SUSPENDED-SEDIMENT AND BEDLOAD MONITORING OF THE KISSIMMEE RIVER RESTORATION, JULY 2007 THROUGH SEPTEMBER 2008

Gellis, A.C., Research Geomorphologist, U.S. Geological Survey, 5522 Research Park Drive, Baltimore, MD 21228 *agellis@usgs.gov*; Pearman, J.L. Hydrologist, U.S. Geological Survey, 12703 Research Parkway, Orlando, FL 32826, *lpearman@usgs.gov*; Valdes, J.J., Senior Hydrogeologist, South Florida Water Management District, Kissimmee Division, PO Box 24680, West Palm Beach, FL 33416-4680 *jvaldes@sfwmd.gov*; Habermehl, P.J., Hydrologic Technician, U.S. Geological Survey, 12703 Research Parkway, Orlando, FL 32826, *phaberm@usgs.gov*

Abstract

The Kissimmee River Restoration is one of the largest stream rehabilitation projects in the United States. Sediment transport monitoring is an important component of the geomorphic monitoring plan, which also includes monitoring of channel morphology and floodplain processes. Suspended-sediment and bedload transport were monitored at the downstream end of the 24 km restored Pool C reach of the Kissimmee River Restoration between July 21, 2007 and September 30, 2008. The importance of storms in transporting sediment is highlighted by the data collected in the Kissimmee River. Fifty-two percent (40,652 Mg) of the suspended-sediment load in the restored channel (78,912 Mg) was transported in 8 days, and 56% (2,363 Mg) of the total bedload (4,237 Mg) was transported in 7 days, both which were transported during Tropical Storm Fay which hit Florida between August 19 and 24, 2008. During Tropical Storm Fay, flows went through a breach in the levee upstream and depending on the estimate used, overbank suspended-sediment loads ranged from 28,960 to 47,292 Mg, which is 33 to 45% of the total suspended-sediment load for this period. Suspended sediment contributed 96 to 97% of the total sediment transport (suspended sediment + bedload) for the period of study. Effective discharge computations indicate that the majority of sediment is transported at 47 m^3/s and 239 m^3/s. The 47 m^3/s effective discharge value is close to the bankfull discharge of 50 m^3/s and may be the channel forming flow. The higher discharge value is associated with tropical storm activity. The sediment data collected as part of the monitoring program will serve as a point of reference to determine whether suspended-sediment concentrations, loads, and bedload in Pool C of the restored Kissimmee River increase, decrease, or remain steady over time. The flow and sediment data will also be used to evaluate subsequent changes in channel morphology.

INTRODUCTION

Mass flooding from Hurricanes in the 1940's led to authorization for the Corps of Engineers to channelize the Kissimmee River. Between 1962 and 1971, the Kissimmee River was channelized and transformed into a series of impounded reservoirs (Koebel, 1995). Water was diverted from the river into a 145 km long, 9 m deep, 90 m wide canal (C-38 Canal) and inflow from the upper basin was regulated by six water-control structures. Excavation of the C-38 Canal and deposition of the resulting spoil eliminated approximately 56 km of river channel and 25,000 ha of floodplain wetland habitat. River channelization and degradation of the floodplain led to severe impacts on the system's ecosystem and loss of biota. In 1992, the Kissimmee River Restoration Project (KRRP) was authorized by Congress to reintroduce flow into the original channel system and restore over 104 square kilometers of river and floodplain ecosystem, including 69 km of meandering river channel and 11,000 ha of wetlands. The primary goal of the KRRP is to reestablish the ecological integrity of the river-floodplain system (Williams et al., 2006). The foundation of ecosystem health is the physical structure of the habitat. Restoration of ecological integrity requires reestablishment of the pre-channelization flows in the Kissimmee

River, reconstruction of the physical form of the river, and removal of structures (levees, roads, and ditches).

Inherent to the success of the KRRP is the long-term stability of the restored river planform and cross-sectional form. The interactions among bedload and suspended load transport, flood frequency and magnitude, and erosion and deposition dictate river morphology and its physical structure. Understanding geomorphic processes of the Kissimmee River and any geomorphic change that might occur as a result of restoration is essential to the success of the Kissimmee River restoration. Although geomorphic monitoring is listed as an integral part of the KRRP (Williams et al., 2005), by 2007 no monitoring plan had been put in place. In 2007, the U.S. Geological Survey (USGS) in partnership with the South Florida Water Management District and the University of Florida, developed a geomorphic monitoring plan for the restored Pool C section of the KRRP (fig. 1); the first reach to undergo restoration. The three main components of the geomorphic monitoring plan are: (1) to establish a suspended-sediment and bedload-transport monitoring program; (2) to quantify channel (cross sectional and planform) changes over time (Mossa et al., 2010; and (3) to document floodplain processes and sedimentation rates over time (Schenk and Hupp, 2010). Data collected and interpreted from each of these monitoring components would inform managers of physical alterations in the fluvial system as a result of restoration.

Phase 1 of the KRRP was completed in 2001 which includes Pool C (fig. 1). In Phase 1, approximately 12 km of the channelized river were backfilled, recarving approximately 2 km of river channel, and reconnecting 24 km of continuous river channel. Continuous flow and intermittent inundation of approximately 4,900 ha of restored floodplain have been achieved by 2009. The remaining phases of restoration are expected to be completed by 2013. This paper describes results of the suspended sediment and bedload transport monitoring in the restored portion of the Kissimmee River in Pool C from July 21, 2007 through September 30, 2008.

