South San Francisco Bay Shoreline Study

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Sediment Transport and Fate from South Bay Streams

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Abstract: In general, the sediment transport capacity of alluvial channels is a function of flow, bed slope, sediment size, and inflowing sediment load. A channel is said to be in equilibrium when it is not actively changing crossection or plan form due to deposition or erosion processes. However, natural channels are dynamic due to factors such as periodic floods and encroachment of vegetation that can initiate localized small scale channel crossection or plan form change. Excessive channel instability such as bank widening and deepening can result in a loss of transport capacity, as well as streamside infrastructure and habitat. Typically, bank stabilization and grade control methods are employed to stabilize stream banks and the channel bed to prevent further damages.

In run-of-river stream reaches, the stream hydrodynamics and resulting sediment transport capacity are highly dependent on flow and flow resistance due to bed roughness channel geometry, and bed sediment properties. For steady sub-critical flows, the stream hydraulics can bed simplified by assuming a normal depth (flow depth parallel to the bed). For stream reaches that are influenced by either steady or varying downstream water surface elevation (reservoirs, lakes, or bays), the upstream most influence of this downstream water surface control will exert control over sediment transport and fate within the channel.

The South San Francisco Bay streams originate in the Santa Cruz mountain range above San Jose and Santa Clara California. The two largest stream systems, Coyote Creek and Guadalupe River, flow into the Eastern portion of the bay, while adjacent streams (Calabazas, Stevens, and Permanente creeks) flow into the Western portion of the bay. All the streams are characterized by steep upper stream reaches with gravel and cobble beds that flow through highly developed areas. As these streams approach the bay, the channel bed slopes are reduced, and tidal effects influence stream hydrodynamics. The bed sediments in these lower stream reaches reflect the subsequent reduction in flow energy, with sand beds found in the upper reaches of the lower stream channels, and fine sediments predominant in the lower bay channels and associated sloughs.

This report documents a sediment transport and fate analysis for the two primary South Bay streams, Coyote Creek and the Guadalupe River. The emphasis of the study was to determine estimates of sediment yield to the lower bay sloughs running adjacent to the salt pond areas, and to simulate how the inflowing sediment load transports and sorts throughout the lower stream channels. Of particular concern to the South Bay Shoreline study is how much and what sediment size classes will be available for nourishing the salt pond wetland areas when the levees are breached.

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Preface

The research presented in this paper was sponsored by the U.S. Army San Francisco District Army Corps of Engineers. This work was conducted in the Coastal and Hydraulics Laboratory (CHL) of the U.S. Army Engineer Research and Development Center (ERDC) during the period of May 2007 – June 2009 under the direction of Thomas J. Richardson, Director, CHL; Bruce Ebersole, Chief of the Flood and Storm Protection Division, CHL; and Dr. Lisa Hubbard, Chief of the River Engineering Branch, CHL.

This investigation of riverine sediment transport was conducted by Dr. Steve Scott of the River Engineering Branch, CHL. Acknowledgements are made to Dr. Rob McAdory, Chief of the Estuarine Engineering Branch, CHL, Dr. Joe Letter, Estuarine Engineering Branch, CHL, and Terry Marks, San Francisco District, for their guidance and assistance during this study.

COL Richard B. Jenkins was Commander and Executive Director of ERDC. Dr. James R. Houston was Director.

Unit Conversion Factors

Multiply	By	To Obtain
cubic feet	.02831685	cubic meters
feet	.3048	meters
inches	.0254	meters
mile	0.621212	kilometer

1 Introduction

Sediment transport in alluvial channels is a function of four variables: system hydraulics, bed material characteristics, channel slope, and inflowing sediment load. A channel is considered to be stable and in equilibrium when the channel crossection and plan form are not actively changing. However, this equilibrium condition is ideal, in that even stable channels will generally respond in a limited fashion to temporary changes in system hydrology or sediment supply.

When natural channels become unstable, many factors may be involved. Urbanization generally results in higher runoff volumes, thus increasing the potential for channels to degrade to meet the increased flow capacity requirements. Channel degradation results in channel widening and deepening, along with excessive sediment transport downstream. Deforestation of upland watersheds can result in sediment delivery to rivers which exceed their sediment transport capacity. The excess sediments deposit in the river resulting in a loss of transport capacity and an increased flood risk.

When evaluating the sediment transport potential for a river system, it is essential that an existing channel assessment be performed to evaluate channel stability. If a channel is actively changing crossection or plan form, sediment transport studies will only represent a snap shot in time of the fate and transport of sediment in the system. The South San Francisco Bay channels flow through very densely populated areas. Originating in the Santa Cruz mountain range, the channels are characterized by steep upland gravel and cobble bed channels which transition into sand and fine bed channels at the confluence with San Francisco Bay. These channels are actively managed to maintain conveyance and reduce flood risk. Some of the smaller channels (Calabasas, Permanente, and Stevens Creek) utilize concrete lined channels to contain the high velocity flows from the steeper reaches of the streams. Although there is some localized evidence of channel degradation, the major channel instability that must be continuously addressed is excessive deposits of gravel that occur between the Bay and the upland areas. These deposits typically occur at reductions in bed slope that reduce the channel capacity to pass gravel and cobble sized sediments.

The study described in this report was conducted to qualify and quantify the potential for sediment to transport to the lower channels of the South San Francisco Bay streams. The proposed modifications to the South Bay salt ponds for wetland restoration purposes requires an understanding of the annual riverine sediment load available to replenish the wetlands. Because of limitations on data availability, this study will concentrate on the larger streams that contribute the bulk of sediment to the bay and ultimately to the salt pond complex adjacent to the lower stream channels (Coyote Creek and Guadalupe River). The channel assessment study described in the channel assessment report provides insight into the sediment transport potential of the smaller streams feeding into the bay (Calabasas Creek, Stevens Creek, and Permanente Creek). Estimates of annual sediment yield will be provided for these smaller streams in this report.

2 Background

The channel assessment report provides valuable insight into the transport potential of the South Bay streams. Historically, the upland watersheds consisted of farm land, however, the land use adjacent to these streams has changed dramatically over the years. Urbanization inevitably increased runoff quantities and duration, resulting in degraded channels. Additionally, base flows in the channels have increased due to increasing industrial and wastewater inflows to the systems.

Although impacts to the streams due to urbanization are inevitable, best management practices (NRCS 2001) have been implemented in the stream corridors. Bank protection works have been utilized at bridge locations throughout the system. Excess sediment is removed from channels to increase flow capacity. Grade control structures have been constructed to stop channel degradation (Stevens Creek below highway 101). During the stream channel assessment field trip, very few observations of active channel instability were noted.

The bed sediment composition and size distribution reveals much about how sediment transports through the stream systems. Generally, the transport or deposition of gravel, sand, silt, and clay in these streams is dependent on inflowing sediment load, system hydraulics, bed slope, and the bay tides. The bed sediments where the streams enter the bay are classified as very fine sands, indicating that a portion of the sand load does enter the bay during flood events.

Only Coyote Creek and Guadalupe River have any significant records of flow and suspended sediment load. These data are essential for supporting any studies of sediment transport and fate, thus only Coyote Creek and Guadalupe River were evaluated in depth for this study. The goal of this study was to evaluate the potential for sediment to transport to the lower stream channels adjacent to the salt pond areas. Of concern to this study is the annual sediment yield from the channels to the bay, as well as the sediment size distribution. Sediment yield was determined from the US Geological Survey (USGS) stream gauging data available for Coyote Creek and Guadalupe River. Sediment yield for the other three smaller streams was estimated as a function of water shed area. A one dimensional sediment transport model, HECRAS, was used to evaluate the fate of inflowing sediments in the lower channels.

Stream flow and suspended sediment load data for Coyote Creek and Guadalupe River are available from the USGS surface water database. In addition to flow and sediment load, limited data are available on the size distribution of the suspended load as a function of discharge in the water quality database. Table 1 lists the USGS site locations and numbers for accessing this data. The Coyote Creek gauging station is just above the Highway 237 Bridge, with approximately 9 years of data record (1999 – 2007). The Guadalupe River has two USGS gauging stations, the San Jose station, which is now inactive, has a long term flow record from 1929 – 2003. The more recent gauging station is located just above the Highway 101 bridge, and has a flow record from 2003 – 2007. In addition to the flow and sediment load data, bed sediment particle size distribution

data obtained from the channel assessment evaluation were used in the sediment transport modeling.

Table 1. USGS surface water / water quality gauging stations

Site Description	Site Number
Coyote Creek Above Hwy 237	11172175
Guadalupe River Above Hwy 101	11169025
Guadalupe River at San Jose	11169000

3 System Hydraulics

The ability of a river system to transport sediments is proportional to the transport capacity of the channel. Low flows generally only transport fine sediments such as silts and clays (wash load), whereas higher flows mobilize bed materials and transport the coarse sediment fractions as both suspended and bed load. The lower South Bay channels are primarily depositional in nature due to the milder bed slopes and tidal influence. However, large flows in these streams are capable of transporting sand fractions to the Bay channels (Alviso and Guadalupe Sloughs). The frequency and magnitude of these larger flow events will determine the total sediment yield and sediment size fractions delivered to the Bay.

The discharge data available from the highway 237 (Coyote Creek) and highway 101 (Guadalupe River) USGS gauging stations represent low flow years (1999 – 2007). Plots of the daily mean average flow record for each location are found in Figures 1 and 2, including peak flows. A long-term data record exists for the Guadalupe River at San Jose (Figure 3). A flow duration curve was developed for this long term flow record to evaluate the frequency that flows occur in the Guadalupe River (Figure 4). Thirty six years of record (1967 – 2003) were used to construct the curve. The data indicate that the probability that flows will exceed 1000 cfs is about two percent, the probability of flows exceeding 100 cfs about 15 percent, and the probability of flows exceeding 10 cfs about 56 percent. This data indicates that the large floods (one year or greater return event probability) occur less than 2 percent of the time on the Guadalupe. These events will have the highest sediment transport capacity in the channel, and therefore will be critical for computing total sediment yield in the river. Table 2 contains simple statistics describing the three data sets.

Table 2. Flow statistics for USGS flow records (cfs)

Statistic	Coyote at Hwy 237	Guadalupe at Hwy 101	Guadalupe at San Jose
Count	3349	2101	13269
Mean	47.2	75.0	61.2
Median	19.0	33.0	7.0
Minimum	7.9	17.0	0.0
Maximum	1410.0	2630.0	7870.0

A flow duration curve is needed for Coyote Creek. However, the existing flow data record only has 9 years of data which represent low flow conditions. To be useful, the flow duration curve must include enough years of flow history to include higher flood flows. To generate an approximate flow duration curve for Coyote Creek, a data regression was performed to predict Coyote Creek discharge using the Guadalupe River discharge data (Figure 5). The Coyote Creek and Guadalupe River watersheds are adjacent to each other, and should be similarly impacted by region wide storms. However, as stated earlier, the data sets used in the regression analysis were limited in time and did not capture large flood events. To generate the flow duration curve, the Coyote Creek predictive function was applied to the long term record of the Guadalupe River at San Jose. The flow duration curve for Coyote Creek is found in Figure 6. The data sets that were used to generate the predictive function indicated that the Coyote Creek discharge was overall lower for the time period comparison, thus the peak flows for Coyote (322 square mile watershed area) were less than the Guadalupe (170 square mile watershed area). This may not be representative of the actual long-term flow history for Coyote, and will only serve as a rough estimate for later determining sediment yield. The estimated return flood flows for the principle channels in the South Bay area are provided in Table 3, including Alameda Creek, the principle tributary on the North side of the bay.

