplain types

	Sinuosity		W/D		D_{max}/D		Valley Slope	
Effect	Average	P-value	Average	P-value	Average	P-value	Average	P-value
Physiography:								
Flatwoods	1.34	0.56	11.26	0.86	1.64	0.36	0.31	0.14
Highlands	1.30		10.91		1.60		0.54	
Geography:								
Northern peninsula	1.33	0.93	8.19	0.01*	1.61	0.82	0.29	0.08
Southern peninsula	1.32		13.24		1.62		0.57	
Floodplain Types:								
Wetland	1.33	0.82	12.70	0.09	1.61	0.52	0.18	<0.01*
Upland	1.31		9.44		1.63		0.64	
Cypress-dominated	1.30	0.79	15.57	0.01*	1.63	0.83	0.09	0.02*
Non-cypress-dominated	1.33		9.66		1.62		0.51	

Notes: W/D = Width-to-depth ratio; D_{max}/D = Maximum depth-to-mean depth; * Represents statistical significance ($p \leq 0.05$)

Table 4-12. Regression equations for bankfull parameters against drainage area and bankfull return intervals for studies conducted throughout the southeastern United States Coastal Plain

	Funding	Bankfull Discharge (cfs)			Bankfull Area (sq ft)			Bankfull Width (ft)			Bankfull Mean Depth (ft)			Bankfull RI
Coastal Plain Region	Agency	Equation	R^2	n	Equation	R^2	n	Equation	R^2	n	Equation	R^2	n	(yrs)
Peninsular FL (Blanton, 2008)	FIPR	$Q_{bkf} = 14.26\ A_w^{0.36}$	0.60	17	$A_{bkf} = 6.05\ A_w^{0.47}$	0.78	45	$W_{bkf} = 6.87\ A_w^{0.30}$	0.81	45	$D_{bkf} = 0.89\ A_w^{0.18}$	0.48	45	<1 to 1.44
North FL (Metcalf, 2004)	FDOT	$Q_{bkf} = 7.54\ A_w^{0.77}$	0.92	12	$A_{bkf} = 6.1\ A_w^{0.71}$	0.98	12	$W_{bkf} = 9.2\ A_w^{0.28}$	0.85	12	$D_{bkf} = 0.67\ A_w^{0.43}$	0.84	12	1 to 1.4
Northwest FL (Metcalf, 2004)	FDOT	$Q_{bkf} = 27.7\ A_w^{0.71}$	0.95	14	$A_{bkf} = 17.1\ A_w^{0.64}$	0.99	14	$W_{bkf} = 10.4\ A_w^{0.39}$	0.96	14	$D_{bkf} = 1.64\ A_w^{0.25}$	0.86	14	1 to 1.4
AL (Metcalf, 2005)	NOAA	$Q_{bkf} = 10.94\ A_w^{0.94}$	0.93	8	$A_{bkf} = 4.35\ A_w^{0.99}$	0.98	8	$W_{bkf} = 5.67\ A_w^{0.52}$	0.94	8	$D_{bkf} = 0.78\ A_w^{0.47}$	0.96	8	1 to 1.1
GA (Buck Engineering, 2004)	GDOT	$Q_{bkf} = 6.80\ A_w^{0.78}$	0.88	20	$A_{bkf} = 5.93\ A_w^{0.72}$	0.96	20	$W_{bkf} = 8.59\ A_w^{0.34}$	0.84	20	$D_{bkf} = 0.68\ A_w^{0.38}$	0.83	20	1 to 1.3
NC (Doll et al., 2003)	Unknown	$Q_{bkf} = 16.56\ A_w^{0.72}$	0.90	16	$A_{bkf} = 14.52\ A_w^{0.66}$	0.88	16	$W_{bkf} = 10.97\ A_w^{0.36}$	0.87	16	$D_{bkf} = 1.29\ A_w^{0.30}$	0.74	16	1.0 to 1.25
NC (Sweet & Geratz, 2003)	Unknown	$Q_{bkf} = 8.79\ A_w^{0.76}$	0.92	22	$A_{bkf} = 9.43\ A_w^{0.74}$	0.96	22	$W_{bkf} = 9.64\ A_w^{0.38}$	0.95	22	$D_{bkf} = 0.98\ A_w^{0.36}$	0.92	22	0.11 to 0.31
VA & MD (Krstolic & Chaplin, 2007)	NOAA	$Q_{bkf} = 28.31\ A_w^{0.60}$	0.79	20	$A_{bkf} = 11.99\ A_w^{0.64}$	0.95	20	$W_{bkf} = 10.45\ A_w^{0.37}$	0.89	20	$D_{bkf} = 1.15\ A_w^{0.27}$	0.87	20	<1 to 2.1

Notes: FIPR = Florida Institute of Phosphate Research; UF = University of Florida; FDOT = Florida Department of Transportation; USFWS = United States Fish and Wildlife Service; NOAA = National Oceanic and Atmospheric Administration; GDOT = Georgia Department of Transportation; Q_{bkf} = Bankfull discharge; A_{bkf} = Bankfull area; W_{bkf} = Bankfull width; D_{bkf} = Bankfull mean depth; A_w = Drainage area; RI = Return interval; yrs = years

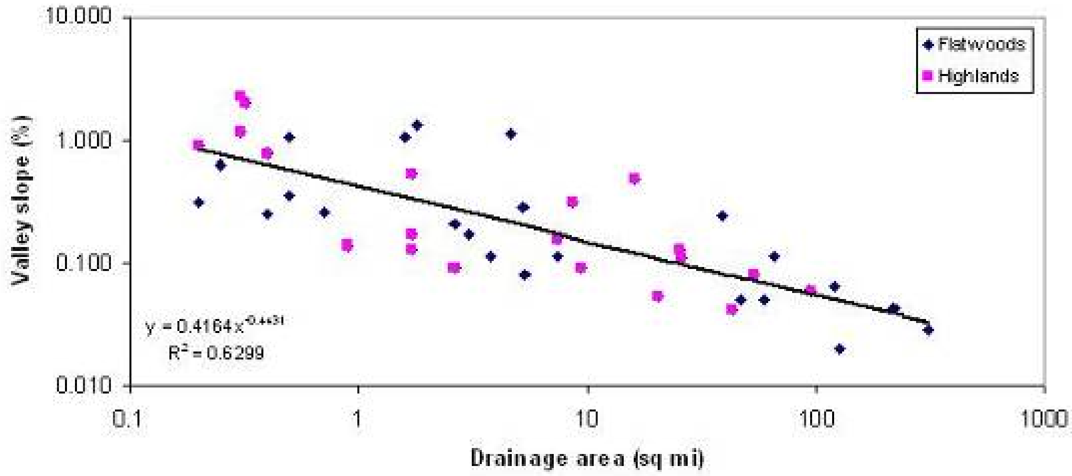


Figure 4-1. Drainage area against valley slope for study sites by physiography.

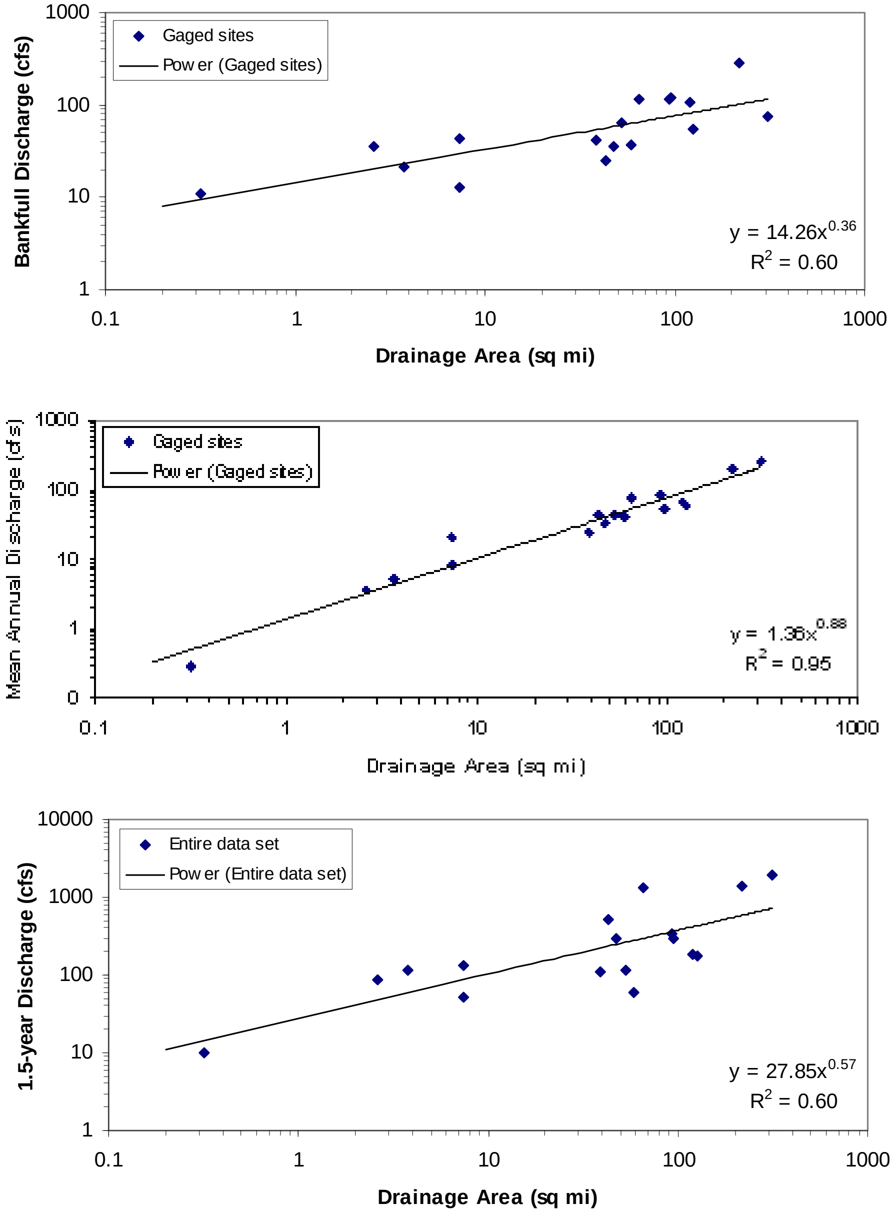


Figure 4-2. Discharge against drainage area regressions for gaged sites. A) Bankfull discharge. B) Mean annual discharge. C) 1.5-year discharge.

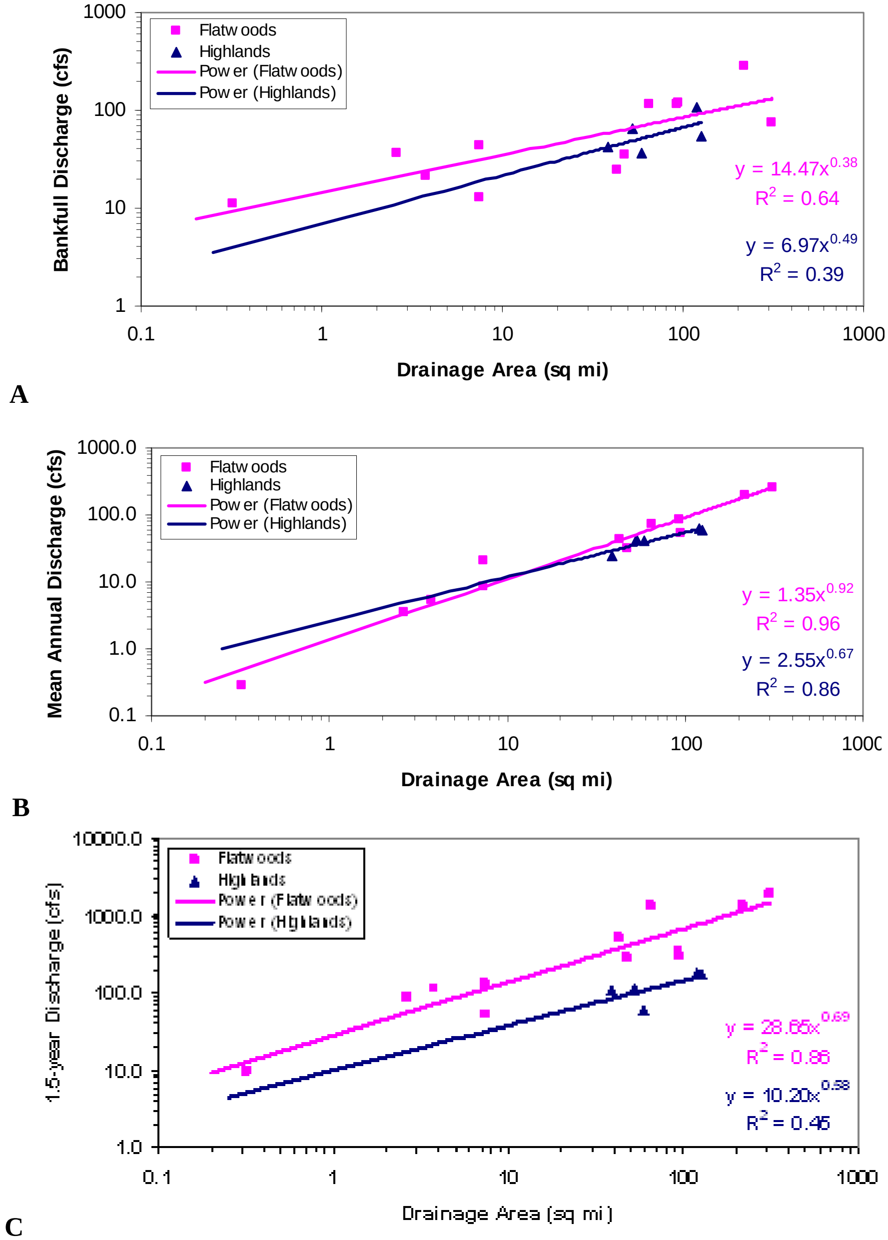
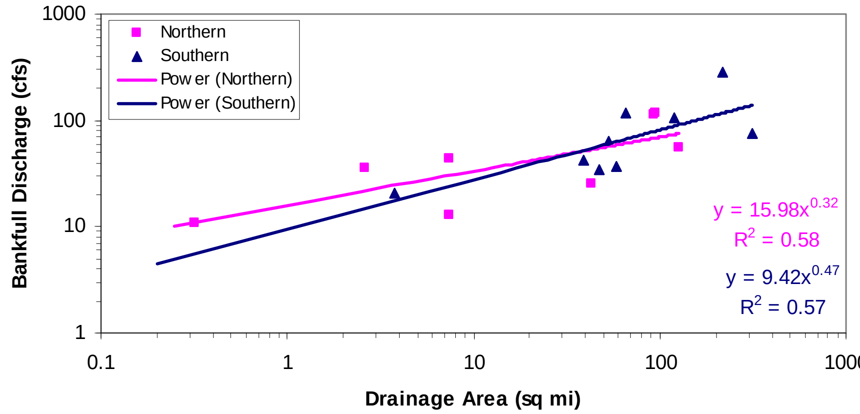
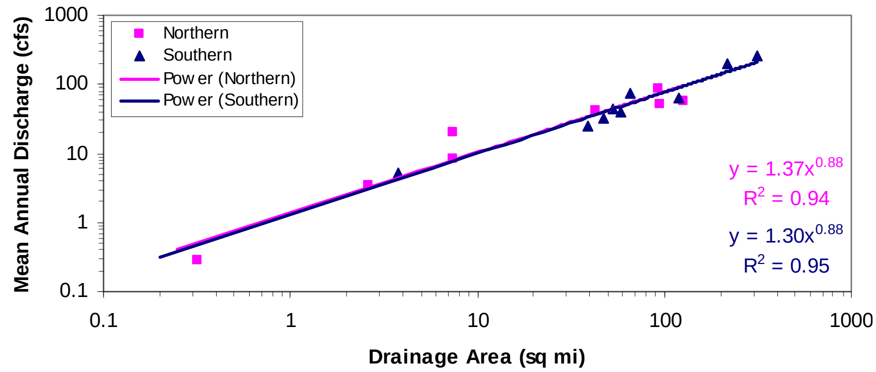


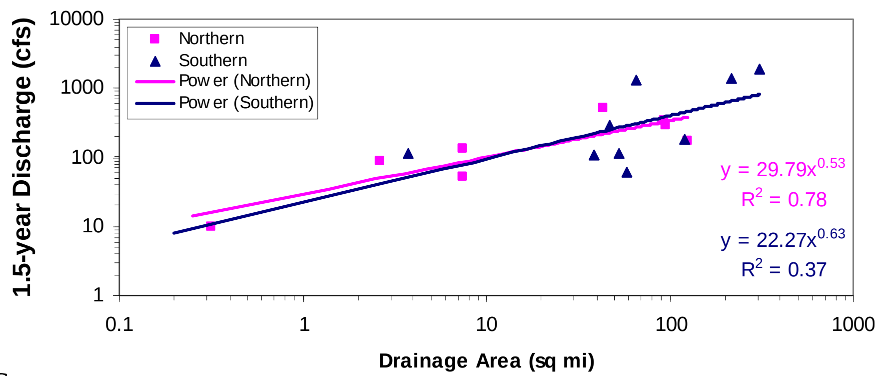
Figure 4-3. Discharge against drainage area regressions for gaged sites by physiography (flatwoods versus highlands). A) Bankfull discharge. B) Mean annual discharge. C) 1.5-year discharge.



A

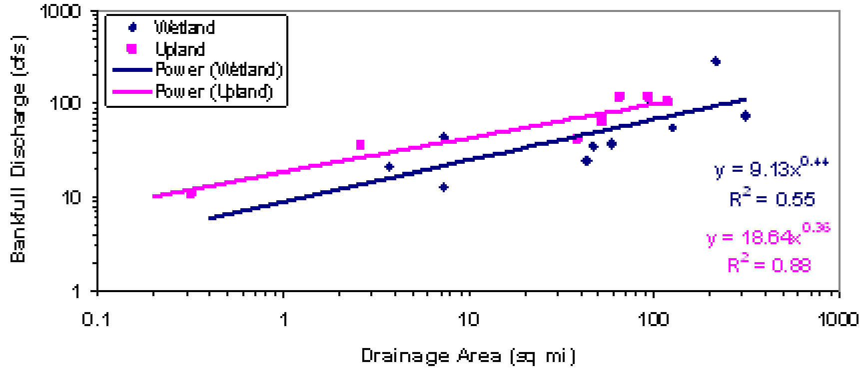


B

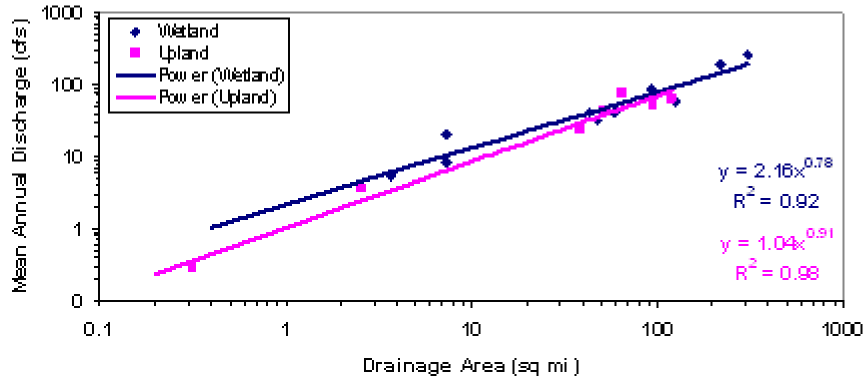


C

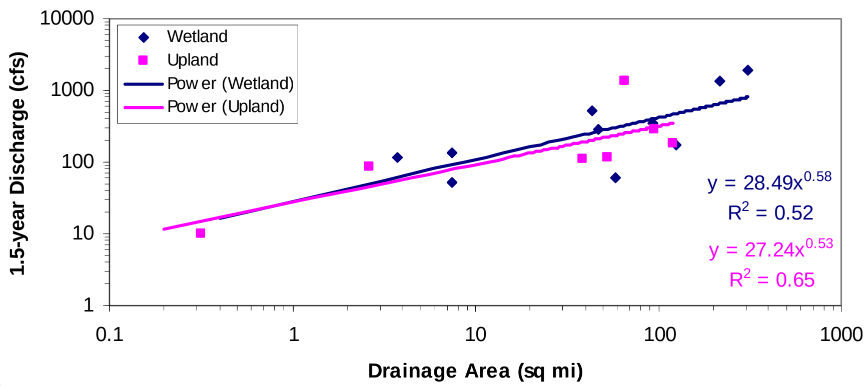
Figure 4-4. Discharge against drainage area regressions for gaged sites by geography (northern versus southern peninsula). A) Bankfull discharge. B) Mean annual discharge. C) 1.5-year discharge.



A



B



C

Figure 4-5. Discharge against drainage area regressions for gaged sites by floodplain type (wetland versus upland). A) Bankfull discharge. B) Mean annual discharge. C) 1.5-year discharge.

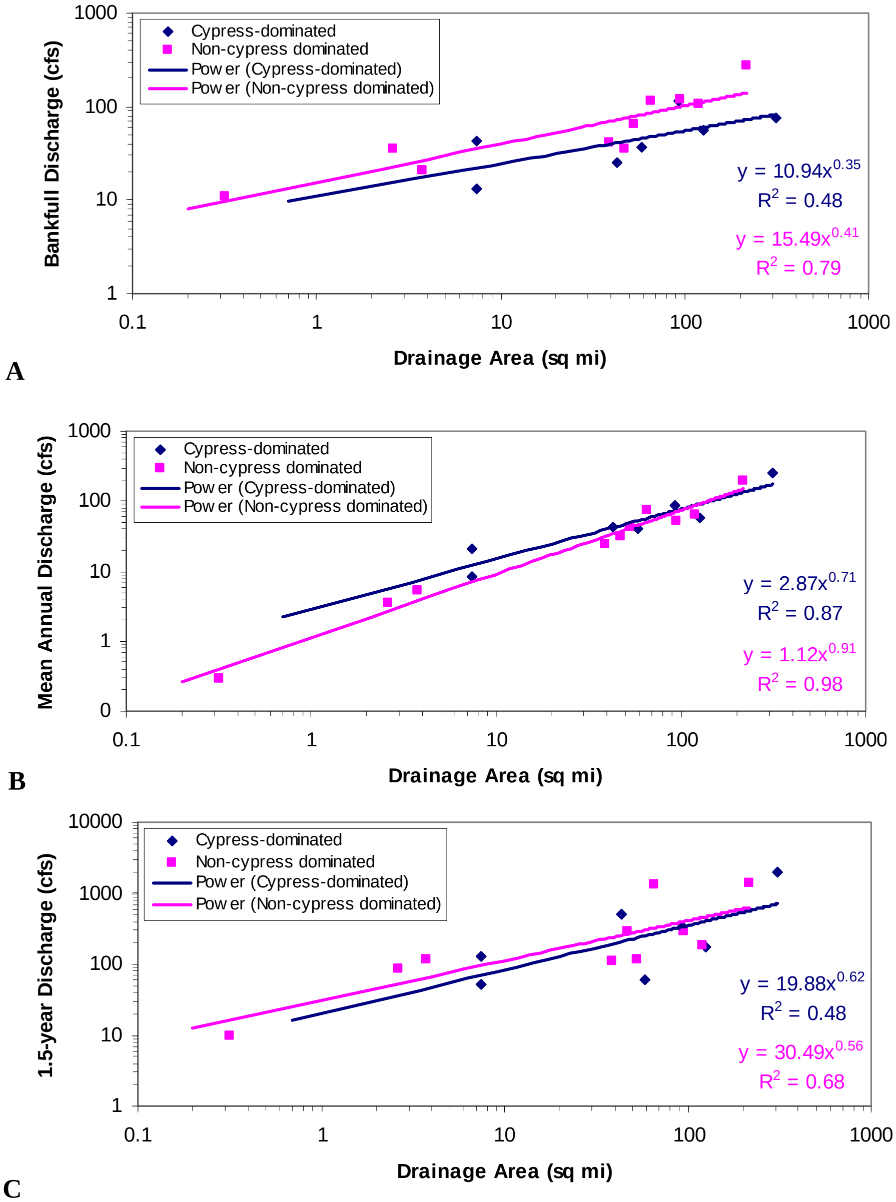


Figure 4-6. Discharge against drainage area regressions for gaged sites by floodplain type (cypress-dominated versus non-cypress-dominated). A) Bankfull discharge. B) Mean annual discharge. C) 1.5-year discharge.

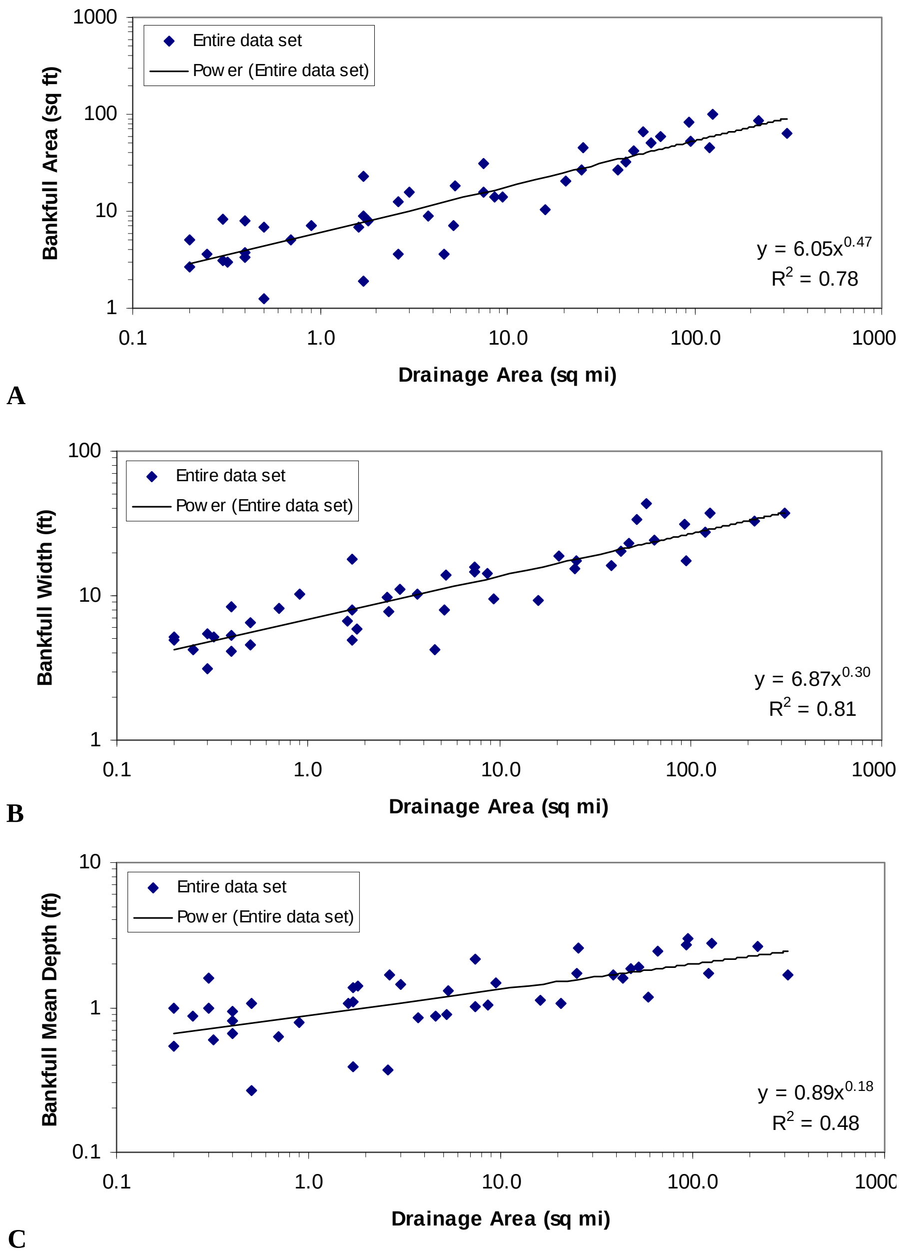


Figure 4-7. Channel geometry against drainage area regressions for all sites. A) Bankfull cross-sectional area. B) Bankfull width. C) Bankfull mean depth.

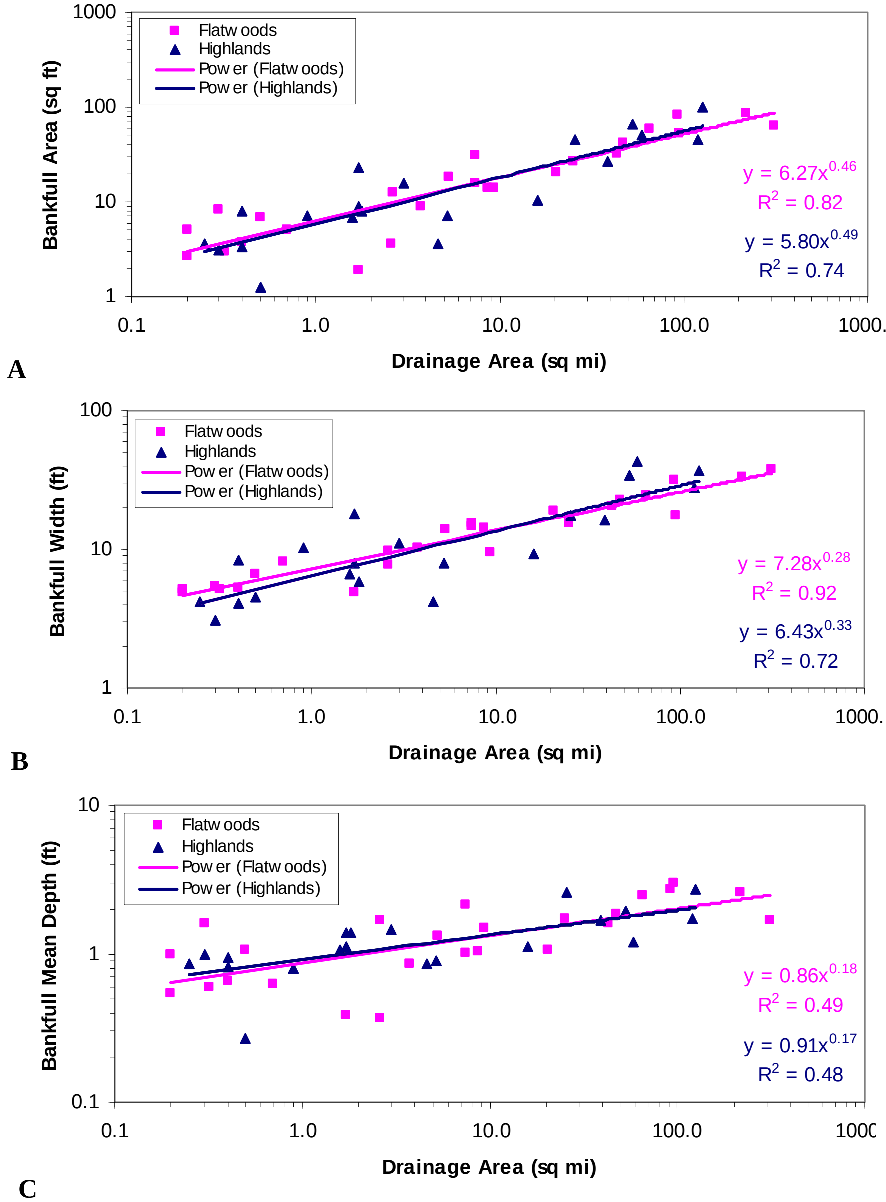


Figure 4-8. Channel geometry against drainage area regressions for all sites by physiography (flatwoods versus highlands). A) Bankfull cross-sectional area. B) Bankfull width. C) Bankfull mean depth.

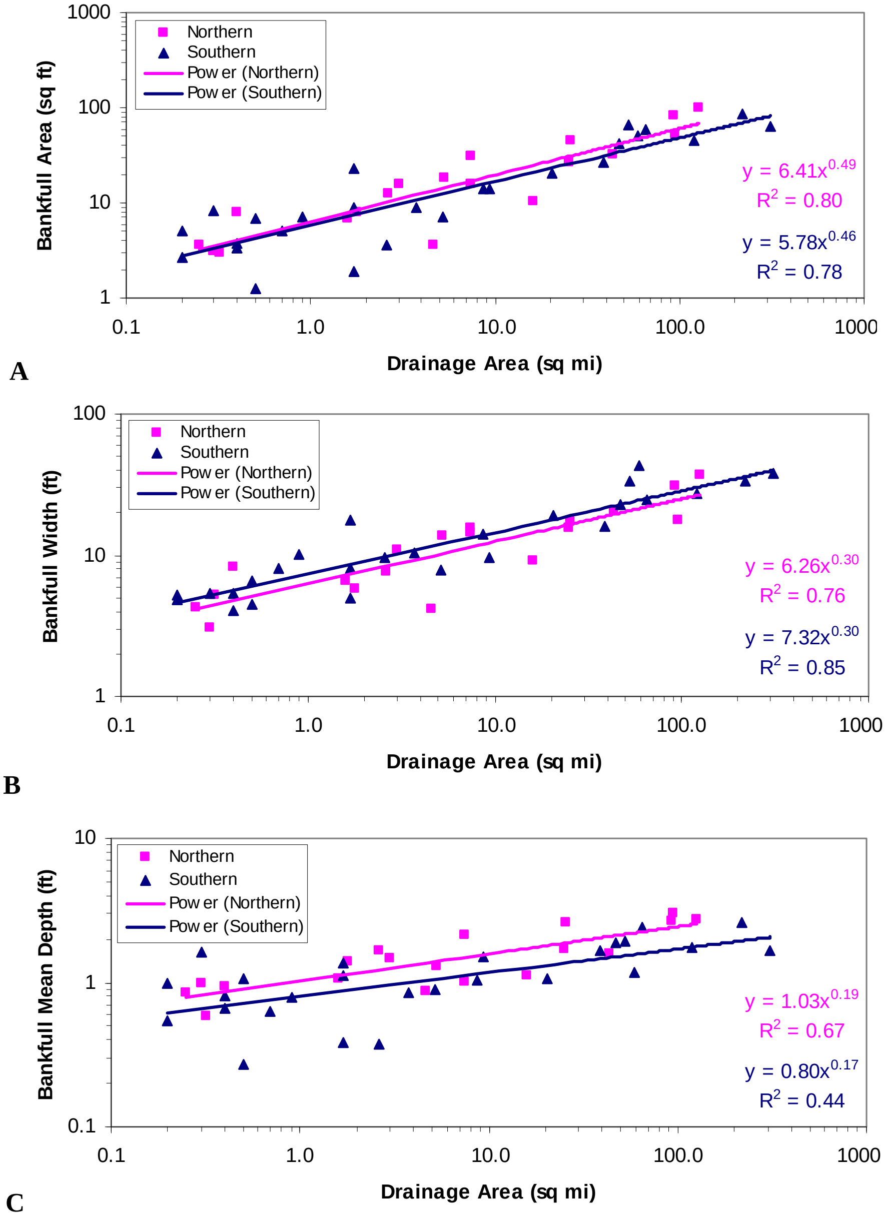


Figure 4-9. Channel geometry against drainage area regressions for all sites by geography (northern versus southern peninsula). A) Bankfull cross-sectional area. B) Bankfull width. C) Bankfull mean depth.

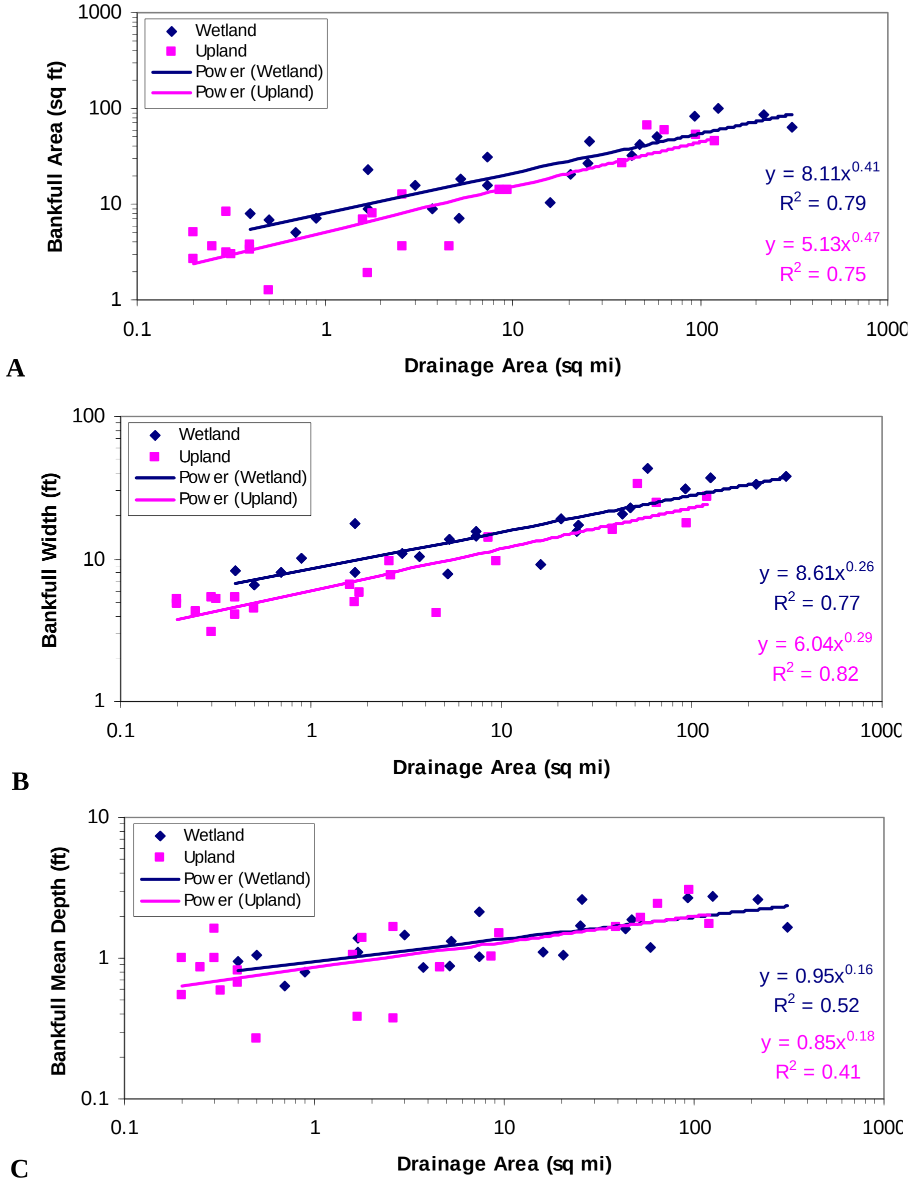
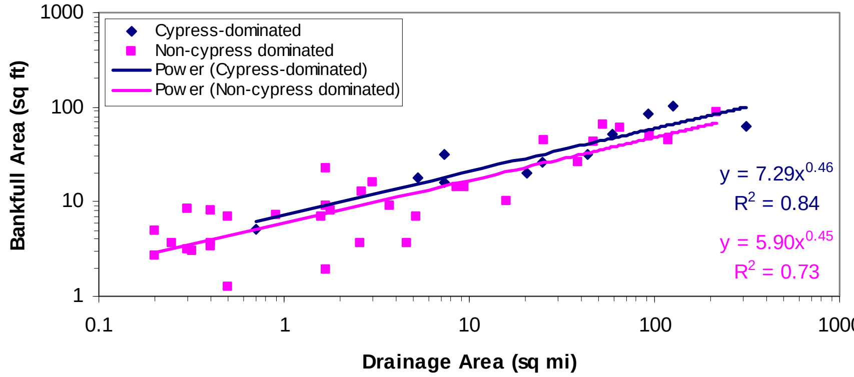
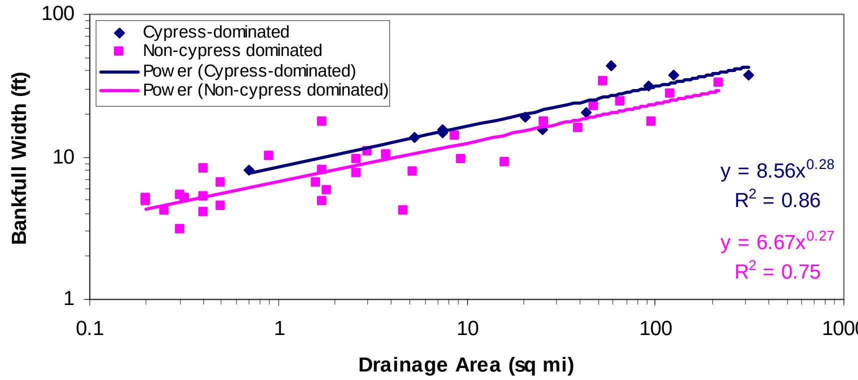


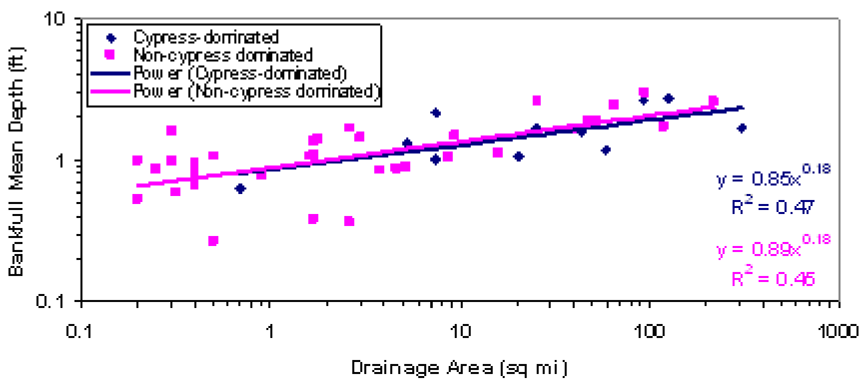
Figure 4-10. Channel geometry against drainage area regressions for all sites by floodplain type (wetland versus upland). A) Bankfull cross-sectional area. B) Bankfull width. C) Bankfull mean depth.



A



B



C

Figure 4-11. Channel geometry against drainage area regressions for all sites by floodplain type (cypress-dominated versus non-cypress-dominated). A) Bankfull cross-sectional area. B) Bankfull width. C) Bankfull mean depth.

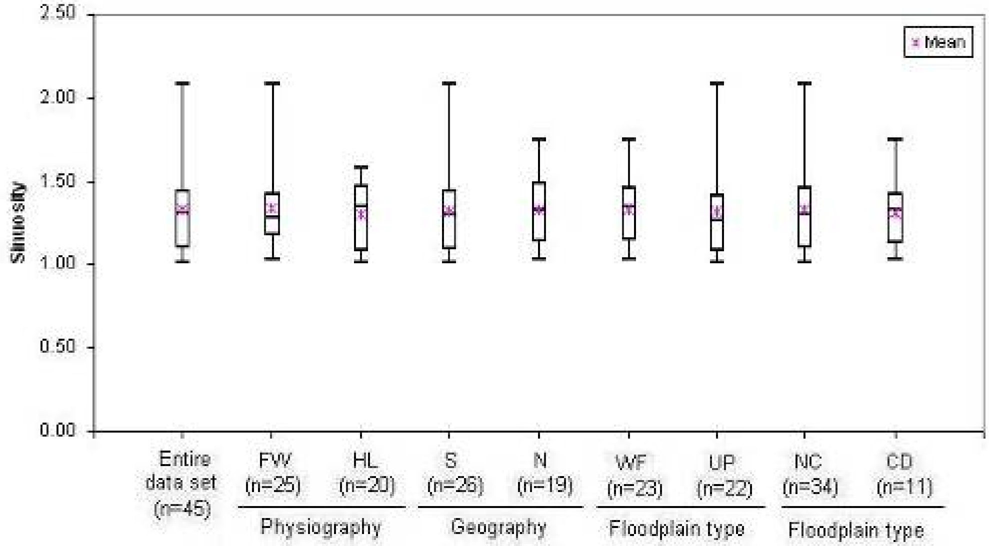


Figure 4-12. Boxplots of sinuosity by the entire data set and subsets representing physiography, geography, and floodplain types.

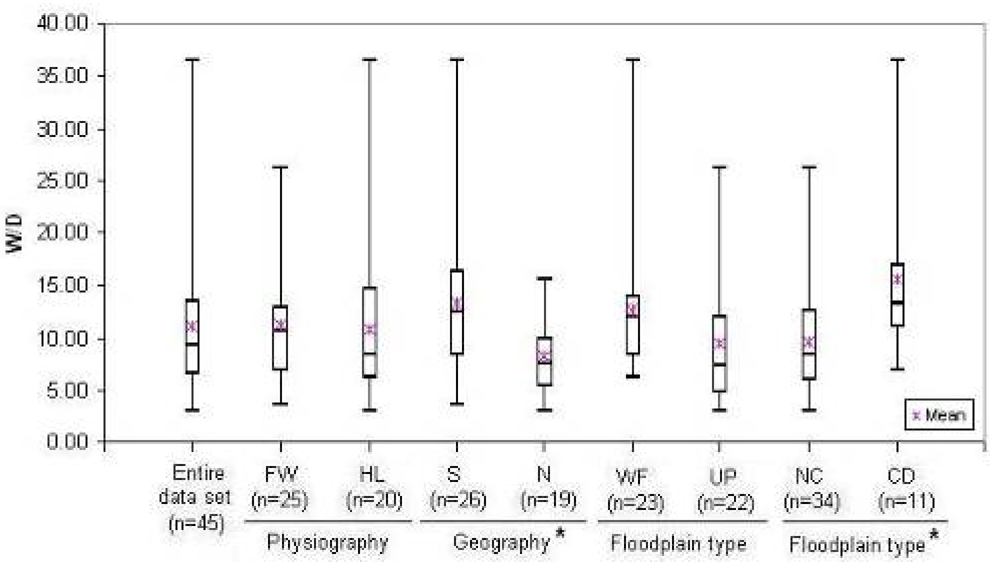


Figure 4-13. Boxplots of width-to-depth ratio by the entire data set and subsets representing physiography, geography, and floodplain types. * Indicates statistical significance ($p \leq 0.05$)

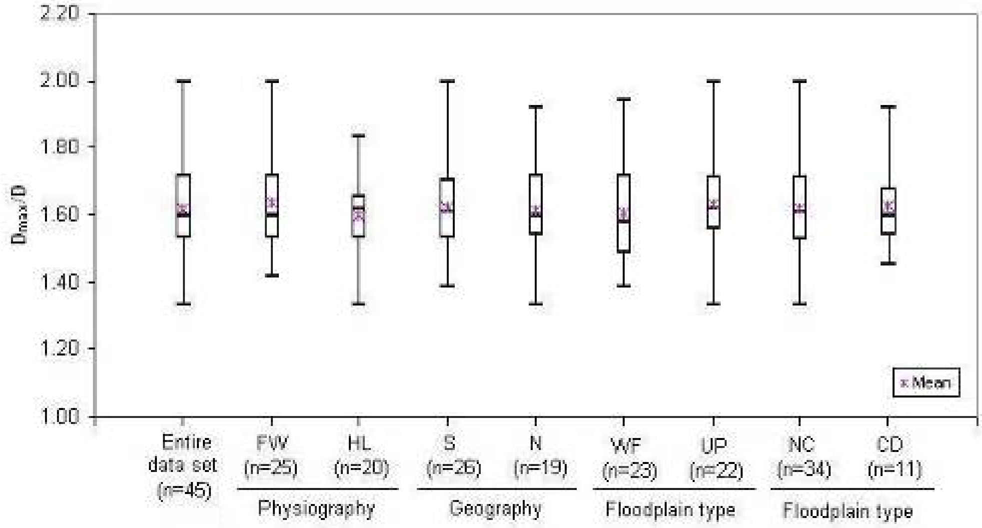


Figure 4-14. Boxplots of maximum depth-to-mean depth ratio by the entire data set and subsets representing physiography, geography, and floodplain types.

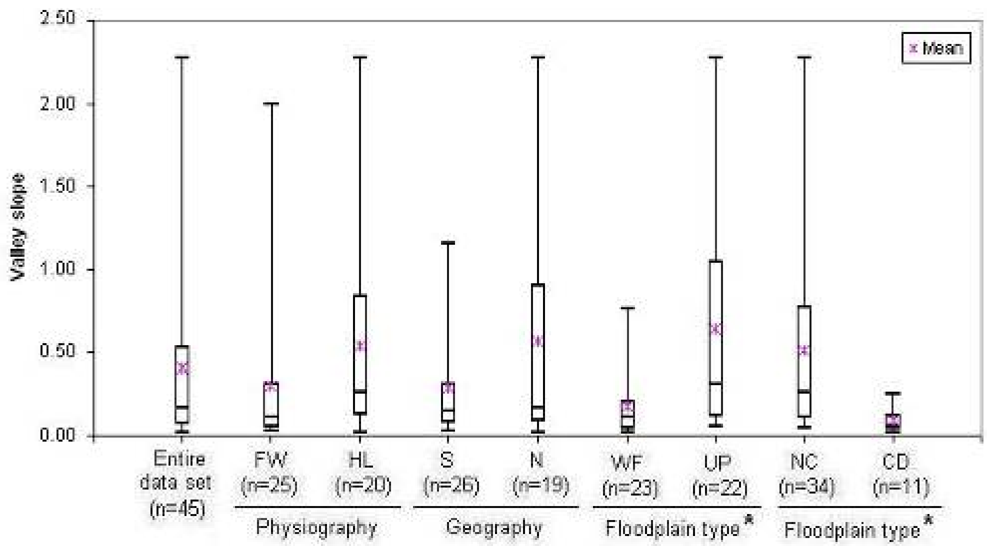


Figure 4-15. Boxplots of valley slope by the entire data set and subsets representing physiography, geography, and floodplain types. * Indicates statistical significance ($p \leq 0.05$)

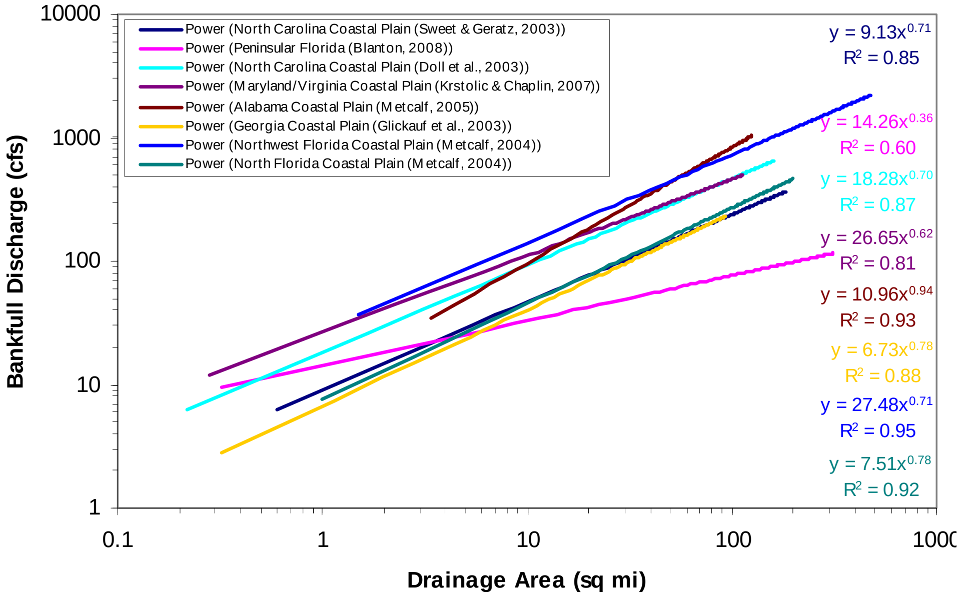


Figure 4-16. Bankfull discharge against drainage area regressions by Coastal Plain study.

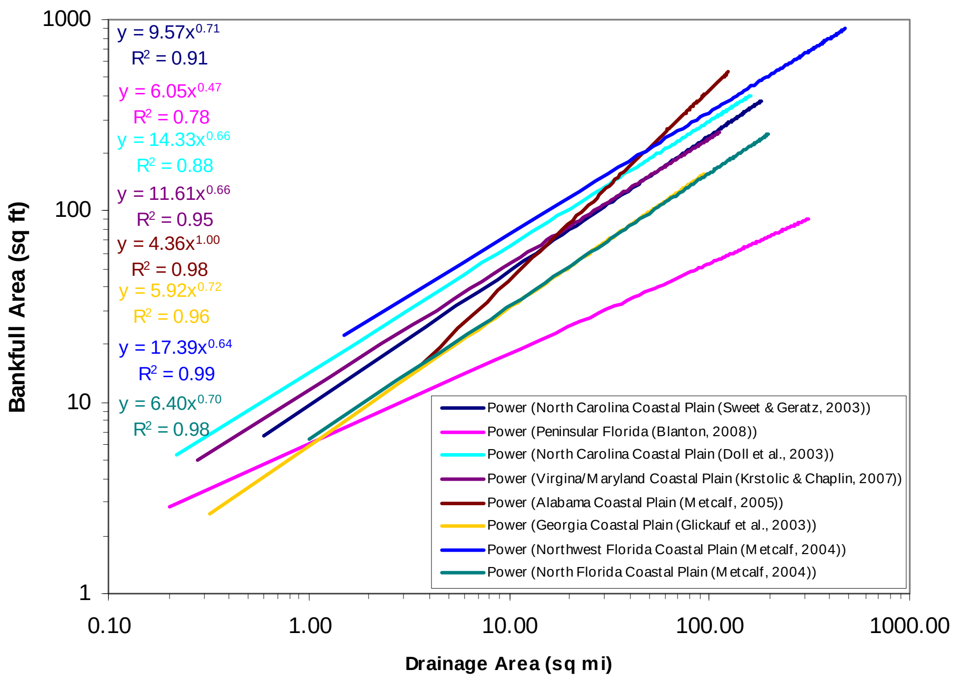


Figure 4-17. Bankfull area against drainage area regressions by Coastal Plain study.

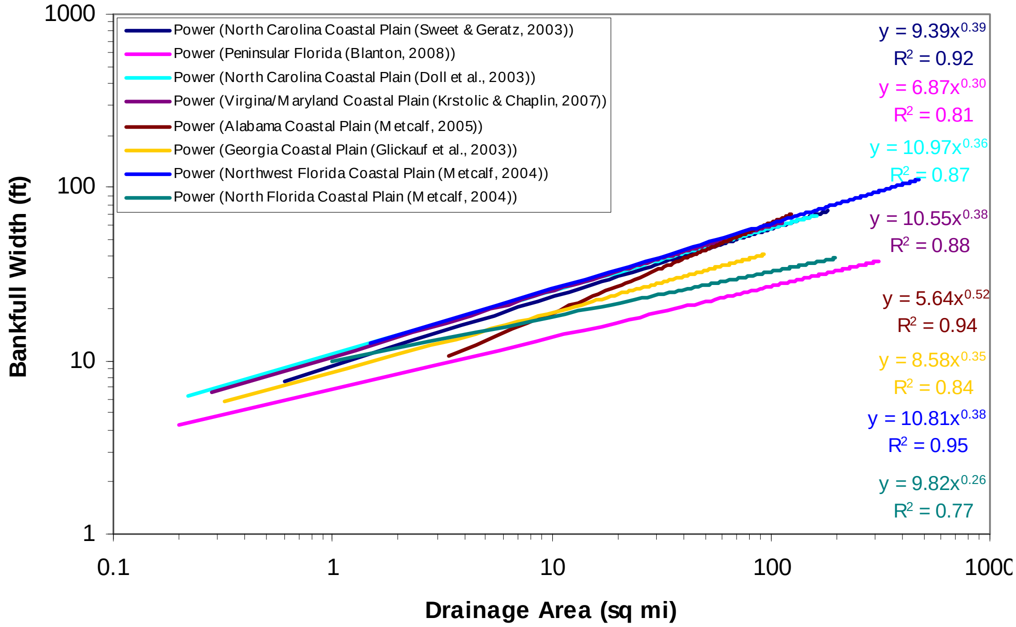


Figure 4-18. Bankfull width against drainage area regressions by Coastal Plain study.

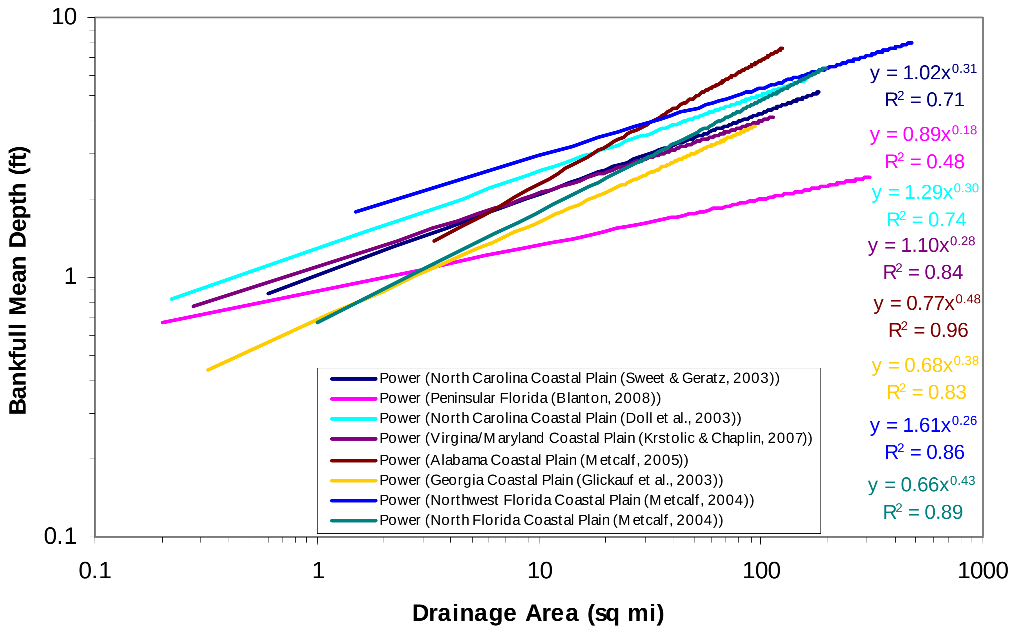


Figure 4-19. Bankfull depth against drainage area regressions by Coastal Plain study.

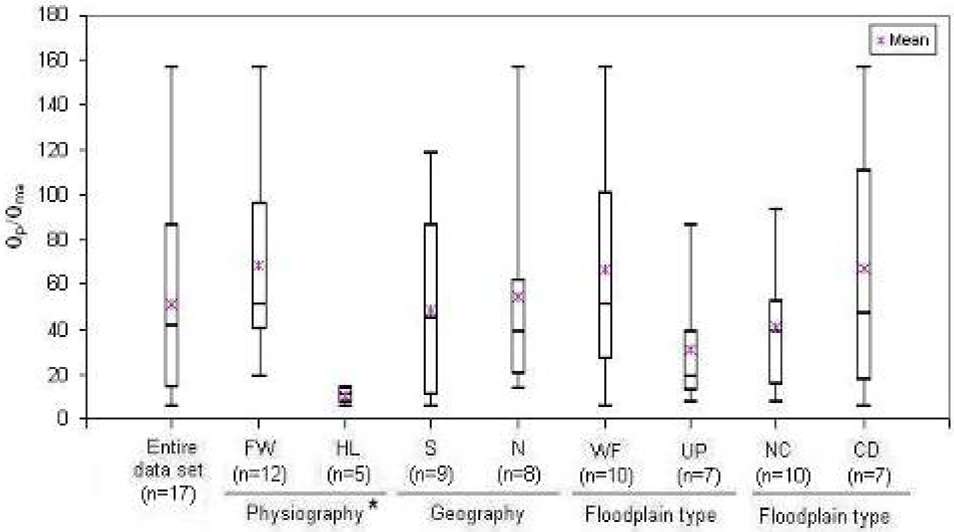


Figure 4-20. Boxplots of maximum discharge-to-mean annual discharge by the entire data set and subsets representing physiography, geography, and floodplain types. * Indicates statistical significance ($p \leq 0.05$)

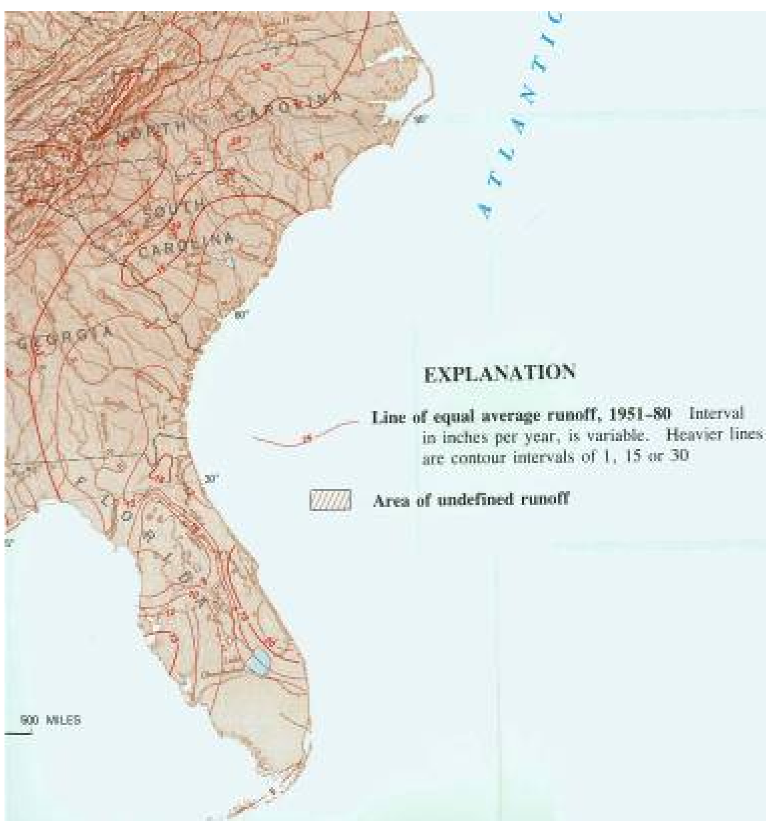


Figure 4-21. Mean annual runoff in the southeastern US Coastal Plain. Source: Gerbert *et al.*, 1987.

CHAPTER 5
SYNTHESIS

Objective 1: Most Reliable Bankfull Indicator for Peninsular Florida Streams

Various indicators of bankfull stage, including elevation of the flat floodplain (BKF-F), the inflection point on the bank (BKF-I), scour lines (BKF-S), moss collars (BKF-M), tops of point bars (BKF-TOPB), and alluvial breaks (BKF-A) were identified, surveyed, and analyzed individually at 45 as near-to-natural peninsular Florida streams to determine if there is a single most reliable bankfull indicator for peninsular Florida streams. The following factors were examined: how prevalent each bankfull indicator is among study sites; how closely the slope of each bankfull indicator matches that of the water; and how frequently and for how long the discharge and stage associated with each bankfull indicator occur.

Based solely on prevalence of various bankfull indicators during the reference reach surveys, BKF-I and BKF-F (for streams with relatively flat wetland floodplains) were the most reliable field indicators of the bankfull stage for peninsular Florida streams. The BKF-I indicator was ubiquitous at all study sites, while the BKF-F indicator was predominantly found at sites with a wetland floodplain. BKF-M and BKF-TOPB were not present at enough sites to be reliable bankfull indicators for peninsular Florida streams. While present at many sites, the BKF-S indicator was noticeably absent at many sites with a cypress-dominated floodplain. The BKF-A indicator was too subjective and difficult to identify in the field to be a reliable bankfull indicator. (Table 3-1)

Slopes of a line best fit through both the survey points of each individual bankfull indicator (BKF-F, BKF-I, BKF-S, BKF-A) and top of bank survey points (TOB) were compared to the slope of a line best fit through the water surface survey points (or the channel bed surface points for those sites that had no flowing water on the day of the survey). Leopold (1994) used this technique to verify the feature as bankfull if the two lines were generally parallel and consistent over a long reach. To determine how parallel the lines were, the water slope was divided by the slope of each bankfull indicator to determine a water slope to bankfull indicator slope ratio. Theoretically, the closer the ratio is to one, the more reliable the indicator. Bankfull indicator slopes within 25% of the water slope, or those with a water slope to bankfull indicator ratio between 0.75 and 1.25, were deemed candidate reliable field indicators (Table 3-3). Based on this type of slopes analysis, BKF-I was the most reliable bankfull indicator, with an average water slope to bankfull indicator slope ratio of 1.01. Variance in water slope to BKF-I slope ratio between streams with water slope less than 0.5% and streams with a water slope greater than 0.5% was not significantly different ($p>0.05$) (Table 3-4). Perhaps more importantly, however, slopes analysis suggested that there is a water slope threshold of approximately 0.5%, above which bankfull indicators become more reliable (except in the case of BKF-I) (Figure 3-2). It is important to note, however, that the population of streams with water slopes greater than 0.5% was rather small ($n=8$), and thus additional research is recommended. These findings further suggest that slope-area techniques for calculating bankfull discharge should not be used in peninsular Florida for sites with a water slope less than 0.5%, or conversely, that calculating discharge using slope-area techniques is acceptable for sites with a water slope greater than 0.5%.

Sites with long-term hydrologic data obtained from the USGS were analyzed to determine the frequency and duration of stage and discharge associated with various bankfull indicators. Based on gage analysis, it is safe to conclude that both BKF-A and BKF-S occur far too frequently and are exceeded for far too much of the time to be considered the best indicator of bankfull discharge, or the most effective discharge in transporting sediment and performing "work" (Tables 3-5 and 3-6). BKF-I and BKF-F were thus further examined. Significant differences were found in durations of discharges and stages associated with top of bank ($p<0.01$) and BKF-I indicator ($p<0.01$) between sites with a wetland floodplain and those without (Table 3-9). Significant differences, however, were not found in durations of discharges and stages associated with BKF-F ($p>0.05$) between sites with a wetland floodplain and sites without. This is likely due to the nature of the BKF-F indicator itself—a flat floodplain, which is generally found at sites with a wetland floodplain and is generally absent from sites without, as these sites are more likely to be incised. Because BKF-I and top of bank were found at every single site, the fact that significant differences exist between sites with a wetland floodplain and sites without suggest that a different indicator should be used between these two floodplain types.

In conclusion, elevation of the flat floodplain (BKF-F) is the most reliable bankfull indicator for peninsular Florida streams with a wetland floodplain, while the inflection point (BKF-I) is the most reliable indicator for incised streams or streams with an upland floodplain.

Objective 2: Development of Regional Curves for Peninsular Florida Streams

Regional curves, which relate bankfull discharge and channel geometry (cross-sectional area, width, and mean depth) to drainage area in regions of similar climate, geology, and vegetation, were developed for peninsular Florida. Data were collected from 45 as near-to-natural peninsular Florida streams, with drainage areas ranging from 0.2 sq mi to 311 sq mi. The data obtained from the reference reach surveys were used to determine bankfull discharge, bankfull cross-sectional area, bankfull width, and bankfull mean depth. A power function regression was fit to the data and the coefficient of determination (R^2) was determined. Due to potential inaccuracies of determining bankfull discharge at gaged sites, mean annual discharge and 1.5-year discharge were also plotted against drainage area to see if these were better correlated with drainage area than the bankfull discharge. More specifically, the 1.5-year return interval was chosen because it is the return interval most often associated with bankfull flow (Leopold, 1994).

Various discharges and bankfull parameters varied directly with drainage area, as expected. Bankfull mean depth had the lowest R^2 values, while mean annual discharge had the highest R^2 values. Relationships for bankfull discharge, mean annual discharge, 1.5-year discharge, bankfull area, bankfull width, and bankfull mean depth are shown in Figures 4-2 through 4-11. Table 4-1 summarizes the discharge data used in peninsular Florida regional curve development, while Table 4-2 summarizes the channel geometry data used. Table 4-3 and 4-4 summarize the power function regression equations, corresponding coefficients of determination, and sample sizes for discharge against drainage area and channel geometry against drainage area, respectively.

Objective 3: Comparisons by Physiography, Geography, and Floodplain Types

Regional curve data were further analyzed to determine whether significant differences exist between streams draining different physiographies (flatwoods versus highlands), geographies (northern versus southern peninsula), and floodplain types (wetland versus upland and cypress-dominated versus non-cypress-dominated), in terms of bankfull parameters and various dimensionless ratios (sinuosity, width-to-depth, maximum depth-to-mean depth, and valley slope). Analysis of Covariance (ANCOVA) tests were performed to determine whether significant differences exist in the slopes and/or intercepts of the bankfull discharge and channel geometry regressions for each data subset (JMP 7), while comparison of means tests were performed using Excel Data Analysis ANOVA: Single factor to determine if significant differences exist in the various dimensionless ratios

Bankfull discharge appears to be higher at flatwoods than highlands sites, at sites with upland floodplains than wetland floodplains, and at sites with non-cypress-dominated floodplains than sites with cypress-dominated-floodplains (Figures 4-3, 4-5, and 4-6). Sites with a non-cypress-dominated floodplain "started out" with a significantly higher bankfull discharge than sites with a cypress-dominated floodplain ($p=0.05$) and had a significantly lower bankfull discharge duration ($p=0.01$) (Table 4-6). Flatwoods streams were flashier than highlands streams, based on having significantly higher maximum discharge to mean discharge ratios ($p=0.01$).

Sites with either wetland floodplains or cypress-dominated floodplains appear to have a greater bankfull area and bankfull width than sites with upland floodplains or non-cypress-dominated floodplains, respectively (Figures 4-10 and 4-11). These wetland floodplain sites also started out with a significantly higher bankfull area ($p=0.03$) and bankfull width ($p<0.01$) than sites with upland floodplains (Tables 4-7 and 4-8). Though not significantly different, peak discharge-to-mean annual discharge ratios were also higher in streams with wetland floodplains and with cypress-dominated floodplains, indicating that these streams are flashier than those with an upland floodplain or a non-cypress-dominated floodplain (Table 4-6, Figure 4-20). Flashiness of these streams may help to explain why they are wider, as Osterkamp (1980) found that streams with a flashier regime and relatively high peak flows tend to develop wider channels. Lastly, sites in the northern peninsula started out with a deeper bankfull mean depth than sites in the southern peninsula ($p=0.02$) (Table 4-9).

No significant differences were found in sinuosity or maximum depth-to-mean depth based on physiography, geography, or floodplain types. Sites with a cypress-dominated floodplain and sites located in the southern peninsula had significantly higher width-to-depth ratio than sites with a non-cypress-dominated floodplain ($p=0.01$) and sites located located in the northern peninsula ($p=0.01$) (Table 4-11). Sites with upland floodplains and non-cypress dominated floodplains had significantly steeper valley slopes than sites with wetland floodplains ($p<0.01$) and cypress-dominated floodplains ($p=0.02$), respectively.

In conclusion, some significant differences existed in bankfull discharge and channel geometry of peninsular Florida streams based on geography and floodplain types, including: 1) bankfull depth and width-to-depth ratio were significantly different in northern versus southern peninsula sites; 2) bankfull area and width (size), as well as valley slope, were significantly different in sites with wetland versus upland floodplains; and 3) bankfull discharge, width-to-depth ratio (shape), and valley slope were significantly different in sites with cypress-dominated versus non-cypress-dominated floodplains. Significant differences, however, were not found in bankfull discharge and channel size and shape of peninsular Florida streams based on physiography (flatwoods versus highlands), though flatwoods streams were significantly flashier than highlands streams.

Objective 4: Estimation of the Bankfull Discharge Return Interval

Return intervals were estimated using the Annual Maximum Series from a Log Pearson Type III distribution and ranged from less than one year to 1.44 years (Table 4-2), which is more frequent than the average 1.5-year return interval often reported in the literature (Dunne and Leopold, 1978; Leopold, 1994), but consistent with findings from other southeastern United States Coastal Plain studies (Sweet and Geratz, 2003) (Table 4-12). This has important implications for flood control, as it indicates that peninsular Florida streams are overtopping their banks more frequently than in other regions. Because Annual Maximum Series cannot determine return intervals that are less than one year, mean and median bankfull return interval values could not be determined for peninsular Florida streams. It is thus recommended that future work includes a partial duration series to refine return intervals that are less than one year.