Study Area

The Kissimmee River watershed of South-Central Florida forms the headwaters of the Kissimmee-Okeechobee-Everglades (KOE) ecosystem, and encompasses an area of approximately 7,800 km^2 (fig. 1). The watershed includes the basins of the Kissimmee River (Lower Basin), the Kissimmee Upper Basin, and Lake Istokpoga. The Kissimmee River flows through a subtropical climate with an average annual rainfall recorded at the S-65E structure near Okeechobee, Florida from 1996 to 2008 of 1,066 mm (fig. 1) (*http://glades.sfwmd.gov/mapwq/stationdata.jsp?station=s65e*; last accessed November, 2009).

The prechannelized Kissimmee River was a sinuous (1.67- 2.1), low gradient channel (0.07 m/km) channel with a bankfull width of 15-35 m and a bankfull depth of 1-3.5 m (Koebel, 1995; Warne, 1998, 2000). Although the Kissimmee River was described as transporting suspended sediment with low concentrations (Warne, 1998, 2000), suspended-sediment and bedload data had not been collected before, during, or after restoration.

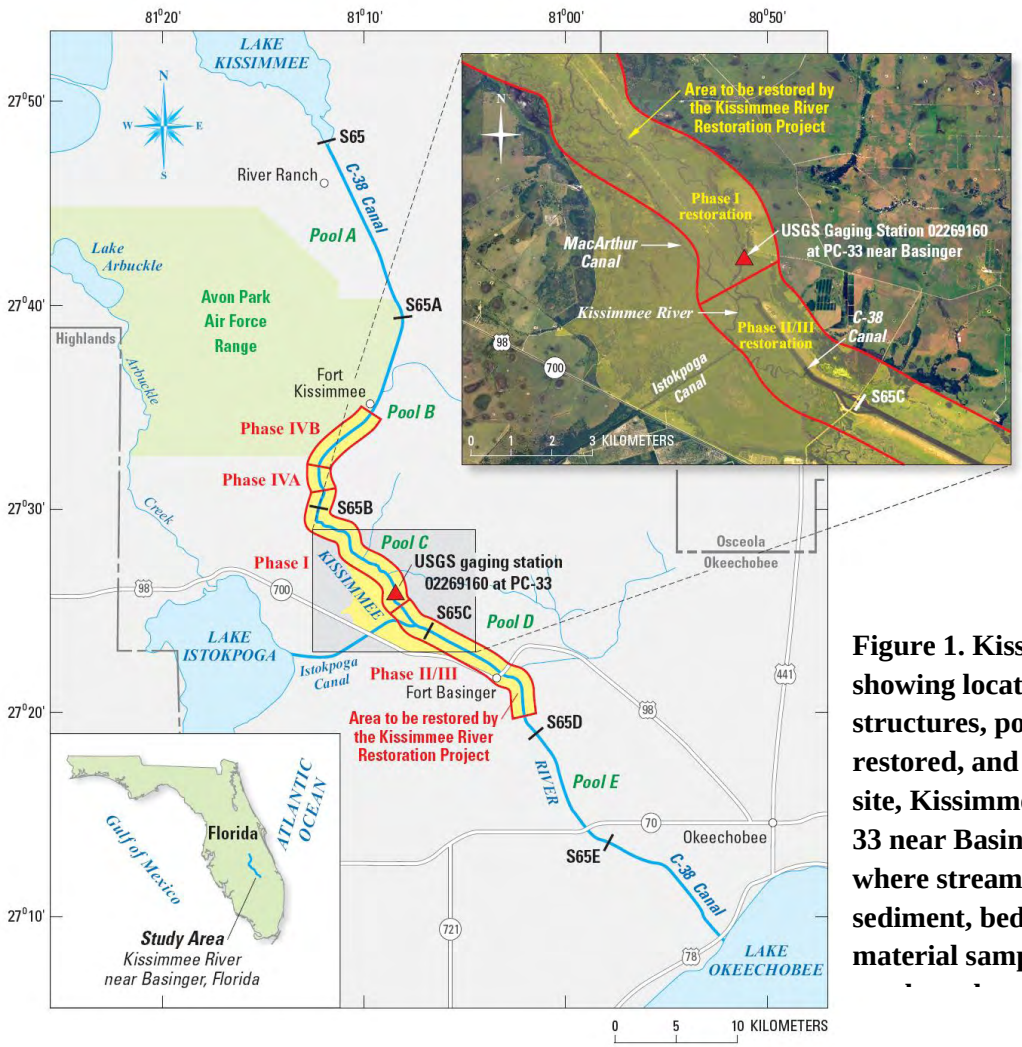

Figure 1. Kissimmee River showing location of structures, pools, area to be restored, and the sampling site, Kissimmee River at PC-33 near Basinger, Florida, where streamflow, suspended sediment, bedload, and bed material sampling were

STREAMFLOW, SUSPENDED-SEDIMENT, AND BEDLOAD DATA COLLECTION

Streamflow, suspended sediment, and bedload data for Pool C were collected from July 21, 2007 through September 30, 2008 at the USGS streamflow-gaging station on the Kissimmee River at PC-33 near Basinger Florida (USGS ID 02269160) (fig. 1). The drainage area of the Kissimmee River at the USGS station is 5,270 km^2.

