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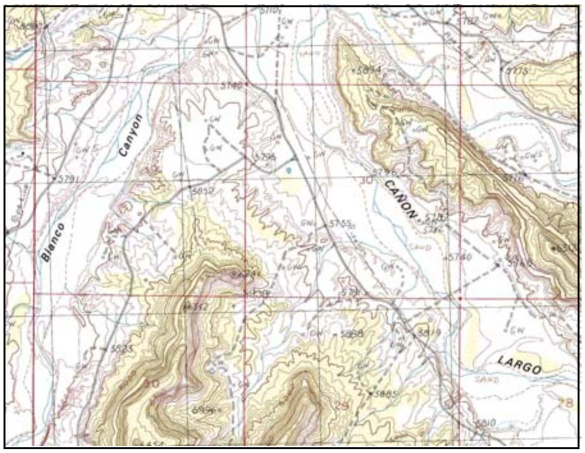

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Channel and Watershed Processes Research Unit
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BED-MATERIAL CHARACTERISTICS OF THE SAN JUAN RIVER AND SELECTED TRIBUTARIES, NEW MEXICO: DEVELOPING PROTOCOLS FOR STREAM-BOTTOM DEPOSITS

By Amanda Heins[1], Andrew Simon[2], Lauren Farrugia[3] and Micah Findeisen[3]

[1] School of Geography, University of Nottingham, United Kingdom
[2] USDA-ARS National Sedimentation Laboratory, Oxford, Mississippi
[3] Department of Geological Engineering, University of Mississippi, Oxford, Mississippi

EXECUTIVE SUMMARY

Five reaches of the San Juan and Animas Rivers of northwestern New Mexico were listed as impaired due to stream bottom deposits on the state's 303(d) list. To evaluate the severity of bed-material conditions along these reaches relative to "background" or "natural" conditions in the region, the USDA, Agricultural Research Service (ARS), National Sedimentation Laboratory conducted a study supported by the New Mexico Environment Department, U.S. EPA Office of Water and USDA-ARS discretionary research funds. In addition, the study determined the dominant sources of fine-grained sediment deposited in the listed reaches.

The overall study approach was to determine bed-material conditions in stable reaches of the region (Ecoregion 22) and the local study area, and to use these as a measure of "background" or "reference" bed-material conditions. Bed-material conditions in the five reaches listed as impaired were then compared to these "reference" values. To accomplish this, bed-material and channel-stability data were collected at sites throughout the five listed reaches as well as at sites in Ecoregion 22. This involved collection of bulk bed-material samples and particle counts, identification of dominant geomorphic processes and completion of geomorphic assessment forms to document relative stability. Sites were subsequently divided into those classified as stable and unstable. The bed-material data were used to provide a longitudinal picture of current bed-material conditions along the San Juan and Animas Rivers. "Reference" conditions were established using a measure of embeddedness defined as the percentage of fine material (less than 2 mm) within a coarse matrix for channels considered to be geomorphically stable.

Percentages of fine bed sediment are the lowest in the reach of the San Juan River just below Navajo Dam (Reach 3) as a result of sediment trapping by the dam. The amount of bed-material fines peak just downstream of the entrance of Cañon Largo, and identifies this tributary as the major source of fine-grained sediment in the San Juan River study area. It appears from a couple of pre-dam bed-material samples, however, that this reach (Reach 2) has long been a major contributor and that sand beds are typical. Reach 1, below the confluence of the Animas River is intermediate in fine-grained composition. No sand-dominated reaches were identified on the Animas River notwithstanding considerable disturbance to parts of the upper watershed due to recent fire.

Using the central tendency of the bed-material particle-size distributions for stable, coarse dominated streambeds, "reference" percentages of fine-grained material were determined. The median fine-grained composition of coarse-dominated streambeds for stable sites in Ecoregion 22 was 20.5%. This value was calculated to be 15.5% for the San Juan River study area. The 75th percentile of fine-grained composition for stable sites in Ecoregion 22 and the San Juan River study area were 21.5% and 29.5% respectively. Only Reach 2 streambeds (San Juan River from the Animas River confluence to Cañon Largo) contained fine-grained compositions beyond both the median and 75th percentile values for stable sites.

The following outlines the recommended protocol for establishment of bed-material reference conditions in a given region:

- Complete Rapid Geomorphic Assessments (RGA) for sites in the study area.
- Carry out bed-material sampling at all RGA locations. (If the bed-material consists of a mixture of coarse and fine material, sampling should comprise of a particle count (PC) accompanied by bulk sample (BS). If the bed consists purely of sand and finer a bulk sample will be sufficient, and if bed-material is entirely coarse material a particle count alone will suffice).
- Determine sites considered to be stable using RGA results (Channel Evolution Model stage I or VI).
- Isolate percent finer than 2 mm for stable sites and calculate the median and interquartile range of this dataset.
- The reference bed-material value for this dataset is the median percent finer than 2 mm for stable sites.
- The median and interquartile range of the percent finer that 2 mm values for the unstable site dataset should be calculated for comparison purposes.

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ABBREVIATIONS USED

AR -	Animas River
BMA -	Bed material analysis
BS -	Bulk Sample
CEM -	Channel Evolution Model
ER -	Ecoregion
GPS -	Global positioning system
NCDC -	National Climatic Data Center
NOAA -	National Oceanic and Atmospheric Administration
NMED -	New Mexico Environment Department
PC -	Particle count
RGA -	Rapid geomorphic assessment
rkm -	River kilometer
RM -	River mile
SJR -	San Juan River

UNIT CONVERSION FACTORS

English	Metric
1 mile	1.609 kilometers
1 cubic foot per second	0.02831 cubic meters per second
1 square mile	2.5899 square kilometer

ACKNOWLEDGMENTS

We would like to express our sincere appreciation to the New Mexico Environment Department (NMED), U.S. Environmental Protection Agency, Office of Water, and the USDA-Agricultural Research Service for providing funding for this research. We would also like to thank Lynette Guevara and other personnel at the NMED for providing considerable assistance in conducting fieldwork, Keller-Bliesner Engineering for supplying insight into the San Juan River hydrology and geomorphology, and Traci Sylte for advice on development of field methods to measure substrate embeddedness. Mean daily flow and instantaneous suspended-sediment data used in this study were downloaded from USGS web site or obtained directly from the staff at the USGS New Mexico, Colorado or Arizona district offices.

1 INTRODUCTION

1.1 Problem Statement

Excessive erosion, transport, and deposition of sediment in surface waters are major water quality concerns in the United States. The 1996 National Water Quality Inventory (Section 305 (b) Report to Congress) ranked sediment as a leading cause of water-quality degradation in assessed rivers and lakes. Five reaches on the San Juan and Animas Rivers have been listed as impaired on the New Mexico 2000 – 2002 Clean Water Act 303(d) list for stream bottom deposits. These reaches will be used to develop monitoring, assessment and total maximum daily load (TMDL) development protocols for stream-bottom deposits in large southwestern rivers. The stream-bottom condition of primary concern is fine sediment that fills interstitial spaces that are important to aquatic biota (NMED, 2000b). Fine sediment is defined as particles less than 2 mm diameter. The aim of this study is to determine bed-material conditions along the listed reaches and to develop a bed-sediment protocol for discriminating between natural and impacted bed-material conditions on the basis of geomorphic stability for large southwestern rivers. This investigation will also attempt to identify the source of fine sediment being deposited in the listed reaches along the San Juan and Animas Rivers. It is hypothesized that the dominant source of fine sediment found on the bed of the San Juan River are large incised tributaries, in particular Cañon Largo.

An embedded streambed is one dominated with coarse bed material (gravel, cobbles and boulders), surrounded by fine sediment (sand, silt and clay). Habitat conditions are degraded due to a number of factors. Filling of interstitial voids with fine sediment lower interparticle dissolved oxygen levels and removes less waste from incubating eggs (Sylte 2002). A river bed that is highly embedded also possesses a reduced rock-surface area needed for fish and macroinvertebrates for the purposes of shelter, spawning and egg incubation (Sylte and Fischenish, 2002). Spawning fish may have difficulty building redds in gravel beds buried by fine-sediment deposits (Rowe *et al.*, 2003). Bed material size is, therefore, related to habitat suitability for fish and macroinvertebrates, and excess sediment can cause a reduction in diversity and density of aquatic insects (Chapman and McLeod, 1987). For example, a key habitat requirement of the endangered Colorado Pikeminnow (*Ptychocheilus Lucius*), is cobble bars with relatively little sand between individual cobbles. Bars of this type are less common on the San Juan River than typical bars with sand in interstitial spaces.

1.2 Geographic Scope of Study

The study focused on five river reaches on the San Juan River listed as being impaired due to stream-bottom conditions. The study area covers the San Juan River from Navajo Dam to the Hogback (located about 32 km downstream of Farmington), the Animas River between its confluence with the San Juan River and the New Mexico-Colorado border, and several other major tributaries of the San Juan River (Figure 1.1; Appendix A). The five listed reaches and their lengths are:

1. San Juan River from the Navajo Nation boundary at the Hogback to the Animas River (35.6 km);
2. San Juan River from the Animas River to Cañon Largo (44.6 km);
3. San Juan River from Cañon Largo to Navajo Dam (33.0 km);
4. Animas River from the mouth on the San Juan River to Estes Arroyo (26.7 km); and
5. Animas River from Estes Arroyo to the New Mexico-Colorado border (29.2 km).

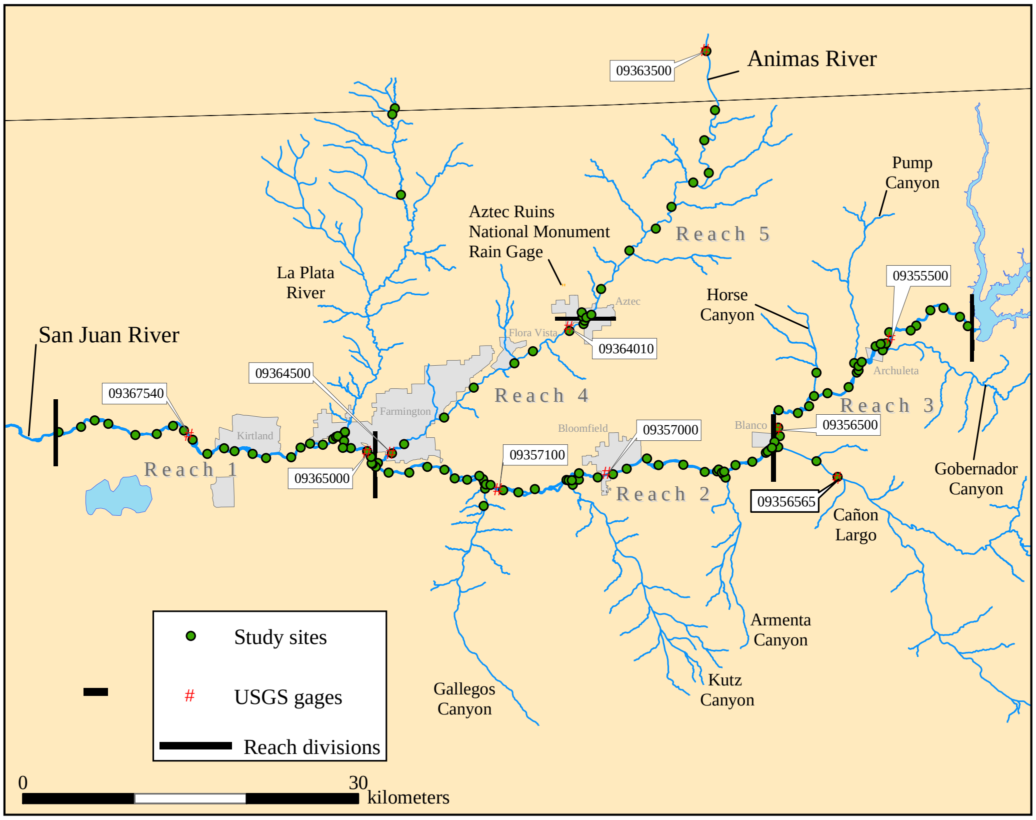

Figure 1.1 – Map of San Juan and Animas Rivers study reaches
(all gage numbers are preceded with 0)

1.2.1 Description of the Study Area

The San Juan River Basin is located predominantly within Ecoregion 22, the Arizona/New Mexico Plateau (Figure 1.2). The characteristics of this Ecoregion are described by Omernik (1995) as a large transitional region between the semiarid grasslands and low relief tablelands of the Southwestern Tablelands Ecoregion in the east and drier shrublands and woodland-covered higher-relief tablelands of the Colorado Plateau in the north. Higher, more forest covered, mountainous Ecoregions border on the northeast and southwest. Local relief in the region varies from a few meters on plains and mesa tops to well over 300 meters along tableland side slopes.

In physiographic terms, the San Juan River Basin is situated in the Navajo section of the Colorado Plateau and is characterized by broad open valleys, mesas, buttes, and hogbacks (sharp ridges with steeply sloping sides). Drainage is mainly by the San Juan River, the only perennial stream in the area. San Juan River is a tributary of the Colorado River. Major tributaries of the San Juan River in northwestern New Mexico include the Animas and La Plata Rivers. The discharge of the San Juan River is regulated by Navajo Dam, located about 80 km northeast of Farmington, New Mexico (Brister and Hoffman, 2002).

Hydrologic and physiologic characteristics of the San Juan River Basin are related to the underlying geologic material. The San Juan Basin is a structural depression at the edge of the Colorado Plateau. The Basin has about 1800 m of structural relief and covers an area of about 65,000 km^2. The basin's climatic zones range from high-elevation alpine forests to low-elevation arid plateaus, with an average-annual precipitation of 230 mm throughout the basin (Brister and Hoffman, 2002). Over 4200 m of sedimentary rocks occur in the deepest part of the basin. These sediments were derived from the San Juan Mountains to the north and the southern tip of the Rocky Mountains (Holden, 1999).

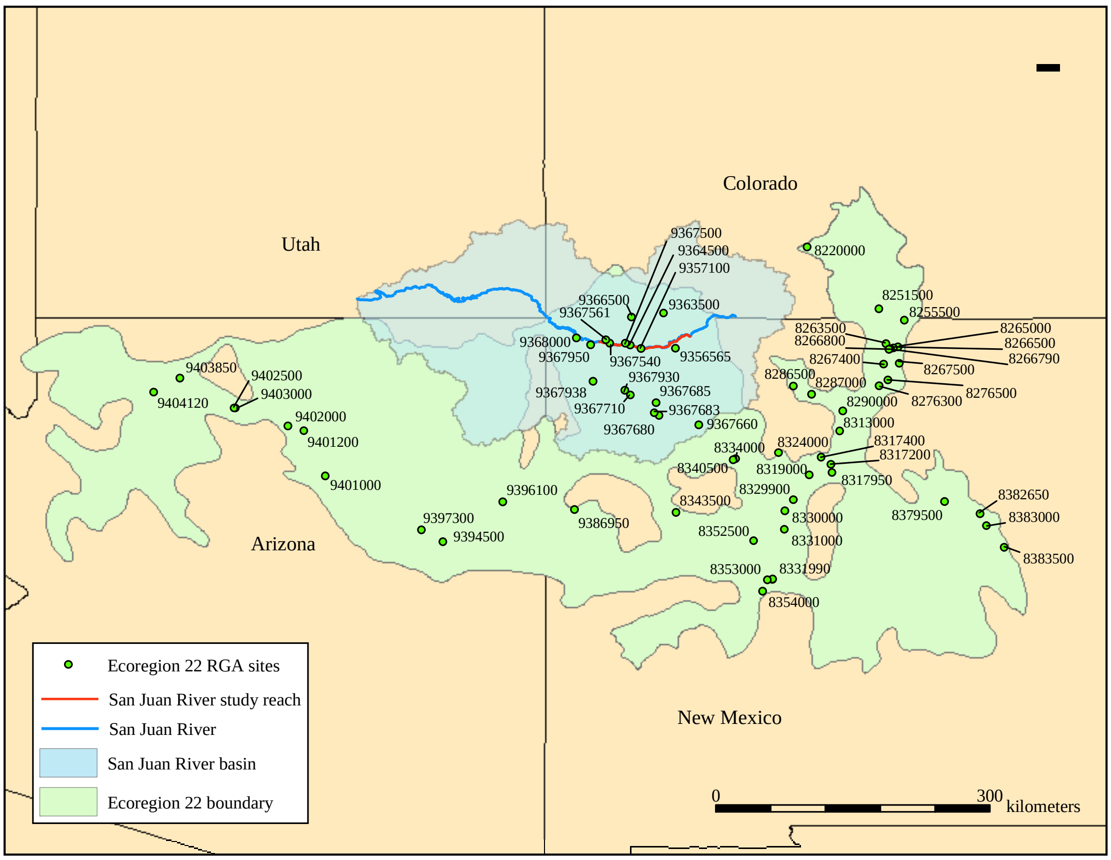

Figure 1.2 – Map of Ecoregion 22, the Arizona/New Mexico Plateau
(all gage numbers are preceded with 0)

Jurassic and older igneous and metamorphic rocks mark the perimeter of the basin. Within the basin, broad bands of Cretaceous and younger rock units crop out (Hunt, 1978). Central and eastern areas are covered by rocks of Tertiary age (Brister and Hoffman, 2002). Quaternary sand, gravel, and cobble deposits overlie floodplains and adjacent terraces. These alluvial deposits were derived from the resistant igneous and metamorphic rock from the San Juan's headwaters (Holden, 1999).

1.2.2 Description of the Study Reach

The San Juan River is similar to other Upper Colorado Basin rivers, in that streambeds are composed mostly of sand and cobble. The San Juan River is steeper than the Green and Upper Colorado Rivers, with higher suspended-sediment concentrations (Holden, 1999. Bliesner and Lamarra (2000) divide the San Juan River between the Navajo Dam and the confluence with the Colorado River into eight geomorphic reaches. Three of these correspond to the section of the San Juan River being investigated in this study (Figure 1.1). Reach 3, the 14.5 km section downstream from Navajo Dam to between Blanco and Archuleta is most directly influenced by the dam. It is mostly a single channel, with a comparatively low number of secondary channels. There is less irrigation and artificial stabilization than other reaches. The channel below the dam has been heavily modified by excavation of material used in dam construction. Water temperature is cooler due to releases from the dam. The main tributaries in this reach are Gobernador, Pump and Horse Canyons.

Reach 2, the section between Blanco and Archuleta to Animas River confluence (51.5 km) is also predominantly single channel. Most banks have been stabilized or diked to control lateral movement and overbank flow. Largo, Armenta, Kutz and Gallegos Canyons are the dominant tributaries in this reach.

Reach 1 stretches 35.4 km between the San Juan River between the Animas River confluence downstream to the Hogback. Several major flow diversions may impede fish passage, and backwater habitat is low in this reach. This reach contains three tributaries: La Plata River, the Animas River (the largest hydrological input in study reach), and Ojo Amarillo (naturally ephemeral, but now perennial due to irrigation return flow). This reach has been modified by dike construction to control lateral channel movement and overbank flow.

Reach 4 covers the Animas River from the confluence with the San Juan River to the Estes Arroyo confluence. Reach 5 extends from the mouth of Estes Arroyo on the Animas River, upstream to where the Animas River crosses the New Mexico/Colorado Border. Both these reaches have comparatively coarser bed material than the three study reaches on the San Juan River. There are four flow notable diversion structures on the two listed reaches of the Animas River (Genualdi R., pers. comm., Feb 2004).

1.2.3 Watershed Hydrology

Flows on the San Juan River were very different before regulation by Navajo Dam began in 1962 (Section 3.3). Before the dam was constructed, the San Juan River was characterized by large spring snowmelt peaks, low summer and winter base flows with additional peaks during high-magnitude, short-duration, late-summer storm events. This regime is typical of large southwestern rivers. Flows on the San Juan are also highly variable, and tend to follow a multi-year cyclic pattern (Holden, 1999).

The hydrograph of the San Juan River was substantially altered by dam closure and subsequent operation. Baseflows were substantially increased, the size of the spring runoff peak was reduced, and timing of the peak was changed considerably (Holden, 1999). Some of the effects of the dam are ameliorated on the section of the San Juan River downstream of Farmington by unregulated contributions from the Animas River.

Between 1992 and 1997 research was carried out by the San Juan River Recovery Implementation Program between Navajo Dam and the confluence with the Colorado River. This project attempted to develop a dam-release flow regime to replicate more natural flows and conserve populations of endangered native fish species, such as the Colorado squawfish and razorback sucker (Holden, 1999). Attempts were made to mimic pre-human intervention flow variability, in order to maintain habitats and a healthy biological community in the long term. Experiments aimed to restore the high-magnitude flushing flows; however the peak-flow magnitudes could not be matched because of outlet operating restrictions at the dam outlet (Holden, 1999). Since this project, the dam has been operated mostly on the basis of the outcome of this research (allowing higher spring peaks and lower baseflows), although a recent drought has limited large releases (pers. comm., Bliesner 2003).

1.2.4 Flow-Diversion Structures

The San Juan River and Animas Rivers contain numerous flow-diversion structures used to primarily capture water for irrigation purposes. Flow-diversion structures vary in form, ranging from a simple pump, to a small side channel with headgate, to a stone dam crossing the entire channel including a diversion channel. The latter have a greater impact on sediment transport by trapping sediment upstream of the structure. The location of flow diversion structures (Figure 1.3) was considered when evaluating the source and distribution of fine sediments on the bed in the study reaches.