Objective 5: Comparisons to Other Southeastern United States Coastal Plain Studies

Regional curves have recently been developed to estimate bankfull discharge and channel geometry throughout the southeastern United States Costal Plain, including Northwest Florida and North Florida Coastal Plain (Metcalf, 2004), Alabama Coastal Plain (Metcalf, 2005), Georgia Coastal Plain (Buck Engineering, 2004), North Carolina Coastal Plain (Doll *et al.,* 2003; Sweet and Geratz, 2003), and Virginia and Maryland Coastal Plain (Krstolic and Chaplin, 2007). Raw data from the present work and from these previous studies conducted throughout the southeastern United States Coastal Plain were entered into Excel and regional curves for each bankfull parameter were compiled into one graph for visual comparison (Table 4-12, Figures 4-16 through 4-19). Analysis of Covariance (ANCOVA) tests were then performed to determine whether significant differences exist in the slopes and/or intercepts of the bankfull discharge and channel geometry regressions between peninsular Florida streams (the baseline regression) and other Coastal Plain regional curves (JMP 7).

The slope of peninsular Florida streams for all bankfull regressions tends to be less steep than the other slopes, indicating that bankfull parameters in peninsular Florida are less sensitive to changes in drainage area size, or in other words that the bankfull parameters in peninsular Florida streams increase at a slower rate with drainage area (Figures 4-16 though 4-19). Only slopes of North Florida bankfull width ($p=0.01$) and bankfull depth (0.04) regressions and Alabama bankfull area ($p=0.01$) and bankfull width ($p=0.01$), however, were significantly different than peninsular Florida (Tables 4-7, 4-8, and 4-9).

When examining intercepts of various Coastal Plain regressions, peninsular Florida bankfull channels started out significantly narrower and shallower than North Carolina ($p<0.01$;

$p=0.01$) and Northwest Florida ($p=0.01$; $p<0.01$) Coastal Plain streams (Table 4-8 and Table 4-9). Perhaps this indicates that peninsular Florida streams are more efficient at conducting water, as peninsular Florida streams tend to be low gradient with sandy bottoms, which may enable them to conform and conduct water more easily than streams with steeper gradients and rocky streambeds. However, peninsular Florida streams start out at a significantly lower bankfull discharge and area than North Carolina ($p=0.01$; $p<0.01$) and Northwest Florida ($p<0.01$; $p=0.02$) Coastal Plain streams, which could indicate that peninsular Florida streams receive less water overall (Tables 4-6 and 4-7). Figure 2-5 shows that peninsular Florida receives approximately ten inches less rain than Northwest Florida, while Figure 4-21 shows that peninsular Florida receives considerably less mean annual runoff (approximately 10 inches) than North Carolina (approximately 15 inches) and Northwest Florida (approximately 25 inches) (Gerbert *et al.,* 1987). Peninsular Florida's low mean annual runoff values are likely attributable to its sandy soils, flat terrain, and deranged drainage networks. Peninsular Florida streams also deepen at a significantly faster rate with increasing drainage area than North Florida streams. Perhaps this is because North Florida streams have a steeper gradient and subsequently down-cut more.

In conclusion, it is difficult to tweak out exactly why peninsular Florida streams are significantly different than other Coastal Plain streams without further research as there are a variety of variables, including the amount of water these systems receives (which depends upon on various factors such as climate, rainfall patterns, runoff patterns, and baseflow), roughness of the streambed, gradient, level of alluvial control, and vegetation.

Conclusions

In conclusion, peninsular Florida's streams are significantly different than other Coastal Plain regions, thus regional curves presented within the present work should provide useful data to public agencies such as the Department of Environmental Protection (DEP), United States Geological Survey (USGS), and the Department of Transportation (DOT), as well as to private industries such as the phosphate mining industry for implementing natural channel designs as a stream restoration technique in peninsular Florida. Though not many significant differences were found within peninsular Florida streams based on physiography, geography, and floodplain types, there are some important differences that should be considered when designing natural channels. For example, streams with wetland floodplains had significantly greater bankfull area and bankfull width than streams with an upland floodplain. Also, streams with cypress-dominated floodplains had a greater width-to-depth ratio than streams with non-cypress-dominated floodplains. These size and shape differences based on floodplain types may be important restoration considerations.

APPENDIX A
SAMPLE PERMISSION LETTER AND FORM

UF Environmental Engineering Sciences
UNIVERSITY of FLORIDA

BCI engineers & scientists

July 13, 2007

Florida Department of Agriculture and Consumer Services
Division of Forestry
ATTN: Joseph A. Bishop
9610 County Road 44
Leesburg, FL 32788

Dear Joseph A. Bishop:

Blackwater Creek, which runs through or adjacent to your property located at Parcel # 1710901, Parcel # 1096162, and Parcel # 1096171 in Seminole Springs State Forest near Cassia in Lake County, Florida, has been selected for a publicly funded study to be performed by the University of Florida and BCI Engineers & Scientists, Inc. a Lakeland-based firm. The goal of the study is to assess the physical habitat of a wide variety of intact Florida stream segments. Your segment of the stream has been selected based on its natural qualities, special contributions to the study requirements, and already available U.S. Geological Survey (USGS) data.

We request and value your permission to access Blackwater Creek from your property in order to complete the study's necessary fieldwork. The fieldwork will be performed by a qualified research team, typically comprised of two personnel, and will last between one to two days. The fieldwork will be confined to the stream and floodplain. Accordingly, your property will not be disturbed and you will likely not even notice our presence.

Please fill out the enclosed form and return it in the enclosed envelope within three weeks of receiving this letter. You may also fax the completed form to my attention at (863) 667-2662. If you have any questions, please feel free to call me at (954) 288-6588 or email me at blantonk@ufl.edu.

Blackwater Creek is an integral piece of this study and your cooperation is greatly appreciated!

Sincerely,

Kristen Blanton, Graduate Research Assistant
University of Florida / BCI Engineers & Scientists, Inc.

Enclosures: reply envelope
site form
site map

PHYSICAL HABITAT ASSESSMENT
PERMISSION FORM

SITE NAME: Blackwater Creek near Cassia, FL

COUNTY: Lake

ACCESS PROPERTY OWNER NAME: Florida Department of Agriculture and Consumer Services, Division of Forestry, ATTN: Joseph A. Bishop

ACCESS PROPERTY ADDRESS: Parcel # 1710901, Parcel # 1096162, and Parcel # 1096171 in Seminole Springs State Forest near Cassia, FL

OWNER MAILING ADDRESS: 9610 County Road 44, Leesburg, FL 32788

PREFERRED METHOD OF CONTACT:

- ☐ TELEPHONE:
- ☐ EMAIL:
- ☐ OTHER:

HOURS OWNER MAY BE CONTACTED:

COMMENTS / SPECIAL INSTRUCTIONS:

I HEREBY GIVE THE UNIVERSITY OF FLORIDA AND BCI ENGINEERS & SCIENTISTS, INC. PERMISSION TO ACCESS THE ABOVE STREAM LOCATED ON OR ADJACENT TO MY PROPERTY TO PERFORM A PHYSICAL HABITAT ASSESSMENT.

____
PRINTED NAME OF LANDOWNER

______________________________ ______________________
SIGNATURE OF LANDOWNER DATE

APPENDIX B
SITE FIGURES: PLAN FORM, LONGITUDINAL PROFILE, CROSS-SECTIONS

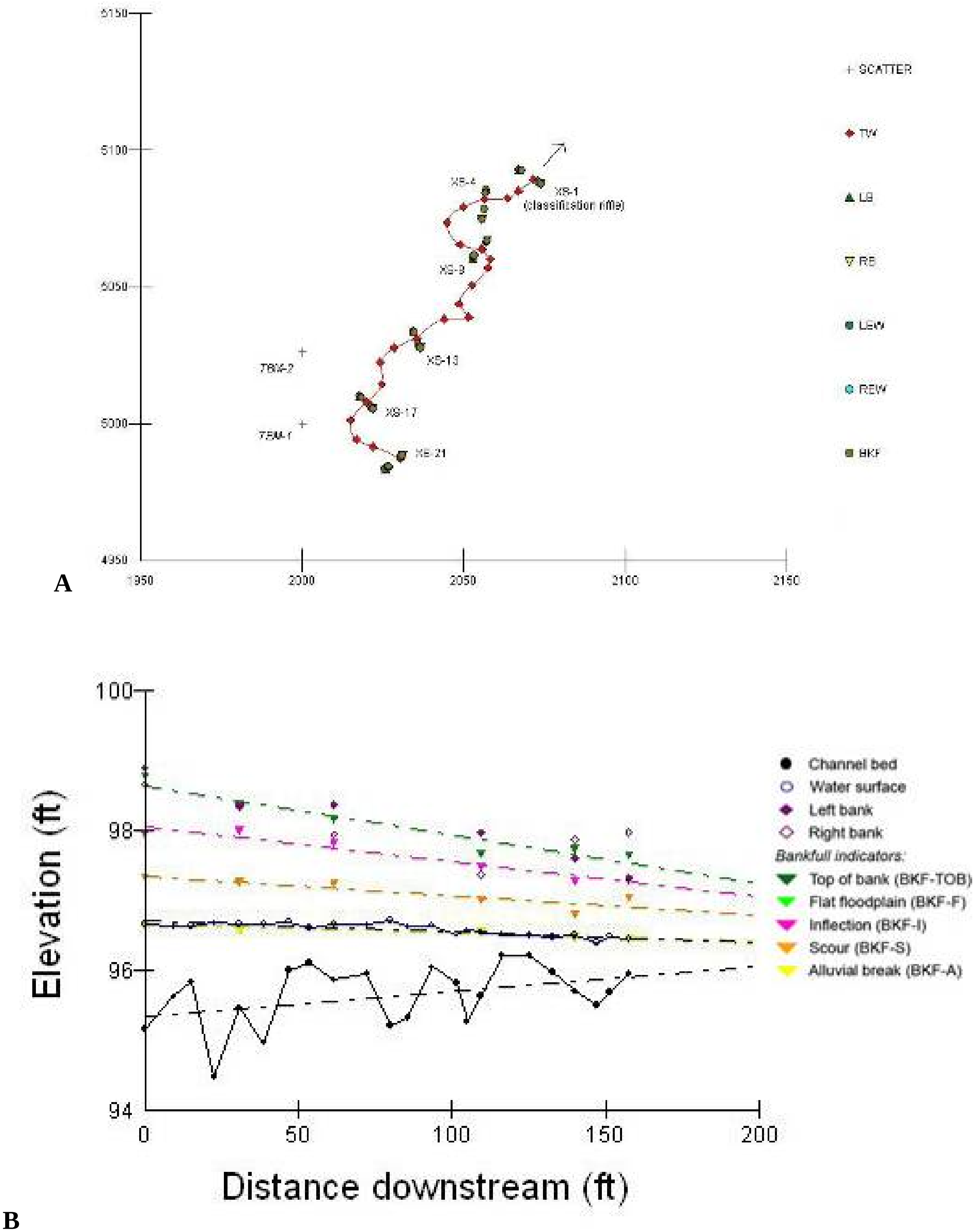
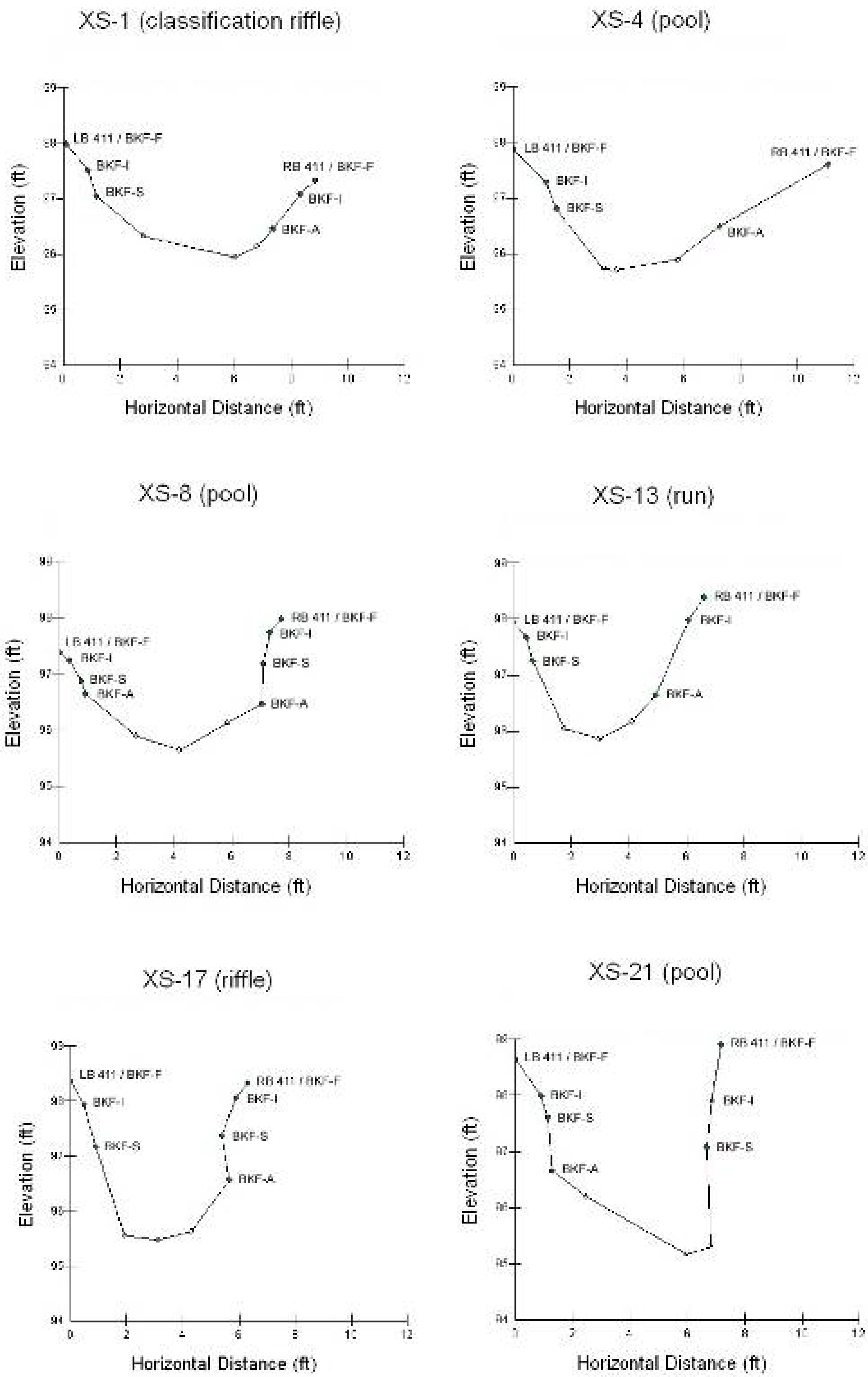
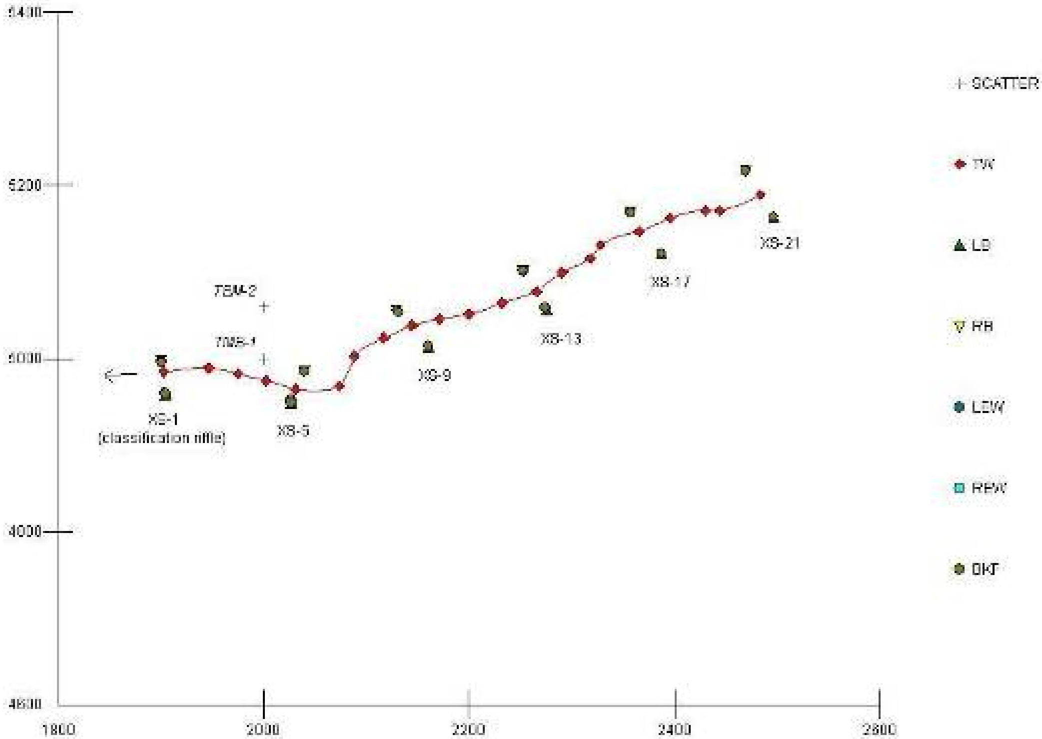


Figure B-1. Alexander Springs tributary 2. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-1. Alexander Springs tributary 2. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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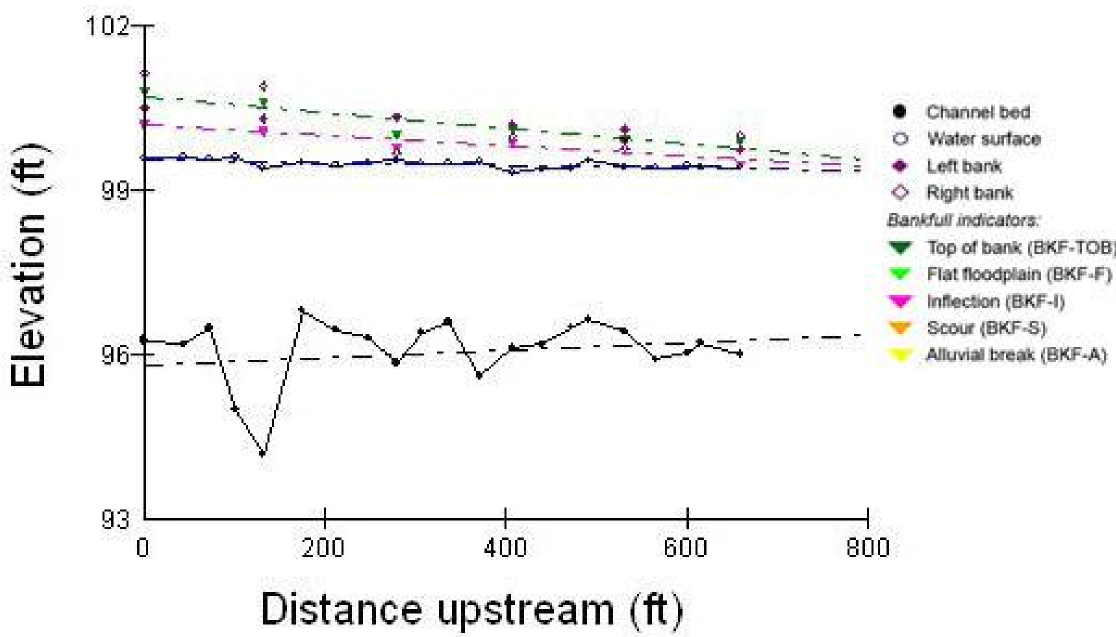

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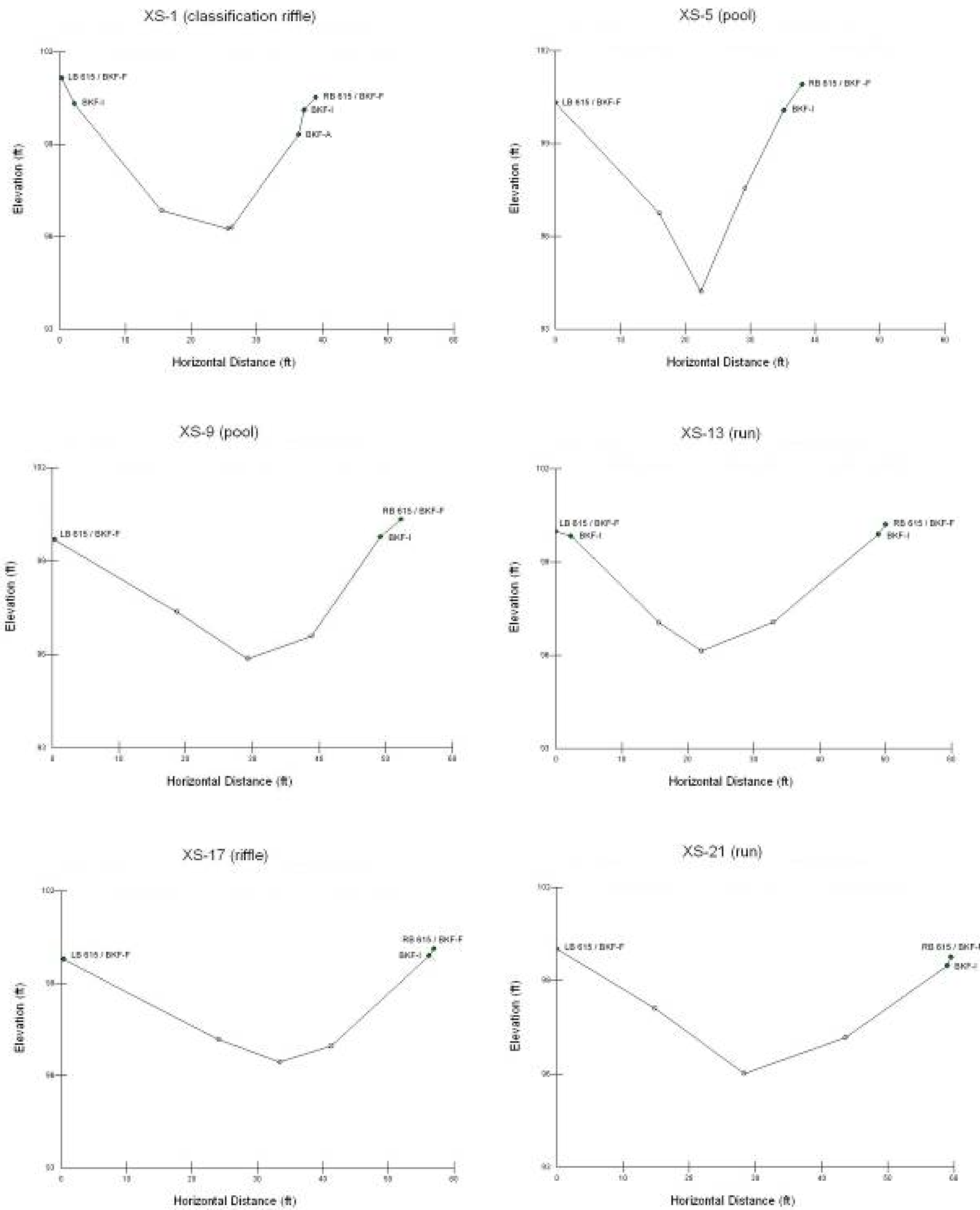
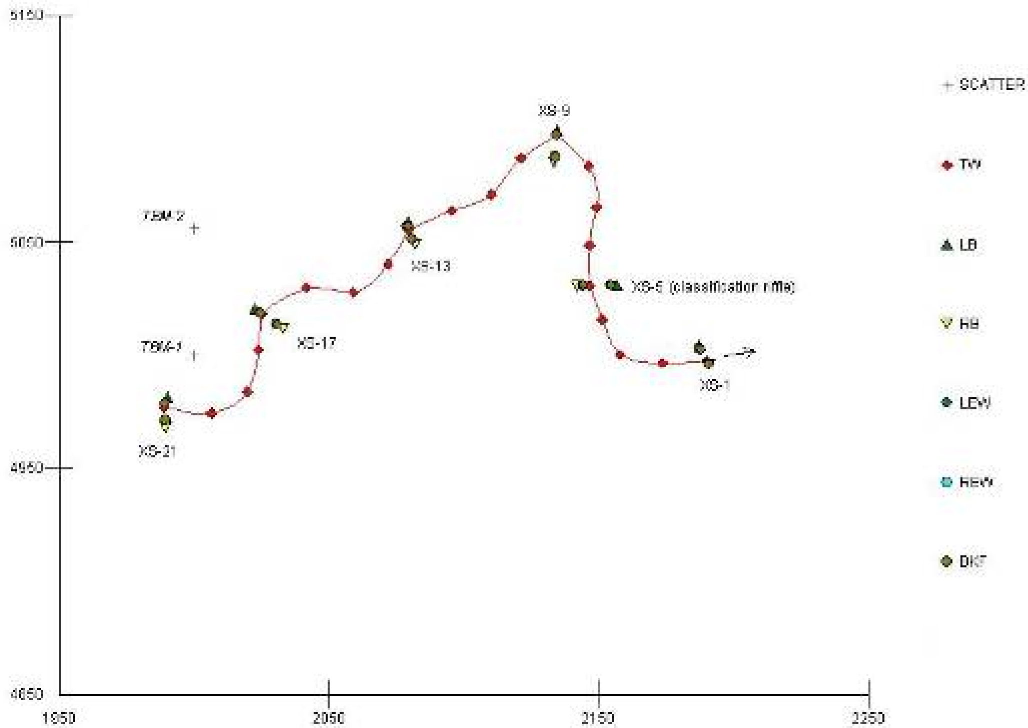
Figure B-2. Blackwater Creek near Cassia. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-2. Blackwater Creek near Cassia. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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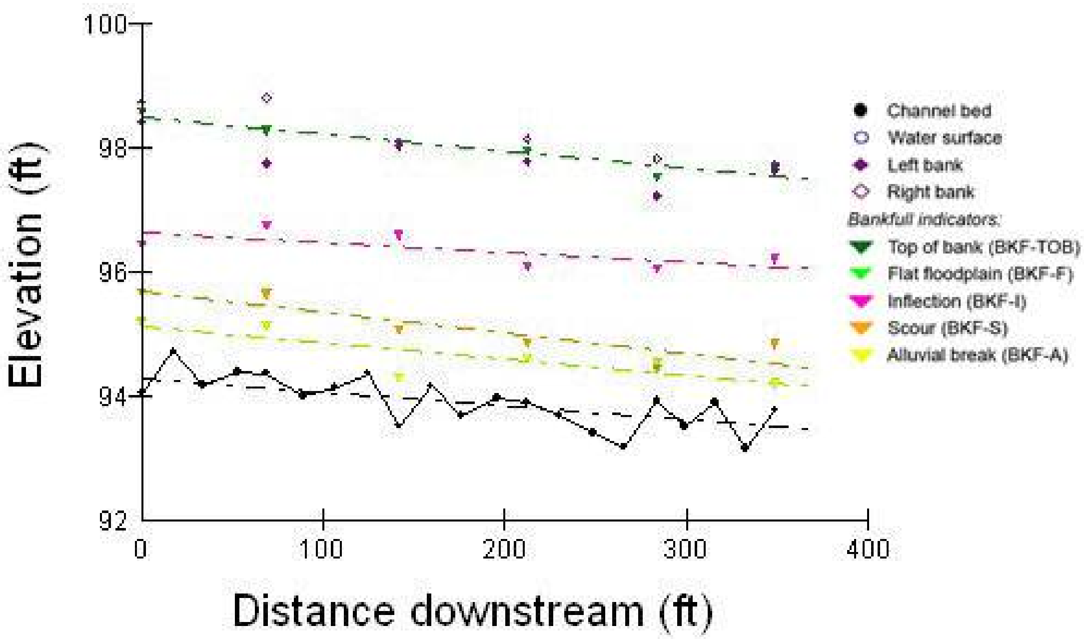

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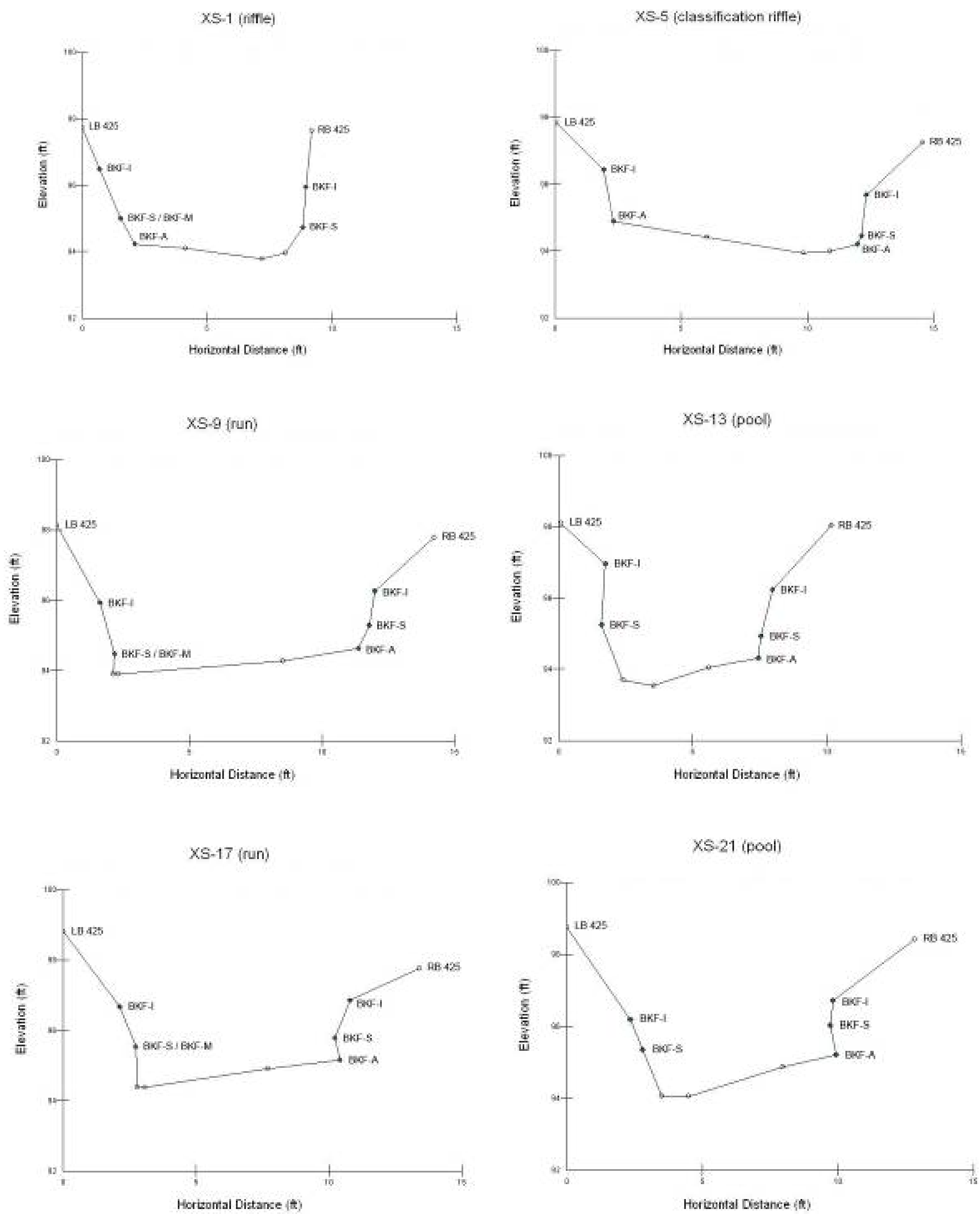
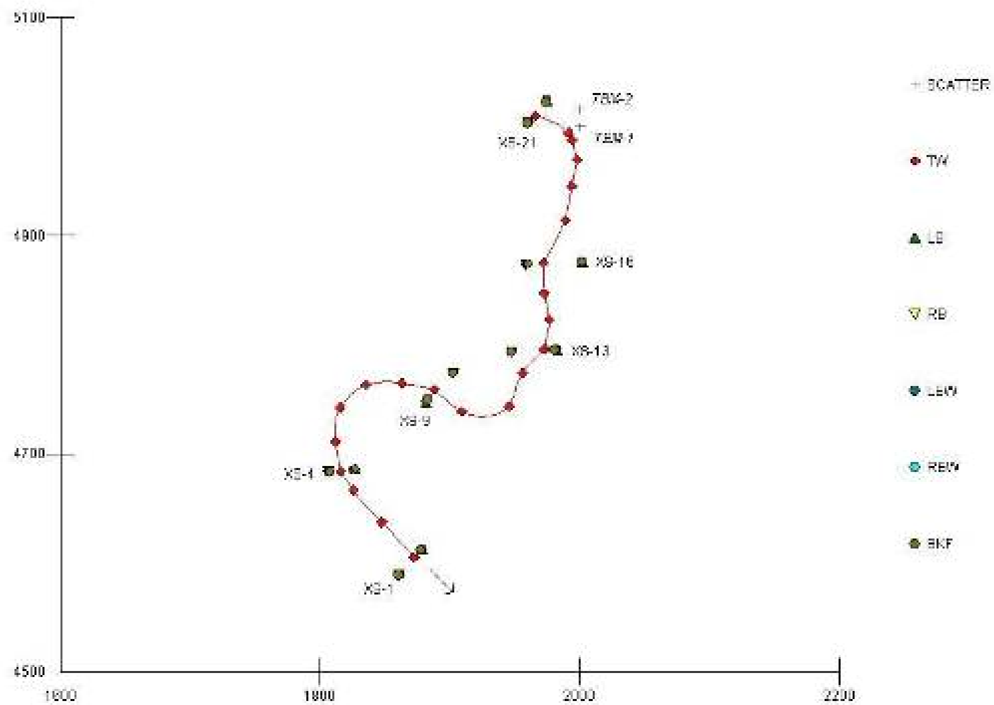
Figure B-3. Blues Creek near Gainesville. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-3. Blues Creek near Gainesville. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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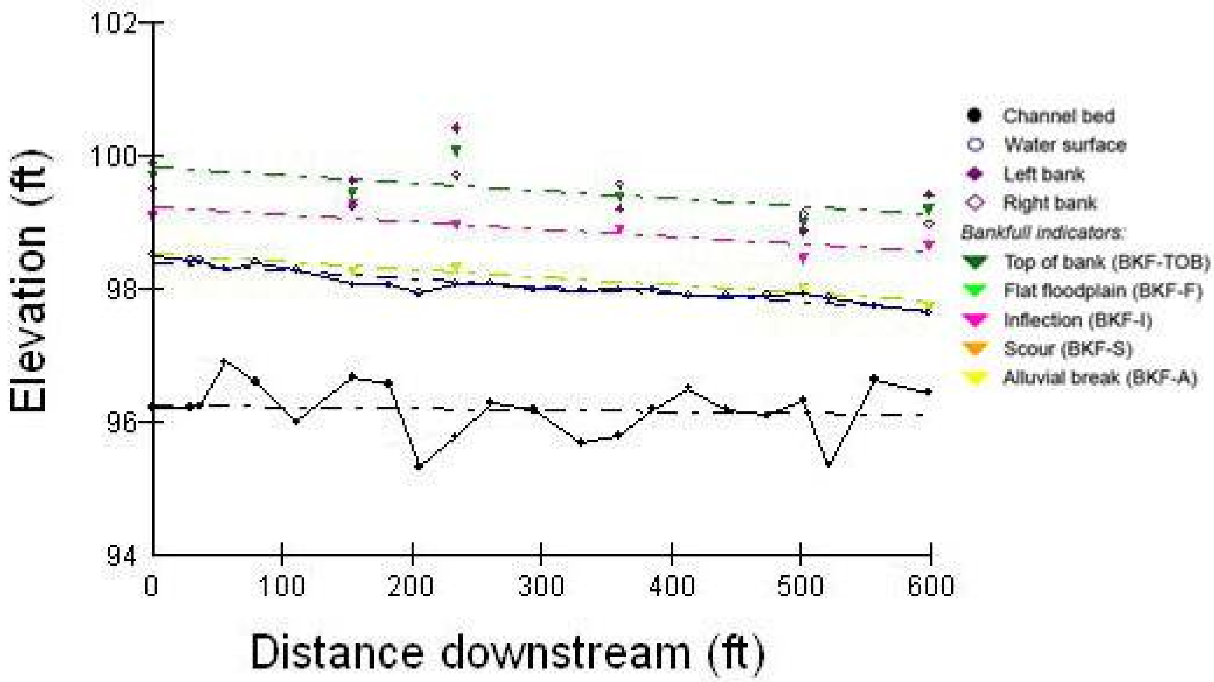
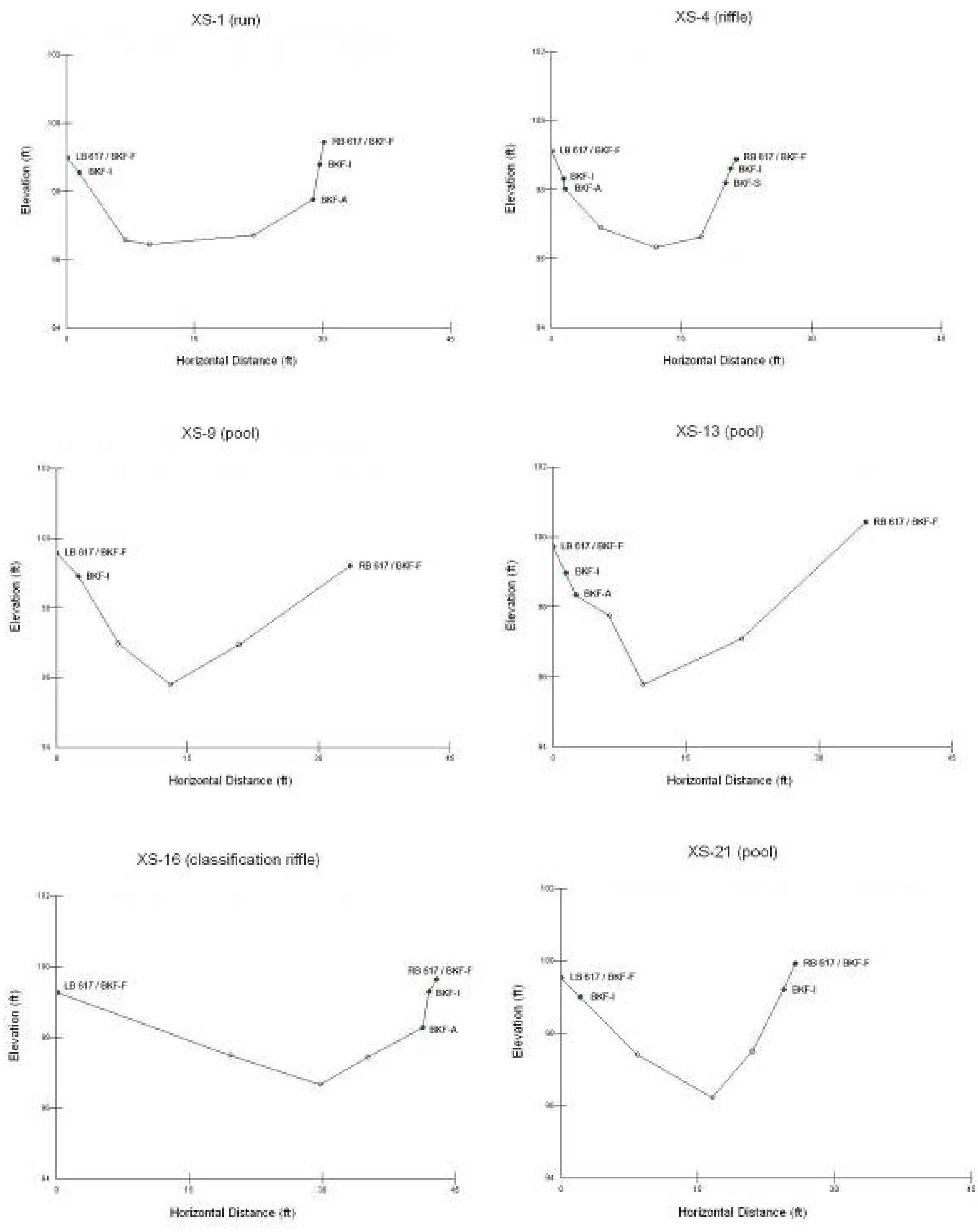


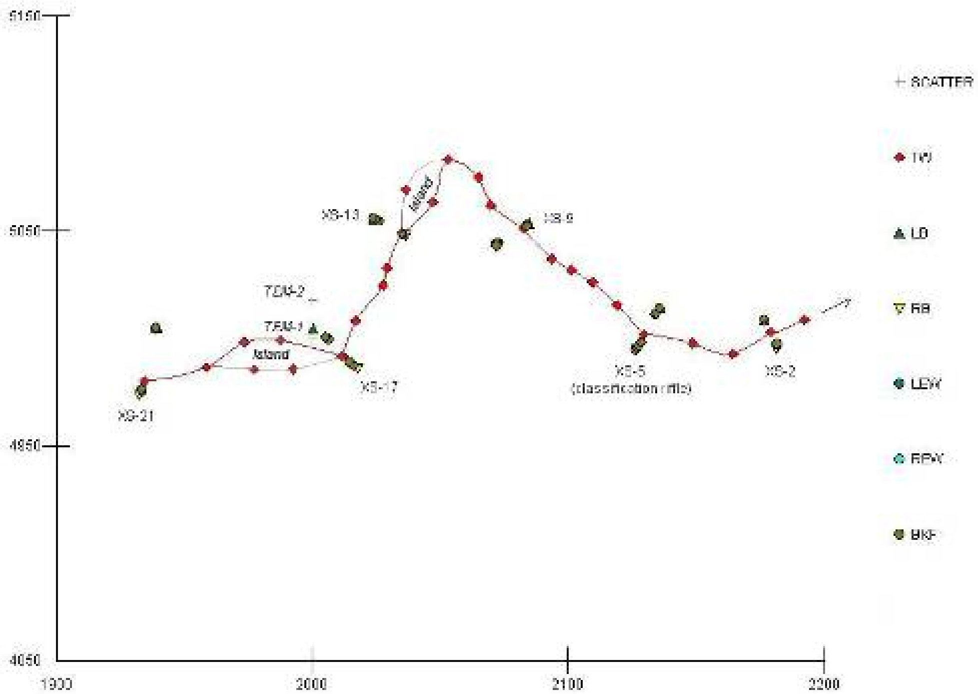
B

Figure B-4. Bowlegs Creek near Fort Meade. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-4. Bowlegs Creek near Fort Meade. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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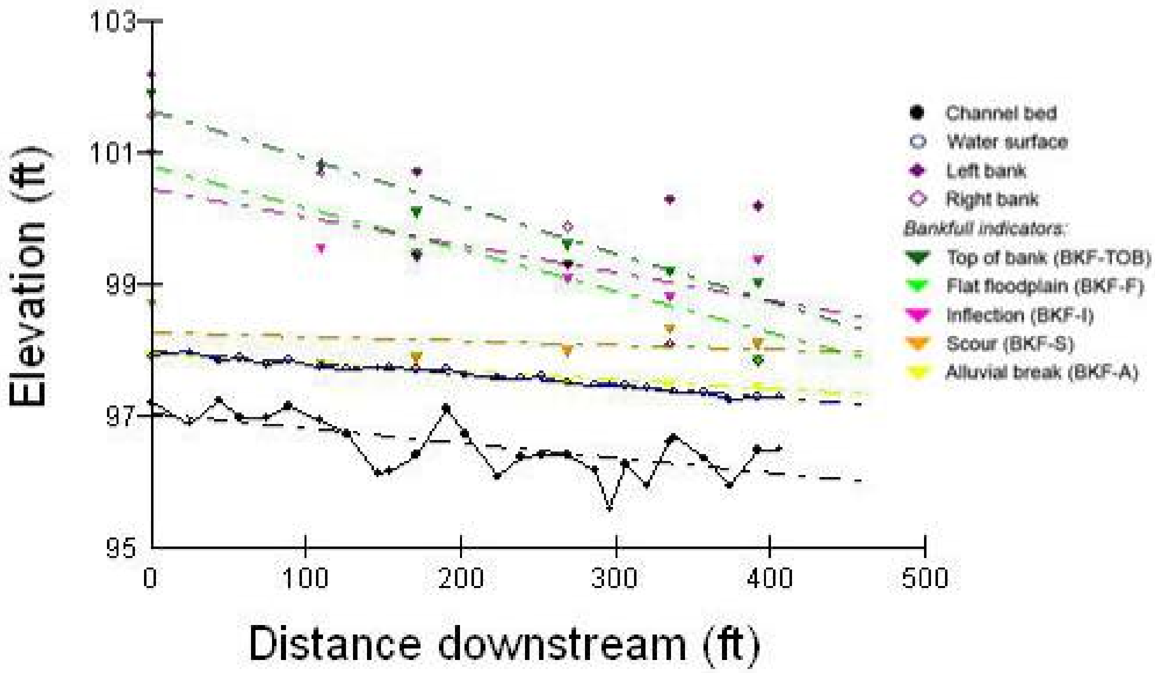
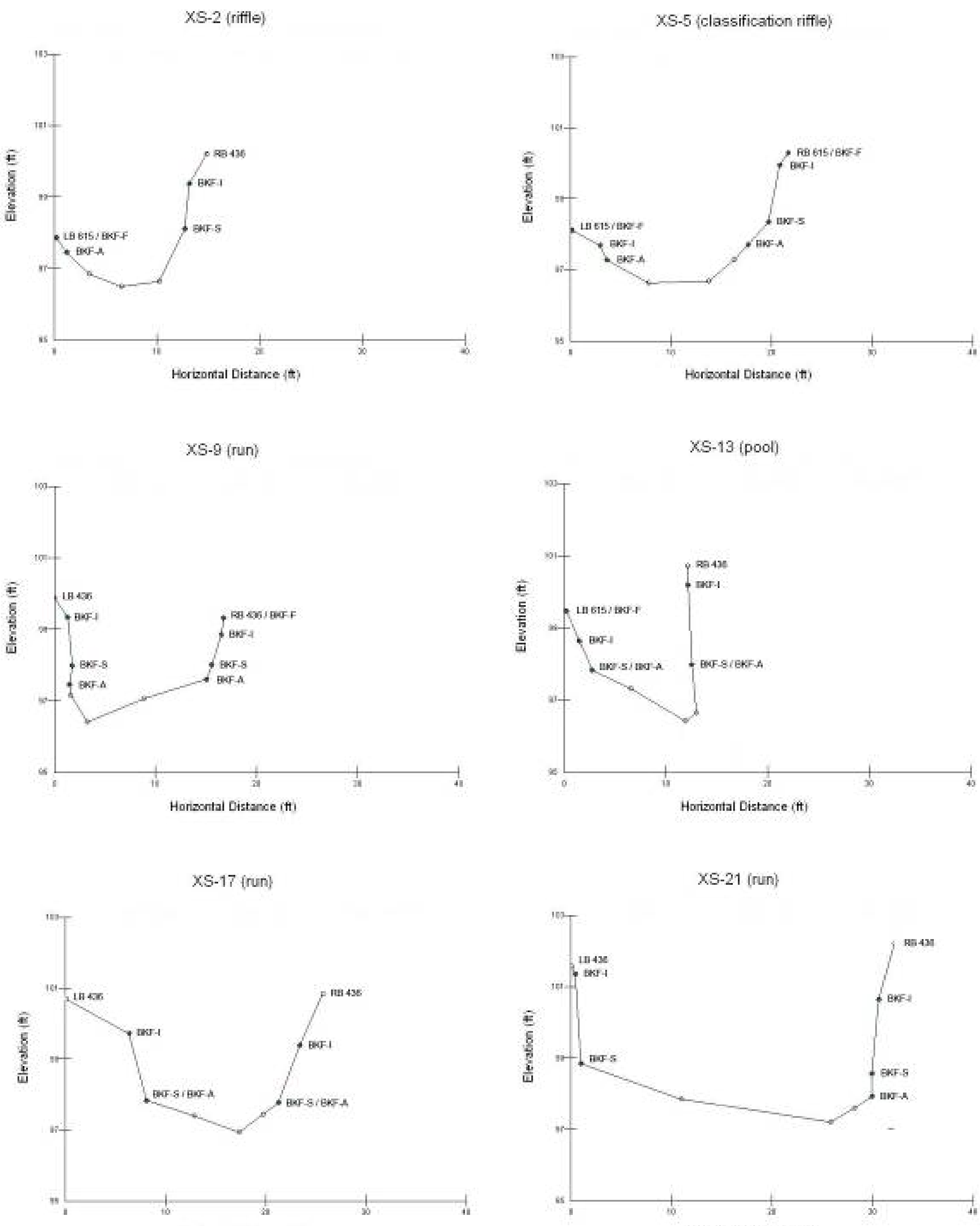


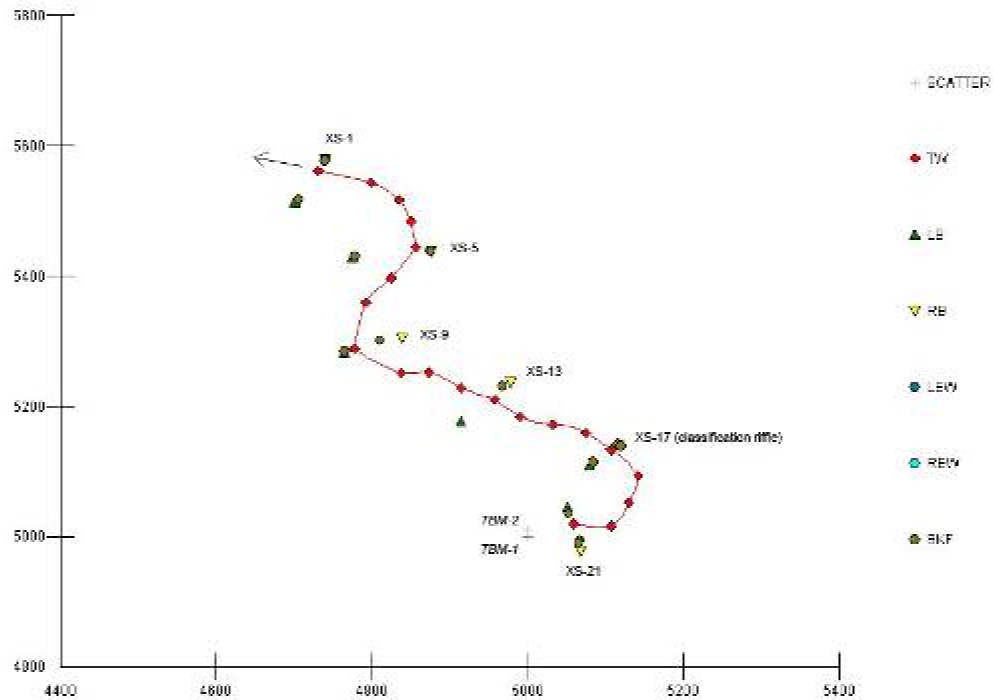
B

Figure B-5. Carter Creek near Sebring. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-5. Carter Creek near Sebring. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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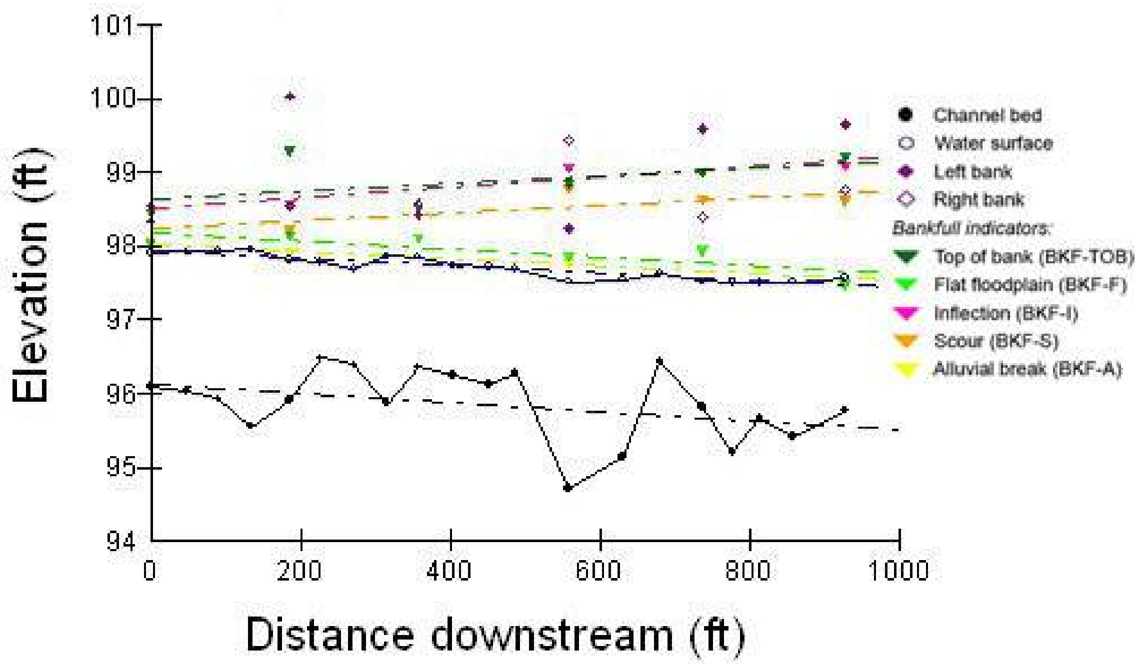
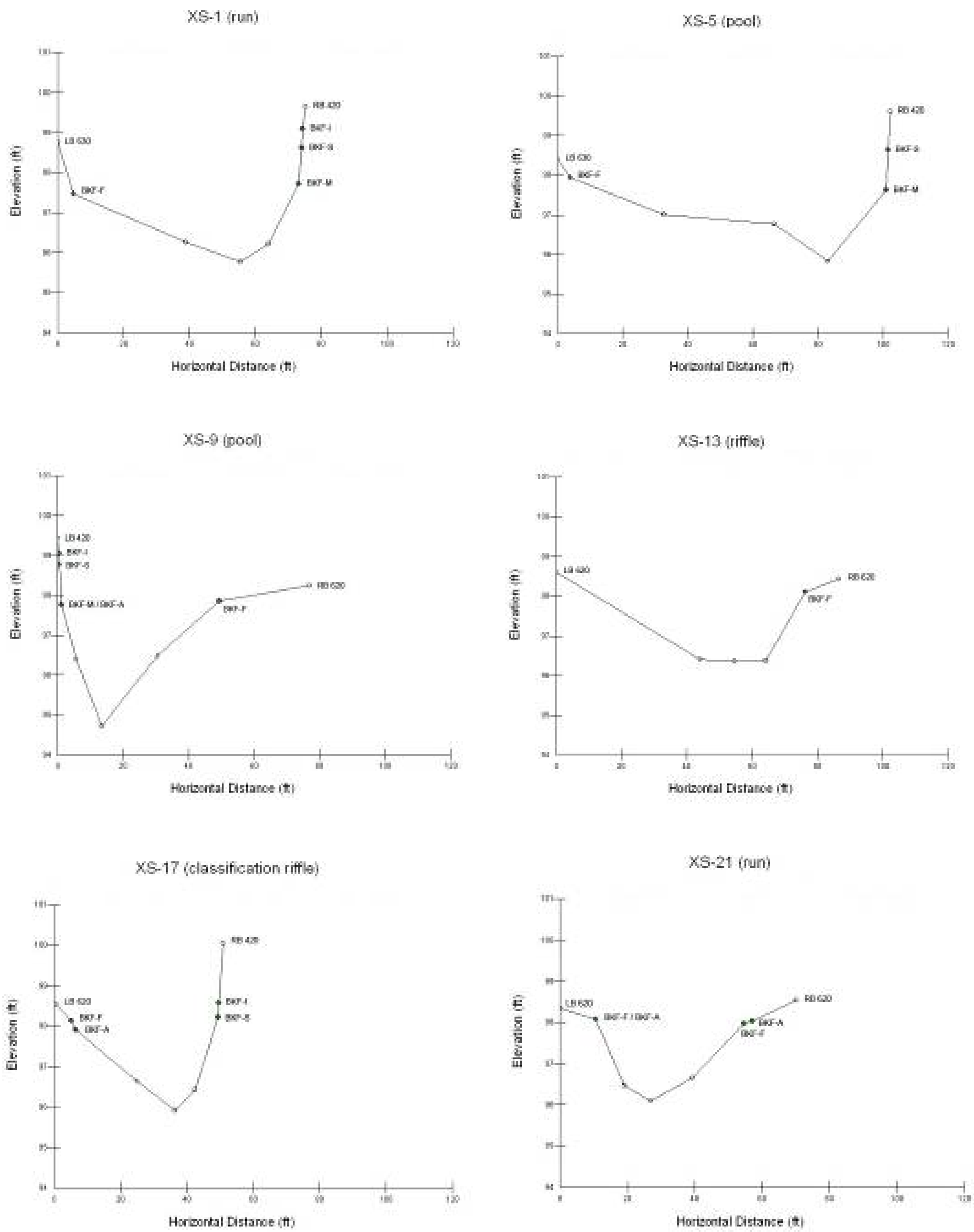


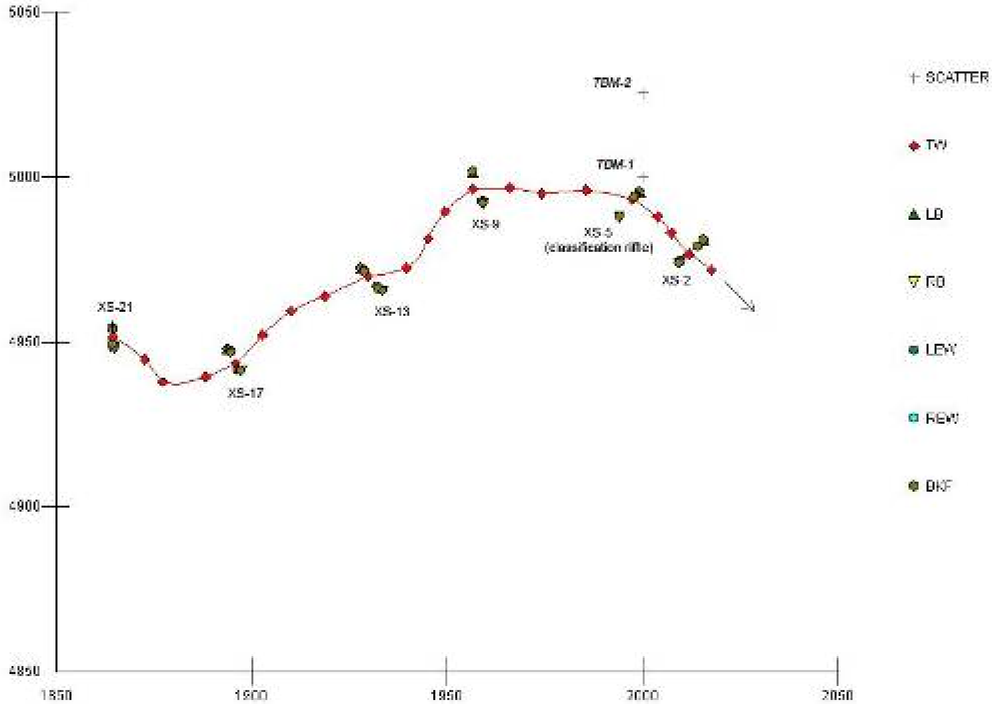
B

Figure B-6. Catfish Creek near Lake Wales. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-6. Catfish Creek near Lake Wales. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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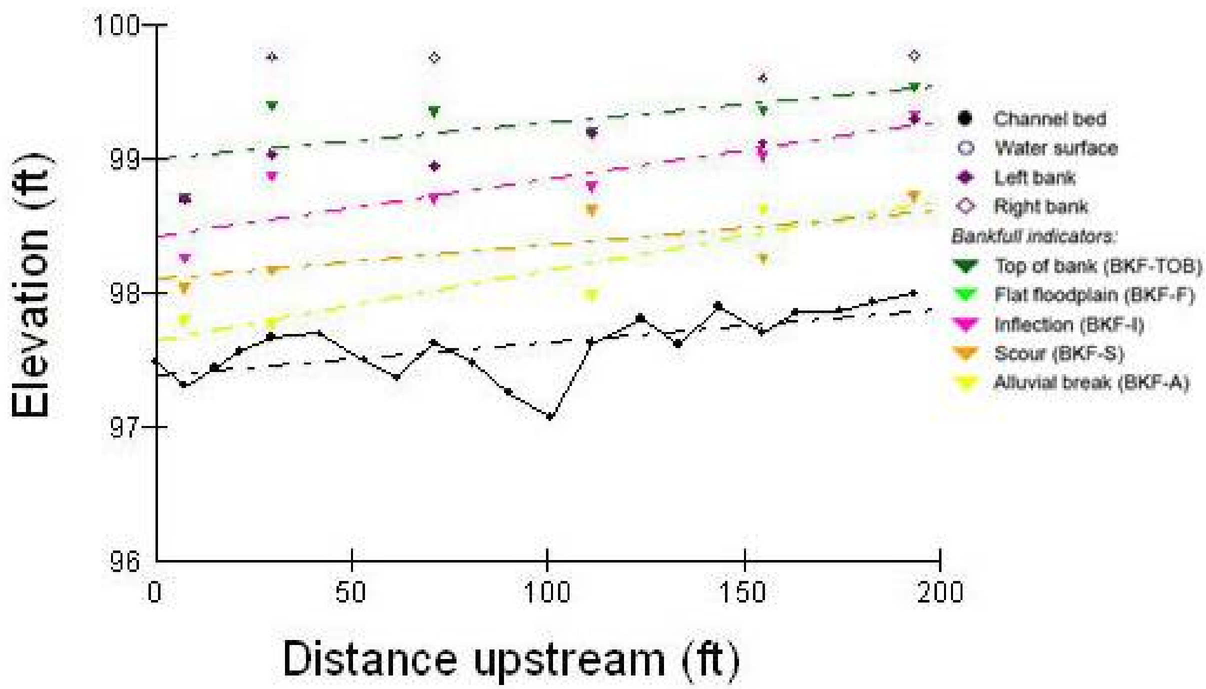

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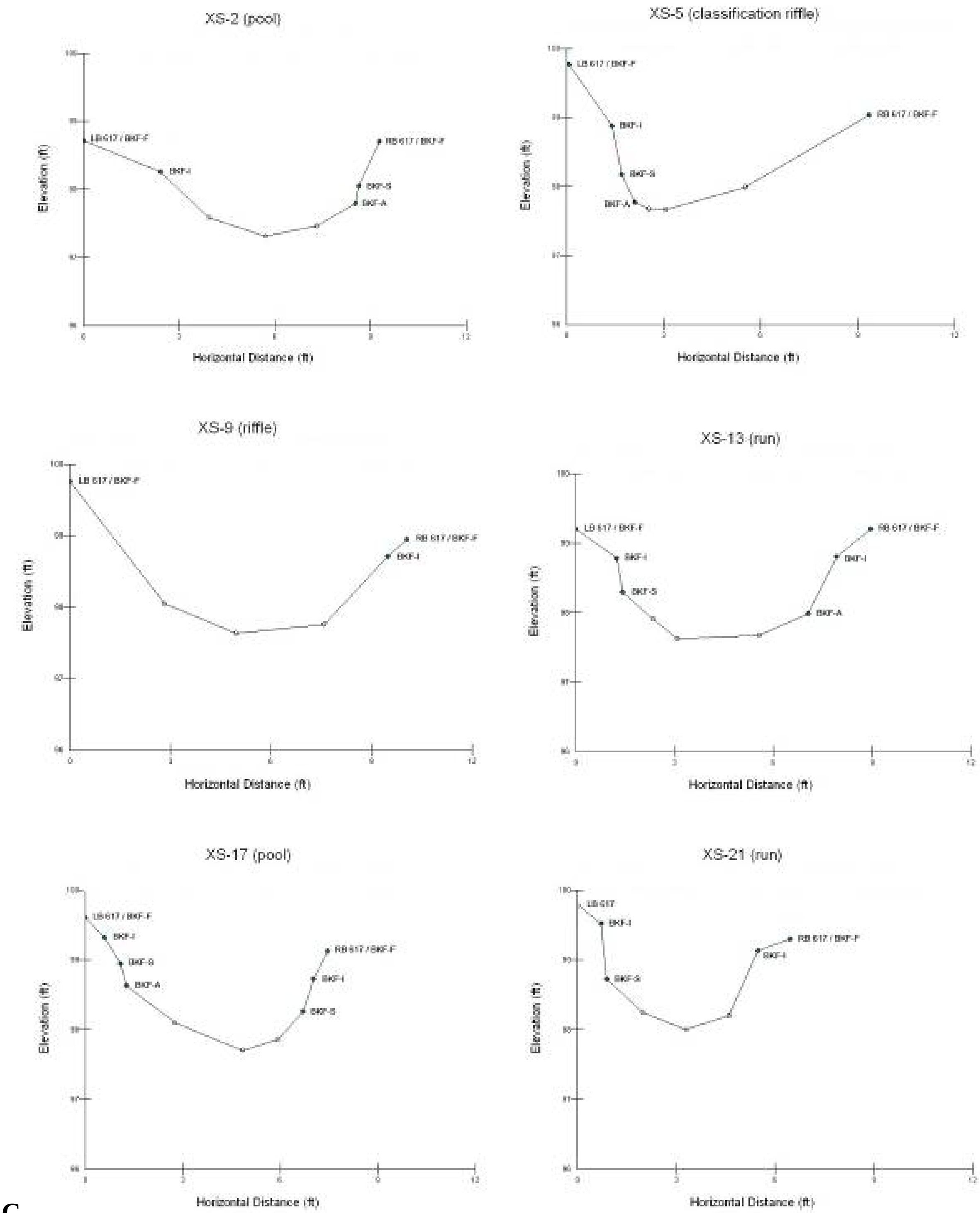
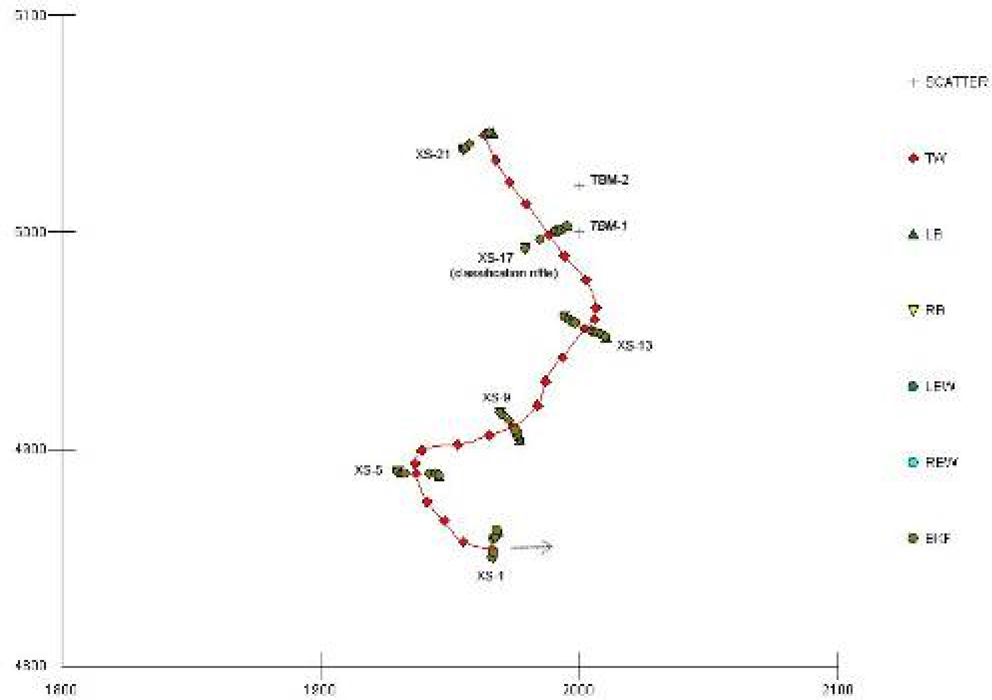
Figure B-7. Coons Bay Branch. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-7. Coons Bay Branch. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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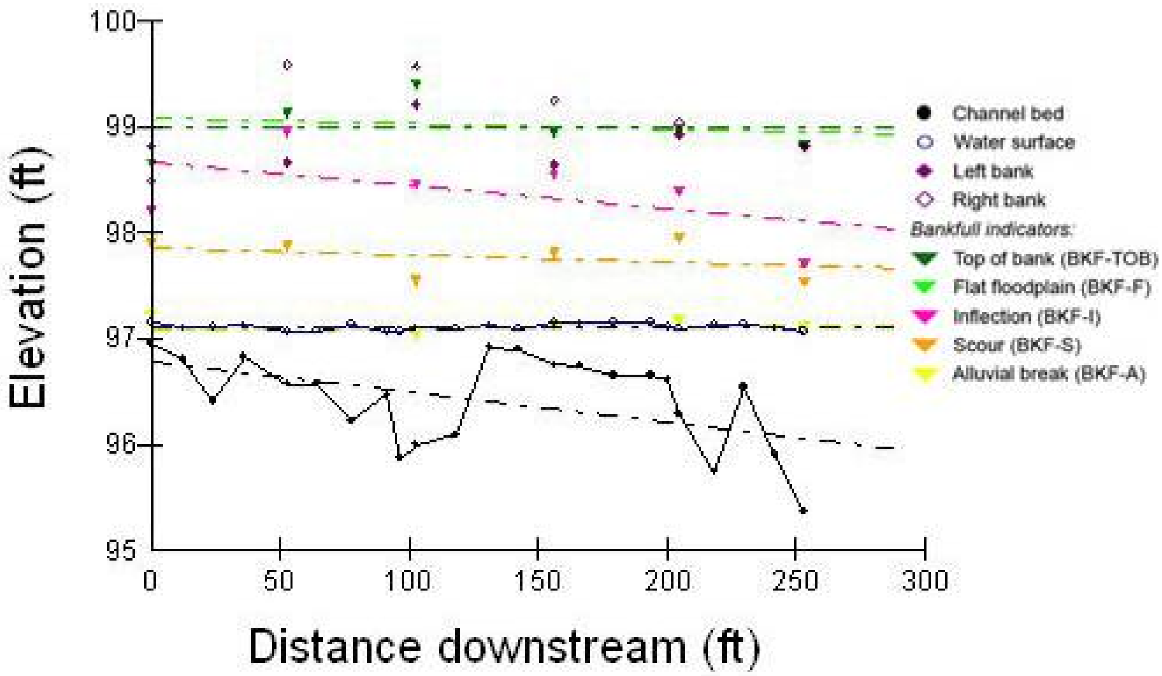
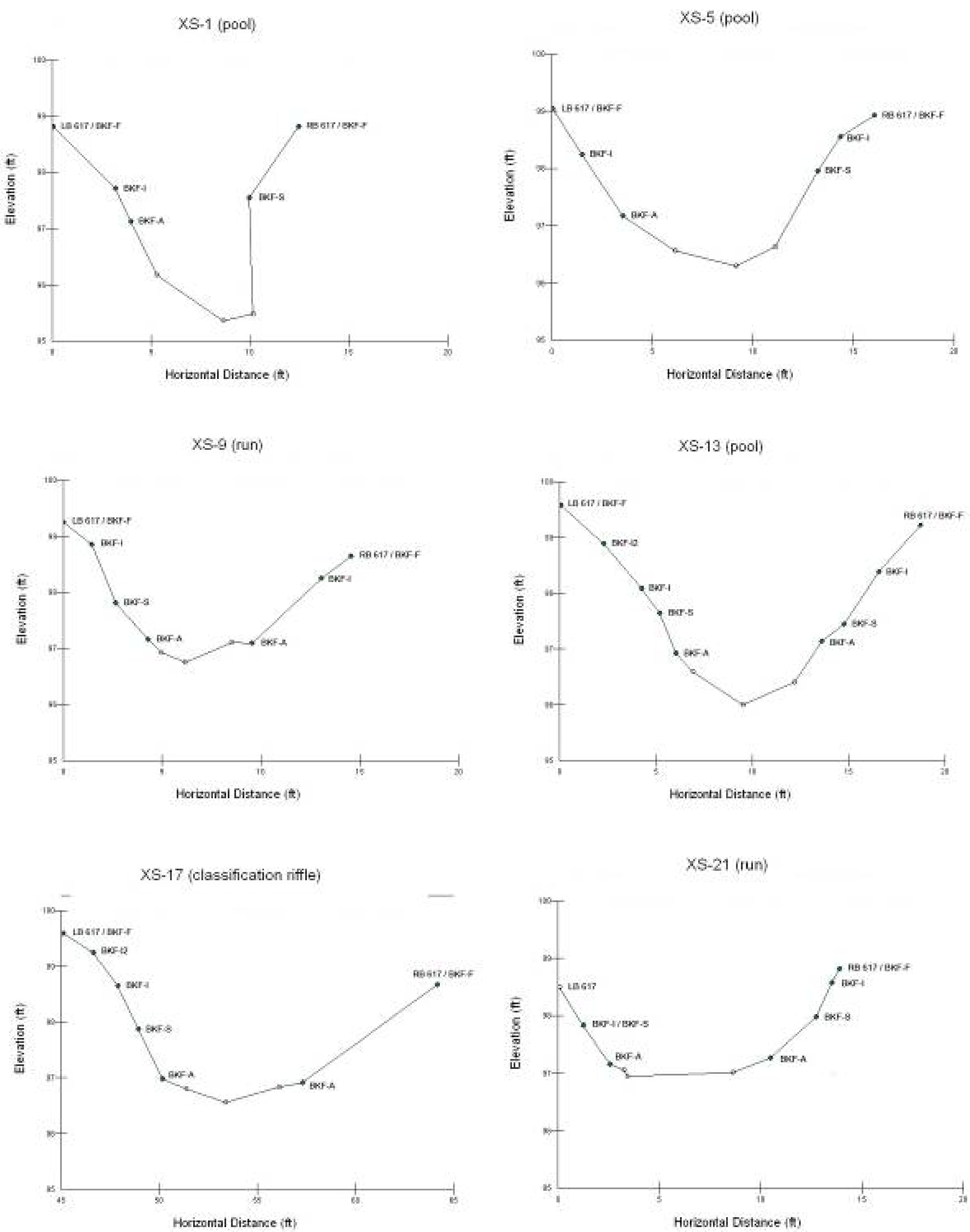