Gage height and velocity data were collected on 30-minute intervals and transmitted by satellite to the USGS office in Orlando, FL. Due to the variable backwater conditions that existed at the site as a result of its location 6 km upstream from structure S-65C (fig. 1), a lock-and-gate water-control structure, a conventional gage height versus discharge rating was inadequate for discharge computation. When water conditions are low, the lock and gates may remain closed and stage can increase as flow decreases. During higher flow conditions, the lock and gates are opened, and an initial decrease in stage with increasing discharge is observed. If high rainfall conditions exist, runoff and discharge will increase and eventually a rise in stage is observed with increasing discharge. Therefore, an index velocity rating was developed as an alternative method.

Discharge measurements (m^3/s) were made by using a boat mounted Acoustic Doppler Current Profiler (ADCP). Discharge measurements were made on a periodic basis (approximately 6 times per year) with additional measurements made during extreme flow conditions such as floods or droughts to develop and maintain the stage-area and index-velocity ratings (Mueller and Wagner, 2009). During high flow events, a substantial volume of flow leaves the main channel through a breach in the natural levee, upstream of the gaging structure, and flows down MacArthur Canal (fig. 1). Discharge was not measured in MacArthur Canal but was estimated using discharge recorded at the S-65C structure, which is managed by the South Florida Water Management District (SFWMD) (*http://my.sfwmd.gov/dbhydroplsql*; last accessed on December 4, 2009). Structure S-65C is located downstream of the USGS streamflow station and the MacArthur Canal (fig. 1). The difference of the mean daily discharge computed at the USGS streamflow station from the mean daily discharge at the S-65C structure is estimated to be the flow that went down MacArthur Canal and bypassed the station. It was assumed that all other inputs upstream of structure S-65C, and downstream of PC-33 and the MacArthur Canal are negligible in comparison to the computed flows.

Suspended-sediment samples used in the computation of suspended-sediment loads were collected using both manual and automatic samplers. Manual suspended-sediment samples were collected at various points (stations) in the cross section using a U.S. Series depth-integrating DH-59 rope sampler and the Equal Width Increment (EWI) and the Equal Discharge Increment (EDI) method (Edwards and Glysson, 1999). Suspended-sediment samples were collected using a boat during scheduled bimonthly site visits, as well as during periods of high flows. An automatic-pumping sampler with a peristaltic pump was installed at the site to collect suspended-sediment samples on a more frequent interval. From July 21, 2007 through November 21, 2007, the automatic sampler was programmed to collect a suspended-sediment sample every 12 hours. From November 21, 2007 through September 30, 2008, the automatic sampler was programmed to collect a suspended-sediment sample every 24 hours after a review of the data indicated that daily samples were adequate to define sediment transport characteristics. Water samples were sent to the USGS Kentucky Water Science Center Sediment Laboratory in Louisville for analysis of suspended-sediment concentrations. Organic sediment is a concern for managing the KRRP. Decomposition of organic matter decreases oxygen levels and may impact the habitat (Harris et. al., 1995). Because organic sediments are a concern for managing the KRRP, selected suspended-sediment samples were also analyzed in the USGS Kentucky Sediment lab for percent organics and percent sand. A dry sediment sample is burned at 550° C for 1 hour (Fishman and Friedman, 1989) and the loss-on-ignition (LOI) corresponds to the organic portion of the suspended sediment and the remaining mass is the inorganic portion. Daily suspended-sediment loads were computed using the subdivision method (Porterfield, 1972) with the USGS-software Program, Graphical Constituent Loading Analysis System (GCLAS).

Bedload samples were collected during the same site visit when suspended-sediment samples were collected (bimonthly and during high flows) using a BLH-84 bedload sampler with a mesh size of 0.125 mm. The EWI method was used in the collection of bedload (Edwards and Glysson, 1999). When bedload samples were collected, they were sent to the USGS Cascades Volcanic Observatory where they were oven-dried at 103° C, weighed in grams (g), and sieved through 16, 8, 4, 2, 1.0, 0.5, 0.25, and 0.125 mm openings. Selected bedload samples were sent

to the USGS National Research Program Dendrochronology Laboratory in Reston, Virginia, for percent organic analysis using the LOI method.

RESULTS

Streamflow

Daily and monthly streamflow recorded for the restored Kissimmee River at PC-33 near Basinger, Florida for the period July 21, 2007 to September 30, 2008 are shown in figure 2. The mean daily discharge for this period was 24.5 m^3/s. Low-flow conditions from July 21, 2007 through July 2, 2008, were interrupted by rainy periods in March and April 2008, and the mean-daily streamflow for this period was 15.7 m^3/s. Beginning on July 3, 2008, tropical storm activity caused wet conditions and the mean daily discharge for the period July 3 through September 30, 2008 was 58.0 m^3/s, which is 3.5 times higher than the drier, earlier period. The highest mean daily discharge during the period of study (157 m^3/s) occurred on August 22, 2008 as a result of heavy rains associated with Tropical Storm Fay which hit Florida between August 19 and 24, 2008.