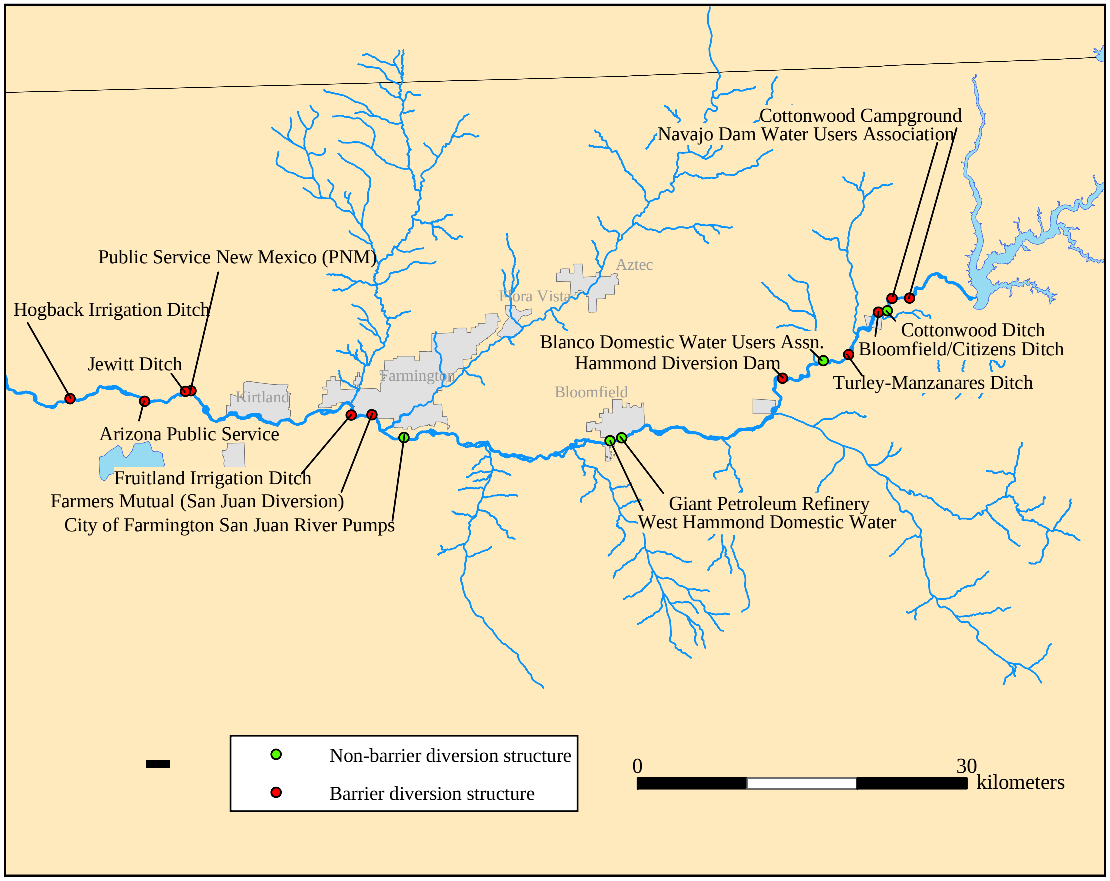

Figure 1.3 – Location of San Juan River and Animas River flow-diversion structures. Sediment barrier diversion structures are those which produce a backwater effect.

2 METHODS

The overall study approach was to determine stream bottom conditions in stable reaches of the region (Ecoregion 22) and the local study area and to use these as a measure of "reference" bed-material conditions. Bed-material conditions in the five reaches listed as impaired could then be compared to these "reference" values. To accomplish this, bed-material and channel-stability data were collected at sites throughout the five study reaches as well as at other sites in Ecoregion 22. This involved collection of bulk bed-material samples (BS) and particle count (PC) data, identification of dominant geomorphic processes and completion of geomorphic assessment forms to document relative stability. Sites were subsequently divided into stable and unstable. The bed-material data were then used to provide a longitudinal picture of current bed-material conditions along the San Juan and Animas Rivers. Reference conditions were established in terms of a metric for embeddedness as the percent of fine material (less than 2 mm) within a coarser matrix for channels considered to be geomorphically stable. This approach has been used successfully in other Ecoregions in other USDA-ARS National Sedimentation Laboratory studies.

2.1 San Juan River and Tributaries Field Methodology

2.1.1 Site Selection

Over the course of three weeks, 136 sites were visited in the San Juan River Basin (Figures 2.1 to 2.5). Ninety-two sites were located on the San Juan River itself, covering a reach approximately 113 km (70.4 miles) in length. On the Animas River, the main tributary of the San Juan River, 21 sites were visited over a 55.9 km (34 mile) reach. Additional sampling was carried out at 23 sites on tributaries thought to contribute large amounts of sediment to the San Juan River. At each site, representative photographs were taken (in upstream, downstream and cross-channel directions) and two field forms were completed: firstly, a channel-stability ranking, and, secondly, a bed material analysis Sheet.

Analysis sites were originally selected by river mile (RM), corresponding to study locations in Bliesner and Lamarra (2000; Figures 2.1 to 2.5). The referencing system used in this study was designed with site identifiers ranging from SJ224 (adjacent to dam) to SJ159 (the Hogback), with letters being used to distinguish extra sites between mile markers (eg. SJ218a). The distance of these sites from the downstream reach boundary was recalculated into metric units (river kilometers, rkm) using a recent channel centerline GIS layer. Sites were concentrated around confluences of tributaries deemed to be major sources of sediment, as depicted from topographic maps and aerial reconnaissance (Table 2.1). Two additional surveys were carried out upstream and downstream of tributary confluences: either every riffle moving away from the confluence or, if no riffles were present, at 300 and 600 m away. On the tributaries themselves, analysis sites were also chosen 300 and 600 m upstream of, and in some cases at, the confluence. One tributary to the Animas River, Estes Arroyo, was sampled in a similar manner.

Table 2.1 - Sampled tributaries of the San Juan and Animas Rivers

Tributary name	Tributary to	rkm at confluence
Shumway Arroyo	San Juan River	261.3
Ojo Amarillo	San Juan River	275.2
La Plata River	San Juan River	286.5
Animas River	San Juan River	291.5
Gallegos Canyon	San Juan River	302.1
Kutz Canyon	San Juan River	312.4
Armenta Canyon	San Juan River	330.5
Cañon Largo	San Juan River	336.0
Horse Canyon	San Juan River	345.4
Pump Canyon	San Juan River	350.8
Gobernador Canyon	San Juan River	354.8
Estes Arroyo	Animas River	26.7

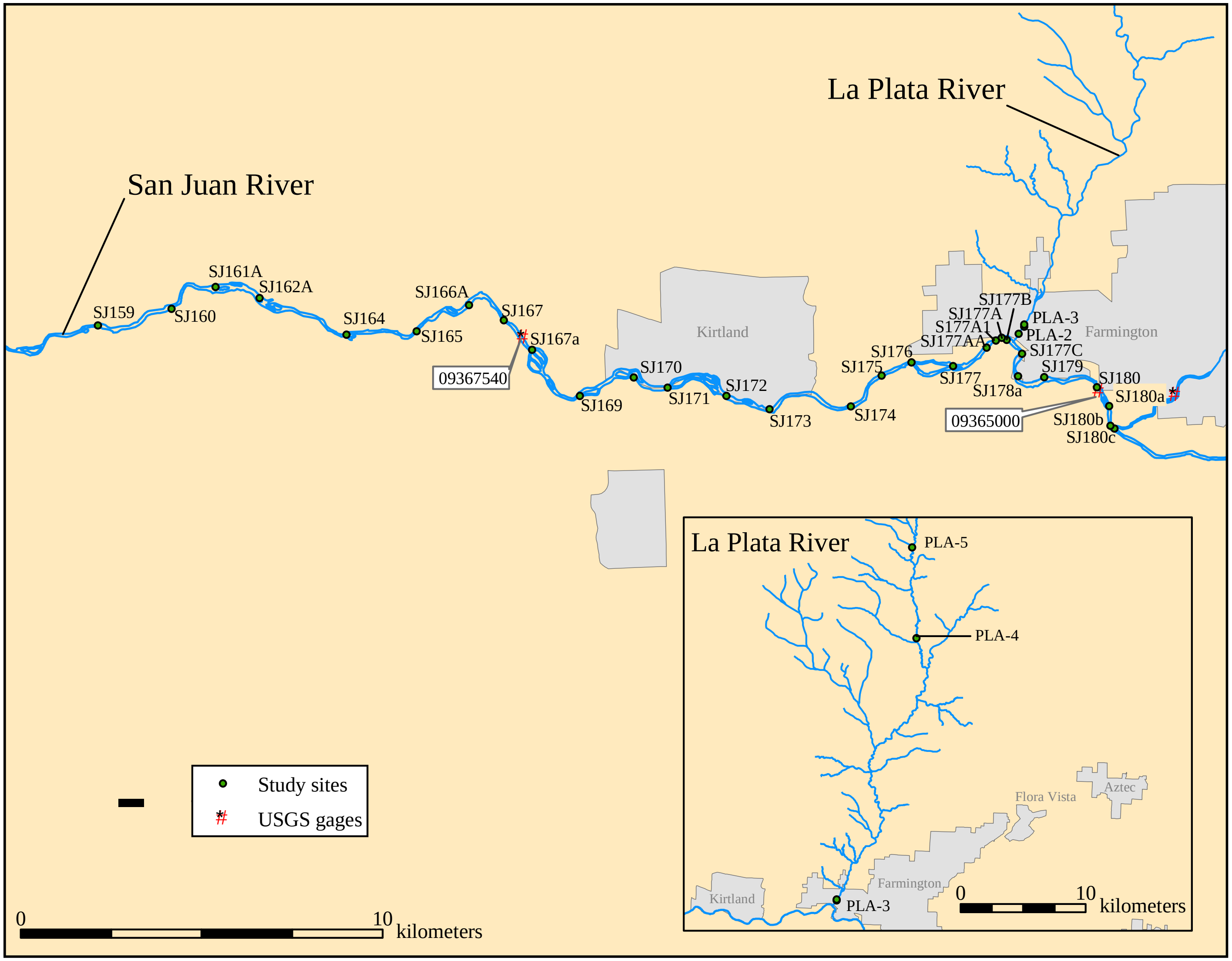

Figure 2.1 – Map of study sites in Reach 1: San Juan River from the Navajo Nation boundary at the Hogback to the Animas River

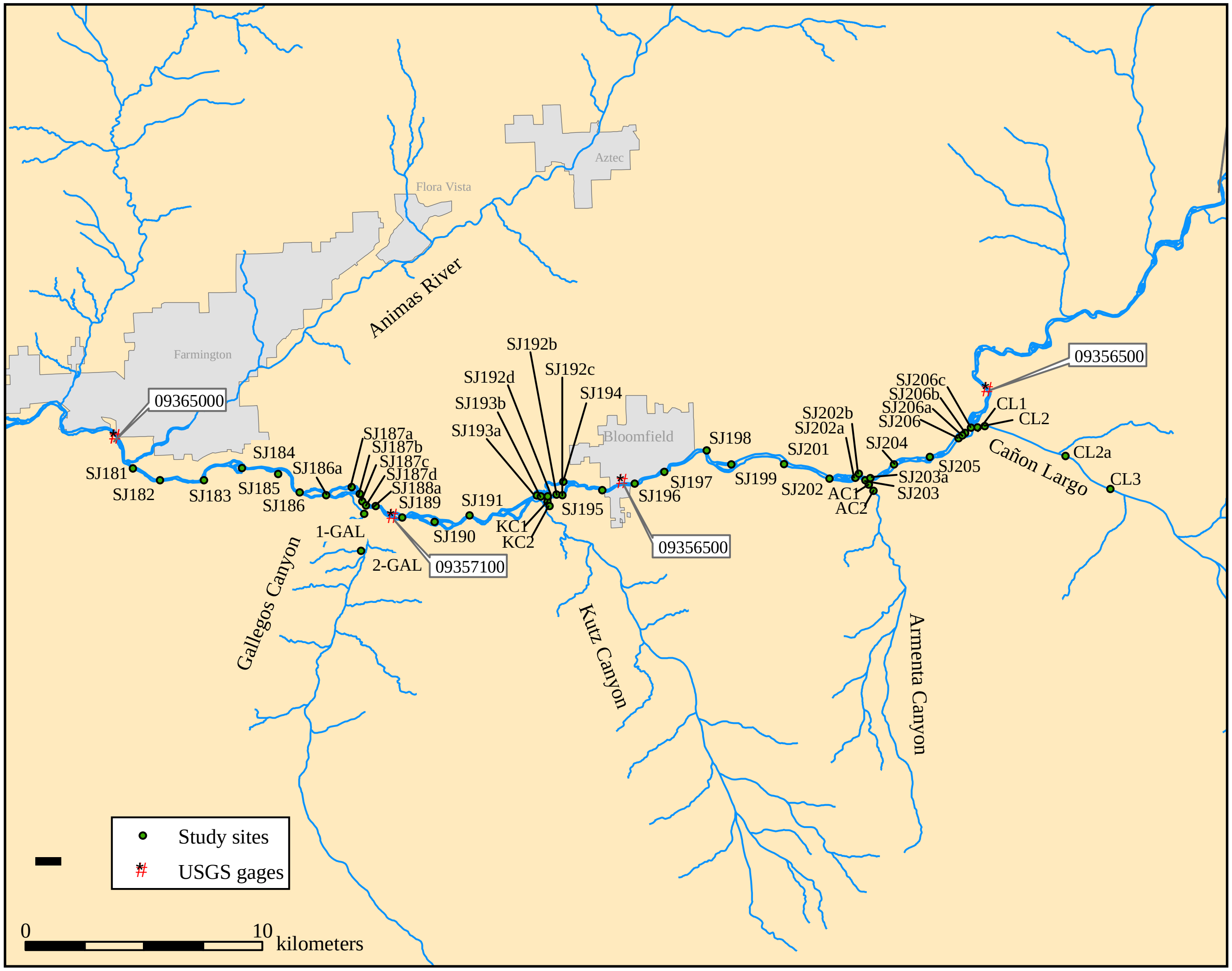

Figure 2.2 – Map of study sites in Reach 2: San Juan River from the Animas River to Cañon Largo

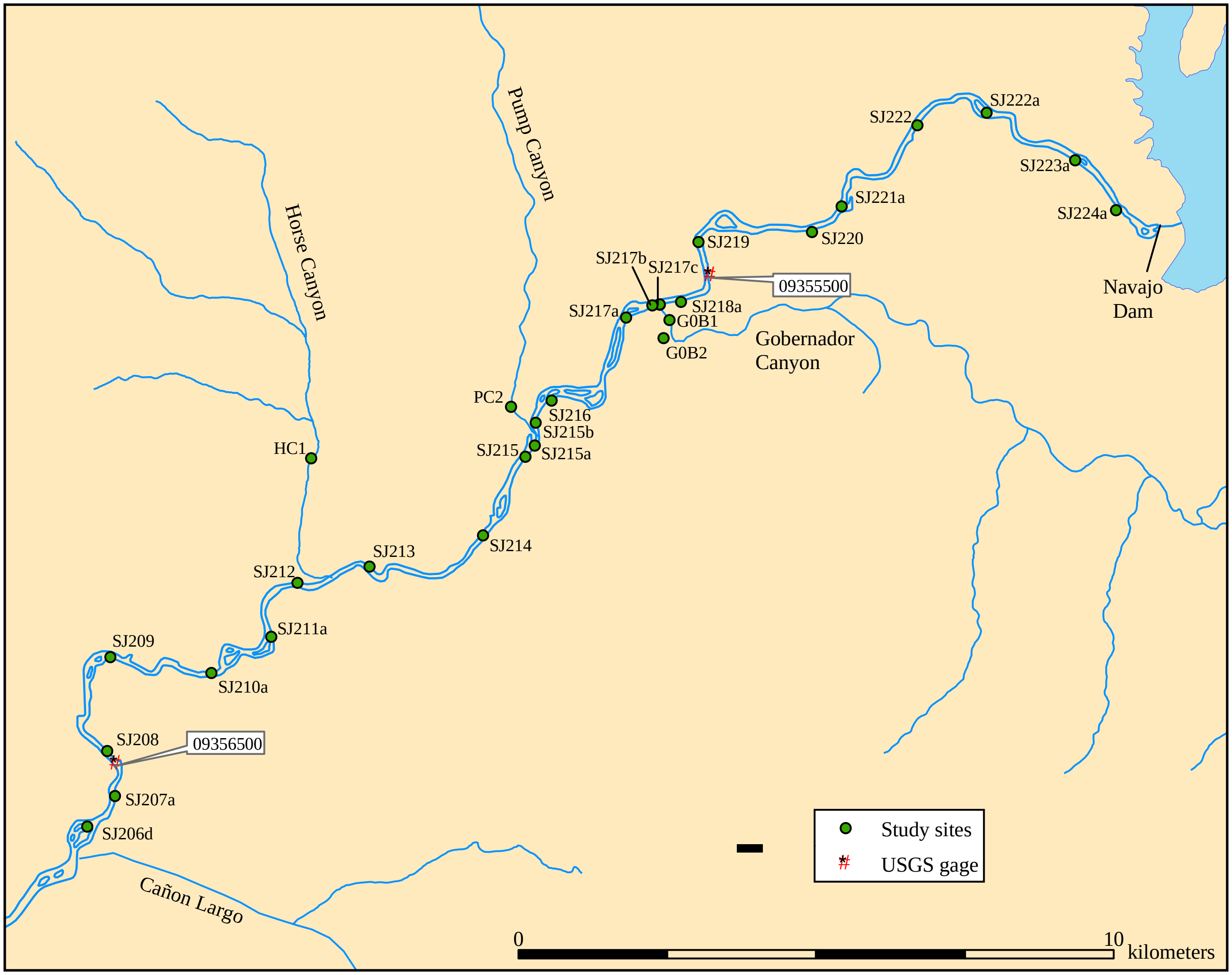

Figure 2.3 – Map of study sites in Reach 3: San Juan River from Cañon Largo to Navajo Dam

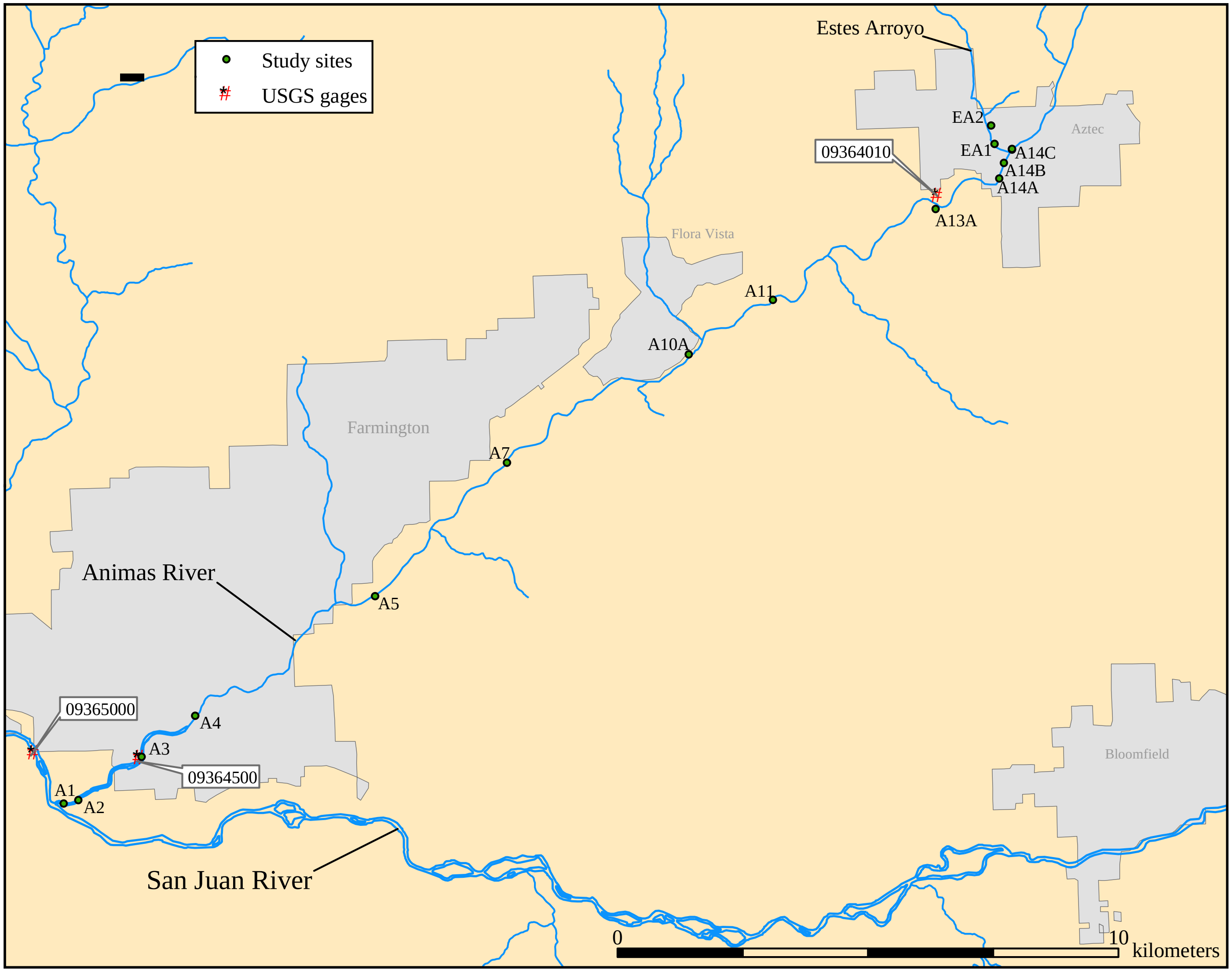

Figure 2.4 – Map of study sites in Reach 4: Animas River from the mouth on the San Juan River to Estes Arroyo

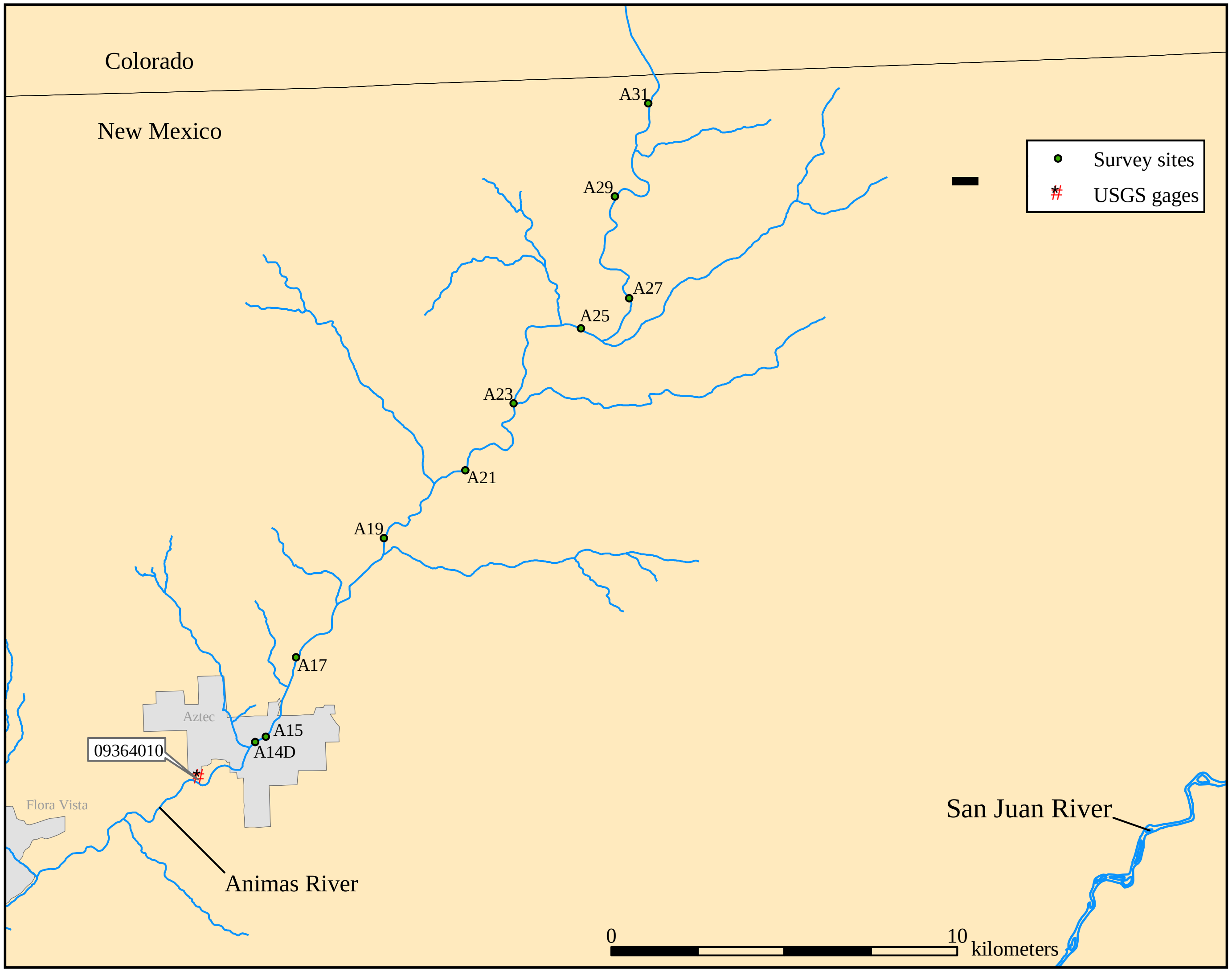

Figure 2.5 – Map of study sites in Reach 5: Animas River from Estes Arroyo to the New Mexico-Colorado border

Access to the river was not possible at all sites. In these cases, sampling locations were moved to a more accessible part of the river nearby. Study sites were marked on USGS 1:24,000 topographic maps, which ranged in date from the 1960s to the 1980s. Since the production date, meanders had migrated, islands had grown or reduced in size, and confluences had been relocated (such as at the mouth of Kutz Canyon). Because of this, sampling location did not necessarily coincide with every river mile along the San Juan River. Site locations were logged in the field using a hand held Global Positioning System (GPS) receiver with an approximate accuracy of ± 10 m, depending on satellite accessibility and relative exposure of the site.