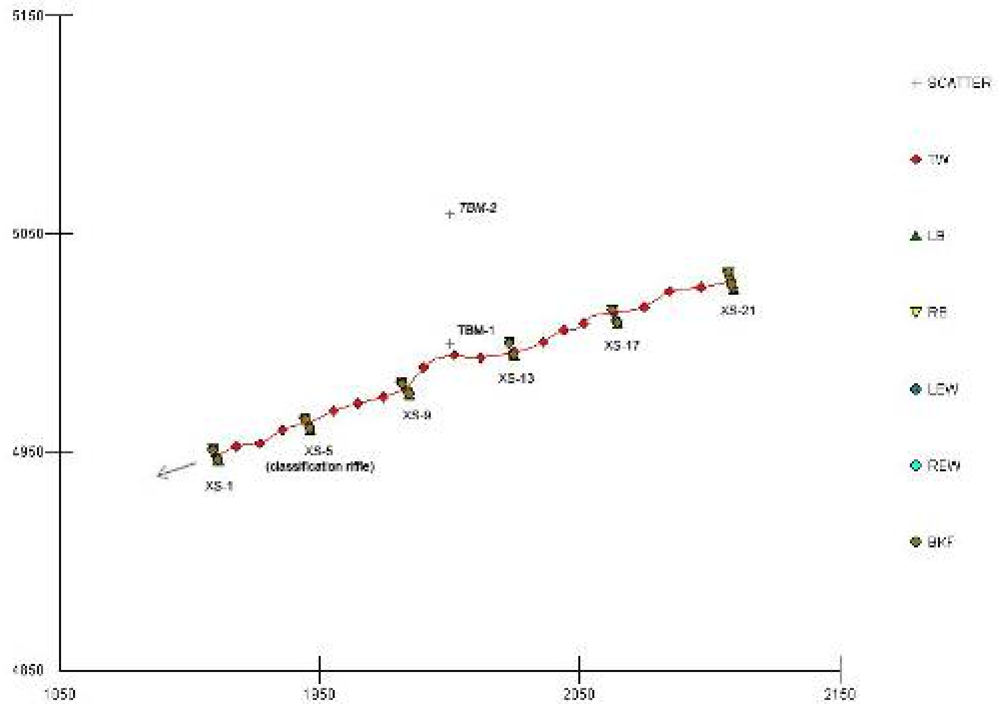
B

Figure B-8. Cow Creek. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-8. Cow Creek. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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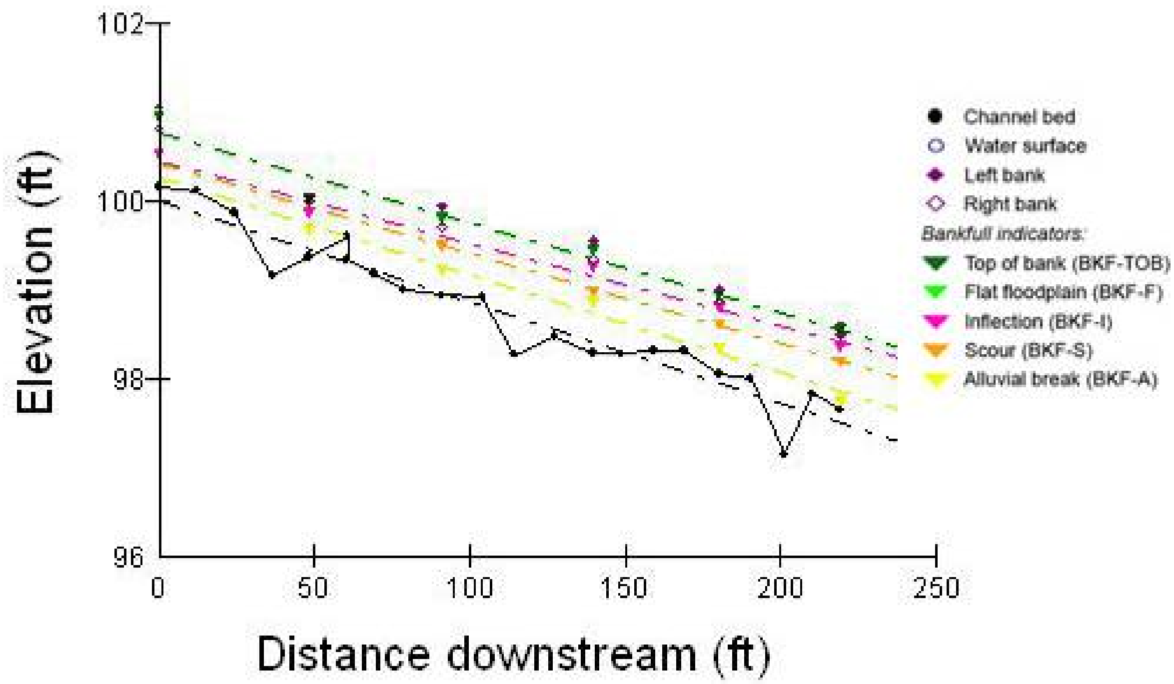
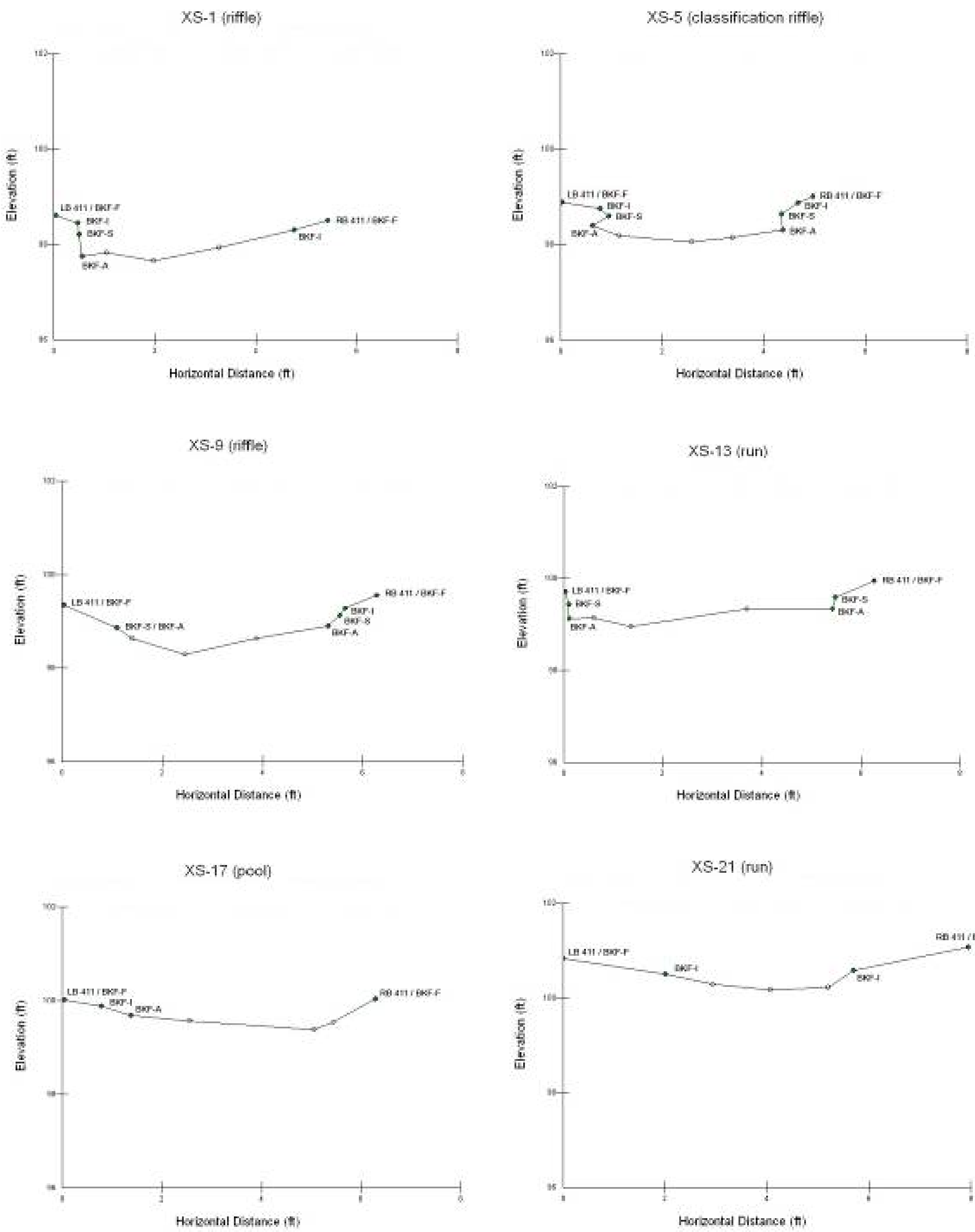


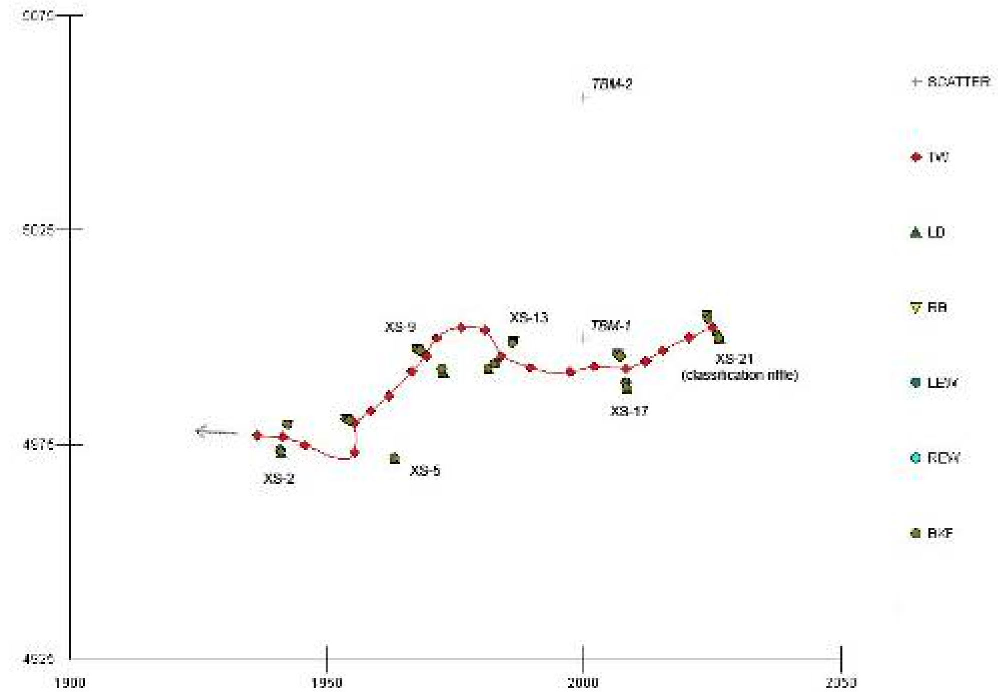
B

Figure B-9. Cypess Slash tributary. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-9. Cypess Slash tributary. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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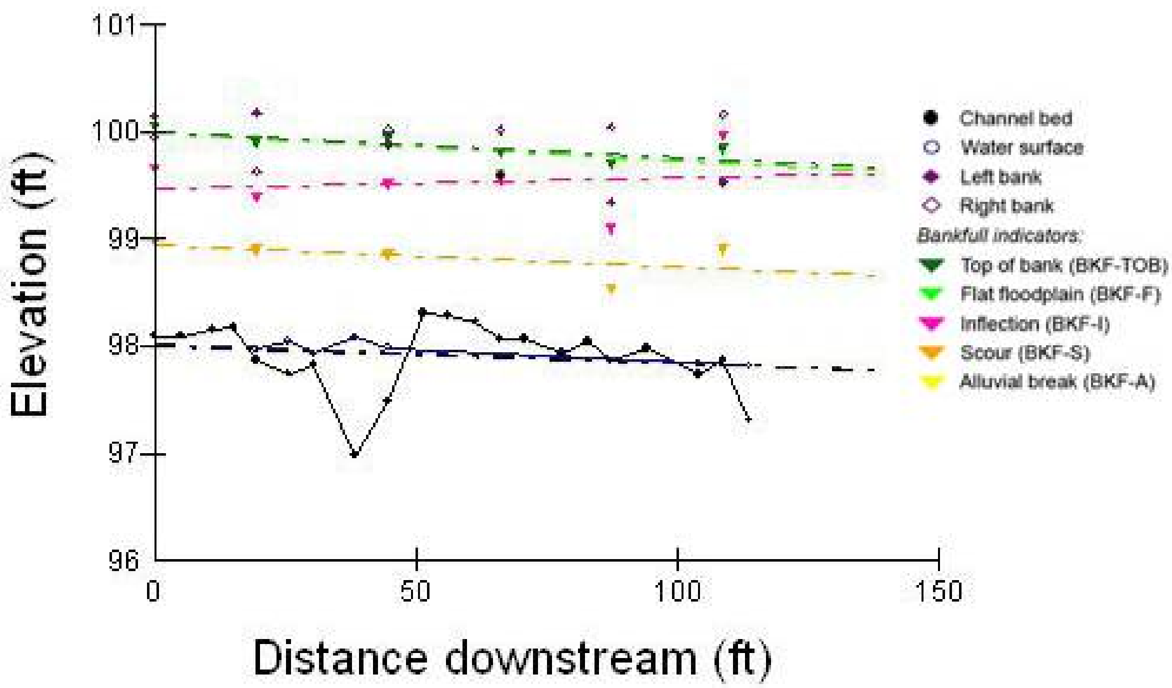
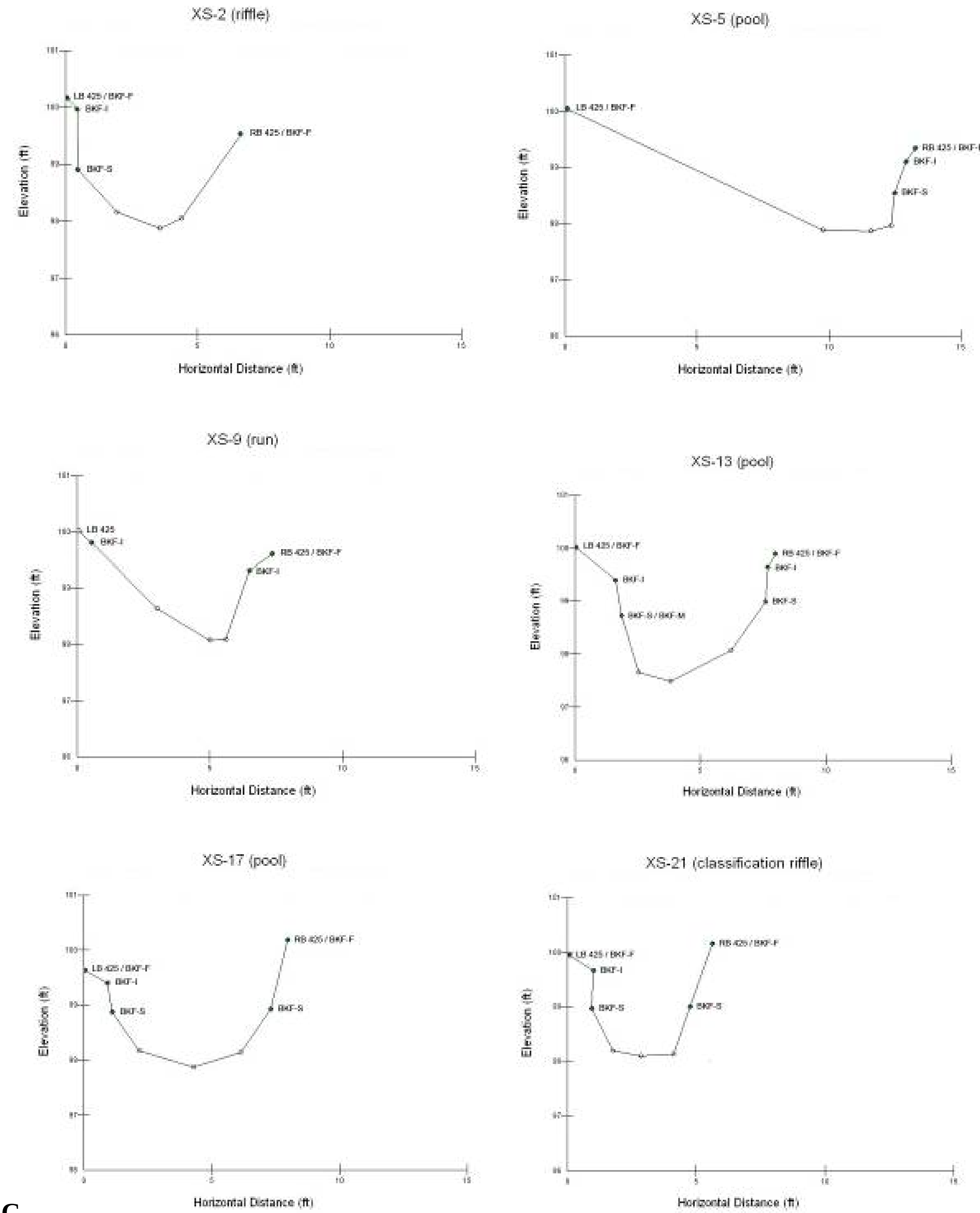


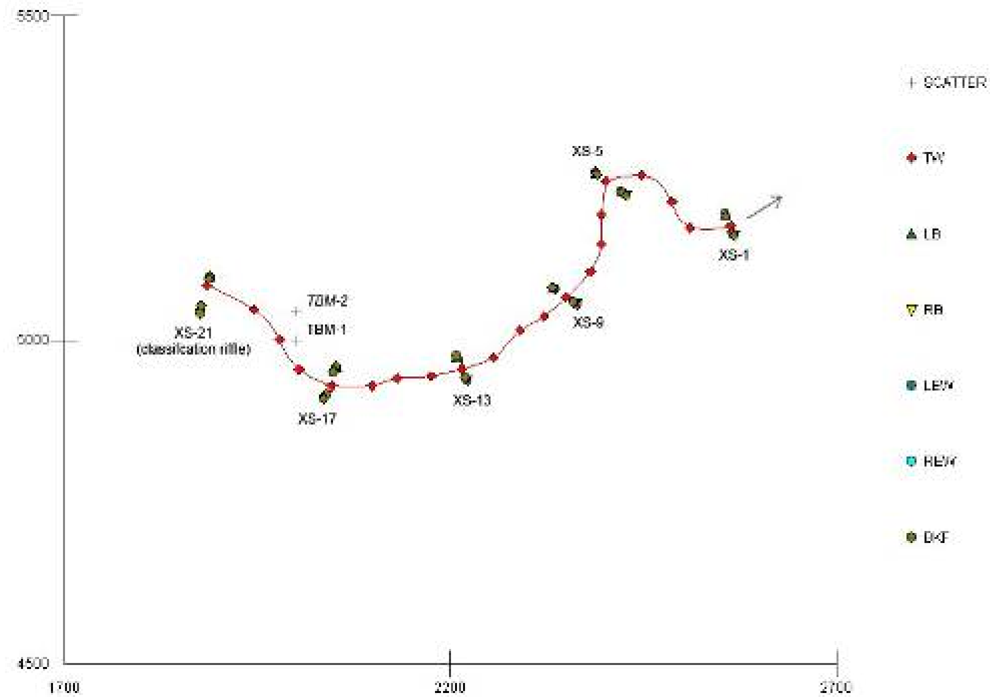
B

Figure B-10. East Fork Manatee River tributary. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-10. East Fork Manatee River tributary. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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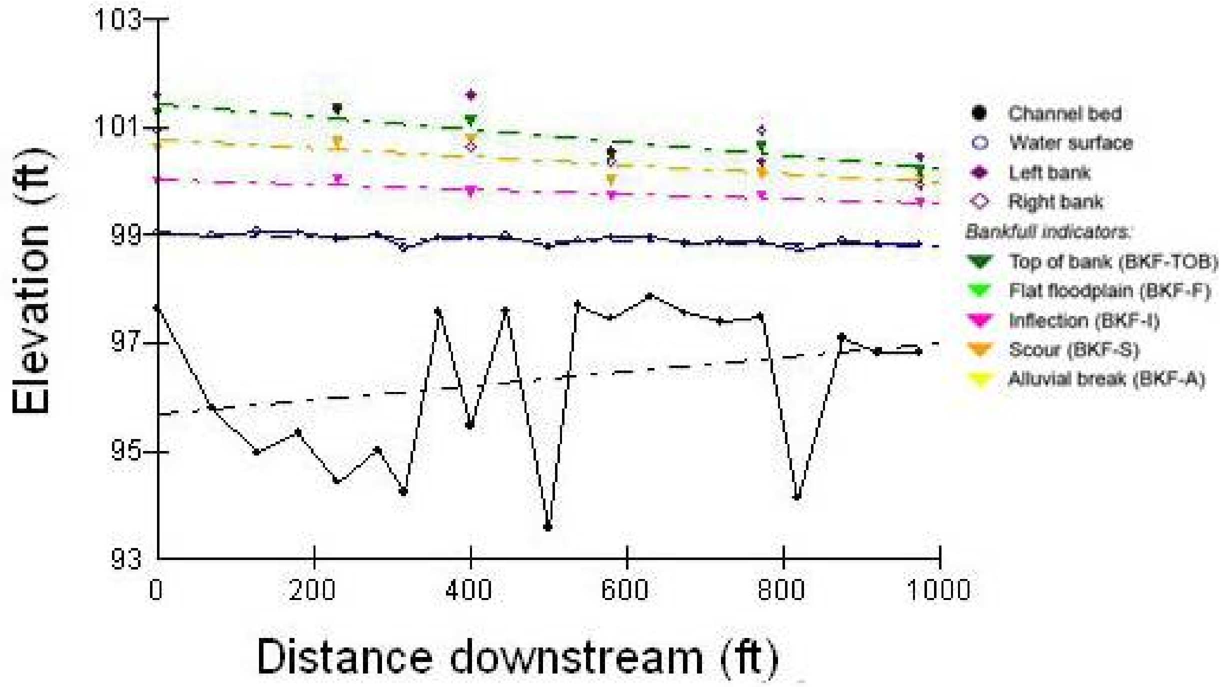
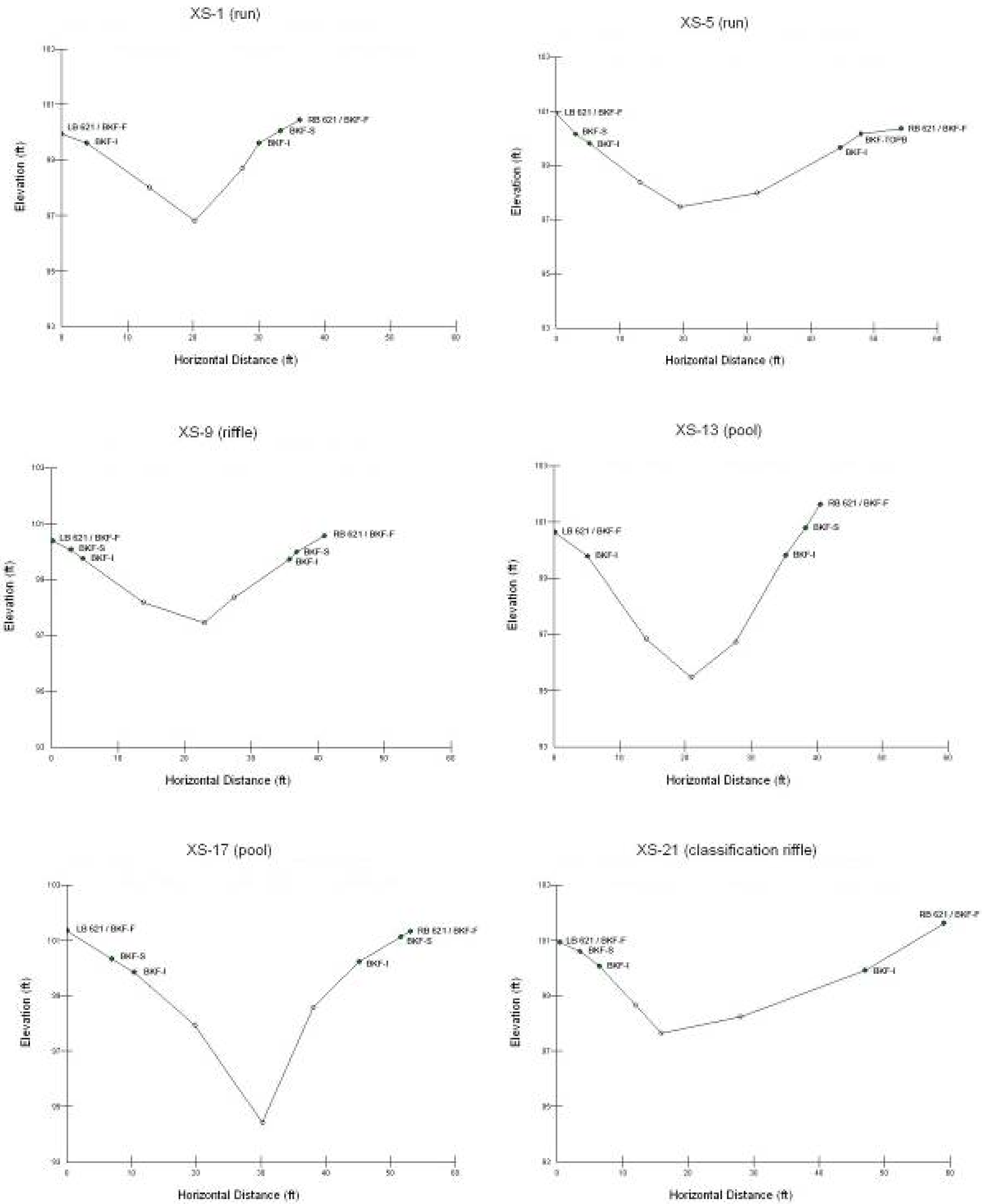


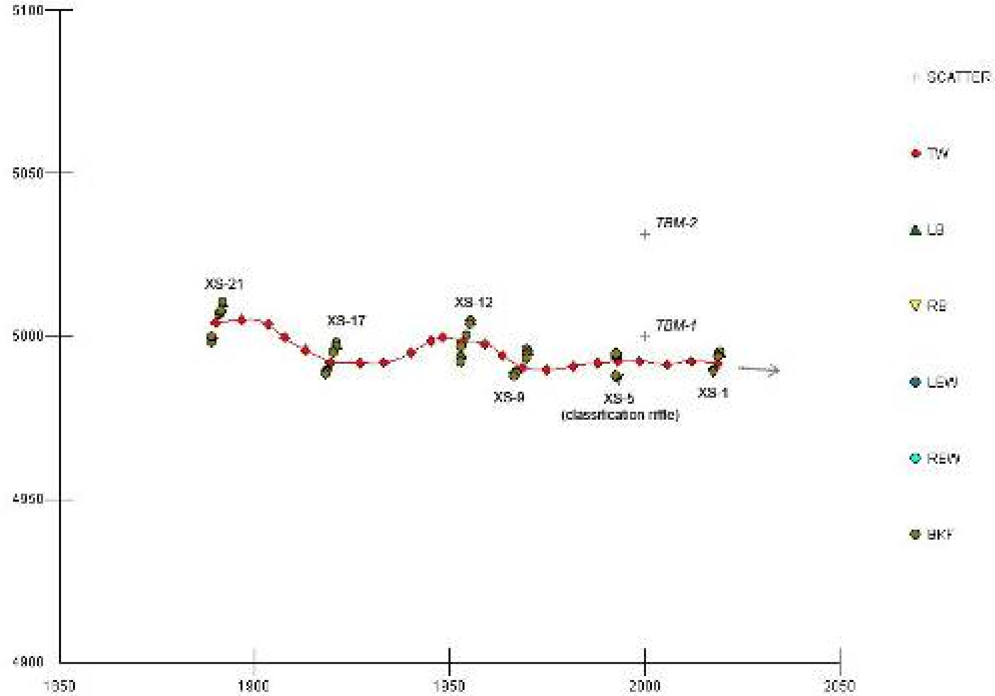
B

Figure B-11. Fisheating Creek at Palmdale. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-11. Fisheating Creek at Palmdale. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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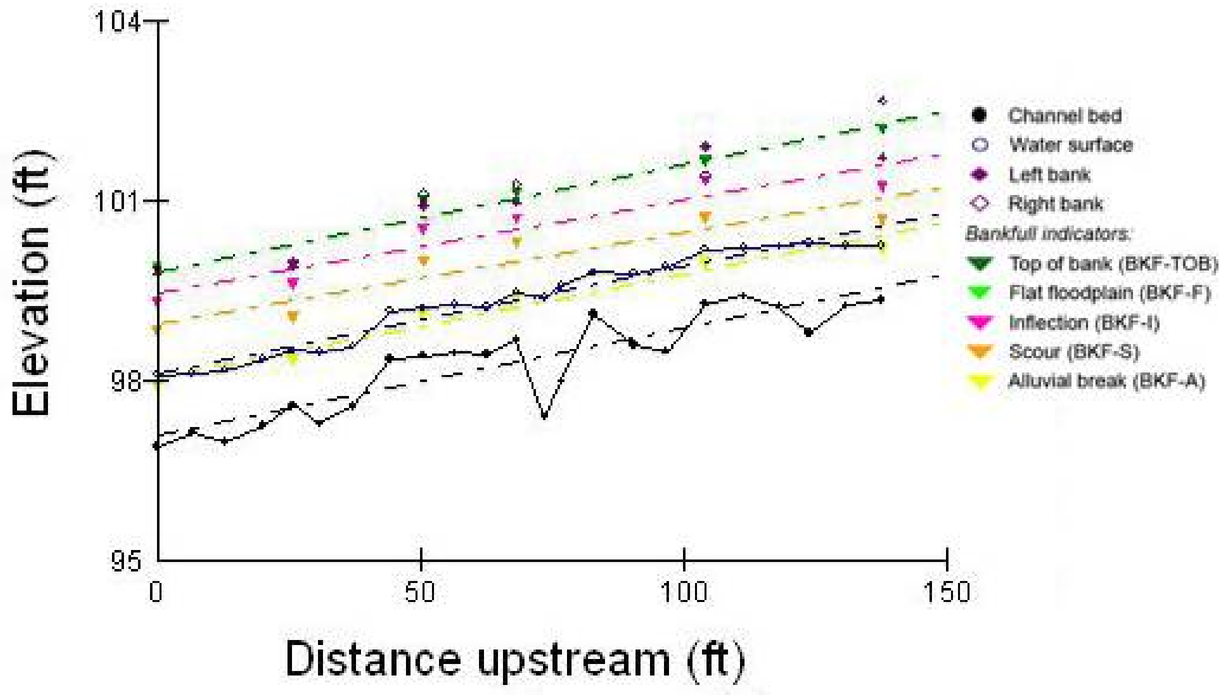
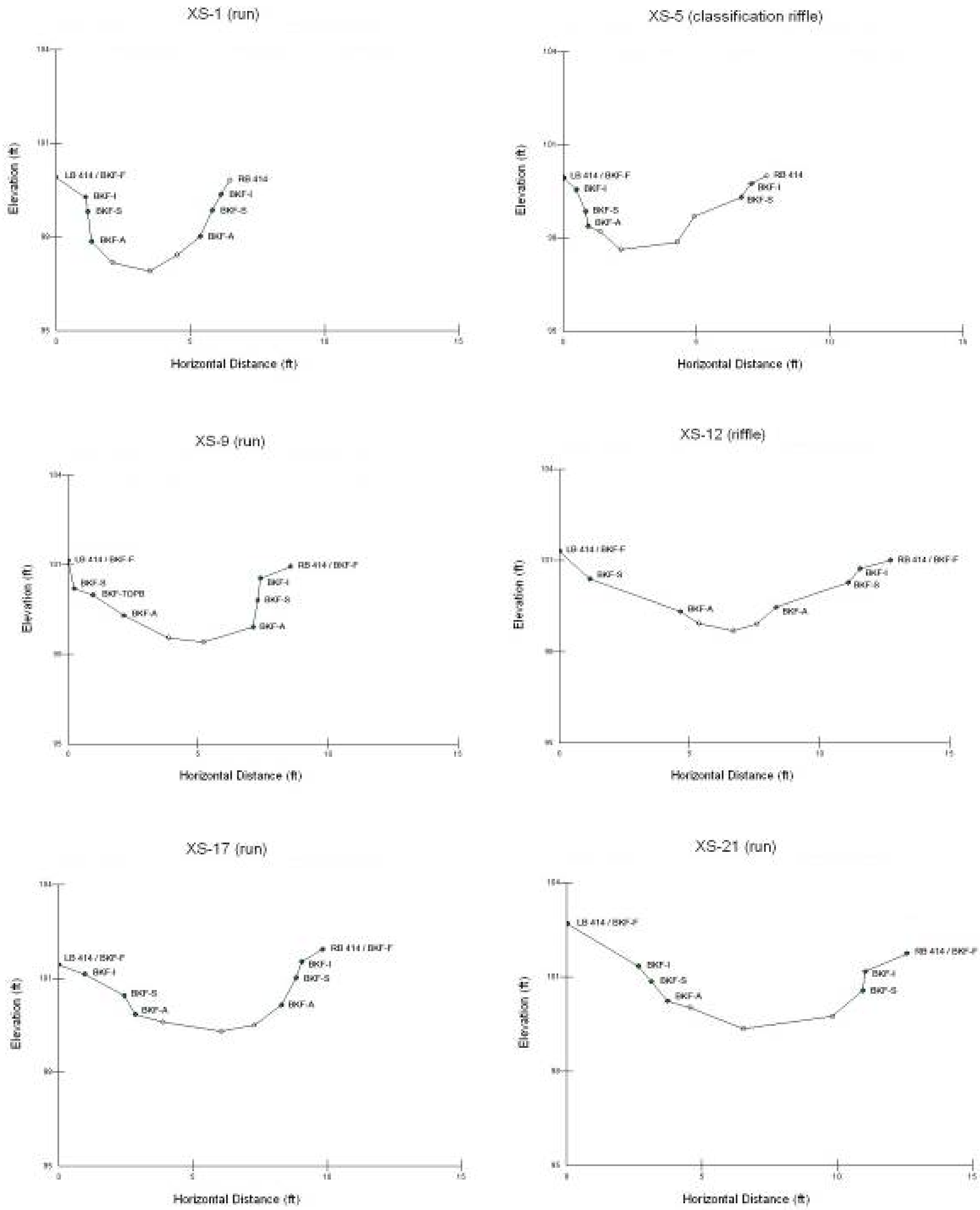


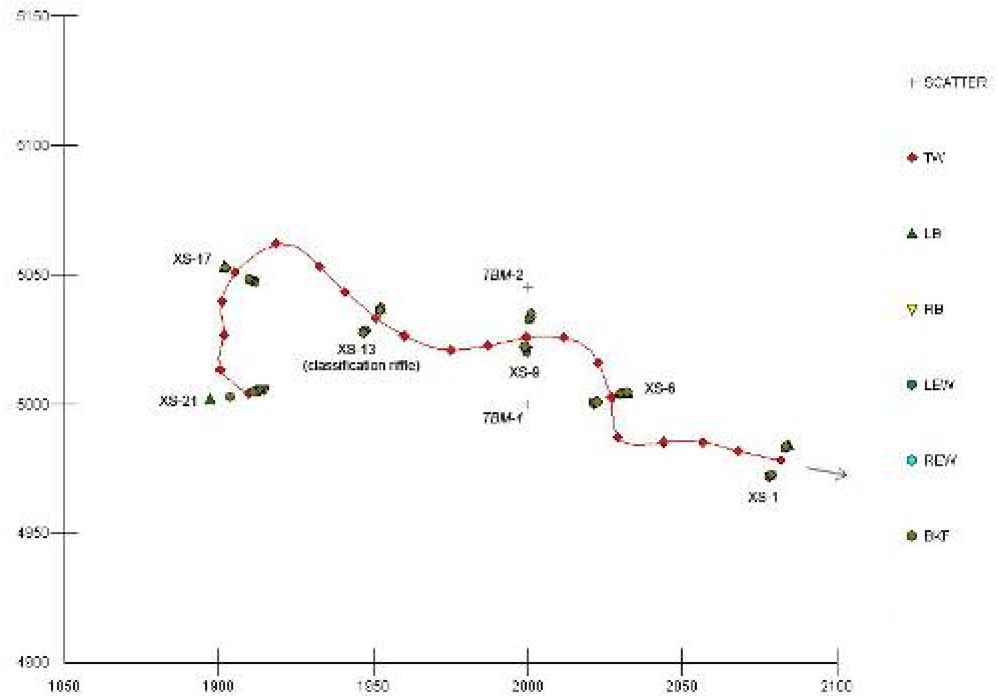
B

Figure B-12. Gold Head Branch. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-12. Gold Head Branch. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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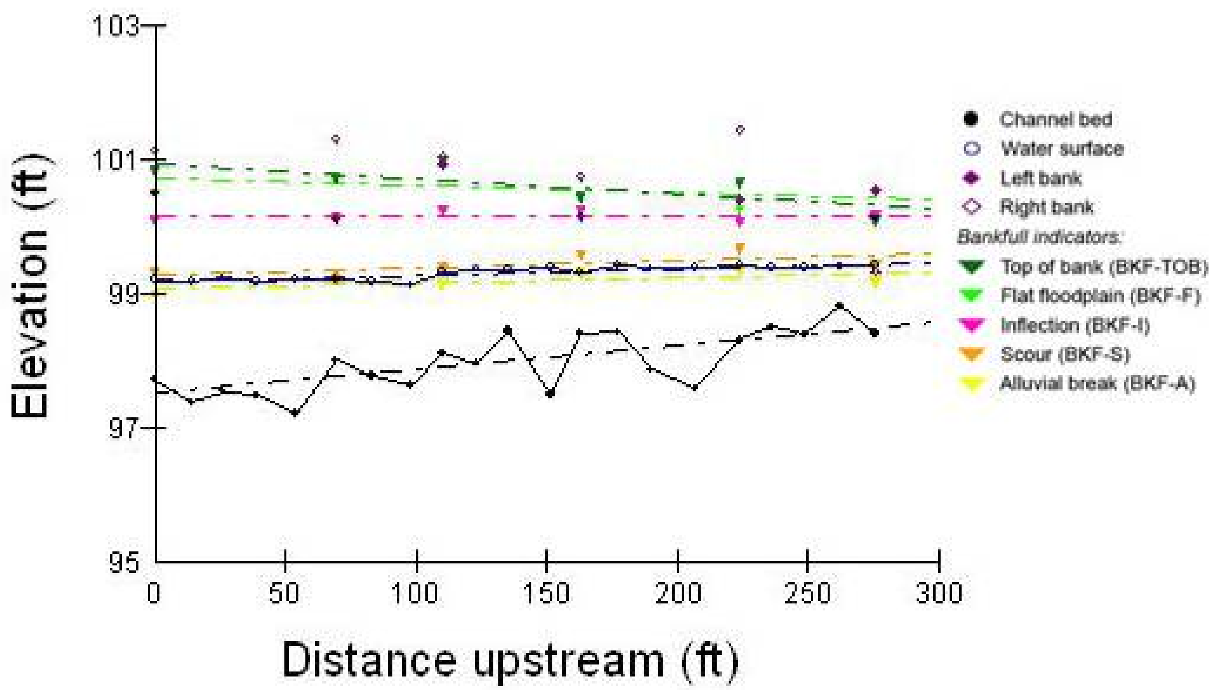

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Figure B-13. Hammock Branch. A) Plan form. B) Longitudinal profile. C) Cross-sections.

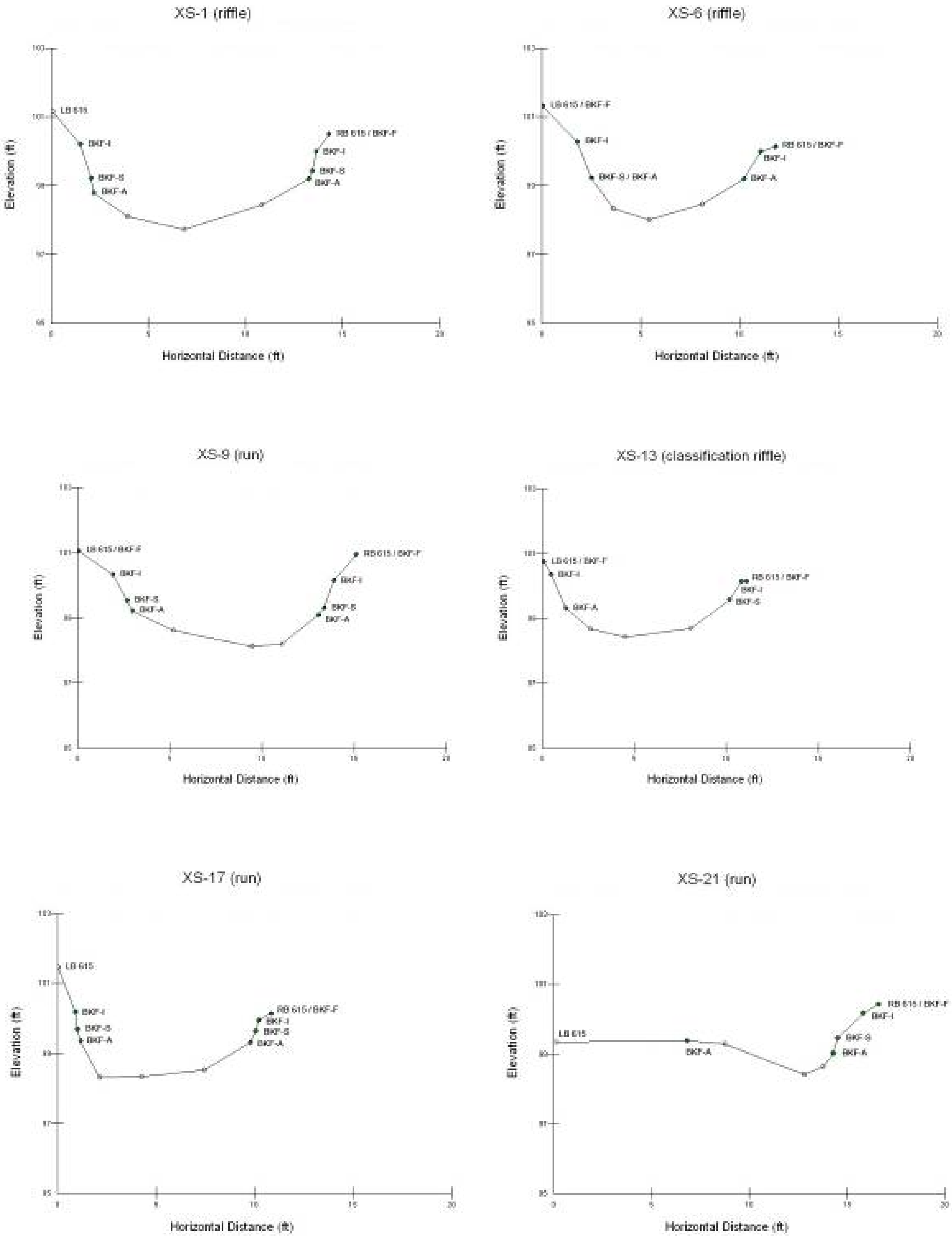

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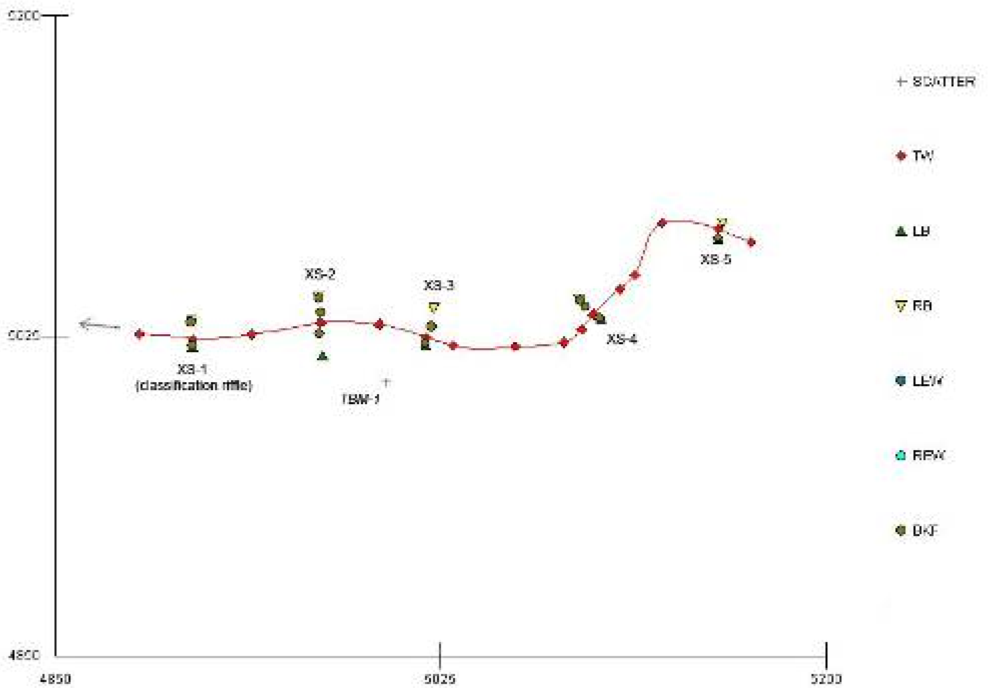
Figure B-13. Hammock Branch. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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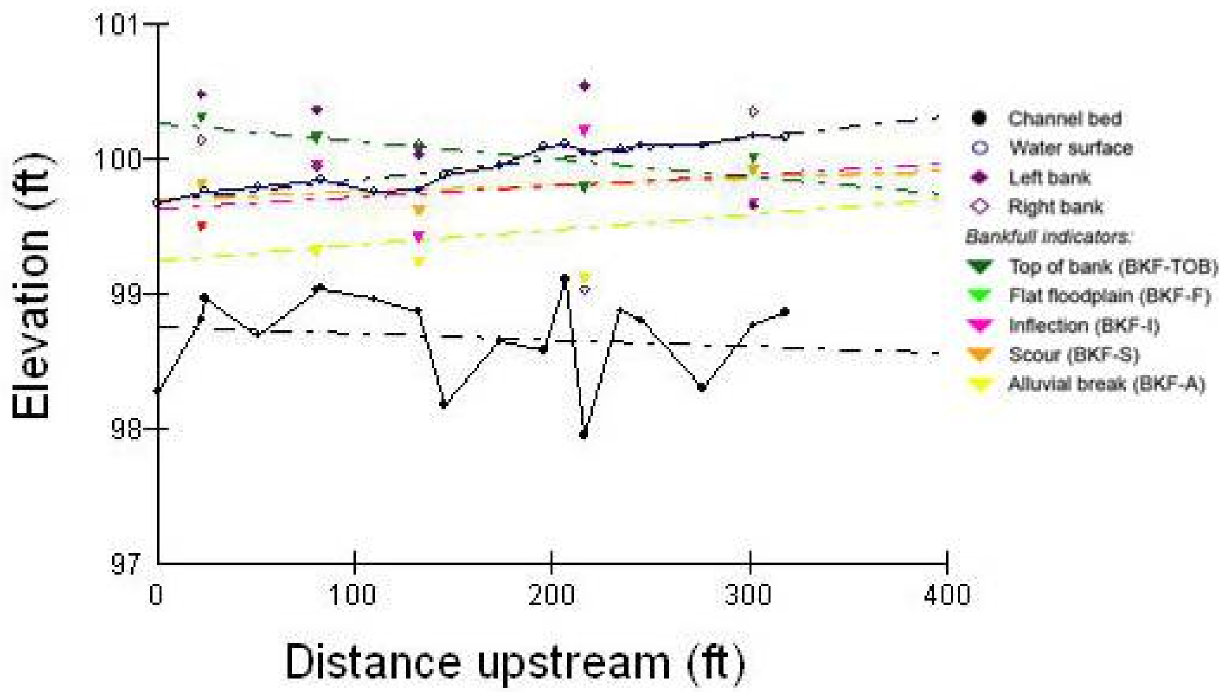
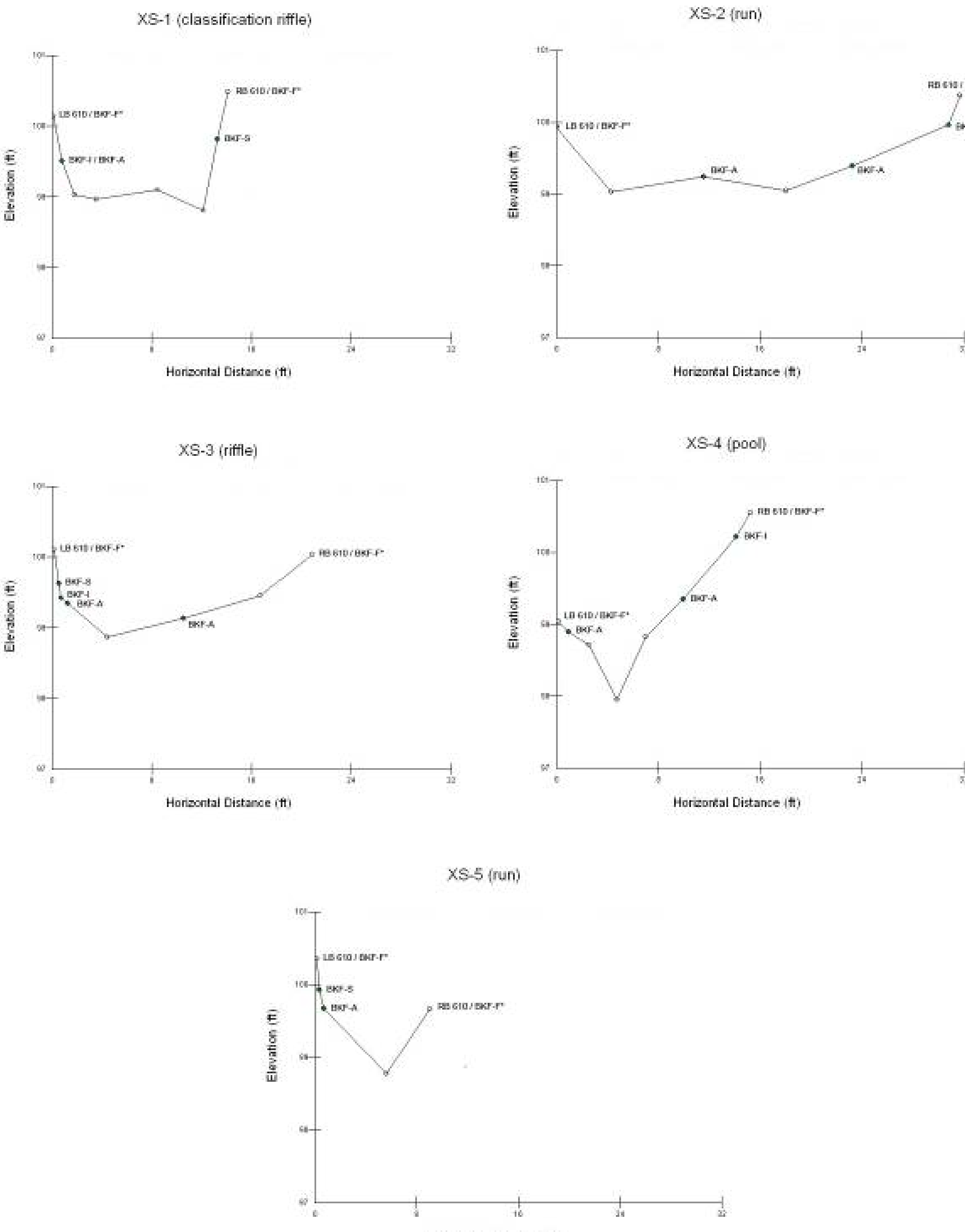


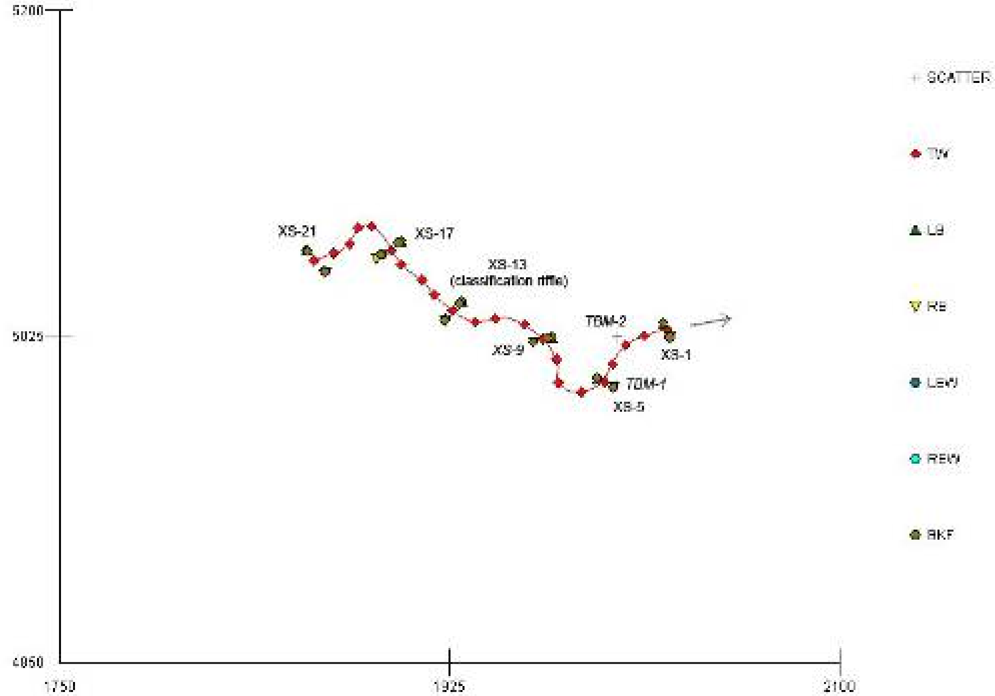
B

Figure B-14. Hickory Creek near Ona. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-14. Hickory Creek near Ona. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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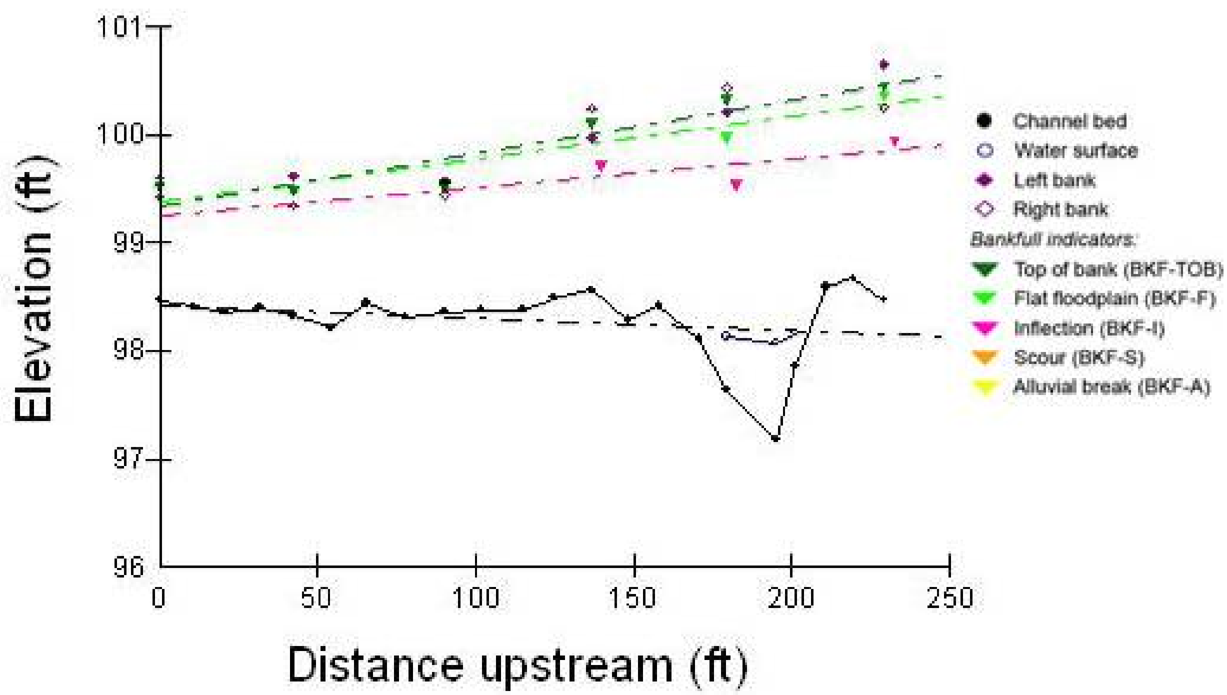

B

Figure B-15. Hillsborough River tributary. A) Plan form. B) Longitudinal profile. C) Cross-sections.

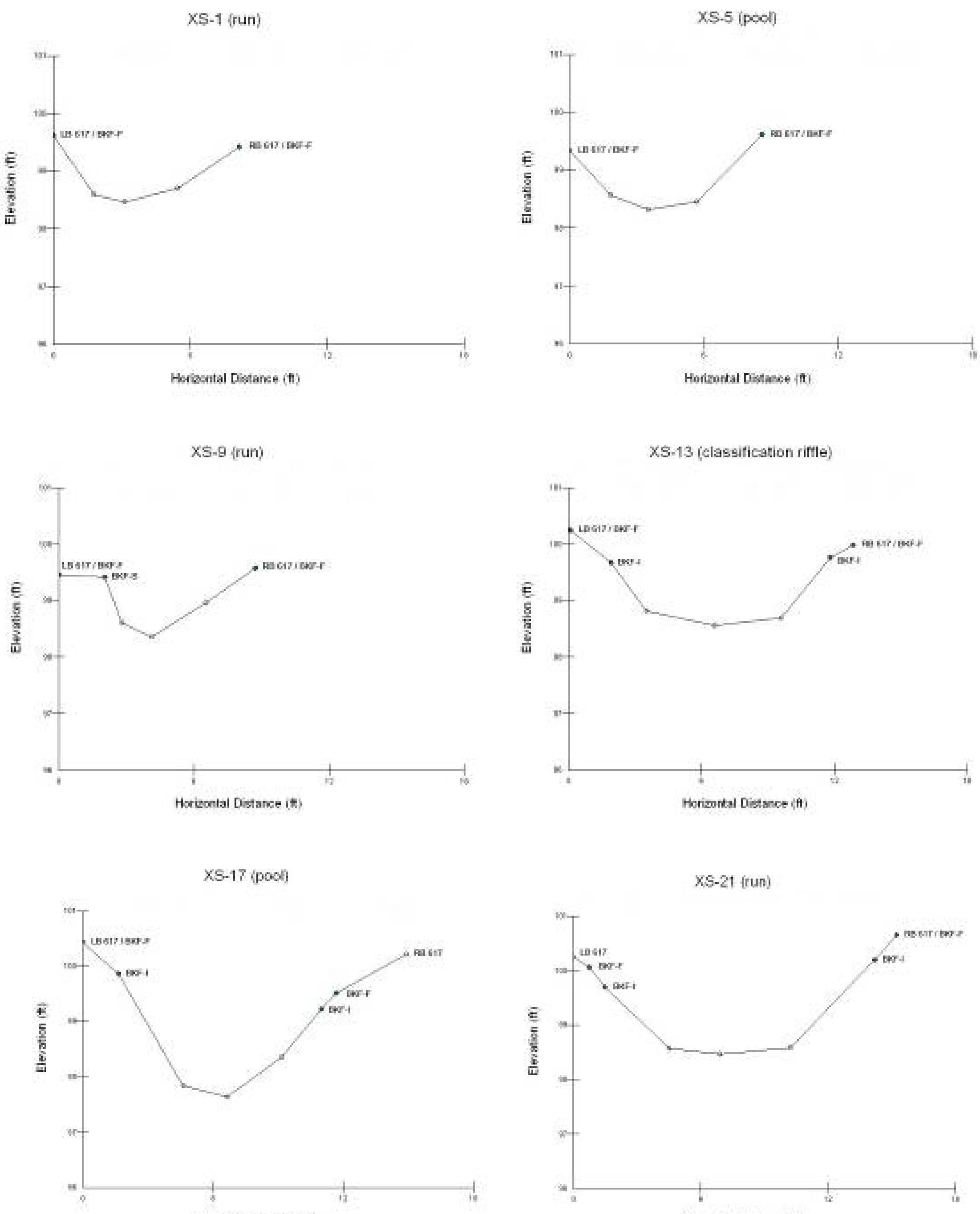

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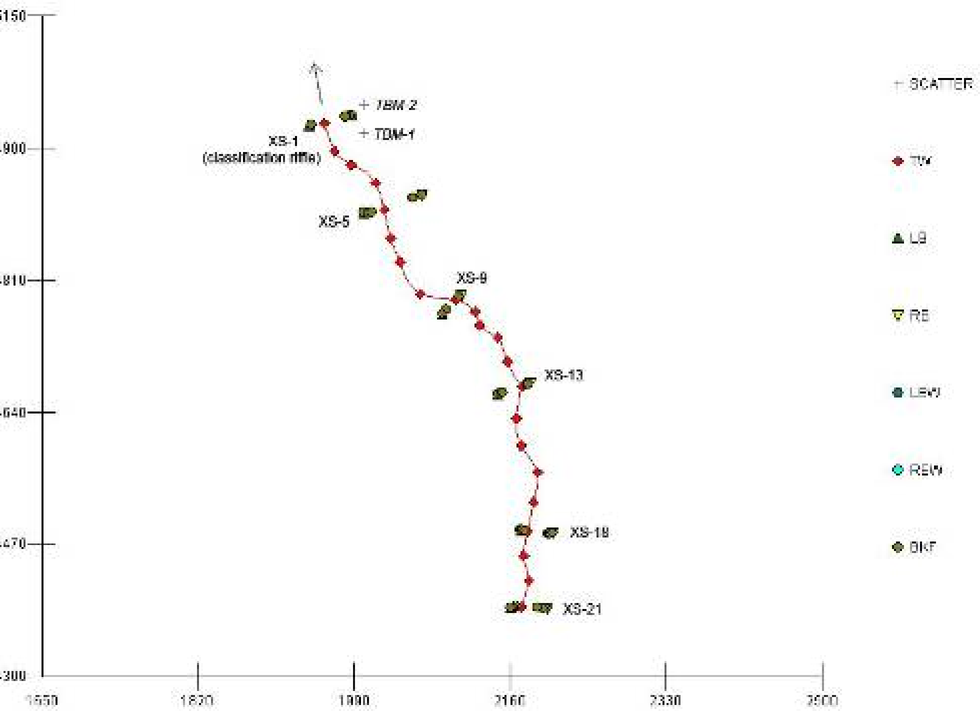
Figure B-15. Hillsborough River tributary. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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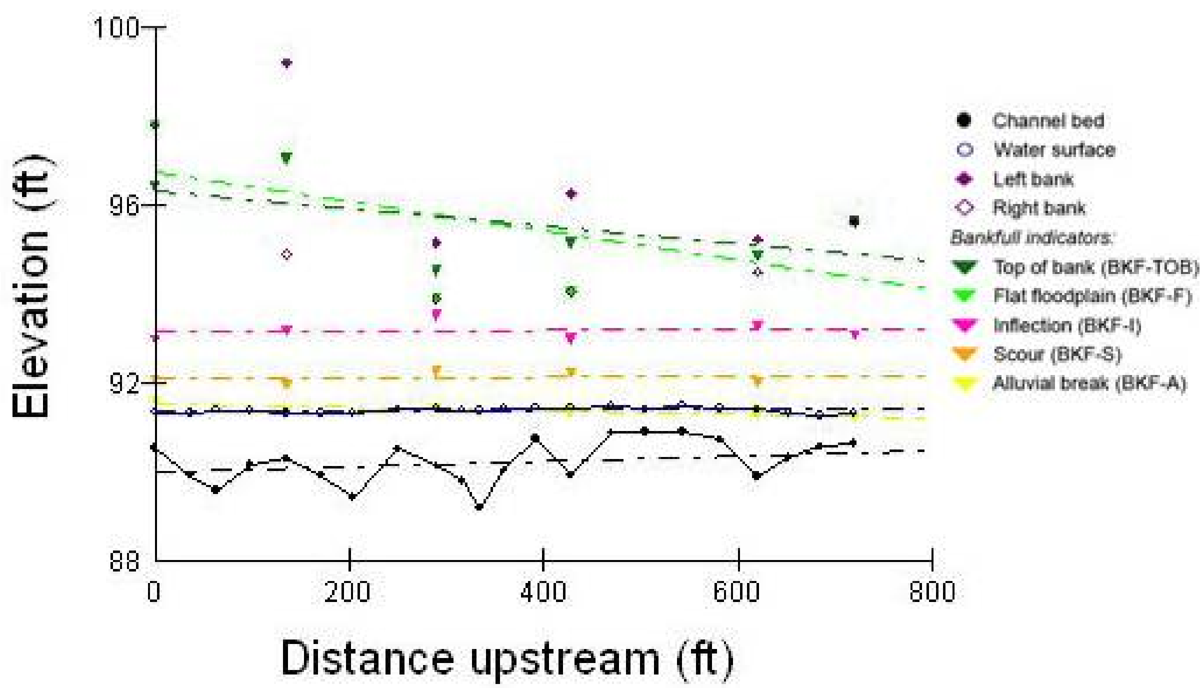
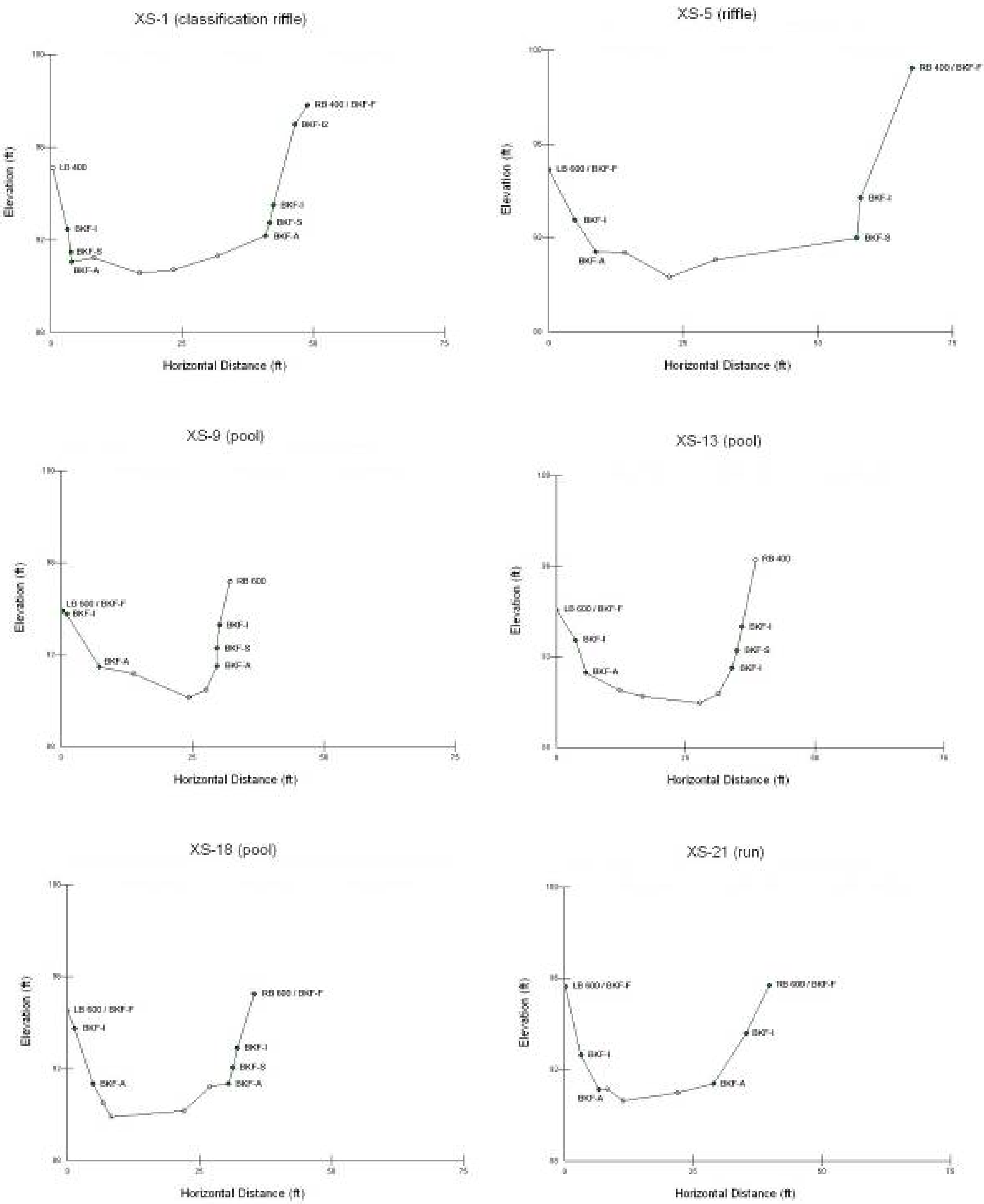