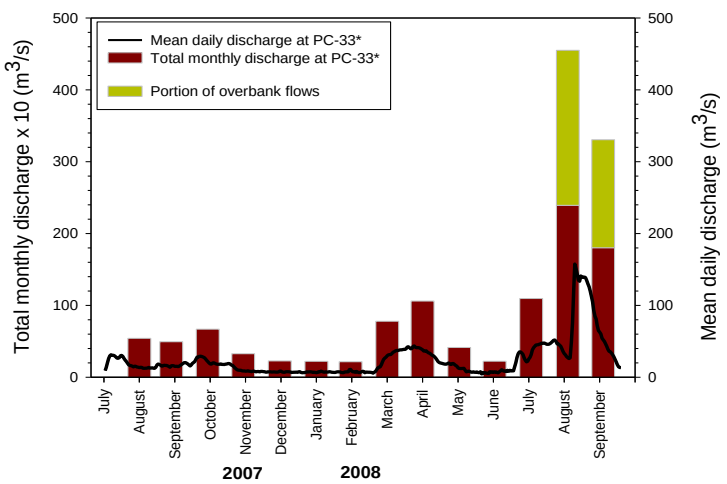

Figure 2. Mean daily and total monthly discharge for the restored section of the Kissimmee River at PC-33 near Basinger, Florida. Also included are the portion of flows that went overbank from August 19 to September 22, 2008. [* discharge values do not include flows that went down MacArthur Canal}

During the period, August 19 to September 22, 2008, the flow went overbank through a breach in the natural levee, upstream of the streamflow-gaging station on the right bank (fig. 1). The flow entered the floodplain and went down the partially backfilled MacArthur Canal where it re-entered the Kissimmee River between the streamflow-gaging station and structure S-65C (fig. 1). Observations during this period indicated that flows went overbank at a discharge of approximately 50 m^3/s, which is considered to be bankfull discharge. During this period, 3.11 x 10^8 m^3 of flow went overbank, which is 52% of the total streamflow (overbank flow + the flow in the restored section) (fig. 2).

Suspended Sediment

During the period of study July 21, 2007 to September 30, 2008, 574 suspended-sediment sample concentrations were determined. Suspended-sediment concentrations ranged from 5 mg/L to 800 mg/L (fig. 3a). The highest value of suspended-sediment concentration, 800 mg/L, was collected on August 22, 2008, at 07:05 a.m. during Tropical Storm Fay.

Monthly suspended-sediment loads are shown in Figure 4a and in Table 1. Similar to mean monthly discharges, the highest monthly suspended-sediment loads were observed in August and September 2008. The total suspended-sediment transported in the restored channel during the period of study, July 21, 2007 to September 30, 2008, was 78,912 Mg (Table 1).

The 8 highest daily suspended-sediment loads occurred between August 21 to August 31, 2008, during tropical storm activity associated with Tropical Storm Fay, and totaled 40,652 g, which is 52% of the total suspended-sediment load measured in the restored channel (78,912 Mg) for the period of study. Suspended-sediment load transported during the highest daily streamflow (10,158 Mg on August 22, 2008) was 13% of the total suspended-sediment load measured in the restored channel for the period of study.

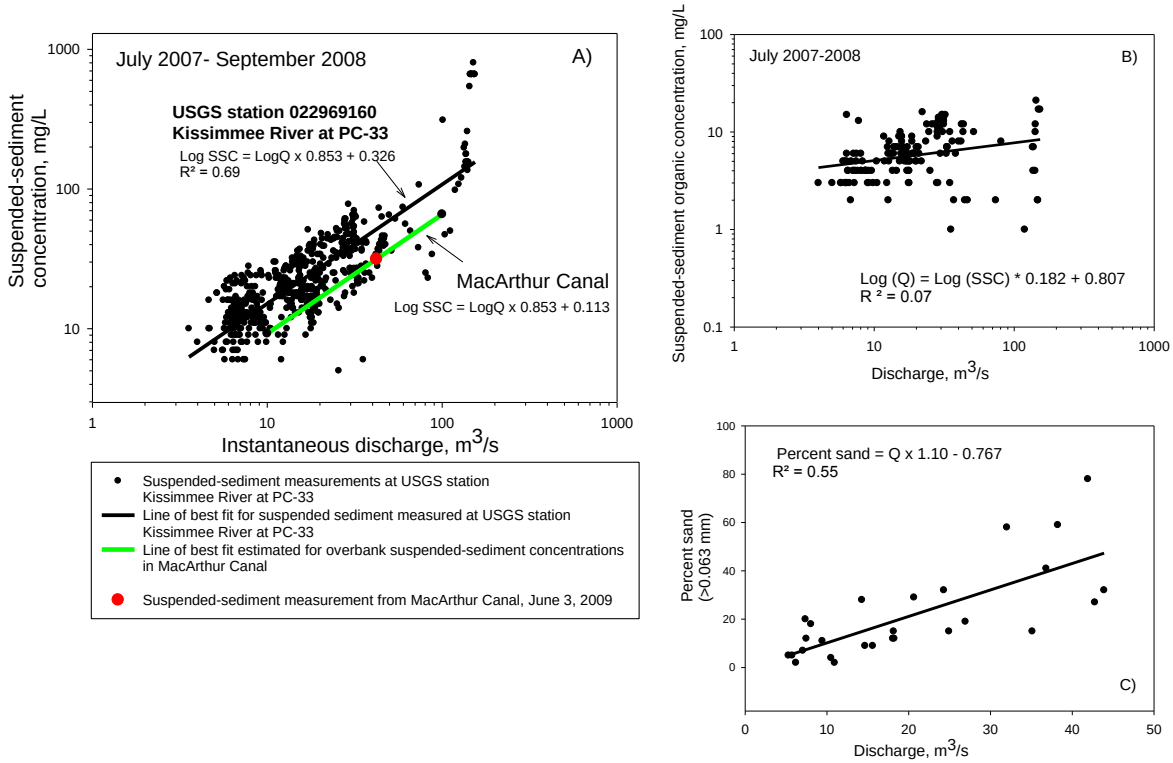

Figure 3. A) Suspended-sediment transport curve for the restored section of the Kissimmee River at PC-33 near Basinger, Florida, July 21, 2007 through September 30, 2008. Also included is the line of best fit used to estimate suspended-sediment concentrations in the overbank portion of flow. B) Organic suspended-sediment transport curve for Kissimmee River at PC-33 near Basinger, Florida, July 21, 2007 through September 30, 2008. C) Discharge versus percent sand in suspension. [SSC = suspended-sediment concentration, mg/L; Q = discharge, m^3/s]