To allow bed-material data to be analyzed in association with benthic macroinvertebrate data collected by the New Mexico Department of Environment (NMED), sampling was conducted at the nearest riffle where NMED samples were to be taken. This became somewhat inconsistent in reaches dominated by sandy bed material and thus no riffles. In such reaches, sampling was carried out at the mile marker. Bed-material sampling at each site was initially collected solely along the wetted perimeter of the riffle, to allow data to be linked to the biologic data collected. Subsequently, the bed-material sampling strategy was altered to include the whole channel, to firstly, generate data that were independent of water level at the time of measurement, and secondly, to match procedures uses in the rest of the Ecoregion. This strategy included parts of the channel that were dry at the time of sampling (a particularly dry period with very low flow) that at other parts of the year would be underwater. For this reason, some of the sites have two measurements of bed material from the field, “wetted perimeter” and “whole channel”. The whole channel dataset, covering the entire system, was used for later analysis. On the Animas River, sites were sampled every 2 miles, with a higher concentration at the confluence with the San Juan River and Estes Arroyo.

2.1.2 Aerial Reconnaissance

Aerial reconnaissance was conducted by helicopter at the outset of the study, over the 180 km of study reaches of the San Juan and Animas Rivers. Excursions were also made up several of the major tributaries. This fulfilled the purposes of identifying probable sources of large volumes of fine sediment, and focusing subsequent fieldwork at these critical locations. This viewing platform also allowed observations to be made that were not possible on the ground, such as comparing turbidity levels where a tributary joins the main channel. Detailed notes and photographs were taken. Selected photographs are included in Appendix I.

2.1.3 Rapid Geomorphic Assessment

Rapid Geomorphic Assessments (RGA) were conducted to determine relative channel stability, and assess whether sites were stable or unstable. These generally consist of a channel stability ranking form which assesses nine diagnostic criteria (Figure 2.6). Channel stability is assessed through examination of a selection of process-related geomorphologic indicators, such as prevalence of fluvial erosion, mass bank failures and

CHANNEL-STABILITY RANKING SCHEME

Station #__________________ **Station Description**____________________________________

Date _____________ **Crew** _______________ **Samples Taken**_________________________

Pictures (circle) upstream downstream cross section **Slope**__________

1. Primary bed material

	Bedrock	Boulder/Cobble	Gravel	Sand	Silt Clay	
	0	1	2	3	4	____

2. Bed/bank protection

	Yes	No	(with)	1 bank protected	2 banks	
	0	1		2	3	____

3. Degree of incision (Relative ele. Of "normal" low water; floodplain/terrace @ 100%)

	0-10%	11-25%	26-50%	51-75%	76-100%	
	4	3	2	1	0	____

4. Degree of constriction (Relative decrease in top-bank width from up to downstream)

	0-10%	11-25%	26-50%	51-75%	76-100%	
	0	1	2	3	4	____

5. Streambank erosion (Each bank)

	None	fluvial	mass wasting (failures)	
Left	0	1	2	____
Right	0	1	2	____

6. Streambank instability (Percent of each bank failing)

	0-10%	11-25%	26-50%	51-75%	76-100%	
Left	0	0.5	1	1.5	2	____
Right	0	0.5	1	1.5	2	____

7. Established ripirian woody-vegetative cover (Each bank)

	0-10%	11-25%	26-50%	51-75%	76-100%	
Left	2	1.5	1	0.5	0	____
Right	2	1.5	1	0.5	0	____

8. Occurrence of bank accretion (Percent of each bank with fluvial deposition)

	0-10%	11-25%	26-50%	51-75%	76-100%	
Left	2	1.5	1	0.5	0	____
Right	2	1.5	1	0.5	0	____

9. Stage of channel evolution

	I	II	III	IV	V	VI	
	0	1	2	4	3	1.5	____

TOTAL ____

Figure 2.6 - Rapid Geomorphic Assessment field form

overbank deposition. Other observations such as evidence of bed or bank protection, channel confinement and the extent of woody-riparian vegetation coverage were noted. The stage of channel evolution for each site was ascertained using Simon and Hupp's (1986) six-stage model (Figure 2.7). Stage I and VI channels are considered stable, and stages III, IV and V are unstable with accelerated erosion and heightened loads. Each observation is given a score and these values are summed to provide an index of relative channel stability. The higher the score, the more unstable. Sites scoring over 20 are particularly unstable, and commonly have failing banks and high sediment production. Stable sites generally score 10 or less.

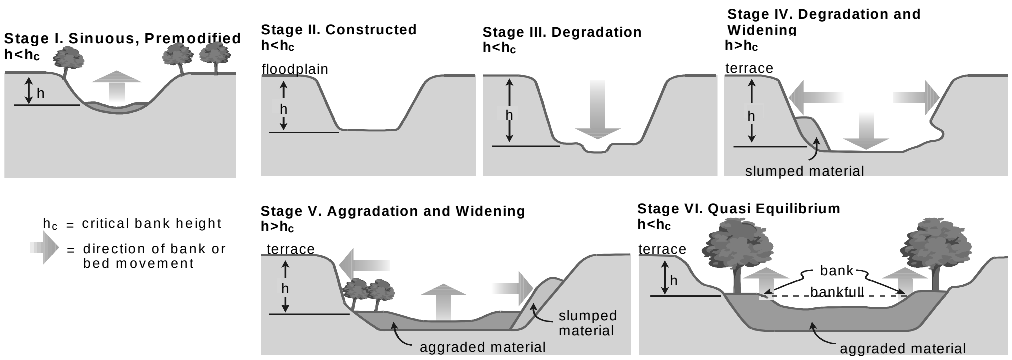

Figure 2.7 – The six stage Channel Evolution Model (Simon and Hupp, 1986)

2.1.4 Bed Material Sampling

A comprehensive description of how to measure embeddedness is not available and the sampling methodology is far from standardized. Sylte (2002) defines embeddedness as the vertical distance of fine sediment surrounding gravel or coarser particles relative to the total height of a sediment grain (Figure 2.8). However, this is an extremely difficult and time consuming variable to measure accurately in the field. For the purposes of this study, "embeddedness" is defined as the percentage of bed-material finer than 2 mm within a gravel/cobble dominated matrix. Embeddedness was assessed in this investigation using two methods frequently used in other studies. The first alternate variable quantifies the extent to which coarse-material dominated river beds (in excess of 50 % of bed material greater than 2 mm) are covered by fine sediments (particles with diameter less than 2 mm) by means of a bed-material bulk sample and particle count. The second alternate variable quantifies embeddedness by estimating percent bed-surface fines visually, using a grid laid on the bed at several locations on a transect across the channel (Sylte, 2002).

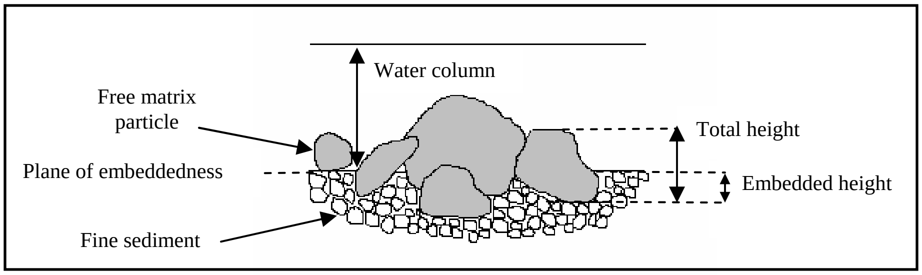

Figure 2.8 – Definition of embeddedness

A bed material analysis form was designed specifically for this study (Figure 2.9). Bed material fines were assessed is two ways; firstly by a combination of a particle count (PC; measuring the intermediate diameter of 100 particles) and bulk sample (BS). In most circumstances, where bed material size was mixed, both a PC and BS were carried out. A PC alone was used for purely coarse bed channels. A BS was used for fine bed channels. Secondly, to assess the proportion of fines on the bed surface, a grid was laid on the channel bed to quantify a percentage of bed surface covered with fine material (defined as 2 mm or finer, namely sand, silt and clay).

There are several inaccuracies associated with both of these methods. One issue is averaging across the channel width; a channel with a bed composed purely of sand from the left bank to the midpoint of the channel, and cobbles from the midpoint to the right bank, will appear to have the same bed material as a channel consisting of cobbles across the width of the channel with sand lying in the spaces between the cobbles. However, these two situations present very different environments for habitat and breeding grounds of macro biota. The former ensures 50% of the channel is cobble bed with clean interstitial spaces, whereas the latter is highly embedded and hereby a poor habitat overall. Another accuracy issue was that sampling was biased towards regions of slower, shallower flow, where particle size may be different from the thalweg. This occurred where parts of the channel were too deep and or fast flowing to enter, thus this part of the channel was not sampled.

Initially, the proposed method for acquisition of a PC/BS bed-sediment sample was to stretch a tape across the channel, and collect samples at regular intervals over the cross section using the distance on the table for a reference. However, most of the reaches visited were too wide for the stretching of a tape across the channel to be practical. In these cases, channel width was estimated, and particles were selected at regular intervals over several transects across the channel perpendicular to the flow direction. For example, if channel width at the site was 25 m, particles would be sampled every meter over 4 transects across the riffle, to provide a fair representation of the bed material size distribution. If greater than 8% of the particles measured were finer than 2 mm in diameter, a bulk sample of the finer material of reasonable weight was collected to obtain a size distribution of this fines fraction.

USDA UNITED STATES DEPARTMENT OF AGRICULTURE ars NATIONAL SEDIMENTATION LABORATORY

BED MATERIAL ANALYSIS SITE SHEET

Date	Time	Survey Crew
River Name		Site Identifier

A. SITE CONDITION

GPS Coordinates N:		E:		
Planform (circle):	Sinuous	Straight	Braided	
Reach classification:	Riffle ………..%	Pool ………..%	Run………. %	
Photographs (circle):	Upstream	Downstream	Cross Section	Bed
Dominant Bed Material (circle): 1. Bedrock 2. Cobble/Boulder 3. Gravel 4. Sand 5. Silt/Clay				

B. SAMPLING METHOD

Maximum depth in meters		Channel width in meters (E = estimated, M = measured)	
Coarse Bed: Particle Count? ………	Method (circle): 1. Wolman 2. Tape		
Fine Bed: N° of samples ……….	25th %ile width ……… /49	50th %ile w ……… /49	50th %ile w ………/49
% Particle Count ………………..		% Sample ………………..	

C. REACH SKETCH

(Include: location of samples, location of particle counts, location of photographs taken)

D. NOTES (eg. flow conditions, site access information, additional photos taken) ……..………………..

…………………………………………………………………………………………………….....

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Figure 2.9 - Bed Material Analysis sheet

To evaluate the percentage of the bed surface covered with fine material, a square sampling grid consisting of 49 intersections (7 wires in both the x and y dimension) making squares 5 cm in length and width was used (Figure 2.10). The grid was placed on the bed at 25, 50 and 75 % of the way across the channel. The number of grid intersection points with particles less than 2 mm lying directly underneath were counted. This method of quantifying percent surface fines had been developed on small streams (Sylte, 2002); however, this proved impractical for a river as deep and fast flowing as the San Juan and with such high turbidity levels. It was only possible to use this method in a few shallow reaches, as the square grid could not be held in place on the bed and or be viewed clearly through the water column above it. The square grid was mostly used on tributaries with very low flows.

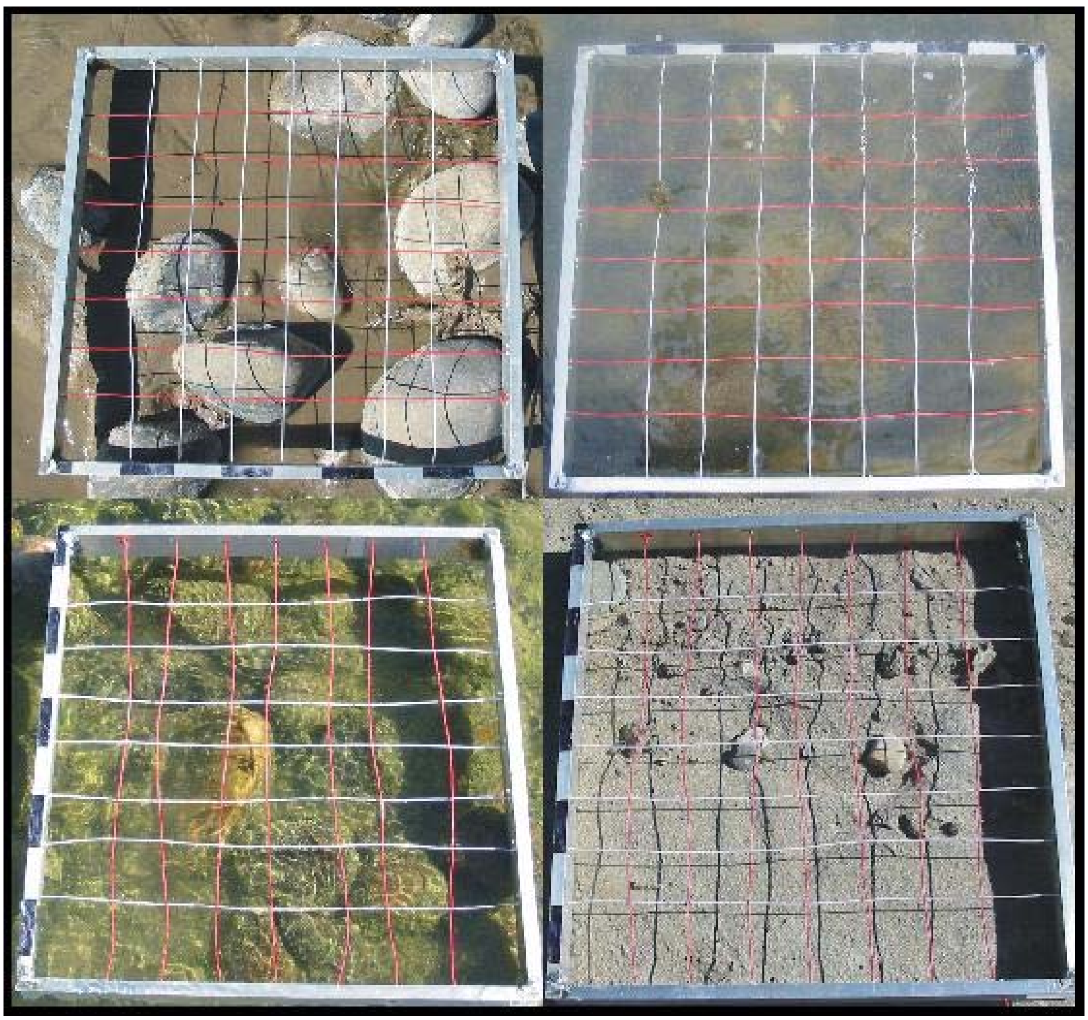

Figure 2.10 – Square grid used to quantify percent surface fine deposits in shallow reaches

In an attempt to combat such problems and adapt the grid method to be used in larger rivers, grids with 17 intersections (squares of 3 cm side length) were marked on the clear base of plexiglas cylinders, or “Snooper Tubes” (Figure 2.11). The cylinder was placed at a viewpoint perpendicular to the bed and the number of intersections crossing areas of fine particles were noted. This was carried out at 25%, 50% and 75% of the way across the channel along the three transects of the particle count and these 9 samples were aggregated to calculate an overall percent finer than 2 mm. For example, if at 25% of the way across the channel, 5/17 intersections fell above fines on the first transect, 5/17 on the second and 7/17 on the third, the ratio of percent fines would be 17/51 or 33%. Several problems were associated with this method of representing surface fines. Similar problems occurred as with the grid. Flow was too fast in some cases to allow the Plexiglas cylinder to be held stationary and normal to the bed. The channel was often deeper than the cylinder length and thus it could not be used. Sometimes, the process of placing the base of the cylinder on the bed formed small eddies beneath it, causing some fines to be picked up into suspension and thus not counted as filling interstitial spaces. A storm event between the field trips meant that the Plexiglas cylinder could not be used in the final week of fieldwork because flow and suspended-sediment concentration of the river were much higher than on the first trip.

Figure 2.11 - Plexiglas cylinder with a 3 cm grid marked on the base used to record percent surface fines

The two grid methods of measuring percent surface fines are not directly comparable because the grids have squares with different length. The grid was laid down once at 25, 50 and 75 % of the width across the channel, whilst the Plexiglas cylinder was used three times at each of the distances across and an average taken.

2.2 Ecoregion 22 Field Methods

To establish reference conditions for the entire Ecoregion, gaging stations in the Arizona/New Mexico Plateau were selected. Sixty-five USGS gaging stations in Ecoregion 22 have greater than 30 suspended-sediment measurements with instantaneous flow values. These are listed in Table 2.2. Ten gages are located in Arizona, four are located in Colorado, and fifty-one are located in New Mexico. Fifty-nine gages possess a mean-daily flow record published by the USGS. A rapid geomorphic assessment, as described in Section 2.1.3, was carried out at each of these sites to establish channel stability. Bed material was sampled by means of a particle count and bulk sample as described earlier.

Table 2.2 – Study sites in Ecoregion 22, Arizona / New Mexico Plateau

Station Number	Station Name	State
09394500	Little Colorado R At Woodruff	AZ
09396100	Puerco River Near Chambers	AZ
09397300	Little Colorado R Nr Joseph City	AZ
09401000	Little Colo. River At Grand Falls	AZ
09401200	Little Colorado R At Cameron	AZ
09402000	Little Colorado River Near Cameron	AZ
09402500	Colorado R. Near Grand Canyon	AZ
09403000	Bright Angel Creek Near Grand Canyon	AZ
09403850	Kanab Creek above Mouth Nr Supai	AZ
09404120	Colorado R above National Canyon Nr Supai	AZ
08220000	Rio Grande Near Del Norte	CO
08251500	Rio Grande Near Lobatos	CO
09363500	Animas River Near Cedar Hill	CO
09366500	La Plata River At Colorado-New Mexico State Line	CO
08255500	Costilla C Nr Costilla	NM
08263500	Rio Grande Near Cerro	NM
08265000	Red River Near Questa	NM
08266500	Red River Bl Questa	NM
08266790	Red River Above State Fish Hatchery Nr Questa	NM
08266800	Red R At Fish Hatch Nr Questa	NM
08266820	Red River Below Fish Hatchery, Near Questa	NM
08267400	Rio Grande Above Rio Hondo At Dunn Bridge	NM
08267500	Rio Hondo Near Valdez	NM
08276300	Rio Pueblo De Taos Below Los Cordovas	NM
08276500	Rio Grande below Taos Junction Bridge Nr Taos	NM
08286500	Rio Chama Ab Abiquiu Re	NM
08287000	Rio Chama Bl Abiquiu Dam	NM
08290000	Rio Chama Near Chamita	NM

08313000	Rio Grande At Otowi Bridge	NM
08317200	Santa Fe River Above Cochiti Lake	NM
08317400	Rio Grande Below Cochiti Dam	NM
08317950	Galisteo Creek Below Galisteo Dam	NM
08319000	Rio Grande At San Felipe	NM
08324000	Jemez River Near Jemez	NM
08329900	N Floodway Channel Nr Alameda	NM
08330000	Rio Grande At Albuquerque	NM
08331000	Rio Grande At Isleta	NM
08331990	Rio Grande Conveyance Channel Near Bernardo	NM
08332010	Rio Grande Floodway Near Bernardo	NM
08334000	Rio Puerco above Arroyo Chico Nr Guadalupe	NM
08340500	Arroyo Chico Nr Guadalupe	NM
08343500	Rio San Jose Near Grants	NM
08352500	Rio Puerco At Rio Puerco	NM
08353000	Rio Puerco Near Bernardo	NM
08354000	Rio Salado Near San Acacia	NM
08379500	Pecos River Near Anton Chico	NM
08382650	Pecos River Above Santa Rosa Lake	NM
08383000	Pecos River At Santa Rosa	NM
08383500	Pecos River Near Puerto De Luna	NM
09356565	Cañon Largo Nr Blanco	NM
09357100	San Juan River At Hammond Br Nr Bloomfield	NM
09364500	Animas River At Farmington	NM
09367500	La Plata River Near Farmington	NM
09367540	San Juan R Nr Fruitland	NM
09367561	Shumway Arroyo Near Waterflow	NM
09367660	Chaco Wash Nr Starlake Trading Post	NM
09367680	Chaco Wash At Chaco Canyon National Monument	NM
09367683	Chaco Wash Nr Pb At Bridge At Chaco Natl Mon	NM
09367685	Ah-Shi-Sle-Pah Wash Near Kimbeto	NM
09367710	De-Na-Zin Wash Nr Bisti Trading Post	NM
09367930	Hunter Wash At Bisti Trading Post	NM
09367938	Chaco River Nr Burnham	NM
09367950	Chaco River Near Waterflow	NM
09368000	San Juan River At Shiprock	NM
09386950	Zuni River above Black Rock Reservoir	NM

In order to produce a representative dataset, gaging stations within 5 km of dams were removed from the analysis dataset (Table 2.3). This amounted to four sites.