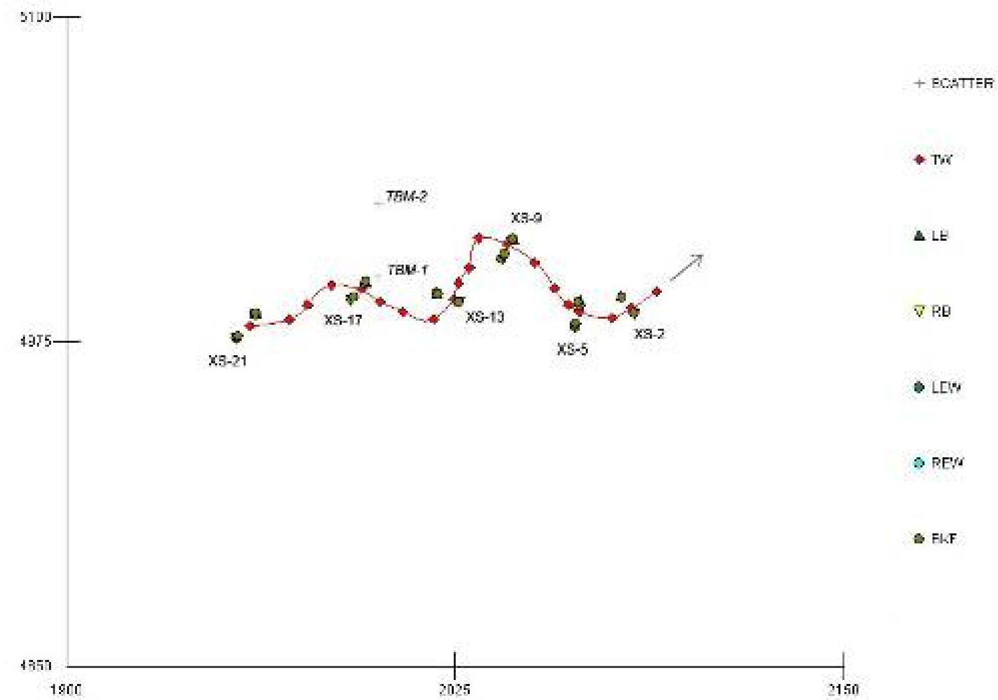
B

Figure B-16. Horse Creek near Arcadia. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-16. Horse Creek near Arcadia. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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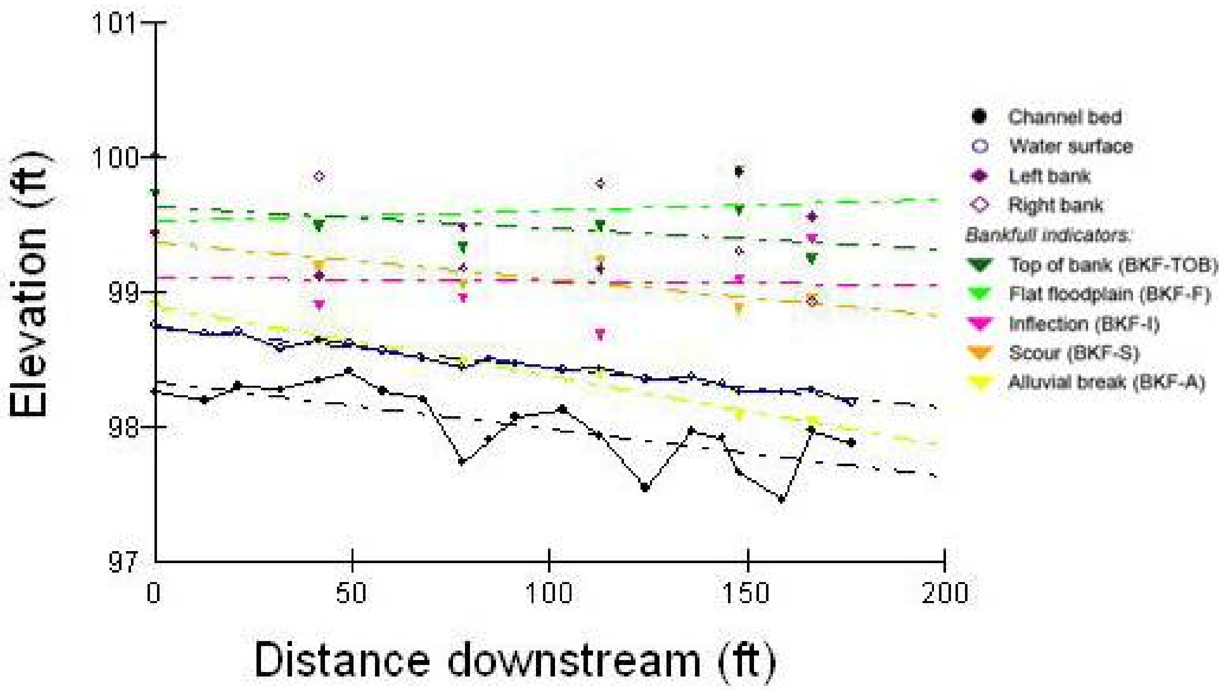
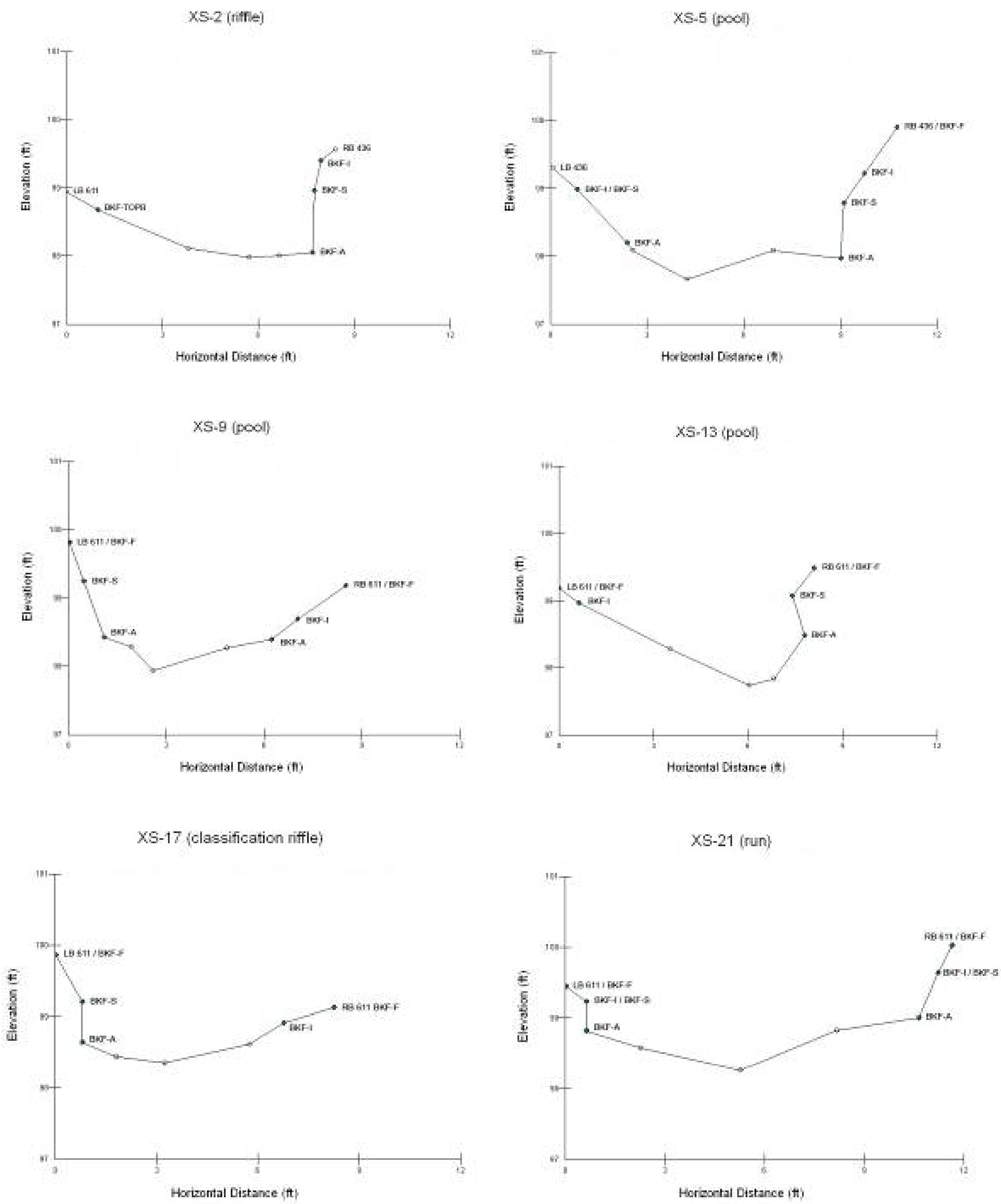


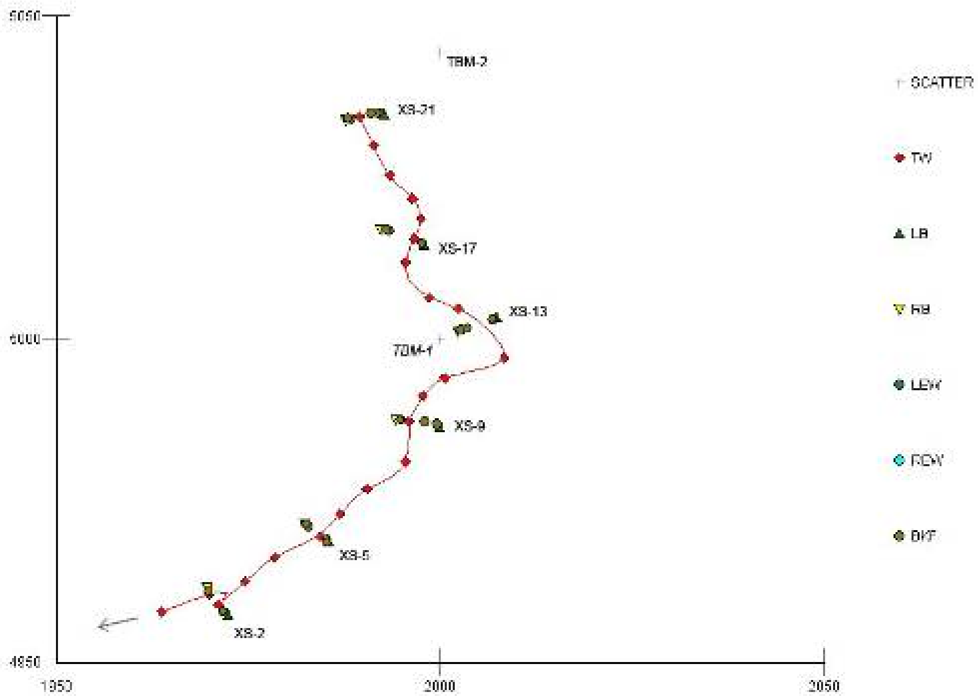
B

Figure B-17. Jack Creek. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-17. Jack Creek. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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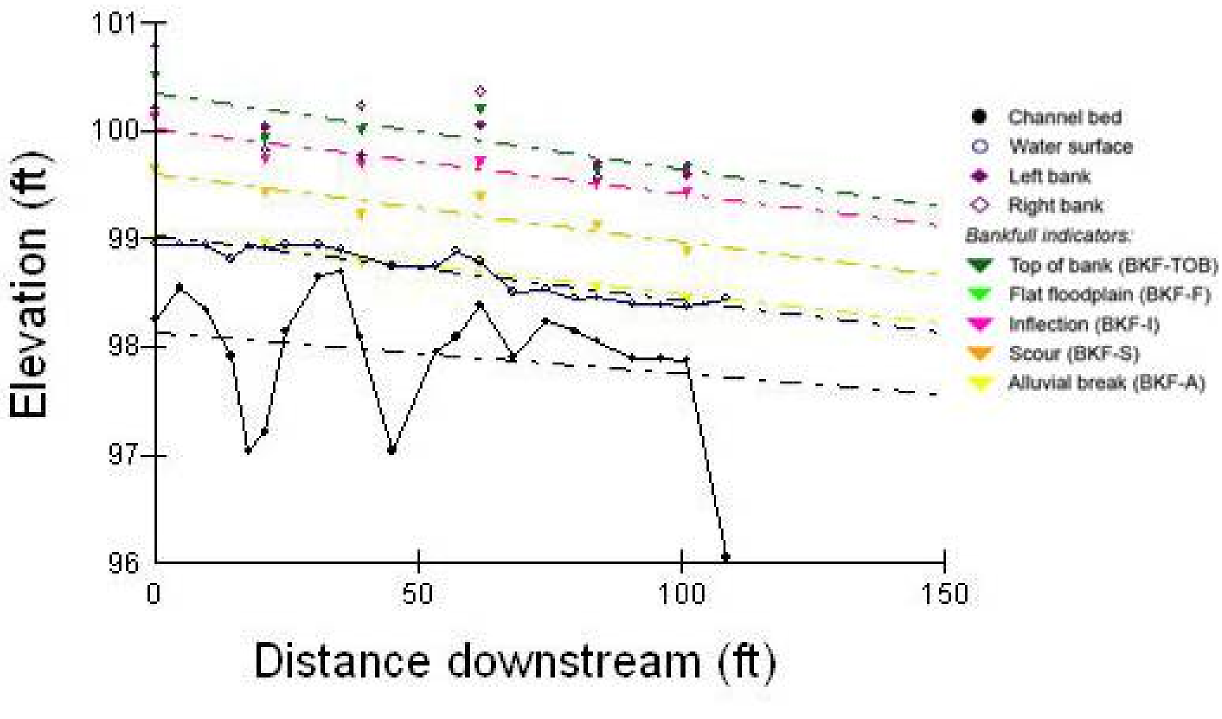
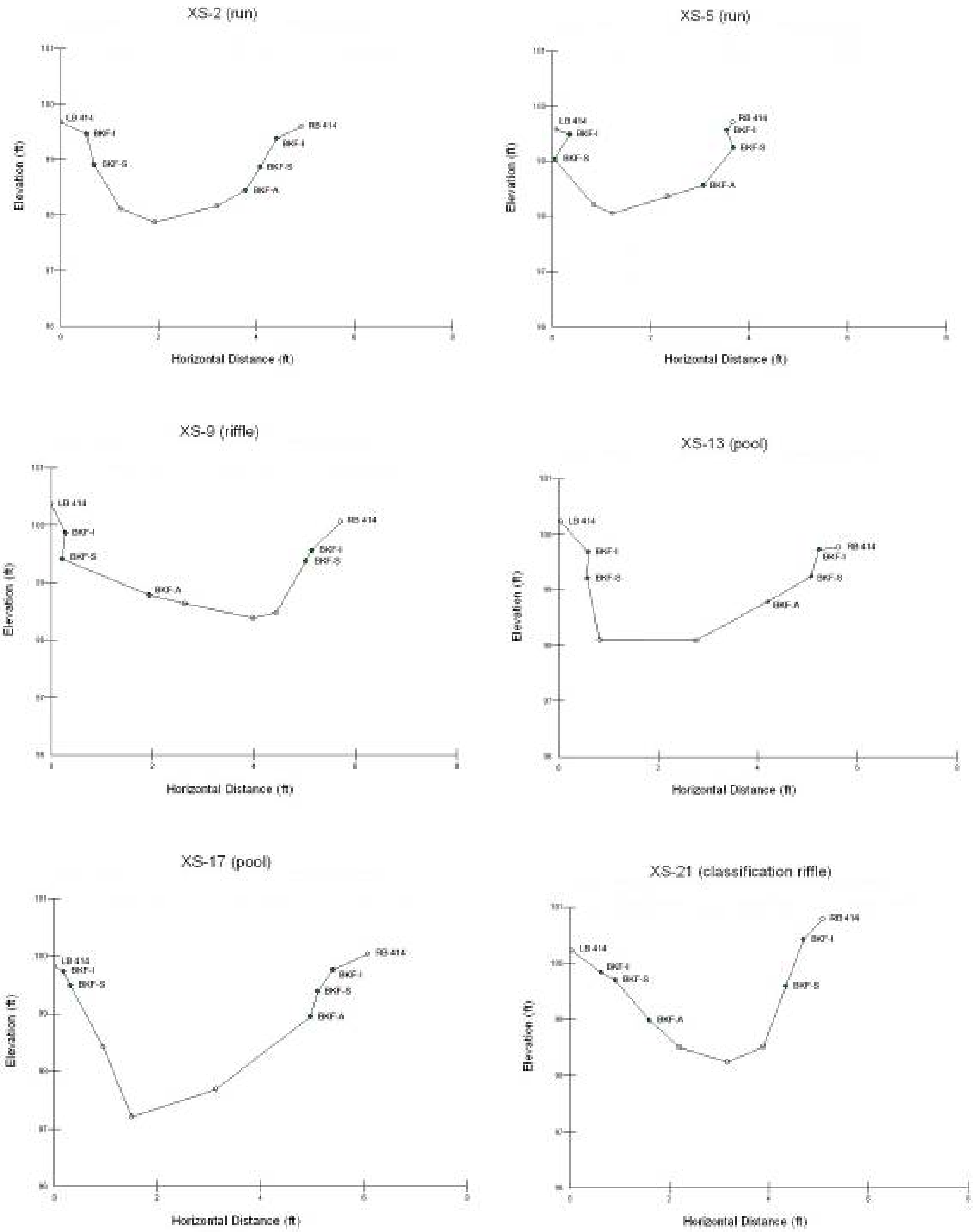


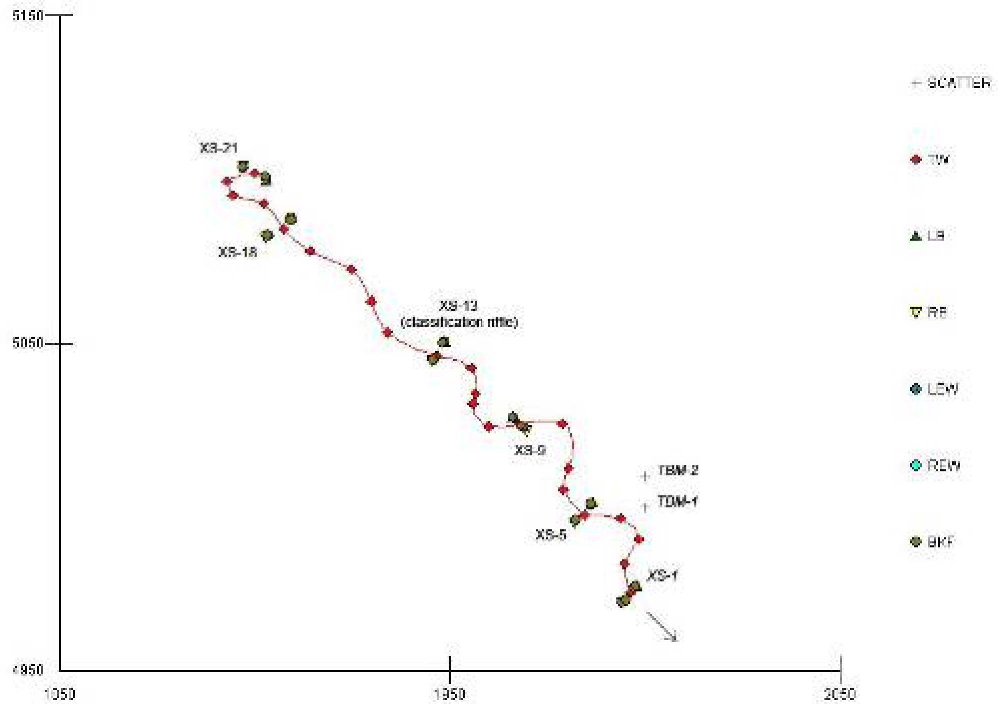
B

Figure B-18. Jumping Gully. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-18. Jumping Gully. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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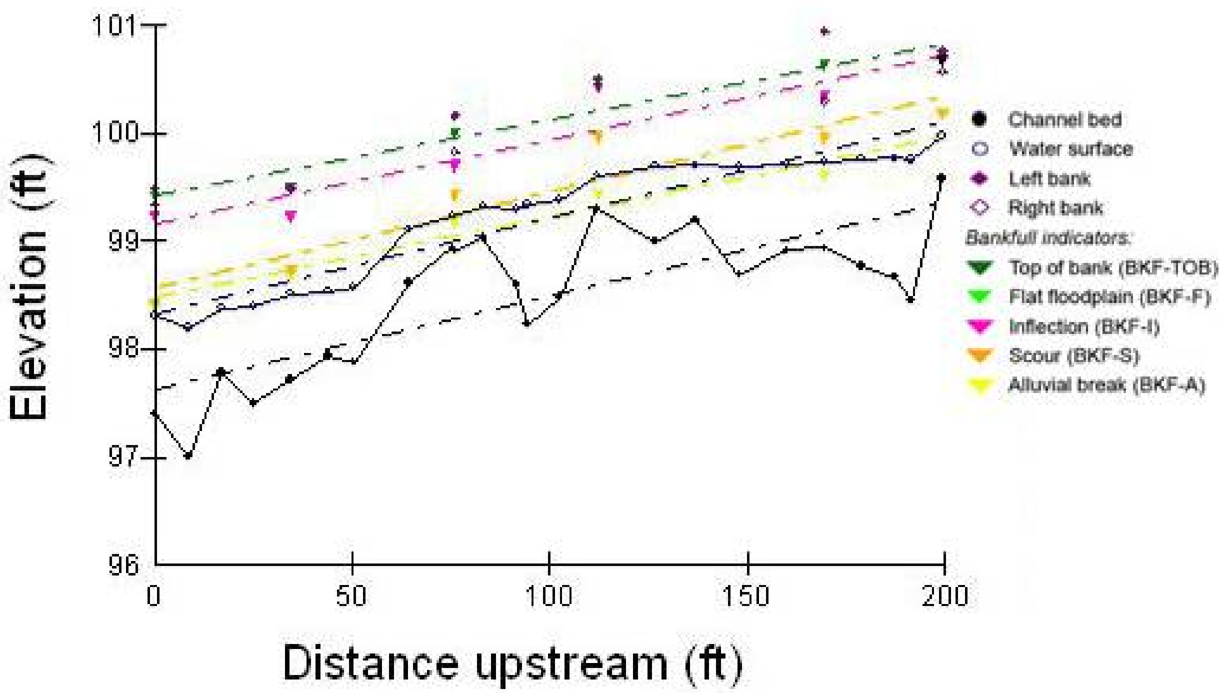
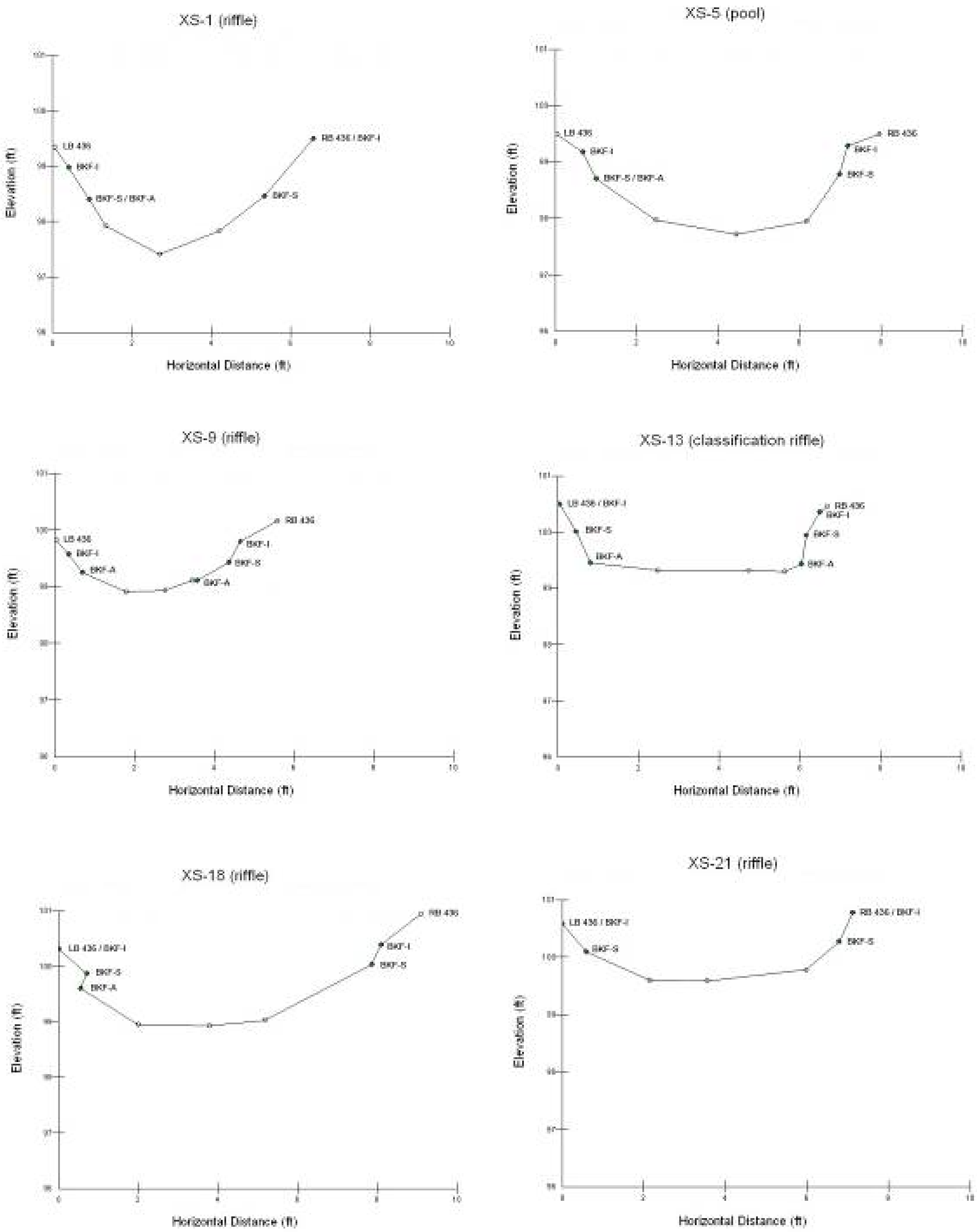


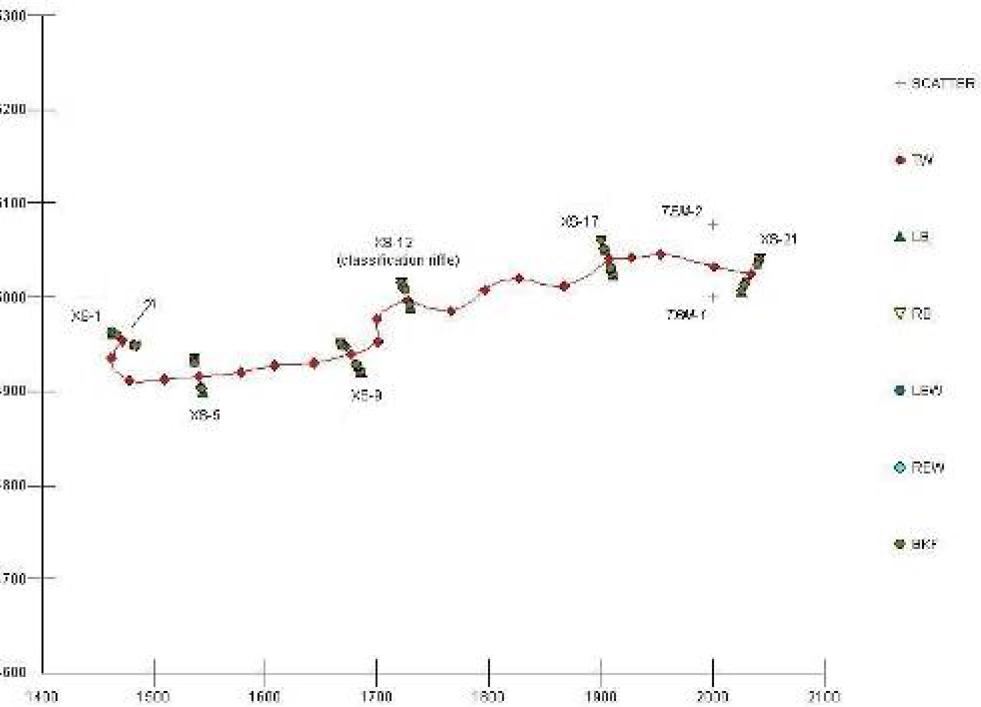
B

Figure B-19. Lake June-in-Winter tributary. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-19. Lake June-in-Winter tributary. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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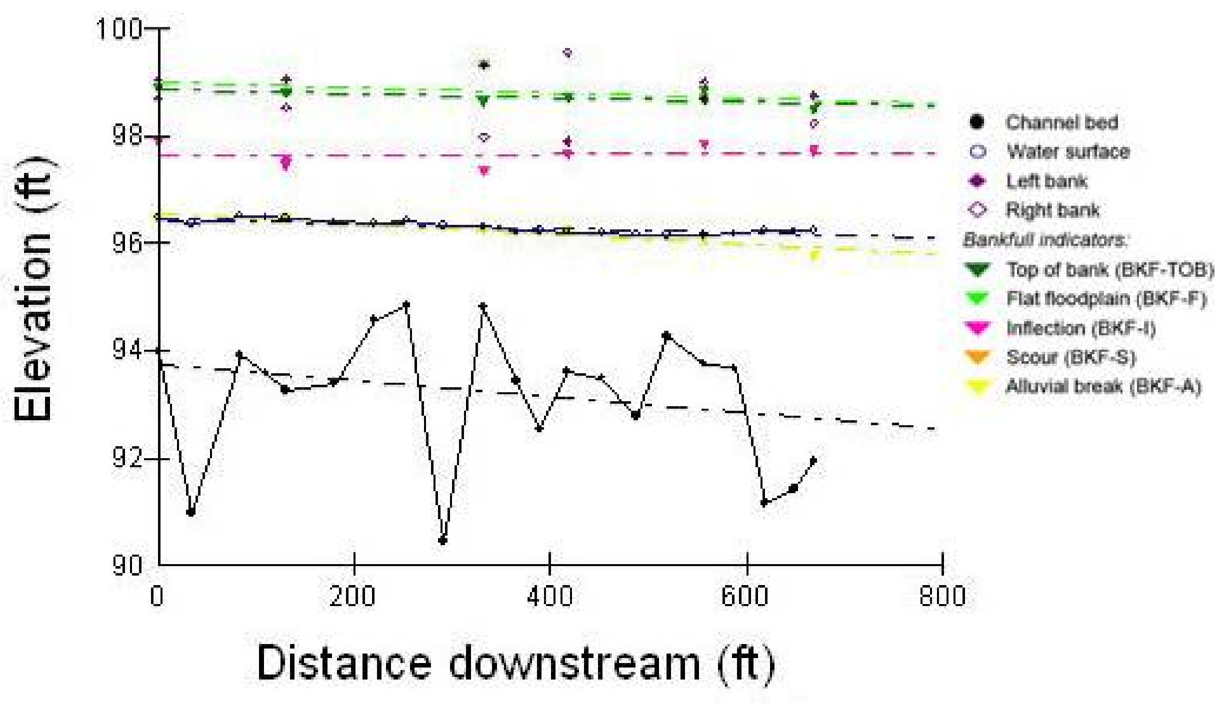
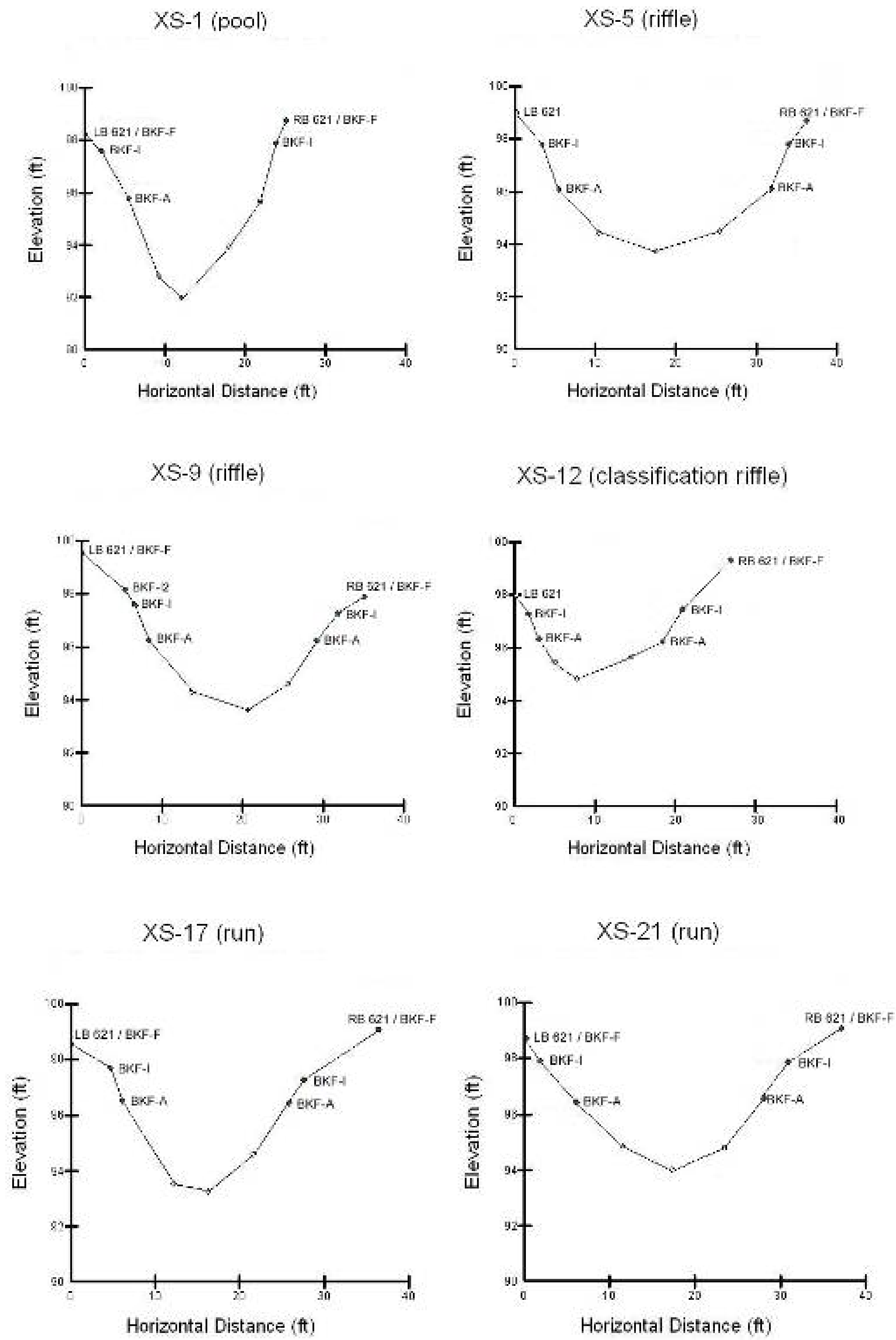


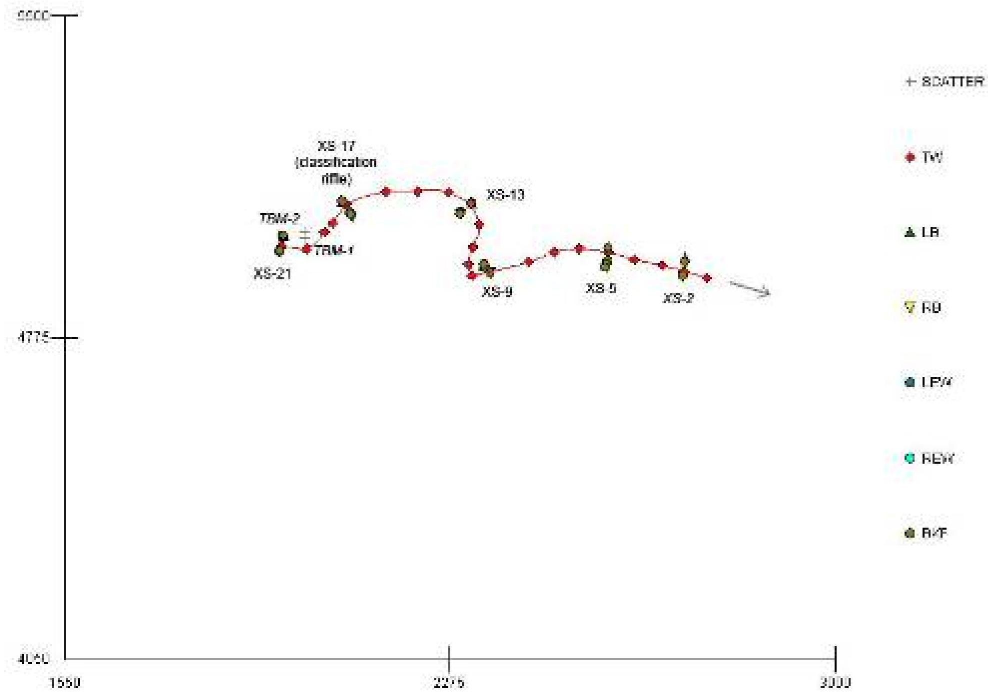
B

Figure B-20. Little Haw Creek near Seville. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-20. Little Haw Creek near Seville. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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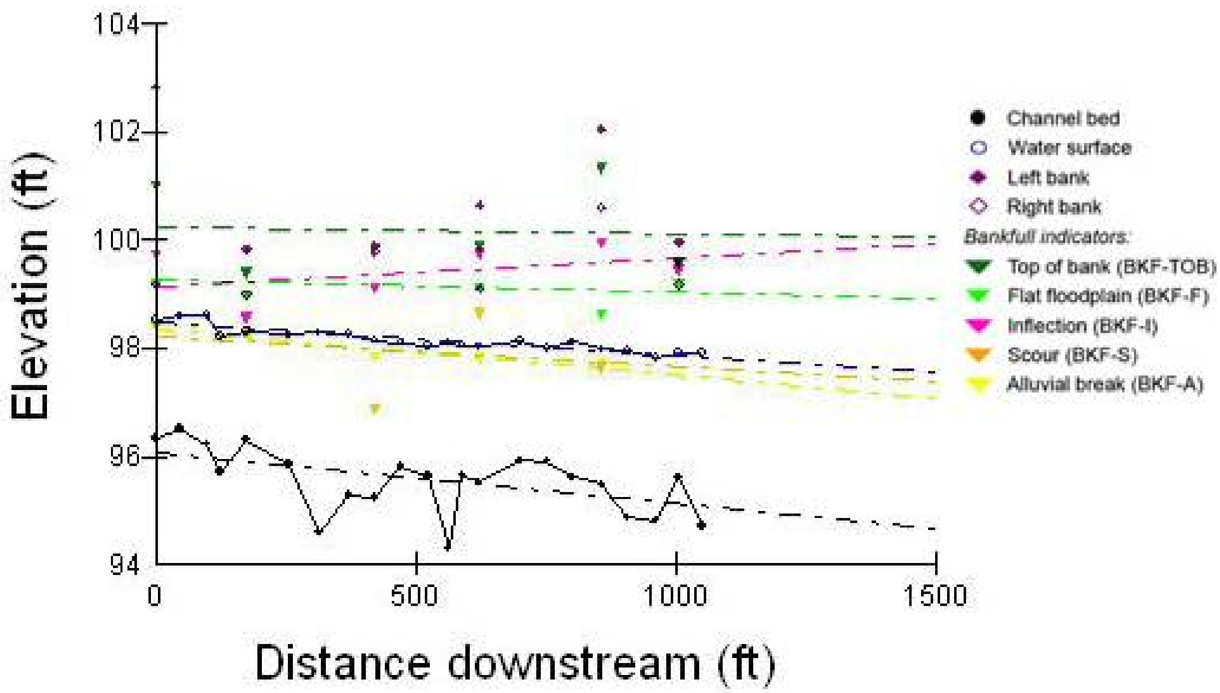
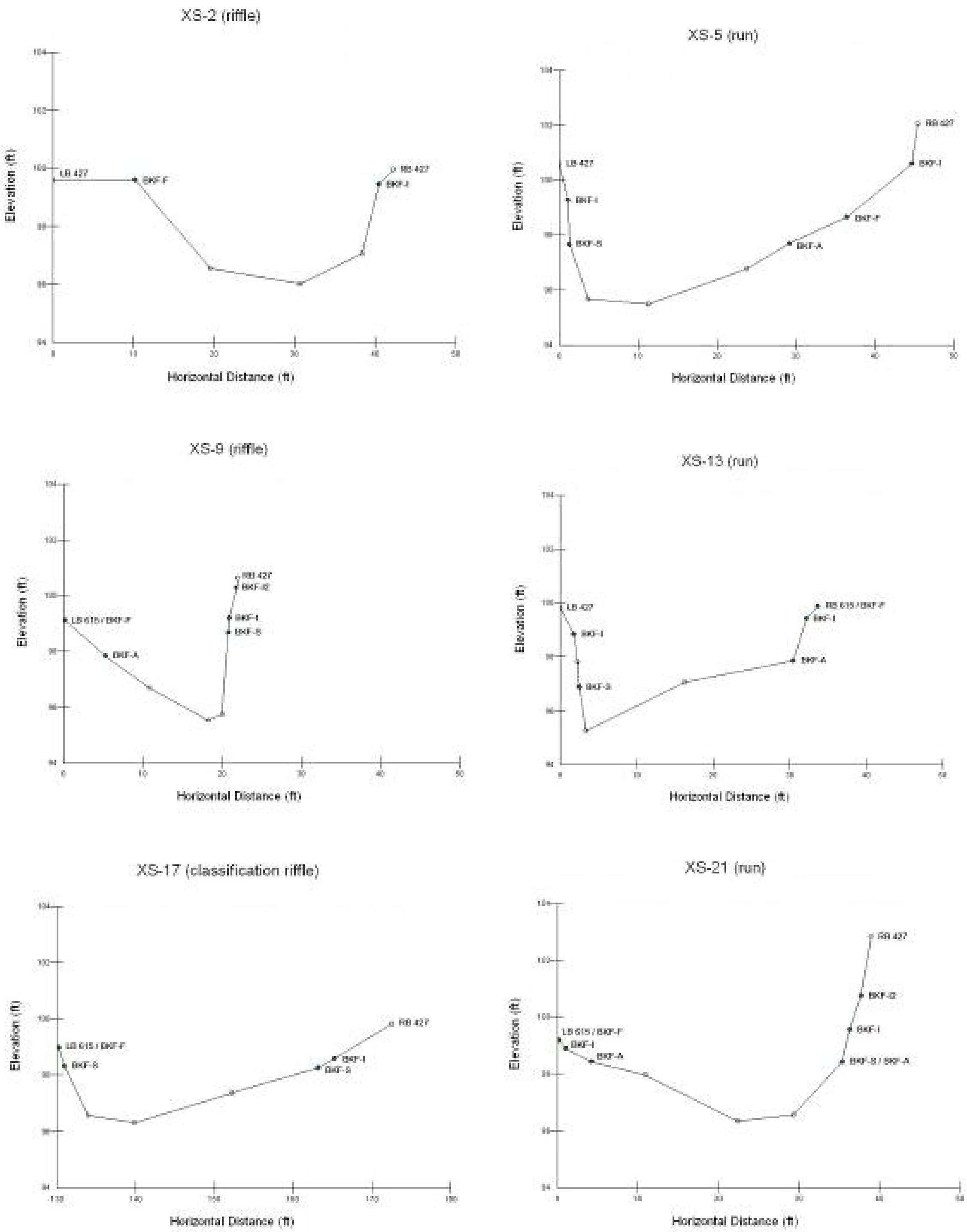


B

Figure B-21. Livingston Creek near Frostproof. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-21. Livingston Creek near Frostproof. A) Plan form. B) Longitudinal profile. C) Cross-sections.

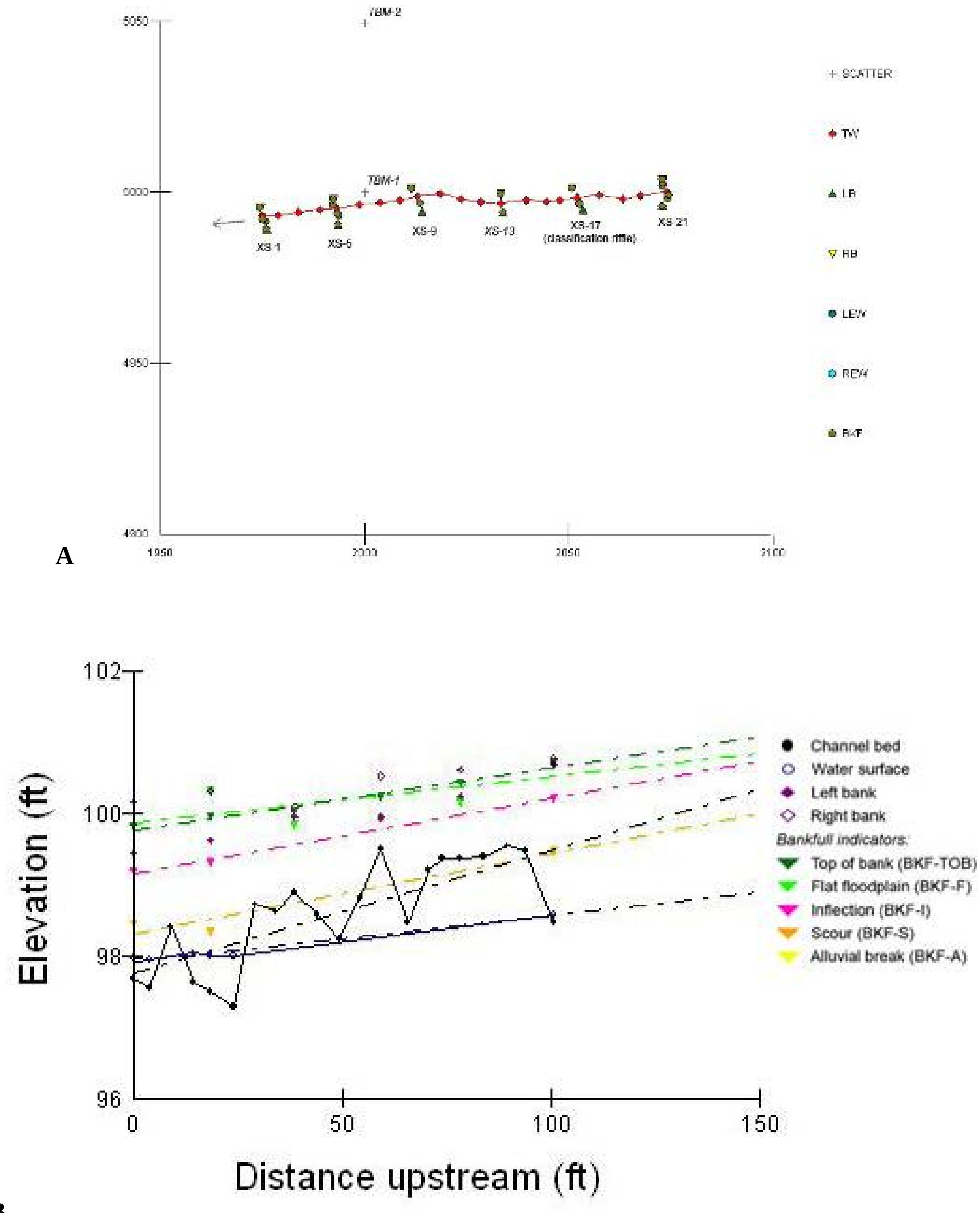
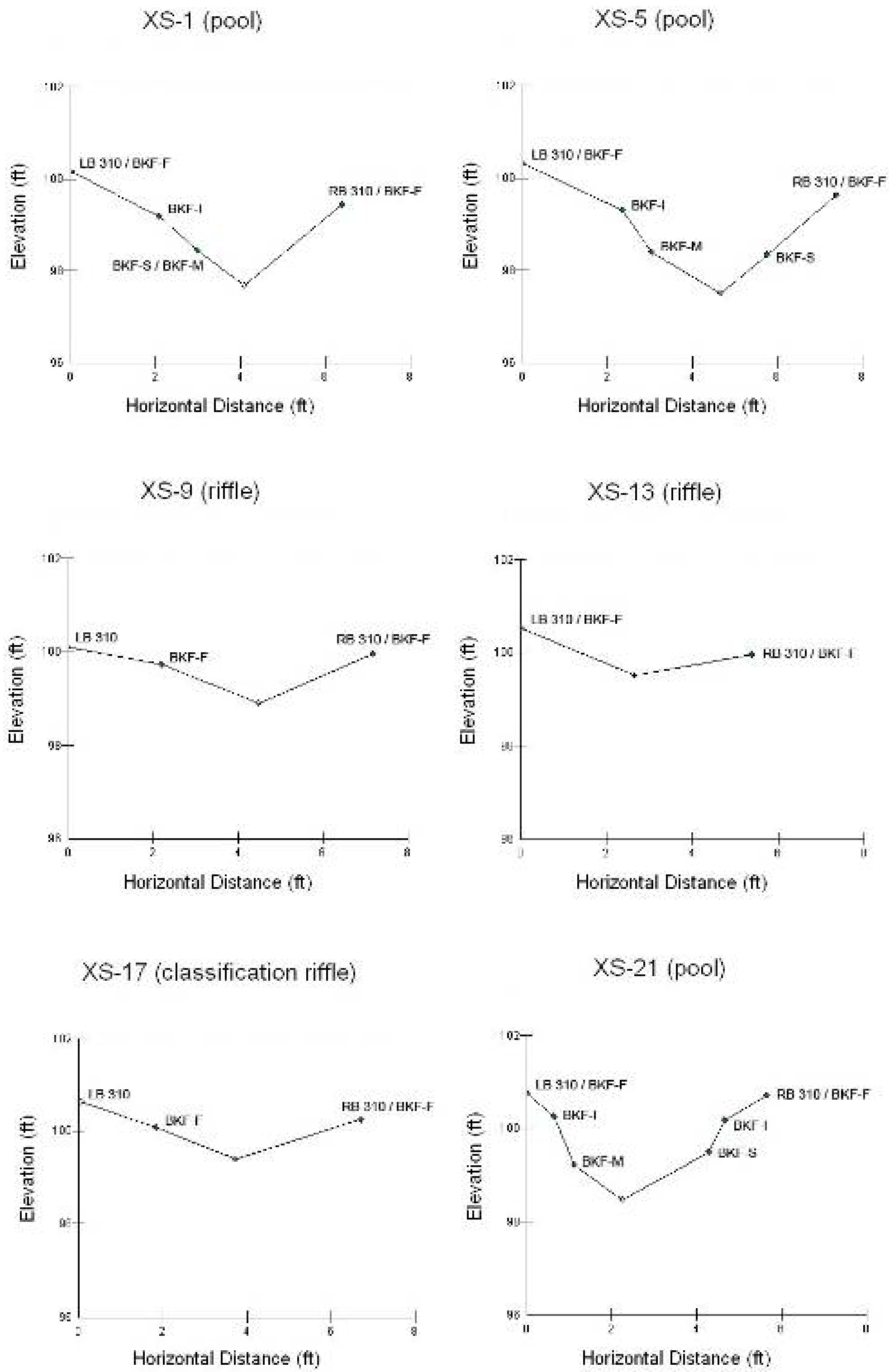
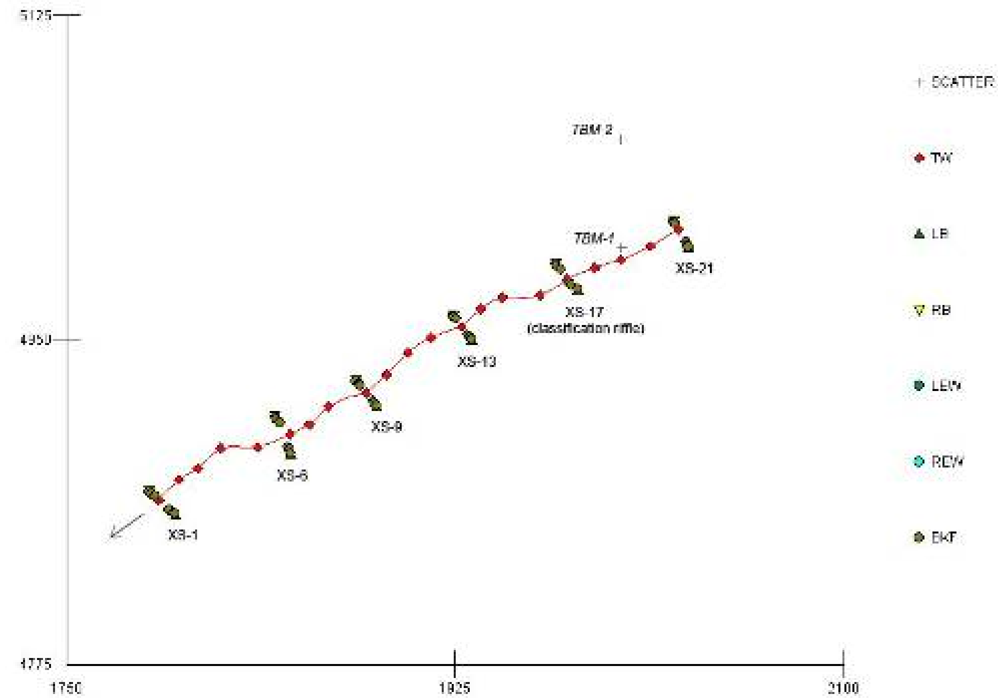


Figure B-22. Livingston Creek tributary. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-22. Livingston Creek tributary. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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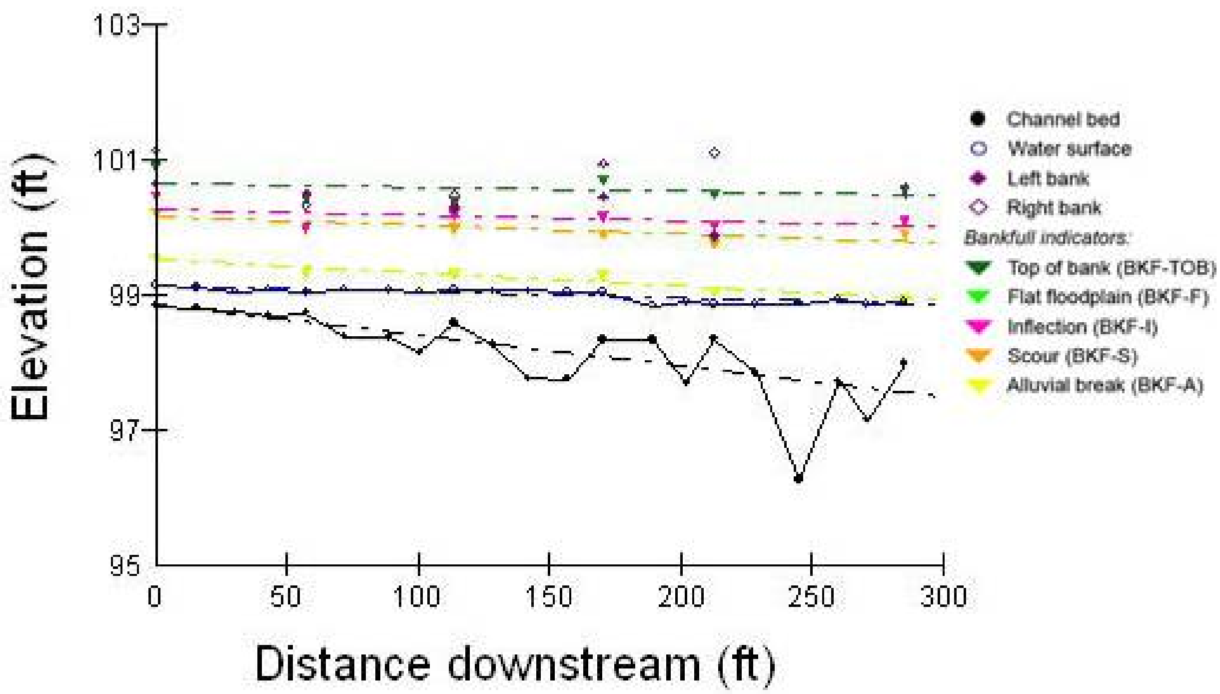
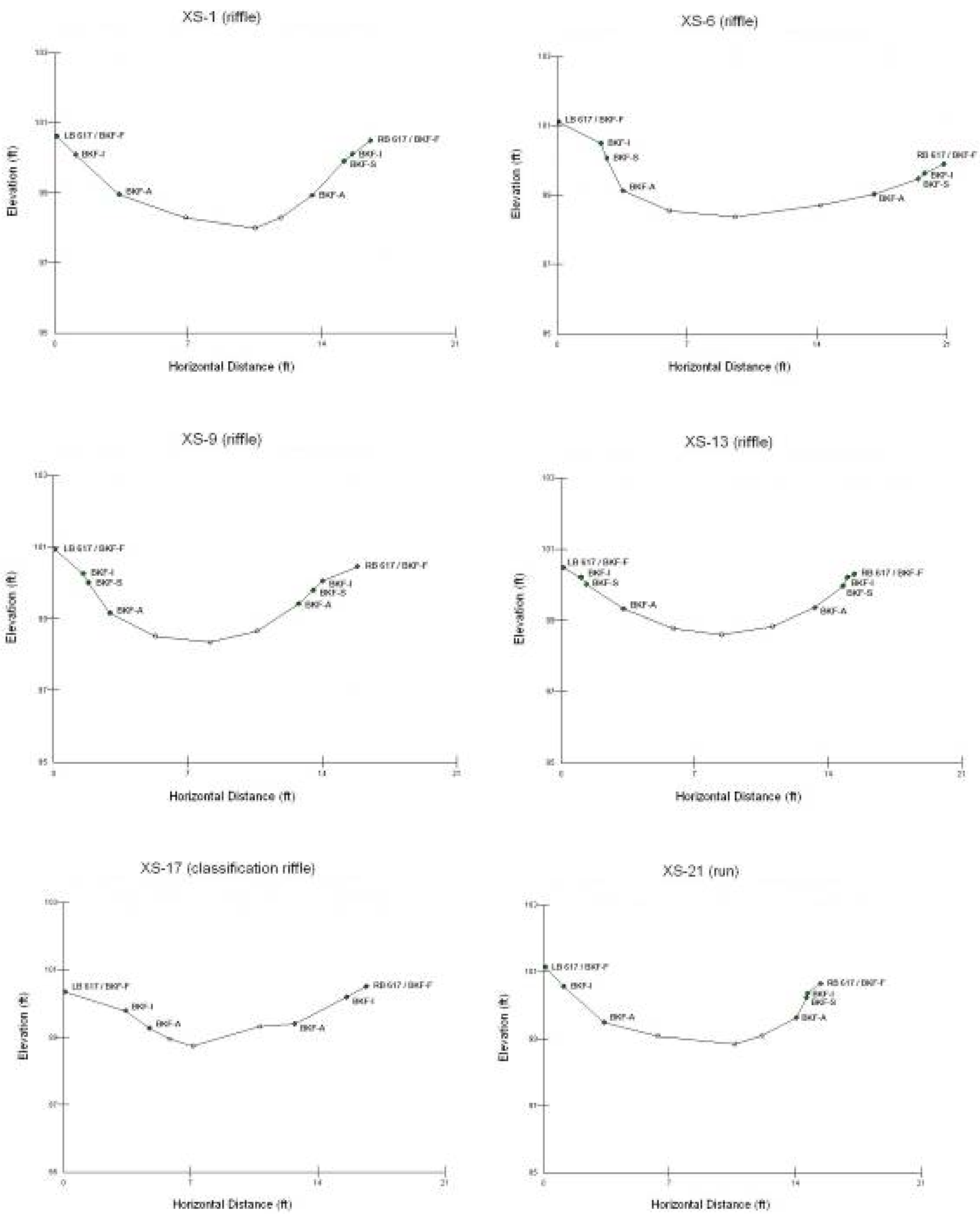


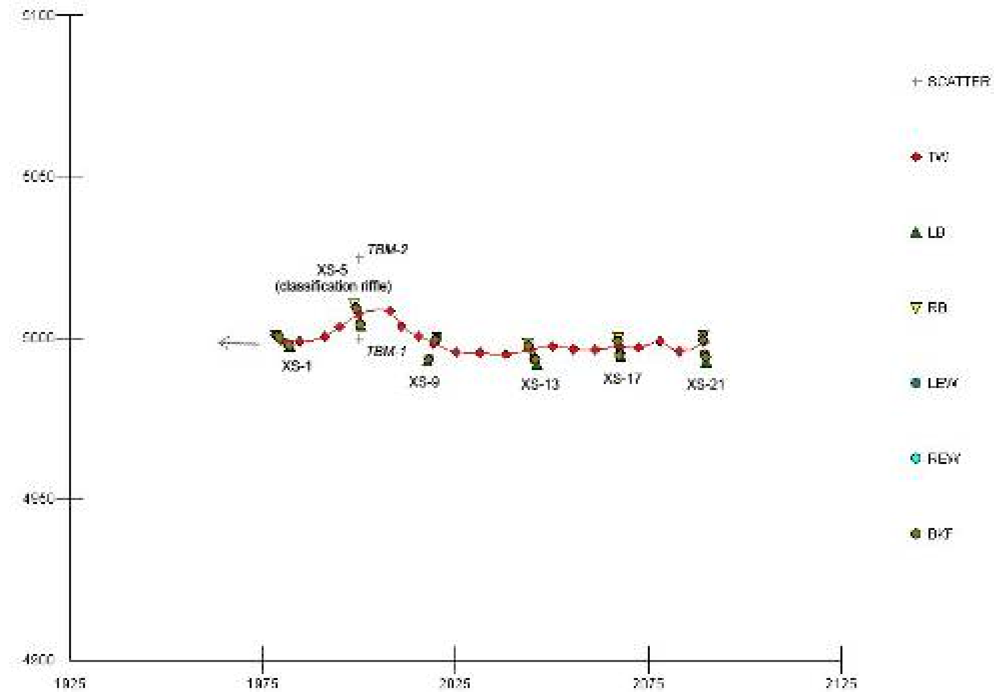
B

Figure B-23. Lochloosa Creek at Grove Park. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-23. Lochloosa Creek at Grove Park. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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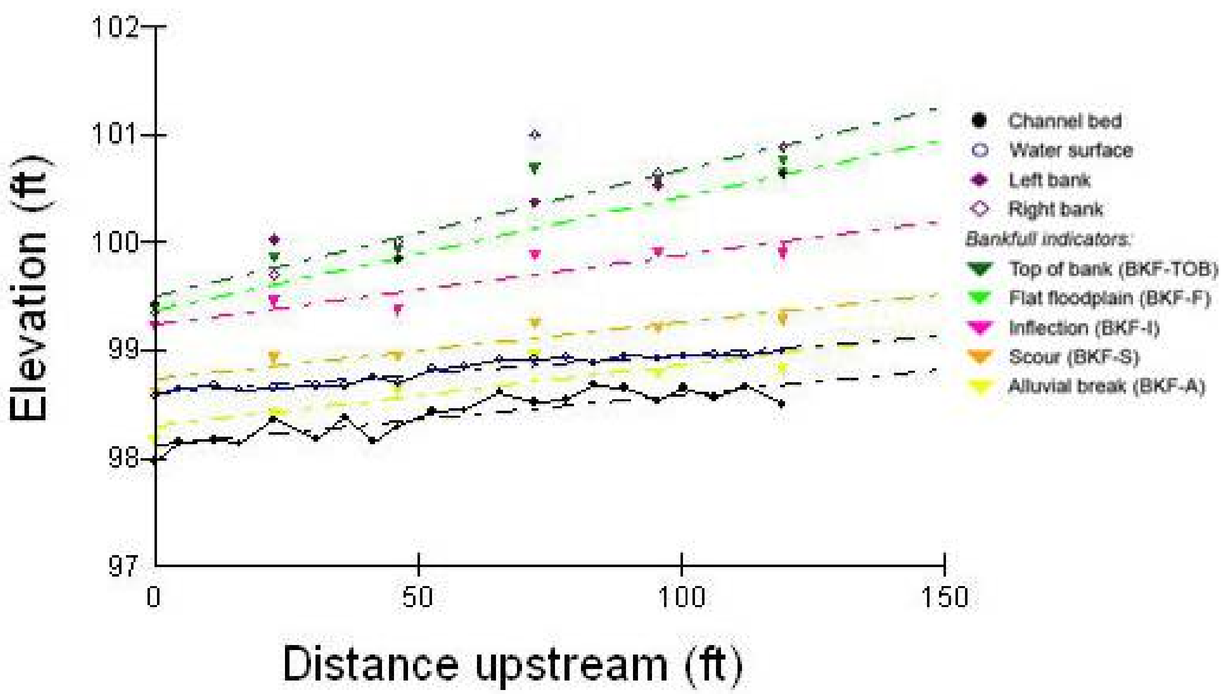
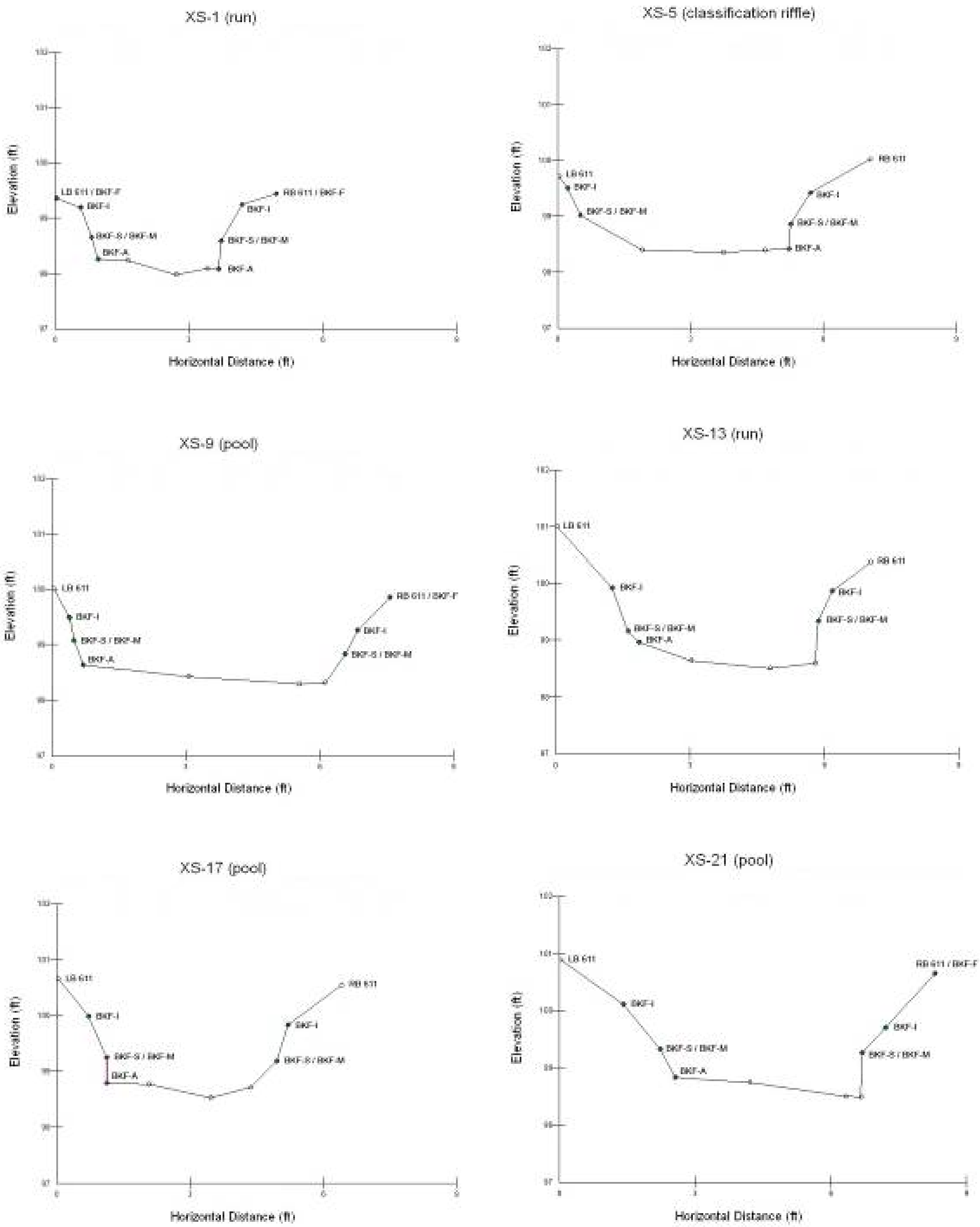


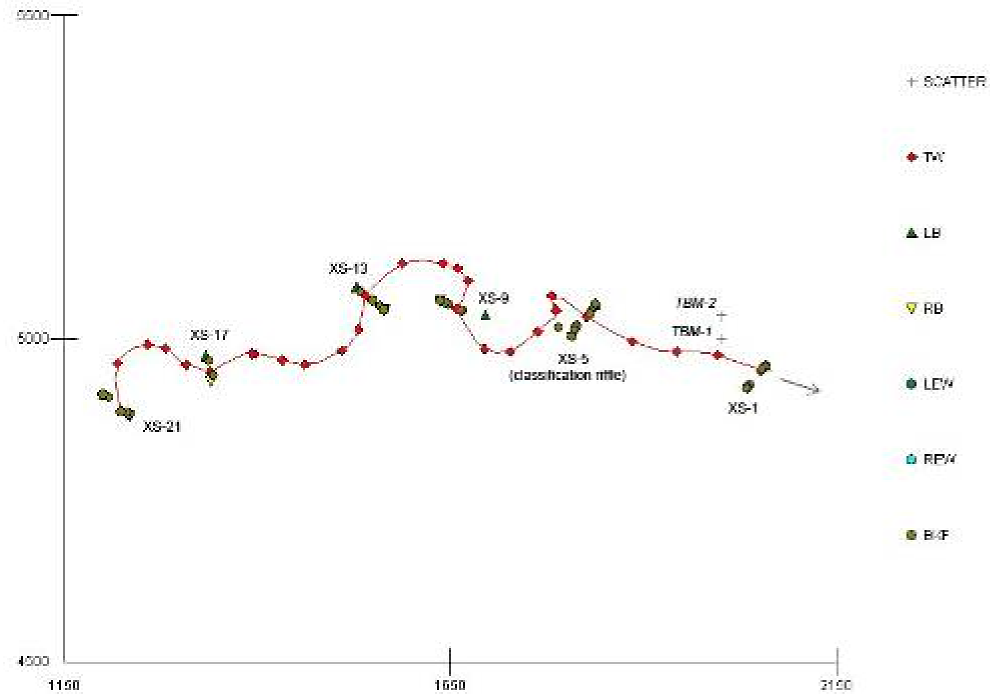
B

Figure B-24. Lowry Lake tributary. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-24. Lowry Lake tributary. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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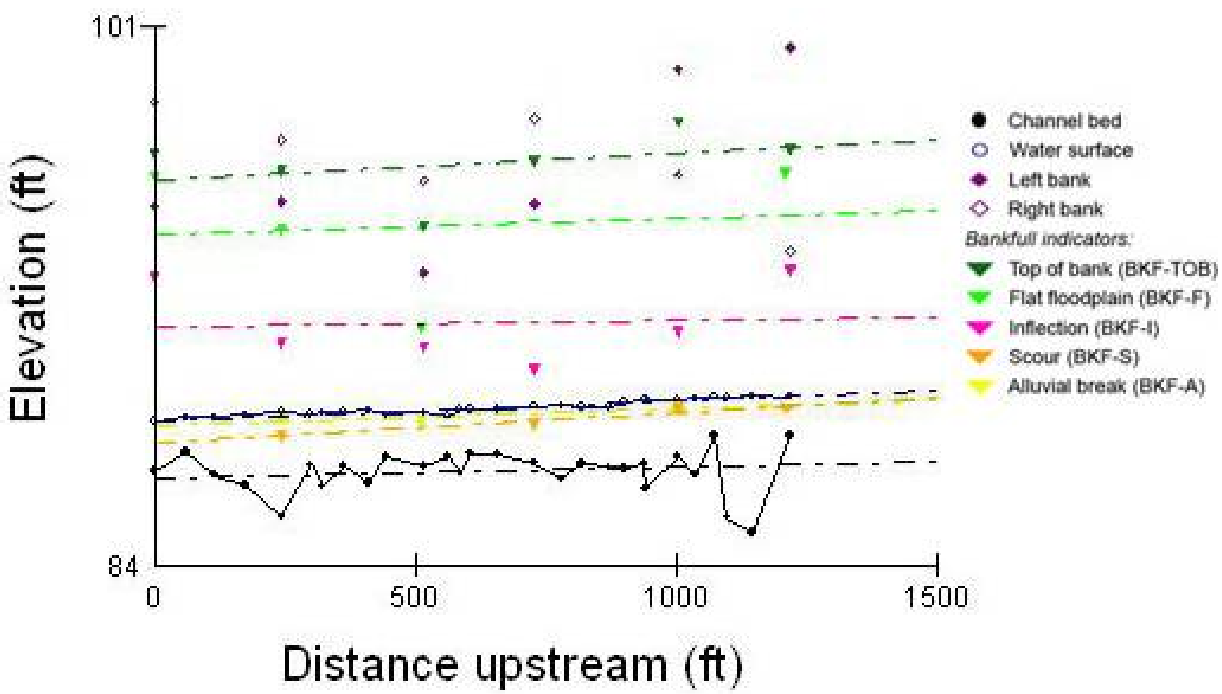
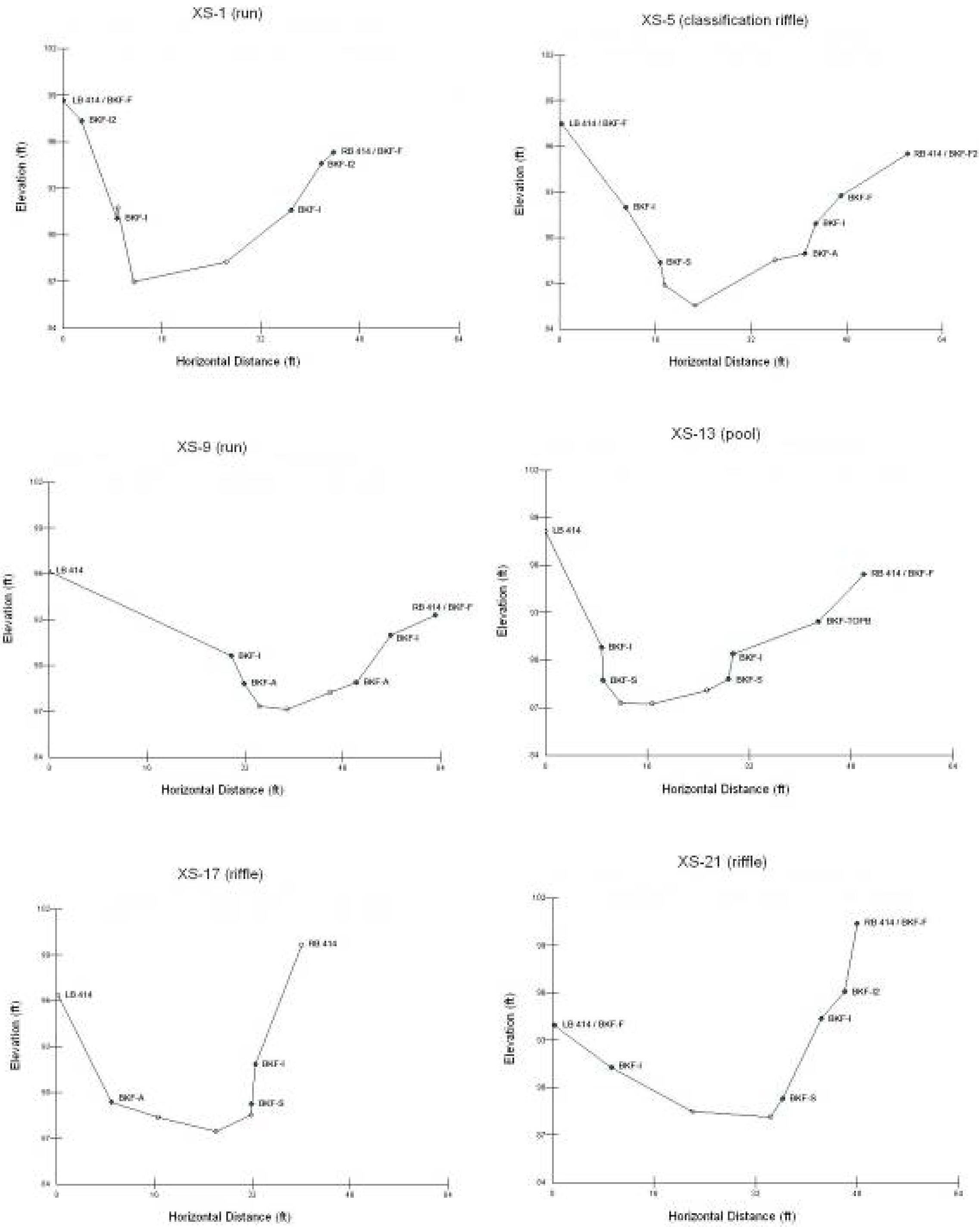