Organic content and the percent sand in suspension were measured in the restored channel. A regression of the organic content of suspended-sediment against discharge shows a weak relation (R^2=0.07) of increasing organic concentration with discharge (fig. 3b). The highest value of organic concentration of suspended sediment was 21 mg/L for a sample collected on August 22, 2008, at 2:34 p.m. during Tropical Storm Fay. A comparison of sand in suspension with instantaneous discharge shows that at higher discharges, more sand is in suspension than at lower

flows (fig. 3c). The percent of sand in suspension ranged from 2% at low flows to 78% at higher flows (fig. 3c).

The total suspended-sediment load minus the organic suspended-sediment load is the inorganic suspended-sediment load. Comparing organic and inorganic monthly suspended-sediment loads shows that for the wettest months, August and September 2008, the majority of the suspended-sediment load is inorganic (fig 5a). Although both inorganic and organic suspended-sediment concentrations increase with flow, inorganic concentration increases are higher with respect to increasing flow than organic concentrations (fig. 5b). This could indicate that, at high discharges, more inorganic sediment is eroded and transported relative to the organic component.

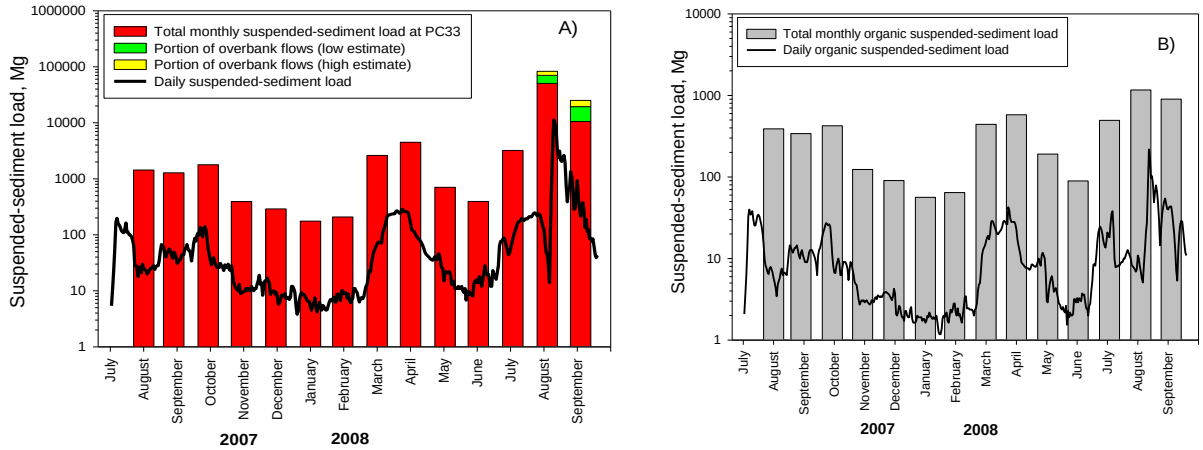

Figure 4. Daily and monthly suspended sediment loads for the restored section of the Kissimmee River at PC-33 near Basinger, Florida. Values do not include sediment that went down MacArthur Canal. A) Total suspended-sediment load . B) Organic suspended-sediment load.

Flows went overbank upstream of the PC-33 station, between August 19 and September 22, 2008, flowed down the MacArthur Canal, and entered the Kissimmee River below PC-33. During this period, flow and suspended-sediment measurements were not made in MacArthur Canal. However, in June 2009, flow again went overbank and a discharge measurement and a suspended-sediment sample were taken on June 3, 2009 in the MacArthur Canal. The suspended-sediment sample was taken using a DH-59 rope sampler. The suspended-sediment concentration was 31.5 mg/L and the discharge was 42.1 m^3/s. At the time of this measurement, the MacArthur Canal was 23 m wide and 3 m deep. When plotted on the sediment-transport curve, the suspended-sediment concentration of 31.5 mg/L falls below the line of best fit (fig 3a).

Suspended-sediment concentrations for the overbank flow during the period August 19 through September 22, 2008 were estimated using two sediment-transport curves. One estimation was based on the line of best fit of the sediment-transport curve for all suspended-sediment samples (fig. 3a). The other estimate was based on the line of best fit of the sediment-transport curve adjusted to the suspended-sediment concentration sampled in MacArthur Canal, while preserving the slope of the line (fig 3a). By using both of these estimates, a range in suspended-sediment loads that were transported overbank and bypassed the station at PC-33 was calculated.

Table 1. Total sediment load, suspended- sediment loads, and bedload for the Kissimmee River at PC-33 near Basinger, Florida, July 21, 2007 to September 30, 2008. Also shown are percent transported as organic and inorganic suspended sediment, and as organic and inorganic bedload. Restored channel sediment includes only the sediment measurements at PC33 and does not include MacArthur Canal.