Table 2.3 – Gages removed from analysis due to close proximity to dams

Gage Number	Gage Name
08266500	Red River below Questa
08266790	Red River above State Fish Hatchery near Questa
08266800	Red River at Fish Hatch near Questa
08266820	Red River below Fish Hatchery, near Questa

2.3 San Juan River Data-Analysis Methods

2.3.1 Bed-Material Analysis

The proportion of fines in bed material in the San Juan River study area were assessed in two ways, firstly, by particle count accompanied with bulk sample (PC/BS), and secondly, using a grid method (either snooper tube or square grid) on the bed surface. Data from the particle count and bulk sample were combined by calculating the percent sand or finer in the particle count, then using the bulk sample size data to complete the distribution. Percent finer than 2 mm using both PC/BS and grid methods were plotted by rkm over the designated reaches on the San Juan and Animas Rivers to examine trends in relation to the location of tributary confluences and flow diversion structures. In addition, a regression analysis was carried to directly compare the results of percent finer than 2 mm by PC/BS and grid methods by study site.

Generally, the grid and PC/BS methods should provide similar results in circumstances where fines are distributed evenly vertically throughout the bed; in this situation observations made on the bed surface would be identical to those made at any depth. In situations where fines are deposited on the surface and have smothered underlying coarser material, the grid method will provide a higher percentage of fines that the PC/BS sampling method. Conversely, the grid method may also give lower percent fines than a PC/BS sample, in circumstances such as when fines have filtered through the coarse matrix and filled interstitial spaces lower in the bed but not up to the bed surface, where coarse material dominates. Another cause of disparity in results is the sampling procedure; the grid method was used at 0.25, 0.5 and 0.75 of channel width on a cross section, whereas particle counts were conducted across continuous transects. If bed-material size varied over the cross section, results of the methods may differ substantially.

2.3.2 Precipitation Data Analysis

Precipitation depth data were acquired from NOAA National Climatic Data Center covering a 74 year period between 1930 and 2003, for the raingage at Aztec Ruins National Monument (located in Figure 1.1). Monthly and annual totals were plotted to identify any temporal precipitation trend. In addition, the mean precipitation total, and distribution of values were calculated for each month of the year.

2.3.3 Gaging Station Hydrological Analysis

Analyses of gaging station hydrological data were carried out to identify the impact of Navajo Dam on streamflow and examine any other temporal changes. Table 2.4 summarizes available data for the eleven USGS gaging stations located within the study area. Sites are mapped on Figure 1.1. Of the six on the San Juan River, only two are still active, the gage near Archuleta and the gage at Farmington. Additional gages are located on three tributaries; two active gages on the Animas River, two active gages on the La Plata River, and one inactive gage on Cañon Largo. Eight of the eleven gages have sufficient suspended-sediment sample data with associated instantaneous flow data to create a rating curve (an empirical relation between discharge and suspended-sediment load).

Table 2.4 - USGS gaging stations in the study area

Gage number	Current status	Gage Name	Duration of Flow Data (Years)	Number of Suspended Sediment Samples
09355500	Active	San Juan River Near Archuleta, NM	47.8	30
09356500	Inactive	San Juan R Nr Blanco, NM	24.3	0
09357000	Inactive	San Juan River At Bloomfield, NM	8.25	1
09357100	Inactive	San Juan River At Hammond Br Nr Bloomfield, NM	4.02	67
09365000	Active	San Juan River At Farmington, NM	72.0	36
09367540	Inactive	San Juan R Nr Fruitland, NM	3.00	83
09356565	Inactive	Cañon Largo Nr Blanco, NM	4.02	47
09363500	Active	Animas River Near Cedar Hill, NM	68.9	47
09364500	Active	Animas River At Farmington, NM	89.0	253
09367000	Active	La Plata River at La Plata, NM	No data	1
09367500	Active	La Plata River near Farmington, NM	64.6	55

Construction of the Navajo Dam commenced in 1962. Storage began June 27th 1962 and the dam was completed June 1963 (pers. comm., D. Byrd, Nov 2003). Mean daily and annual peak flow data covering the period before and after the dam was constructed are available for two gaging stations on the San Juan River:

1. 09355500 San Juan River near Archuleta (13.1 km downstream of the dam); and
2. 09365000 San Juan River at Farmington (78.7 km downstream of the dam, just downstream of the Animas River confluence).

To investigate modification of San Juan River flow regime caused by Navajo Dam, the following analyses were conducted for both gages, for pre- and post-dam conditions:

- Annual-maximum discharge over period of record,

- Mean annual discharge analysis over period of record,
- Recurrence intervals based on annual peak-flow data (using a macro based on the method of Riggs, 1968),
- Flow percent exceedence using mean-daily flow data, and
- Mean-daily discharge by day of the year (to identify alterations to the annual flow regime).

Experimentation with the flow regime was carried out between 1992 and 1997, to attempt to replicate the natural flow patterns and create a habitat more suitable for native fish species (R. Bliesner, November 2003, pers. comm.). Following this period, releases from the dam were controlled on the basis of findings from these trials. Therefore, the latter two of the analyses listed were conducted after dividing information into three datasets:

1. Pre dam: start of data collection to June 1962.
2. Post dam 1: July 1962 to December 1991.
3. Post dam 2: Jan 1992 to end of record (this includes the flow experimentation period and subsequent flow operations).

2.3.4 Gaging Station Suspended-Sediment Analysis

Suspended-sediment rating curves were developed to enable suspended-sediment loads to be calculated on the basis of flow data. A scattergraph of suspended-sediment load (in tonnes per day) against discharge (in cubic meters per second) was plotted in log-log space, and linear regression was carried out. Rating relations were of the form:

$$L = aQ^b$$

Where: L = suspended-sediment load in tonnes per day;
Q = discharge in cubic meters per second; and
a and b = regression constants.

In some cases, it was necessary to add a second section to more accurately represent the trend in the data. The suspended-sediment rating curves for gages on the San Juan River, Animas River and tributaries are included in Appendix H. The rating equation was applied to mean daily flow data firstly for the gaging station on the San Juan River near Archuleta (the closest gage downstream of the dam), to calculate daily loads and yields. In addition, a partial daily load dataset for the earliest part of the record period for this gage was downloaded from the USGS suspended-sediment online database. The overall period of suspended-sediment load data availability are presented in Table 2.5. Annual loads were calculated by applying the suspended-sediment rating equation to mean daily flow data, then aggregating daily loads by calendar year. The rating equation was also used with $Q_{1.5}$, the discharge that occurs on average every 1.5 years, to calculate suspended-sediment load at this discharge.

Table 2.5 – Duration of pre and post dam records for gages with USGS load data

Gage number	Gage Location	Record period (duration in years)	
		Pre Dam	Post Dam
09355500	SJR near Archuleta	12/1/54 – 6/30/62	7/1/62 – 9/30/02

		(7.6 years)	(40.3 years)
09356500	SJR near Blanco	3/15/49 – 12/25/54 (5.8 years)	No data
09357000	SJR at Bloomfield	11/1/55 – 6/30/62 (6.7 years)	7/1/62 – 12/31/63 (1.5 years)
09368000	SJR at Shiprock	12/16/50 – 6/30/62 (11.5 years)	7/1/62 – 9/30/86 (24.3 years)
09356565	CL near Blanco	No data	10/1/77 – 10/9/81 (4.02 years)
09364500	AR at Farmington	12/15/50 – 6/30/62 (11.5 years)	7/1/62 – 9/30/93 (31.2 years)

Suspended-sediment loads at $Q_{1.5}$ were also calculated for all sites in Ecoregion 22 using the same methods, to enable reference values for suspended-sediment to be calculated.

3 RESULTS

3.1 Geomorphic Conditions Along the San Juan and Animas Rivers

Rapid geomorphic assessments were conducted at all sites where bed-material sampling was undertaken. The purpose of these assessments was to determine relative channel stability, to differentiate between stable and unstable reaches, and to identify reaches of high sediment production. This work benefited from an aerial reconnaissance by helicopter, as it helped to identify major sources of sediment and provide low-level views of turbidity conditions along the main stem channels.

Results of rapid geomorphic assessments for the San Juan River, Animas River and other tributaries are presented in Appendix C. Stage of channel evolution by study site is plotted longitudinally in Figure 3.1 and mapped in Figure 3.2. Note the shift in stage in the vicinity of the Cañon Largo confluence. All sites located in Reach 3 adjacent to the Navajo Dam are classified as stable stage VI channels, and, therefore may prove useful as references. In Reach 2, most sites were classified as unstable stage V channels (actively widening with aggrading beds) including those on Cañon Largo itself. One incising stage III site is located downstream of Gallegos Canyon. Additional tributaries entering this reach such as Kutz, Armenta, and Gallegos Canyons are also considered unstable. Further downstream in Reach 1, conditions are intermediate with sites classified as mostly stage VI with some stage V widening sections.

The combined stability index is an indication of overall channel stability, calculated on the basis of geomorphic indicators such as observed erosion and deposition processes, riparian vegetation cover, channel constriction and presence of bank protection. Stability index values are presented by river kilometer in Figure 3.3 and geographically in Figure 3.4. Values less that 10 generally indicate a stable channel, whereas those above 20 suggest considerable instability. Again, a sharp trend towards instability is indicated by the data in the vicinity of the Cañon Largo confluence. Sites in Reach 3 just downstream of the dam are comparatively stable with most values below 12. Conversely, the upper section of Reach 2, from the mouth of Cañon Largo to that of Kutz Canyon is unstable due to delivery of large quantities of sediment from Cañon Largo. Most sites in this section rank over 20, indicating considerable instability. From Kutz Canyon downstream, the channel recovers somewhat with sites scoring generally 15 and below. Sites along Reach 1 on the San Juan River, and Reaches 4 and 5 on the Animas River, fall mostly in the stable category.

By mapping particular criteria from the rapid geomorphic assessment form, a picture of the extent of certain channel processes can be identified. For example, Figure 3.5 shows the relative percentage of streambank failures occurring along study reaches. Streambanks can provide enormous quantities of fine-grained sediment. Sites in Reach 3 exhibit very low percentages of unstable streambanks, except for a site on lower Horse Canyon. Downstream of the mouth of Cañon Largo, a different picture emerges, with a consistent high proportion of banks failing in the section of Reach 2 between the mouths of Cañon Largo and Kutz Canyon. Channel banks at sites on Cañon Largo, Armenta and

Kutz Canyons were observed to possess highly unstable banks. From the mouth of Gallegos Canyon to the end of Reach 2, banks show comparatively fewer failures. Reach 1 on the whole is relatively stable, with a few less stable sites located on the lower end. Generally, the banks of the Animas River show few failures, although immediately downstream of the Estes Arroyo banks are less stable (Reach 5).

Results of the rapid geomorphic assessments helped identify Cañon Largo and other tributaries such as Kutz and Gallegos Canyons as major contributors of fine sediment. The effects of these tributaries can be clearly seen on associated maps included in this section.

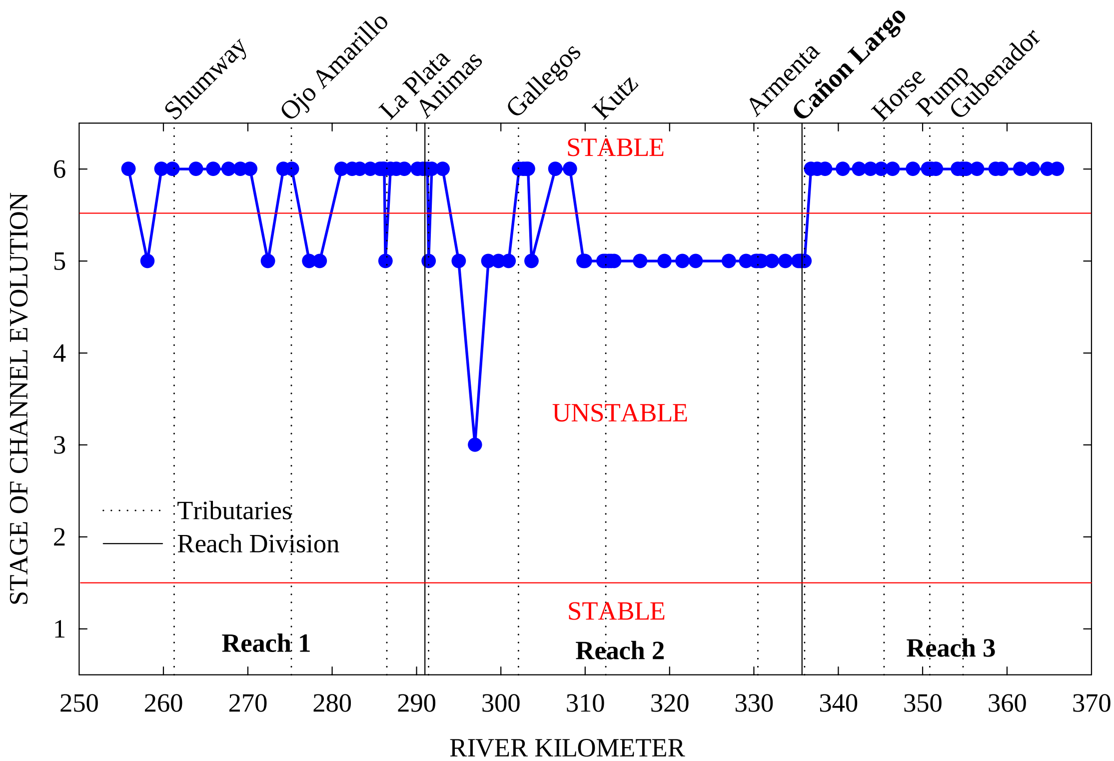

Figure 3.1 – Stage of channel evolution by river kilometer

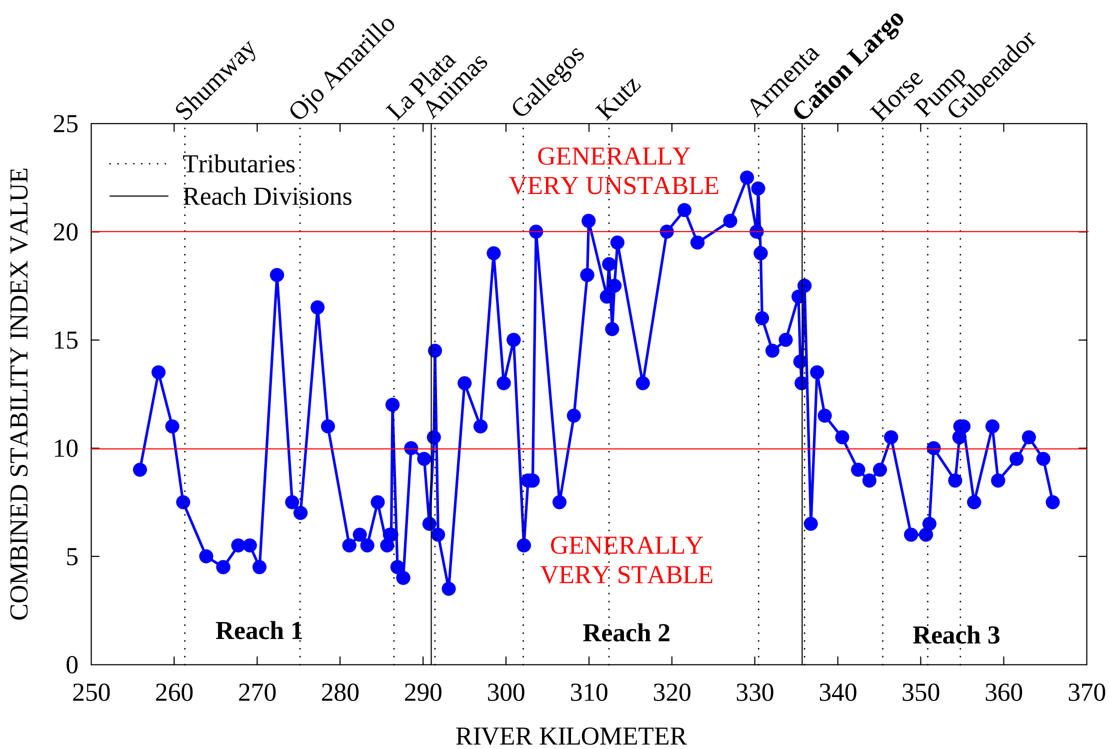

Figure 3.3 – Combined stability index by river kilometer

3.2 Bed Material Composition

The five stream reaches of particular concern in this study were listed as being impaired due a perceived preponderance of fine-grained materials clogging interstitial spaces in gravel- or cobble-dominated streambeds. To address this issue relative to our definition of embeddedness, the percent of material finer than 2 mm was used as a measure of impact. A long profile showing the percent of bed material finer than 2 mm along the San Juan River using data collected by PC/BS method shows a systematic variation over the reach (Figure 3.6). A three period moving average was used to smooth data. A peak in the bed percent fines value at the location of confluence with another river is interpreted as an input of fine sediment load from this tributary.

The most striking feature of Figure 3.6 is the rapid increase in the percent material finer than 2 mm at about rkm 335, the confluence of Cañon Largo. Upstream from this confluence, fine-grained bed composition is generally about 6% to 15%. Downstream, however the percent fines increases to 100% 5 km downstream. These data are a clear indication of the role of sediment loadings from Cañon Largo on bed-material conditions along this reach of the San Juan River.

Reach 3, extending from the Navajo Dam to the Cañon Largo, exhibits the lowest percent fines values (generally below 15 %) due to the sediment-trapping effects of the dam. A small increase in percent fines is observed at Gobernador Canyon, indicating this tributary inputs fine sediment to the San Juan River. High percent fines values are sustained throughout Reach 2, due to Cañon Largo. An additional peak is observed at the mouth of Gallegos Canyon. A reduction in percent fines occurs further downstream in Reach 1 (Animas River to the Hogback) as the Animas River delivers lower-concentration flows to the San Juan River. Still, the amount of fine-grained bed sediments are not nearly as low as in Reach 3 adjacent to the dam. Percent fines sharply increases at La Plata River and at a flow diversion that traps sediment upstream of the structure. At the mouth of the Animas River, a reduction in percent fines in observed, indicating this is not an important source of fine sediment, and the substantial runoff from this perennial stream aids in entraining and transporting fine-bed sediment in the San Juan River. Aerial photographs taken at the confluence and the San Juan and Animas Rivers clearly show differences in turbidity, with flow in the Animas being much less turbid than that in the San Juan River (Appendix I).

A long profile of D_{50} values on the San Juan River (Figure 3.7) reflects the same trends as the percent finer than 2 mm data. D_{50} values for Reaches 1 and 3 range from coarse gravel to cobble, whereas D_{50} values for Reach 2 are generally in the sand or fine gravel range. Spikes of sand dominated locations are observed at four locations, corresponding to the mouths of tributaries: Cañon Largo, Kutz and Gallegos Canyons and the La Plata River.

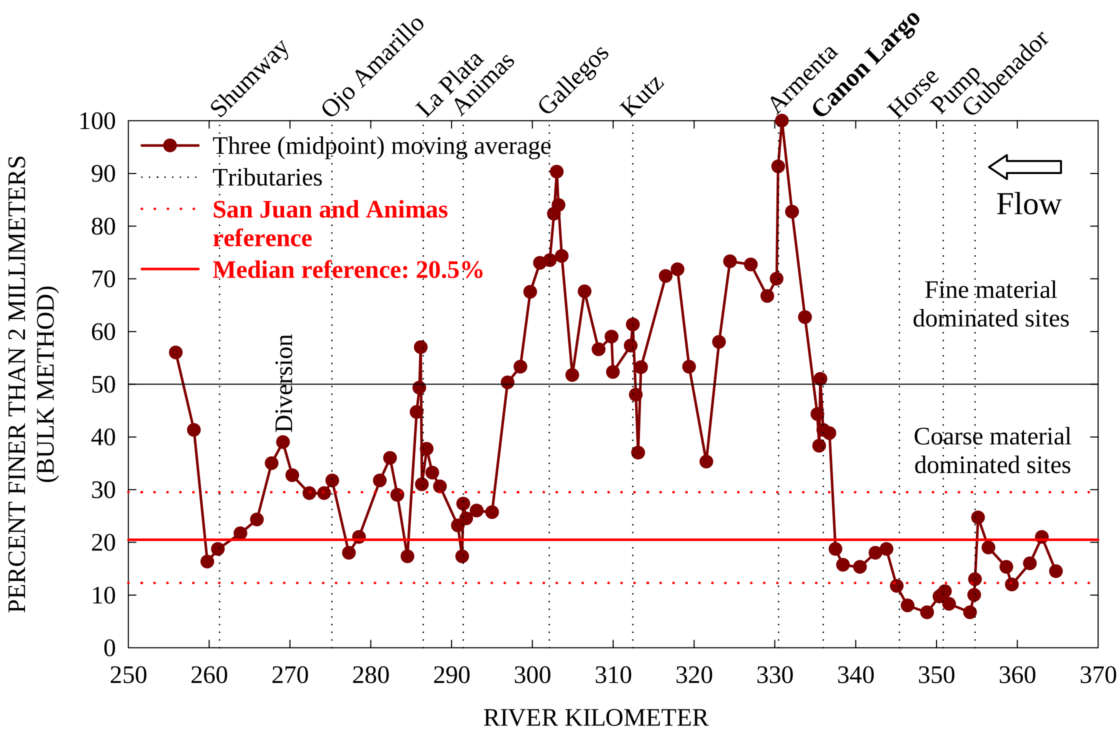

Figure 3.6 - Bed material percent fines on San Juan River by rkm, using PC/BS method

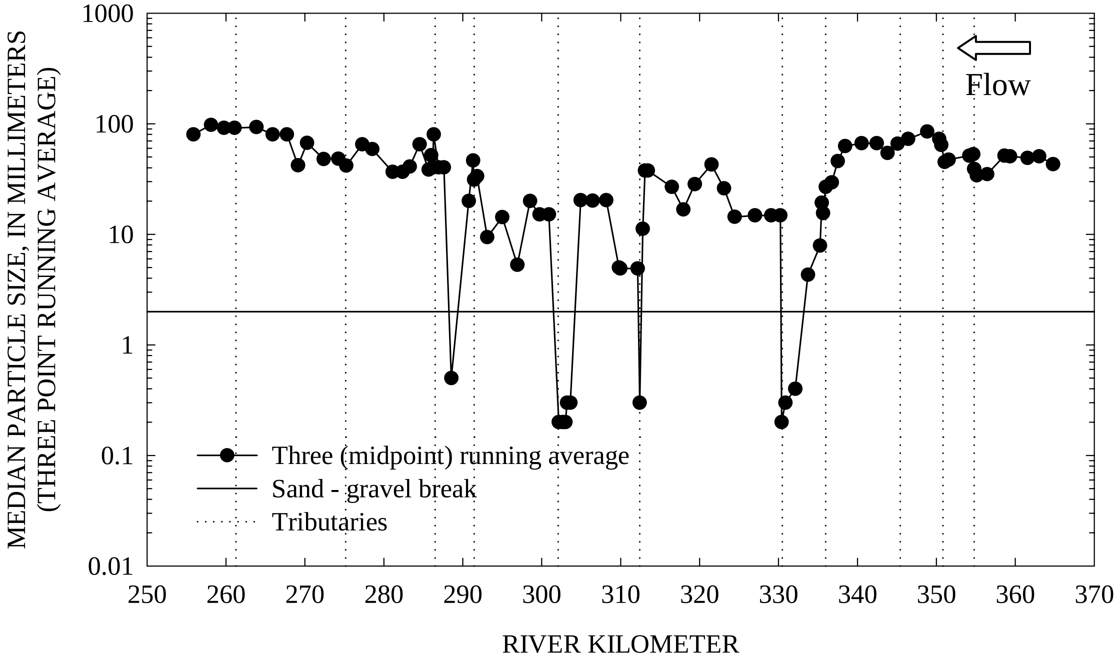

Figure 3.7 – Bed material D_{50} long profile of the San Juan River, using PC/BS method

Results using the grid-sampling method (Figure 3.8) show similar trends with data collected using the PC/BS method when displayed as a 3-point moving average (Figure 3.9). Peaks in percent of bed material finer than 2 mm using the grid method are located at Cañon Largo, Gallegos Canyon and La Plata River (Figure 3.8). A scattergraph was plotted to directly compare corresponding bed percent fines values using both the PC/BS and grid methods (Figure 3.10). This plot includes datapoints from the San Juan and Animas Rivers, in addition to other sampled tributaries. Data are positively correlated with an r^2 value of 0.68 (122 pairs of data). On average, a PC/BS sample was shown to generate slightly lower values than a grid sample (mean of 85 % of the grid value). This general trend is attributed to the distribution of fines in the bed; in most cases lying on top of coarser underlying material, rather than being evenly mixed vertically.