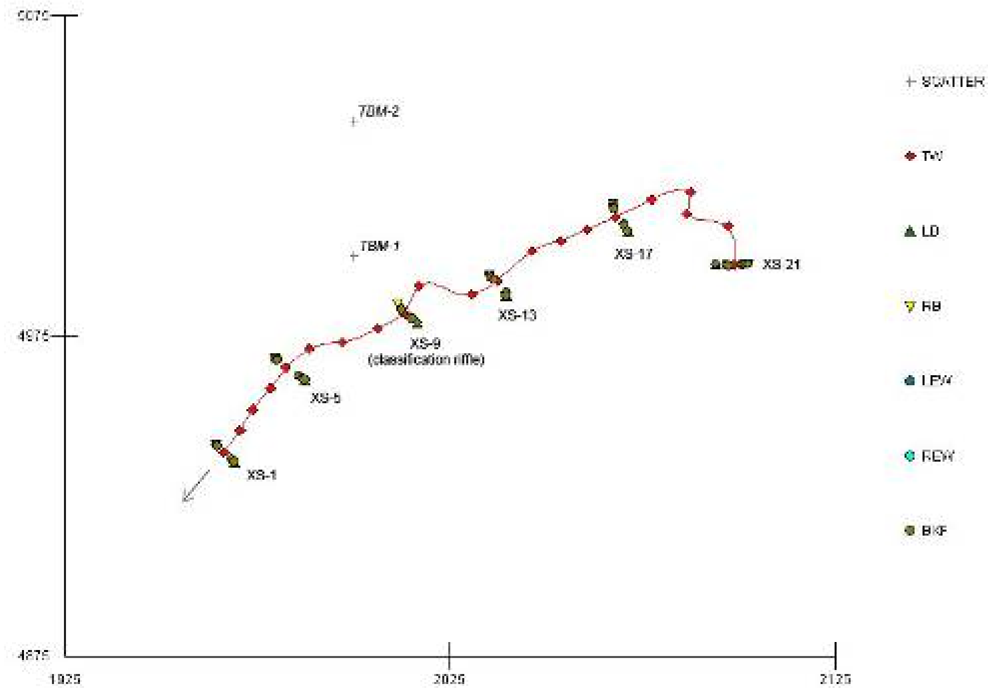
B

Figure B-25. Manatee River near Myakka Head. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-25. Manatee River near Myakka Head. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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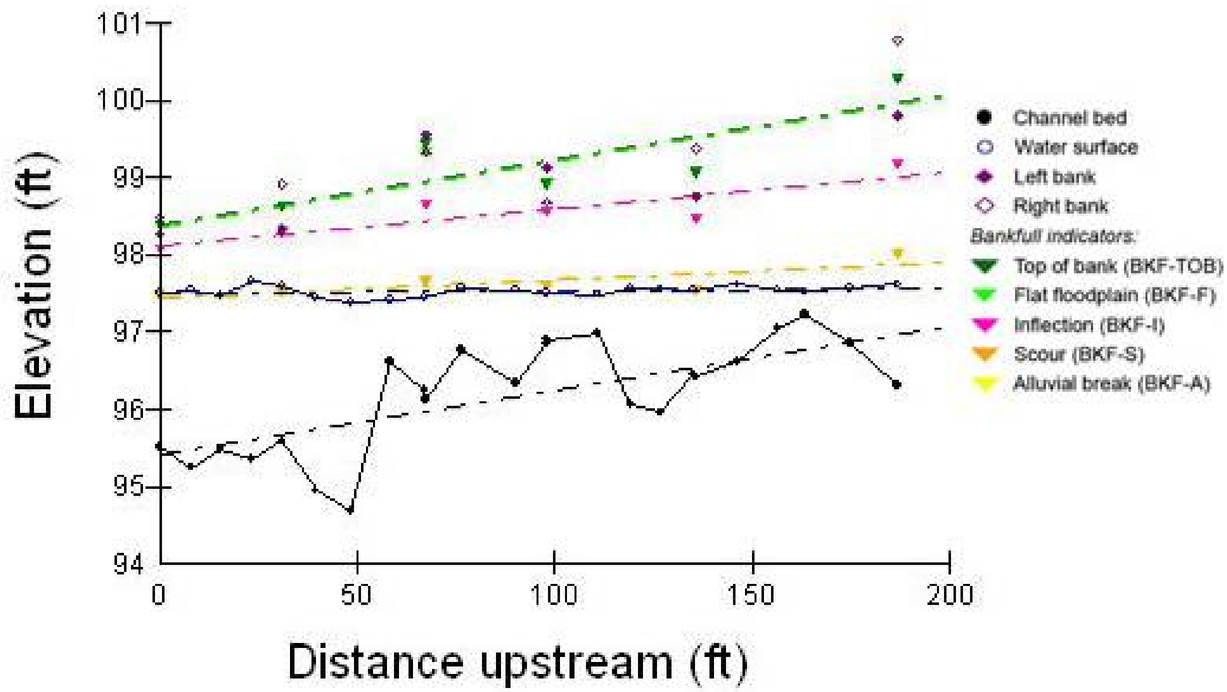
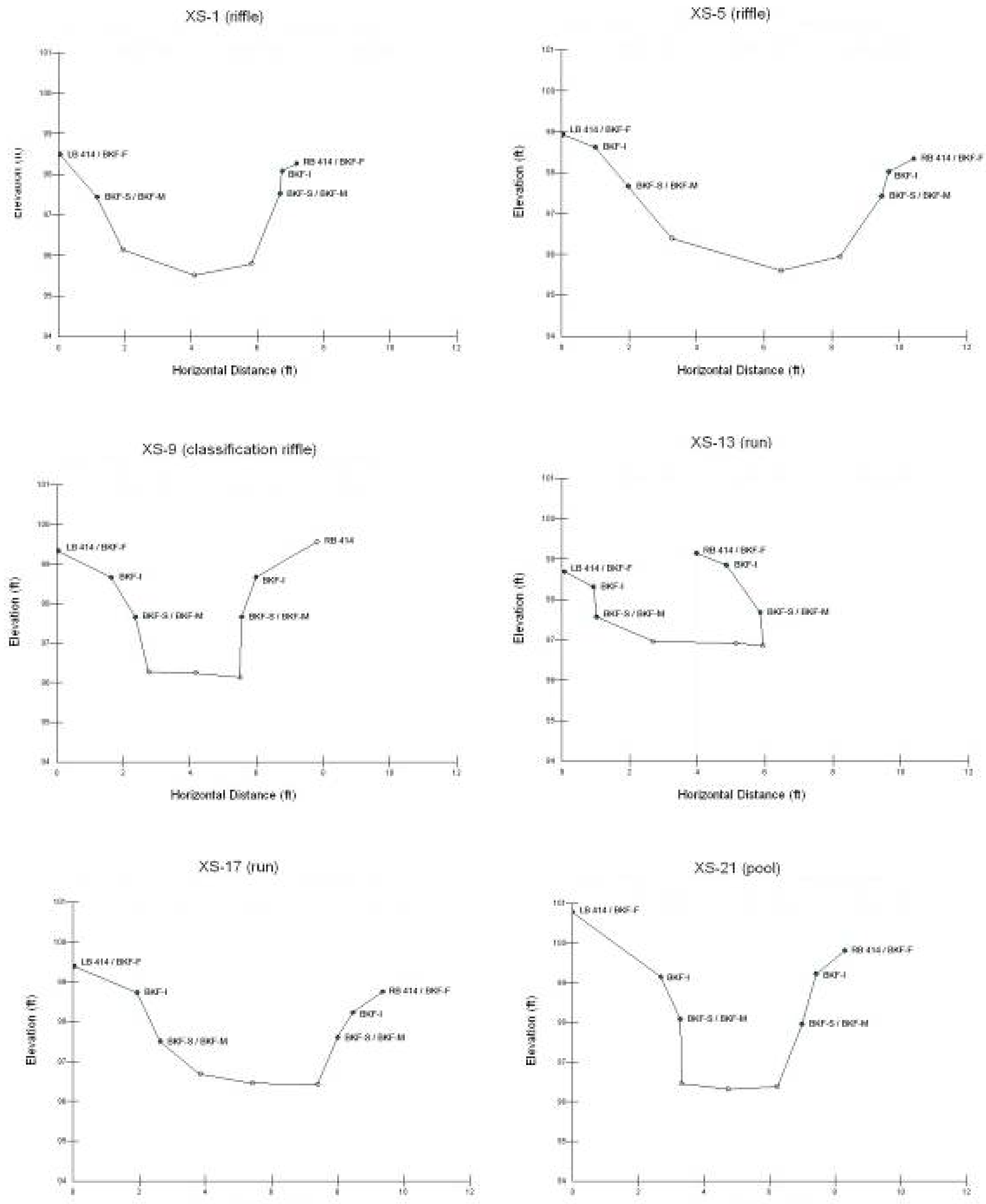


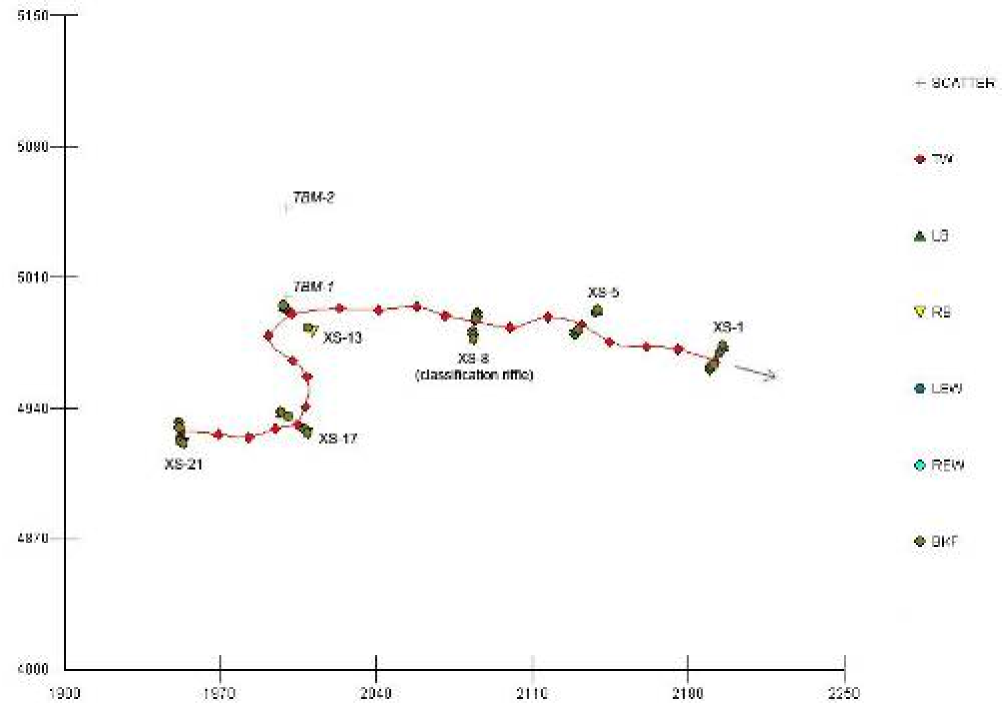
B

Figure B-26. Manatee River tributary. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-26. Manatee River tributary. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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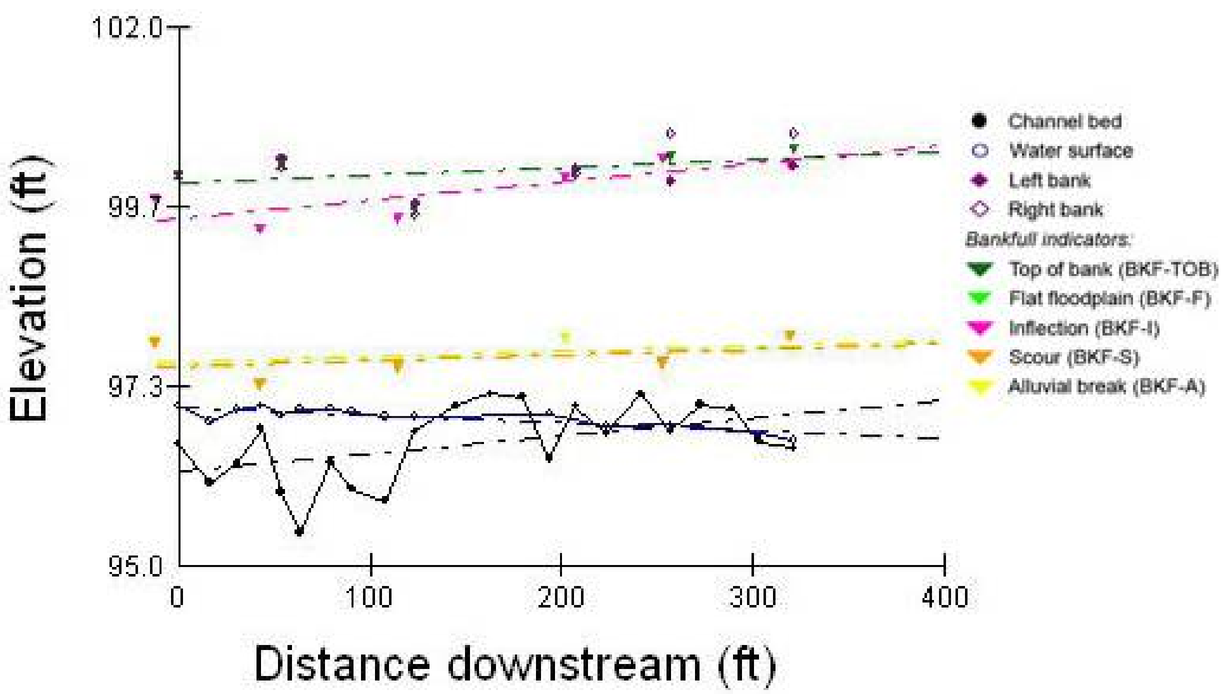
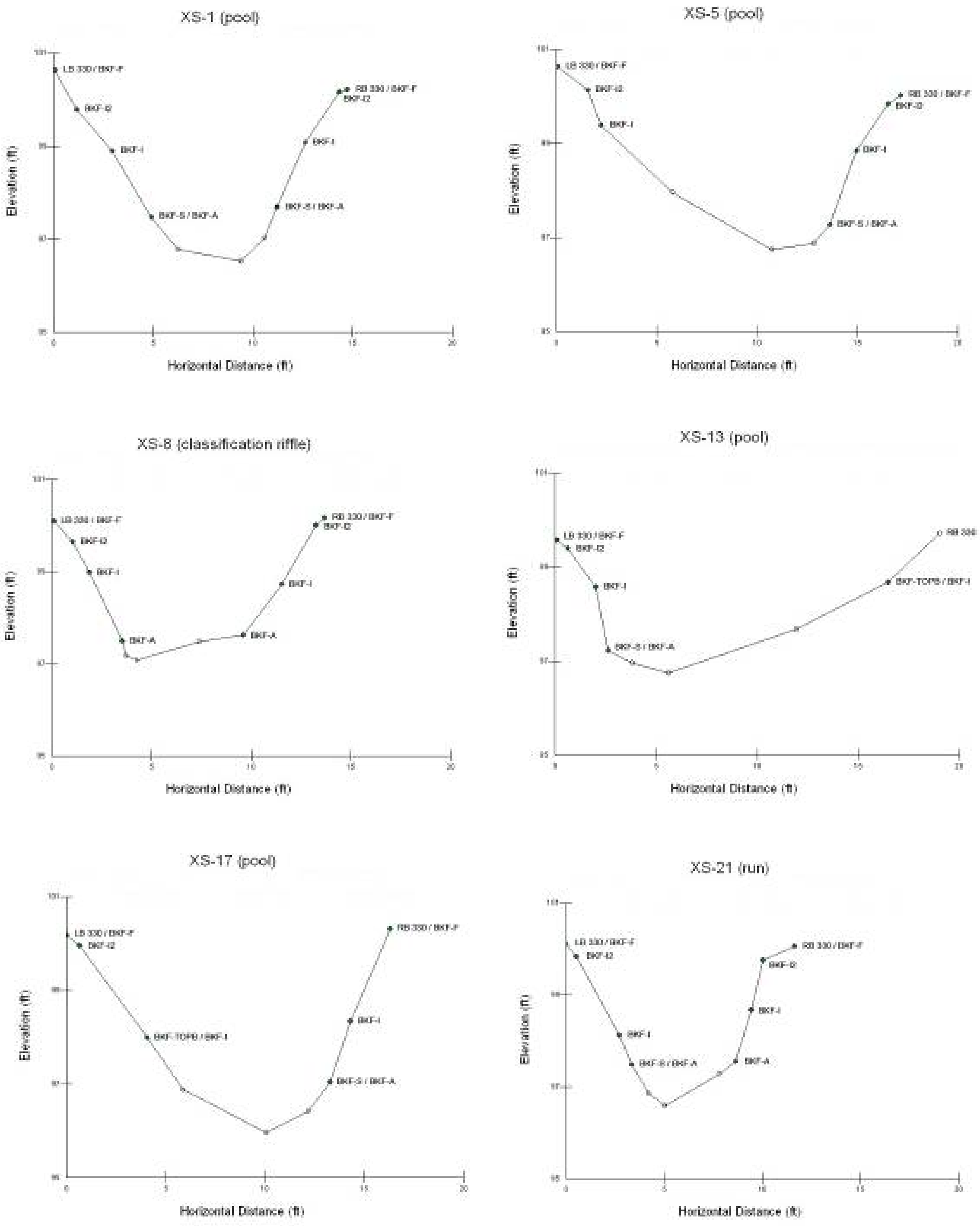


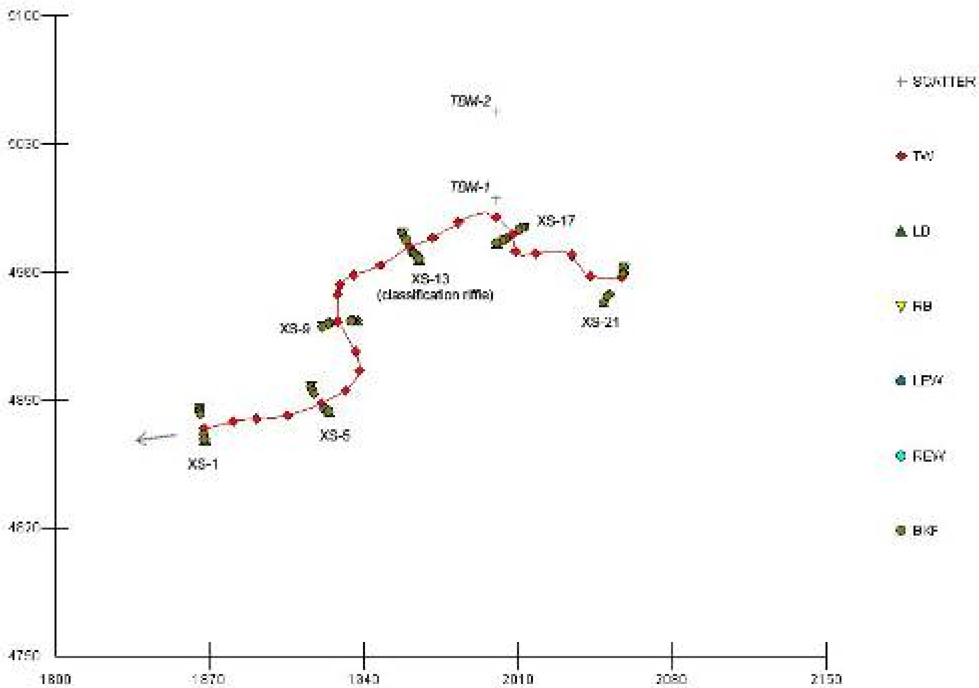
B

Figure B-27. Morgan Hole Creek. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-27. Morgan Hole Creek. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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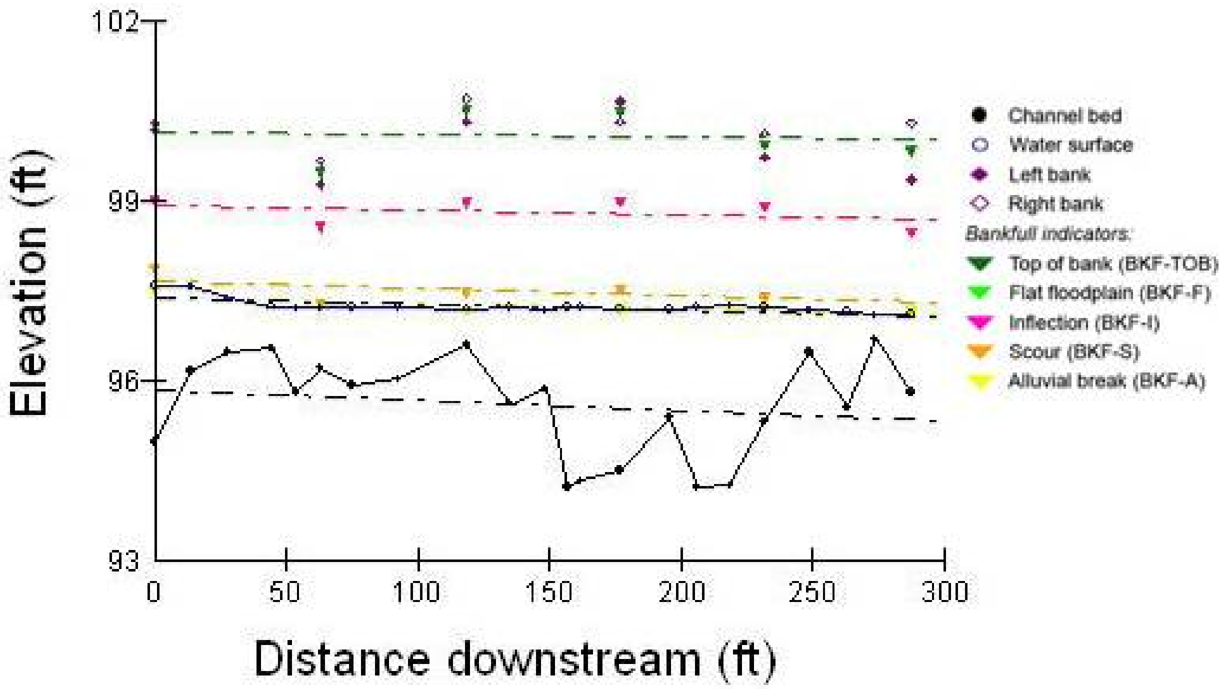
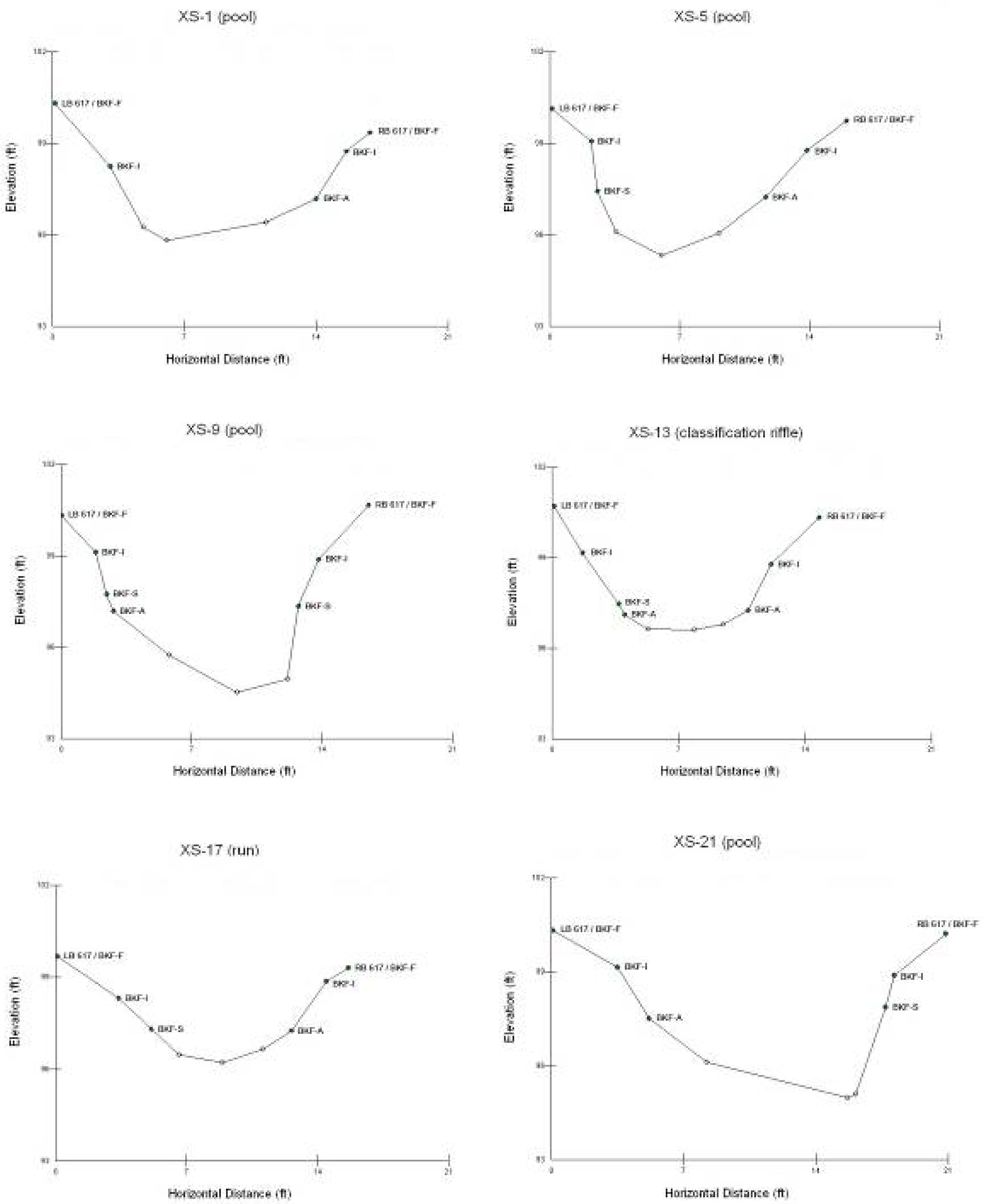


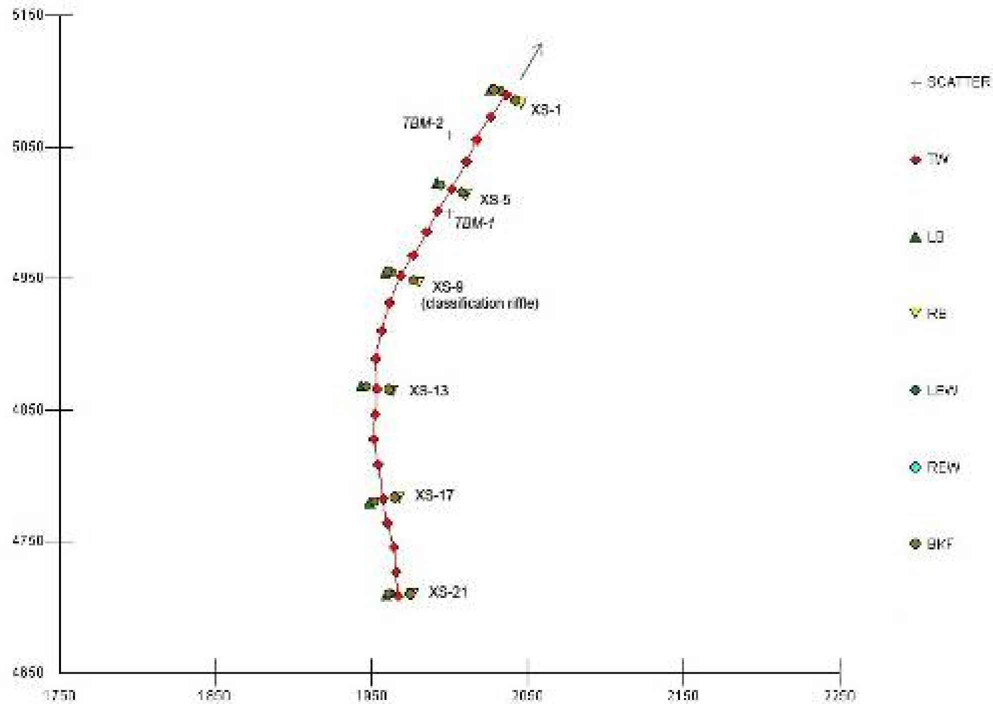
B

Figure B-28. Moses Creek near Moultrie. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-28. Moses Creek near Moultrie. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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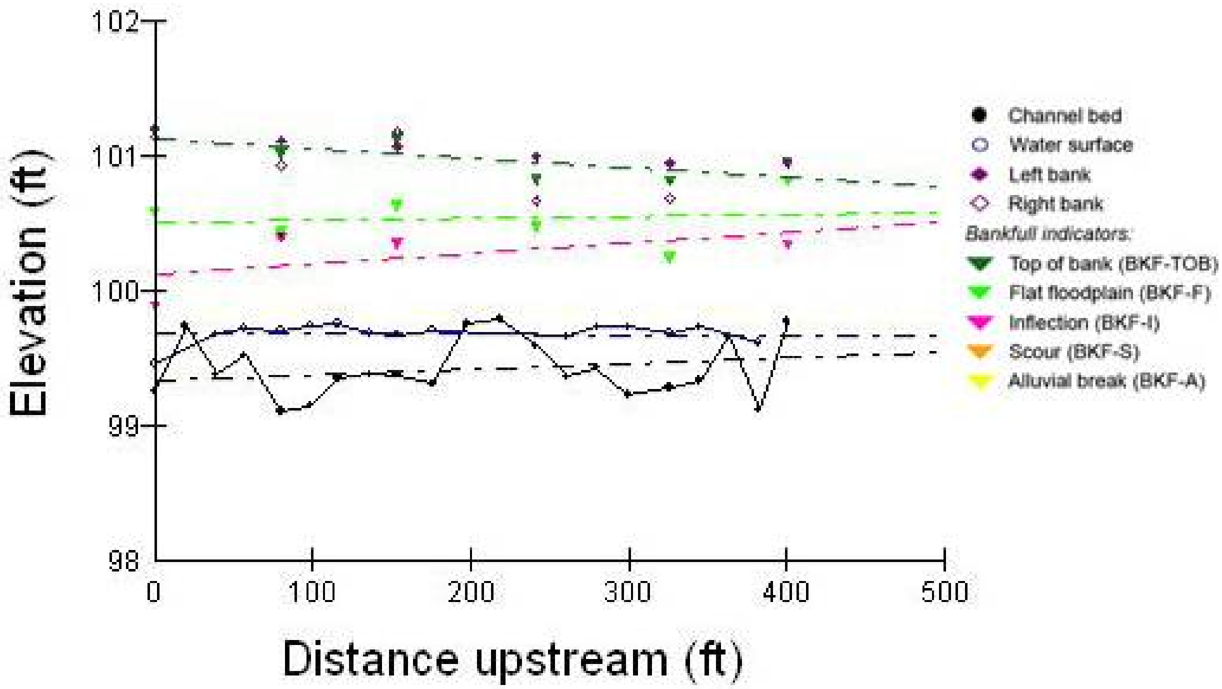
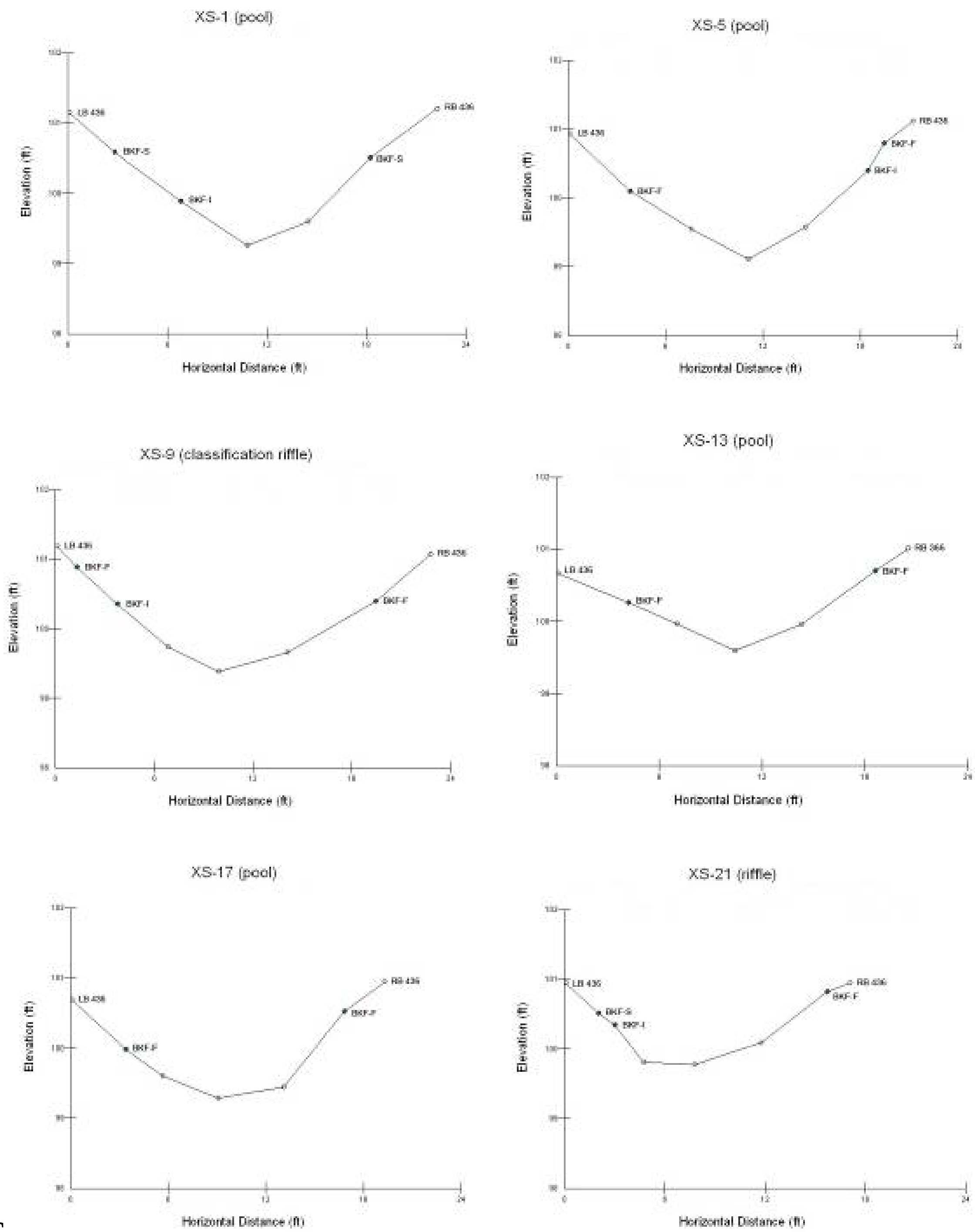


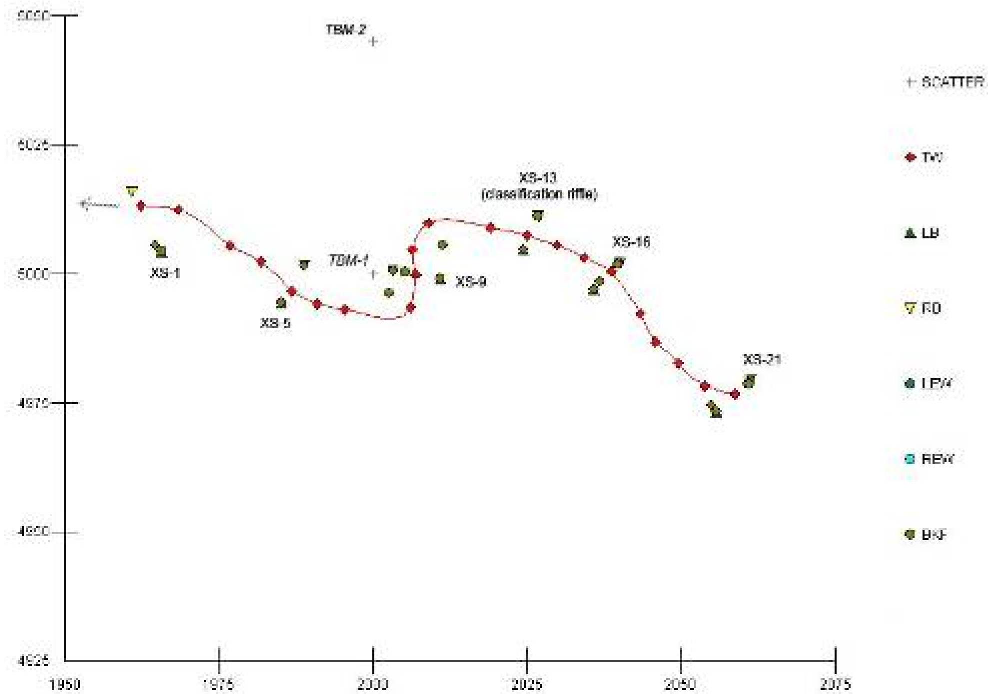
B

Figure B-29. Myakka River tributary 1. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-29. Myakka River tributary 1. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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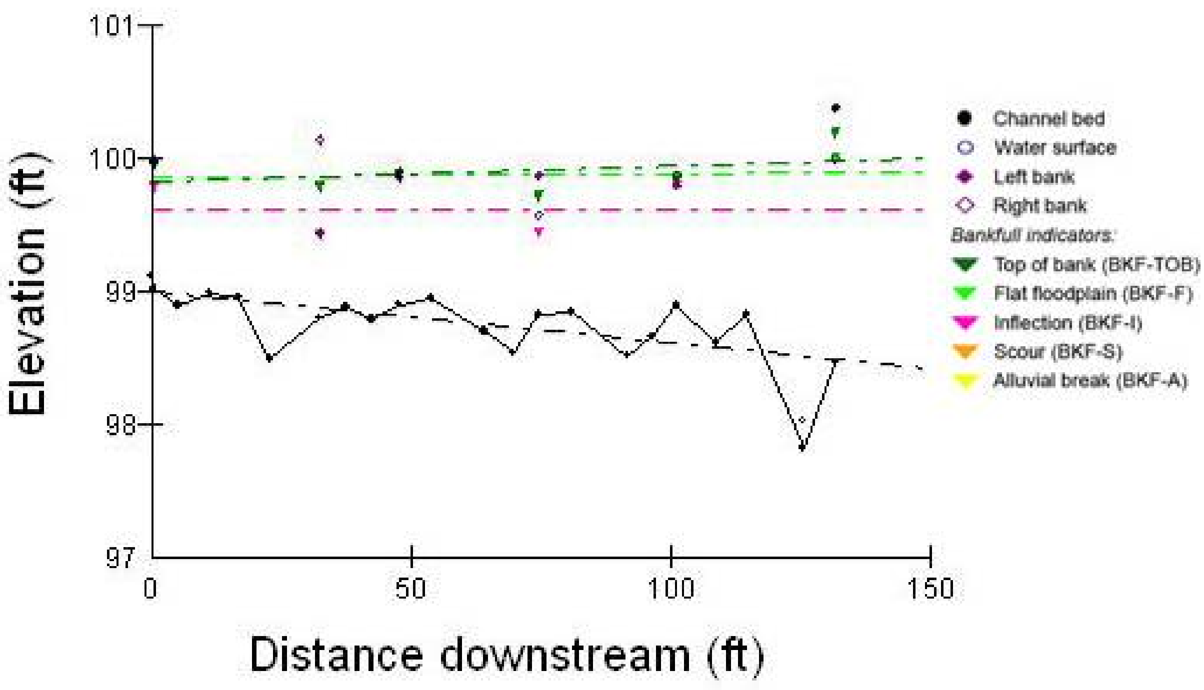
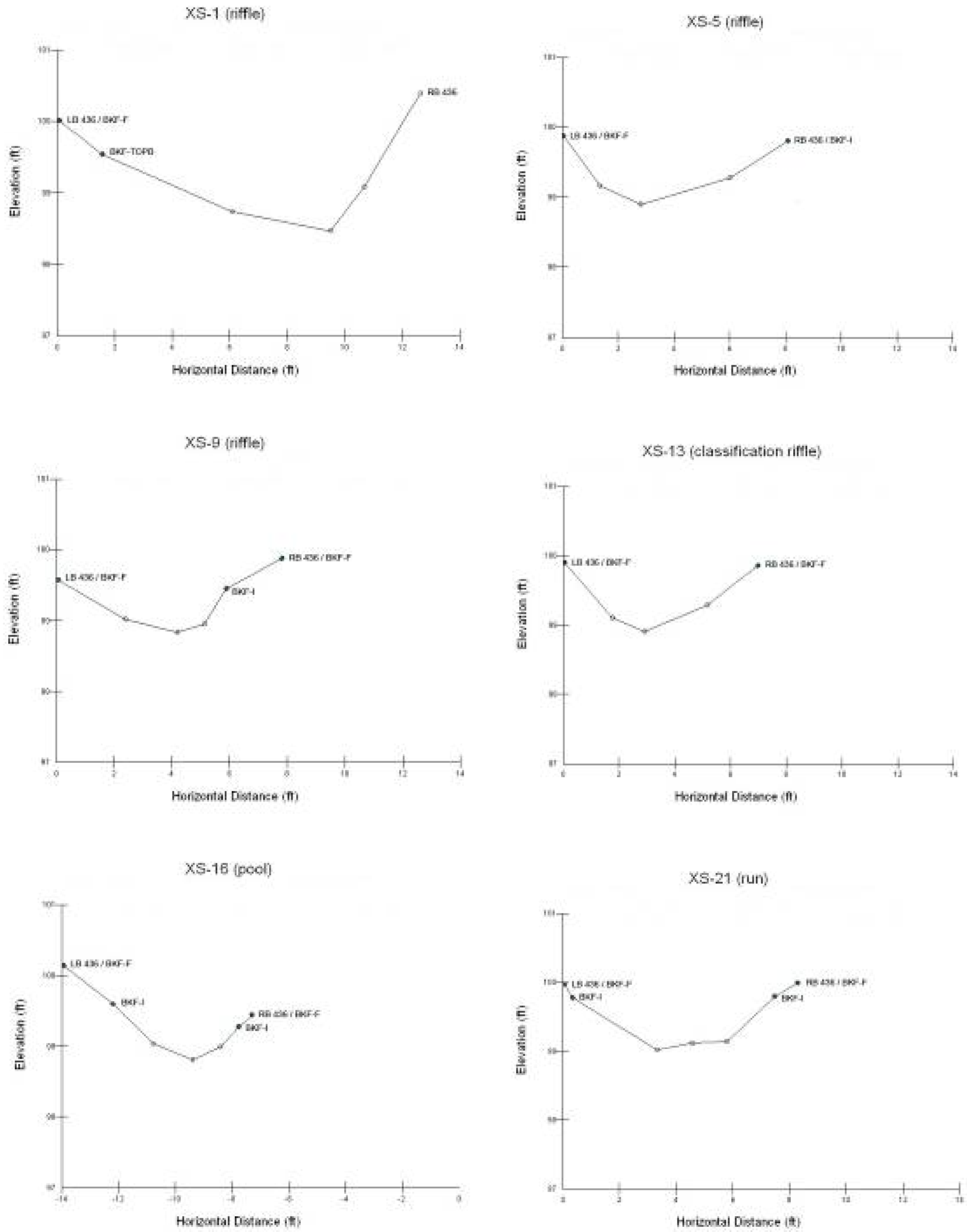


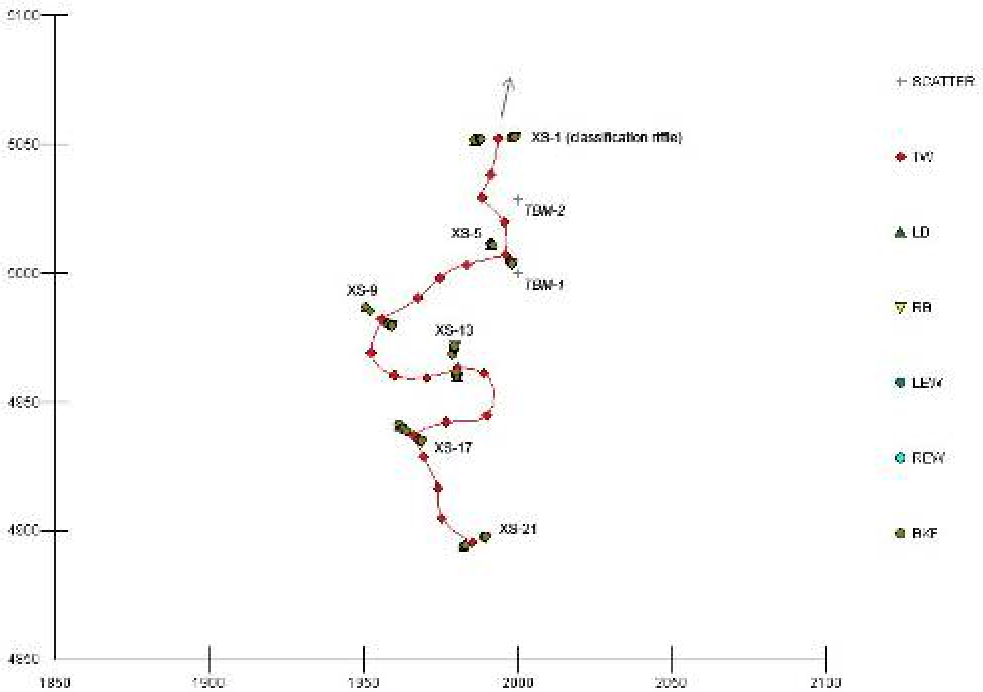
B

Figure B-30. Myakka River tributary 2. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-30. Myakka River tributary 2. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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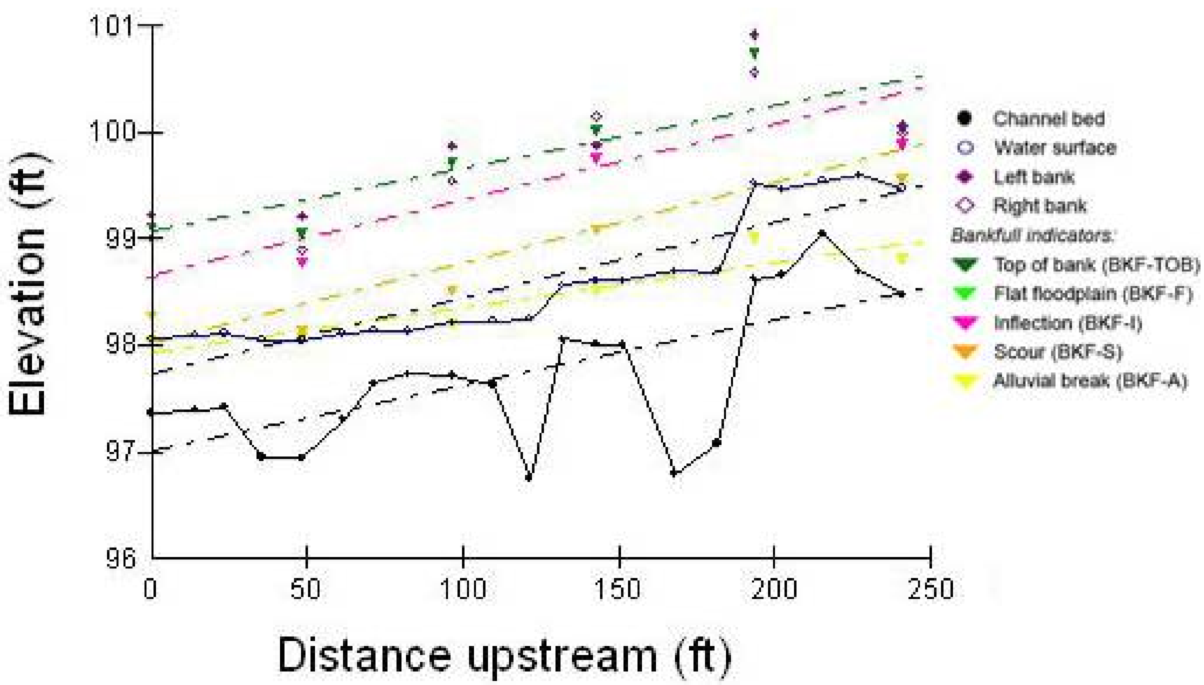
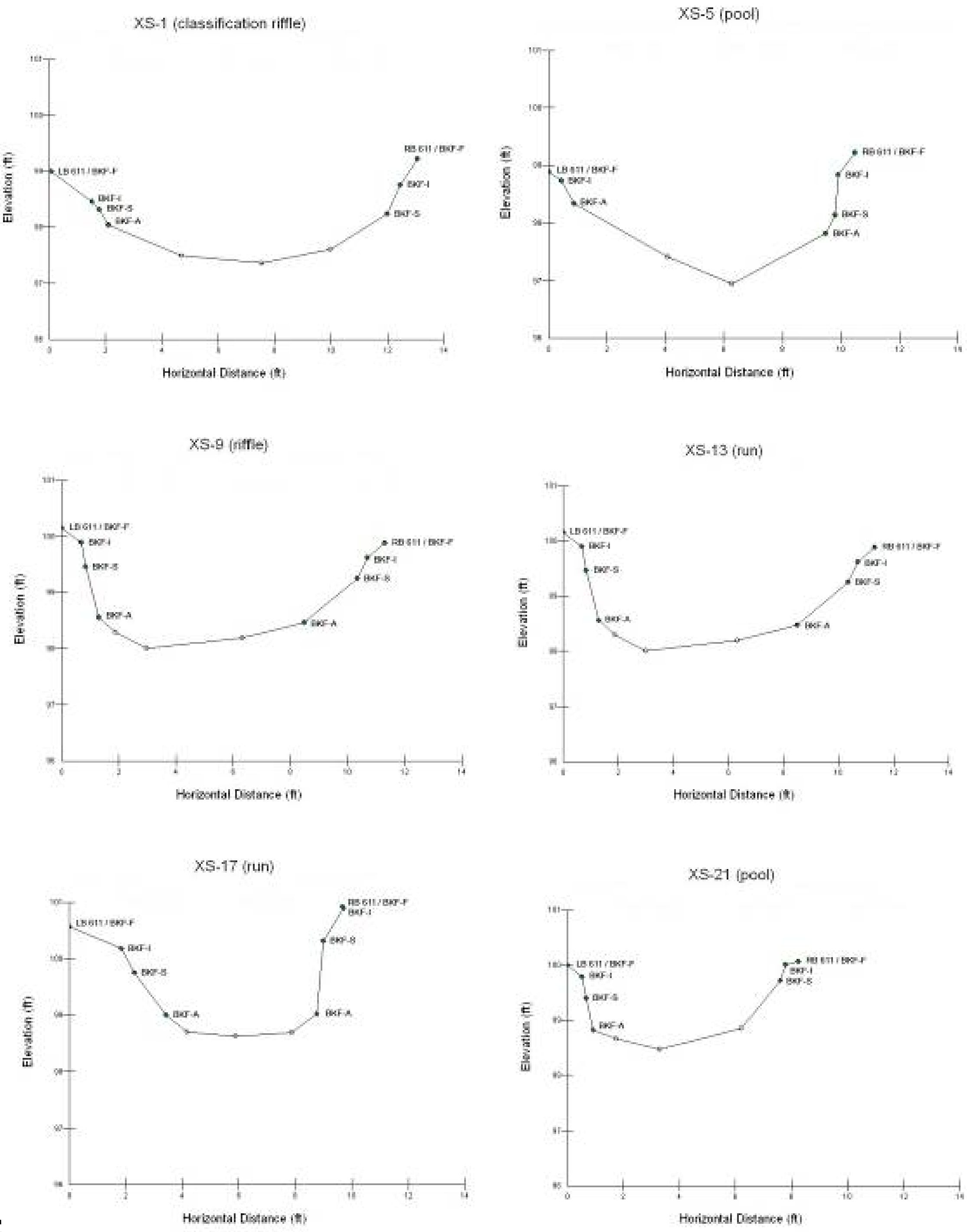


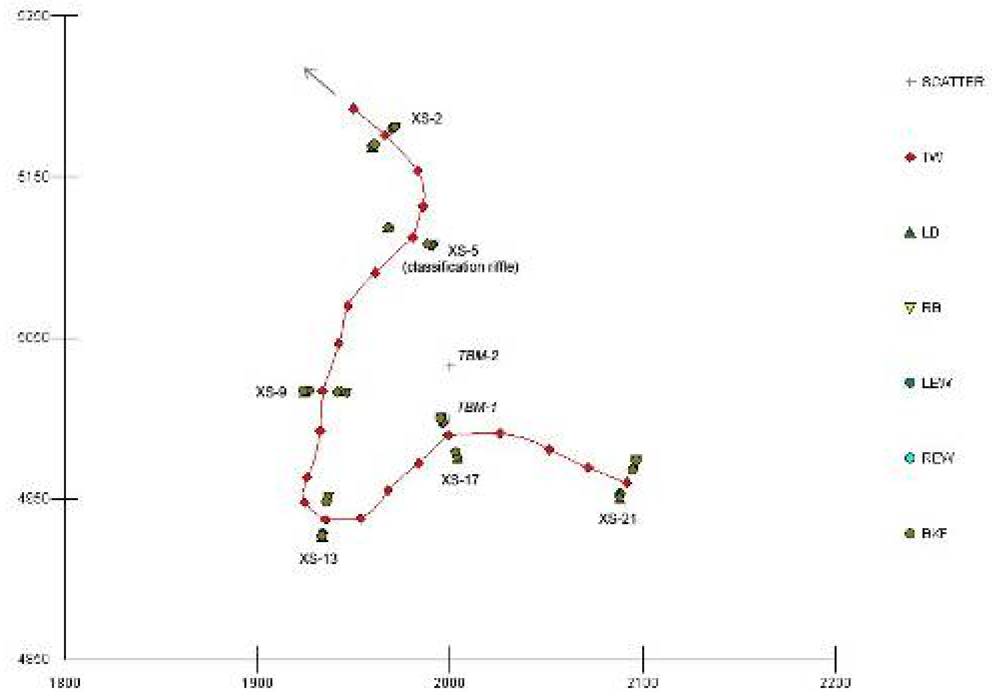
B

Figure B-31. Nine Mile Creek. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-31. Nine Mile Creek. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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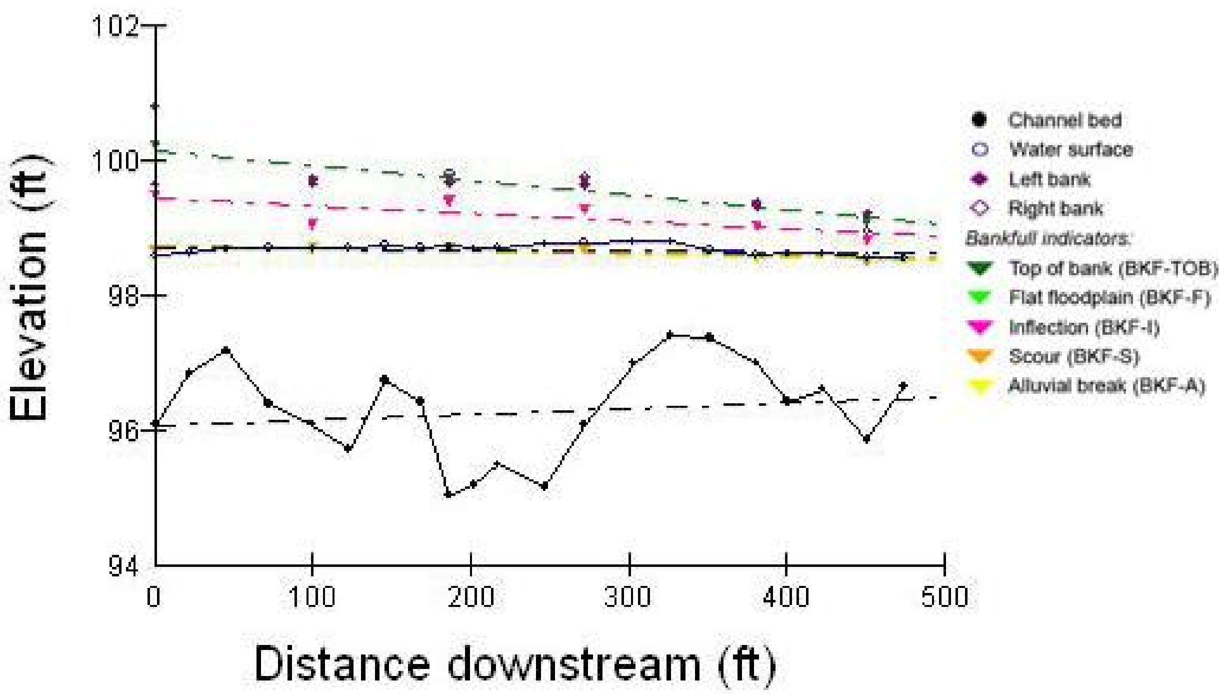
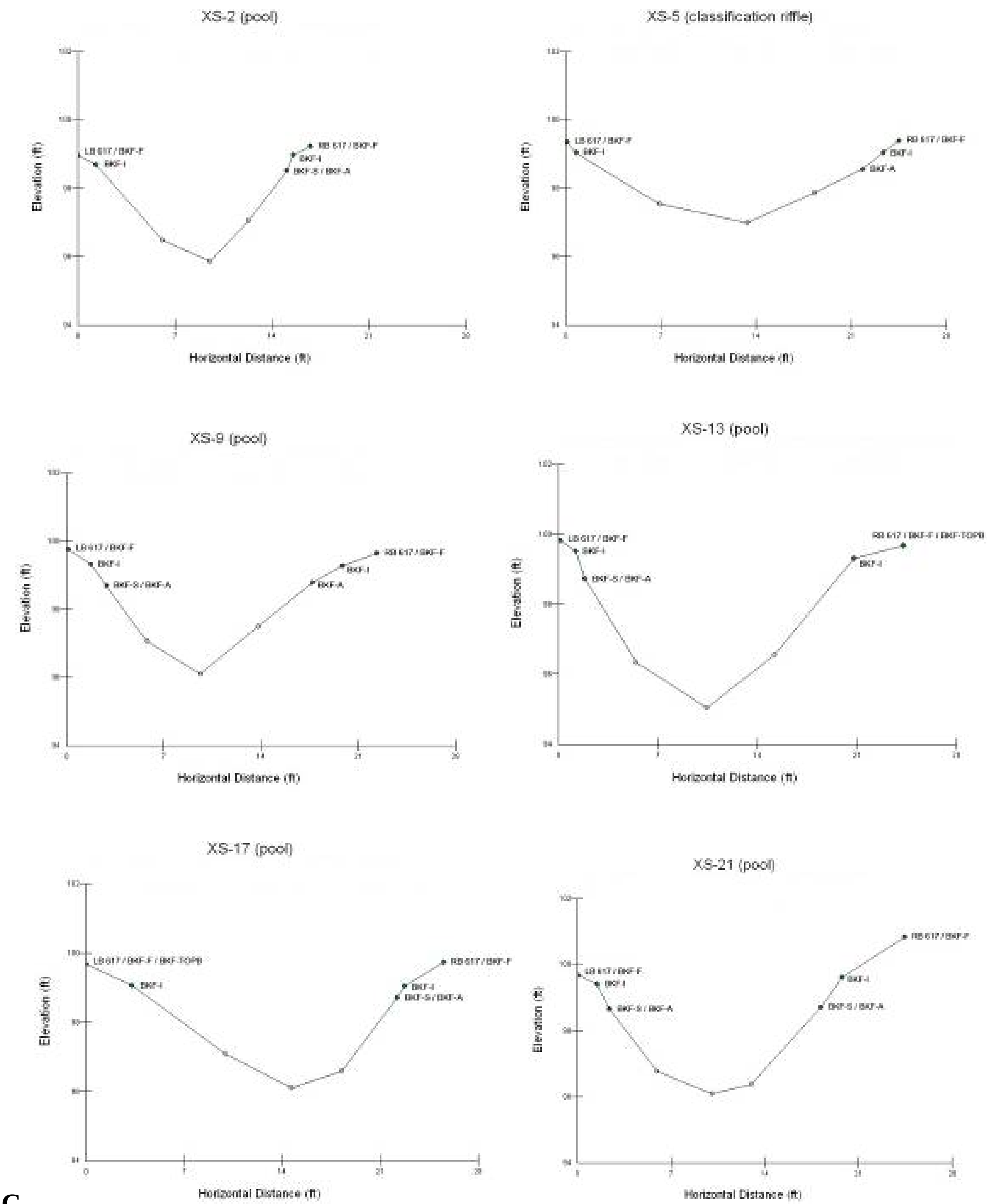


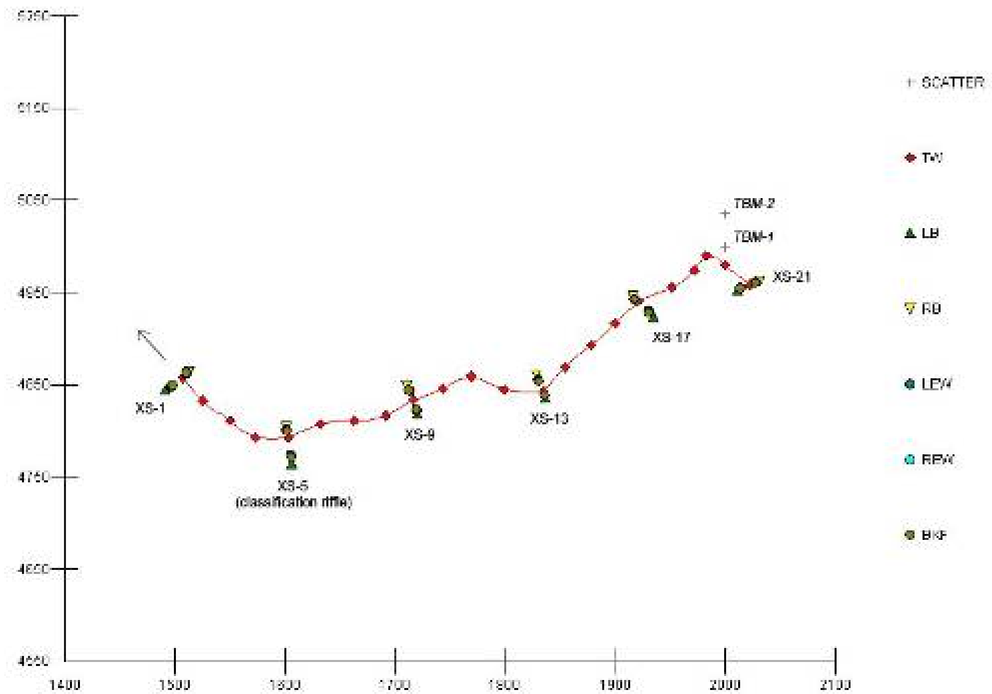
B

Figure B-32. Rice Creek near Springside. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-32. Rice Creek near Springside. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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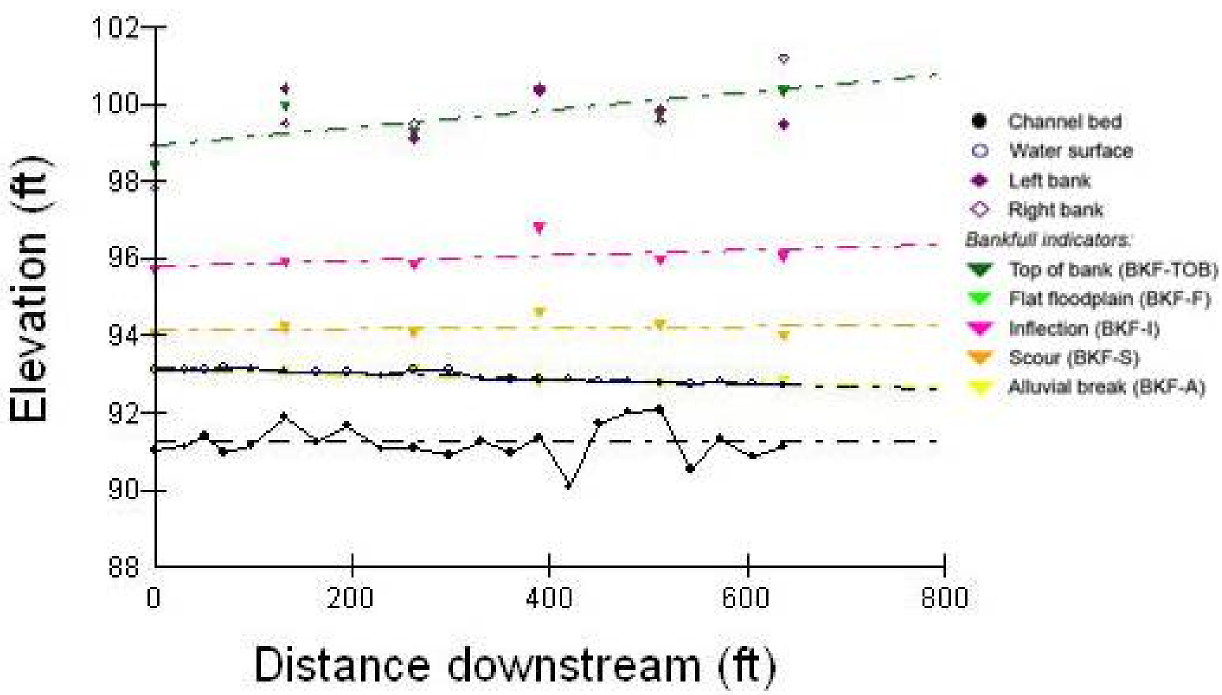
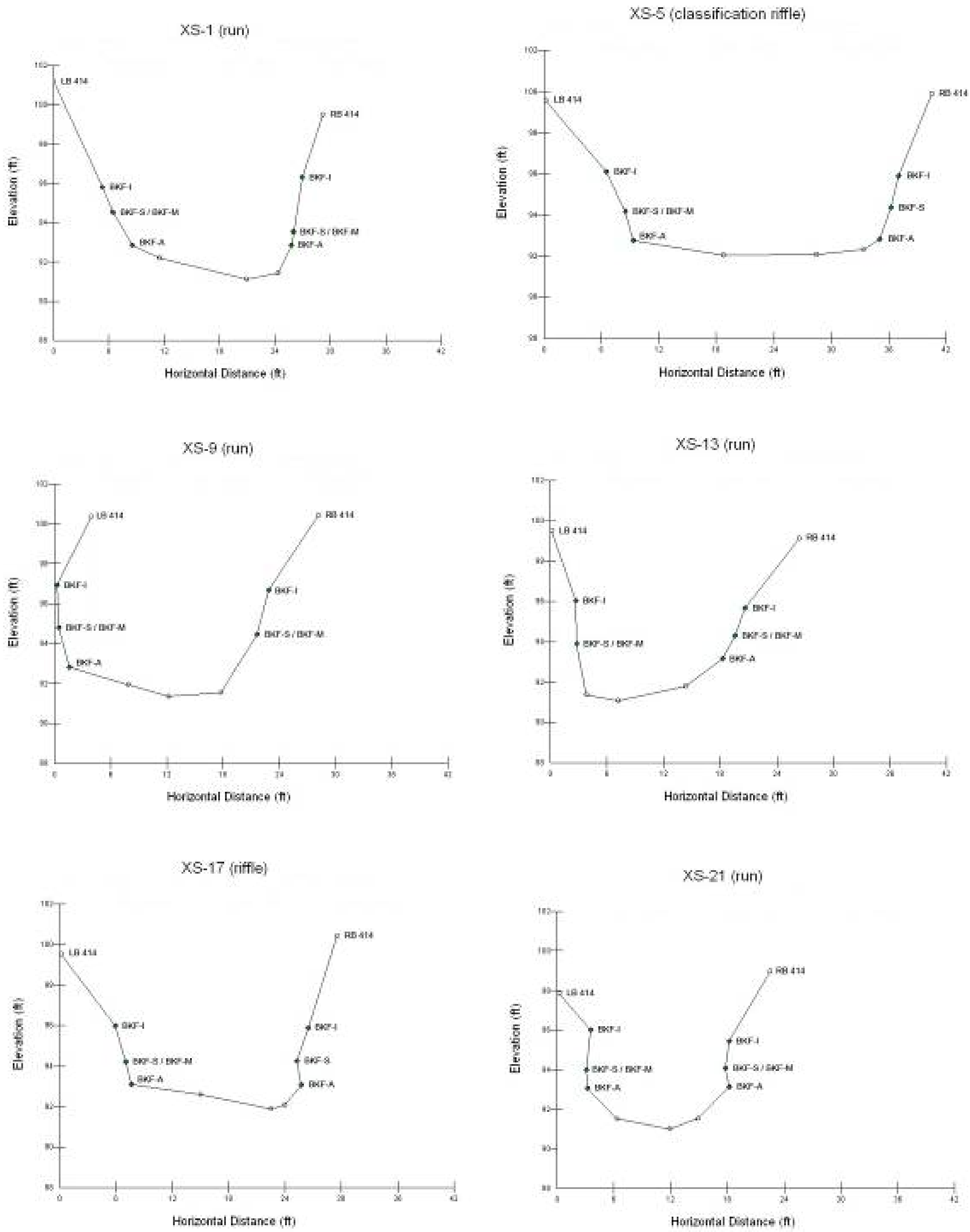