Table 3. Approximate return flood flows for South Bay streams

Stream	Area – mi^2	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
Coyote Cr	322	3900	6773	8500	11000	12700	14500
Guadalupe River	*170	2900	5773	7780	10206	11882	13427
Calabazas Cr	**32	1600	2200	2650	3200	3600	3900
Stevens Cr	***30	2500	3800	4900	6300	7200	8100
Permanente Cr	28	420	810	1200	1700	2200	2600
Alameda Cr	633	4220	10265	14396	19027	21896	26242

***** Guadalupe River at San Jose
****** Includes Sunnyvale channels
*** Permanente Creek flood flows routed through Stevens Creek

4 Annual Sediment Yield to the Lower Bay Channels

The annual sediment yield from a river system can be estimated using various methods. Typically, gross annual sediment yields from watersheds are estimated by considering total watershed runoff, relief of the topography, and application of empirical based relations for estimating total soil erosion, entrainment, and transport to watershed fluvial channels. The Universal Soil Loss Equation (USLE) is typically applied to generate estimates of annual watershed yield. A number of predictive equations have been developed for estimating sediment yield. Dendy and Bolten (1976) proposed the following equation for predicting watershed yield as a function of watershed area based on data from 800 watersheds from across the United States.

$$SY = 674 * A^{-0.16} \qquad (1)$$

with SY the total sediment yield in tons per square kilometer per year, and A the area in kilometers. In a study of suspended sediment loading from local San Francisco Bay tributaries, Philip Williams and Associates (PWA 2005) developed the following equation based on local area watersheds:

$$SY = 2474.17 * A^{-0.51} \qquad (2)$$

These sediment yield estimates are for total watershed yield and may not applicable for determining what portion of the yield is actually transported throughout the river system from the source to the sink. Sediment loads originating from the watershed will be distributed within the channels based on transport capacity. Typically, the slope of the topography is much steeper in the watershed, with a gradual reduction in river bed slope throughout the watershed. The more coarse sediments will sort in the upper reaches of the river, with a gradual fining of sediment size in the lower river reaches. The only reliable methods for validating sediment loading is to either measure inflowing suspended sediment loads to the river channel reach in question, or determine sediment deposition histories at the terminus of the river (reservoir etc).

Limited suspended sediment measurements are available from the USGS gauging stations presented in Table 1 of this report. Additionally, PWA correlated daily turbidity measurements to USGS measured data to provide a continuous record of suspended sediment concentrations at the Guadalupe River USGS station at the highway 101 bridge. Figure 7 presents suspended sediment concentration data for the Coyote Creek and Guadalupe River. As with all suspended sediment measurements, there is significant scatter of data, thus any predictive function determined from curve fitting the data is highly uncertain. To facilitate a predictive curve fit, the data were converted to suspended sediment load (tons per day), and plotted as a function of discharge. These data are presented in Figure 8, with a power fit to the data. The high correlation coefficient is due primarily to the fact that the ordinate (load) is a function of the abscissa (flow). The PWA data are presented in Figure 9.

The estimated annual sediment yield from Coyote Creek and the Guadalupe River was computed by integrating the sediment load rating curves (Figure 8) and the flow duration curves (Figures 4 and 6). In addition, average annual sediment yield was computed for the historical data records for the low water year comparisons using the curve fits in Figure 8. The computed sediment yield for the Guadalupe River and Coyote Creek are approximately 11,000 and 13,000 tons per year respectively, with the historical average annual sediment yield from the gauging station data 5,000 and 6,000 tons per year respectively. These data are summarized in Table 3. The combined watershed area of the smaller streams west of the Guadalupe River (Calabazas, Sunnyvale, Stevens, and Permanente Creeks) is approximately 90 square miles. The total annual sediment yield for these watersheds combined is estimated to be 8375 tons per year based on the ratio of the total small stream annual sediment yield to the adjacent Guadalupe River watershed

yield as calculated by equation 2. The sediment yield from the Coyote Creek and Guadalupe River systems to the bay is highly uncertain due to the limited number of suspended sediment measurements, and the limited number of significant flow events sampled.

For the nine year Coyote Creek flow record, none of the events sampled for suspended sediment had a peak flow representing or exceeding the two year return flood event (3900 cfs). The Guadalupe River was sampled for four peak flow events at or exceeding the two year return flood event (2900 cfs). The suspended sediment data records for both streams were heavily weighted to lower flows with subsequent lower suspended sediment concentrations. To evaluate the possible bias to the data curve fits, only flows greater than 100 cfs were plotted and fit with a power curve fit. The results indicated only a slight increase in sediment load for Coyote Creek and no increase for the Guadalupe River.

To further investigate the impact of watershed area on sediment yield, the Alameda Creek flow and suspended sediment data were analyzed. Alameda Creek, located on the North side of the bay, has a watershed area approximately twice that of Coyote Creek (633 square miles). Flow and suspended sediment records date back to 1959. Sediment load was computed as described for the other channels, with a power fit to the data. Figure 10 clearly shows that the curve fit is biased by the high number of low flows represented. If the total yield is computed using the curve fit for all flows, the yield is estimated to be 35,000 tons per year. However, if the rating curve is divided into two parts with curve fits to data less than 100 cfs and data greater than 100 cfs, the yield is computed to be approximately 185,000 tons per year. Approximately six of the Alameda Creek suspended load data represented peak flows higher than the two year flood event (4220 cfs). Obviously, the suspended load data record for Alameda Creek is much more non-linear (greater sediments loads at higher flows) than that of Coyote Creek and the Guadalupe River. This infers that other variables such as relief or land use may be more dominant than watershed area on the Alameda Creek watershed. Table 4 summarizes the annual sediment yield results utilizing the USGS data, along with computations from the equations developed by Dendy (equation 1) and PWA (equation 2).

Table 4. Estimated Annual Sediment yield from South Bay streams (tons)

Stream	Area – km^2	Dendy	PWA	USGS
Guadalupe	422	108,124	47,844	11,185
Coyote	838	192,391	66,960	13,215
*** Others**	234	65,887	35,838	8,375
Alameda	1,647	339,377	93,241	**35,000

* Calabazas (Sunnyvale), Stevens, and Permanente Creeks
** Calculated yield utilizing all data. For data >100 cfs, the calculated yield is approximately 185,000 tons

In addition to suspended sediment load, selected USGS suspended sediment samples were analyzed for particle size distribution. This data provides some insight on the distribution of the coarse and fine sediment size fractions as a function of discharge.

Figure 11 presents the percent of fine sediment (<63 microns) as a function of flow. The data suggests approximately 80-90 percent of suspended load consists of fine sediment for the range of flow sampled. However, the regression coefficient is low for this fit indicating no significant trend to the data. For flows higher than represented in Figure 11, the coarser bed material will potentially mobilize and likely constitute a higher percent of the total sediment load. An example of this phenomenon is presented in Figure 12. This is a plot of the change in the fine and coarse fractions of suspended load for the Mississippi River. As discharge increases in the channel during the initial flood phase, most of the suspended load is fine sediment from tributary runoff. However, as the transport capacity increases within the channel, the coarser bed material begins to mobilize, and become a higher fraction of the suspended load. Obviously, the hydraulic and sediment transport characteristics of South Bay streams are far removed from the Mississippi River, but the concept shown in Figure 12 applies. The sediment transport and fate conceptual model for sediment delivered to the lower reaches of the South Bay streams would therefore be a high fine sediment load during the rising limb of the flood hydrograph (90 percent fines), with an increasing coarse sediment load (coarse, medium, and fine sand) delivered at the higher to peak flows. To validate this conceptual model, more suspended sediment samples need to be collected for the higher flood flows.

5 Sediment Transport and Fate Potential

Sediment transport simulations for Coyote Creek and the Guadalupe River were conducted using the HECRAS model that was utilized for the flood routing portion of the South San Francisco Bay Shoreline Study. The sediment transport model was based on the flood routing model geometry and associated inputs. Bed sample gradation data resulting from the field channel assessment study were used to populate the model.

The purpose of the model simulations was to evaluate how sediment sorts through the lower bay channels, with deposition the primary sediment transport mechanism. Both Coyote Creek and the Guadalupe River have numerous bridges along the lower channel reach that have a direct influence on how sediment routs through the system. For Coyote Creek, the lower channel is defined as the channel from Montague Bridge to the bay, whereas the lower channel for Guadalupe River is from the Highway 101 Bridge to the Bay. These lower channels rapidly transition from high gradient stream reaches dominated by a gravel substrate to depositional reaches for sand sized sediments. Additionally, the South Bay tides influence stream hydraulics just below the above mentioned bridge locations as well as significant areas of in-stream and streamside vegetation.

Coyote Creek channel characteristics

The Coyote Creek stream channel has a complex geometry that is better suited to a two dimensional model application. The channel transitions from a relatively narrow channel corridor above Montague Bridge to a wide floodway that bounds the channel to just above Highway 237. The width of this floodway ranges from approximately 500 – 1000 feet. Flows up to a one year event (~1000 cfs) are confined in the main channel, with

higher flows spilling into the floodway. Field observations indicate that the floodways are the likely fate for sand sized sediments during the larger events. However, sediment samples within the main channel indicate that fine gravel transport occurs below the transition reach for flows lower than transported in the floodway. The bridge locations are also very complex areas for attempting to perform sediment transport simulations, regardless of the model. The models are best suited for simulating the back water profiles due to bridge resistance to flow, thus creating a depositional environment. Scour around the bridge, and downstream of the bridge is very difficult to model and is beyond the capability of the model to predict with any certainty given the limited field data available. In addition to the uncertainties of the complex channel geometry and numerous bridge locations, the Coyote Creek flood routing model utilized for the sediment study only contained a by-pass channel for routing flows to the bay. The low flow channel in lower Coyote Creek was not in the model. This has several implications for the model simulations. Only higher flows representative of flood flows can be routed through the model. From the Coyote Creek flow duration curve, this represents only about one to two percent of the flows. Sediment transport through the low flow channel is neglected. Although the larger flood flows contain much of the sediment delivered to the bay, the elevation of the by-pass diversion is such that the back water profile creates an environment for deposition. In the one dimensional model, the sand load is deposited within this zone with no sand transport permitted through the non-existent low flow channel. Bed samples in Guadalupe Slough indicate a median grain size of very fine sand, thus indicating that the model utilizing only the by-pass channel is not representative of transport of the coarse sand fraction to Guadalupe Slough.

Guadalupe River channel characteristics

Below the Highway 101 bridge, the channel rapidly transitions to a primarily sand bed channel (below Trimble Bridge). The Channel corridor is relatively narrow between the levees (250 – 350 feet), with heavy vegetation growing on previous sediment deposits in the channel. As with Coyote Creek, the Guadalupe River is spanned by four highway bridges before it empties into Alviso Slough. The median bed sediment size in Alviso Slough is a very fine sand, much like that found at the mouth of the other adjacent Bay stream streams. As with Coyote Creek, one of the main constraints of modeling the Guadalupe is simulating the scour and deposition around the bridges. Additionally, the affects of heavy vegetation on sediment transport in the Guadalupe River channel below Highway 101 can only be addressed through channel roughness in the model. The extensive vegetation will increase resistance to flow, resulting in higher water surface elevations and reduced velocities. This creates a depositional environment which will trap most of the coarse sand in the system. The vegetation in this area is periodically cleaned out to restore channel capacity and reduce flood risk, thus the potential for transport of coarse sediments to Alviso Slough may vary depending on the condition of the flow capacity of the upstream channel.

Simulation of Sediment Transport and Fate

The goal of the modeling effort was to evaluate how sediment size classes sort through the lower channels. The channels were treated as primarily depositional reaches based on field data collection and observation efforts. Although high flows during low frequency floods will most certainly mobilize sediments in the channel, the majority of time the channels are depositional and act as a sediment trap for coarse sediments. The conceptual sediment transport model used for the simulations is based on bed gradations, USGS suspended sediment samples analyzed for size distribution, and the total annual yield calculation. The incoming sediment load to the models was based on high fine sediment concentrations at the lower to intermediate flows, with increasing sand fractions for flows exceeding the two year flood event. The discharge into the models was formulated from the flow duration curve for the streams. A quasi-unsteady hydrograph was created to include both the low frequency high flow events and the higher frequency occurring intermediate to low events. The sediment rating curves developed for Coyote Creek and Guadalupe River (Figure 8) were used in the model. The Coyote Creek simulation was limited to flows greater than 1000 cfs because of the flood by-pass channel restriction in the model. The variation in sediment size fraction in flow used in the modeling is depicted in Figure 13. The very low flows that do no contribute substantial amounts of sediment into the system (<20 cfs) were not included in the simulation. For all simulations, the downstream model boundary water surface elevation was approximately 7.0 feet NAD 88. This elevation is somewhat higher than the mean tide based on the potential for sea level rise.