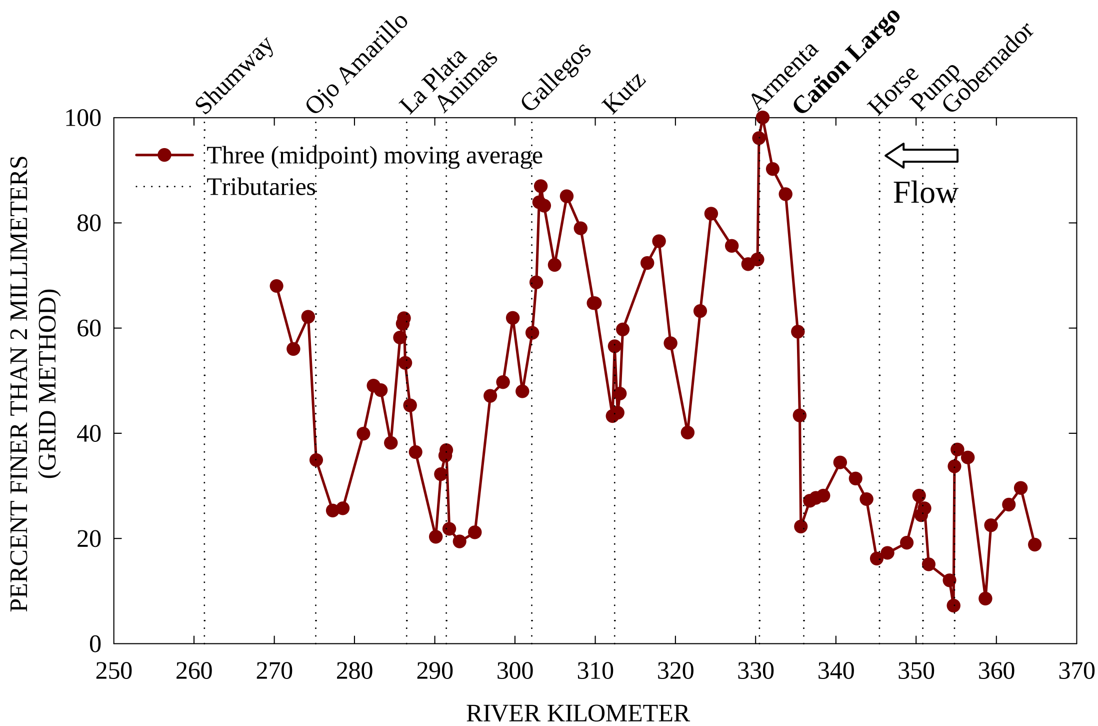

Figure 3.8 - Bed material percent fines on San Juan River by rkm, by grid method

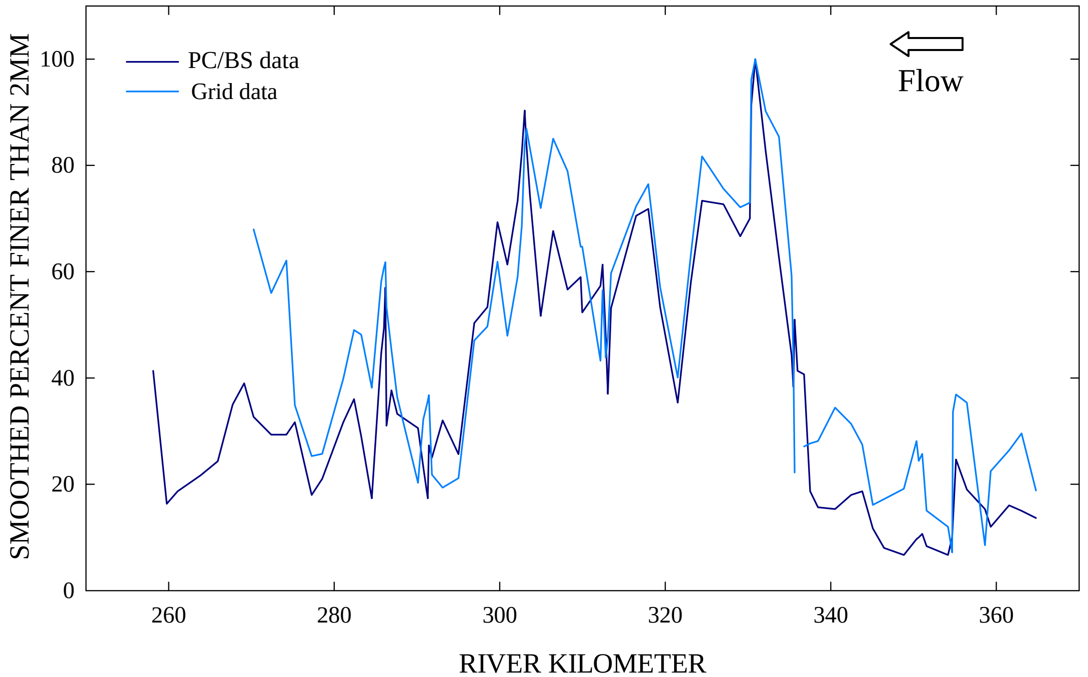

Figure 3.9 - Bed material percent fines on San Juan River by rkm: comparison of PC/BS and grid methods (data smoothed over 3 samples)

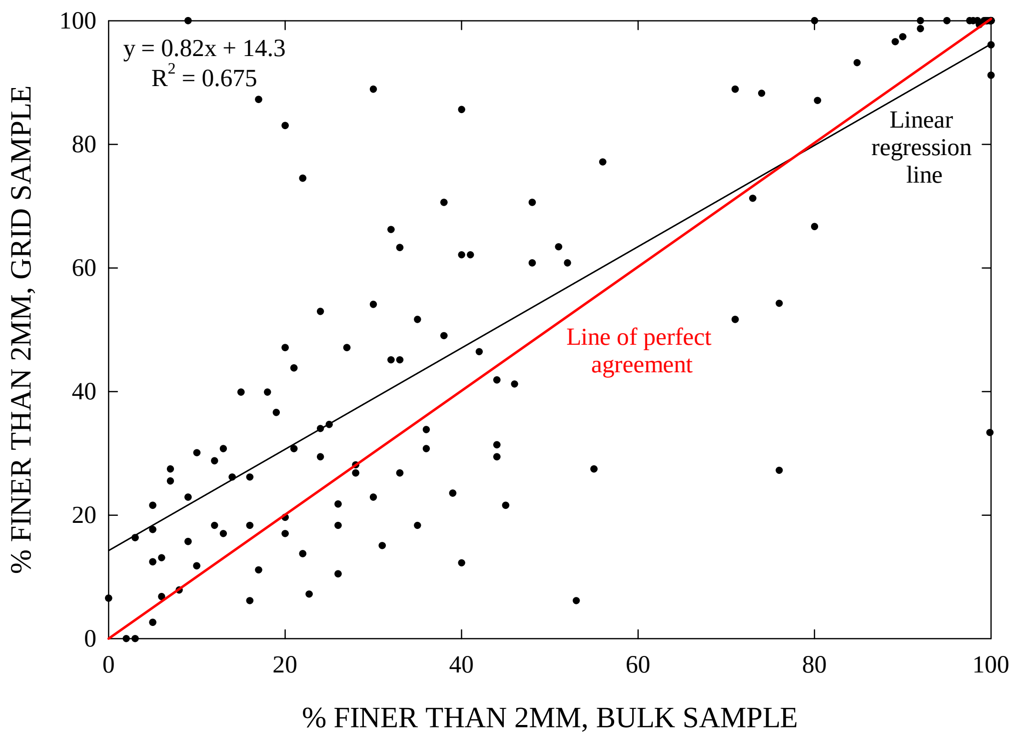

Figure 3.10 – Comparison of percent fines calculated by PC/BS sample and grid method by site (includes data from San Juan River, Animas River and tributaries sampled)

The Animas River shows comparatively less fines in the bed than the San Juan River (Figure 3.11). The mean percent fines values for all Animas sites is 24.5 % compared with 39.5 % for those on the San Juan. The absolute (unsmoothed) results of the PC/BS and grid methods correspond closely without using a running average, except around Estes Arroyo where the grid sample produces much higher percentages. This is attributed to fines from Estes Arroyo smothering underlying coarse material, and therefore, appearing as higher proportions when the bed surface is analyzed using the grid. The median bed material size of study sites sampled on the Animas River falls in the coarse gravel / boulder classes (Figure 3.12).

The results of bed-material sampling and analysis show distinct trends in fine-grained composition that can be related to the delivery of large quantities of fine sediment from tributaries, particularly Cañon Largo. Reach 2, between the Animas River and Cañon Largo confluences, shows the highest percentages of fine-grained sediments of either San Juan or Animas Rivers. This pattern raises a series of questions as to whether these conditions are responses to recent changes in streamflow or sediment delivery to the river.

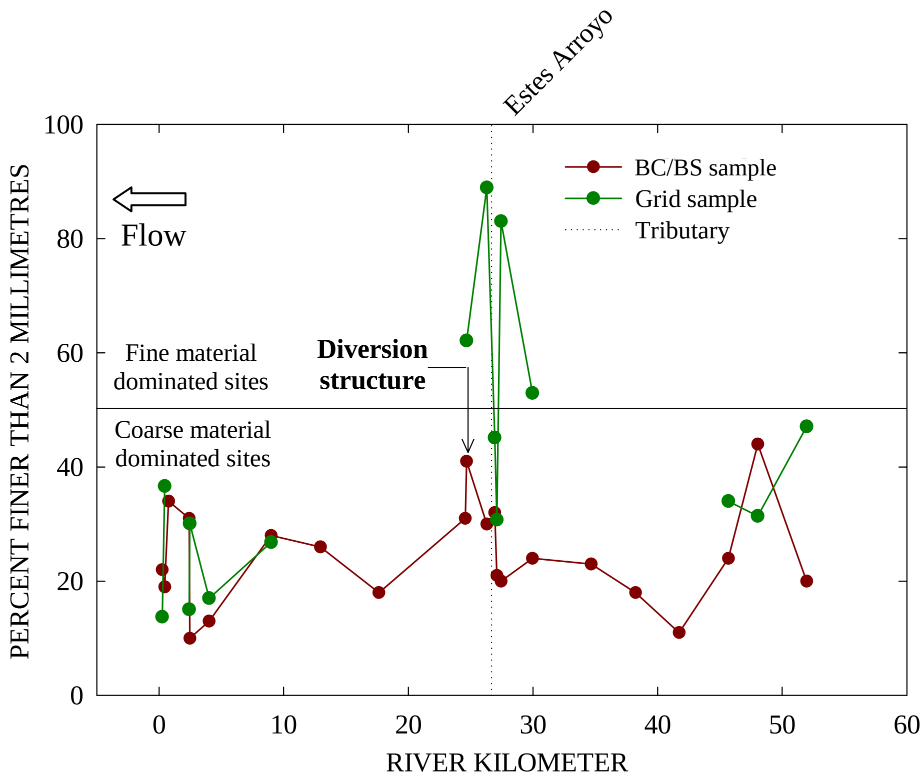

Figure 3.11 - Bed material percent fines on the Animas River by rkm: comparison of methods

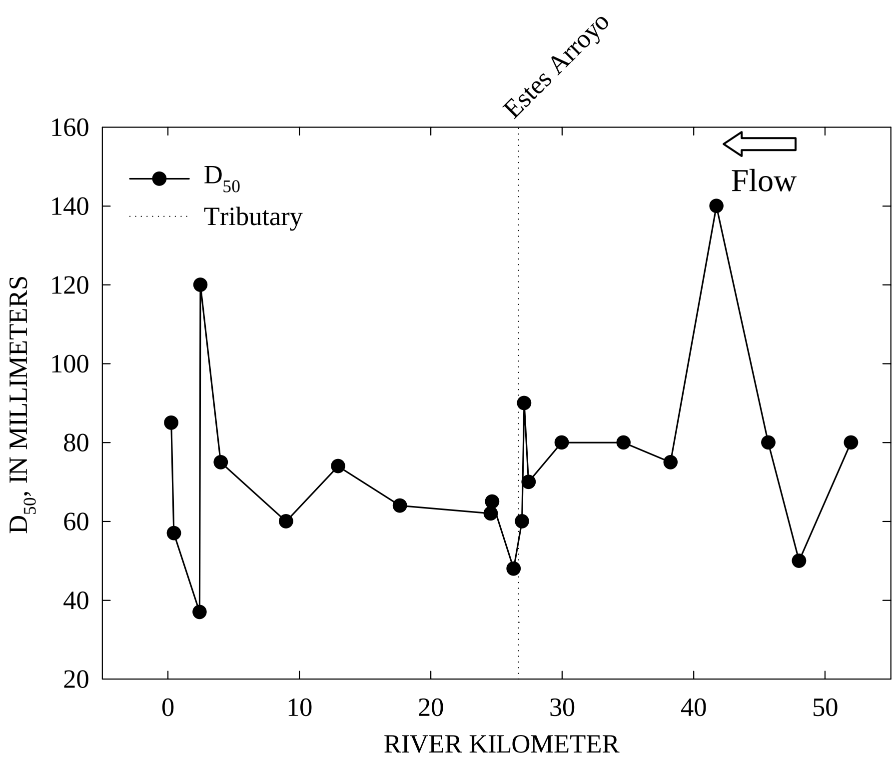

Figure 3.12 – D_{50} long profile of the Animas River

3.3 Pre and Post Dam Hydrological Analysis

In an attempt to address issues related to changes in flow and sediment-transport regimes that could be related to bed-material conditions along the San Juan and Animas Rivers, historical flow and sediment-transport data were obtained from the U.S. Geological Survey. These data were analyzed in the context of comparing pre- and post-dam conditions.

3.3.1 Peak Flow Analysis

As one would expect, annual peak discharges for the gaging stations at Archuleta and Farmington over the period of record show distinct changes after 1962 when Navajo Dam began operations (Figures 3.13 and 3.14, and Table 3.1). As with similar structures, the purpose of Navajo Dam is to reduce the threat of damaging floods and to provide baseflow levels sufficient for irrigation and diversion. At Archuleta, peak flows decreased substantially following dam construction, by an average of 61%. A similar pattern is also evident at the Farmington gage, however, this reduction is less than that at Archuleta due to flow inputs from the unregulated Animas River (49% reduction in mean value).

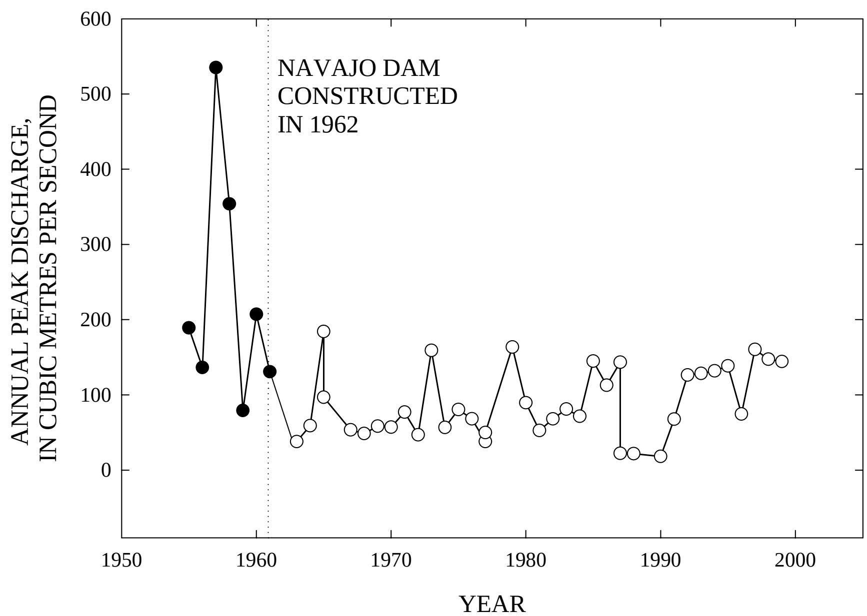

Figure 3.13 – Annual peak flow at 09355500 (San Juan River near Archuleta), prior to and following construction of Navajo Dam

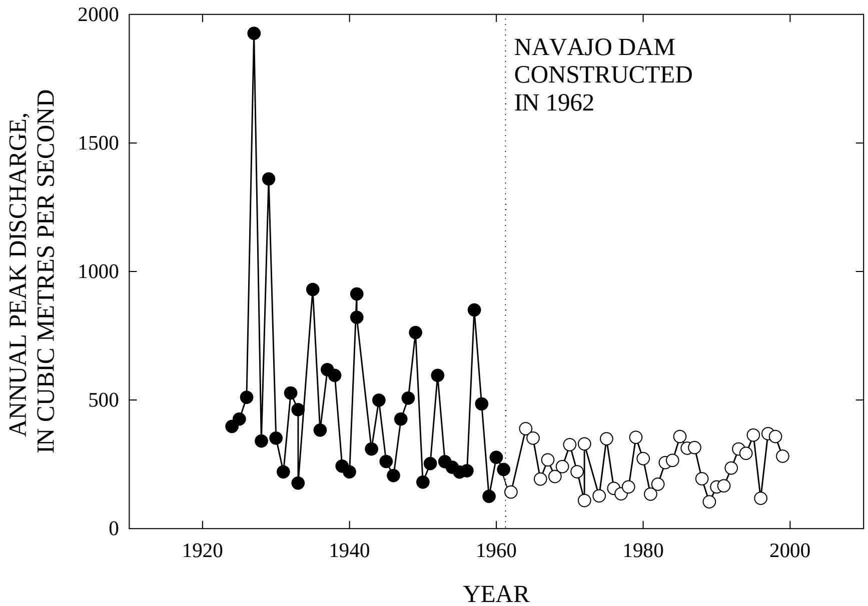

Figure 3.14 – Annual peak flow at 09365000 (San Juan River at Farmington), prior to and following Navajo Dam construction

Table 3.1 – Pre- and post-dam annual peak-flow summary

Flow variable	**USGS gaging station**	
	09355500 San Juan River near Archuleta	**09365000 San Juan River at Farmington**
Dates of peak flow data	1955 – 1999 (45 years)	1924 – 1999 (75 years)
A. Overall mean annual peak flow	114	364
Standard error of A dataset	13.6	32.7
B. Mean pre-dam annual peak flow	233	482
Standard error of B dataset	60.1	58.1
C. Mean post-dam annual peak flow	88.7	245
Standard error of C dataset	7.64	14.7
Percentage change pre-post dam	- 61%	- 49%

Recurrence interval series generated on the basis of annual peak flow data are compared in Tables 3.2 and 3.3. $Q_{1.5}$ is often considered to be approximately equivalent to the effective or channel-forming discharge (Simon *et al*, 2004), or that discharge that transports the most sediment over the long term. The post-dam $Q_{1.5}$ was less than half of the pre-dam value at the Archuleta gage, indicating that the capacity of the San Juan River to transport sand and coarser sediment was greatly reduced following dam construction. This, however, must be balanced with the knowledge that considerably less sediment is emanating from the San Juan River upstream of Archuleta because of the dam. Discharges for other recurrence interval flows at this gage show a reduction of between 57 and 72 % for the pre- and post- dam periods. It should be pointed out the duration of pre- and post-dam data varies considerably, therefore the standard error has for each dataset has been added to Table 3.1 for comparison purposes.

Table 3.2 – Pre and post dam recurrence-interval flows for 09355500 (San Juan River near Archuleta)

Recurrence interval	Discharge, in cubic meters per second			Pre to post dam % reduction
	All data	Pre dam (1955 - 1961)	Post dam (1962 – 2002)	
1.01	17.2	51.7	14.7	72
1.11	36.6	87.8	34.3	61
1.5	67.1	143	61.7	57
2	90.6	187	80.2	57
2.33	102	209	88.8	58
5	162	328	126	61
10	220	452	156	65
20	283	598	184	69

At 09365000 (Farmington), flows for specified recurrence intervals are also shown to have reduced between prior to and following dam construction (Table 3.3), although the change in magnitude is less than at 09355500 (Archuleta). This gage is located almost 80 km downstream on the dam, and several significant tributaries have joined the San Juan River before this gage, most notably the Animas River (drainage area of 3520 km^2).