Month	Year	Total sediment load, Mg (suspended sediment load in the restored channel + overbank load + bedload)	Suspended sediment load measured in restored channel, Mg	Suspended sediment		Bedload, Mg	Organic suspended-sediment, % of total suspended-sediment load, measured in restored channel	Inorganic suspended-sediment, % of total suspended-sediment load, measured in restored channel	Organic bedload, % of total bedload	Inorganic bedload, % of total bedload
				Lower estimate	Higher estimate					
July 21-31	2007	1,027	1,026			0.56	25	75	77	23
August	2007	1,433	1,433			0.27	27	73	78	22
September	2007	1,282	1,282			0	27	73	0	100
October	2007	1,784	1,784			0.23	24	76	87	13
November	2007	391	391			0	32	68	0	100
December	2007	290	290			0	31	69	0	100
January	2008	176	176			0	32	68	0	100
February	2008	208	208			0	31	69	0	100
March	2008	2,620	2,616			3.8	17	83	45	55
April	2008	4,503	4,494			8.8	13	87	35	65
May	2008	704	704			0	27	73	0	100
June	2008	394	394			0	23	77	0	100
July	2008	3,221	3,208			13	15	85	25	75
August	2008	73,659 to 86,336	50,388	20,026	32,703	3,245	2	1	1	99
September	2008	20,416 to 26,071	10,518	8,934	14,589	964	9	2	2	98
Total		**112,108 to 130,440**	**78,912**	**28,960**	**47,292**	**4,236**	**7**	**93**	**1**	**99**

The daily suspended-sediment load (Mg/day) for the overbank flows was computed as the suspended-sediment concentration (mg/L), estimated from both sediment-transport curves (fig. 3a), times the mean-daily discharge (m^3/s) of the overbank flows and multiplied by a conversion factor (0.0864) (Porterfield, 1972). The suspended-sediment load transported in the overbank flow, during the period August 19 through September 22, 2008, was estimated to range from 28,960 to 47,292 Mg (Table 1), which is 33 to 45% of the total suspended-sediment transported in the Kissimmee River during this period [restored channel suspended-sediment load (57,783 Mg) + overbank suspended-sediment load (28,960 to 47,292 Mg)]. The overbank contribution of sediment was 27 to 37% of the total suspended-sediment load for the period of study (overbank (28,960 to 47,292 Mg) + restored (78,912 Mg) = 107,872 to 126,204 Mg). It should be emphasized that the suspended-sediment loads for the overbank flows are an estimate. In the future, additional samples will be collected in MacArthur Canal to establish a better estimate of the suspended-sediment loads that are transported overbank.

Bedload

Bedload transport was measured five times between July 21, 2007 and September 30, 2008. At four other times during this period, when the station was visited on a routine basis, the BL-84 bedload sampler did not record bedload transport. The median grain size of the bed material from two measurements made on January 15, 2008 and August 23, 2008 varied from 0.18 to 0.33 mm, respectively. Examination of the Hjulstrum curve for the initiation of sediment transport indicates that for the range of median bed-material sizes found on the Kissimmee River (fine to medium sand), sediment movement is initiated when the velocity at the channel bed approaches 20 cm/s (fig. 6). The discharge measurement made on March 20, 2008 of 33.1 m^3/s had velocities near the bed which were just above this threshold to initiate bedload transport. Bedload measured on March 20, 2008 was 0.11 Mg. Based on figure 6 and the bedload transport curve (fig. 7), a discharge slightly below 33.1 m^3/s, of 28.3 m^3/s, was estimated to be the discharge at which bedload transport begins.

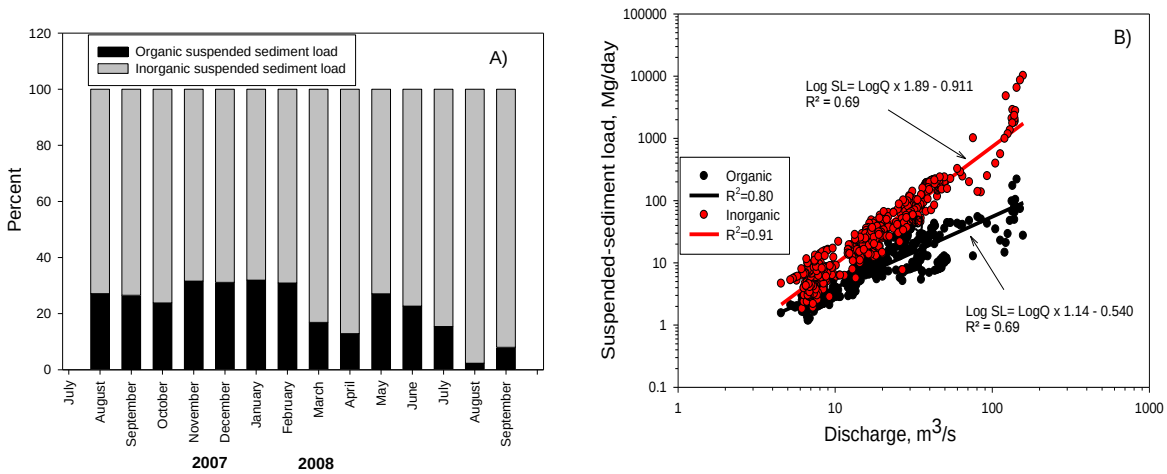

Figure 5. A) Monthly organic and inorganic suspended-sediment load percentages for the restored section of the Kissimmee River at PC-33 near Basinger, Florida. B) Sediment transport curves of organic and inorganic suspended sediment. [SL = suspended-sediment load, Mg/day; Q = discharge, m^3/s]

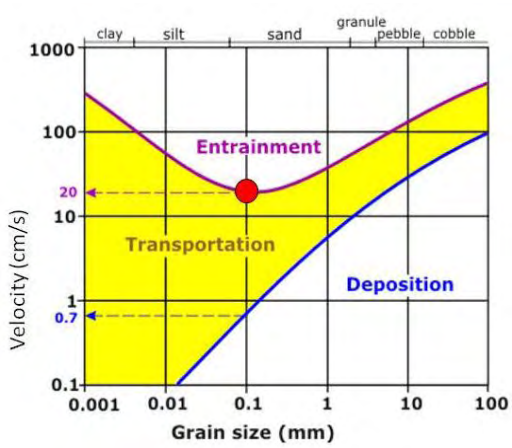

Figure 6. Hjulstrum curve for the initiation of sediment motion. The red circle indicates the range of median bed-material sizes found on the Kissimmee River, which would be entrained at velocities near 20 cm/s (after Hjulstrom, 1935).