6 Sediment Transport Simulations

Before any sediment transport simulations were performed, the system hydrodynamics were evaluated along with the bed sediment and channel slope along the lower channel. This provides insight into where various sediment size classes have been historically distributed in the channel as a function of flow energy. Figures 14 and 15 present the energy slope for three flows on Guadalupe River and Coyote Creek. The energy slope is the water surface slope along with the velocity head, and provides an indicator of the total energy in the flow for transporting sediment. The bed sediment composition indicates that historically, the bulk of the coarse sediment deposits upstream of the Highway 237 bridge for the Guadalupe, and from the by-pass channel to Trimble Bridge on Coyote Creek. This is reasonable because of the reduction in flow capacity in the Guadalupe River due to vegetation and the impact of the upper floodway and the by-pass channel on Coyote Creek. However, sediment transport is highly unsteady in these systems, and will vary according to flow. For the infrequent large events, deposits of sand will most likely mobilize within the channel and transport to lower reaches, including the Bay. However, USGS samples indicate that for the more frequent flows, the percentage of coarse sediments is low (10 – 20 percent) thus the impacts of sand erosion and deposition in the lower channels is small compared to the total transport of fine sediments to the Sloughs and ultimately to the bay.

Simulation Results

The simulation results are presented in Figures 16 – 25. The results are presented as cumulative load and sediment size fraction distribution along the lower channels.

Guadalupe River

For the Guadalupe River simulation, the total sediment load into the system was approximately 10,800 tons (Figure 16), with the sediment load consisting of approximately 14 percent sand and 86 percent fines. The deposition of sand begins between the Trimble and Montague Bridge, with all of the sand depositing before entering the Bay (Figure 17). The total load sediment load depositing below Highway 237 is approximately 2300 tons, of which 21 percent are sand. Only about eight percent of the clay load remains within the lower channel, with the silt fractions comprising the balance of the fine sediment deposit between highway 237 and the mouth of Alviso Slough (Figure 18). A break out of sediment size fraction as a function of location along the channel is found in Figures 19 and 20.

Coyote Creek

As described previously in the report, the HECRAS Coyote Creek flood routing model is not a good representation of the lower Coyote Creek channel. This is due to the two dimensional aspects of the floodway between Montague Bridge and the Highway 237 bridge and that the lower Coyote Creek channel that was represented by a flood by-pass channel. The low flow channel was not included in the model, and thus only flows at or exceeding 1000 cfs were used in the simulation. With this in mind, the simulation results for Coyote Creek are presented in Figures 21-25. The total load simulated was approximately 7300 tons (Figure 21), which consisted of 88 percent fine sediment. The simulation results indicate that the wide floodway just below Montague Bridge is an efficient trap for the coarse and medium sand in the system (Figure 22), with only the very fine sand fraction reaching the by-pass channel. In reality, a low flow channel conveys flows to Guadalupe Slough during all flows and thus some sand will transport and deposit in the channel reach below the by-pass. Bed sediment samples show a sediment median grain size representing a very fine sand in Guadalupe Slough, thus the model as constructed is limited for sand transport to the Slough. The cumulative fine sediment load is presented in Figure 23. These data indicate that a portion of the medium and coarse silt deposit in the wide floodway in the upper channel (3 percent of the fine sediment load), with the balance either depositing below the by-pass channel (31 percent) or leaving Guadalupe Slough (66 percent, of which 48 percent is the clay fraction). Figures 24 and 25 describe sediment deposit size fractions as a function of location along the channel.

7 Observations and Conclusions

Limited data are available for supporting sediment transport studies in the lower stream reaches of Coyote Creek and the Guadalupe River. The following conclusions are based

on site observations during the channel assessment phase of the work, analysis of existing data, and a computational study utilizing a one dimensional model. Model simulations were conducted to evaluate the fate of sediments in the lower channels based on estimated annual suspended sediment yield, estimated suspended sediment size gradation and estimated sediment load size fraction. Because of model limitations, bed erosion and sorting were not allowed in the vicinity of the bridge locations. In addition, no data were available to validate model hydrodynamics or sediment transport, thus model results should be interpreted as an effort to quantitatively validate the conceptual model of sediment transport to the lower stream channels, not as an effort to provide a validated predictive model for computing long-term channel morphology change. Additionally, the lower model stage boundary in the Bay was constant, thus fluctuating water surface elevations due to Bay tides was not considered in this analysis.

Field data and observations indicate the lower stream channels below Montague Bridge (Coyote Creek) and the Highway 101 Bridge (Guadalupe River) transition from steep gradient gravel bed streams to mild gradient channels that are primarily depositional for coarse sediments. Sand deposits were observed in the channels as well as floodways associated with the channels. Vegetation had colonized many of the previously deposited sediments. Sediment samples revealed a gradual fining of bed sediments from coarse to fine, to very fine sands, particularly below the zone of tidal influence.

Flow duration data for the streams indicates that flows exceeding 1000 cfs occur only 1 – 2 percent of the time. This indicates that the bulk of sediment transport to the bay occurs during relatively few large annual events. Although the lower channels are depositional in nature, events exceeding the instantaneous 2 year return flood (~3,000 cfs) are capable of scouring existing sand deposits from the bed and transporting very fine to fine sand to the Bay sloughs.

The computed sediment yield from Coyote Creek and the Guadalupe River is lower than that predicted by empirical equations that relate watershed sediment yield to water shed area. The suspended sediment load data from USGS gauge locations is limited to 7 – 9 years of data which represent low flow years for the region. Additionally, the relationship between suspended sediment concentration and flow is traditionally very uncertain and does not correlate well. The sediment yields presented in this study should be interpreted as a first cut estimate, with improved yield predictions likely as data becomes available in the future. As the watersheds continue to urbanize, and watershed management practices improve, the suspended sediment load to the bay will potentially decrease in the future. Thus South Bay sediment migration into the lower stream channels may be the primary vehicle for delivering sediment to the salt pond restoration area.

The computational sediment transport model study conducted with the HECRAS flood routing model validated the stream system sediment transport conceptual model formulated from site observations, suspended sediment grain size data, bed sediment data, and flow histories for the streams. The model study simulated annual yield to the Bay, assuming that overall the system is depositional and dominated by fine sediment

transport. The Guadalupe River model study results validated field observations of bed sediment sorting throughout the lower channel. However, the Coyote Creek model results were limited in value due to the two dimensional aspects of the upper channel and the exclusion of the low flow channel segment in the model.

The lower South Bay stream channels are subject to both unsteady inflows and varying tidal conditions, thus fluvial sediment transport and fate is subject to the timing of large flow events that carry most of the sediment with the existing tide condition in the Bay. This can result in a wide spatial variation of sediment deposition and re-suspension within the channel. Based on hydrodynamic and sediment transport characteristics of the streams, one can surmise that the inevitable result of sea level rise will be to, on the average, decrease the channel capacity to transport sediments a given distance further upstream than with existing Bay mean tide conditions.

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Natural Resource Conservation Service (NRCS), *Stream Corridor Restoration: Principles, Processes, and Practice*, August 2001.

Philip Williams and Associates, Ltd.2005. *Trends in Suspended Sediment Input to the San Francisco Bay from Local Tributary Watersheds.* Project report for the San Francisco Estuary Institute, PWA Ref. Number 1765.

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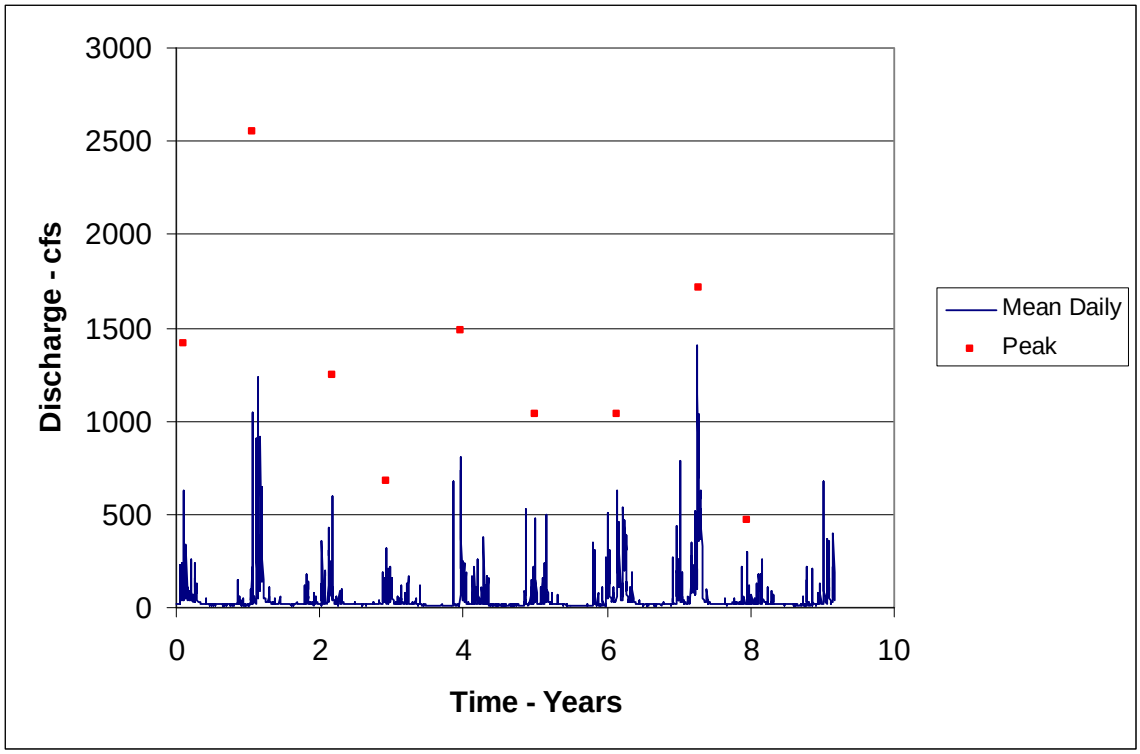

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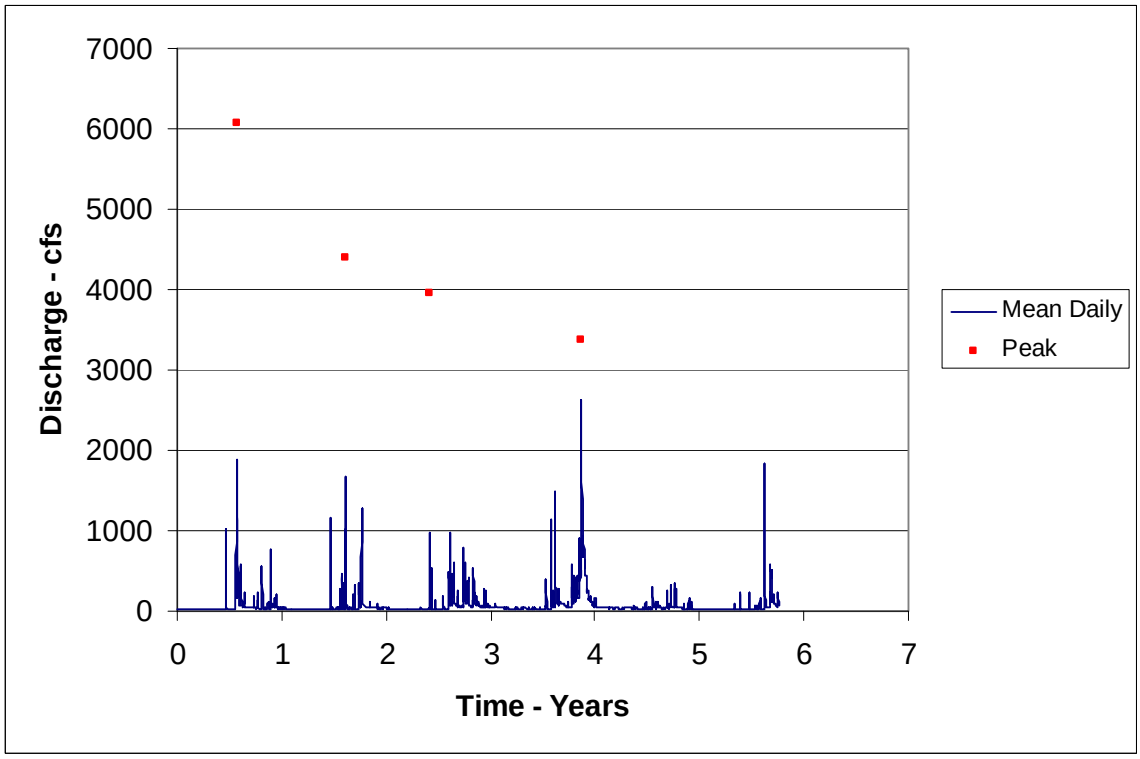