Table 3.3 – Pre and post dam flow recurrence interval data for 09365000 (San Juan River at Farmington)

Recurrence Interval (years)	Discharge, in cubic meters per second			Pre to post dam % reduction
	All data	Pre dam (1955 - 1961)	Post dam (1962 – 2002)	
1.01	103	119	77.5	35
1.11	150	187	133	29
1.5	224	292	197	33
2	282	374	234	37
2.33	313	418	251	40
5	476	645	321	50
10	652	887	373	58
20	865	1180	419	64

3.3.2 Mean Annual Flows

Mean daily flow data were averaged by calendar year to generate the average-annual discharge for the two long term gaging stations along the San Juan River: 09355500 and 09365000. Daily flows at Archuleta varied tremendously; between 9.1 m^3/s (in 1963) and 72.1 m^3/s (in 1985), with an overall mean value of 33.6 m^3/s (Figure 3.15). Post-dam values were, on average, 4.6 % below those before the dam was constructed. Similar patterns were shown for the gage at Farmington where post-dam flows were 10.3 % less than those pre-dam, with values varying between 20.4 and 163 m^3/s (Figure 3.16).

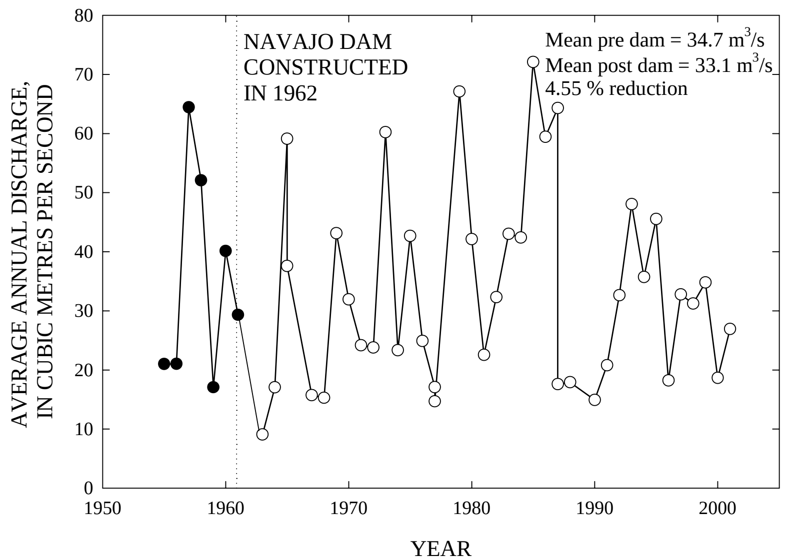

Figure 3.15 – Average daily flow at 09355500 (San Juan River near Archuleta), prior to and following Navajo Dam construction

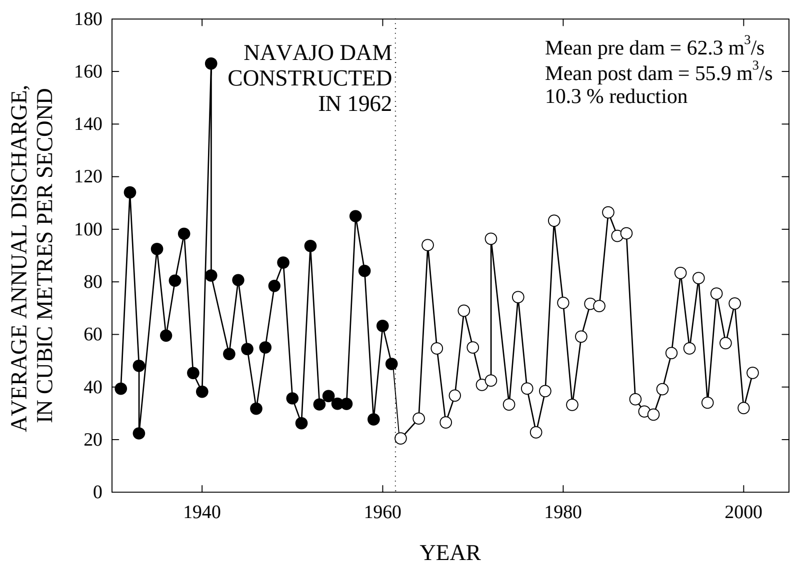

Figure 3.16 – Average daily flow at 09365000 (San Juan River at Farmington), prior to and following Navajo Dam construction

A convenient way to look at potential changes in flow regime is through flow durations curves that describe the percentage of time that given flow is equaled or exceeded. This presents a clear picture of average daily values over the entire range of flows. At both San Juan gage locations the period immediately following dam construction exhibits lower peak flows and higher baseflows (Figures 3.17 and 3.18). In the second post dam period, a slightly better match to pre-dam conditions is met with the occurrence of mid-range flows, but again high-magnitude flows are not achieved. For comparison purposes, an equivalent plot has been added for the gaging station at Farmington on the unregulated Animas River (09364500; Figure 3.19). In this case, although the highest flows occur less frequently in the pre-dam period, the reduction in frequency is of lower magnitude, and there is little change in the frequency of occurrence of mid-range and baseflows.

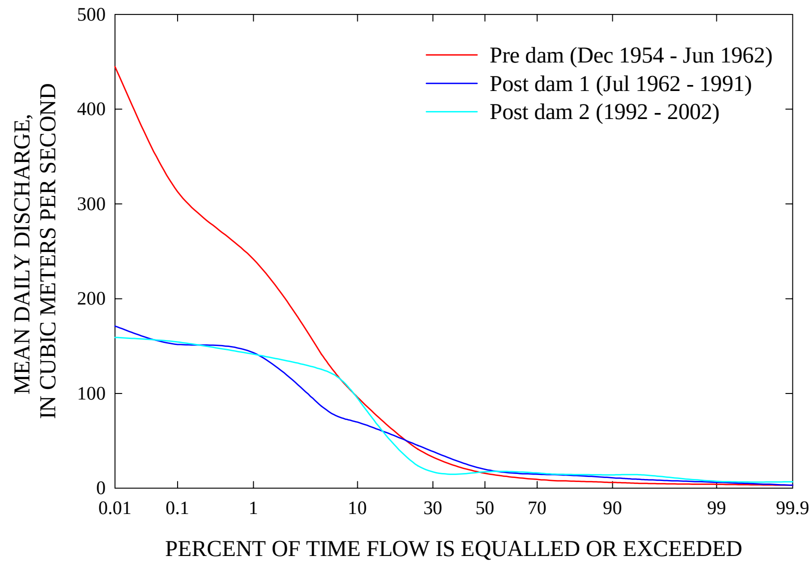

Figure 3.17 – Flow percentage exceedence plot for 09355500 (San Juan River near Archuleta)

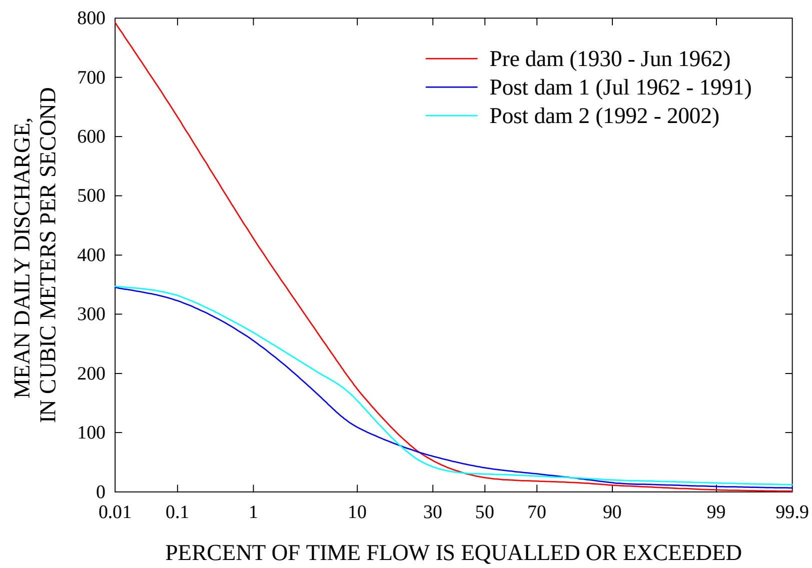

Figure 3.18 – Flow percentage exceedence plot 09365000 (San Juan River at Farmington)

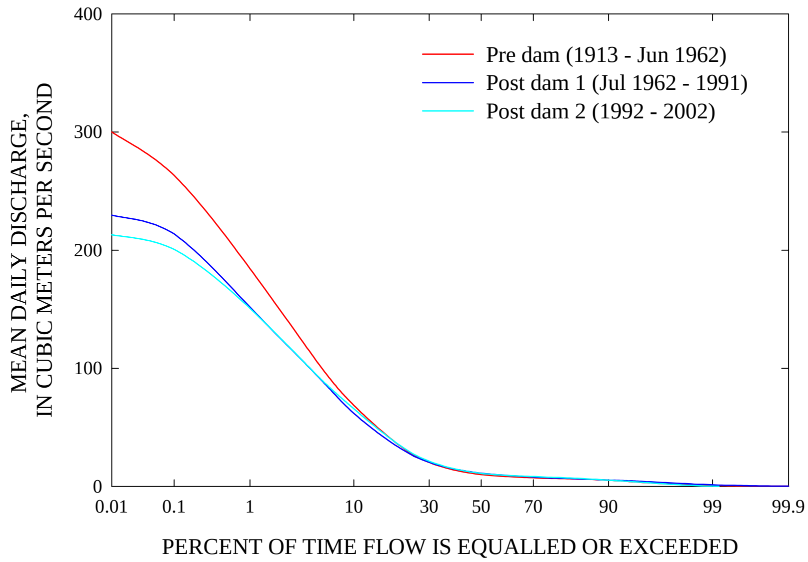

Figure 3.19 – Flow percentage exceedence plot 09364500 (Animas River at Farmington)

3.4 Precipitation

Analysis of the historical precipitation record was conducted to identify trends that might be related to shifts in runoff in the study area. Substantial variation in annual precipitation is evident between years (mean annual precipitation = 250 mm, ranging from 110 mm to 595 mm). A linear regression indicates a slight increase in precipitation during the 73-year period of record (Figure 3.20). On average there has been a 10 % increase in annual precipitation between 1930 and 2003. This trend, however, is not statistically significant.

When examining these data by month, a similar, slightly upward trend can be identified (Figure 3.21). A trendline indicates there has been a slight overall increase in precipitation, however this is masked by scatter in the dataset. The annual precipitation pattern exhibits highest values in August to October, with the lowest values in April to June (Figure 3.22). In summary, assuming rainfall at this gage is indicative of rainfall patterns in the entire study area, there has been no significant change in precipitation inputs to the San Juan River system in the study area. Differences in pre- and post-dam flows are a result of operations at Navajo Dam.

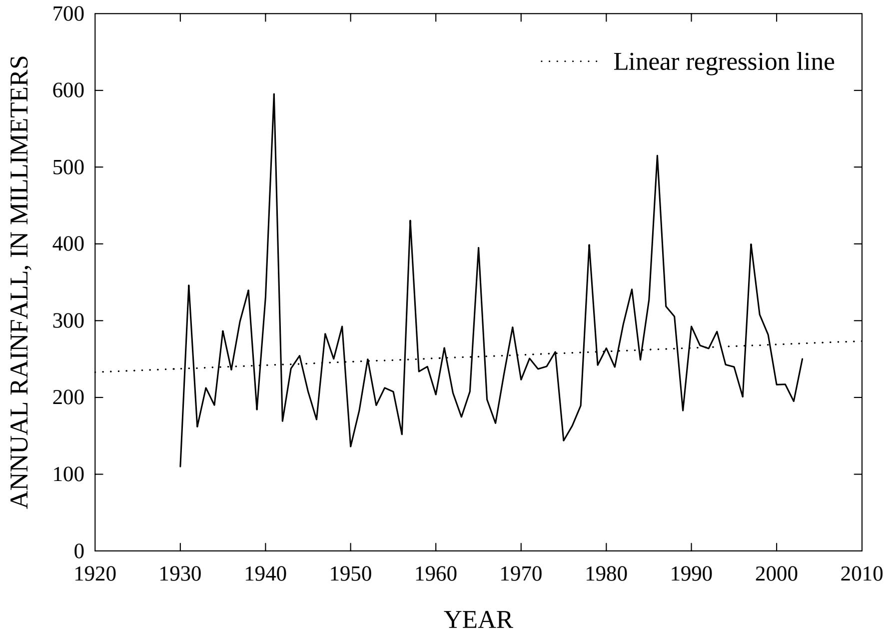

Figure 3.20 – Annual rainfall at Aztec Ruins National Monument (Source: NOAA NCDC)

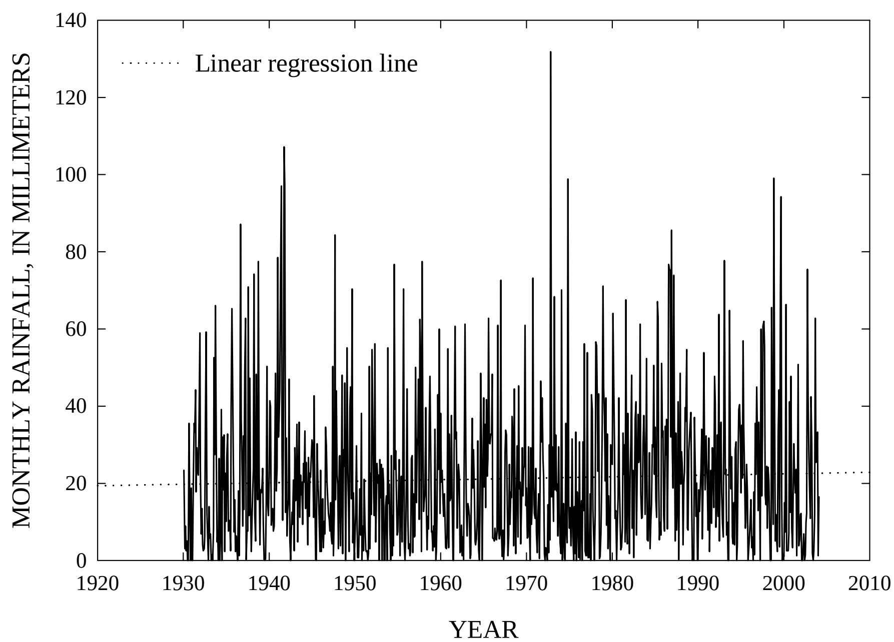

Figure 3.21 – Monthly rainfall at Aztec Ruins National Monument (Source: NOAA NCDC)

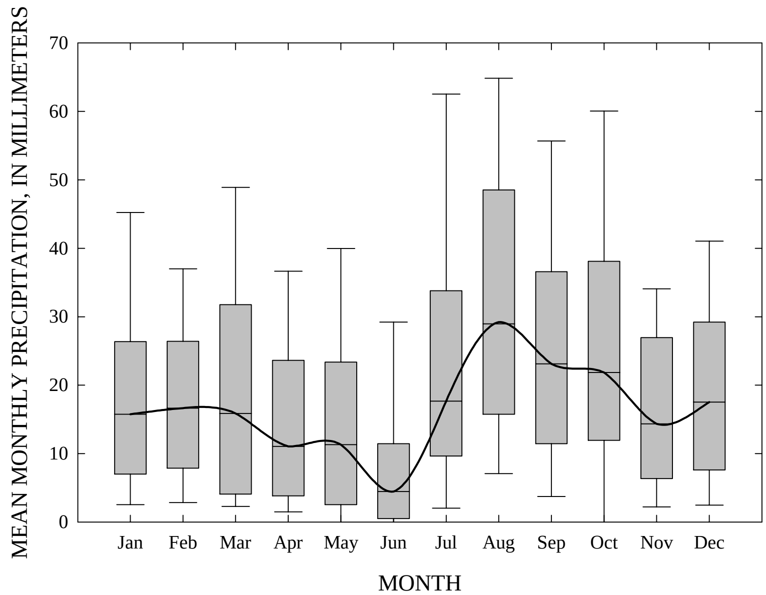

Figure 3.22 – Average Rainfall by month at Aztec Ruins National Monument. Error bars represent standard deviation (Source: NOAA NCDC)

3.4.1 Seasonality of Flows

Mean-daily flow data were divided into three periods; pre-dam, post-dam prior to the flow experimentation period (July 1962 to 1991), and post-dam during the experiment period and continuing to the end of the record (1992 – 2002). Mean-daily flows for each day of the year were calculated for each dataset (Figure 3.23).

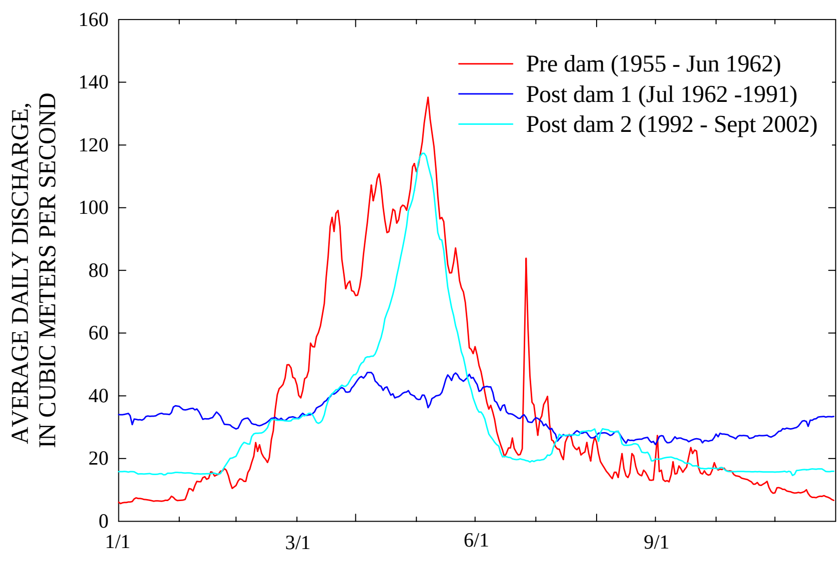

Figure 3.23 – Average annual flow patterns for 09355500 (San Juan River near Archuleta) pre-dam, post-dam prior to flow experimentation and post-dam during flow experimentation dam continuing to present

Prior to dam construction, annual flows peaked between April and June due to snowmelt (average 135 m^3/s), with baseflows during December and January dropping to 6 m^3/s. In the period following dam construction to the commencement of the flow experimentation period, very little seasonal variation is evident in the annual flow regime, with spring snowmelt discharges being heavily attenuated and baseflows being augmented significantly to around 30 m^3/s. In the final period, an attempt was made to restore the snowmelt peak by flow releases from the dam. The peak flow magnitude has almost reached pre-dam conditions, but the duration of peak is much shorter, with intermediate flows occurring for a short percentage of the time. Baseflow during the November to February period was reduced from the period immediately following dam construction to an average of 17 m^3/s. However, this discharge is still nearly twice that of the natural baseflow value.

3.5 Suspended-Sediment Loads

Although considerable variation is evident in daily suspended-sediment loads at the Archuleta gage (09355500), the drastic reduction in loads following dam construction is evident (Figure 3.24), with loads decreasing to 0.8 % of their pre-dam value. It should be noted that in the period of overlapping data, loads reported by USGS differ slightly from those calculated in this study due to the use of 15 minute flow data which were unavailable to the authors of this report.

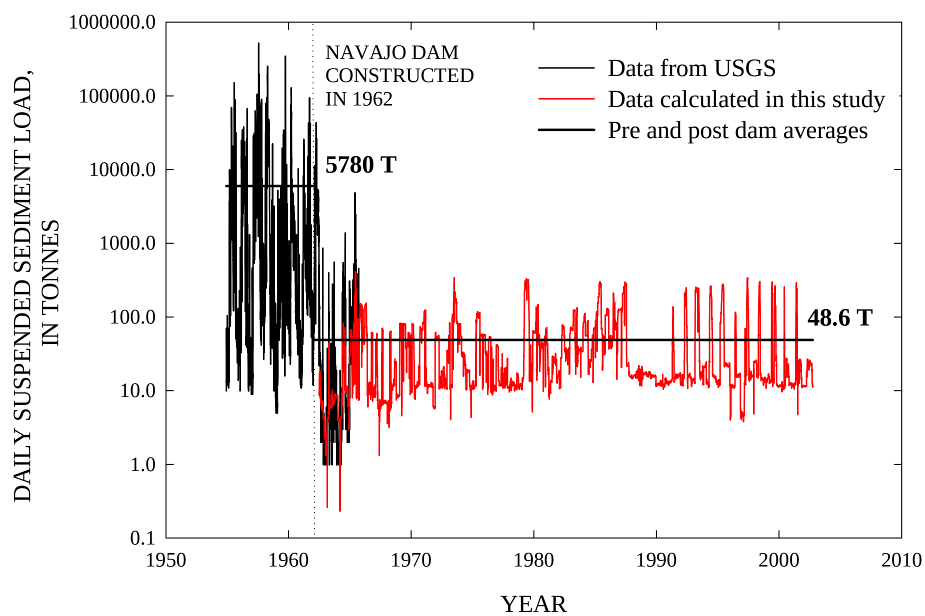

Figure 3.24 – Mean daily suspended load at San Juan River at Archuleta, 1954 - 2002

Daily suspended-sediment load and concentration data were available from the USGS for five additional gages in the study area (Table 3.4). In addition, daily suspended-sediment loads were calculated for the gage on Cañon Largo using the flow and suspended-sediment data from Cañon Largo gage and the methodology employed for the Archuleta gage describe previously. Load values were then normalized by drainage area to calculate suspended-sediment yields, enabling values to be compared independent of drainage area. Mean values for each gage were computed for pre- and post-dam conditions (Table 3.4, Figure 3.25). Unfortunately, due to insufficient data availability, it was impossible to compare a matching data period for pre- and post-dam conditions for all gages; therefore, climatic differences experienced during the period of record for each gage may influence average yield values presented.

Table 3.4 – Mean pre- and post-dam suspended-sediment yields

Gage number	Gage Location	Mean Annual Suspended Yield (tonnes/km^2)	
		Pre Dam	**Post Dam**
09355500	SJR near Archuleta	0.71	0.006
09356500	SJR near Blanco	0.49	No data
09357000	SJR at Bloomfield	1.2	0.18
09368000	SJR at Shiprock	0.73	0.48
09356565	Cañon Largo near Blanco	No data	0.8
09364500	Animas River at Farmington	0.62	0.44

Several important points can be made based on the data in Table 3.4, the most notable being the considerable reduction in mean-annual sediment yields at the San Juan River stations pre- and post-dam. This effect is attenuated with increasing distance downstream from the dam (for example, the gage at Shiprock). It is interesting to note that suspended-sediment yields at Archuleta are in the same range as those at Shiprock, as well as the Animas River at Farmington. The higher yield value for the pre-dam Bloomfield dataset may suggest the influence of Cañon Largo although this value is based on a short dataset. If we assume that sediment delivery from Cañon Largo has not changed drastically since dam construction it is interesting that sediment yield from this watershed is comparable to the pre-dam San Juan as reflected in the data at Archuleta. Interestingly, a 29% reduction in average annual yield was also experienced by the unregulated Animas River.