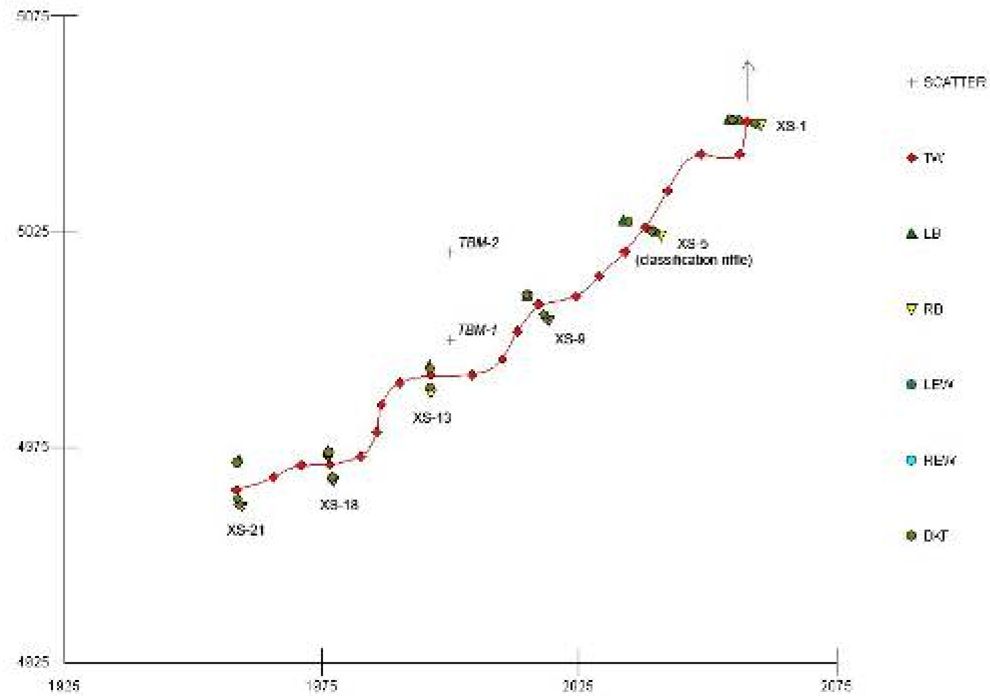
B

Figure B-33. Santa Fe River near Graham. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-33. Santa Fe River near Graham. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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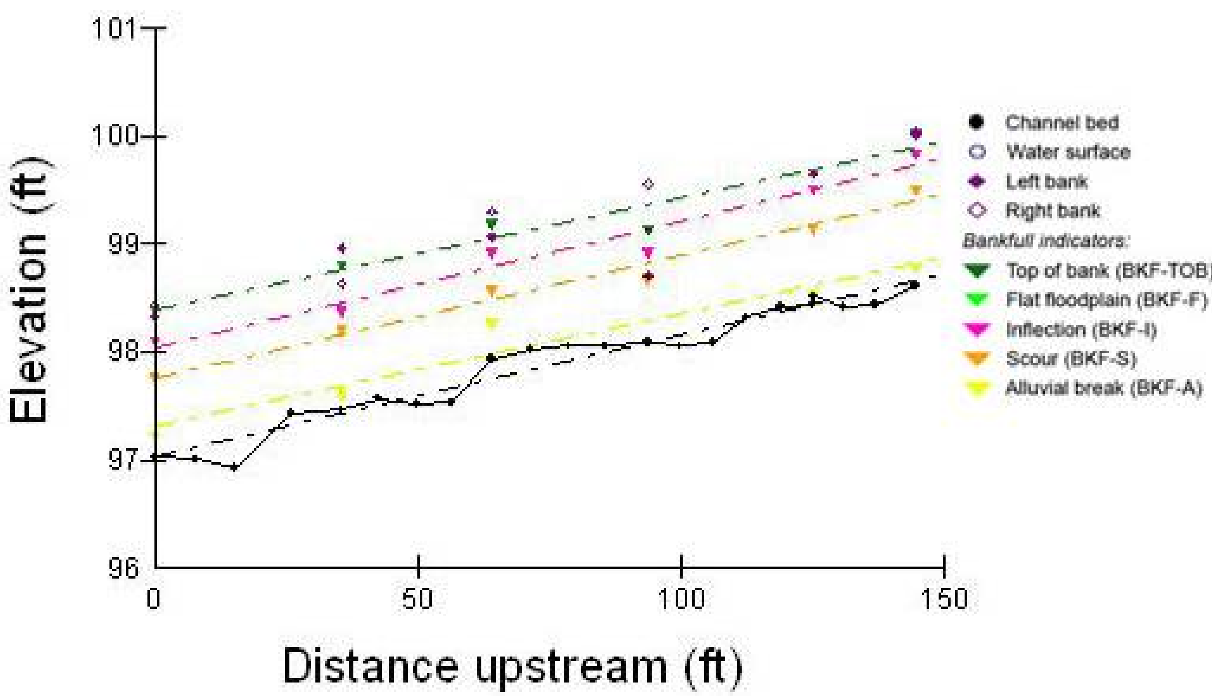
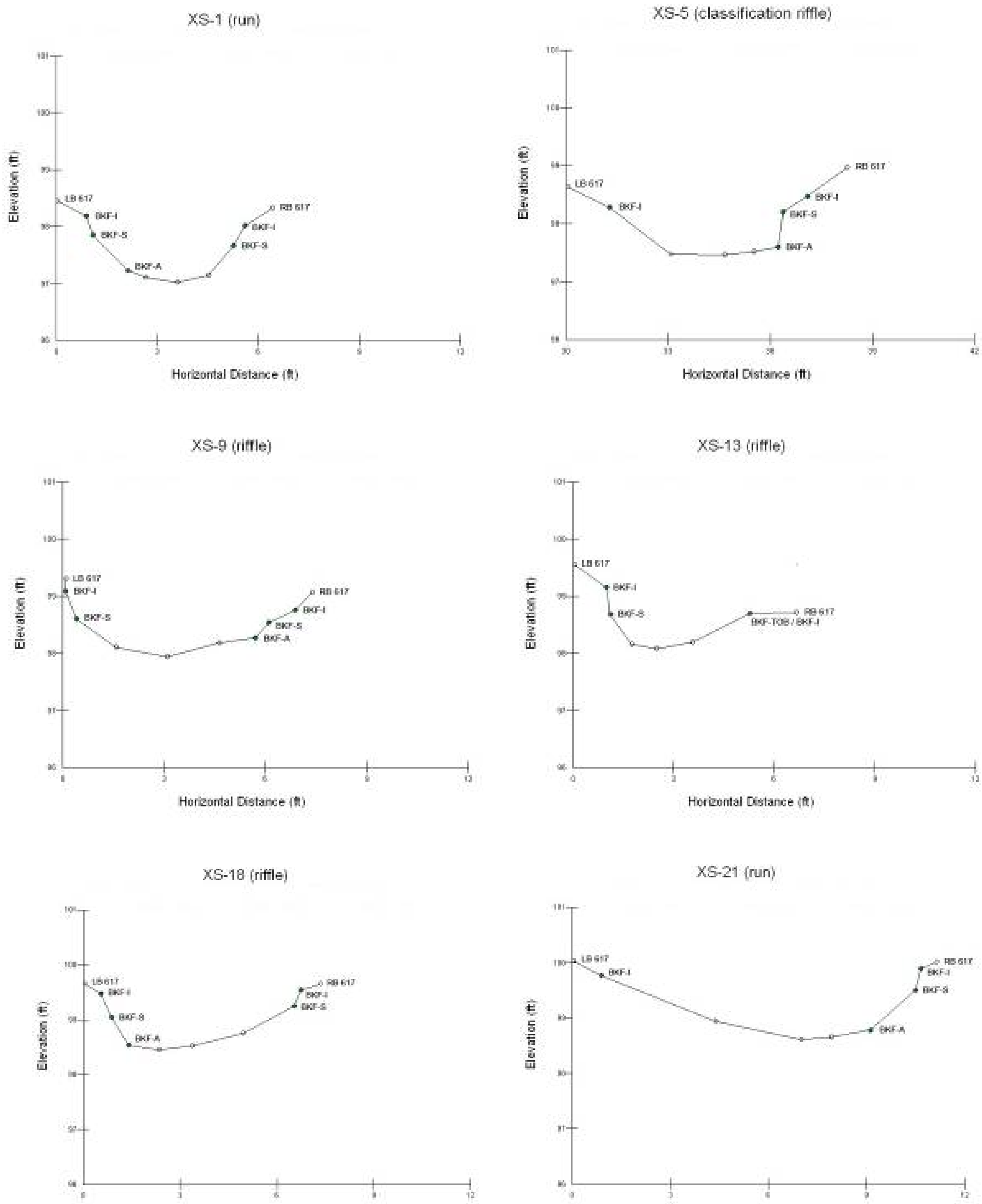


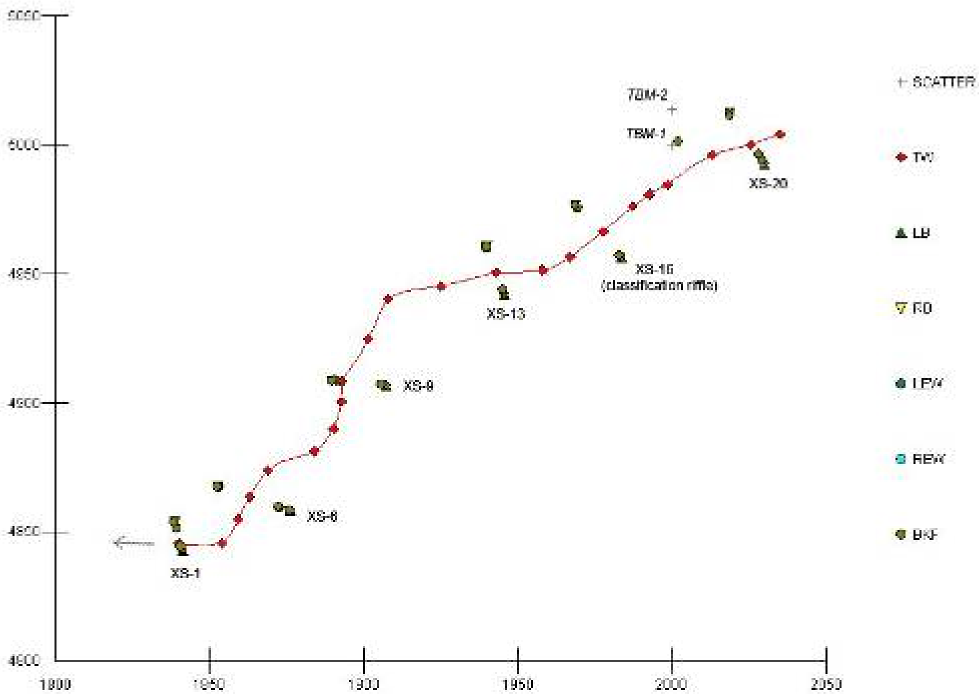
B

Figure B-34. Shiloh Run near Alachua. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-34. Shiloh Run near Alachua. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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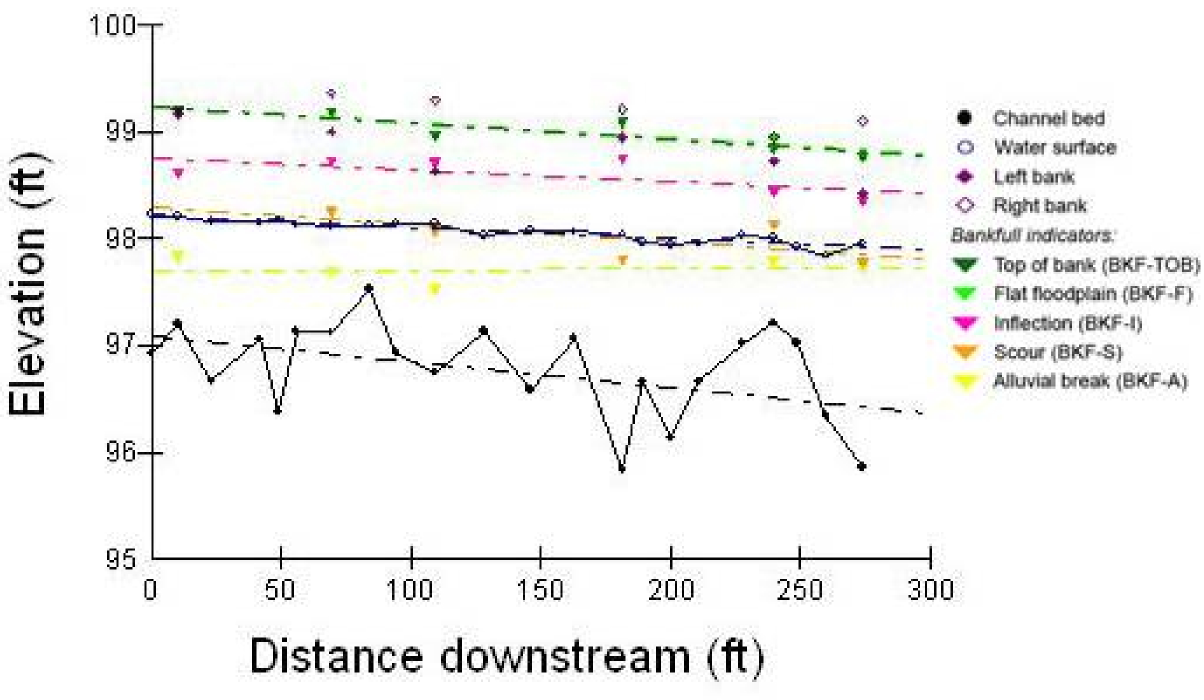
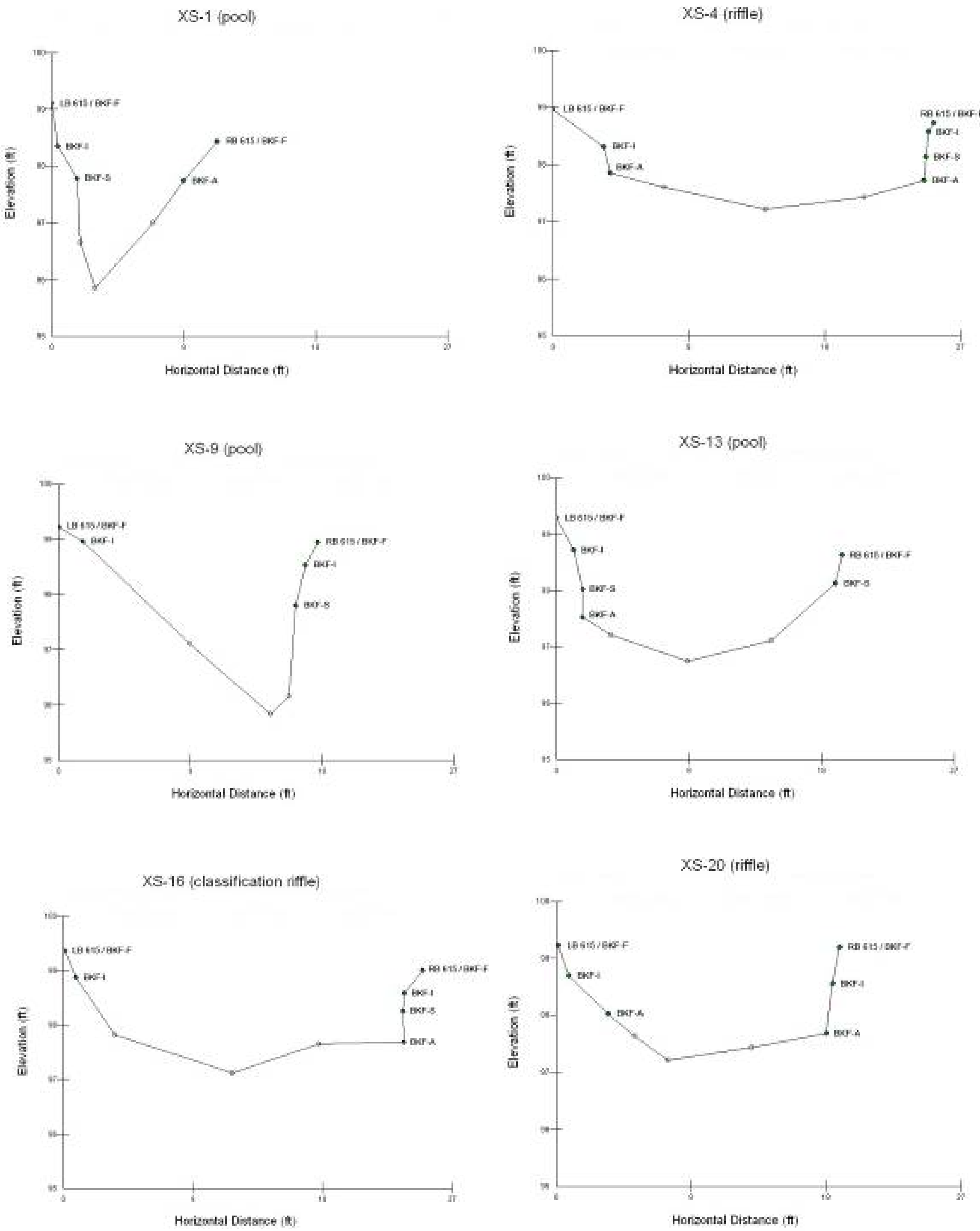


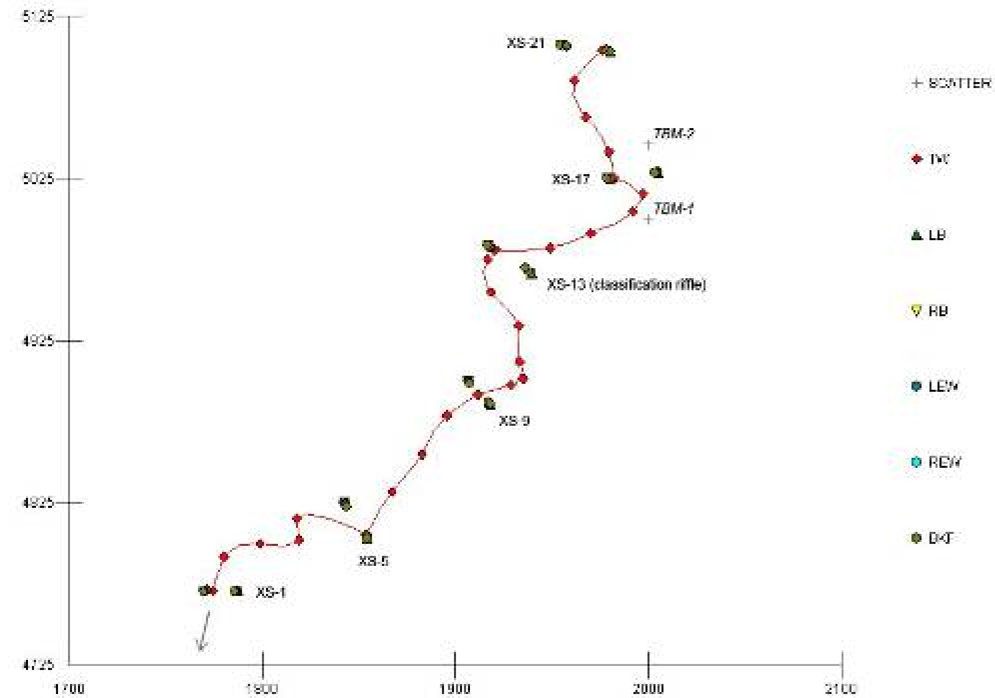
B

Figure B-35. Snell Creek. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-35. Snell Creek. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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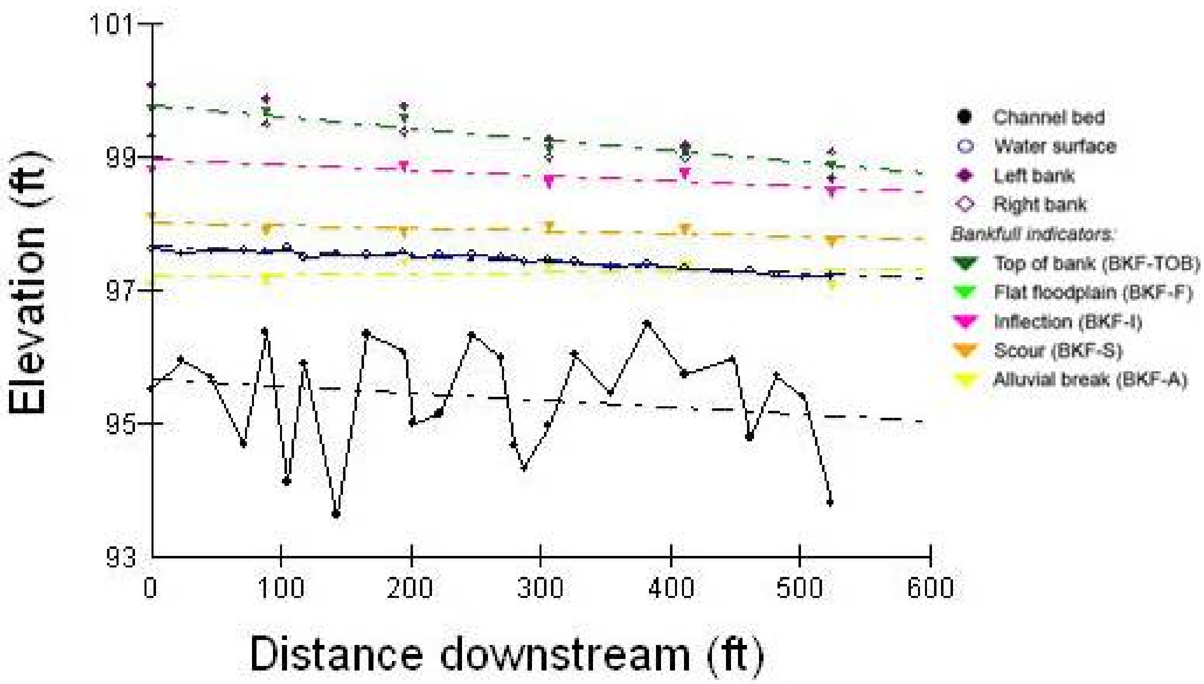
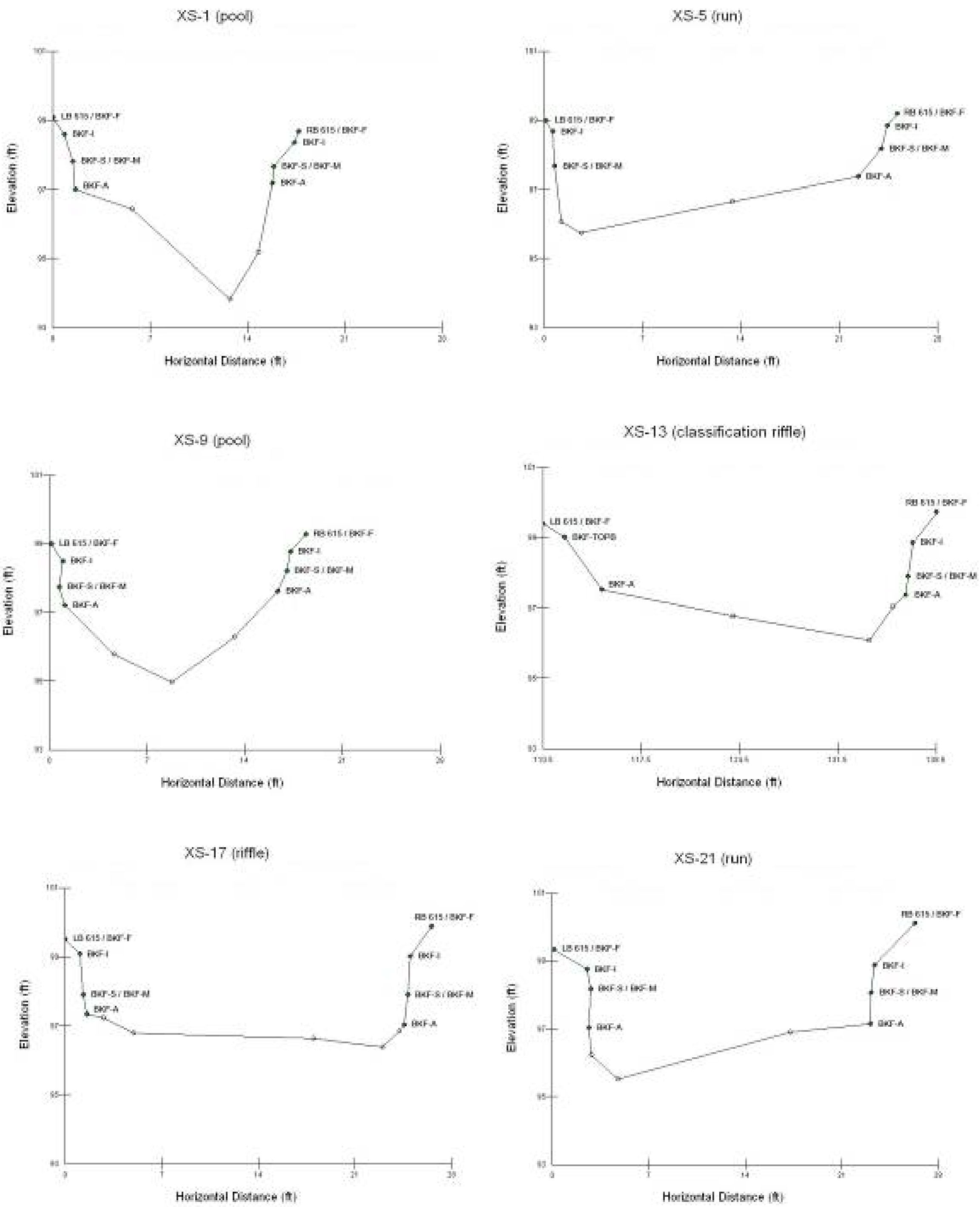


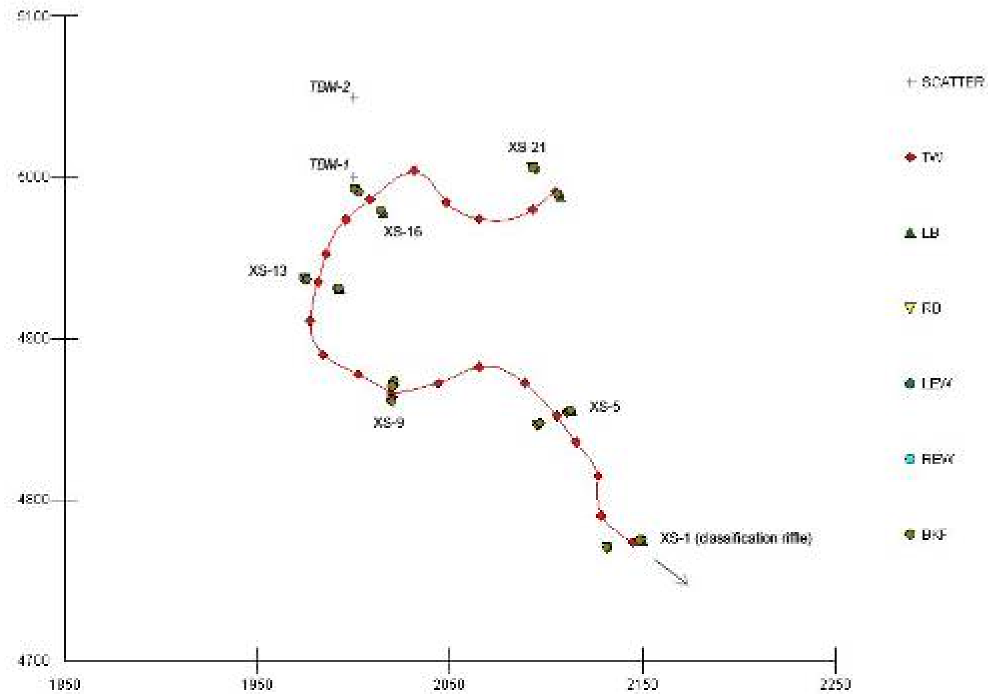
B

Figure B-36. South Fork Black Creek. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-36. South Fork Black Creek. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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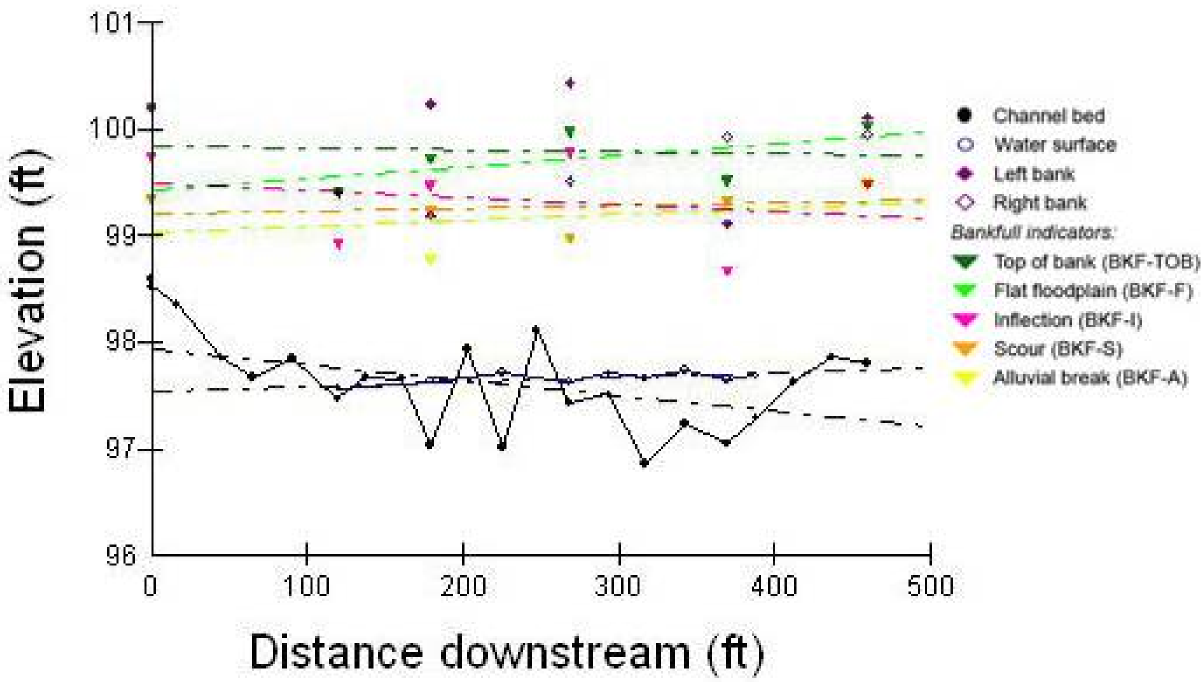
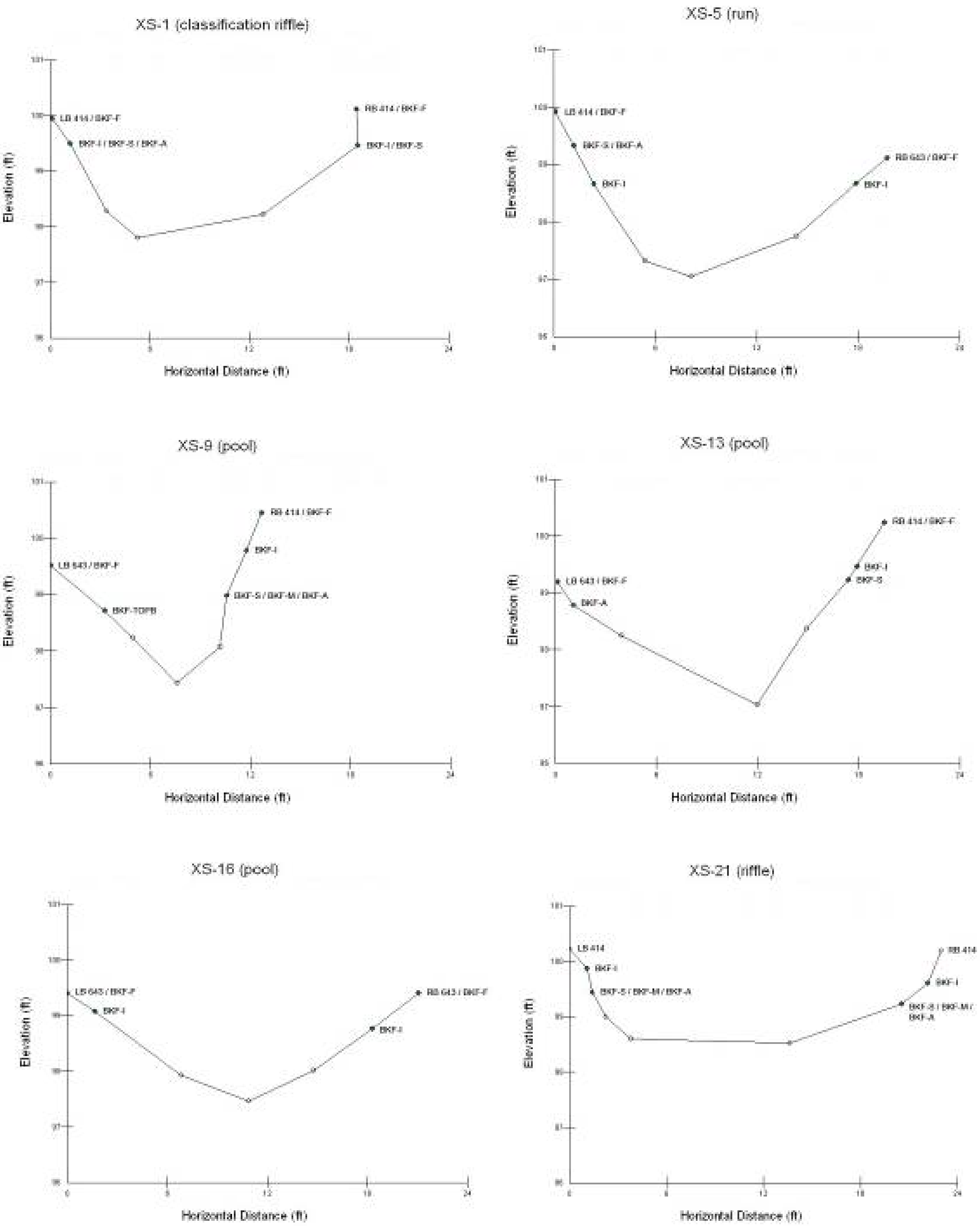


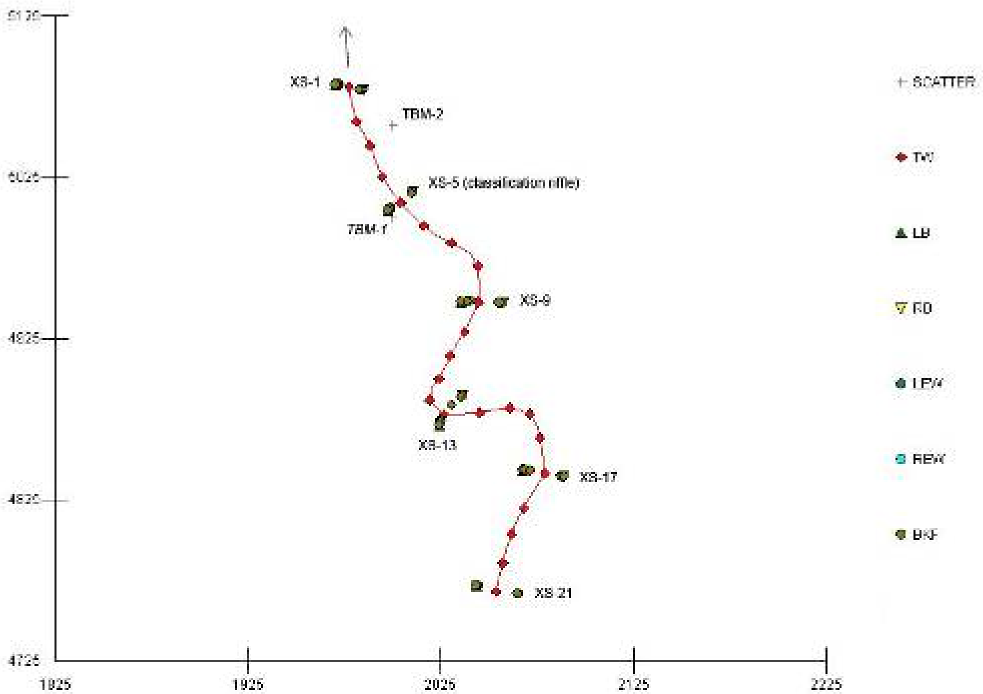
B

Figure B-37. Spoil Bank tributary. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-37. Spoil Bank tributary. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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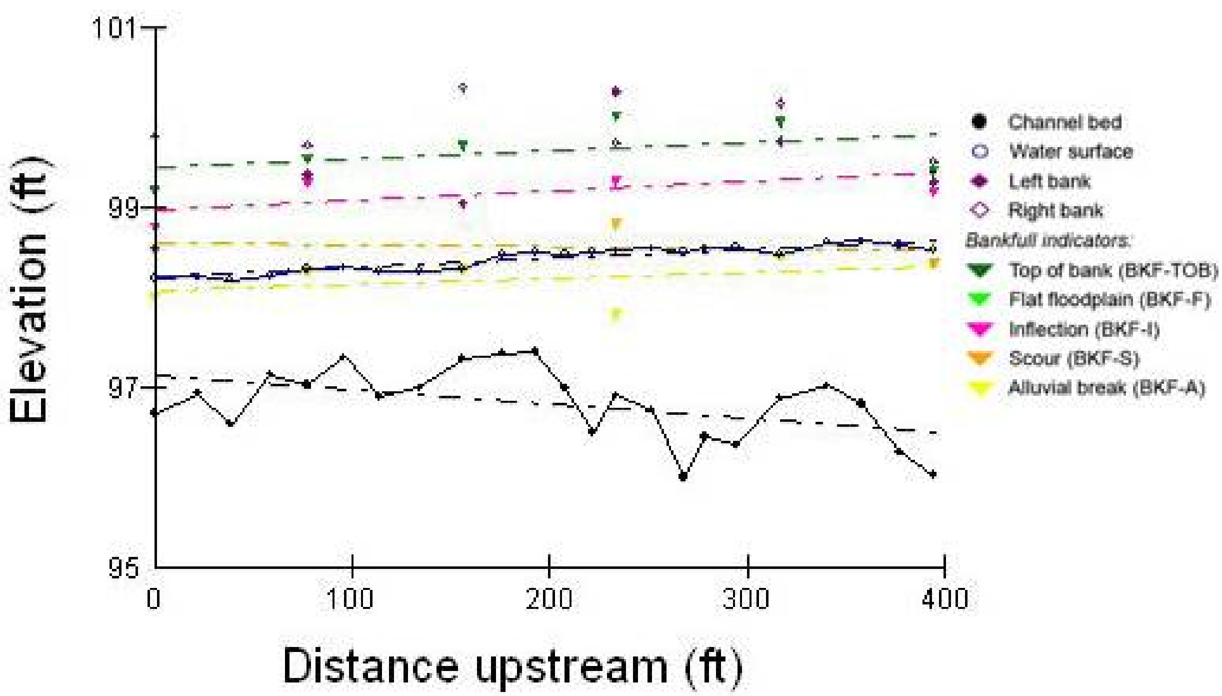
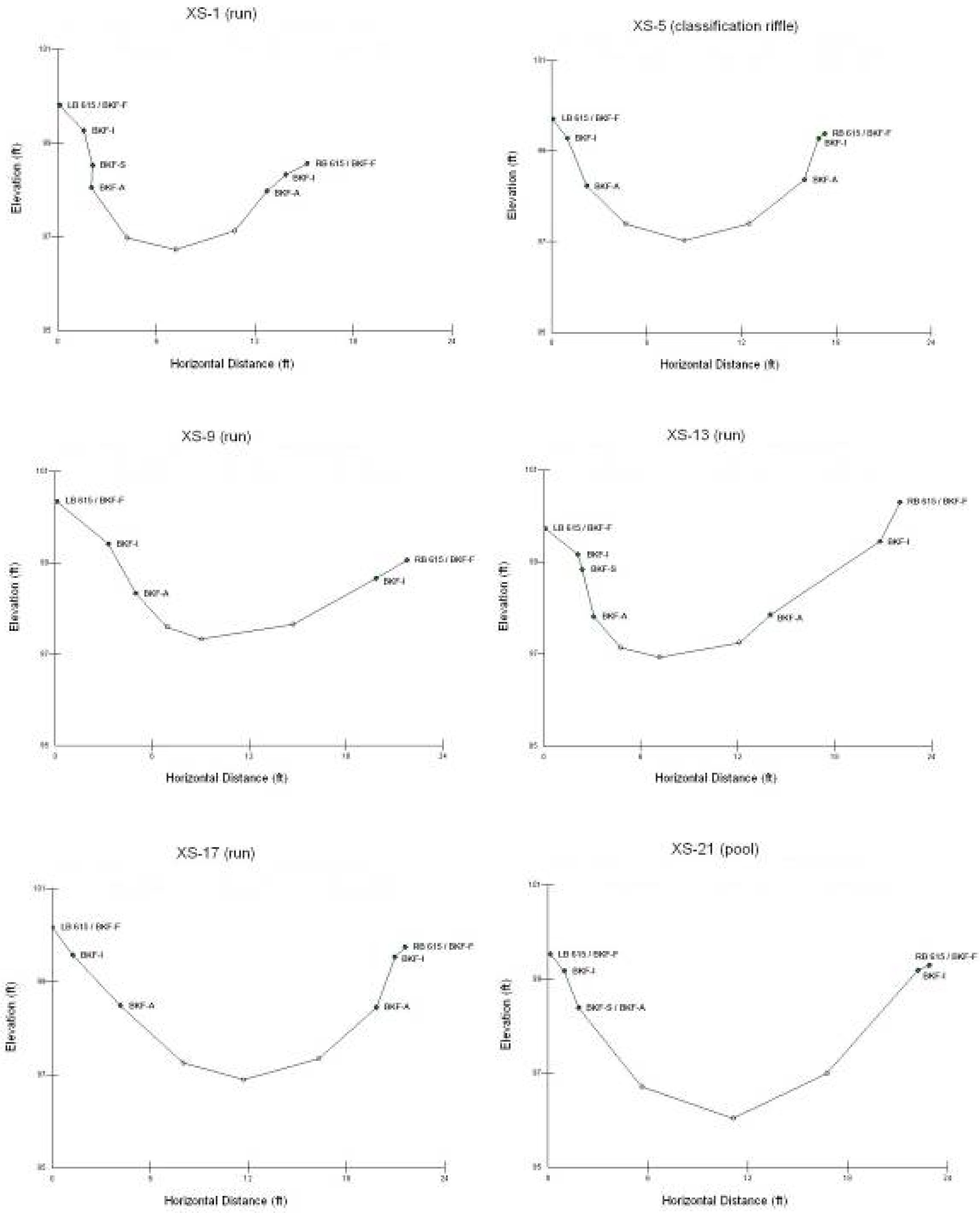


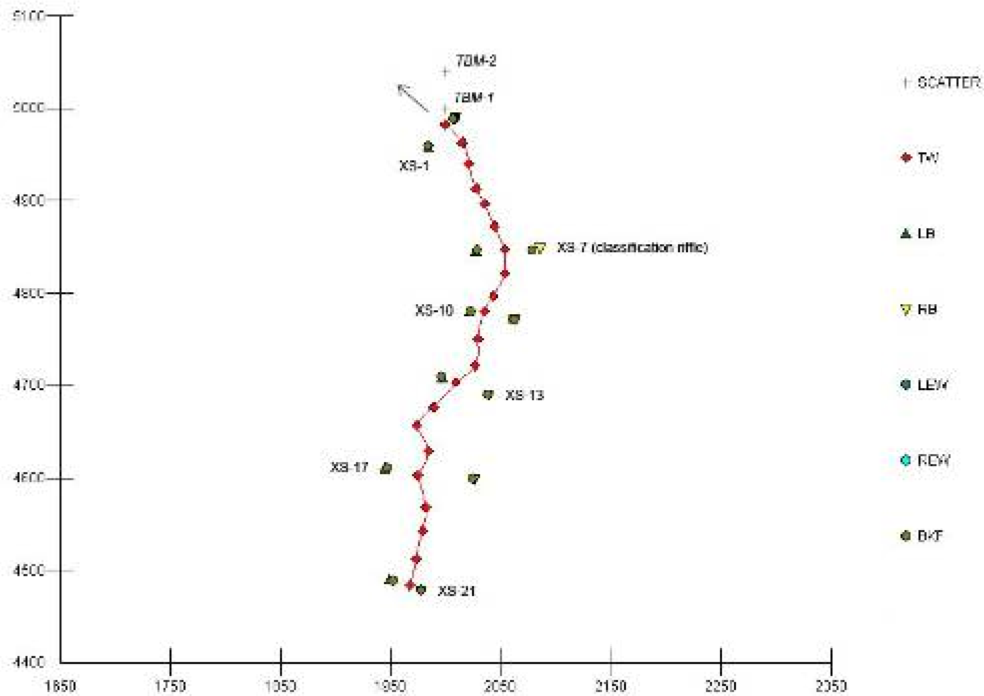
B

Figure B-38. Ten Mile Creek. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-38. Ten Mile Creek. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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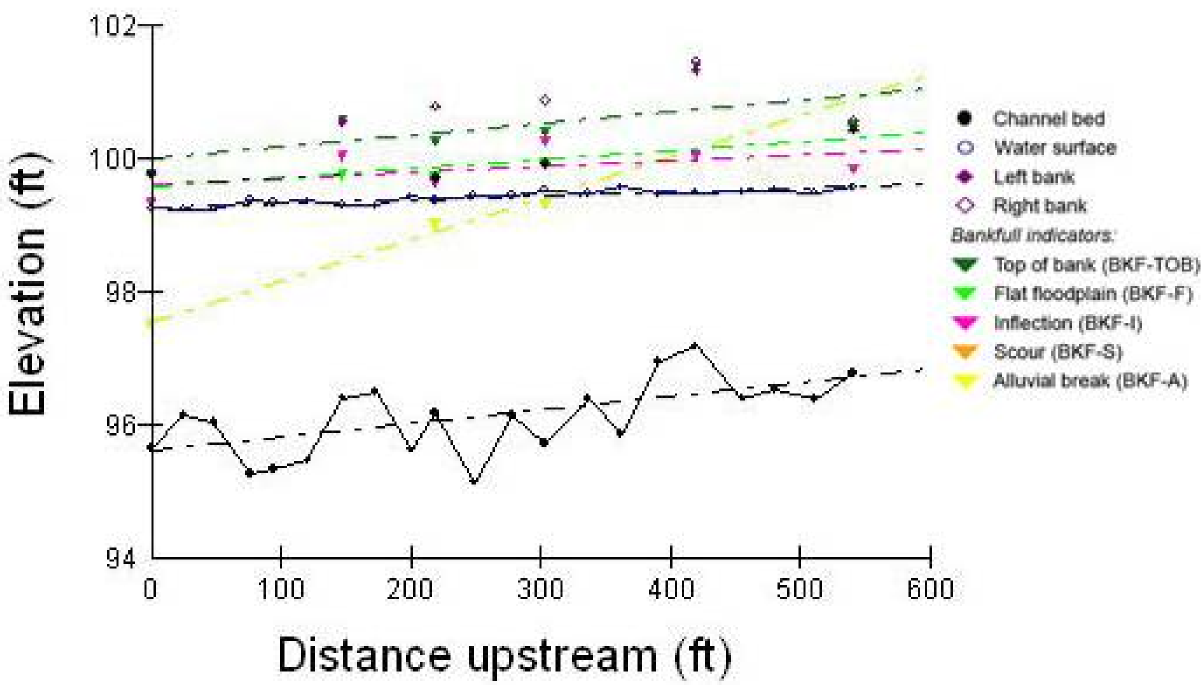
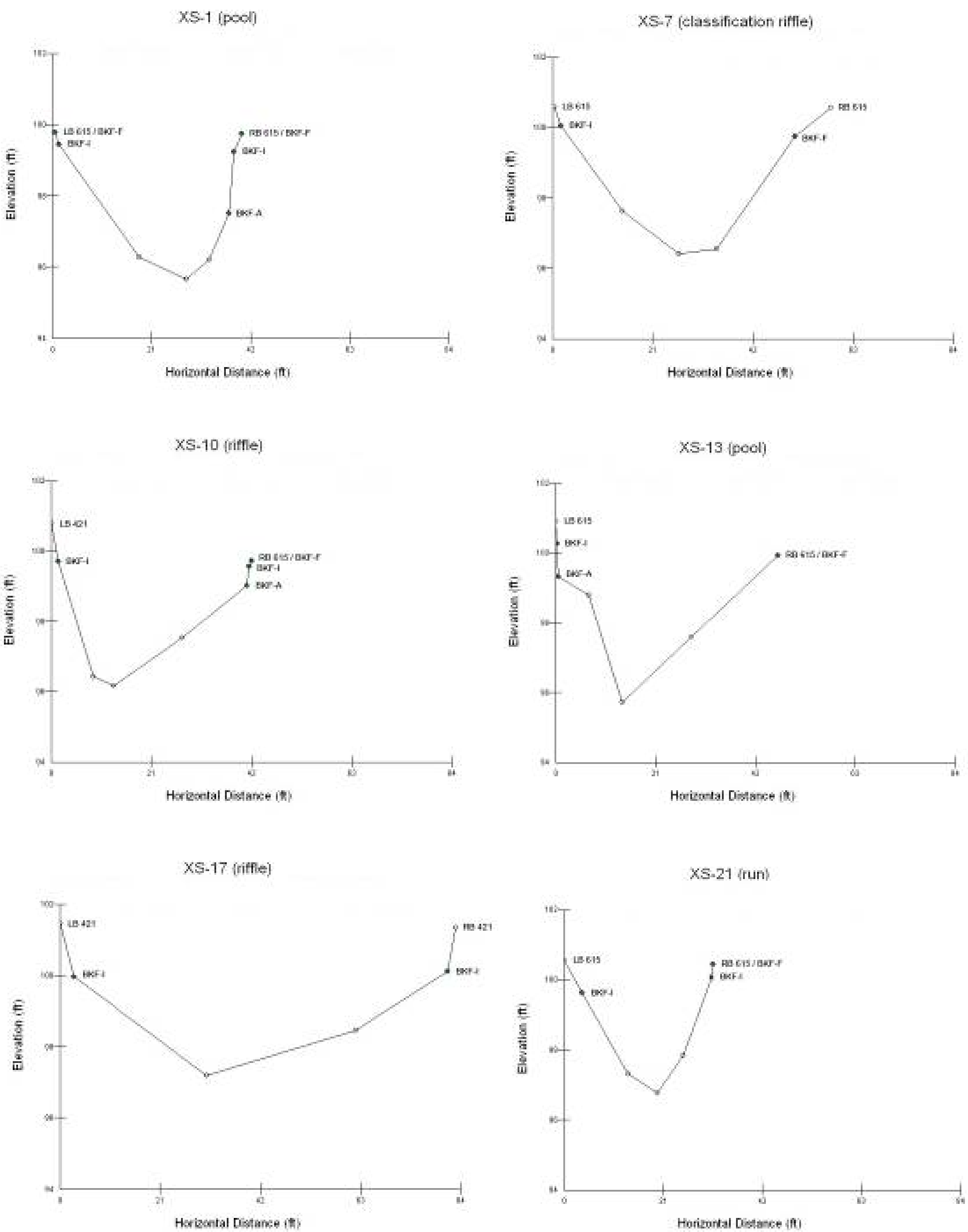


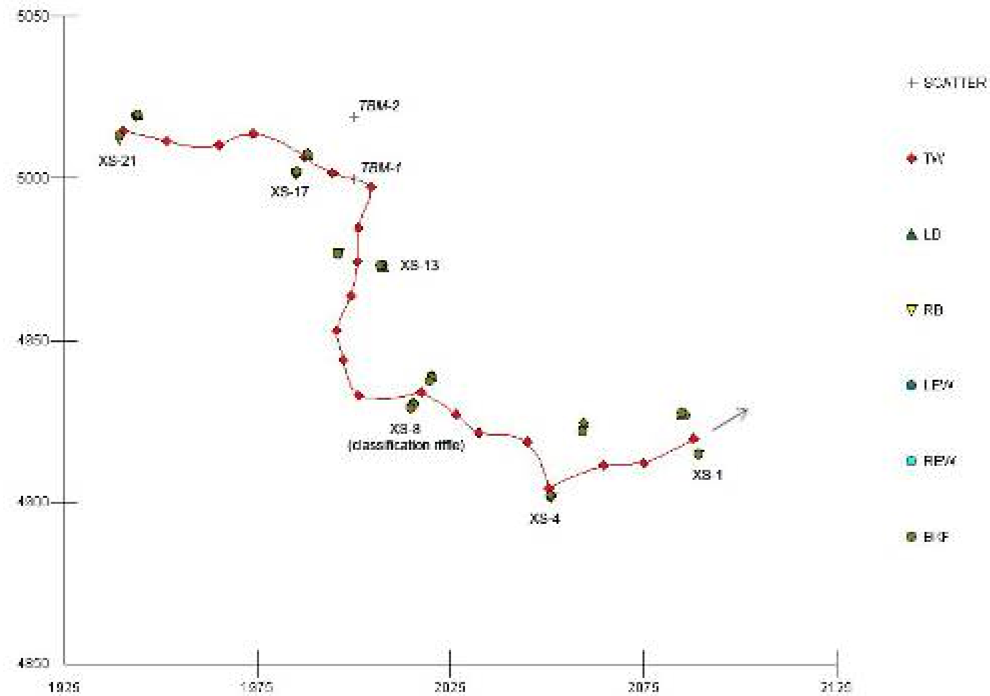
B

Figure B-39. Tiger Creek near Babson Park. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-39. Tiger Creek near Babson Park. A) Plan form. B) Longitudinal profile. C) Cross-sections.



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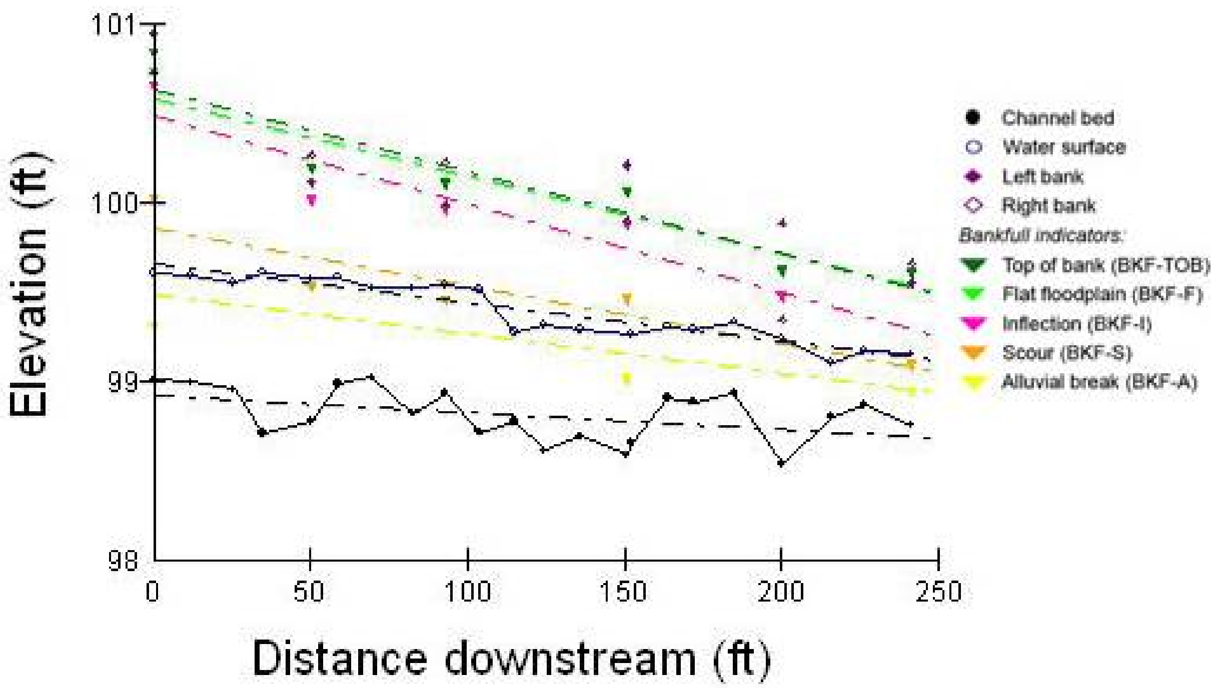
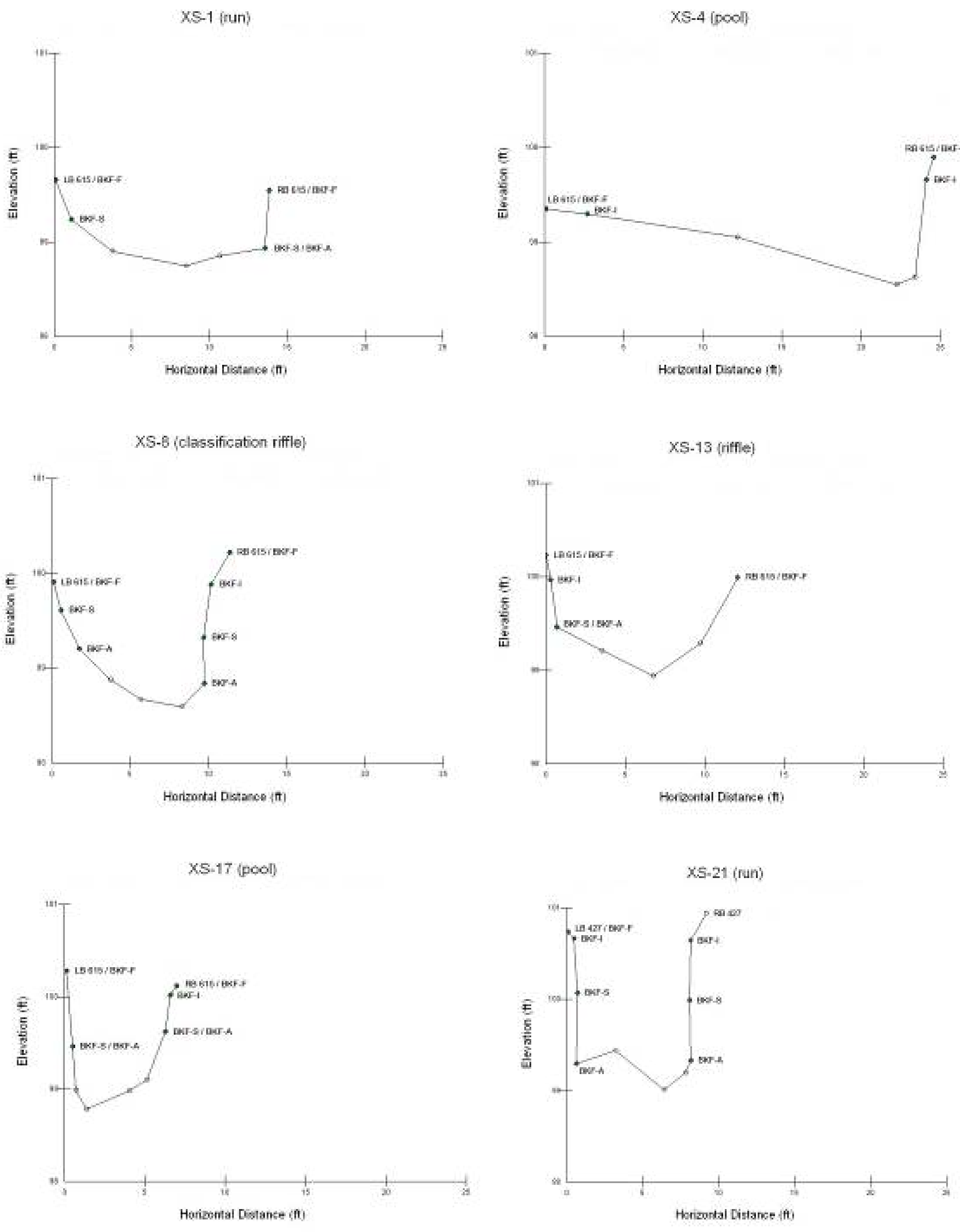


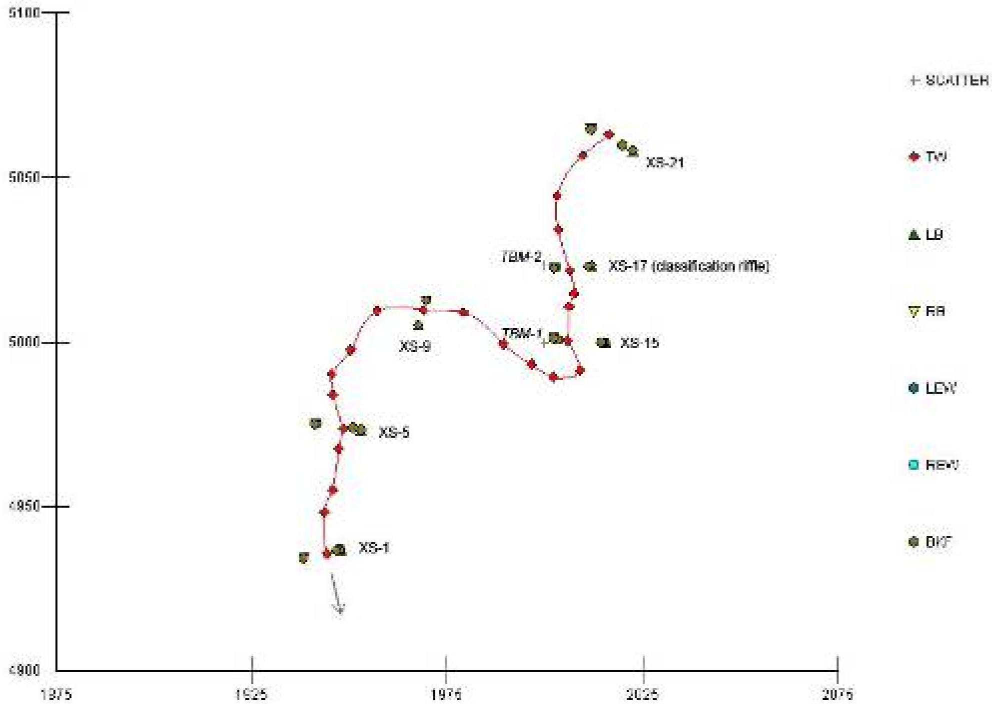
B

Figure B-40. Tiger Creek tributary. A) Plan form. B) Longitudinal profile. C) Cross-sections.

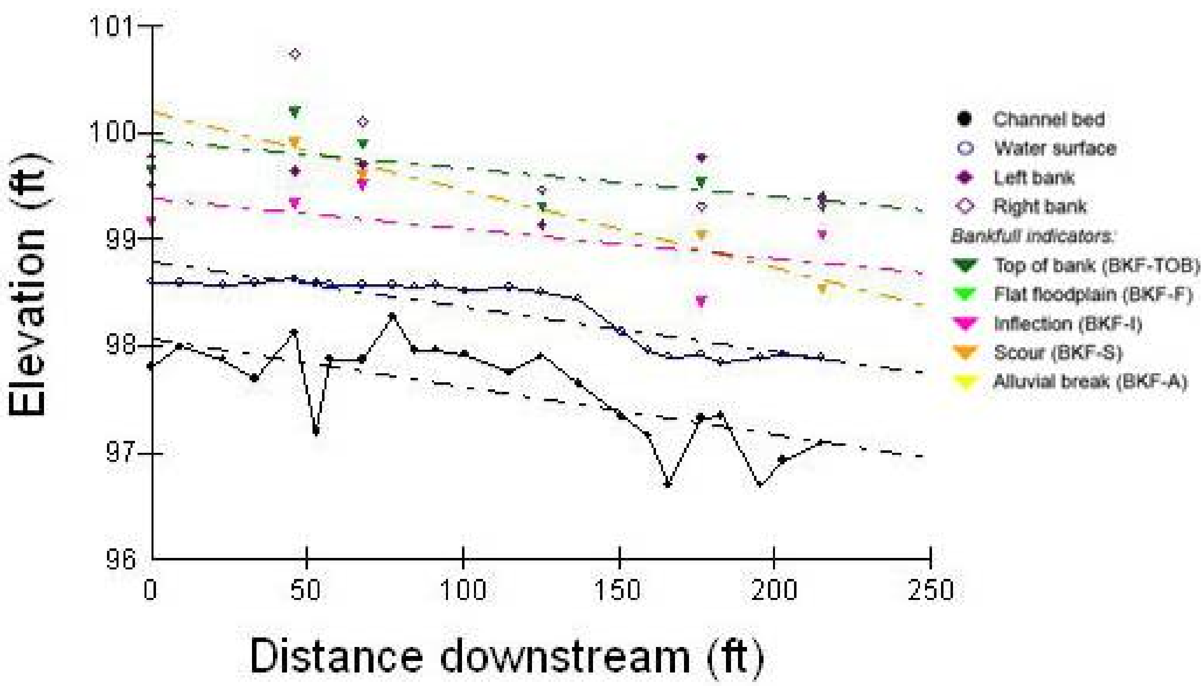


C

Figure B-40. Tiger Creek tributary. A) Plan form. B) Longitudinal profile. C) Cross-sections.

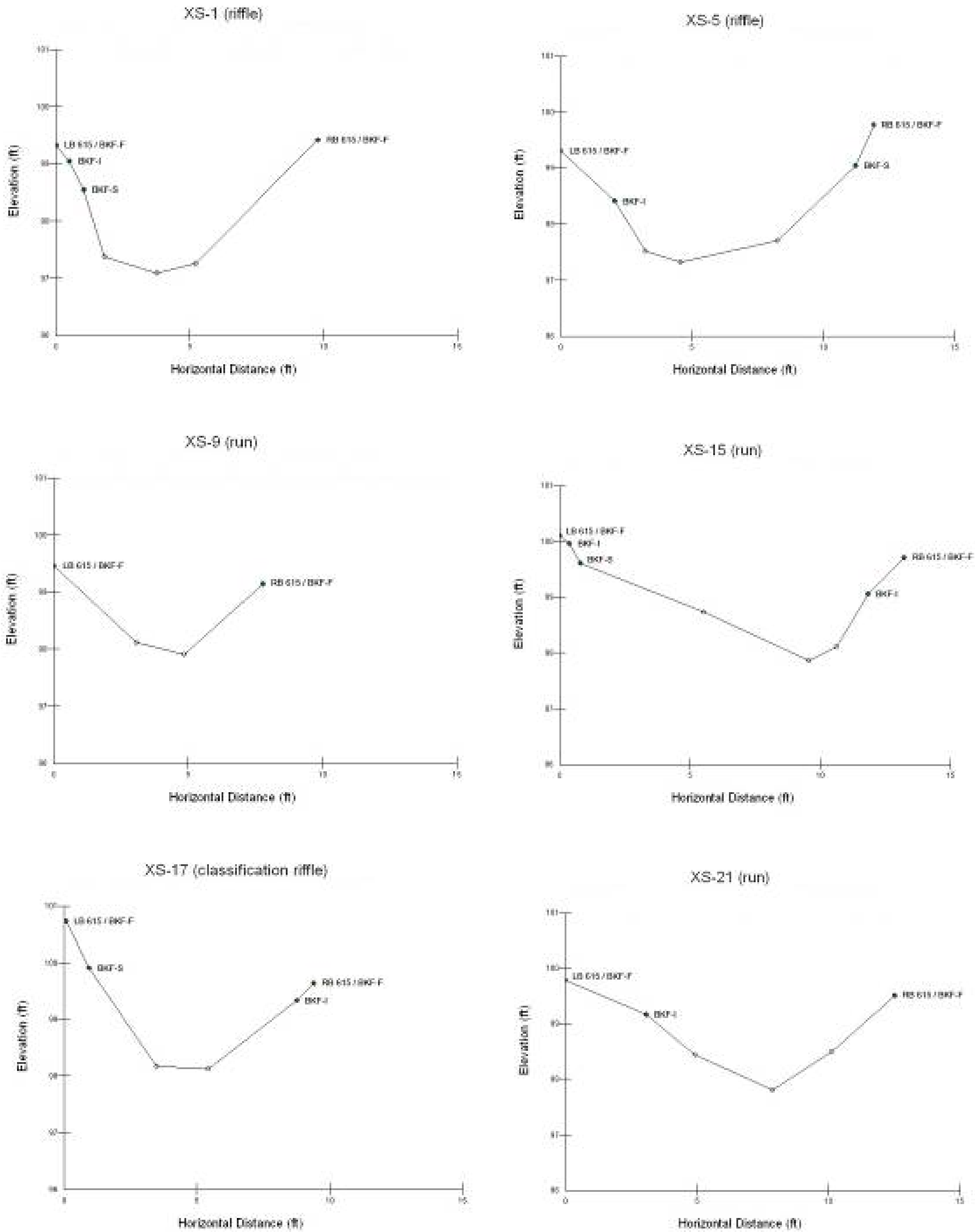


A



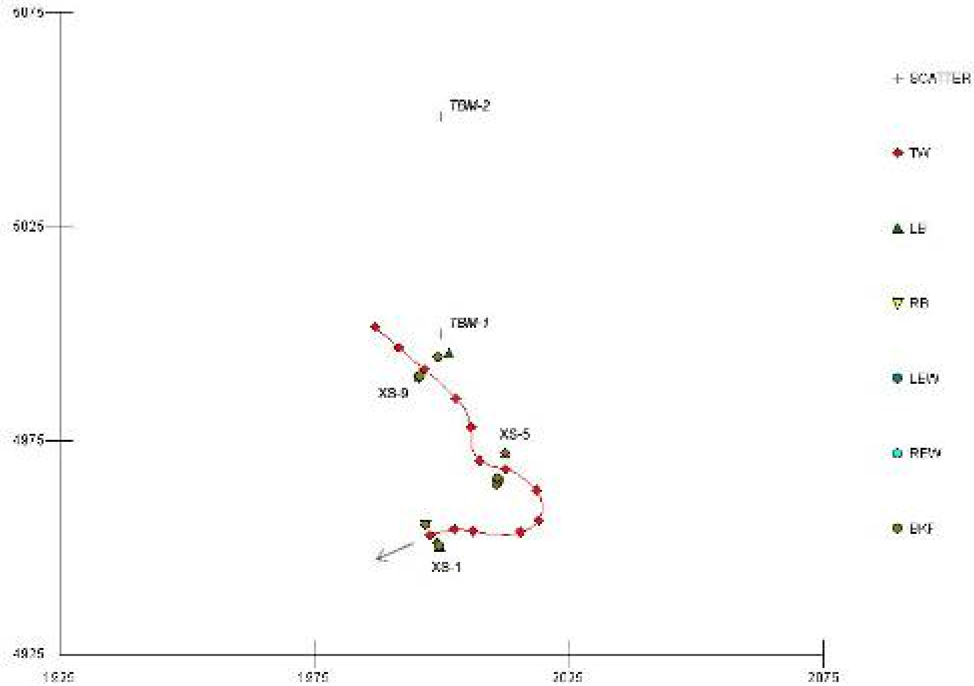
B

Figure B-41. Triple Creek unnamed tributary 1. A) Plan form. B) Longitudinal profile. C) Cross-sections.

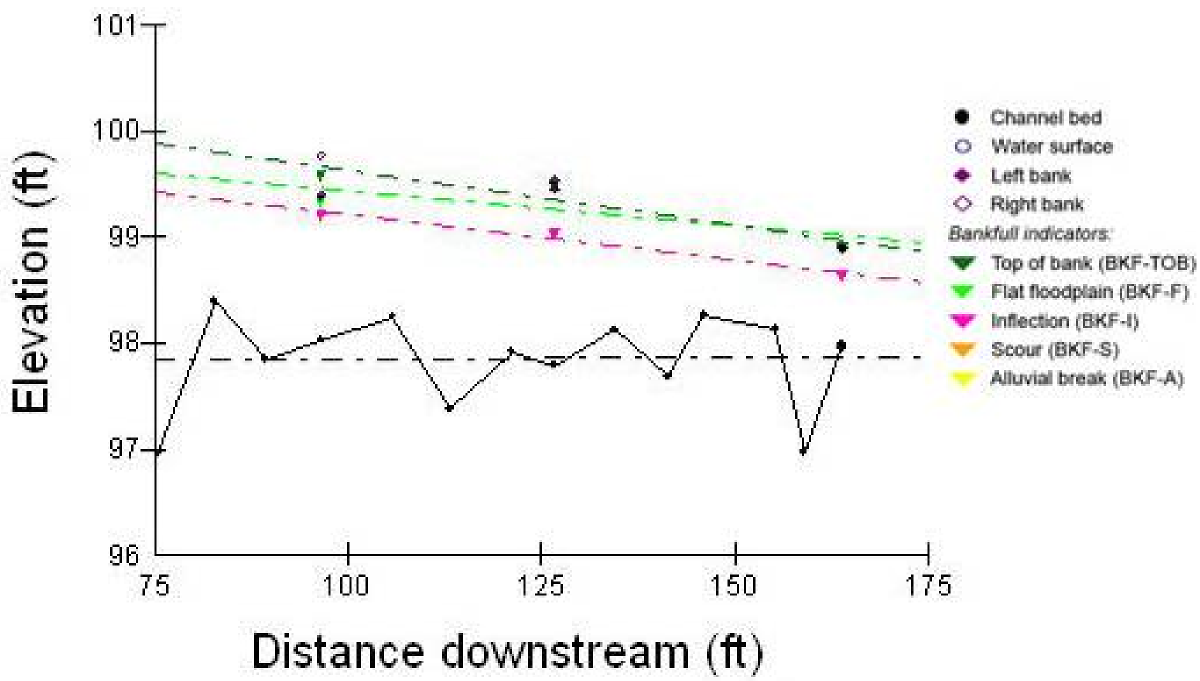


C

Figure B-41. Triple Creek unnamed tributary 1. A) Plan form. B) Longitudinal profile. C) Cross-sections.