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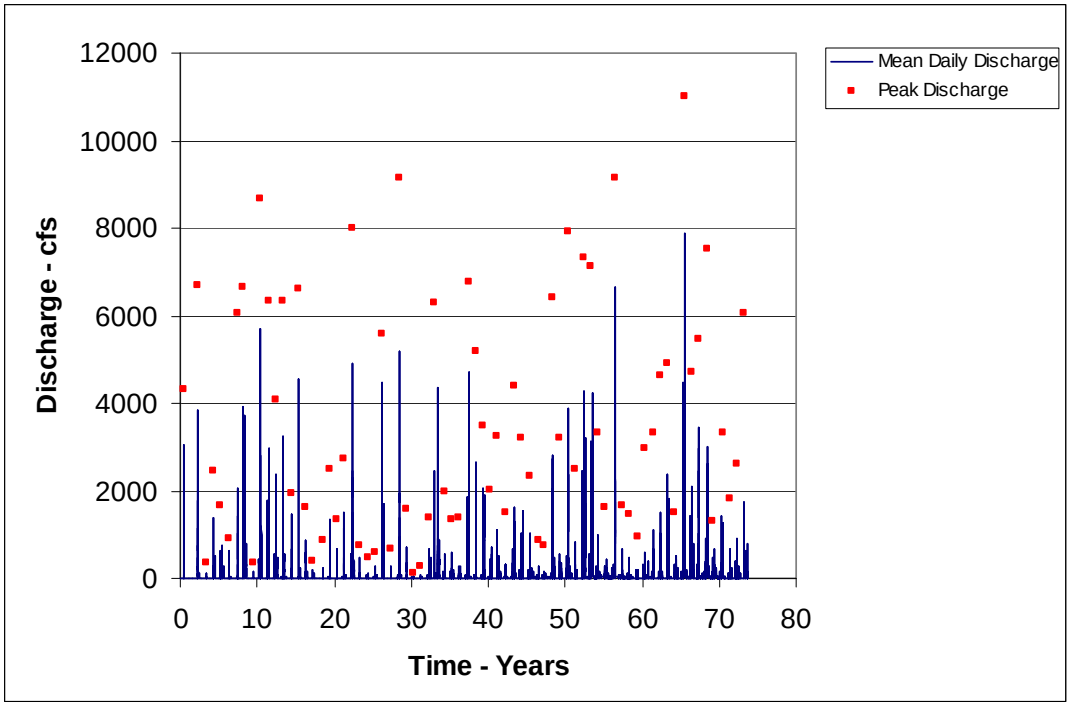

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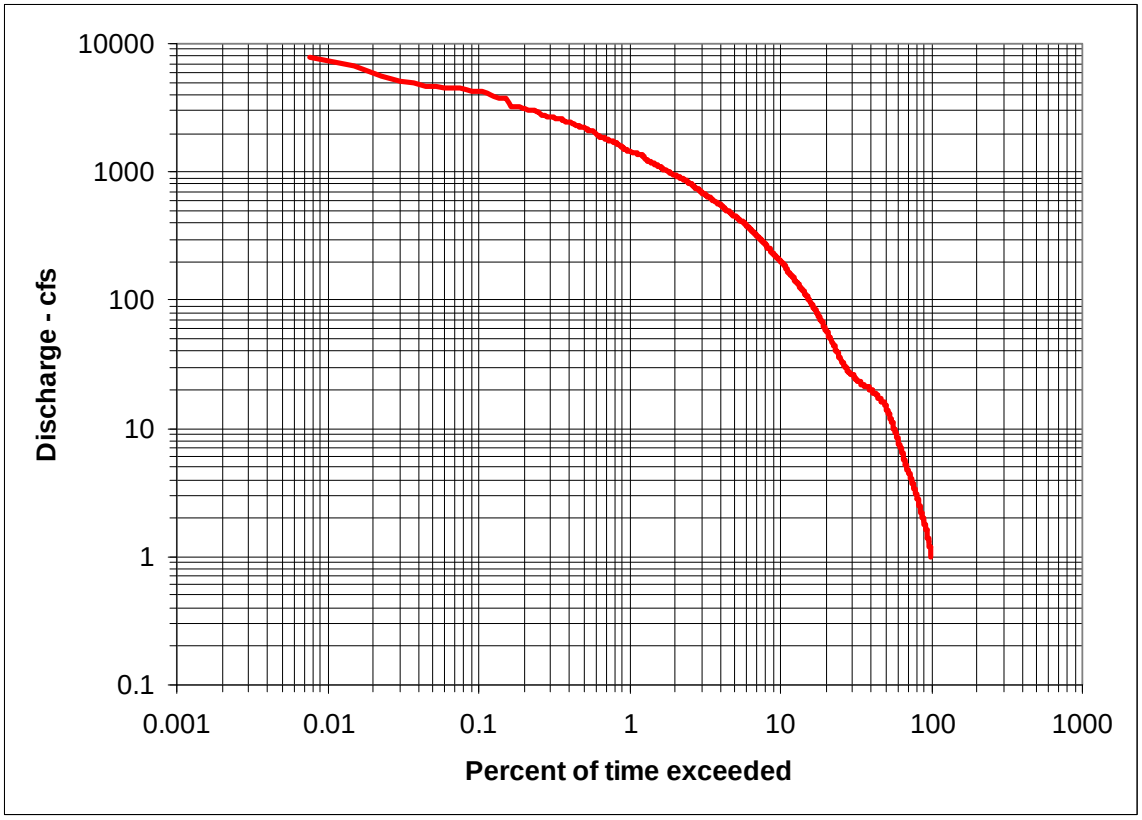

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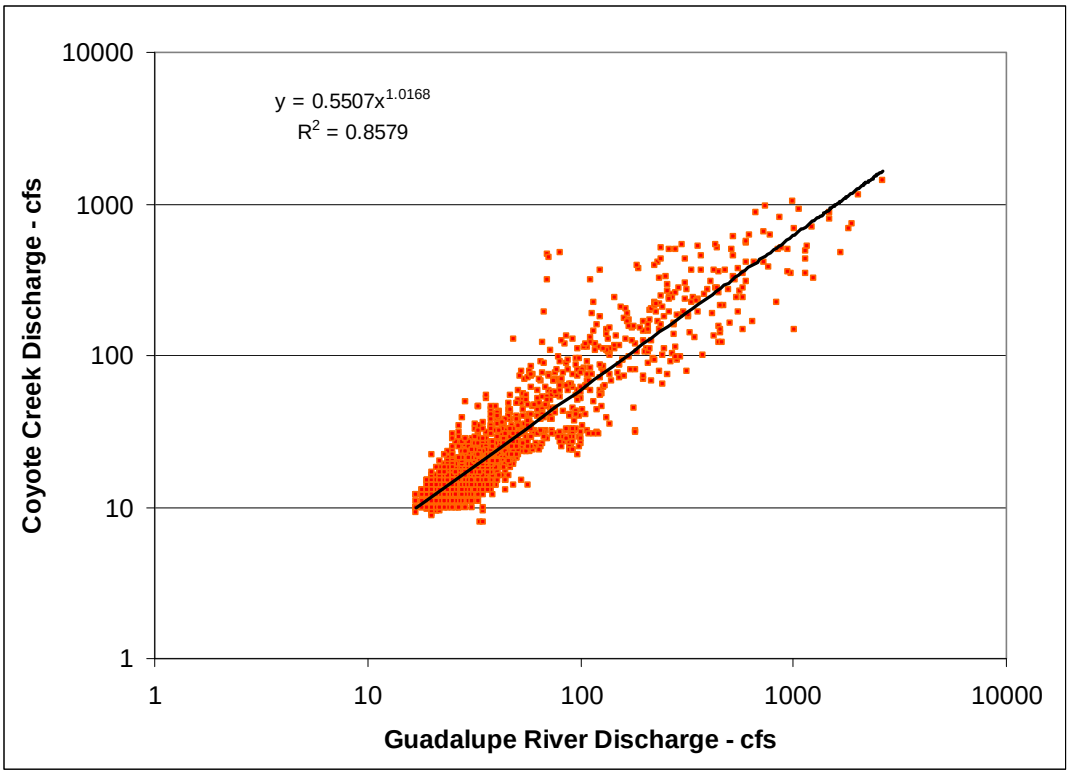

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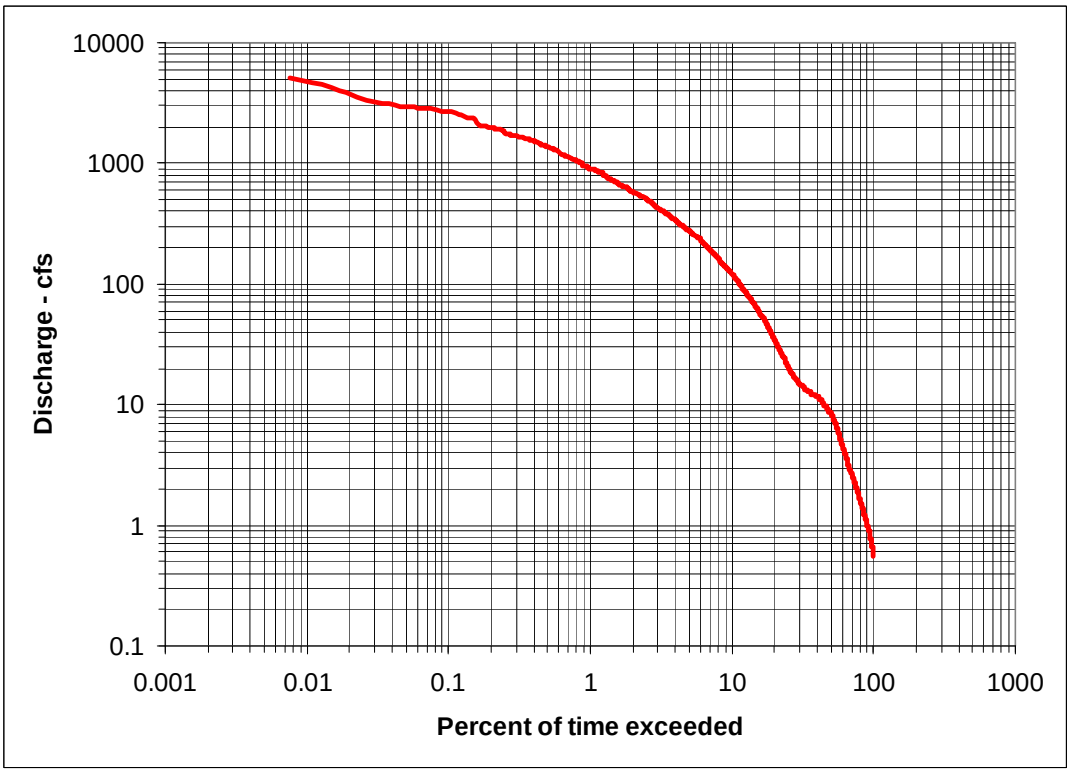

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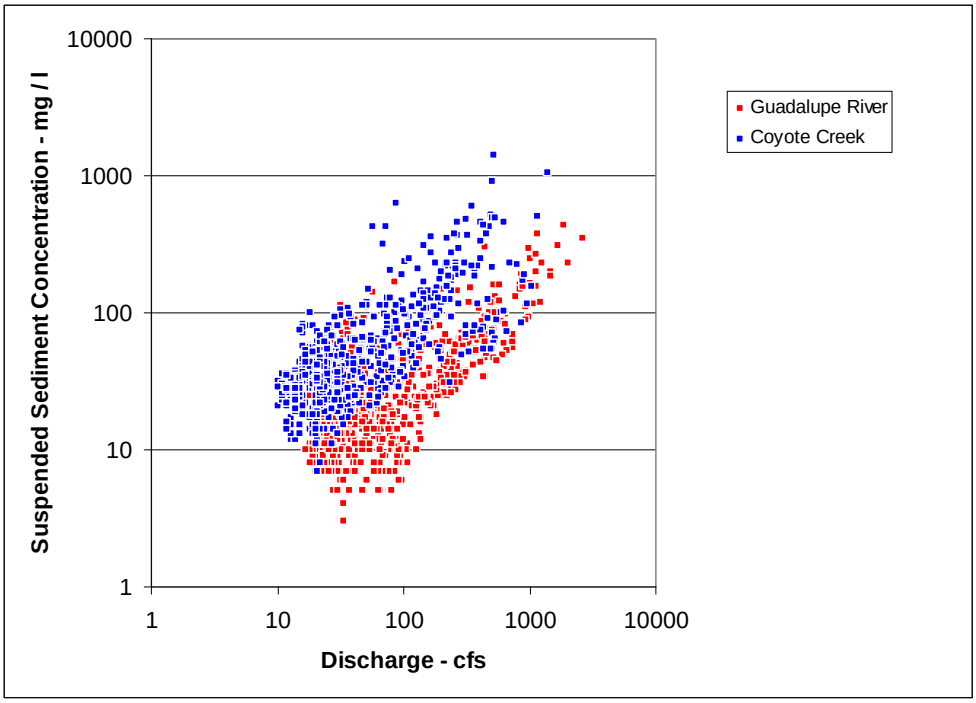