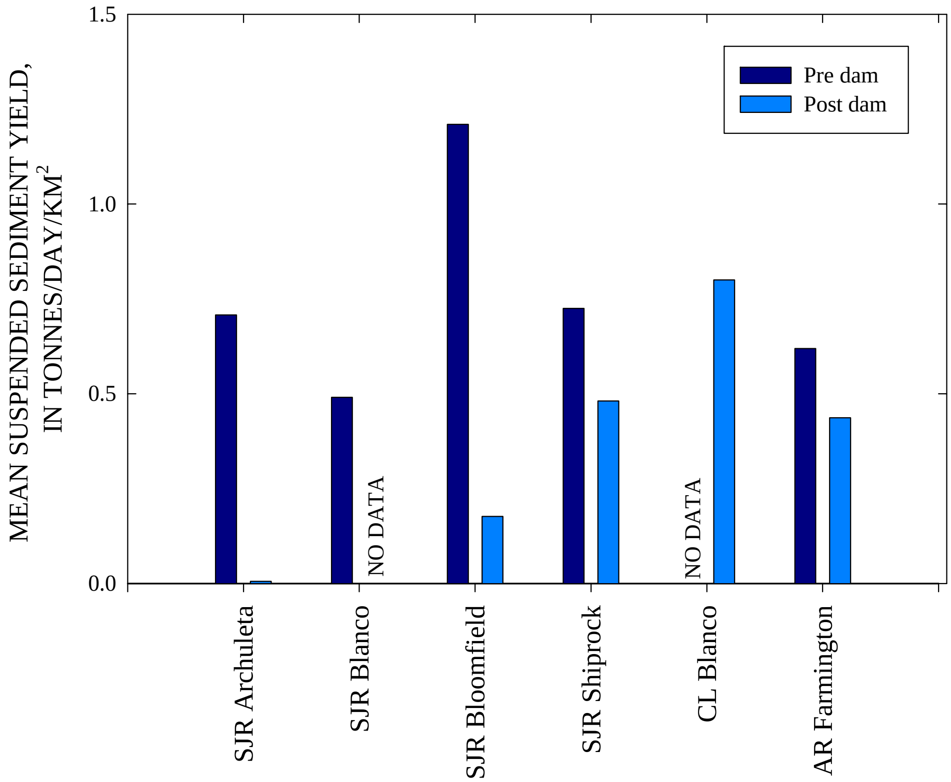

Figure 3.25 - Mean pre- and post-dam suspended-sediment yield histogram

3.6 Pre-Dam Bed Material Data

To ascertain whether current bed-material composition along the study reaches were similar to those of the past, a search of historical bed-material data was undertaken. Data from only two pre-dam bed-material samples were available for USGS gaging stations in the study reaches. These are provided in Table 3.5. Both these samples were taken at the gage at Bloomfield (09357000), and confirm that even prior to dam construction, the bed material of this site was dominated by fine-grained materials.

Table 3.5 – Pre-dam bed material sample data on the San Juan River

Gage Number	Gage Name	Sample Date	Percent finer than 2mm
09357000	San Juan River at Bloomfield	5/24/61	56
09357000	San Juan River at Bloomfield	6/8/61	88

3.7 Ecoregion 22 Suspended-Sediment Analysis

Historical suspended-sediment data from the gaging stations in Ecoregion 22 (Table 2.2) were used to determine relative magnitudes of sediment transport for sites in the study area compared to values throughout the Ecoregion. Sediment-transport data were calculated for the flow that occurs on average, every 1.5 years ($Q_{1.5}$) as this often represents the discharge that transports the most sediment over the long term (Simon *et* *al*., 2004). The distribution of suspended-sediment transport rates are shown in Figures 3. 26 and 3.27; with median concentrations and yields at the $Q_{1.5}$ of 4,140 mg/l and 6.5 T/d/km^2, respectively. Concentrations such as these rank as some of the highest in the nation (Simon et al., 2004) and are not surprising given the large quantities of available sediment and flashy nature of runoff events. Suspended-sediment yields are, however, intermediate at the national scale because of the general lack of precipitation in the semi-arid southwest.

Results of Rapid Geomorphic Assessments in Ecoregion 22 established which sites were stable and which were unstable (Appendix F), permitting data to be divided into stable (stages I and VI) and unstable (stages III, IV and V) categories. In addition, mean annual loads and yields were calculated for sites in Ecoregion 22 using mean-daily flow data and suspended-sediment rating curves developed for each site. Data were then sorted by calendar year, and values divided by drainage areas to produce annual yields.

"Reference" suspended-sediment concentration and yield values were defined as the median value for stable sites within the dataset, with the range of reference values being between the first and third quartiles (Figure 3.28 and 3.29, Table 3.6). Values for unstable sites are observed to be consistently higher than those for stable sites, due to additional sediment supply from unstable channels and other sources.

Suspended sediment transport rates at $Q_{1.5}$ are shown for all sites in Table 3.7. Note that the four of the five sites within the San Juan River study area (in bold) have suspended-sediment yields in excess of the median value for stable sites in the Ecoregion. Values for the Animas River at Farmington (09364500) and the San Juan River at Shiprock (09368000) fall within the same order of magnitude as the reference. Suspended-sediment yield values for the La Plata River (09367500) and Cañon Largo (09356565) are one, and two orders of magnitude greater, respectively and further supports the bed-material evidence that Cañon Largo is the major source of fine sediment. Suspended-sediment yield and concentration values at $Q_{1.5}$ for the San Juan River at Archuleta (09355500) are anomalously low due to sediment trapping by Navajo Dam.

Table 3.6 – Suspended-sediment concentration and yield reference values for Ecoregion 22

Quartile	Values for stable sites in Ecoregion 22	
	Concentration, in mg/l	**Yield, in T/d/km^2**
25th percentile	294	0.32
Median	**1800**	**1.3**
75th percentile	25300	17.3

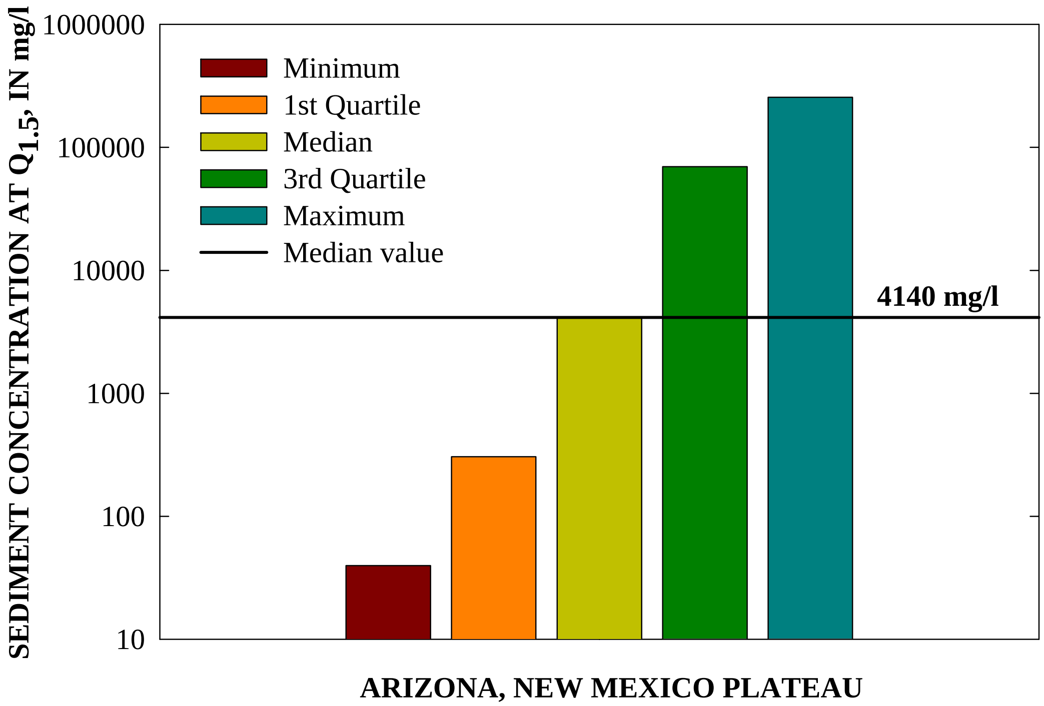

Figure 3.26 – Histogram of suspended-sediment concentrations at the $Q_{1.5}$ for all sites in Ecoregion 22.

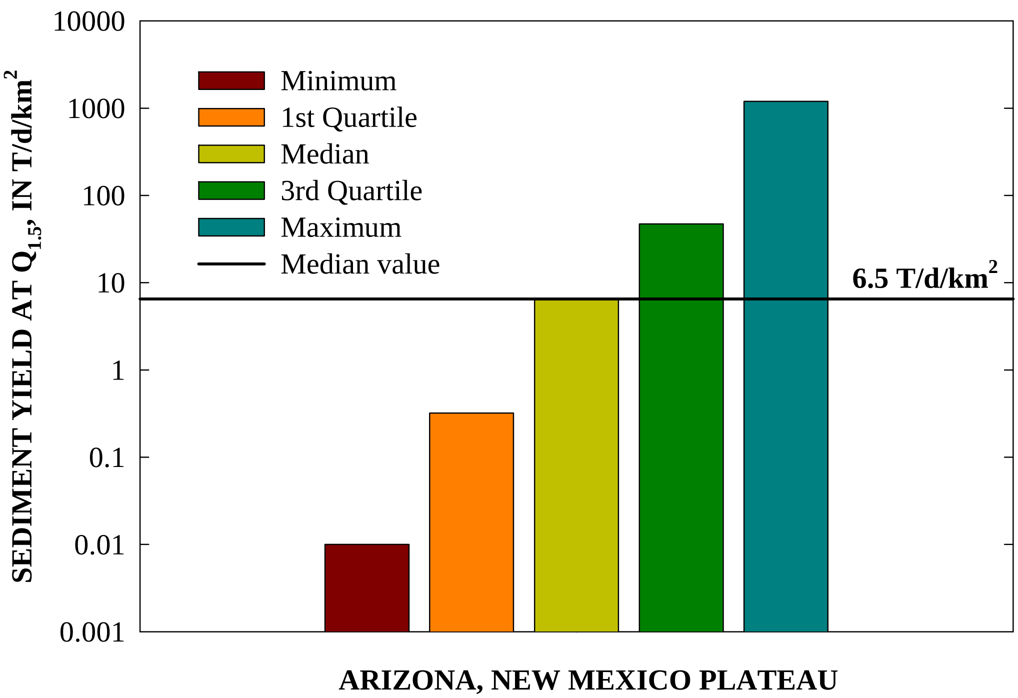

Figure 3.27 – Histogram of suspended-sediment yields at the $Q_{1.5}$ for all sites in Ecoregion 22.

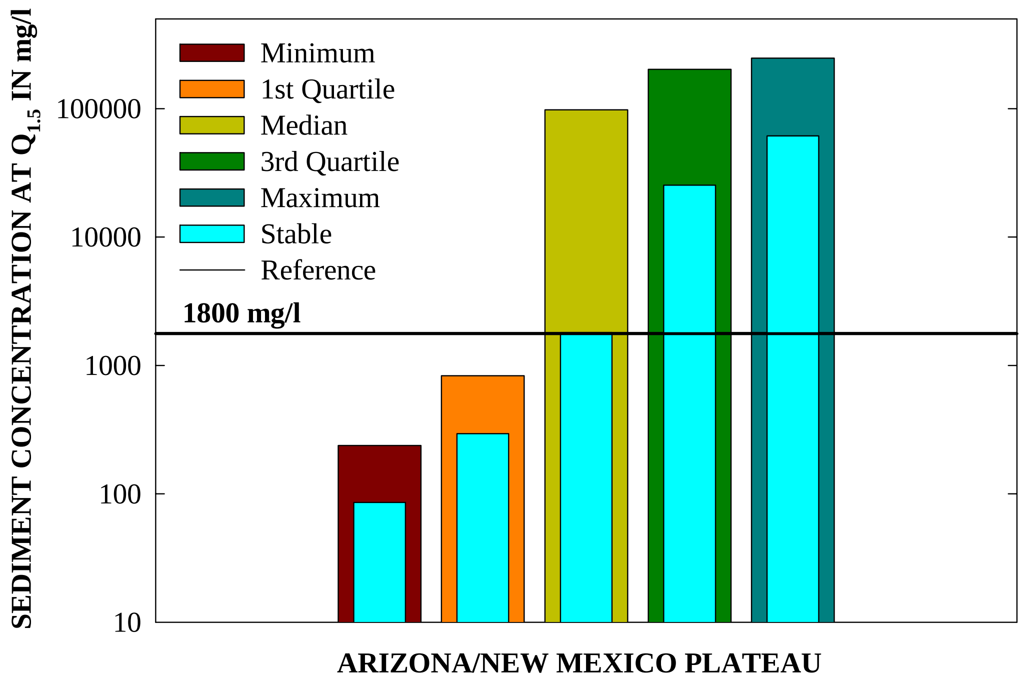

Figure 3.28 – Histogram of concentration at the $Q_{1.5}$ for stable and unstable sites in Ecoregion 22.

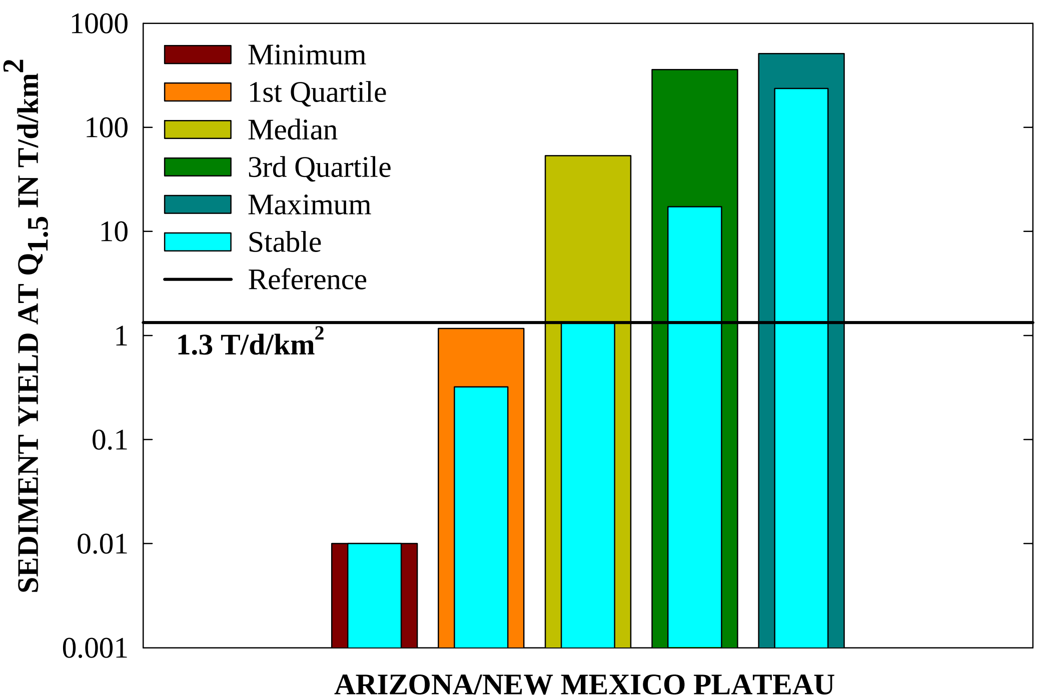

Figure 3.29 – Histogram of suspended-sediment yields at $Q_{1.5}$ for stable and unstable sites in Ecoregion 22.

Table 3.7 – Ecoregion 22 suspended-sediment load, yield and concentration at $Q_{1.5}$. Data are in ascending order of suspended-sediment yield. Note: a = dam effected sites; b = insufficient peak flow data; sites shown in **bold** are within the San Juan River study area.

State	Gage number	$Q_{1.5}$ (m^3/s)	Load at $Q_{1.5}$ (T/d)	Yield at $Q_{1.5}$ ($T/d/km^2$)	Concentration at $Q_{1.5}$ (mg/l)
NM	08317400	104	220	0.006	24.5
NM	08263500	36	194	0.009	62.3
NM	08343500	3	70.2	0.012	271
NM	**09355500**	**67**	**103**	**0.012**	**23.1**
CO	08251500	52	281	0.014	62.5
NM	08276500	66	646	0.026	113
NM	08276300	13	41.0	0.042	36.5
NM	08287000	48	252	0.045	60.8
NM	08267500	4	4.74	0.051	13.7
NM	08319000	156	3300	0.079	245
CO	08220000	119	689	0.201	67.0
NM	08265000	5	74	0.253	171
NM	09386950	11	694	0.316	730
NM	08330000	145	14600	0.324	1170
NM	08255500	6	188	0.372	362
NM	08290000	82	3100	0.381	437
NM	08266820	8	218	0.457	316
NM	08313000	163	17100	0.462	1220
NM	08324000	30	685	0.563	264
AZ	09402500	1070	256000	0.698	2760
NM	08286500	77	4250	1.03	638
CO	09366500	14	1000	1.17	829
REFERENCE YIELD = 1.3 $T/d/km^2$					
CO	09363500	135	4620	1.64	396
NM	**09368000**	**241**	**115000**	**3.45**	**5530**
AZ	09401000	162	286000	5.24	20400
AZ	09402000	150	532000	7.77	41000
NM	**09364500**	**138**	**28500**	**8.10**	**2390**
NM	**09367500**	**26**	**16700**	**11.1**	**7430**
NM	09367660	2	2310	15.1	13400
AZ	09403000	8	4700	18.0	6800
NM	09367680	10	33400	22.3	38700
NM	09367561	2	4660	24.4	27000

AZ	09394500	79	521000	24.9	76300
NM	09367950	76	300000	26.6	45700
AZ	09397300	159	1380000	43.0	100000
NM	08353000	62	857000	45.0	160000
NM	08383000	120	312000	45.4	30000
NM	08317950	24	80000	51.7	38600
NM	09367938	83	504000	53.4	70200
NM	08329900	80	18800	82.5	2720
NM	08352500	136	2380000	139	202000
NM	08354000	128	1260000	353	114000
NM	**09356565**	**84**	**1580000**	**359**	**218000**
NM	08340500	86	2080000	577	280000
NM	08334000	37	629000	578	197000
NM	09367710	35	296041	625	97900
AZ	09396100	109	3570000	639	379000
NM	09367930	17	120000	1020	81600
NM	09367685	11	66000	3100	69400
GAGES WITH INSUFFICIENT DATA					
AZ	09401200	a	a	a	a
AZ	09403850	a	a	a	a
AZ	09404120	a	a	a	a
NM	08266500	a	a	a	a
NM	08266790	a	a	a	a
NM	08266800	a	a	a	a
NM	08267400	a	a	a	a
NM	08331000	a	a	a	a
NM	08331990	a	a	a	a
NM	08332010	a	a	a	a
NM	**09357100**	**a**	**a**	**a**	**a**
NM	**09367540**	**a**	**a**	**a**	**a**
NM	09367683	a	a	a	a
NM	08317200	b	b	b	b
NM	08379500	b	b	b	b
NM	08382650	b	b	b	b
NM	08383500	b	b	b	b

Reference values for annual yields are calculated using a method similar to those for $Q_{1.5}$. The median annual yield value for stable sites is 48.5 T/km^2, with the interquartile range spanning from 11.5 T/km^2 to 85.3 T/km^2 (Figure 3.30, Table 3.8). The values for each quartile again are vastly greater for unstable sites than stable sites.

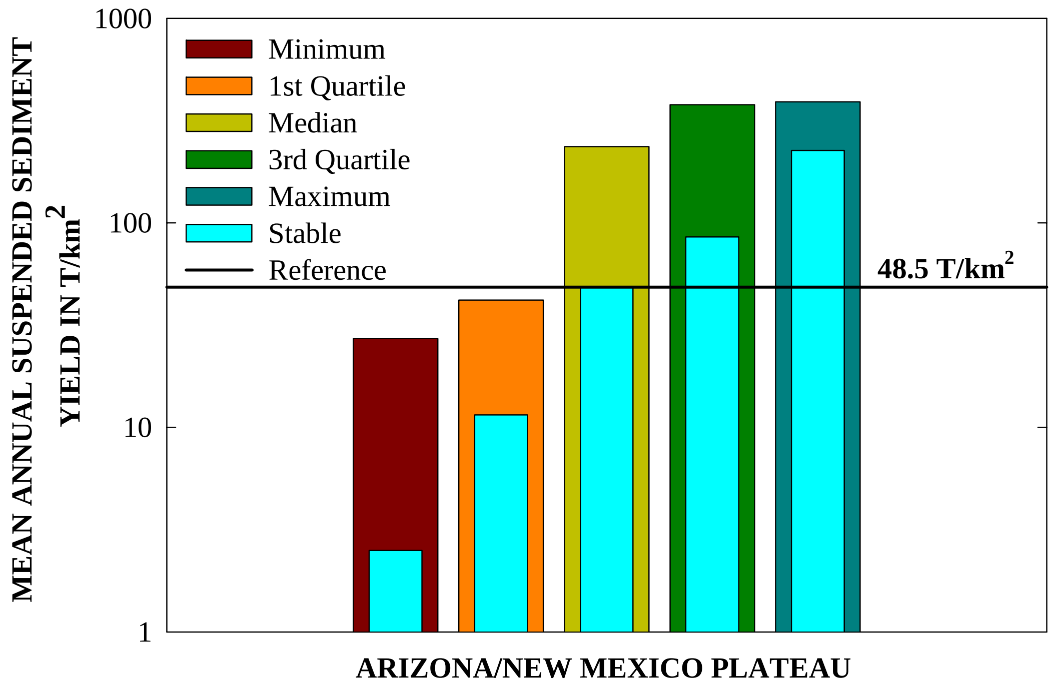

Figure 3.30 - Histogram of annual suspended-sediment yields for stable and unstable sites in Ecoregion 22

Table 3.8 – Annual suspended-sediment yield for Ecoregion 22

Quartile	Annual yield in T/y	
	Stable sites	Unstable sites
25th percentile	11.5	42
Median	**48.5**	236
75th percentile	85.3	378

4 DISCUSSION

4.1 Bed-Material Reference Values

Bed-material reference values for coarse-material dominated sites (greater than 50% coarser than 2 mm) were developed using PC/BS data. The reference value was defined as the median percentage of bed sediment finer than 2 mm for channels considered to be stable using the Channel Evolution Model (CEM; Figure 2.6), with sites within 5 km of dams being removed. Reference values are presented for two datasets (Table 4.1; Figure 4.1 and 4.2):

1. Large southwestern rivers (data from the San Juan River and Animas Rivers).
2. Ecoregion 22 sites (data from all USGS gaging stations investigated in the Arizona / New Mexico Plateau).