The highest bedload transport measured was on August 23, 2008 during Tropical Storm Fay at a discharge of 152 m^3/s when 430 Mg of sediment was transported. Daily bedload transport was determined by using the line of best fit from the bedload transport curve (fig. 7a) applied to the mean daily discharge record at the Kissimmee River at PC-33 on days when the daily-mean discharge exceeded 28.3 m^3/s. Daily bedload values were totaled to obtain monthly loads (Table 1). The bedload for the period of study (4,236 Mg) is 3 to 4 % of the total sediment load (112,108 to 130,440 Mg) [bedload (4,236 Mg) + restored channel suspended-sediment load (78,912 Mg) + estimates of suspended-sediment transported overbank (28,960 to 47,292 Mg)].

The percent organic material was determined for 4 of the 5 bedload measurements. An organic bedload transport curve was produced and the line of best fit was applied to the mean daily discharge to obtain daily organic bedload transport (fig. 7b). The daily organic bedload were summed to obtain monthly organic bedload values. The percentage of organic bedload was highest during the lower flow months (Table 1). The inorganic daily bedload transport is computed by subtracting the organic from the total bedload. Inorganic bedload ranged from 13 to 99 percent of the total bedload and organic bedload ranged from 0 to 87%.

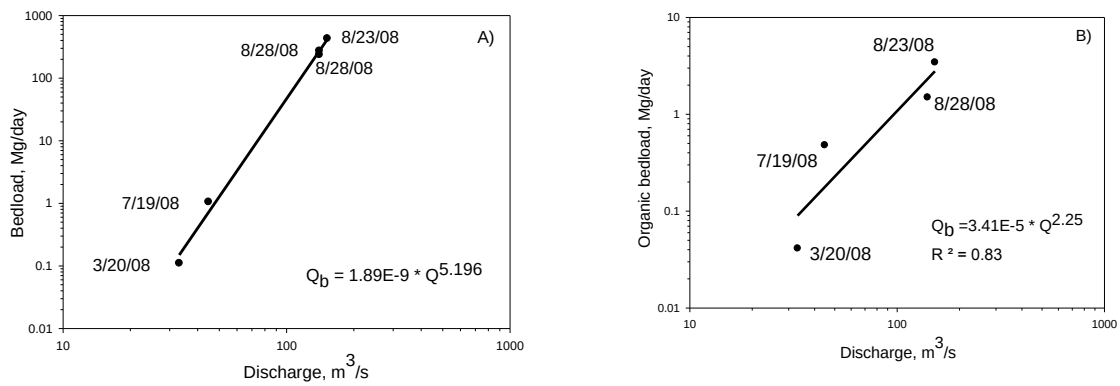

Figure 7. (A) Bedload transport curve for the Kissimmee River at PC-33 near Basinger, Florida, July 21, 2007 – 9/30/2008. B) Organic bedload transport curve. [Q_b = Bedload, Mg; Q= discharge, m^3/s].

Effective Discharge

The dimensions of a channel in many river systems have been found to be related to a single discharge or an effective discharge (Wolman and Miller, 1960; Biedenharn et al., 2000). Channel-forming flows can be estimated using three methodologies: (1) bankfull discharge, referring to the discharge that fills the channel to the top of its banks; (2) recurrence interval discharge, typically assigned to flows between the mean annual and 5-year recurrence interval; and (3) effective discharge, or the class of flows that transports the most sediment (Biedenharn et al., 2000). Although effective discharge can be computed for suspended sediment, bedload, or total load, bedload is considered the portion of sediment movement that will most affect channel morphology (Ward and Trimble, 2004).

Effective discharge computations were made for the Kissimmee River using procedures outlined by Biedenharn et al. (2000). The procedure to determine the effective discharge involves three steps: (1) a mean-daily discharge flow-frequency distribution is developed; (2) a bedload transport curve (fig. 7) is constructed; and (3) the flow-frequency distribution and bedload-rating curve are combined to produce a bedload histogram which displays bedload as a function of discharge for the period of record (fig. 8). The histogram peak indicates the effective discharge (Biedenharn et al., 2000).

Bankfull flow occurred at a discharge of approximately 50 m^3/s when a substantial volume of flow leaves the main channel upstream of the gaging station. The histogram of mean daily discharges for the period July 21, 2007 through September 30, 2008 was created using 78 flow classes of 2.0 m^3/s size (fig. 8). The large number of size classes was required to ensure that the largest size class did not occur in the first class and that high discharges were included. The histogram illustrates that the majority of flows are 7 m^3/s (n=116; fig. 8). The large number of flows at 7 m^3/s is partially due to the controlled flow on the Kissimmee River which attempts to maintain a minimum gage height necessary for navigation. The bedload transport curve is shown in figure 8 along with the collective bedload discharge histogram. There are two high points on the collective bedload discharge histogram; one value at 47 m^3/s, the other value at a higher flow of 139 m^3/s. The lower value at 47 m^3/s is close to the value we have selected as bankfull discharge (50 m^3/s), thus, the Kissimmee River's channel morphology could be related to the effective discharge. The higher effective discharge value at 139 m^3/s is due to the large number of high flows that occurred during tropical storm activity associated with Tropical Storm Fay that clustered in this size class. Since flows are out of bank at 50 m^3/s, it seems unlikely that these are channel-forming flows but may be flows that impact the floodplain.