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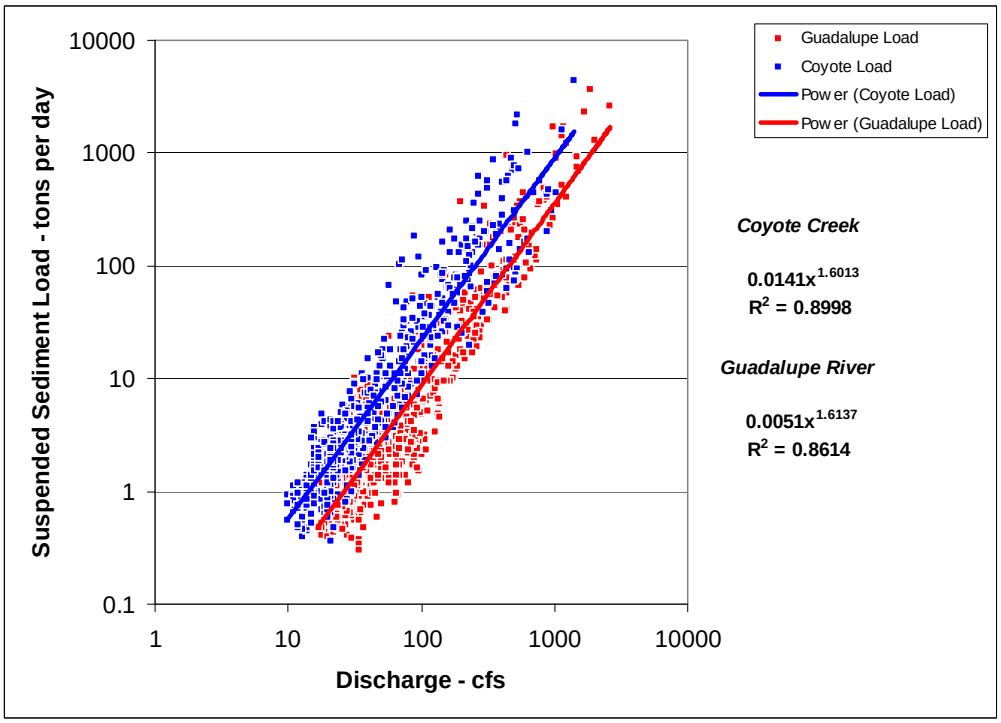

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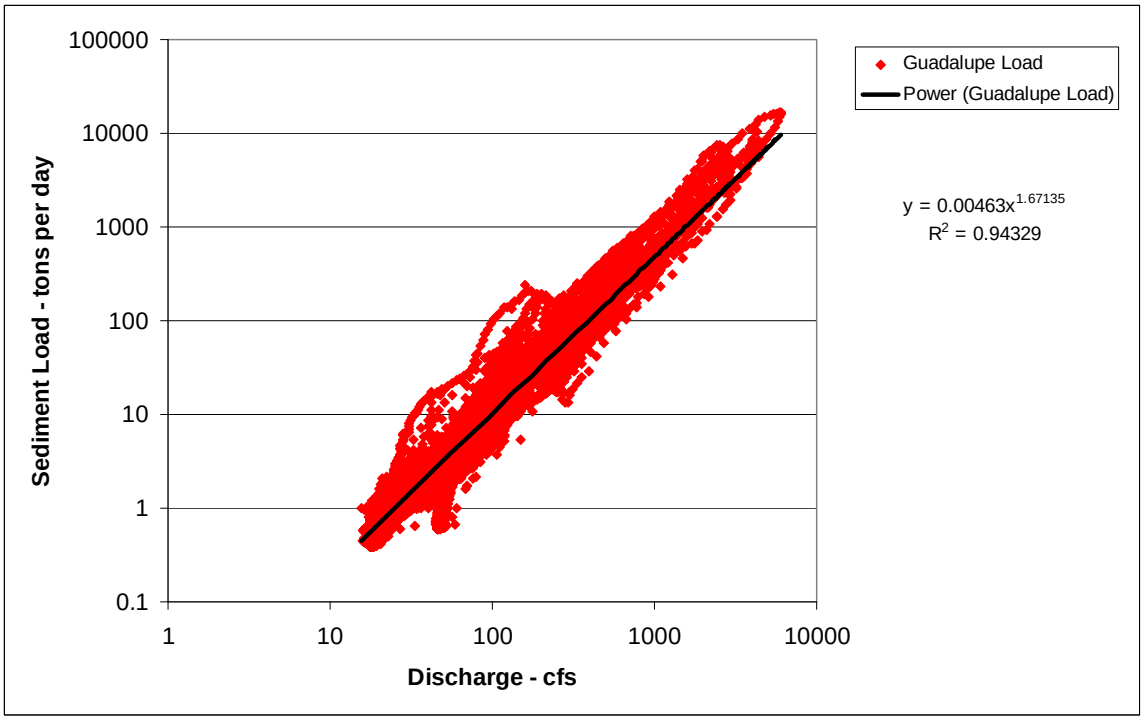

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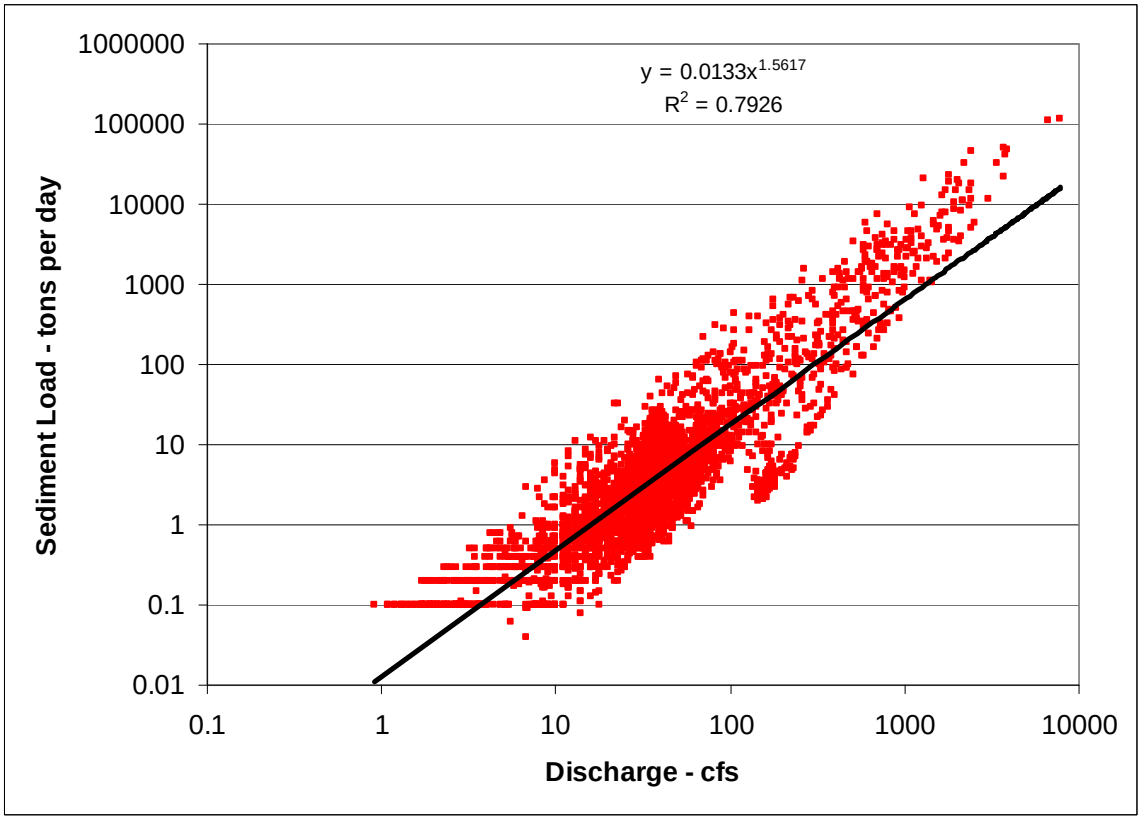

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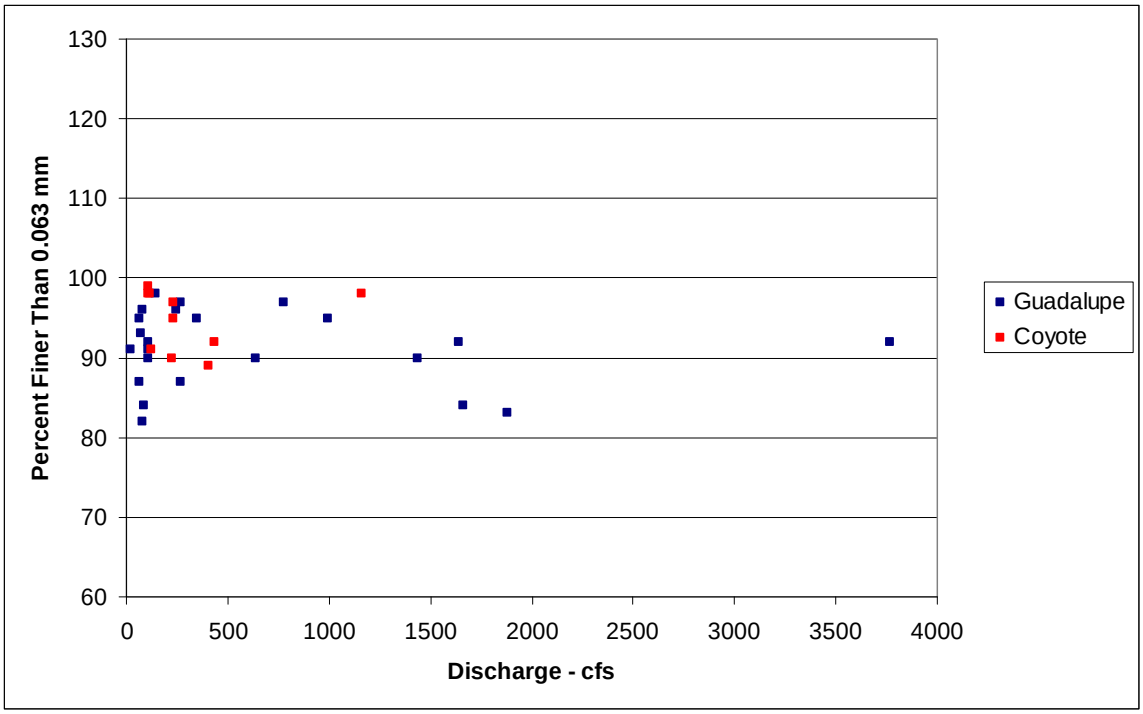