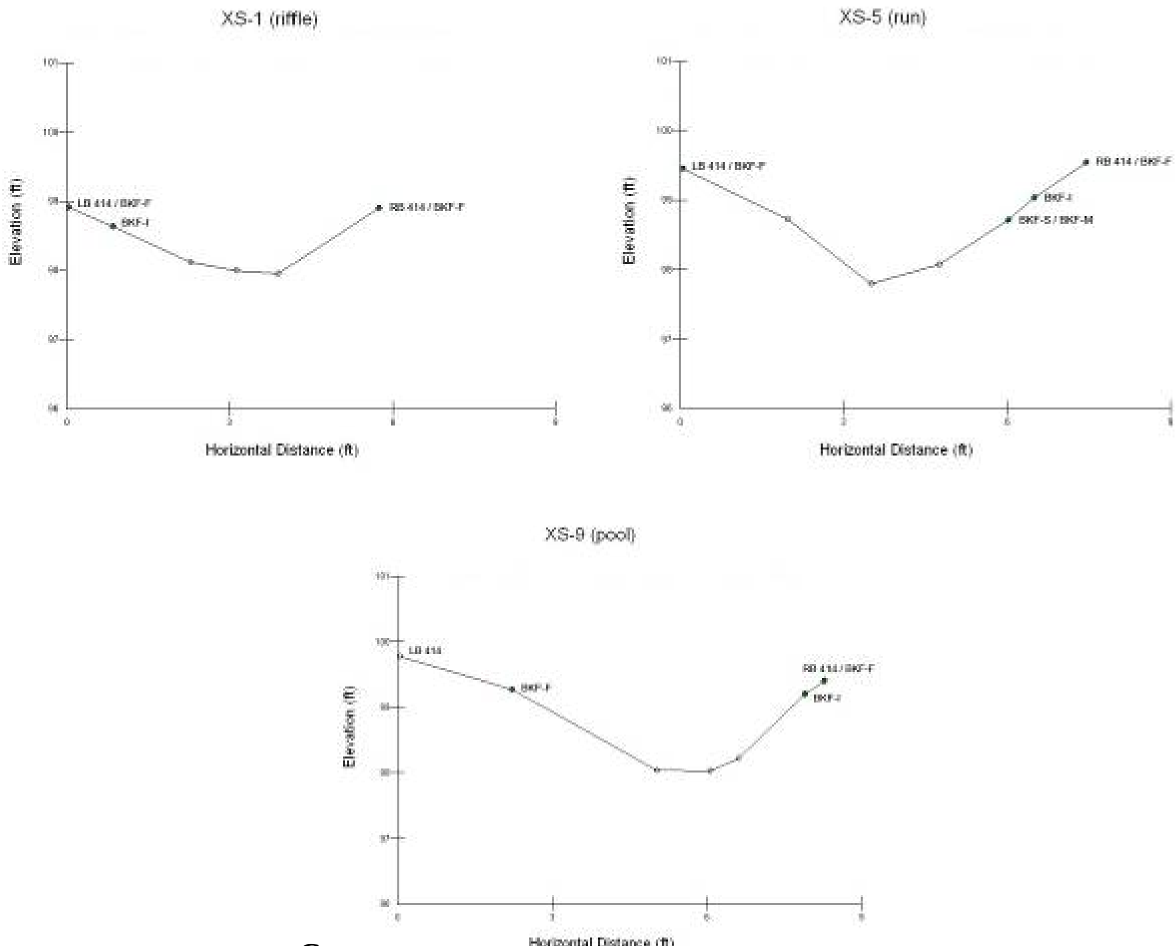


A



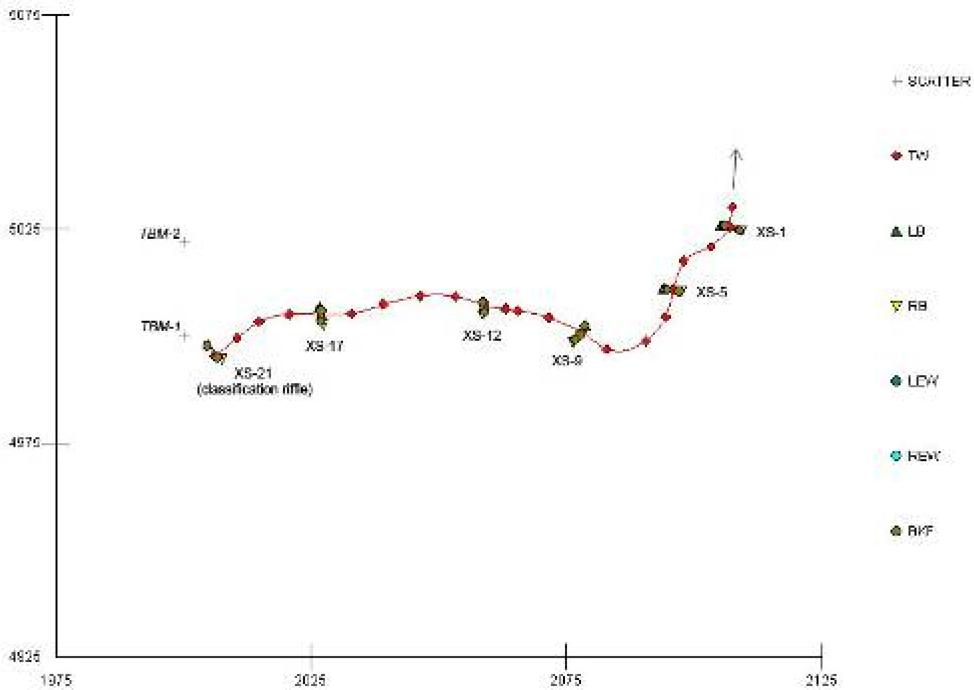
B

Figure B-42. Triple Creek unnamed tributary 2. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-42. Triple Creek unnamed tributary 2. A) Plan form. B) Longitudinal profile. C) Cross-sections.



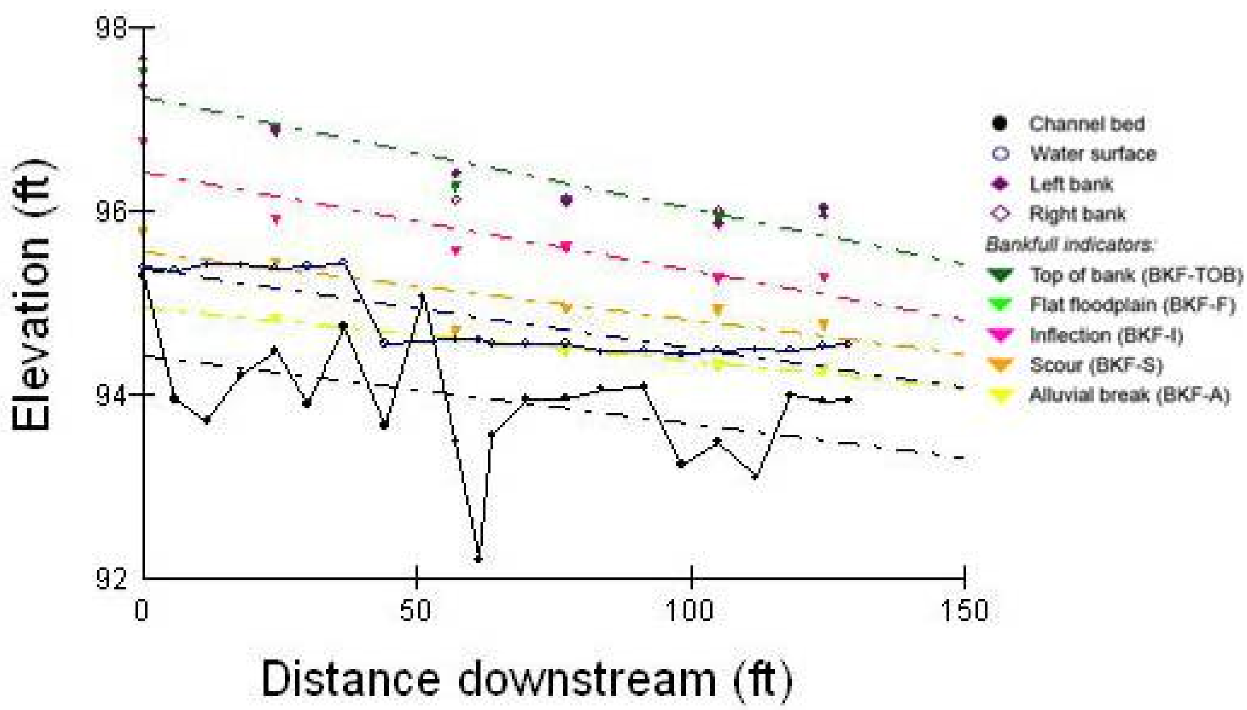
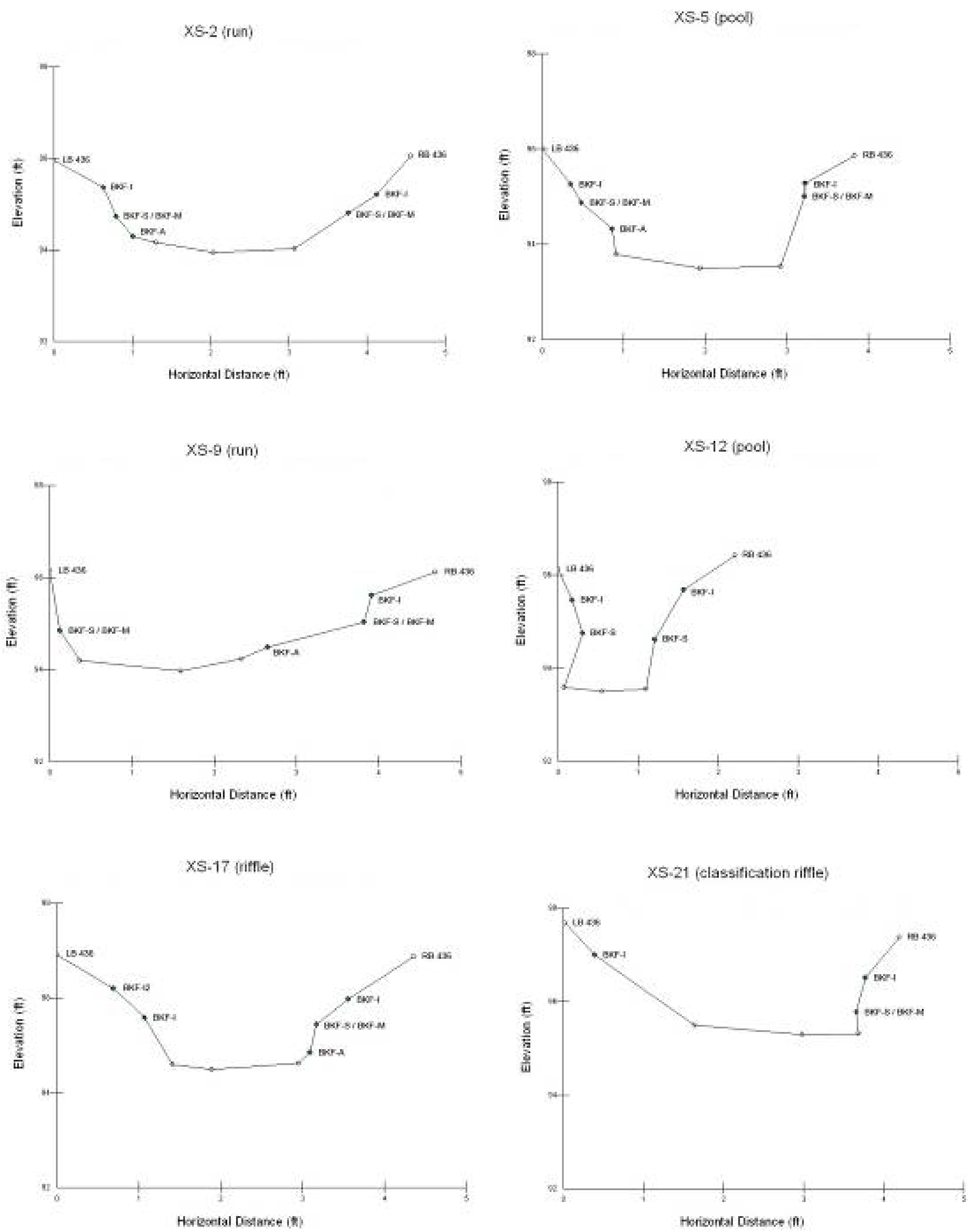
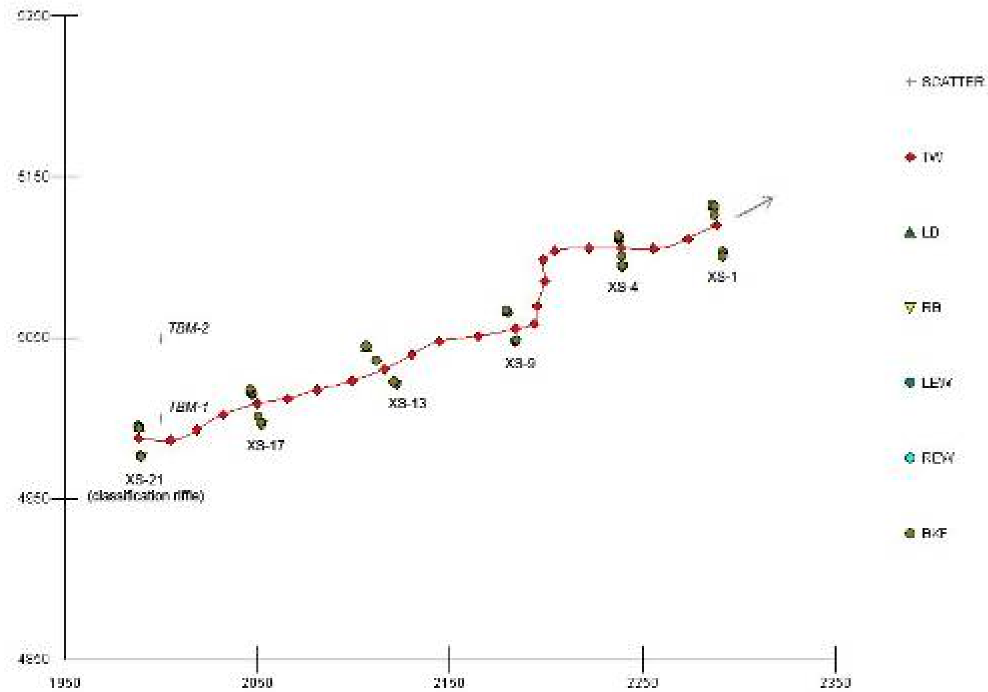


Figure B-43. Tuscawilla Lake tributary. A) Plan form. B) Longitudinal profile. C) Cross-sections.

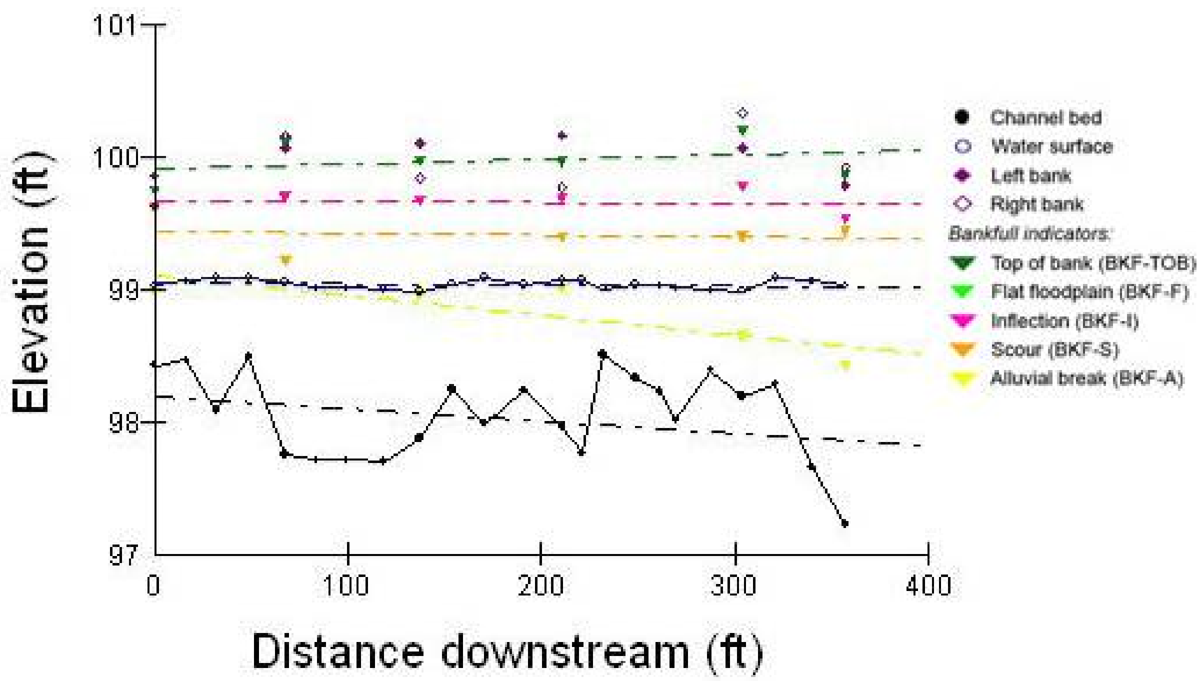


C

Figure B-43. Tuscawilla Lake tributary. A) Plan form. B) Longitudinal profile. C) Cross-sections.

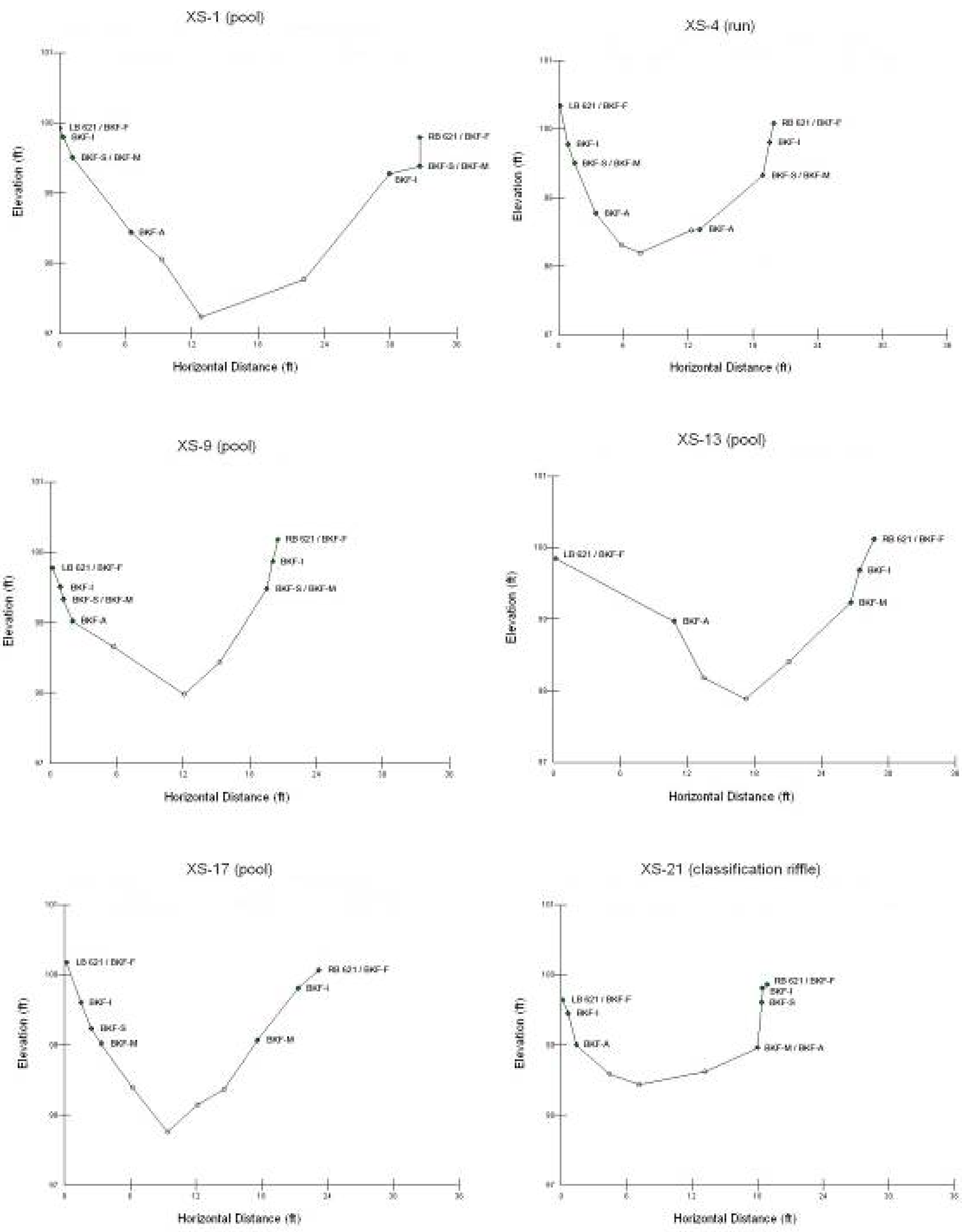


A



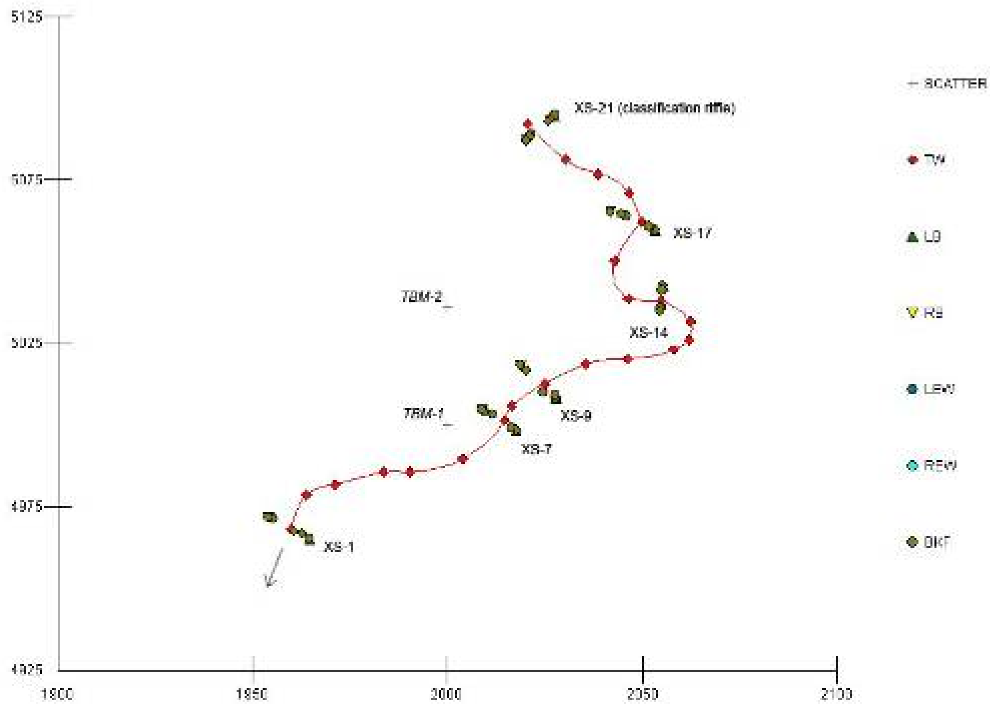
B

Figure B-44. Tyson Creek. A) Plan form. B) Longitudinal profile. C) Cross-sections.

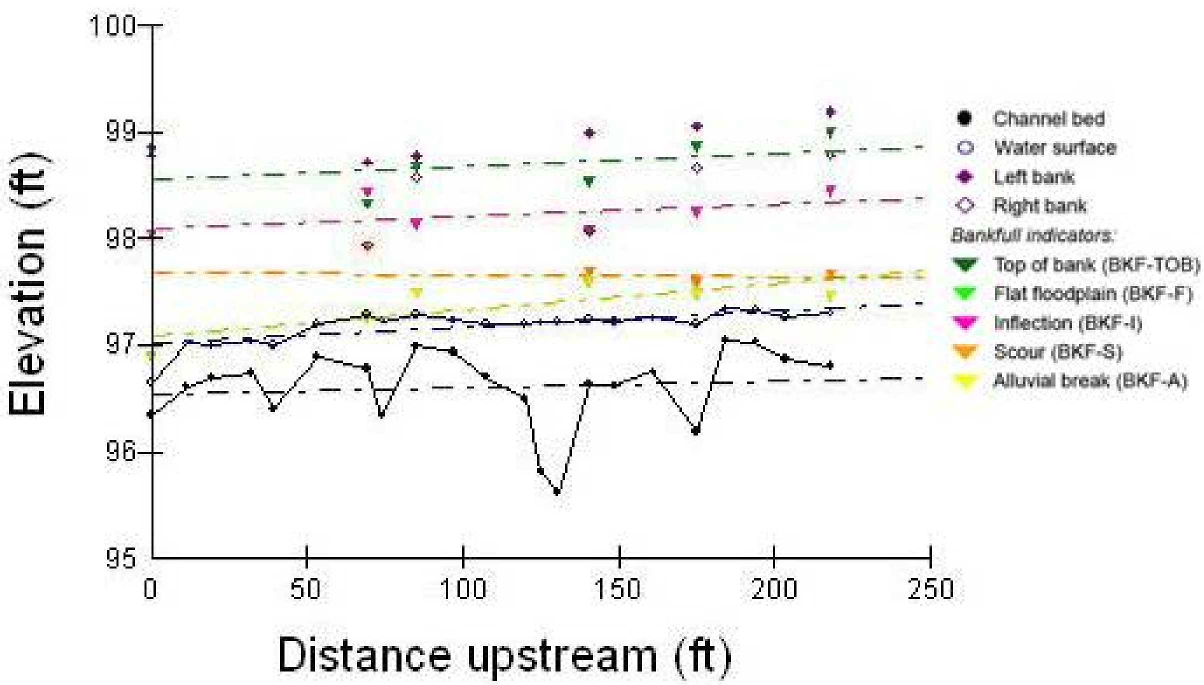


C

Figure B-44. Tyson Creek. A) Plan form. B) Longitudinal profile. C) Cross-sections.

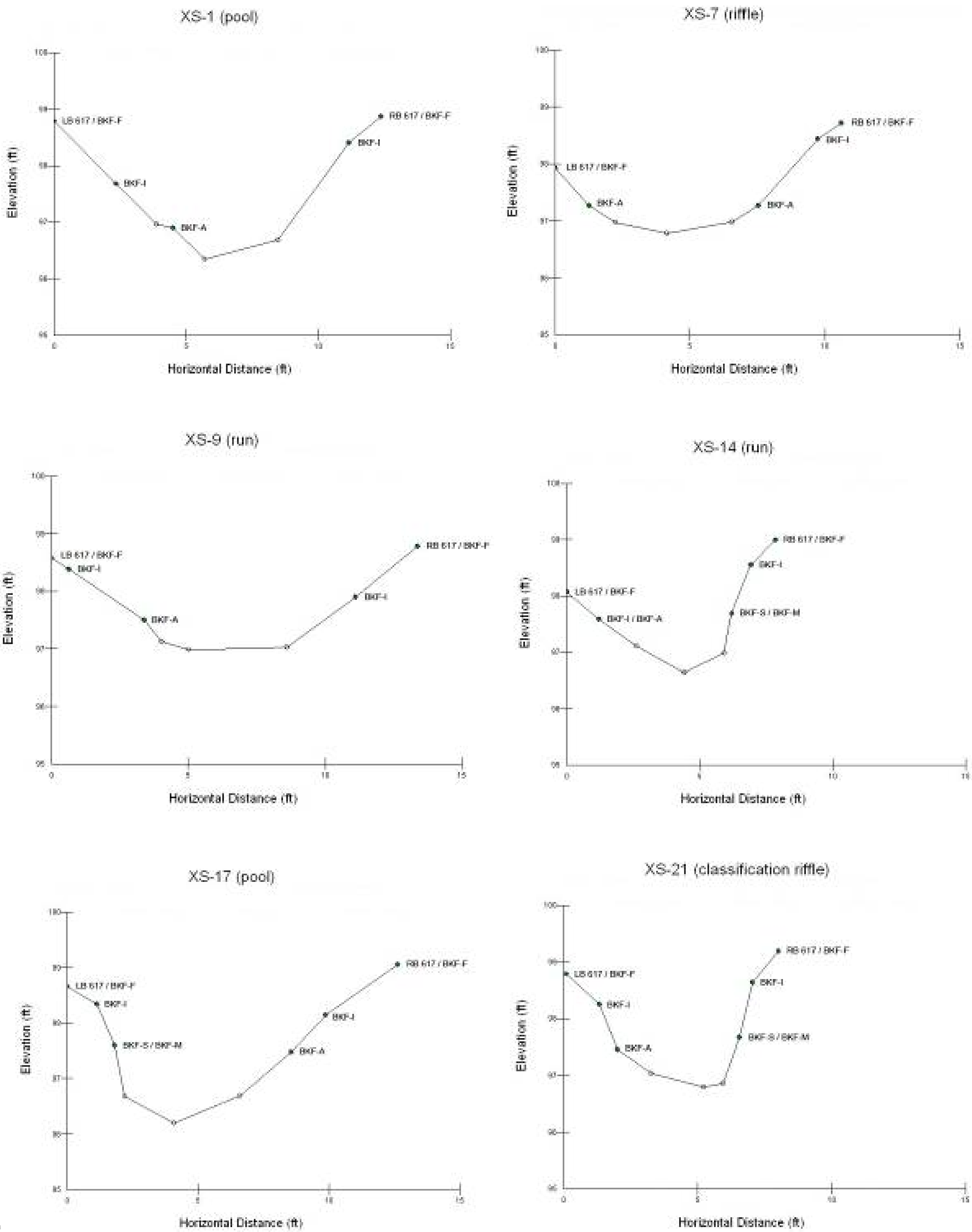


A



B

Figure B-45. Unnamed Lower Wekiva tributary. A) Plan form. B) Longitudinal profile. C) Cross-sections.



C

Figure B-45. Unnamed Lower Wekiva tributary. A) Plan form. B) Longitudinal profile. C) Cross-sections.

APPENDIX C
SITE PHOTOGRAPHS

Alexander Springs tributary 2
(February 28, 2008)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Blackwater Creek near Cassia
(March 3, 2008)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Blues Creek near Gainesville
(January 10, 2008)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Bowlegs Creek near Fort Meade
(December 3, 2007)

DOWNSTREAM

UPSTREAM

LEFT BANK

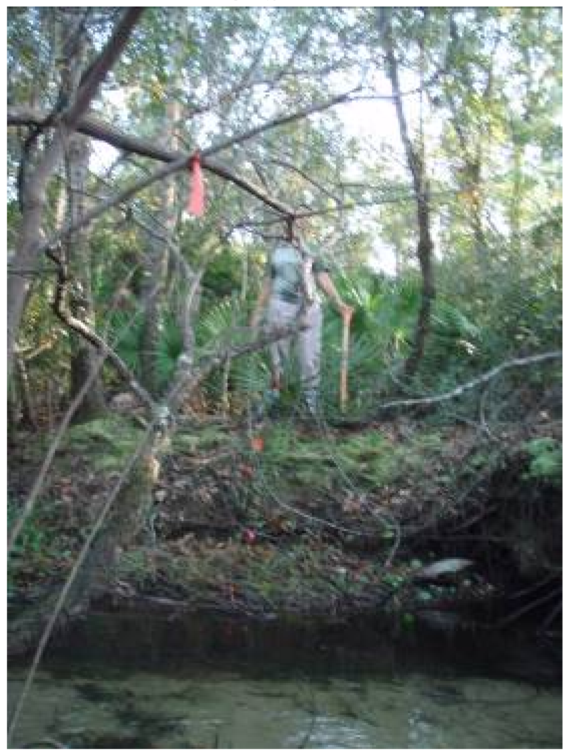
RIGHT BANK

Carter Creek near Sebring
(December 7, 2007)

DOWNSTREAM

UPSTREAM

LEFT BANK



RIGHT BANK

Catfish Creek near Lake Wales
(September 27, 2007)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Coons Bay Branch
(November 13, 2007)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Cow Creek
(January 3, 2007)

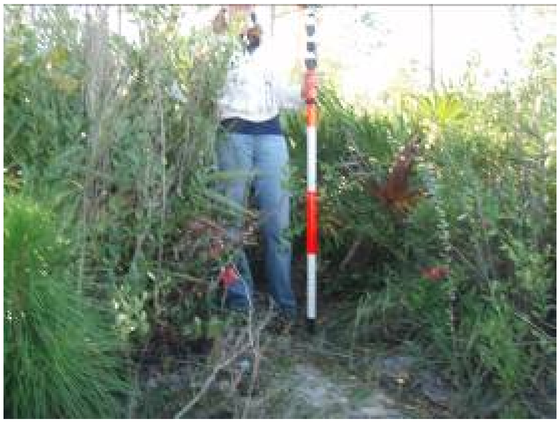
DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Cypress Slash tributary
(December 17, 2007)



DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

East Fork Manatee River tributary
(November 5, 2007)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Fisheating Creek at Palmdale
(March 20, 2008)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Gold Head Branch
(March, 2008)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Hammock Branch
(February 18, 2008)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Hickory Creek near Ona
(AugUpstreamt 9, 2007)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Hillsborough River tributary
(November 1, 2007)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Horse Creek near Arcadia
(March 17, 2008)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Jack Creek
(December 13, 2007)

Jumping Gully
(February, 2008)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Lake June-in-Winter tributary
(December 10, 2007)

DOWNSTREAM

LEFT BANK

RIGHT BANK

Little Haw Creek near Seville
(February 29, 2008)


DOWNSTREAM


UPSTREAM


LEFT BANK


RIGHT BANK

Livingston Creek near Frostproof
(December 5, 2007)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Livingston Creek tributary
(October 5, 2007)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Lochloosa Creek at Grove Park
(January 7, 2008)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Lowry Lake tributary
(February 14, 2004)

DOWNSTREAM

UPSTREAM

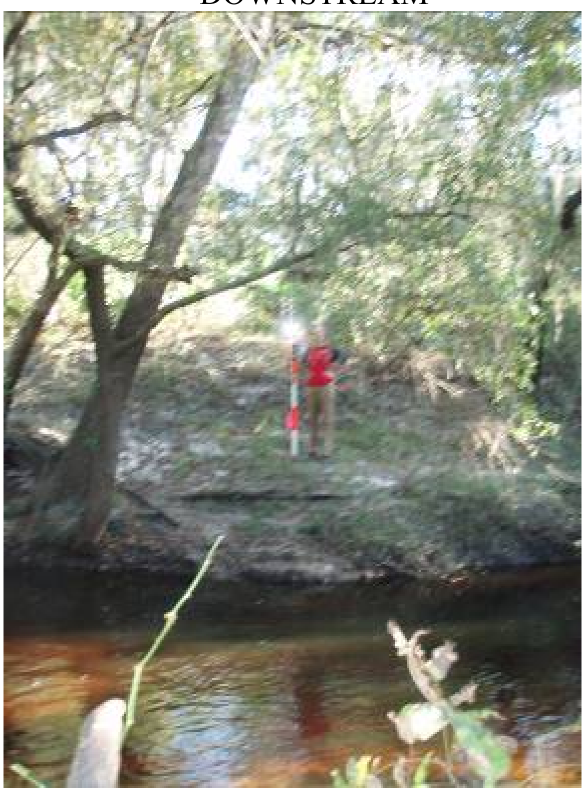
LEFT BANK

RIGHT BANK

Manatee River near Myakka Head
(November 9, 2007)

DOWNSTREAM

UPSTREAM



LEFT BANK

RIGHT BANK

Manatee River tributary
(November 2, 2007)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Morgan Hole Creek
(December 17, 2007)


DOWNSTREAM


UPSTREAM


LEFT BANK


RIGHT BANK

Moses Creek near Moultrie
(January 18, 2008)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Myakka River tributary 1
(October 15, 2007)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Myakka River tributary 2
(October 16, 2007)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Nine Mile Creek
(March 12, 2008)


DOWNSTREAM


UPSTREAM


LEFT BANK


RIGHT BANK

Rice Creek near Springside
(January 11, 2008)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Santa Fe River near Graham
(January 16, 2008)


DOWNSTREAM


UPSTREAM


LEFT BANK


RIGHT BANK

Shiloh Run near Alachua
(January 8, 2008)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Snell Creek
(November 12, 2007)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

South Fork Black Creek
(February, 2008)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Ten Mile Creek
(March 6, 2008)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Tiger Creek near Babson Park
(March 14, 2008)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Tiger Creek tributary
(December 6, 2007)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Triple Creek unnamed tributary 1
(October 4, 2007)

Triple Creek unnamed tributary 2
(October 11, 2007)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

TUpstreamcawilla Lake tributary
(January 28, 2008)


DOWNSTREAM


UPSTREAM


LEFT BANK


RIGHT BANK

Tyson Creek
(December 18, 2007)

DOWNSTREAM

UPSTREAM

LEFT BANK

RIGHT BANK

Unnamed Wekiva River tributary
(October 30, 2007)

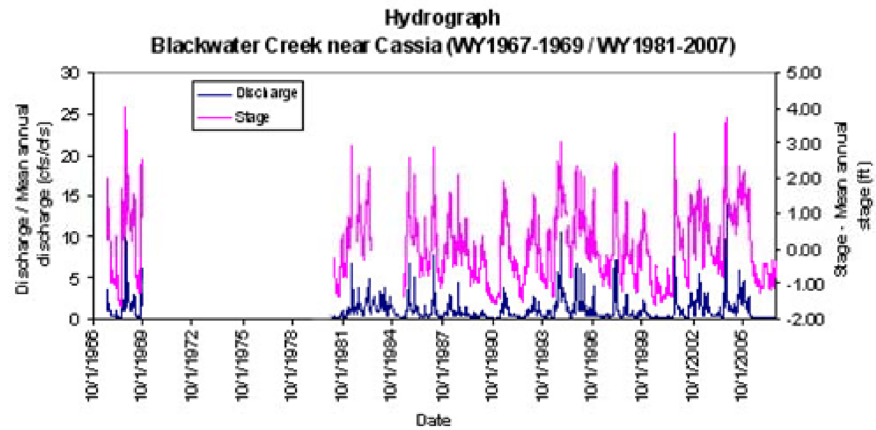
DOWNSTREAM

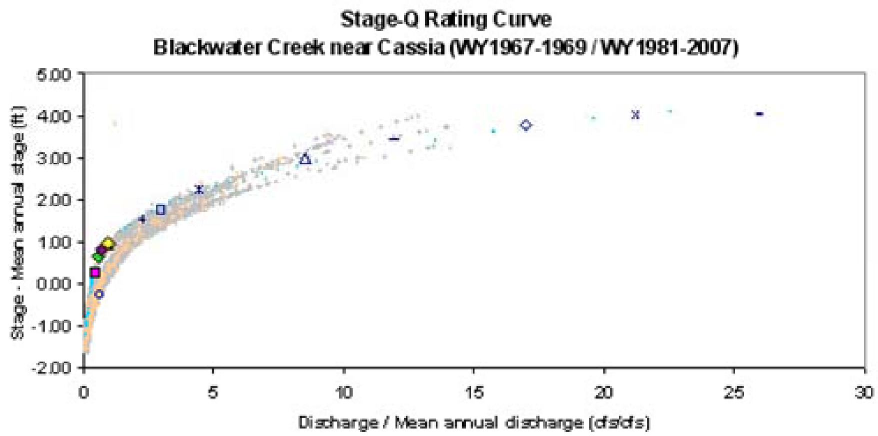
UPSTREAM

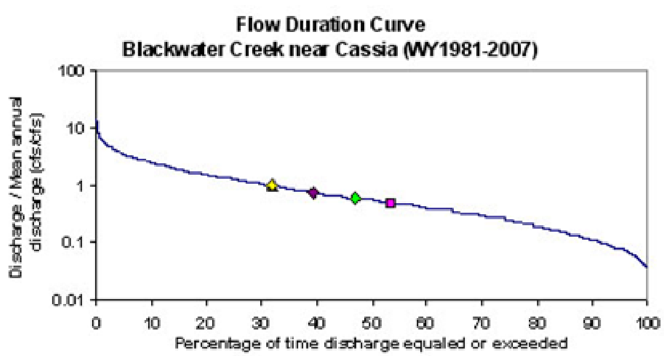
LEFT BANK

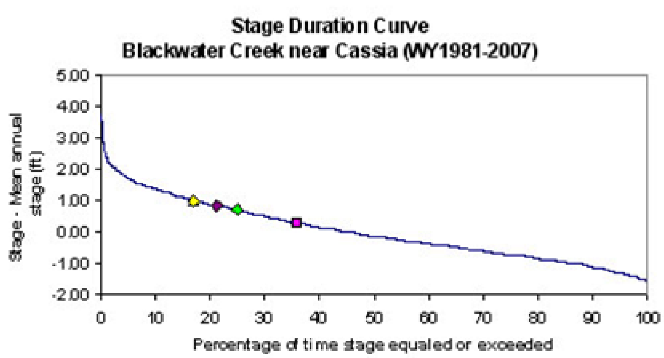
RIGHT BANK

APPENDIX D
GAGED SITE FIGURES: HYDROGRAPH, STAGE-Q RATING CURVE, FLOW AND STAGE DURATION CURVES



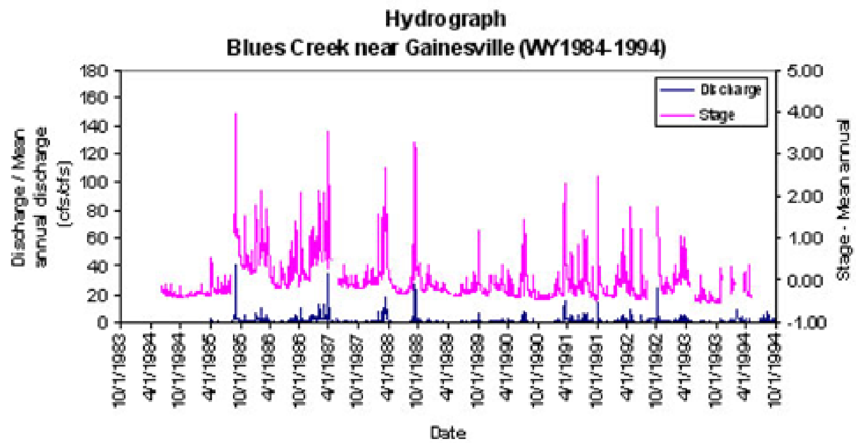


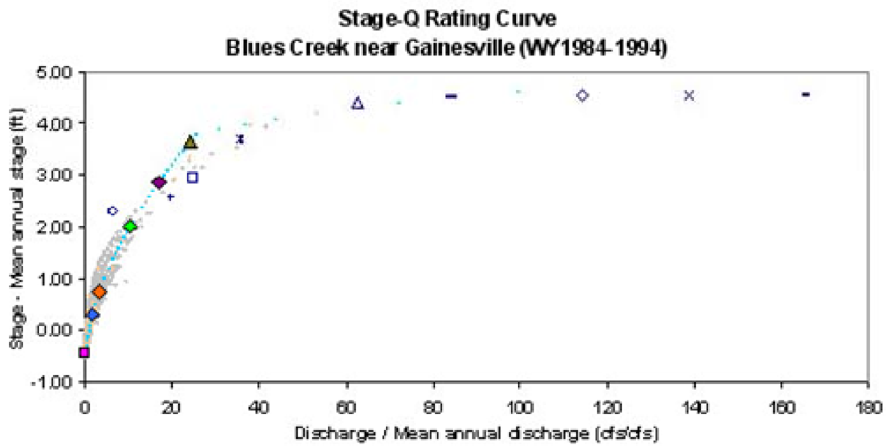


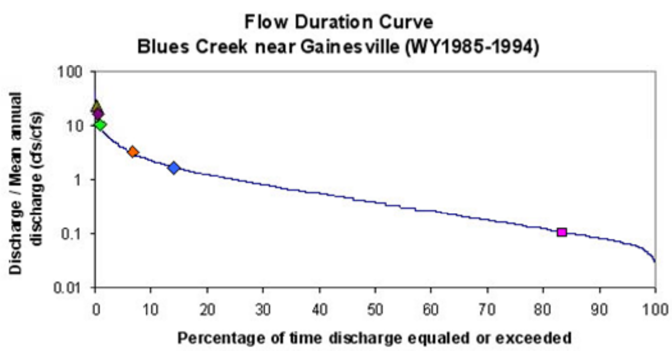


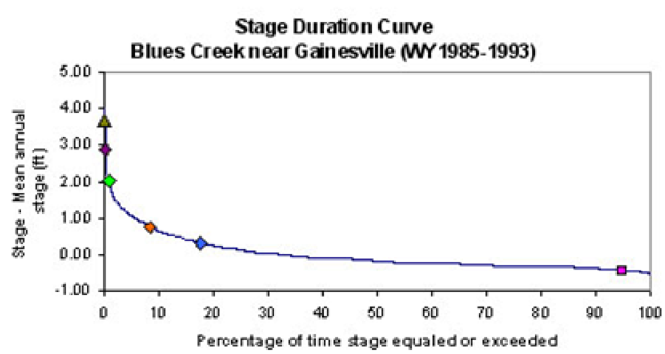
Legend:

- USGS Recorded data
- USGS Field Measurements
- Current USGS Rating Curve
- Survey Datum
- Top of bank (TOB)
- Flat floodplain (BKF-F)
- Inflection (BKF-I)
- Scour (BKF-S)
- Alluvial break (BKF-A)
- Minimum W/D ratio (BKF-W/D)
- 100 year event
- 50 year event
- 25 year event
- 10 year event
- 5 year event
- 2 year event
- 1.5 year event
- 1.25 year event
- 1.0101 year event


Hydrograph
Blues Creek near Gainesville (WY1984-1994)
Discharge / Mean annual discharge (cfs/cfs)
Stage - Mean annual stage (ft)
Discharge
Stage
Date

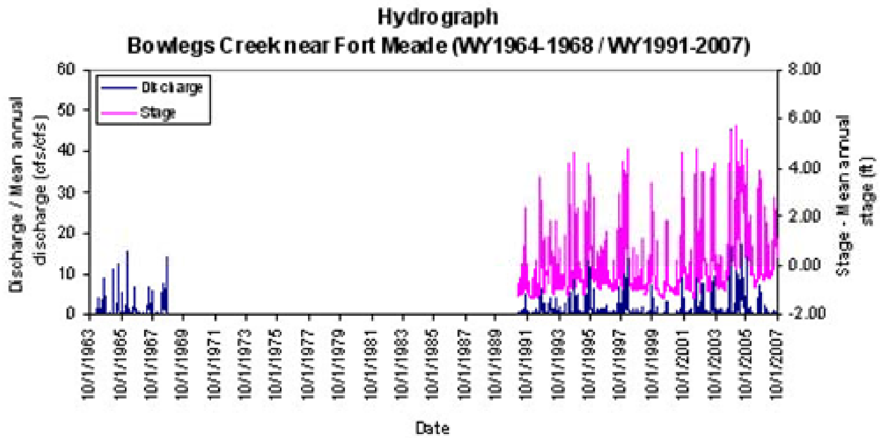

Stage-Q Rating Curve
Blues Creek near Gainesville (WY1984-1994)
Stage - Mean annual stage (ft)
Discharge / Mean annual discharge (cfs/cfs)

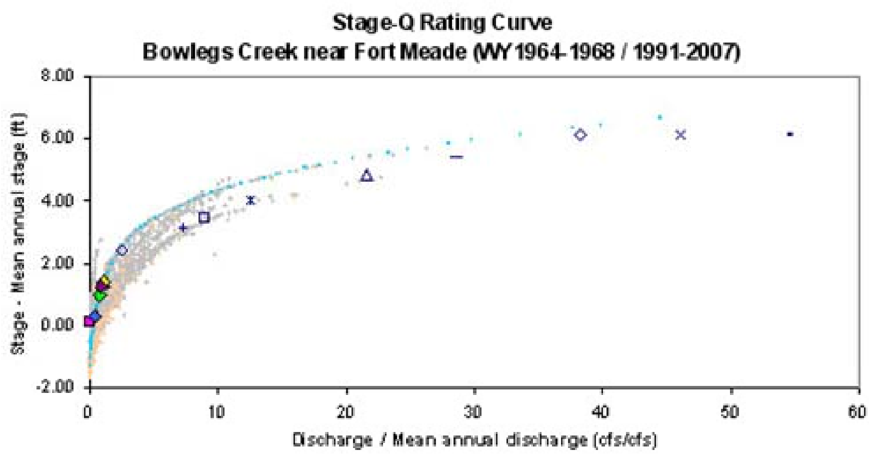

Flow Duration Curve
Blues Creek near Gainesville (WY1985-1994)
Discharge / Mean annual discharge (cfs/cfs)
Percentage of time discharge equaled or exceeded

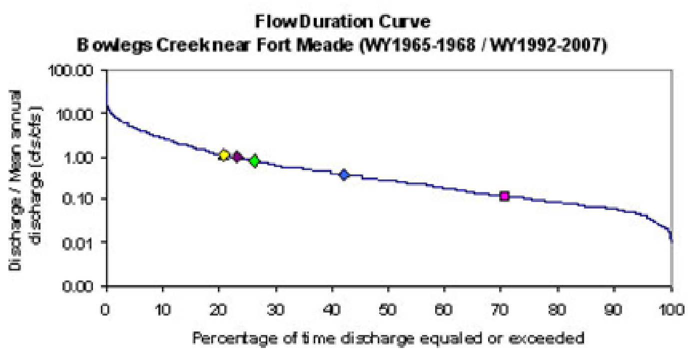

Stage Duration Curve
Blues Creek near Gainesville (WY1985-1993)
Stage - Mean annual stage (ft)
Percentage of time stage equaled or exceeded

Legend:

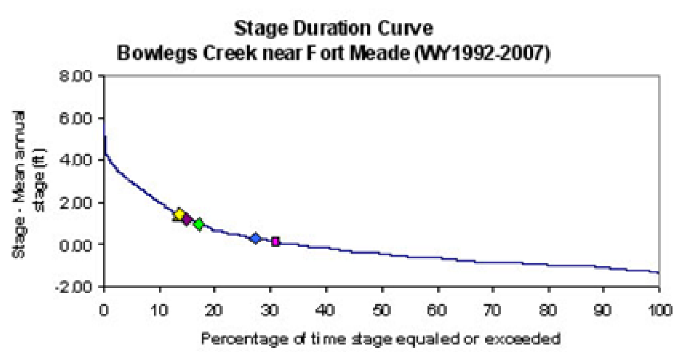

USGS Recorded data
USGS Field Measurements
Current USGS Rating Curve
Survey Datum
Top of bank (TOB)
Flat floodplain (BKF-F)
Inflection (BKF-I)
Scour (BKF-S)
Alluvial break (BKF-A)
Minimum W/D ratio (BKF-W/D)
100 year event
50 year event
25 year event
10 year event
5 year event
2 year event
1.5 year event
1.25 year event
1.0101 year event

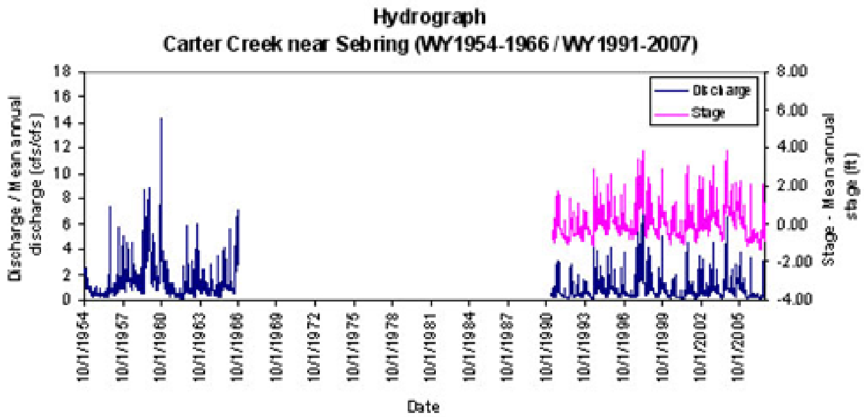

Hydrograph
Bowlegs Creek near Fort Meade (WY1964-1968 / WY1991-2007)
Discharge
Stage
Discharge / Mean annual discharge (cfs/cfs)
Stage - Mean annual stage (ft)
Date


Stage-Q Rating Curve
Bowlegs Creek near Fort Meade (WY1964-1968 / 1991-2007)
Stage - Mean annual stage (ft)
Discharge / Mean annual discharge (cfs/cfs)


Flow Duration Curve
Bowlegs Creek near Fort Meade (WY1965-1968 / WY1992-2007)
Discharge / Mean annual discharge (cfs/cfs)
Percentage of time discharge equaled or exceeded


Legend:
USGS Recorded data
USGS Field Measurements
Current USGS Rating Curve
Survey Datum
Top of bank (TOB)
Flat floodplain (BKF-F)
Inflection (BKF-I)
Scour (BKF-S)
Alluvial break (BKF-A)
Minimum W/D ratio (BKF-W/D)
100 year event
50 year event
25 year event
10 year event
5 year event
2 year event
1.5 year event
1.25 year event
1.0101 year event


Stage Duration Curve
Bowlegs Creek near Fort Meade (WY1992-2007)
Stage - Mean annual stage (ft)
Percentage of time stage equaled or exceeded


Hydrograph
Carter Creek near Sebring (WY1954-1966 / WY1991-2007)
Discharge / Mean annual discharge (cfs/cfs)
Stage - Mean annual stage (ft)
Discharge
Stage
Date
10/1/1954
10/1/1957
10/1/1960
10/1/1963
10/1/1966
10/1/1969
10/1/1972
10/1/1975
10/1/1978
10/1/1981
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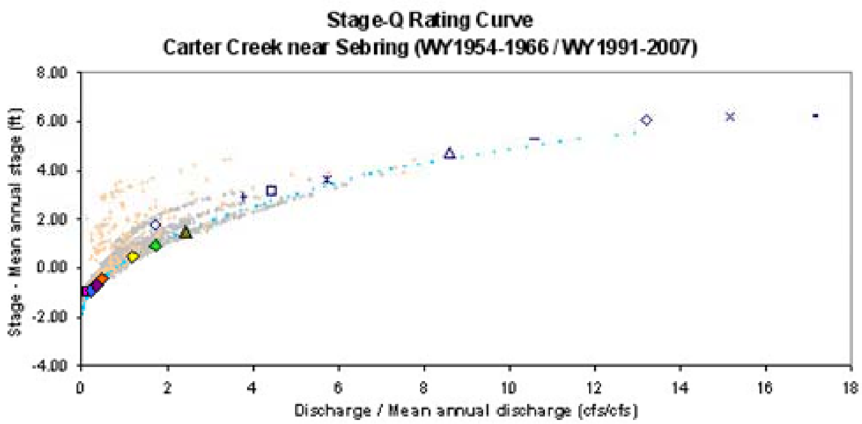
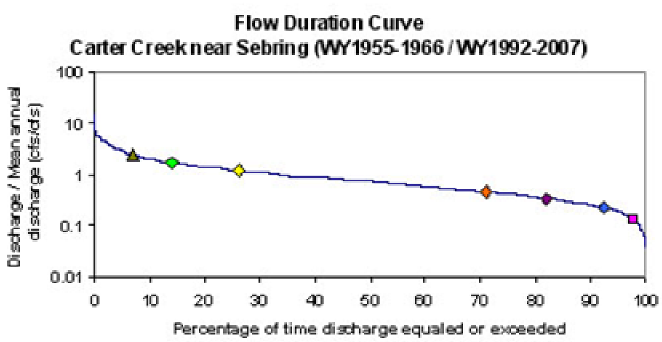
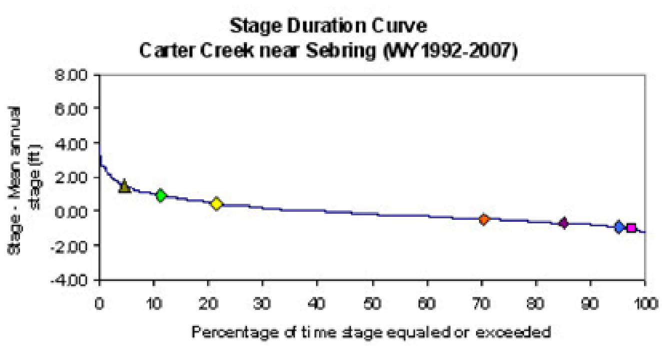
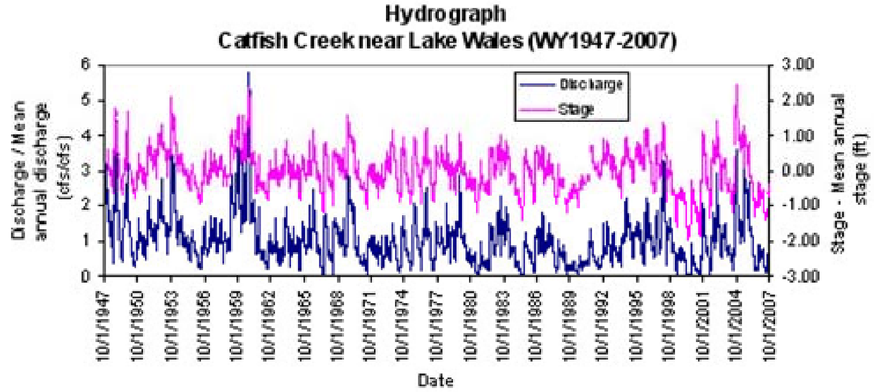
10/1/1999
10/1/2002
10/1/2005

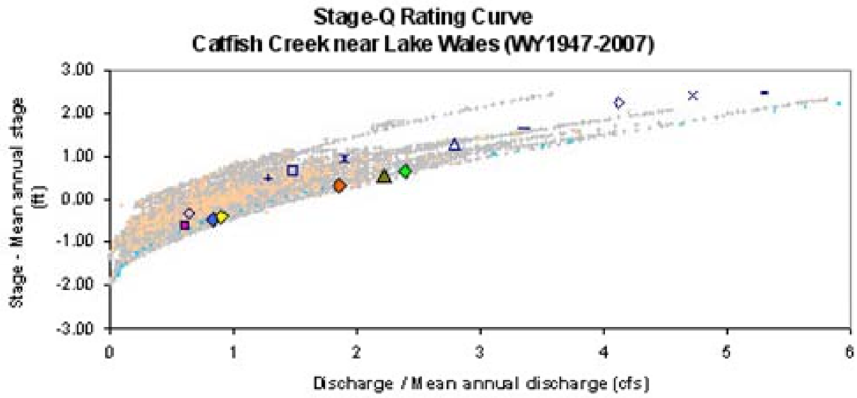

Stage-Q Rating Curve
Carter Creek near Sebring (WY1954-1966 / WY1991-2007)
Stage - Mean annual stage (ft)
Discharge / Mean annual discharge (cfs/cfs)

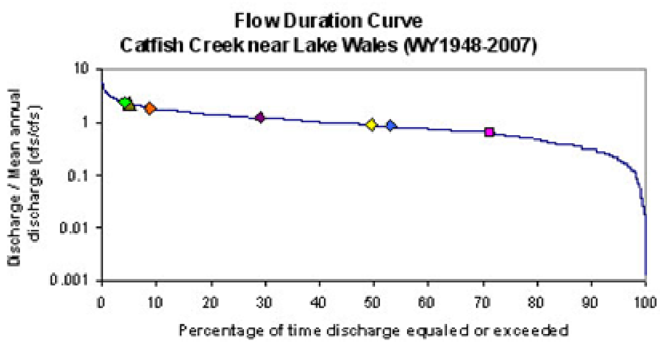

Flow Duration Curve
Carter Creek near Sebring (WY1955-1966 / WY1992-2007)
Discharge / Mean annual discharge (cfs/cfs)
Percentage of time discharge equaled or exceeded

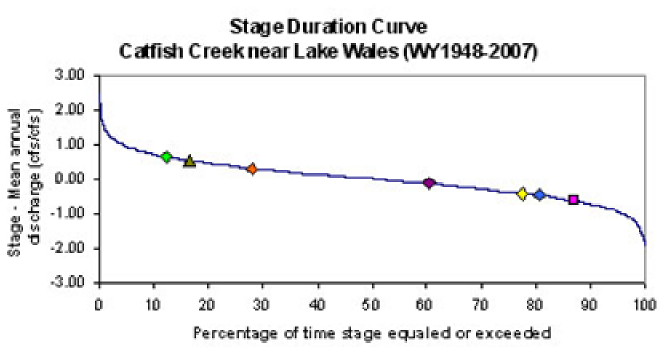

Legend:
USGS Recorded data
USGS Field Measurements
Current USGS Rating Curve
Survey Datum
Top of bank (TOB)
Flat floodplain (BKF-F)
Inflection (BKF-I)
Scour (BKF-S)
Alluvial break (BKF-A)
Minimum W/D ratio (BKF-W/D)
100 year event
50 year event
25 year event
10 year event
5 year event
2 year event
1.5 year event
1.25 year event
1.0101 year event


Stage Duration Curve
Carter Creek near Sebring (WY1992-2007)
Stage - Mean annual stage (ft)
Percentage of time stage equaled or exceeded

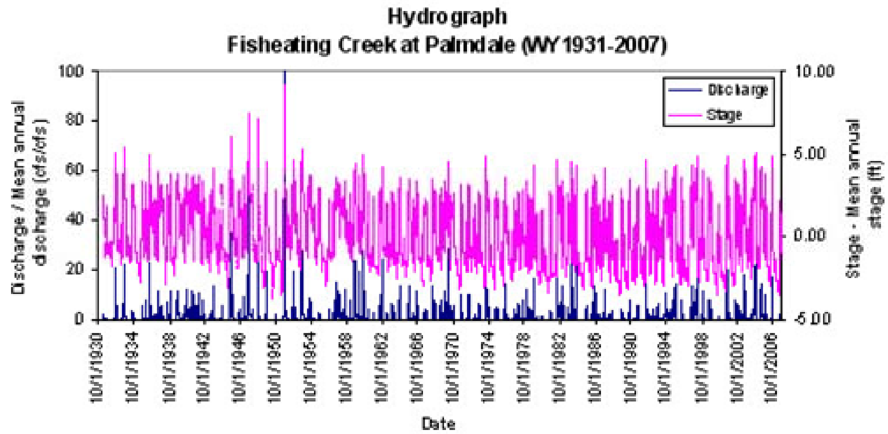

Hydrograph
Catfish Creek near Lake Wales (WY1947-2007)
Discharge / Mean annual discharge (cfs/cfs)
Stage - Mean annual stage (ft)
Discharge
Stage
Date

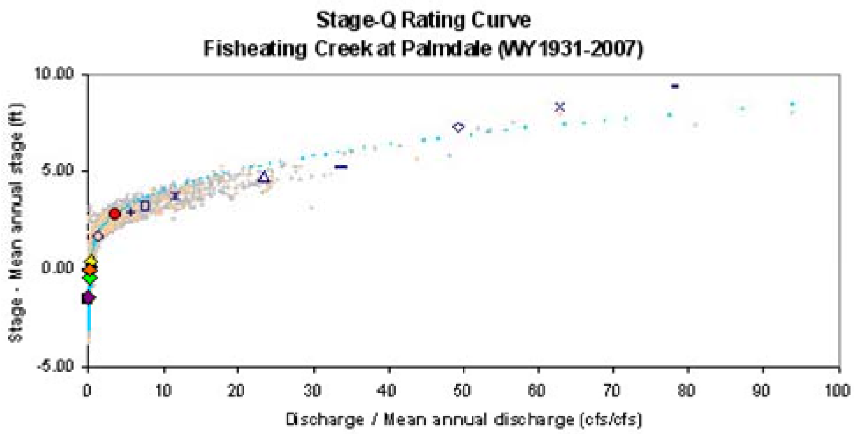

Stage-Q Rating Curve
Catfish Creek near Lake Wales (WY1947-2007)
Stage - Mean annual stage (ft)
Discharge / Mean annual discharge (cfs)

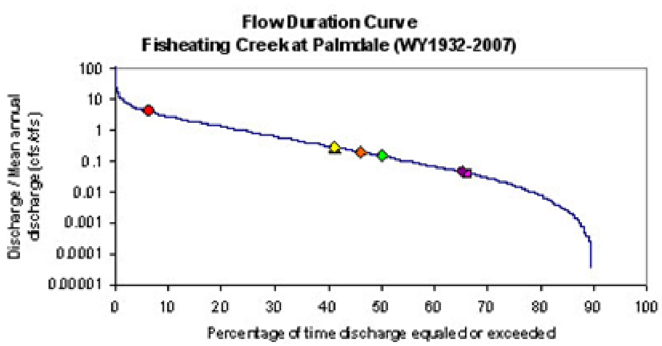

Flow Duration Curve
Catfish Creek near Lake Wales (WY1948-2007)
Discharge / Mean annual discharge (cfs/cfs)
Percentage of time discharge equaled or exceeded

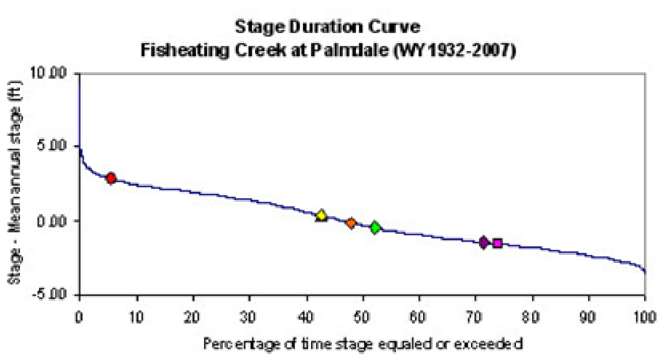

Stage Duration Curve
Catfish Creek near Lake Wales (WY1948-2007)
Stage - Mean annual discharge (cfs/cfs)
Percentage of time stage equaled or exceeded


Legend:
USGS Recorded data
USGS Field Measurements
Current USGS Rating Curve
Survey Datum
Top of bank (TOB)
Flat floodplain (BKF-F)
Inflection (BKF-I)
Scour (BKF-S)
Alluvial break (BKF-A)
Minimum W/D ratio (BKF-W/D)
100 year event
50 year event
25 year event
10 year event
5 year event
2 year event
1.5 year event
1.25 year event
1.0101 year event


Hydrograph
Fisheating Creek at Palmdale (WY1931-2007)
Discharge / Mean annual discharge (cfs/cfs)
Stage - Mean annual stage (ft)
Discharge
Stage
Date

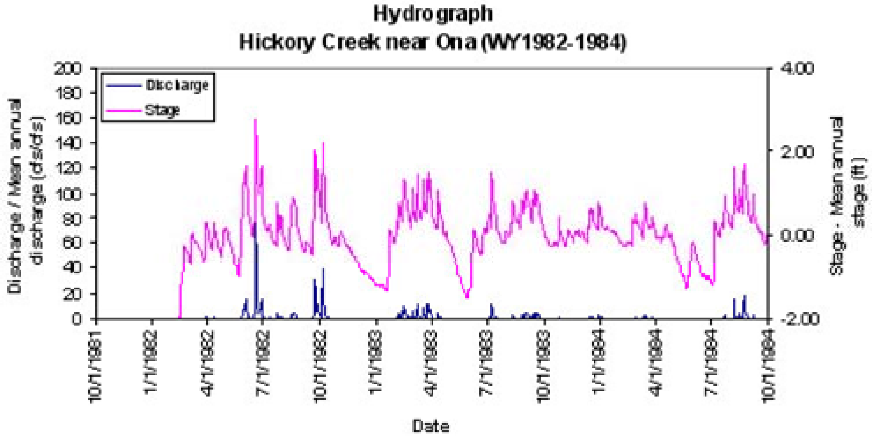

Stage-Q Rating Curve
Fisheating Creek at Palmdale (WY1931-2007)
Stage - Mean annual stage (ft)
Discharge / Mean annual discharge (cfs/cfs)

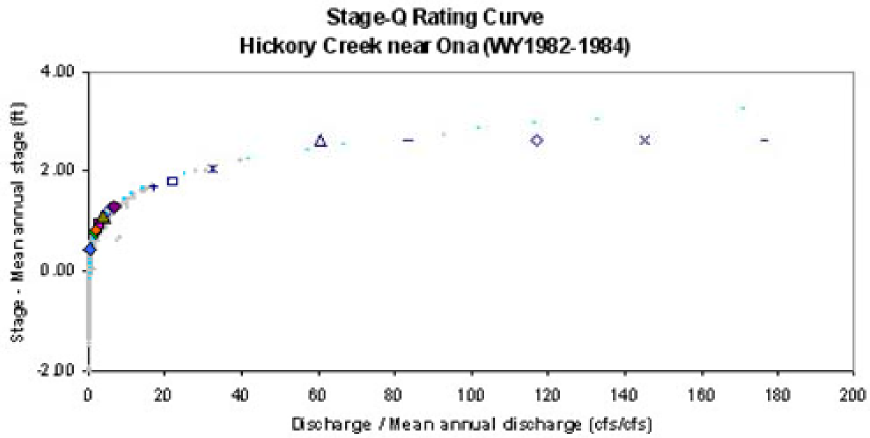

Flow Duration Curve
Fisheating Creek at Palmdale (WY1932-2007)
Discharge / Mean annual discharge (cfs/cfs)
Percentage of time discharge equaled or exceeded

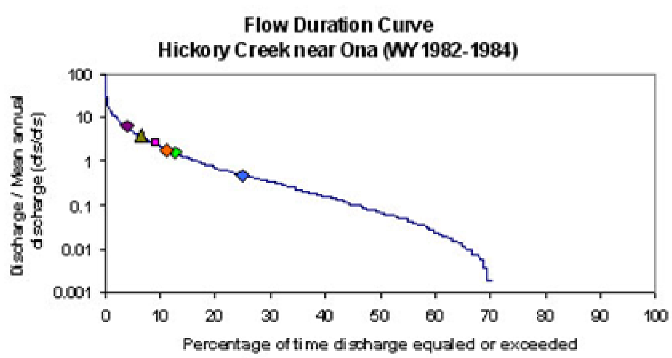

Stage Duration Curve
Fisheating Creek at Palmdale (WY1932-2007)
Stage - Mean annual stage (ft)
Percentage of time stage equaled or exceeded

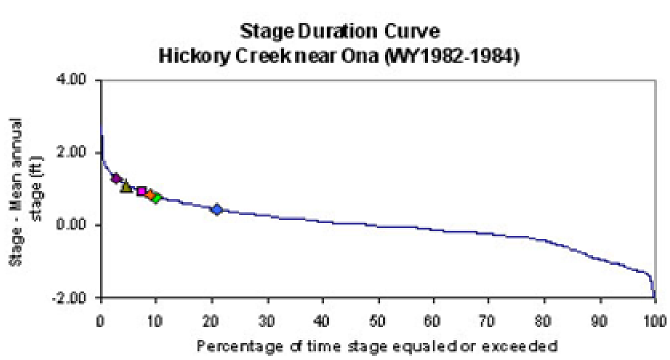
Legend:


USGS Recorded data
USGS Field Measurements
Current USGS Rating Curve
Survey Datum
Top of bank (TOB)
Flat floodplain (BKF-F)
Inflection (BKF-I)
Scour (BKF-S)
Alluvial break (BKF-A)
Minimum W/D ratio (BKF-W/D)
100 year event
50 year event
25 year event
10 year event
5 year event
2 year event
1.5 year event
1.25 year event
1.0101 year event