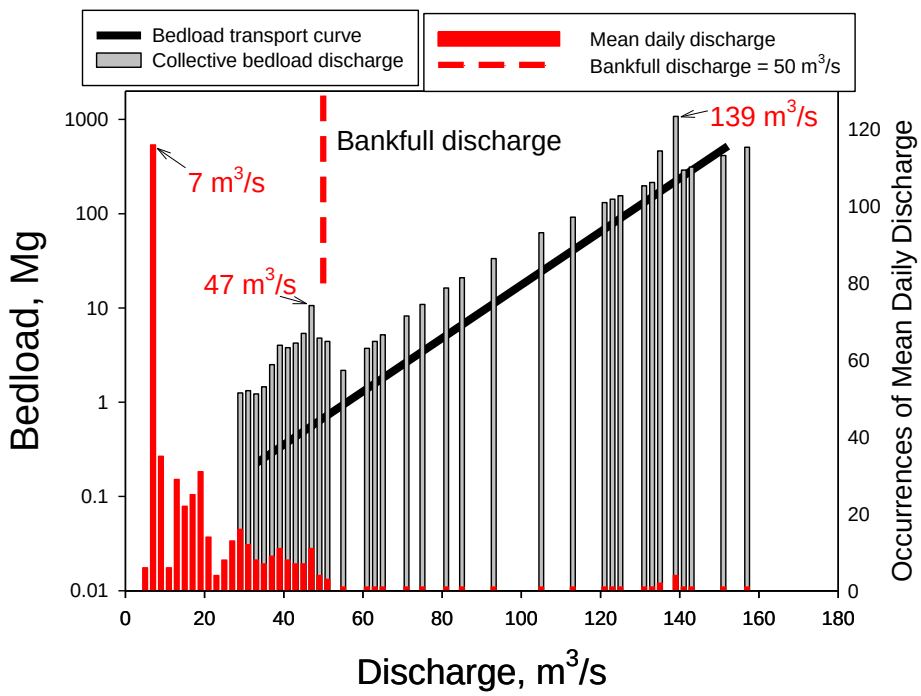

Figure 8. Effective discharge for the restored section of the Kissimmee River at PC-33 near Basinger, Florida, July 2007 to September, 2008.

SUMMARY OF SEDIMENT TRANSPORT

The Kissimmee River is a fine to medium grained sand-bed river. Suspended sediment and bedload were collected for the period July 21, 2007 through September 30, 2008 in Pool C of the restored section of the Kissimmee River. Similar to many world rivers, the dominant mode of sediment transport in the Kissimmee River was suspended, which depending on the estimate used for overbank suspended-sediment loads, ranged from 107,872 to 126,204 Mg (96 to 97%) of the total sediment load of 112,108 to 130,440 Mg. Of the total suspended-sediment load for the period of study, 78,912 Mg was transported in the restored channel. Overbank flows occurred from August 19 to September 22, 2008 (9% of the study period) and accounted for 52% of the total flow (restored channel + overbank flows) during this period and 25% of the total flow for the period of study. The overbank flows were estimated to have transported 28,960 to 47,292 Mg of suspended sediment, which is 33 to 45% of the total suspended-sediment transported in the Kissimmee River from August 19 to September 22, 2008. Overbank suspended-sediment loads were estimated to transport 27 to 37 % of the total suspended-sediment load for the period of study. Seven percent of the suspended-sediment transported in the restored channel was organic suspended-sediment, and 93 %was inorganic suspended-sediment.

Bedload transport was 4,236 Mg (3 to 4 percent of the total sediment load). The median grain size of the bed material was a fine to medium sand and incipient motion of bed material was estimated to occur at approximately 28.3 m^3/s. The organic percentage of the bedload was greater than 25% (up to 85%) during the low flow period of July 2007 through July 2008, to less than 25% (as low as 0.9%) during the high flow period, July through September, 2008.

Effective discharge computations indicate that the majority of sediment was transported at 47 m^3/s and 139 m^3/s. The 47 m^3/s effective discharge value is near the bankfull discharge of 50 m^3/s and may be the channel forming flow. The 139 m^3/s effective discharge value is related to the high flows that occurred during Tropical Storm Fay. These flows may be important in floodplain processes, but more research is needed to confirm this.

The importance of storms in transporting sediment is highlighted by the data collected in the Kissimmee River. During the period of study, 52% of the total suspended-sediment load measured in the restored channel was transported in 8 days between August 21 and 31, 2008 and 56% of the total bedload was transported in 7 days between August 22 and 30, 2008. For both the suspended-sediment and bedload, this transport occurred during Tropical Storm Fay.

Suspended-sediment or bedload data were not available on the restored Kissimmee River prior to channelization, during the channelized period, or immediately after restoration. Therefore, the sediment data (suspended sediment and bedload) presented here serve as a point of reference to determine whether suspended sediment-concentrations, loads, and bedload will increase, decrease, or remain steady over time. The flow and sediment data presented here, along with their ongoing collection as part of the geomorphic monitoring plan, will provide useful information to evaluate changes in channel morphology.

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