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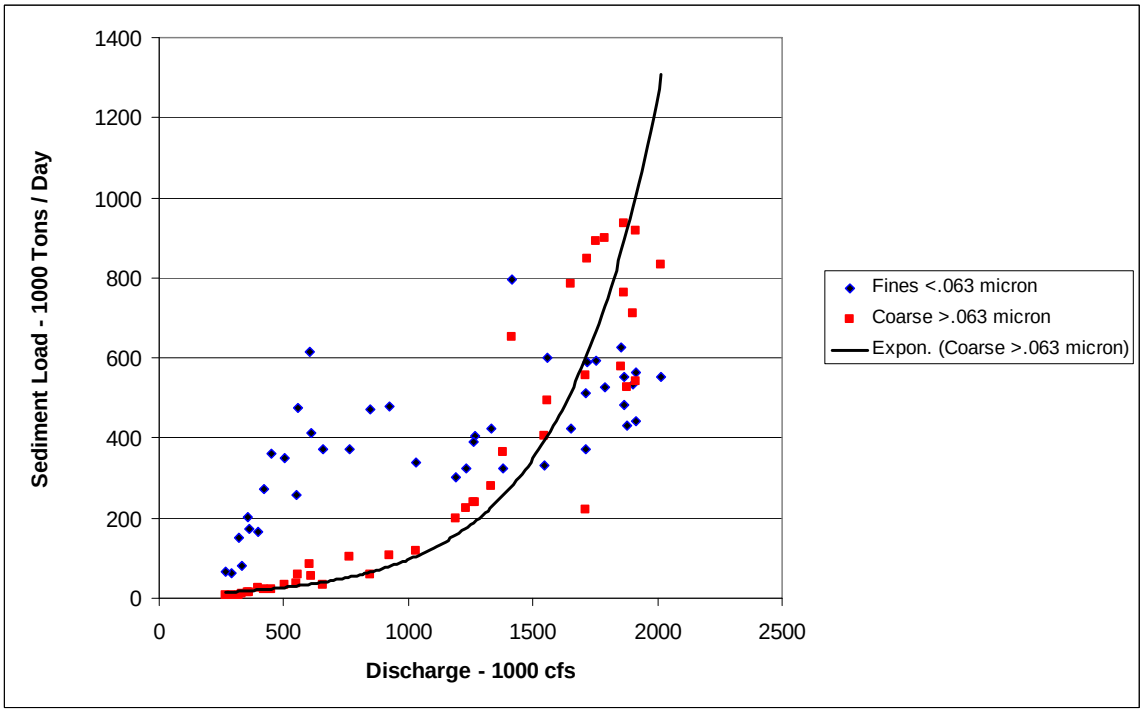

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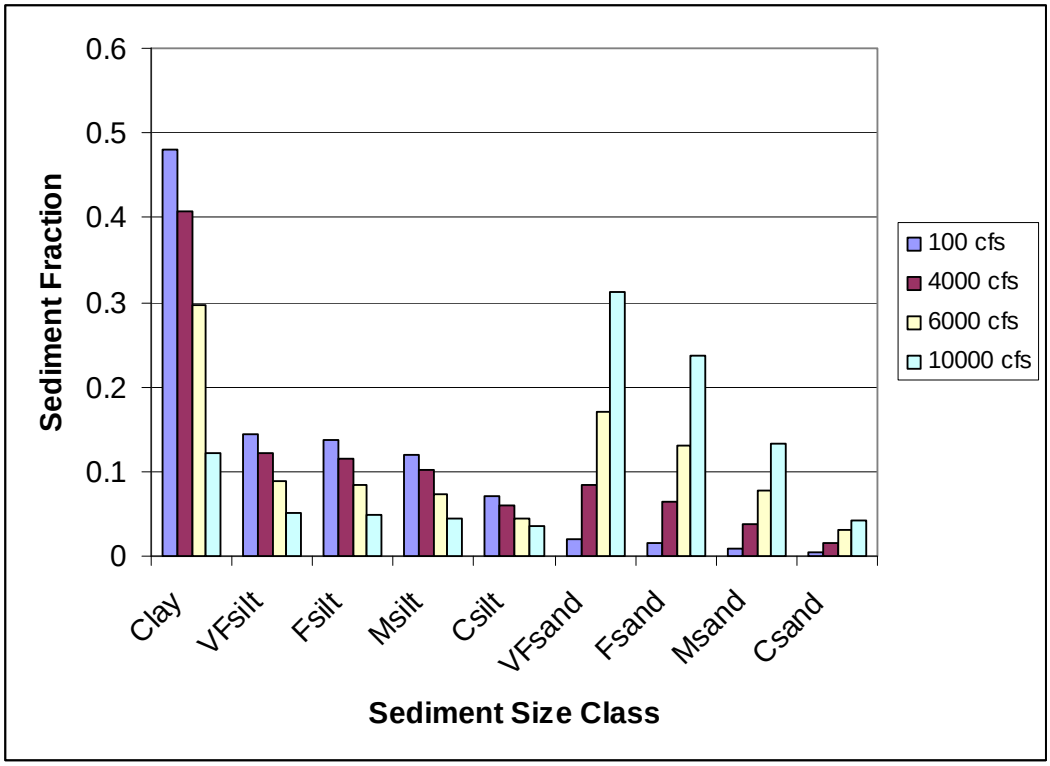

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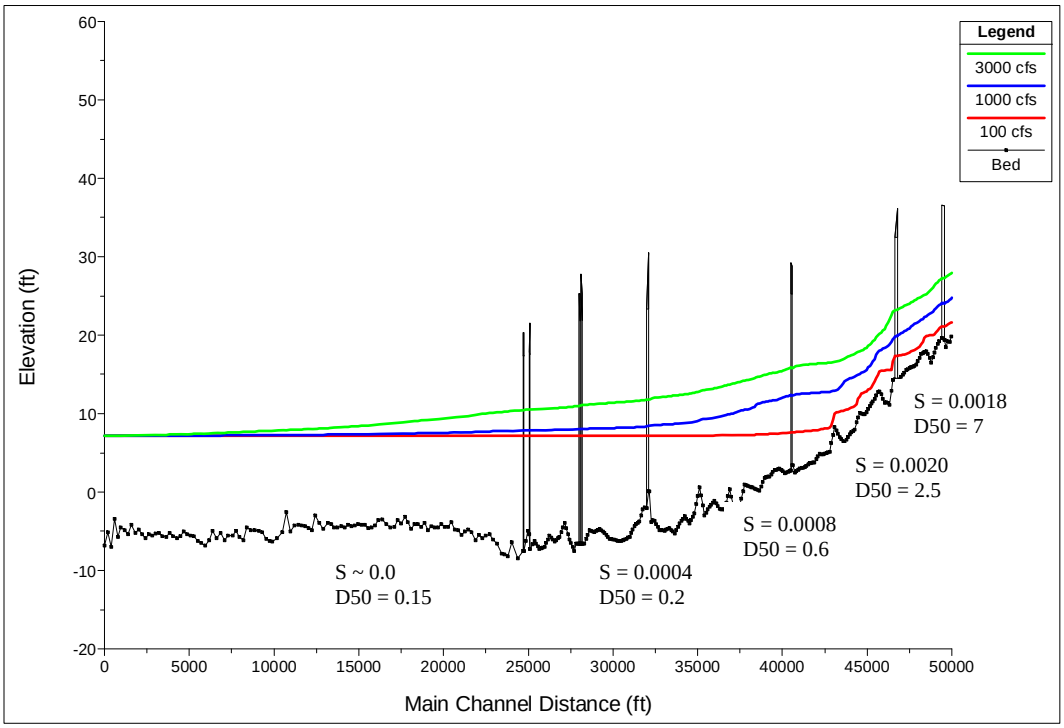

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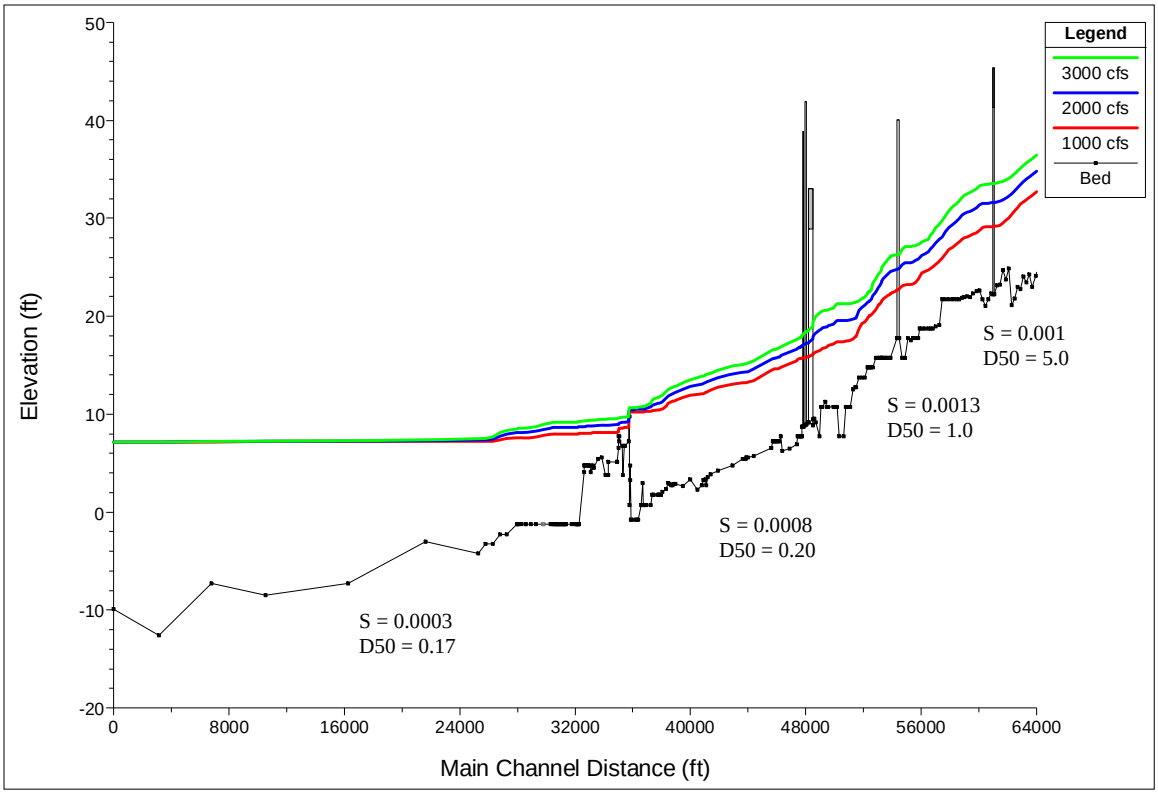

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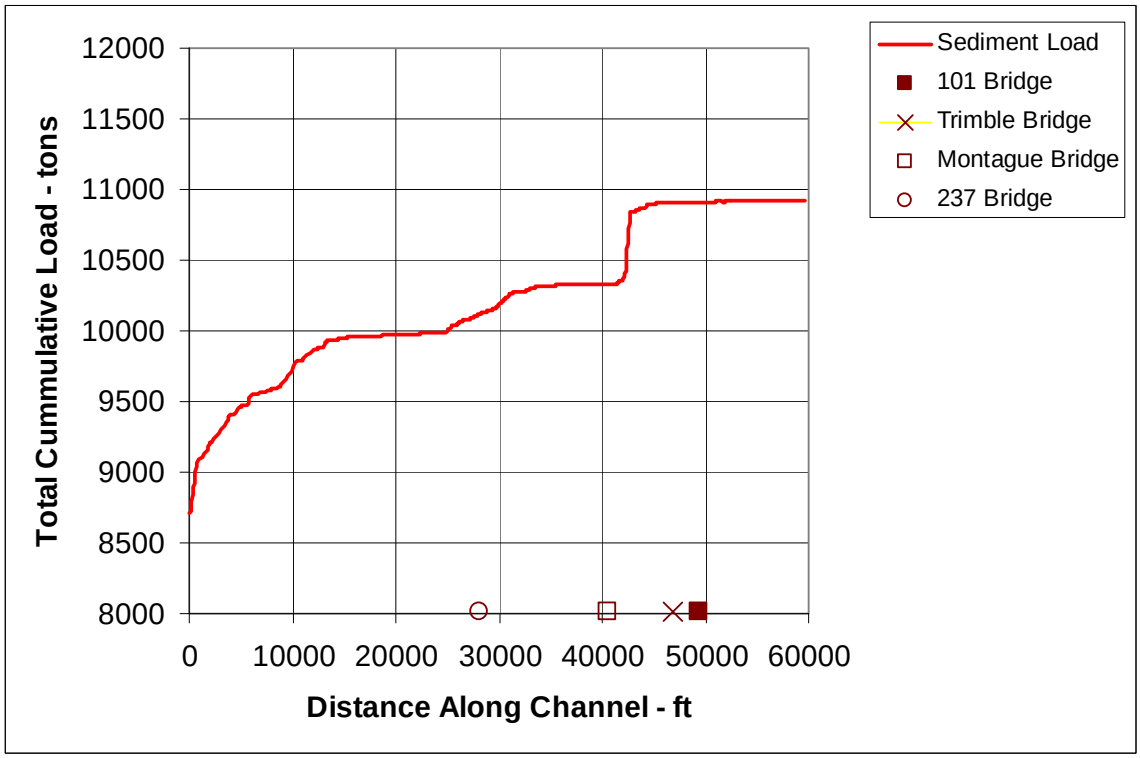