Hydrograph
Hickory Creek near Ona (WY1982-1984)
Discharge
Stage
Discharge / Mean annual discharge (cfs/cfs)
Stage - Mean annual stage (ft)
Date

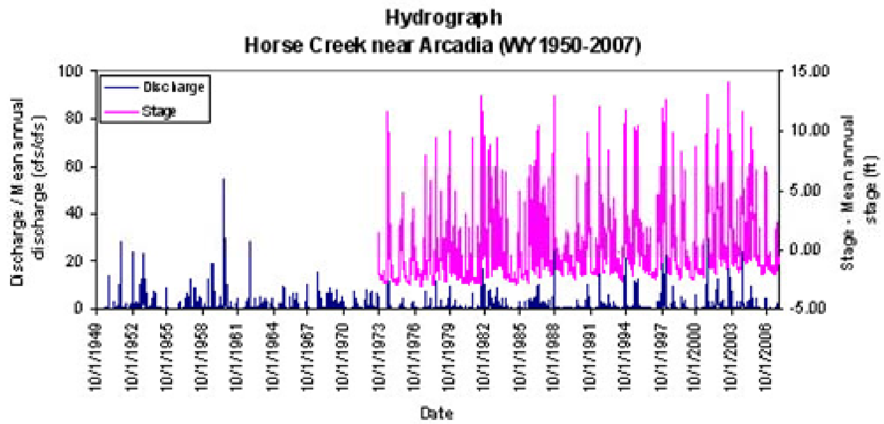

Stage-Q Rating Curve
Hickory Creek near Ona (WY1982-1984)
Stage - Mean annual stage (ft)
Discharge / Mean annual discharge (cfs/cfs)

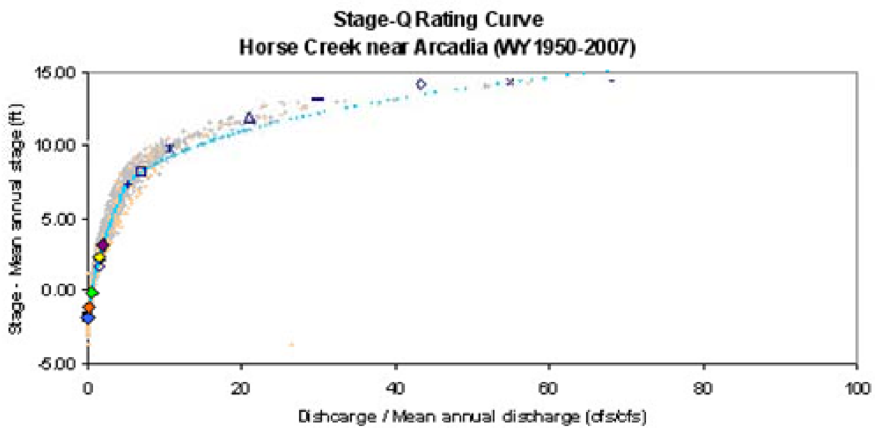

Flow Duration Curve
Hickory Creek near Ona (WY1982-1984)
Discharge / Mean annual discharge (cfs/cfs)
Percentage of time discharge equaled or exceeded

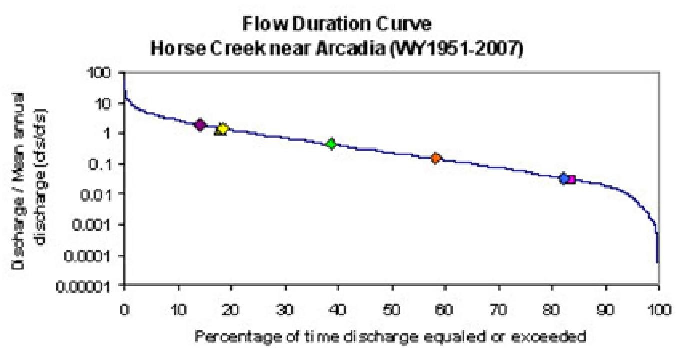

Stage Duration Curve
Hickory Creek near Ona (WY1982-1984)
Stage - Mean annual stage (ft)
Percentage of time stage equaled or exceeded

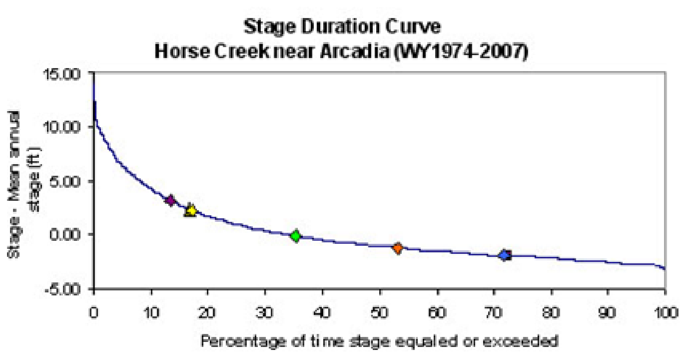
Legend:


USGS Recorded data
USGS Field Measurements
Current USGS Rating Curve
Survey Datum
Top of bank (TOB)
Flat floodplain (BKF-F)
Inflection (BKF-I)
Scour (BKF-S)
Alluvial break (BKF-A)
Minimum W/D ratio (BKF-W/D)
100 year event
50 year event
25 year event
10 year event
5 year event
2 year event
1.5 year event
1.25 year event
1.0101 year event


Hydrograph
Horse Creek near Arcadia (WY1950-2007)
Discharge
Stage
Discharge / Mean annual discharge (cfs/cfs)
Stage - Mean annual stage (ft)
Date
10/1/1949
10/1/1952
10/1/1955
10/1/1958
10/1/1961
10/1/1964
10/1/1967
10/1/1970
10/1/1973
10/1/1976
10/1/1979
10/1/1982
10/1/1985
10/1/1988
10/1/1991
10/1/1994
10/1/1997
10/1/2000
10/1/2003
10/1/2006


Stage-Q Rating Curve
Horse Creek near Arcadia (WY1950-2007)
Stage - Mean annual stage (ft)
Dishcarge / Mean annual discharge (cfs/cfs)

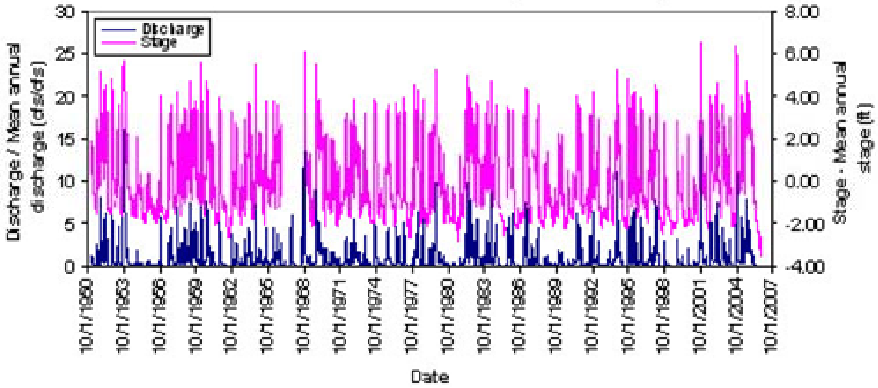

Flow Duration Curve
Horse Creek near Arcadia (WY1951-2007)
Discharge / Mean annual discharge (cfs/cfs)
Percentage of time discharge equaled or exceeded


Stage Duration Curve
Horse Creek near Arcadia (WY1974-2007)
Stage - Mean annual stage (ft)
Percentage of time stage equaled or exceeded

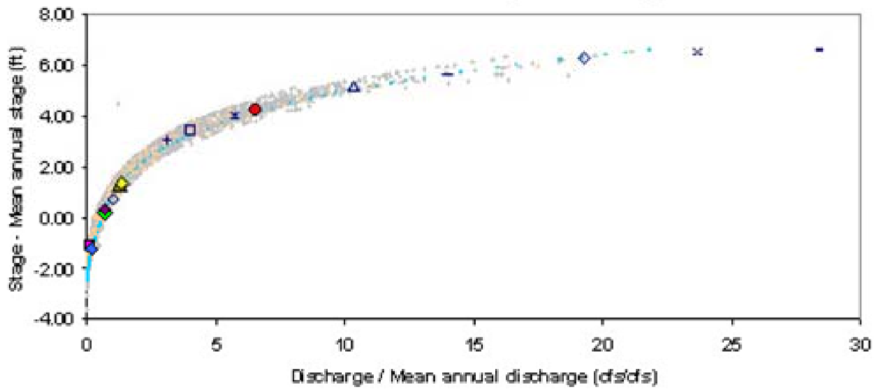
Legend:


USGS Recorded data
USGS Field Measurements
Current USGS Rating Curve
Survey Datum
Top of bank (TOB)
Flat floodplain (BKF-F)
Inflection (BKF-I)
Scour (BKF-S)
Alluvial break (BKF-A)
Minimum W/D ratio (BKF-W/D)
100 year event
50 year event
25 year event
10 year event
5 year event
2 year event
1.5 year event
1.25 year event
1.0101 year event

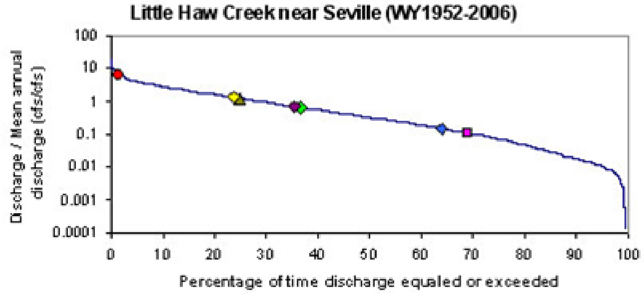
Hydrograph
Little Haw Creek near Seville (WY1991-2007)



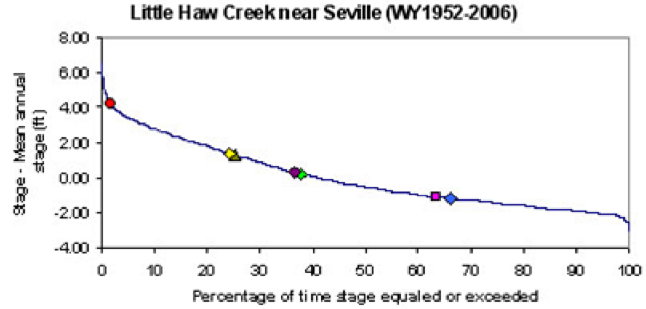
Stage-Q Rating Curve
Little Haw Creek near Seville (WY1951-2007)



Flow Duration Curve
Little Haw Creek near Seville (WY1952-2006)

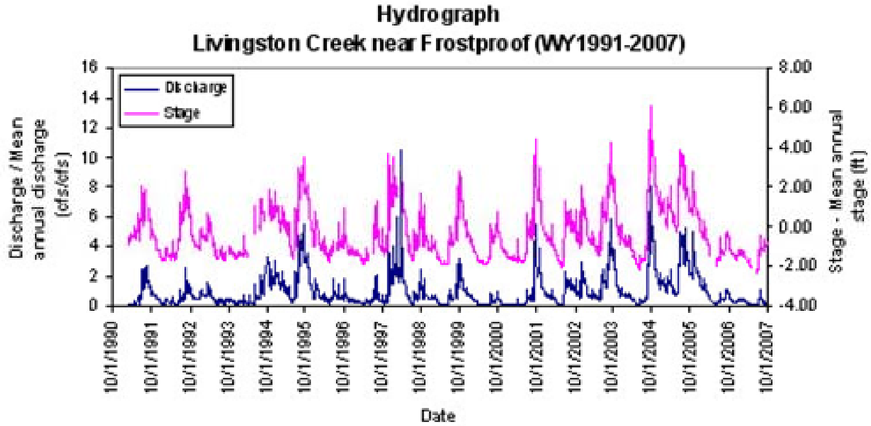


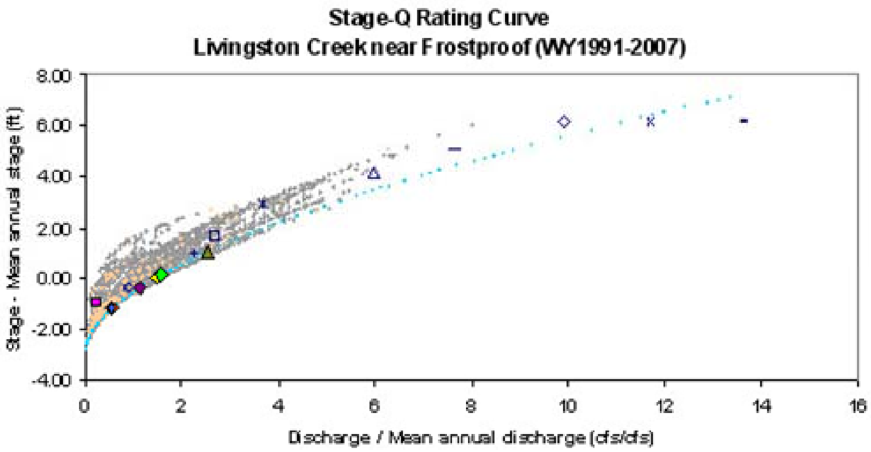
Stage Duration Curve
Little Haw Creek near Seville (WY1952-2006)

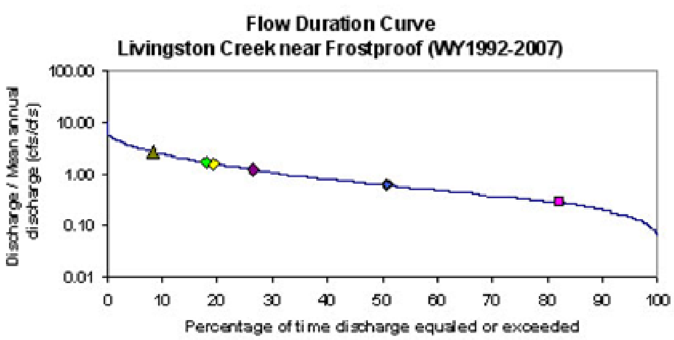


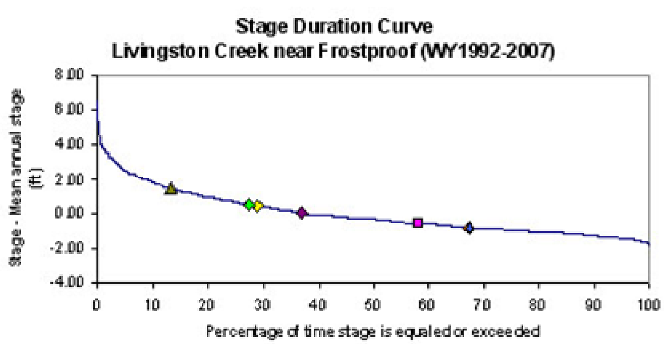
Legend:

- USGS Recorded data
- USGS Field Measurements
- Current USGS Rating Curve
- Survey Datum
- Top of bank (TOB)
- Flat floodplain (BKF-F)
- Inflection (BKF-I)
- Scour (BKF-S)
- Alluvial break (BKF-A)
- Minimum W/D ratio (BKF-W/D)
- 100 year event
- 50 year event
- 25 year event
- 10 year event
- 5 year event
- 2 year event
- 1.5 year event
- 1.25 year event
- 1.0101 year event


Hydrograph
Livingston Creek near Frostproof (WY1991-2007)
Discharge
Stage
Discharge / Mean annual discharge (cfs/cfs)
Stage - Mean annual stage (ft)
Date
10/1/1990
10/1/1991
10/1/1992
10/1/1993
10/1/1994
10/1/1995
10/1/1996
10/1/1997
10/1/1998
10/1/1999
10/1/2000
10/1/2001
10/1/2002
10/1/2003
10/1/2004
10/1/2005
10/1/2006
10/1/2007

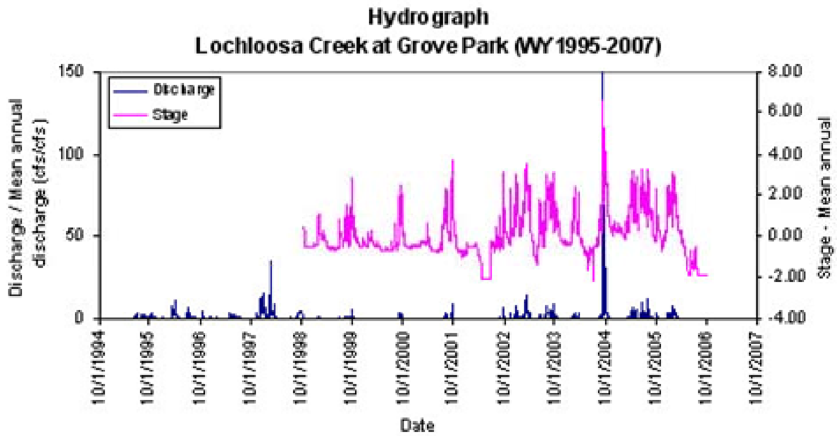

Stage-Q Rating Curve
Livingston Creek near Frostproof (WY1991-2007)
Stage - Mean annual stage (ft)
Discharge / Mean annual discharge (cfs/cfs)

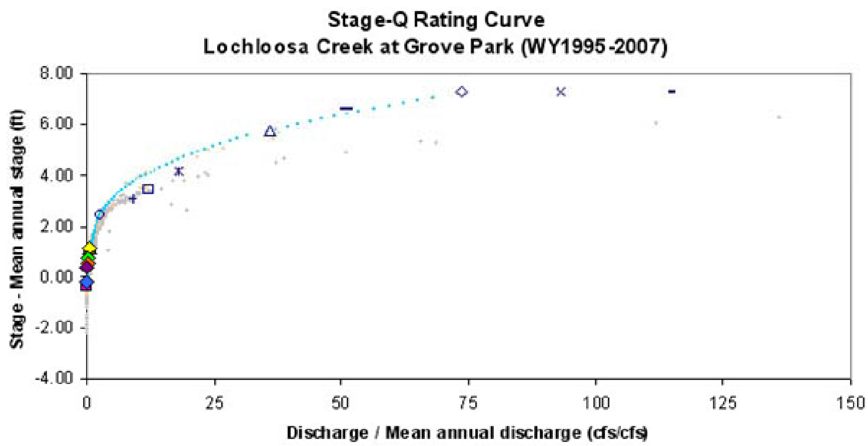

Flow Duration Curve
Livingston Creek near Frostproof (WY1992-2007)
Discharge / Mean annual discharge (cfs/cfs)
Percentage of time discharge equaled or exceeded

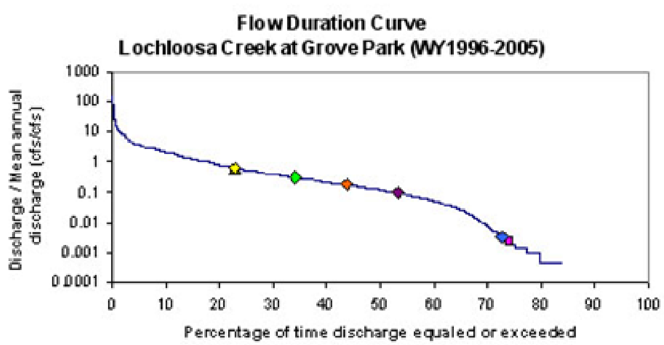

Stage Duration Curve
Livingston Creek near Frostproof (WY1992-2007)
Stage - Mean annual stage (ft)
Percentage of time stage is equaled or exceeded

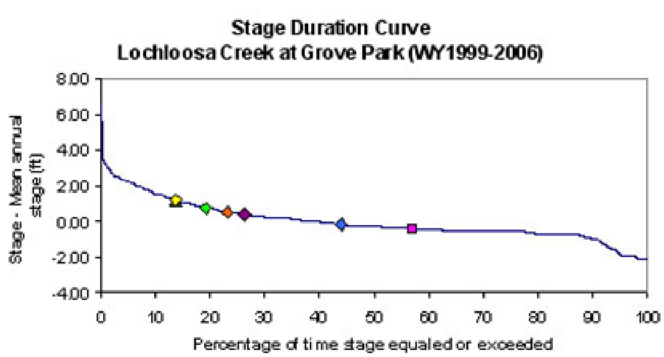
Legend:


USGS Recorded data
USGS Field Measurements
Current USGS Rating Curve
Survey Datum
Top of bank (TOB)
Flat floodplain (BKF-F)
Inflection (BKF-I)
Scour (BKF-S)
Alluvial break (BKF-A)
Minimum W/D ratio (BKF-W/D)
100 year event
50 year event
25 year event
10 year event
5 year event
2 year event
1.5 year event
1.25 year event
1.0101 year event









Legend:

- USGS Recorded data
- USGS Field Measurements
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- Survey Datum
- Top of bank (TOB)
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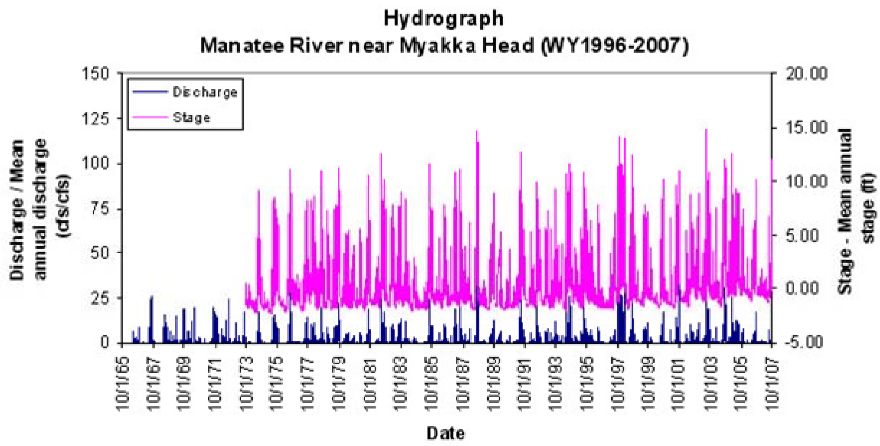
- 1.25 year event
- 1.0101 year event


Hydrograph
Manatee River near Myakka Head (WY1996-2007)
Discharge
Stage
Discharge / Mean annual discharge (cfs/cfs)
Stage - Mean annual stage (ft)
Date
150
125
100
75
50
25
0
20.00
15.00
10.00
5.00
0.00
-5.00
10/1/65
10/1/67
10/1/69
10/1/71
10/1/73
10/1/75
10/1/77
10/1/79
10/1/81
10/1/83
10/1/85
10/1/87
10/1/89
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10/1/99
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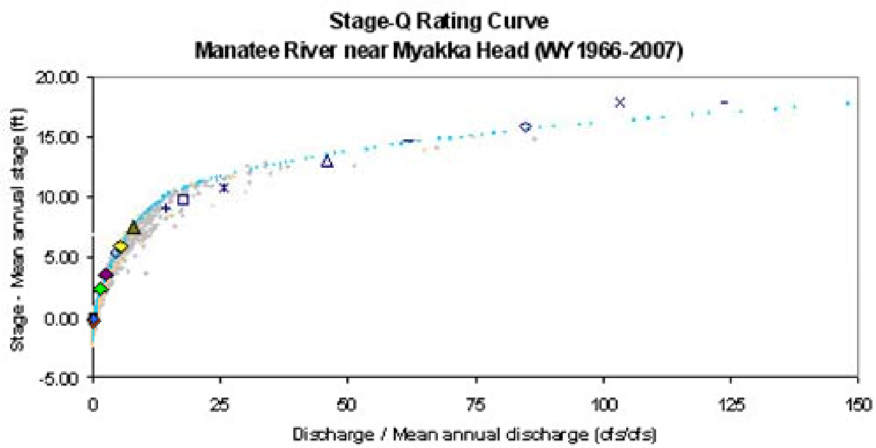
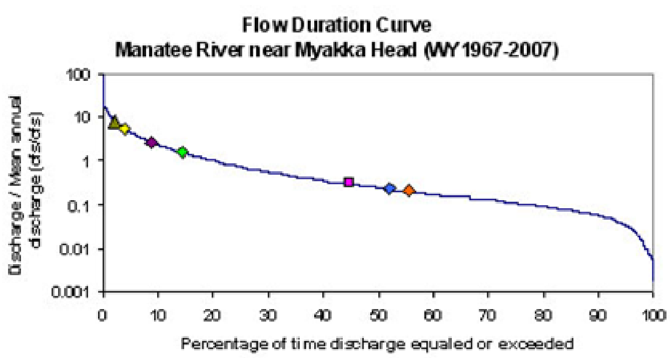
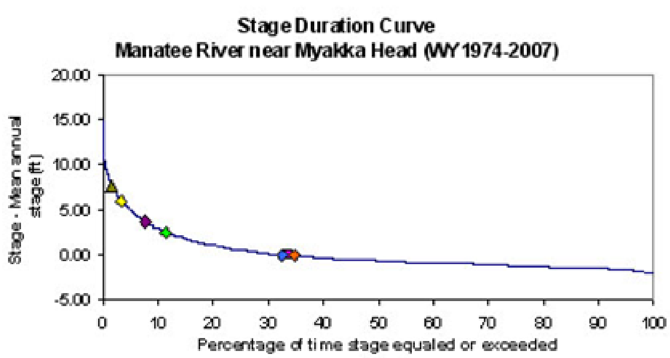
10/1/03
10/1/05
10/1/07


Stage-Q Rating Curve
Manatee River near Myakka Head (WY 1966-2007)
Stage - Mean annual stage (ft)
Discharge / Mean annual discharge (cfs/cfs)
20.00
15.00
10.00
5.00
0.00
-5.00
0
25
50
75
100
125
150


Flow Duration Curve
Manatee River near Myakka Head (WY 1967-2007)
Discharge / Mean annual discharge (cfs/cfs)
Percentage of time discharge equaled or exceeded
100
10
1
0.1
0.01
0.001
0
10
20
30
40
50
60
70
80
90
100


Stage Duration Curve
Manatee River near Myakka Head (WY 1974-2007)
Stage - Mean annual stage (ft)
Percentage of time stage equaled or exceeded
20.00
15.00
10.00
5.00
0.00
-5.00
0
10
20
30
40
50
60
70
80
90
100


Legend:
USGS Recorded data
USGS Field Measurements
Current USGS Rating Curve
Survey Datum
Top of bank (TOB)
Flat floodplain (BKF-F)
Inflection (BKF-I)
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Alluvial break (BKF-A)
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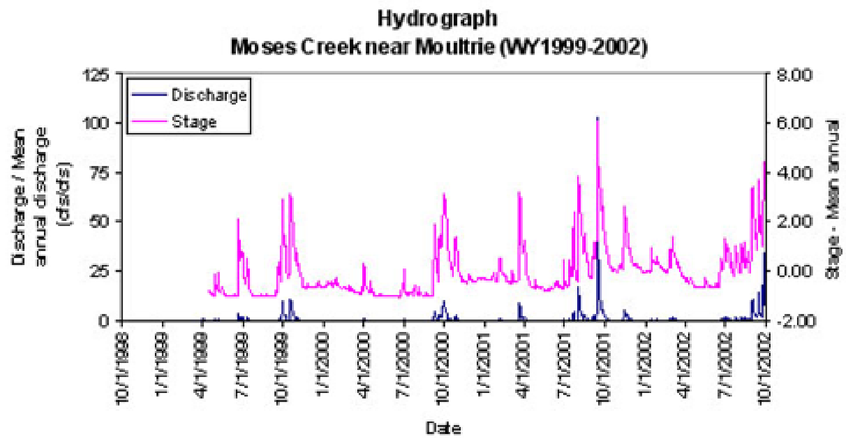
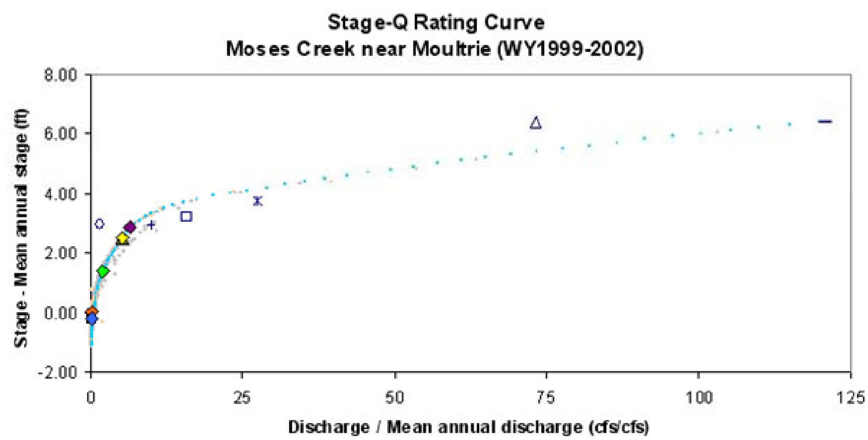
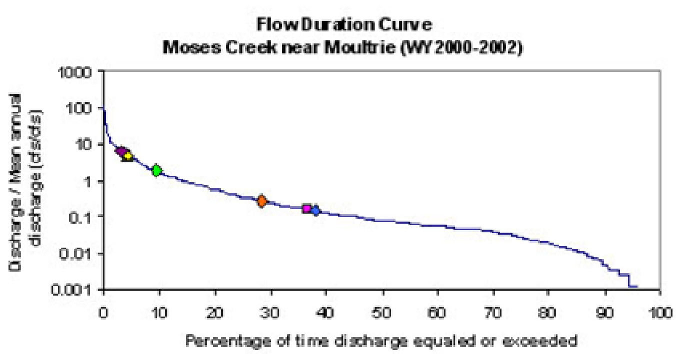
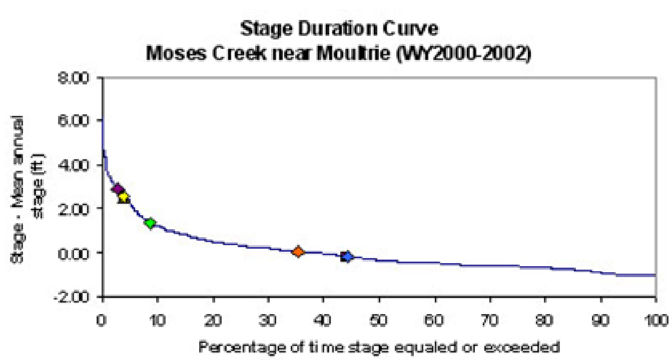
100 year event
50 year event
25 year event
10 year event
5 year event
2 year event
1.5 year event
1.25 year event
1.0101 year event









Legend:

- USGS Recorded data
- USGS Field Measurements
- Current USGS Rating Curve
- Survey Datum
- Top of bank (TOB)
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- Inflection (BKF-I)
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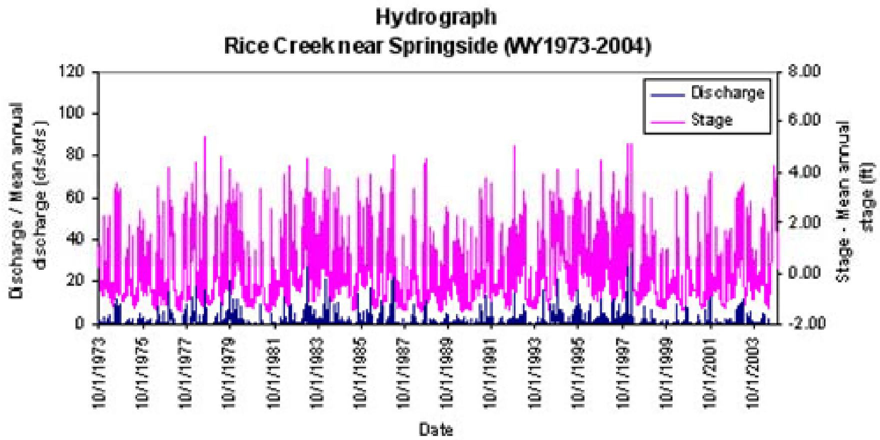
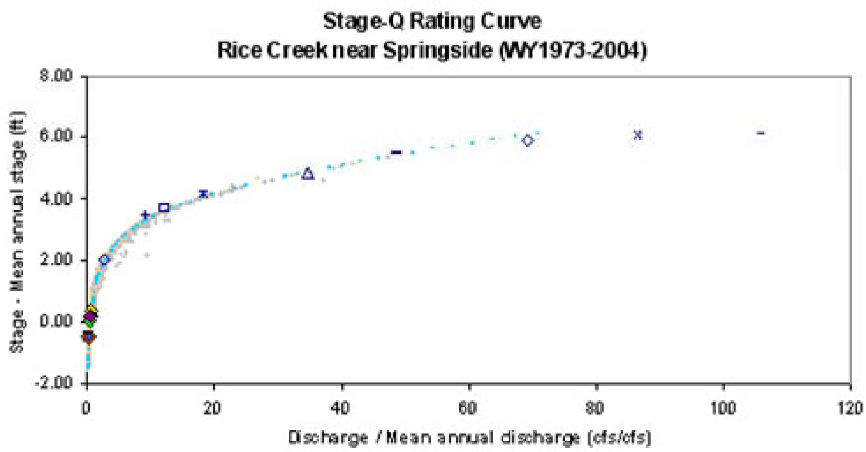
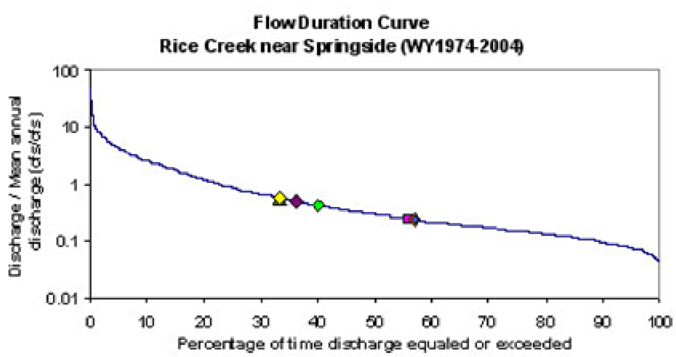
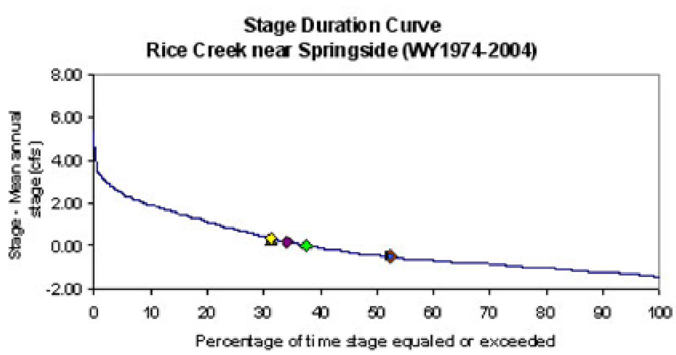
- 1.0101 year event


Hydrograph
Rice Creek near Springside (WY1973-2004)
Discharge / Mean annual discharge (cfs/cfs)
Stage - Mean annual stage (ft)
Discharge
Stage
Date


Stage-Q Rating Curve
Rice Creek near Springside (WY1973-2004)
Stage - Mean annual stage (ft)
Discharge / Mean annual discharge (cfs/cfs)


Flow Duration Curve
Rice Creek near Springside (WY1974-2004)
Discharge / Mean annual discharge (cfs/cfs)
Percentage of time discharge equaled or exceeded


Stage Duration Curve
Rice Creek near Springside (WY1974-2004)
Stage - Mean annual stage (cfs)
Percentage of time stage equaled or exceeded

Legend:


USGS Recorded data
USGS Field Measurements
Current USGS Rating Curve
Survey Datum
Top of bank (TOB)
Flat floodplain (BKF-F)
Inflection (BKF-I)
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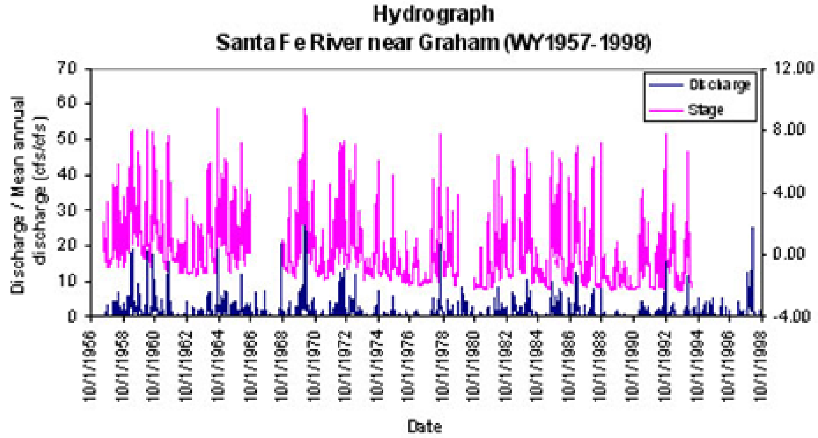
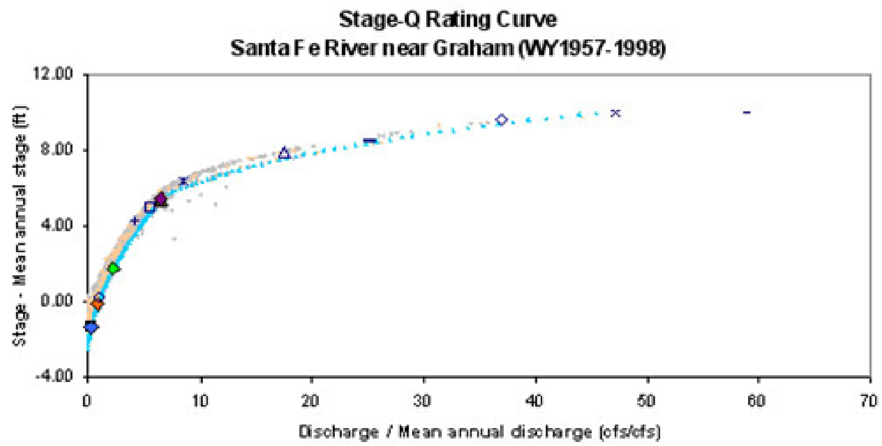
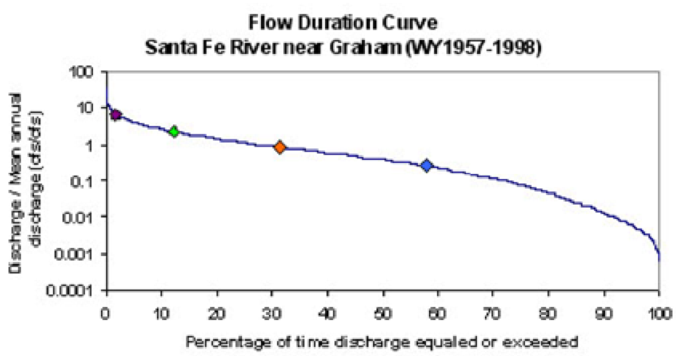
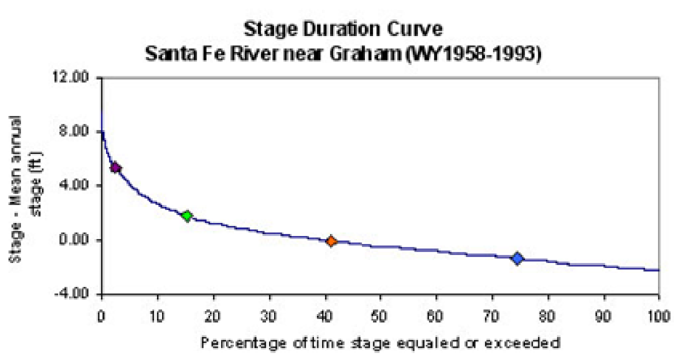
1.0101 year event









Legend:

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- Survey Datum
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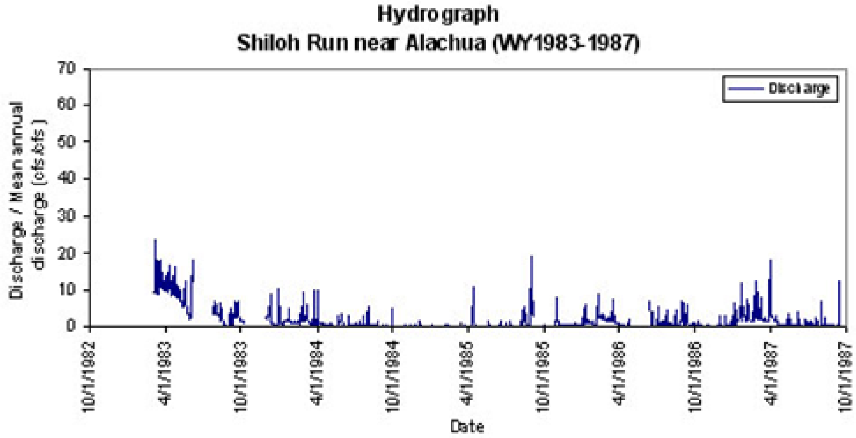

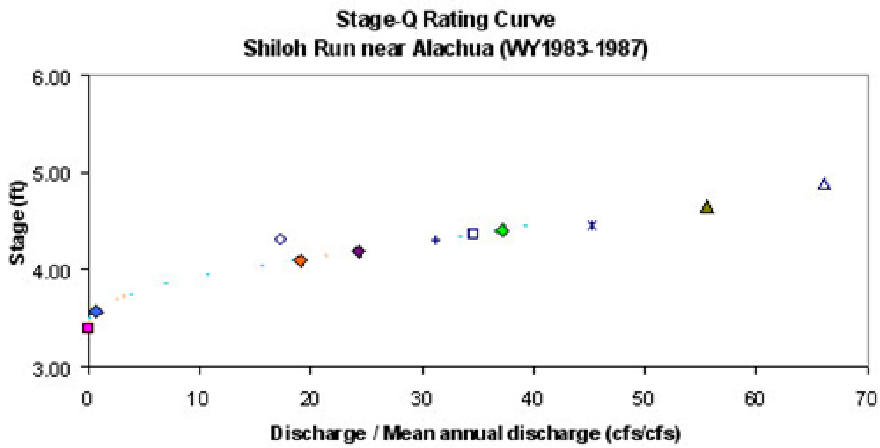

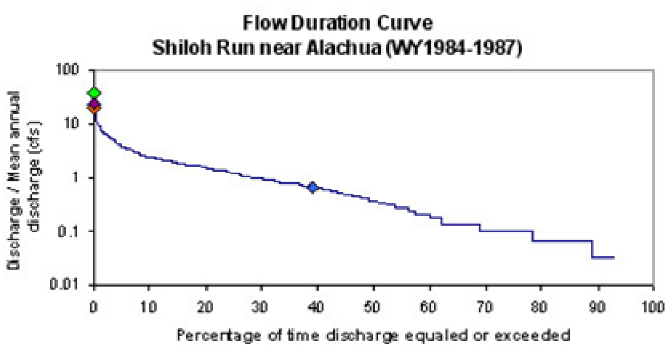

Legend:

- USGS Recorded data
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- Current USGS Rating Curve
- Survey Datum
- Top of bank (TOB)
- Flat floodplain (BKF-F)
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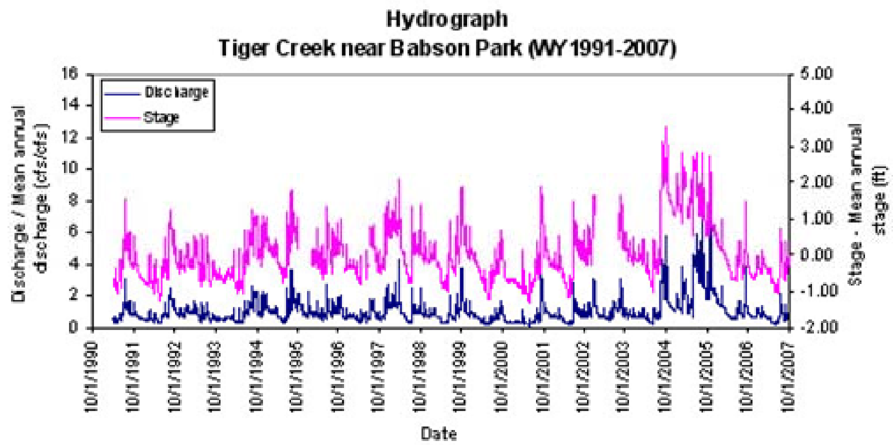

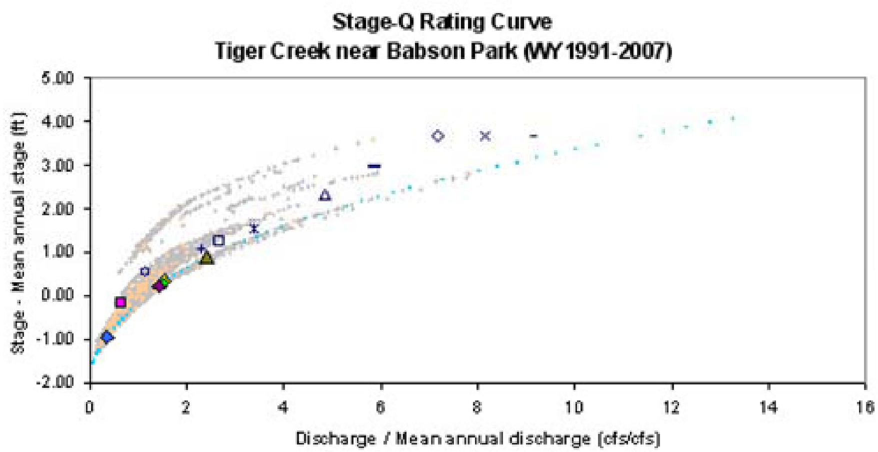

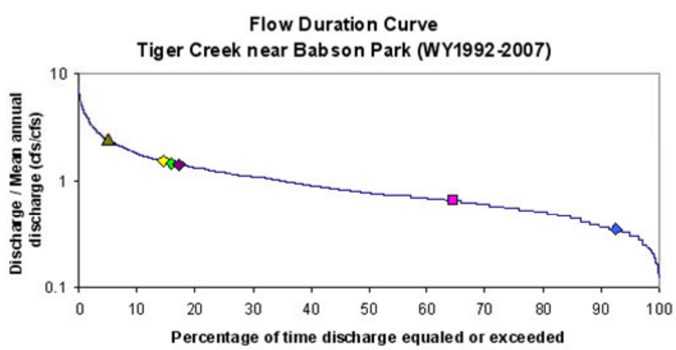

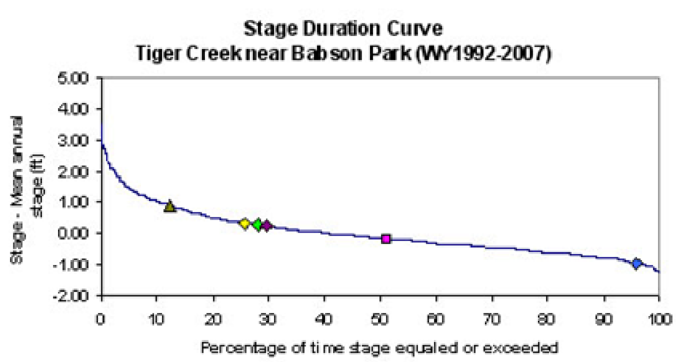

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- Survey Datum
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- Scour (BKF-S)
- Alluvial break (BKF-A)
- Minimum W/D ratio (BKF-W/D)
- 100 year event
- 50 year event
- 25 year event
- 10 year event
- 5 year event
- 2 year event
- 1.5 year event
- 1.25 year event
- 1.0101 year event

APPENDIX E
STAGE AGAINST WIDTH GRAPHS

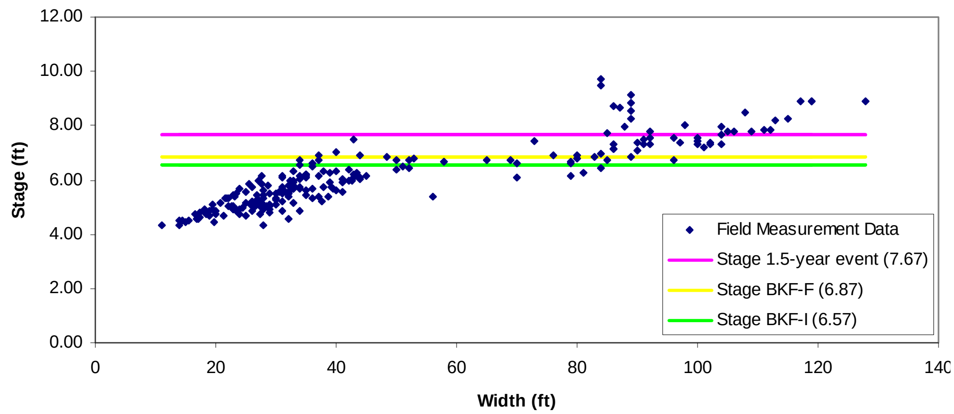

Figure E-1. Width versus stage: Blackwater Creek near Cassia.

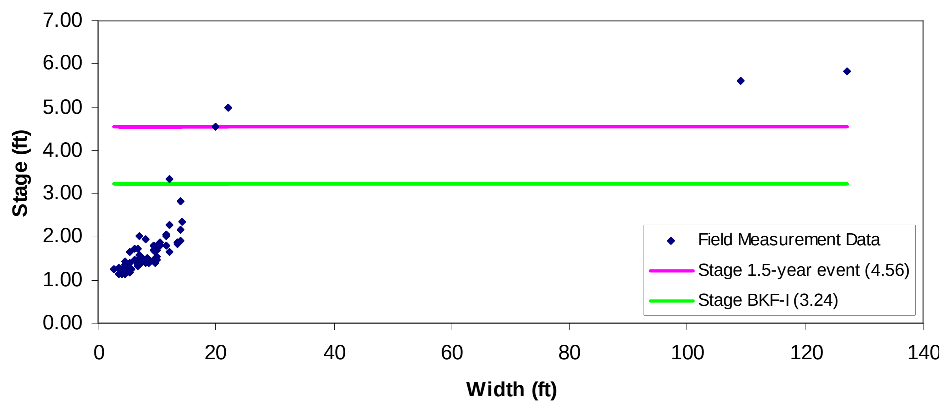

Figure E-2. Width versus stage: Blues Creek near Gainesville.

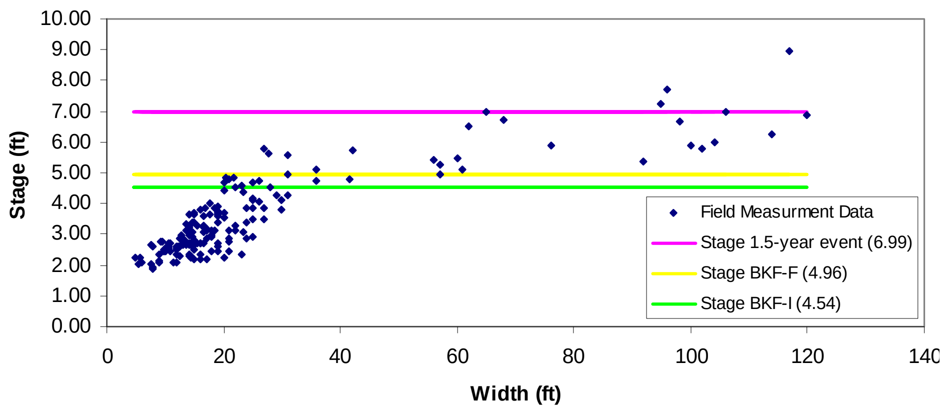

Figure E-3. Width versus stage: Bowlegs Creek near Fort Meade.

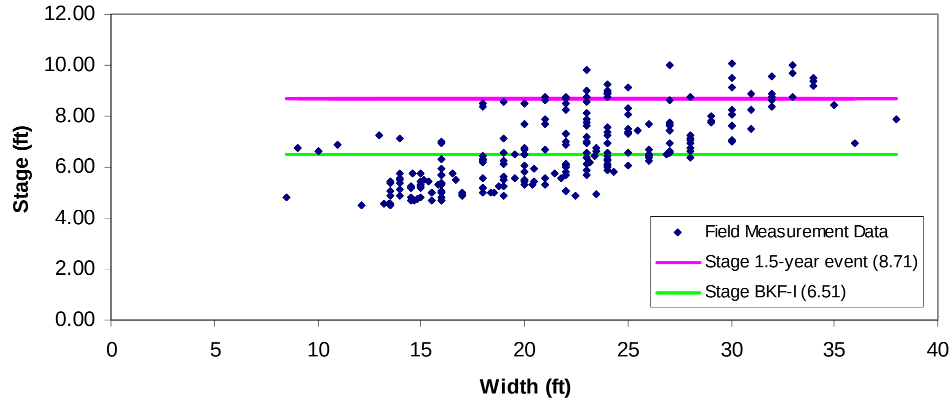

Figure E-4. Width versus stage: Carter Creek near Sebring.

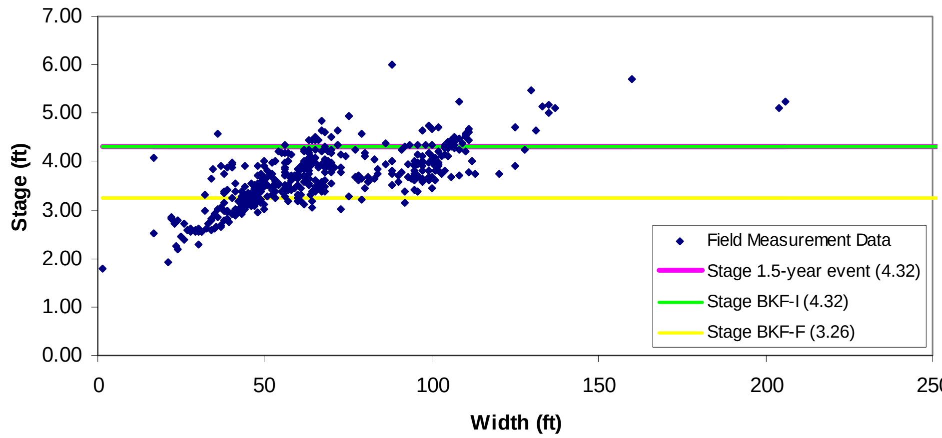

Figure E-5. Width versus stage: Catfish Creek near Lake Wales.

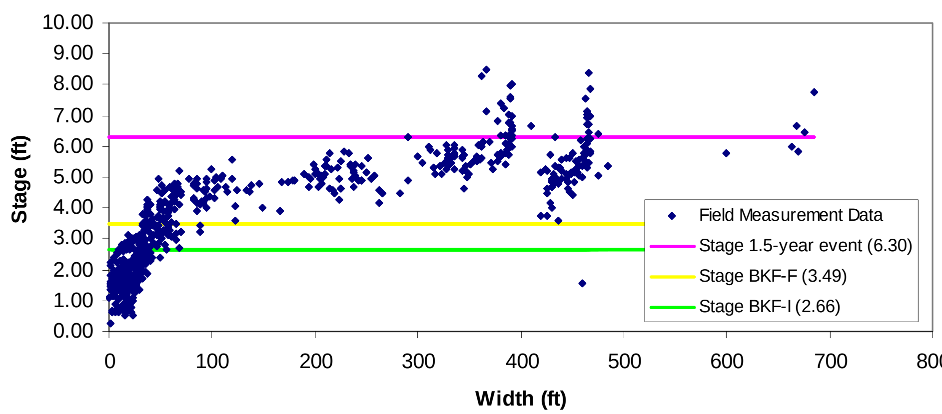

Figure E-6. Width versus stage: Fisheating Creek at Palmdale.

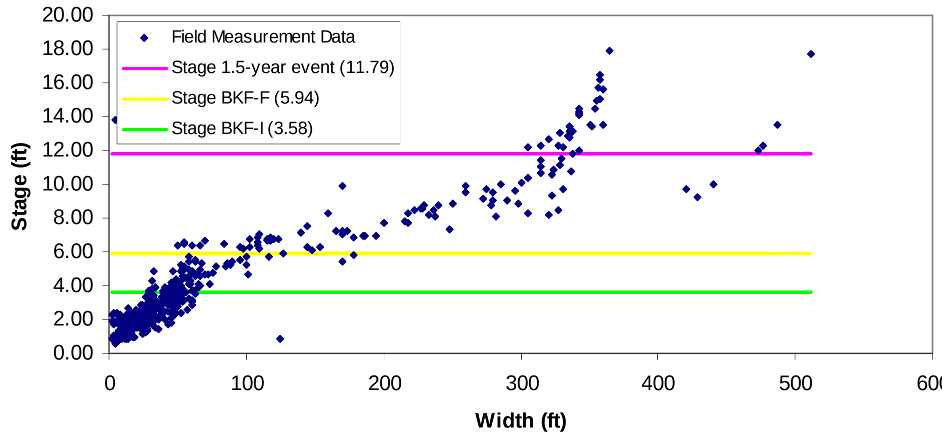

Figure E-7. Width versus stage: Horse Creek near Arcadia.

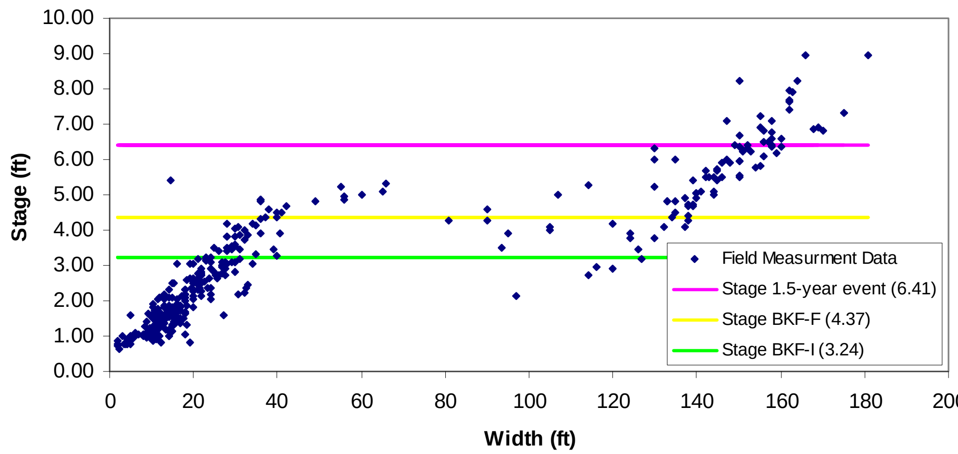

Figure E-8. Width versus stage: Little Haw Creek near Seville.

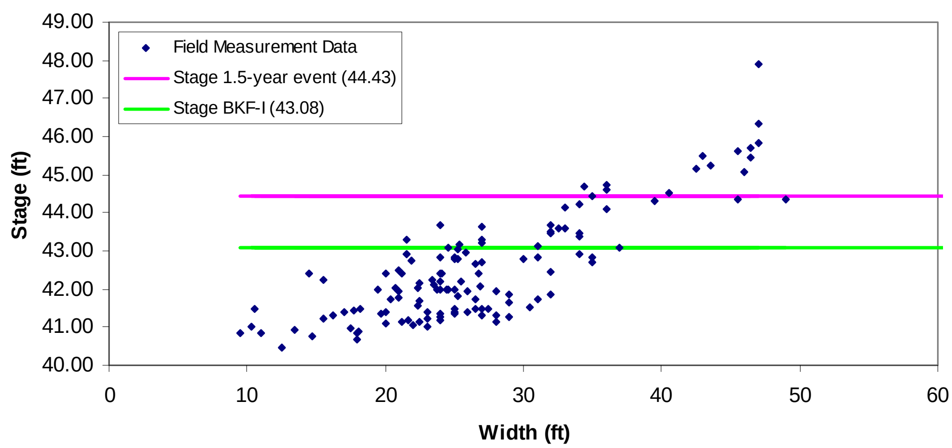

Figure E-9. Width versus stage: Livingston Creek near Frostproof.

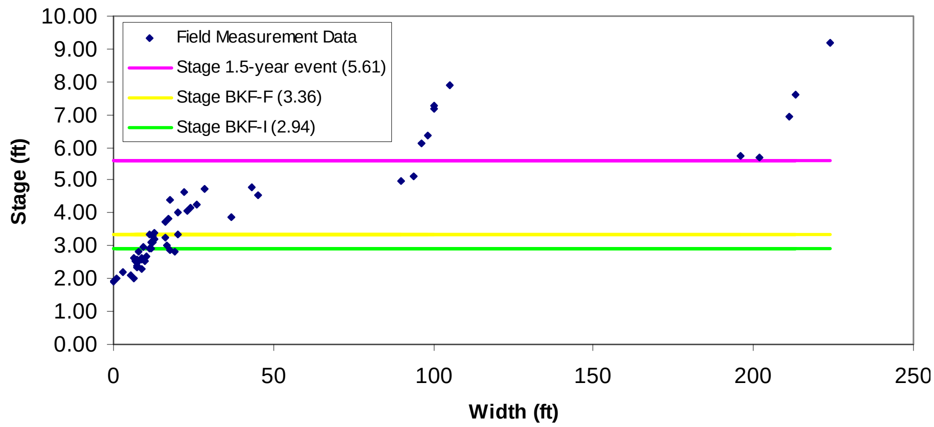

Figure E-10. Width versus stage: Lochloosa Creek at Grove Park.

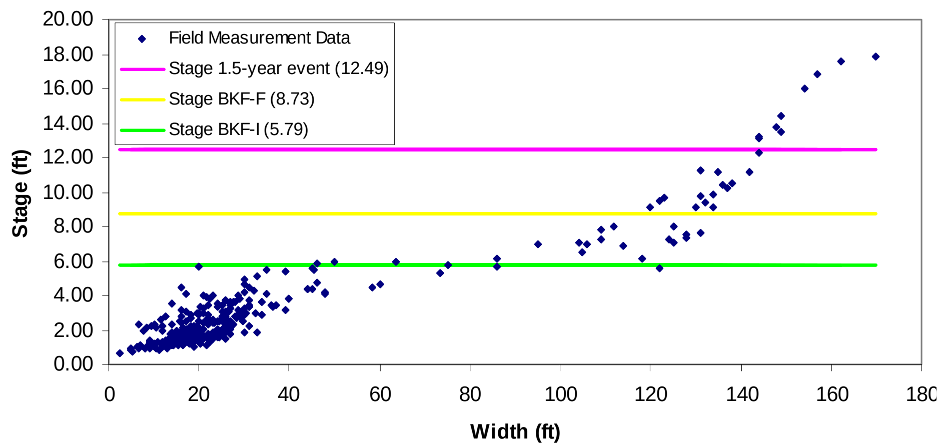

Figure E-11. Width versus stage: Manatee River near Myakka Head.

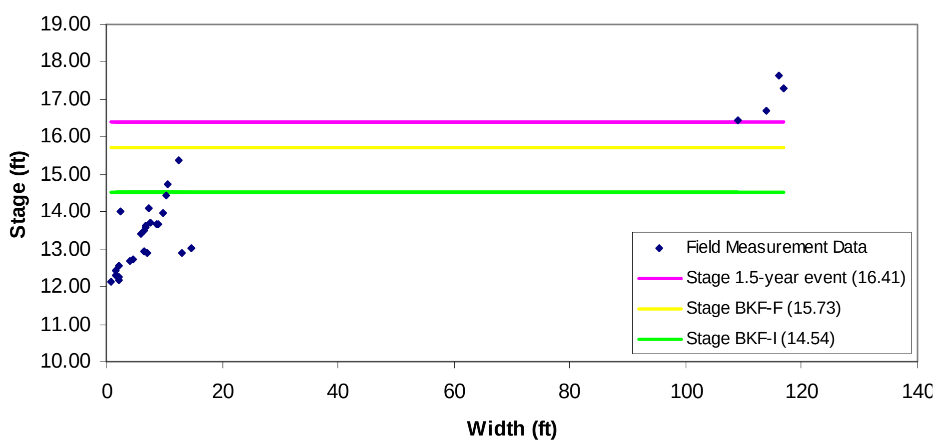

Figure E-12. Width versus stage: Moses Creek near Moultrie.

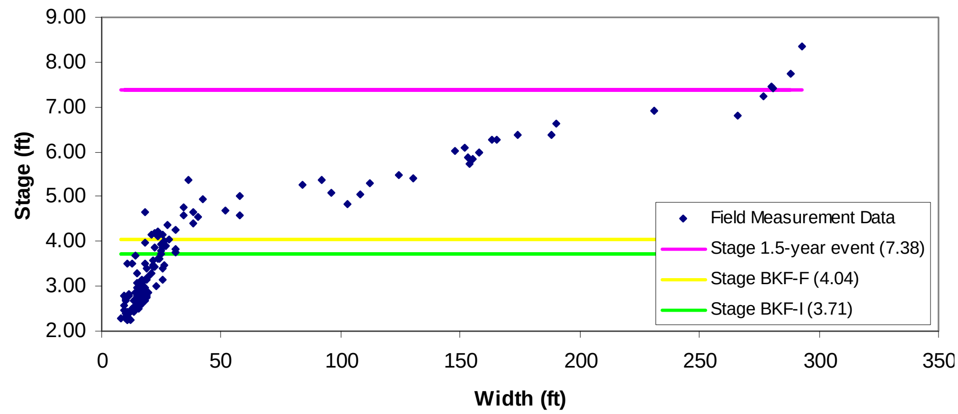

Figure E-13. Width versus stage: Rice Creek near Springside.

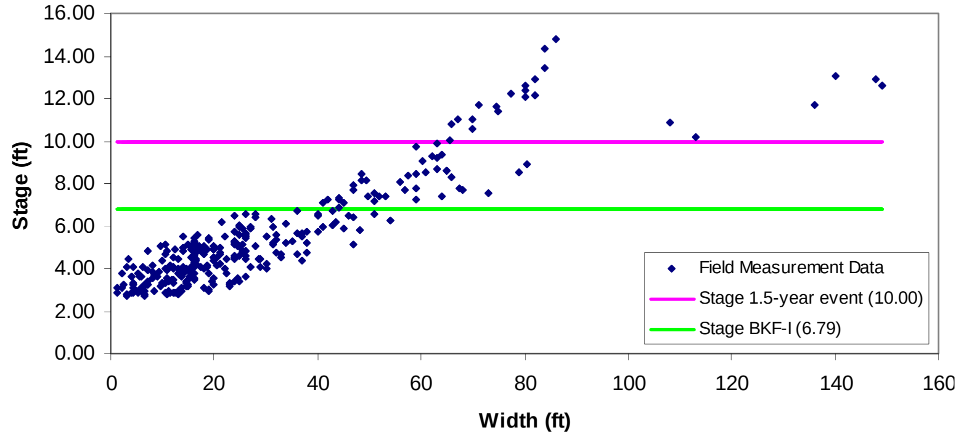

Figure E-14. Width versus stage: Santa Fe River near Graham.

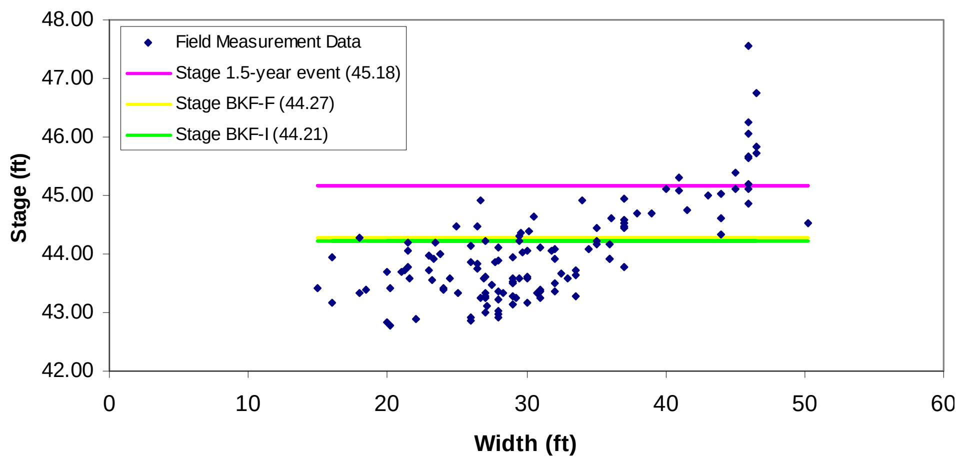

Figure E-15. Width versus stage: Tiger Creek near Babson Park.

APPENDIX F
SUPPLEMENTAL STAGE DATA

Appendix F. Stage data presented to supplement the discharge data used in penisular Florida regional curve development and analysis

		Data Subsets			Stage					Duration		
Site name	Period of record (WY)	Physio-graphy	Geo-graphy	Flood-plain type	Mean annual stage (ft)	BKF stage - Mean annual stage (ft)	1.5-year stage - Mean annual stage (ft)	1.5-year stage - BKF stage (%)	Peak stage - Mean annual stage (ft)	Mean annual stage (% of time)	BKF stage (% of time)	1.5-year stage (% of time)
Blackwater Creek near Cassia	81-07	HL	N	WFC	5.90	0.97	1.77	0.80	3.72	45	17	4.2
Blues Creek near Gainesville	85-93	FW	N	UP	106.62	2.00	2.94	0.94	3.95	32	0.8	0.3
Bowlegs Creek near Ft Meade	92-07	FW	S	WF	3.56	1.41	3.43	2.03	5.72	34	14	2.8
Carter Creek near Sebring	92-07	HL	S	UP	5.57	0.94	3.14	2.20	3.83	41	11	0.1
Catfish Creek near Lake Wales	48-07	HL	S	WFC	3.68	-0.42**	0.64	1.06	2.44	50	78	12
Fisheating Creek at Palmdale	32-07	FW	S	WFC	3.12	0.37	3.18	2.81	9.17	47	43	3.0
Hickory Creek near Ona	82-84*	FW	S	WF	12.26	1.09	1.78	0.69	2.75	50	4.5	0.6
Horse Creek near Arcadia	74-07	FW	S	WF	3.69	2.25	8.10	5.85	14.03	34	17	2.8
Little Haw Creek near Seville	52-06	FW	N	WFC	3.01	1.37	3.40	2.04	6.51	41	24	5.1
Livingston Creek near Frostproof	92-07	HL	S	UP	42.37	0.54	2.06	1.52	6.47	38	27	8.2
Lochloosa Creek at Grove Park	99-06*	FW	N	WFC	2.19	1.16	3.42	2.25	6.55	39	14	0.6
Manatee River near Myakka Head	74-07	FW	S	UP	2.83	2.39	9.66	7.27	14.87	31	11	0.5
Moses Creek near Moultrie	00-02*	FW	N	WFC	13.17	2.55	3.24	0.69	6.09	37	3.9	1.8
Rice Creek near Springside	74-04	FW	N	WFC	3.68	0.36	3.70	3.34	5.37	38	31	0.4
Santa Fe River near Graham	58-93	FW	N	UP	108.60	1.74	4.95	3.21	9.41	39	15	3.1
Shiloh Run near Alachua	N/A	FW	N	UP	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tiger Creek near Babson Park	92-07	HL	S	UP	43.94	0.27	1.24	0.97	3.82	41	28	7.0
Minimum					2.19	-0.42	0.64	0.69	2.44	31	0.8	0.1
Maximum					108.60	2.55	9.66	7.27	14.87	50	78	12
Mean					22.76	1.19	3.54	2.35	6.54	40	21	3.3
Median					4.63	1.13	3.21	2.03	5.91	39	16	2.8

Notes: WY = Water year; ft = feet; BKF = Bankfull; N/A = Not applicable -- no stage data; * Period of gage record insufficient (less than 10 years) for proper gage analysis, but rough approximations are presented; ** Bankfull stage less than the mean annual stage (unexpected result)

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BIOGRAPHICAL SKETCH

Kristen Blanton was born and raised in Fort Lauderdale, Florida, the land of canals. She attended Wellesley College in Wellesley, Massachusetts where she pursued a major in environmental studies, graduating in May 2004. During college, she spent a rewarding summer at Archbold Biological Station in Lake Placid, Florida, where she came to appreciate Florida's natural systems. Upon graduation, Kristen worked as a geologist at Roux Associates, Inc. (Boston, Massachusetts). While at that job, Kristen was given the opportunity to be trained as a wetlands scientist and to work on various wetland restoration projects. In August 2006, seeking to trade the cold northeast for her sunny home state, Kristen moved to Gainesville, Florida to begin her master's work with Dr. Wise in the University of Florida's Environmental Engineering Sciences Department. For her master's work, Kristen was lucky enough to join the "stream team" and to explore some of Florida's most beautiful and natural streams—the opposite of canals. Kristen is now hoping to begin a career in land conservation, so she can protect the natural areas she loves.