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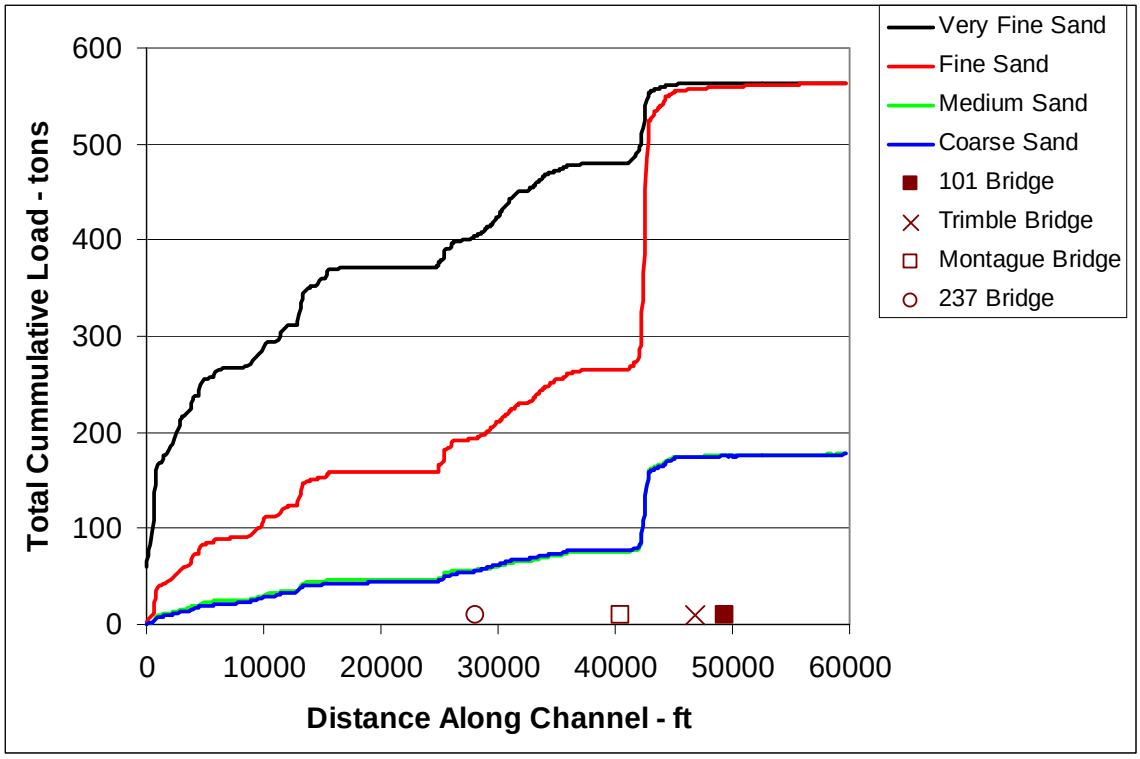

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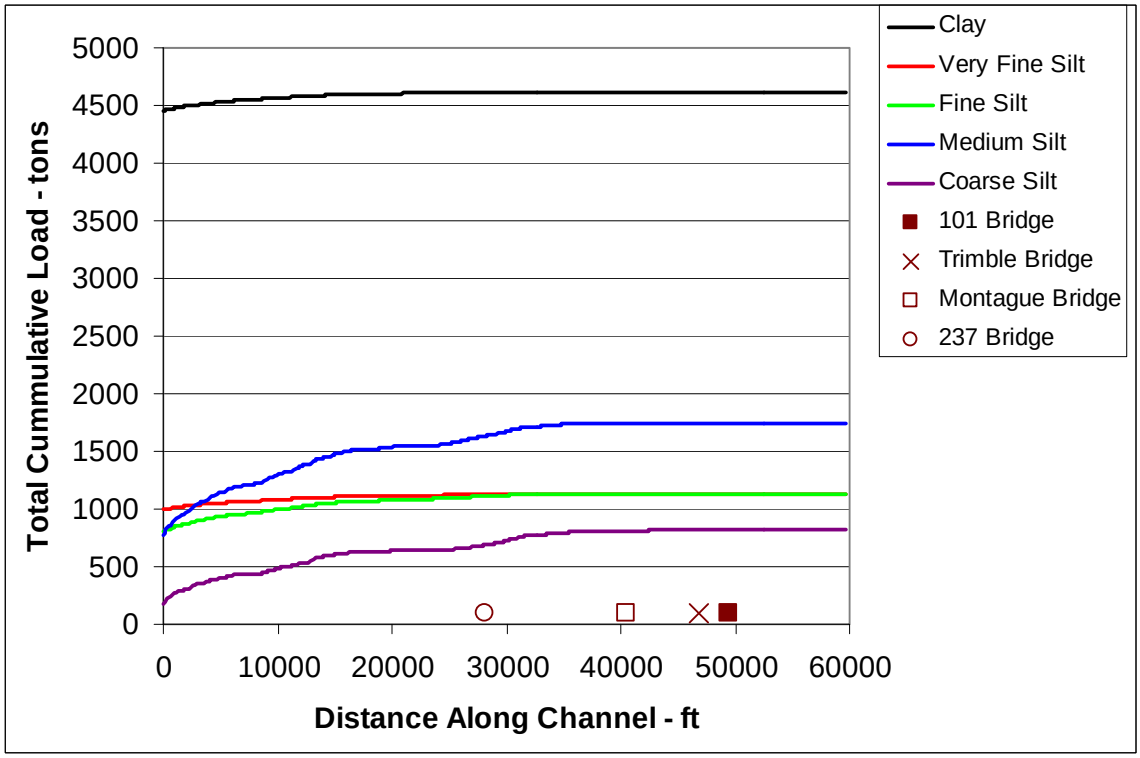

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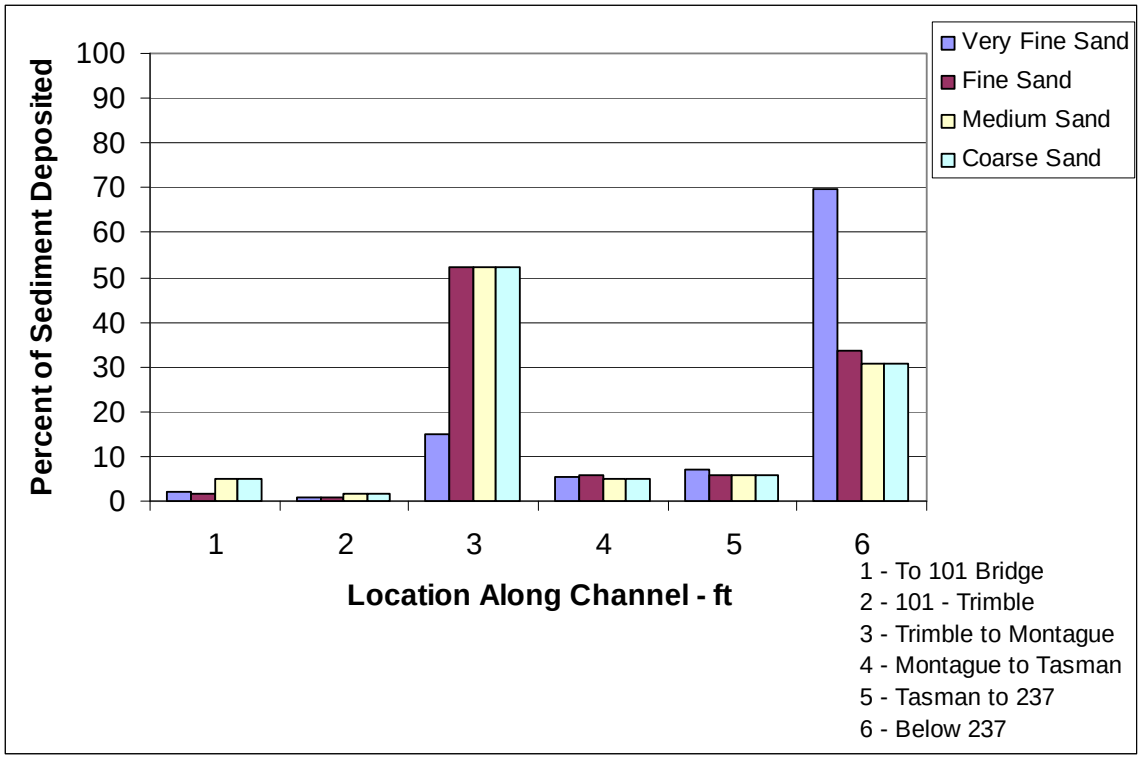

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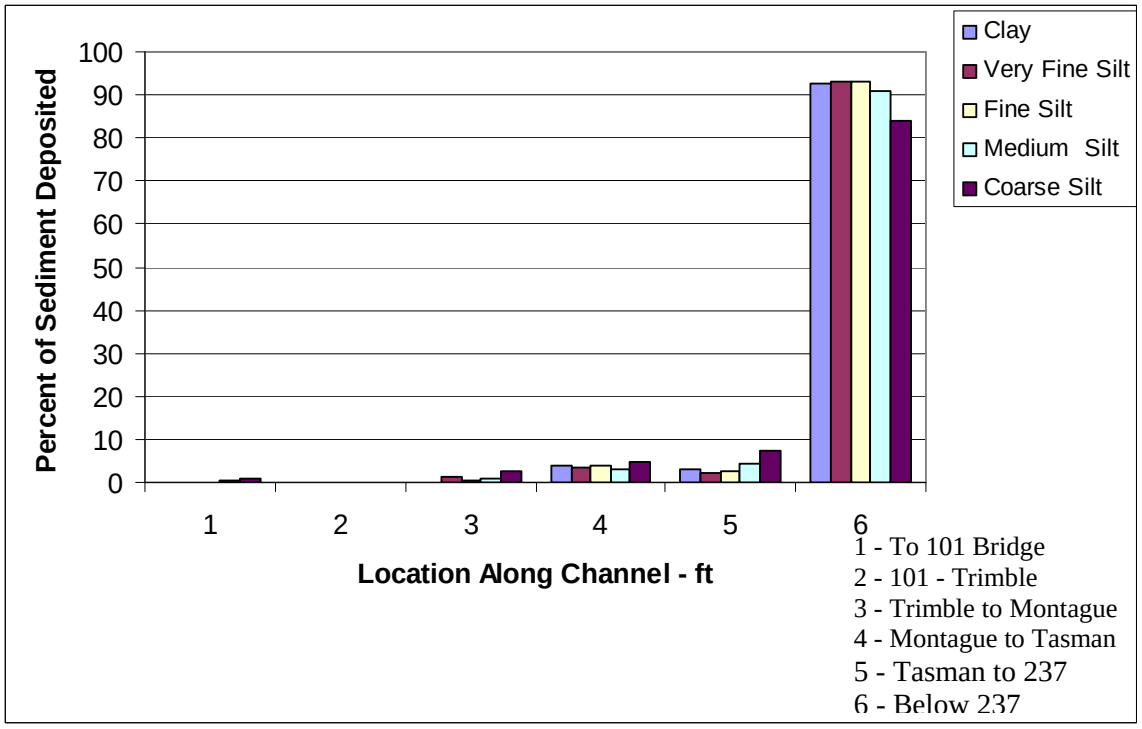

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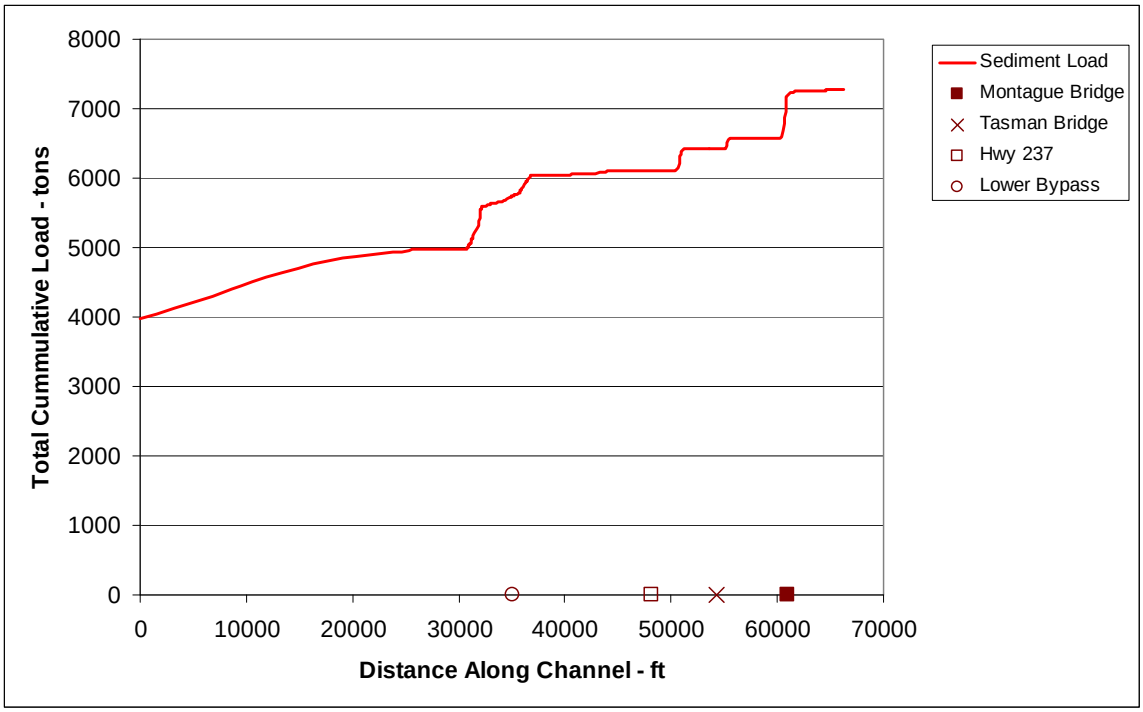

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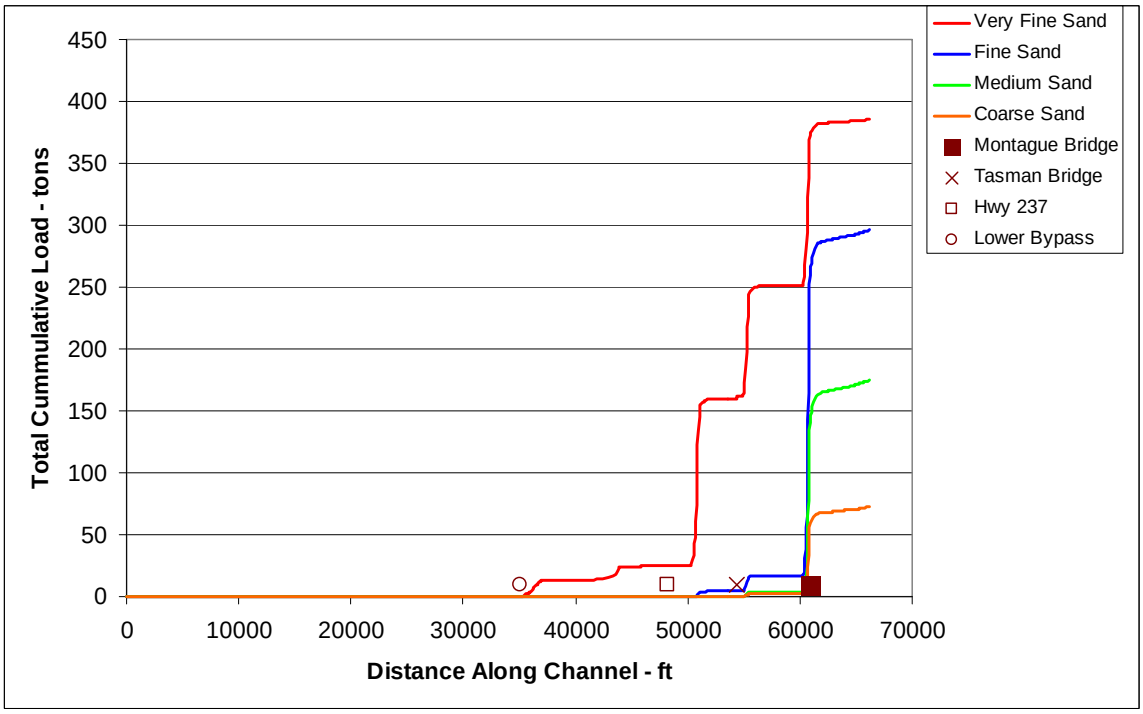

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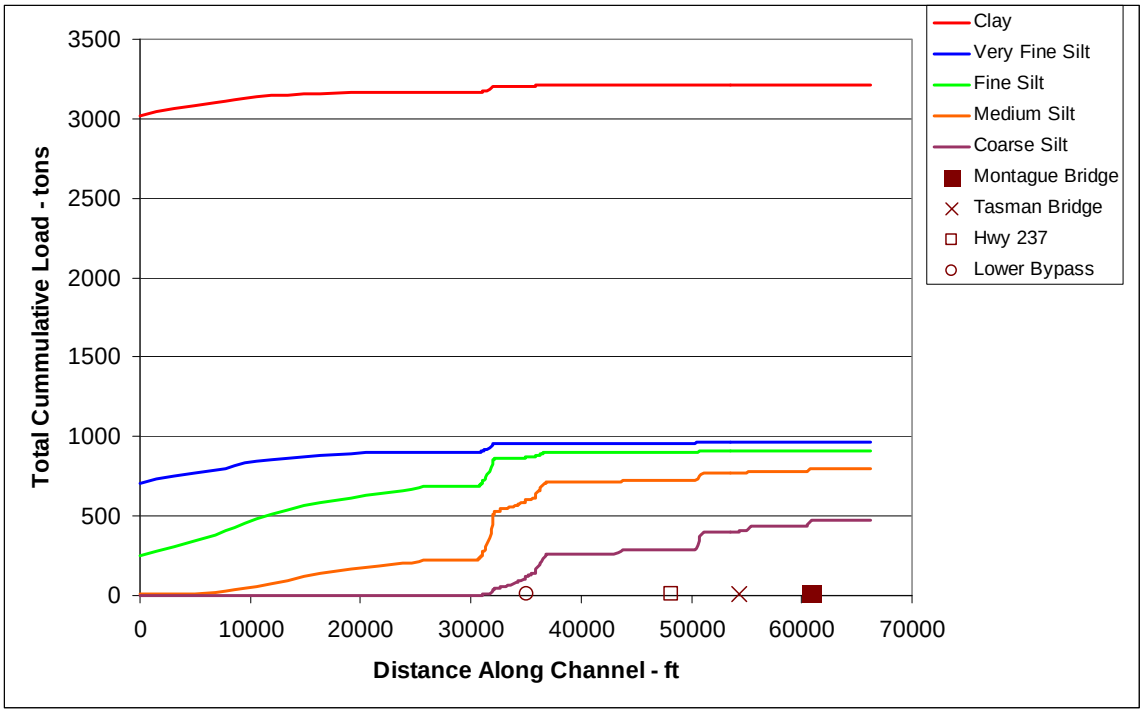

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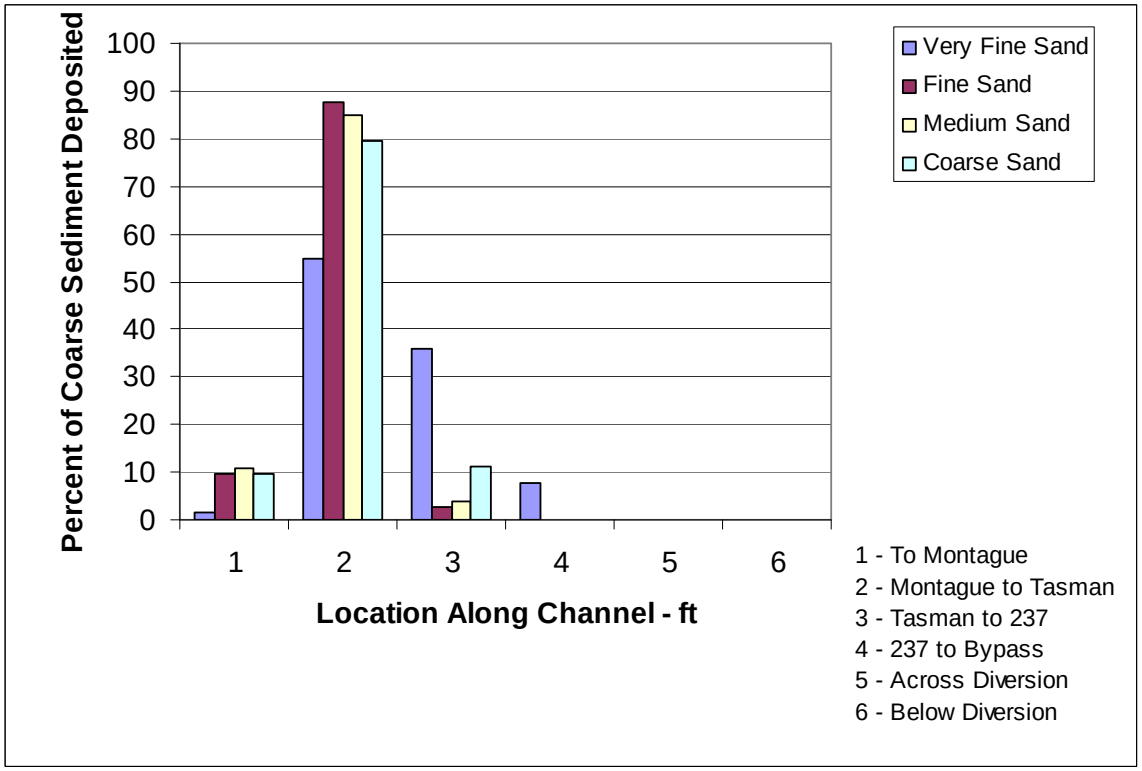

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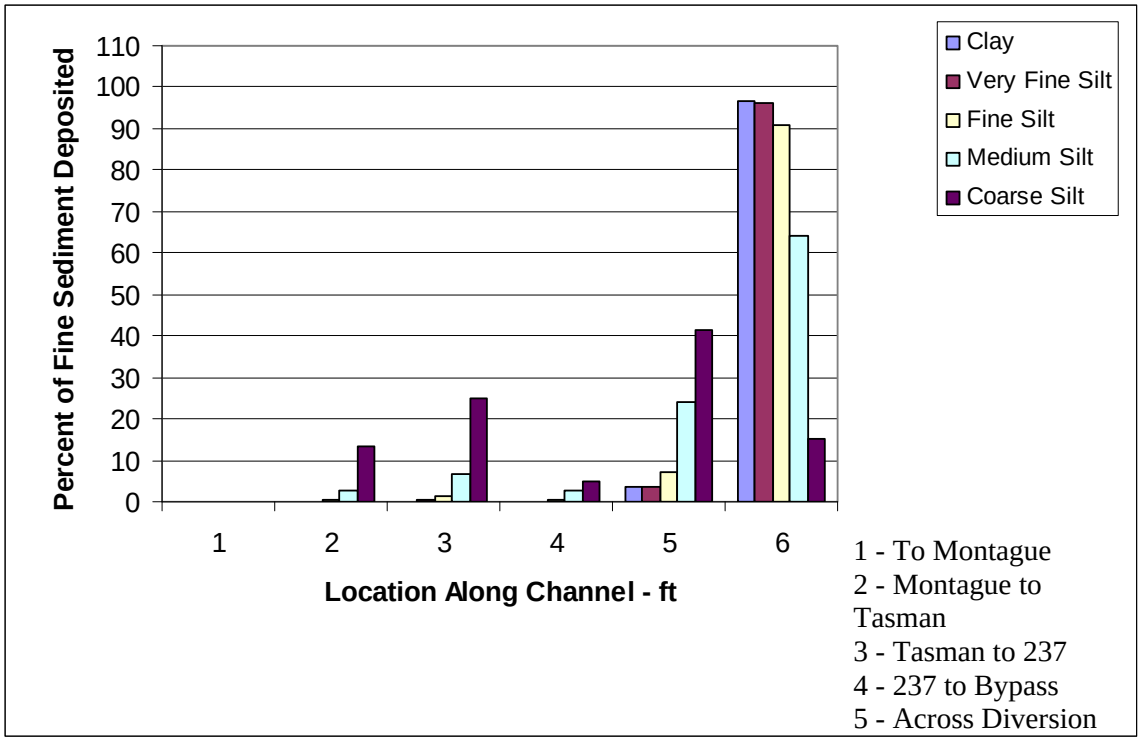

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