Additional reference values have been calculated for the San Juan River and Animas River in isolation to compare bed-material characteristics of stables channels in a regulated and unregulated system (Table 4.1). The calculated reference value for stable, coarse-dominated sites over the five designated reaches listed as impaired on the San Juan and Animas Rivers on the New Mexico 303-D list is 20.5 %. This is 5.5 % greater than the value for locations meeting reference criteria in Ecoregion 22.

Table 4.1 – Reference bed sediment values (stable coarse-bed channels)

Dataset	Percent finer than 2 mm		
	25th percentile	Median (reference)	75th percentile
San Juan and Animas Rivers	12.8	**20.5**	29.5
San Juan River (R1, R2, R3)	11.5	20.0	28.5
San Juan River (R1, R2)	21.0	26.0	33.0
Animas River (R4, R5)	19.3	22.5	29.5
Ecoregion 22	0.25	**15.5**	21.5

The percentage of bed material finer than 2 mm for coarse-bed study sites varies considerably by reach (Figure 4.3). This plot is produced using data from all sites in each, not just those with greater than 50% coarse material (used to define reference conditions). The center-line of each box represents the distribution median value, the top and bottom edges show the 1st and 3rd quartile values, and the whiskers extending from the box are the 10th and 90th percentile values. Reach 3 (Navajo Dam to Cañon Largo) possesses a substantially lower percentage of bed material finer than 2 mm than other reaches, due to the sediment barrier effects of the dam.

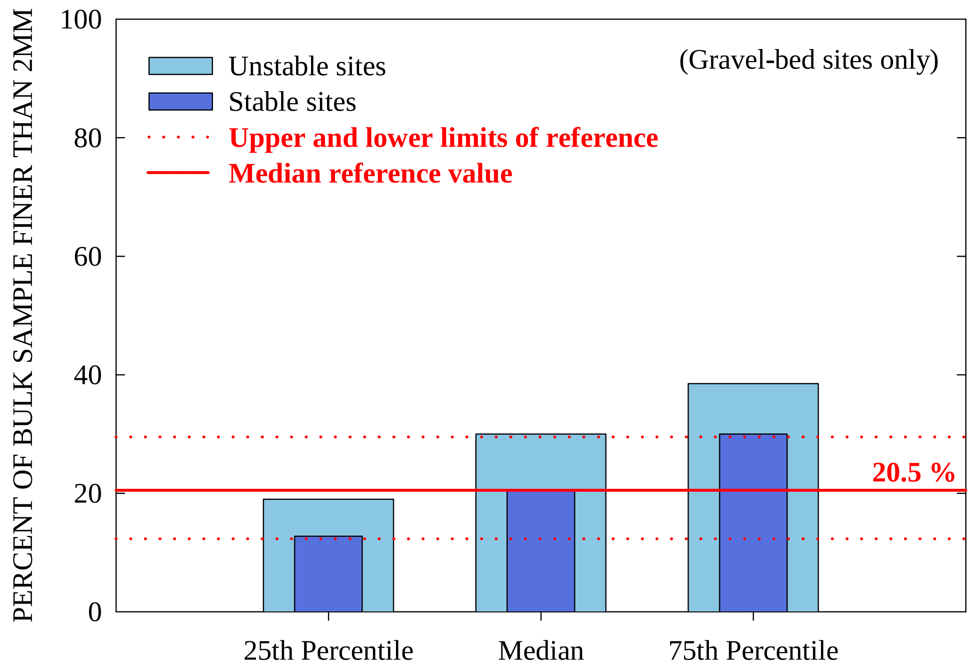

Figure 4.1 – Histogram of reference bed material finer than 2 mm for coarse bed streams in the San Juan and Animas Rivers

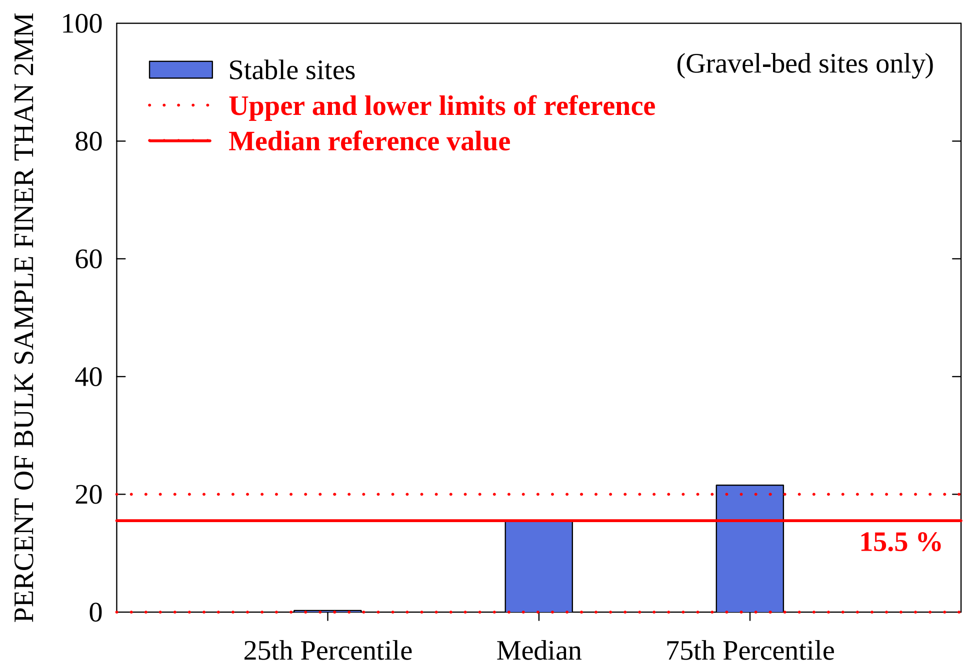

Figure 4.2 - Histogram of reference bed material finer than 2 mm for coarse bed stream in ER22

It could be disputed whether the sites most affected by the dam should be used in calculation of the reference to be applied to the whole Southwest. For comparison purposes, calculations were repeated for the San Juan and Animas Rivers dataset, excluding all sites in Reach 3 (a total of 24 sites). The resultant percentages of fines for the first quartile, median and third quartiles were 20.0%, 24.0% and 32.5%, respectively. Excluding data over this 33 km reach increased the overall reference (median value) slightly by 3.5%, from 20.5% to 24.0%. However, despite possible bias being introduced into the reference dataset from inclusion of sediment-starved reach 3 sites, as dams are a common feature of this region, it is proposed that the reference conditions for the San Juan and Animas Rivers should include sites in Reach 3 beyond 5 km from the dam, and the reference value of 20.5% be used. This ensures consistency in the analysis methodologies adopted for both Ecoregion 22 and the San Juan and Animas Rivers dataset.

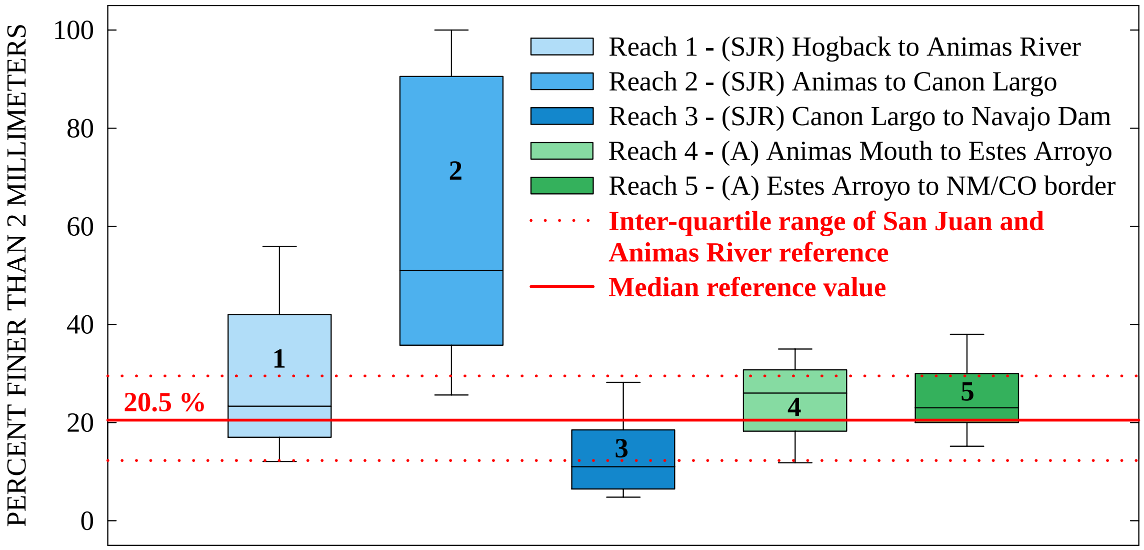

Figure 4.3 – Percent fines box plots for all study sites by designated reach. Reference value provided is the median value for all stable sites.

4.2 <u>Source of Fine Sediment in the San Juan River</u>

At the outset of this study, it was hypothesized that Cañon Largo was the major source of fine sediment in the study reach of the San Juan River. Several types of data collected in this investigation support this.

4.2.1 Long Profile of Percent Fines

The percent of PC/BS sample finer than 2 mm was plotted by river kilometer to examine the variation in bed material fines over the study reach. The long section shows a sharp increase in fines in the vicinity of Cañon Largo peaking at Armenta, and sustaining at this level until Gallegos, where it peaks again then drops quite rapidly (Figure 3.6). When raw data are scrutinized the unsmoothed percent fines values just upstream of the Cañon Largo confluence are also higher than the rest of the study reach. No other tributary confluence is present at this location, indicating the extremely wide mouth of Cañon Largo may divert some flow in an upstream direction on the San Juan River when its water level is higher than that of the San Juan. Peaks in percent finer than 2 mm correspond with a reduction in the D_{50} value (Figures 3.1 and 3.2).

Additional peaks of fine material in the substrate were observed at the location of the other tributaries, including Kutz Canyon, Gallegos Canyon and La Plata River (Figure 3.1). These peaks were generally smaller in magnitude than that from Cañon Largo and extend for a shorter distance downstream, indicating comparatively less fine material contributed.

4.2.2 Study Area Reconnaissance

Five rapid geomorphic assessments were carried out on Cañon Largo itself. All sites surveyed were classified as stage V channels (Appendix B3). At the time of field assessment this several hundred meter wide channel had no flow. Common observations at these sites include high proportions of failing banks and visible aggradation on the bed (Appendix B3). Photographs included in Figure 4.4 illustrate this more clearly. These observations would indicate that during sporadic periods of high flow in this ephemeral channel, a large supply of fine sediment is available for transport into the San Juan River.

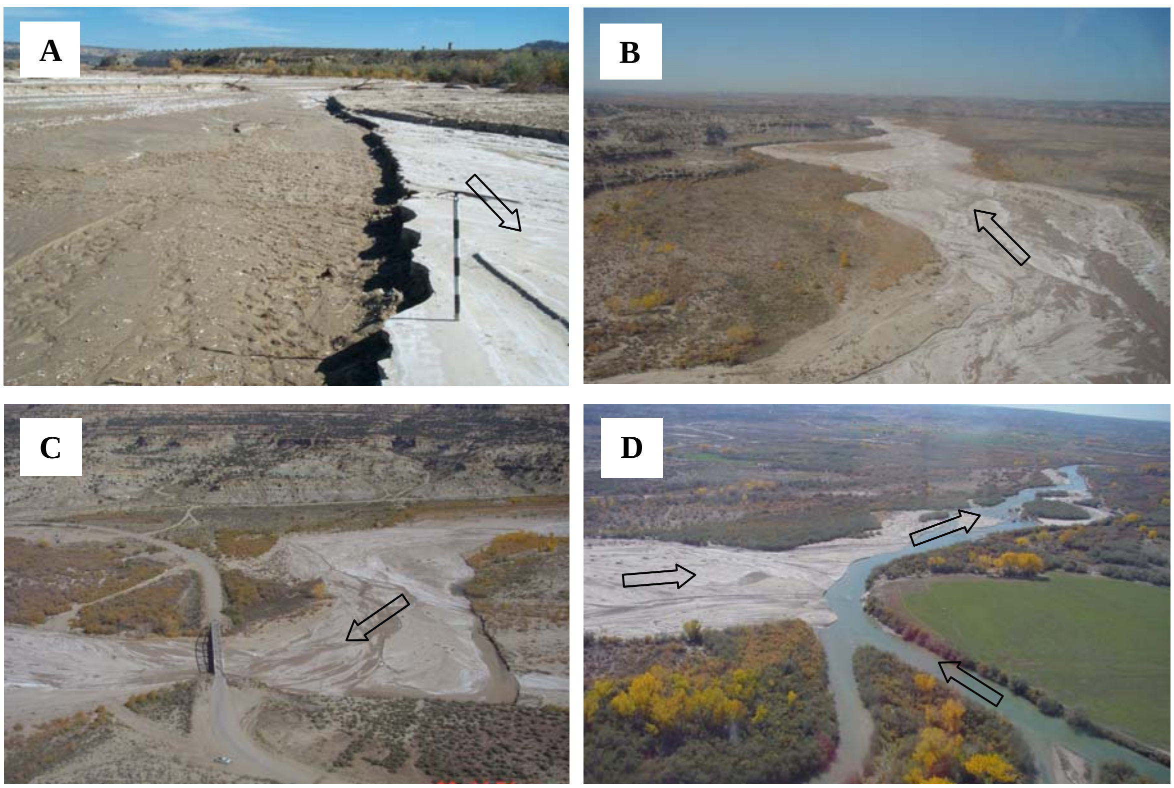

Figure 4.4 – Aerial and ground photographs of Cañon Largo
A. View upstream on Cañon Largo from near confluence with San Juan River
B. Cañon Largo looking in downstream direction
C. Cañon Largo Bridge near USGS gage
D. Cañon Largo mouth on San Juan River

For comparison purposes, Figure 4.5 presents aerial photographs of several other tributaries of the San Juan River. Examination of the proportion of bed-material fines long profile has indicated the Animas River contributes a minimal amount of fine sediment to the San Juan River. Figure 4.5A shows the mouth of this tributary, where some sand has been deposited as flow velocity on the Animas reduces to below the settling velocity of suspended load. Most striking about the photograph however is the sharp disparity in turbidity levels between the flow in San Juan and Animas Rivers, with apparent turbidity being much higher in the former than the latter. Gallegos, La Plata and Kutz Canyons (Figure 4.5 B, C and D respectively) have been shown to produce substantial increases in fine material in the substrate of the San Juan River, which is clearly shown in the confluence photographs.

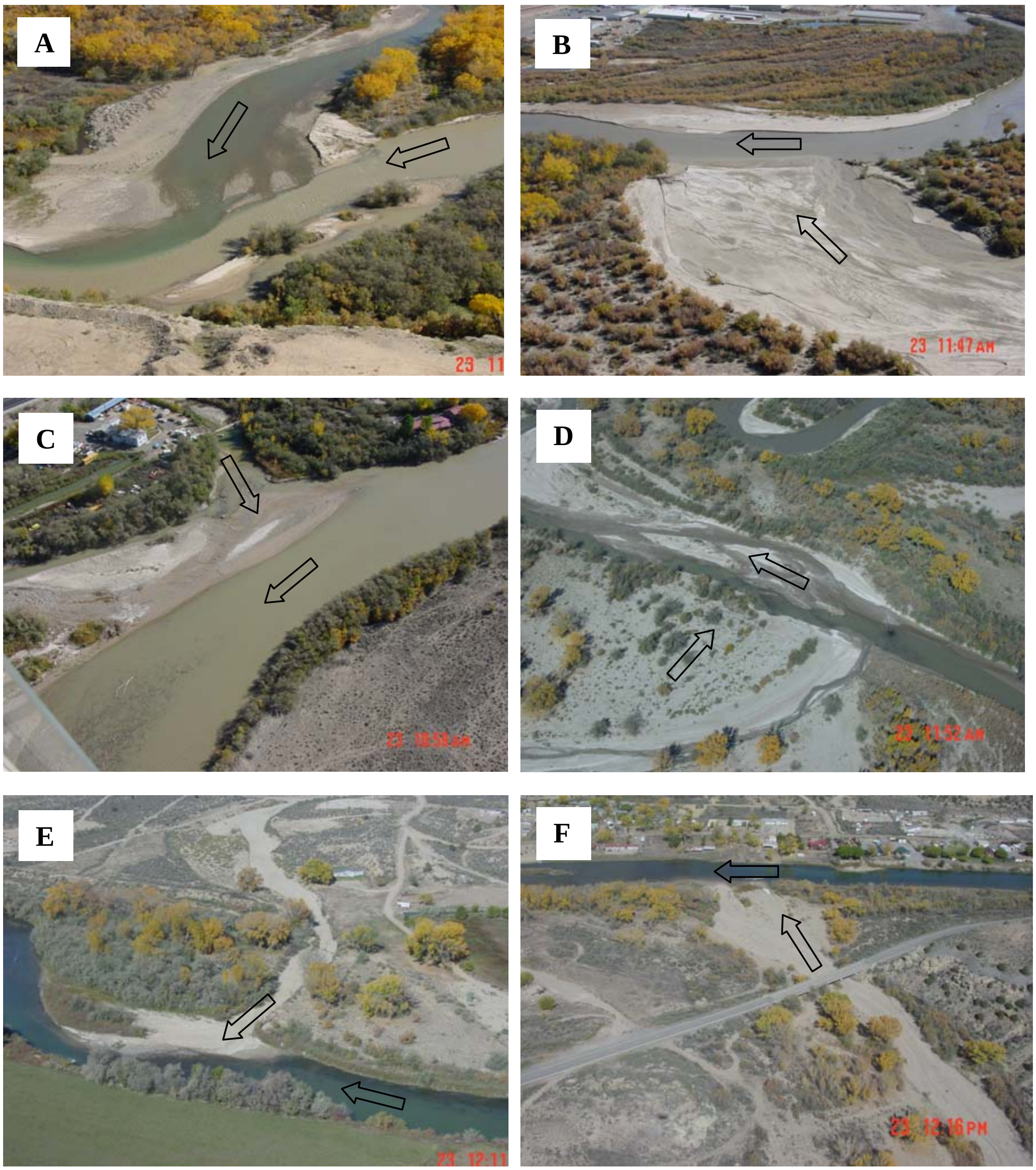

Figure 4.5 – Aerial photographs of tributary confluences on the San Juan River

A. Animas River
B. Gallegos Canyon
C. La Plata River
D. Kutz Canyon
E. Horse Canyon
F. Gobernador Canyon

4.2.3 Hydrological Analysis

Two USGS gages possess a streamflow record covering period both before and after the Navajo Dam was constructed in 1962; San Juan River near Archuleta (09355500), and San Juan River at Farmington (09365000). Analysis of discharge records at these two locations have shown in the period following dam construction, the magnitude of peak flows have decreased substantially (Figures 3.13 and 3.14). Consequently, the percentage of time where the bed shear stress exceeds the critical shear stress to move dominant bed material has also reduced. It is proposed that the huge sediment volumes emanating from Cañon Largo have not changed substantially over time (Bliesner R., pers. comm., March 2004), but the apparent accumulation of sediment in the reaches downstream from Cañon Largo is partially the result of a reduction in flow competence to transport away sediment supplied from this eroding arroyo since dam construction in 1962.

4.3 Source of Fine Sediment in Cañon Largo

One origin of the fine sediment emanating from Cañon Largo is the channel sources. Bed samples from unstable reaches tend to have higher percent fines than samples from stable reaches; this is due to unstable channels providing fine sediment from failing banks. RGAs conducted at locations on Cañon Largo conclude that this deeply incised arroyo is a Stage V channel, with long reaches of mass failures observed on banks surveyed (Appendix B3, Figure 3.5). The nature of the flow regime on this tributary is ephemeral and extremely flashy. Basic streamflow runoff analysis was carried out using limited mean daily flow dataset from the only gage on Cañon Largo (09356565), approximately 6 km from its confluence with San Juan River. The average mean daily discharge between October 1977 and September 1981 was extremely low (0.481 m^3/s). This gage experienced zero flow for 47.1% of the time, and flows at this gage were less than 1 m^3/s 93.1% of the year. However, the average annual peak discharge is 99.9 m^3/s. Consequently, during these short-duration but high-magnitude events, a colossal sediment supply is available (for which the critical shear stress value is comparatively low) and flow has the competence to transport huge volumes of fine sediment through the canyon into Reach 2 of the San Juan River.

An additional source of fine sediment in Cañon Largo is input from watershed geology. Surficial geology varies between the north and south sides of the San Juan River. To the south, a large area of aeolian deposits (50 km by 50 km) are present between Cañon Largo and Chaco River to the west (Hunt, 1978). Sheets of friable sand and silt laid down by the wind forms shale flakes during prolonged drought. This material provides a substantial source of fine sediments into Cañon Largo, as calcium carbonate cementing particles is readily dissolved in water, and therefore the loess is easily washed away with rainfall. The orientation of the low, active cresentic and linear dunes indicates dominant winds are from the southwest, directly into Cañon Largo (Ward, 1990). These windblown deposits are located on a south to north sloping butte, which drops approximately 50 m over 50 km, then an additional 50 m over the 1.5 km to the San Juan River, meaning some surface runoff will enter the San Juan River and tributaries directly.

There have also been some anthropogenic changes in the Cañon Largo watershed over the last few decades. Increases in the oil and gas industry in this region have meant numerous access roads to wells have been constructed, which tend not to be paved and have been used to transport heavy machinery. However, research currently in progress by the USGS indicates these unpaved roads are not the main reason for the high suspended loads emanating from Cañon Largo, as they are not used during periods of heavy rainfall when road surface material liquefies and is most erodible (Matherne A. M., Feb 2004, pers. comm.).

4.4 Sources of Error

Field data collection will generally only sample a small percentage of an area, assume these data are representative of the entire site. An effort was made to sample locations which summarize the reach adequately (for example, in the case of PC/BS bed material collection across a several points on a cross section), but this may not be successful. Due to time limitations bed material data were only collected at systematic but limited number of positions of a cross section; however, at some sites, between these locations the bed surface composition was observed to vary. Obviously, field personnel made best efforts to collect the most accurate and reliable datasets as possible in the time available, but field data will never be a perfect reflection of the complexities of nature.

The grid and snooper tube methods to establish bed surface fines were used in order to maximize objectivity among field personnel. However, there will inherently be some bias between different people collecting the data. In order to address this issue, an attempt was made to minimize the number of people collecting this information and ensure all had identical training. Additionally, there are some problems associated with utilizing percent surface fines using a grid on the surface to quantify embeddedness. A cobble bed completely smothered by fine sediment so the cobbles are no longer visible (i.e. a highly degradated habitat) is classified the same as a fine bed channel, with no coarse material whatsoever. For this reason the PC/BS and grid methods of quantifying bed surface fines were used in association.

Manual digitization of channel banklines from aerial photography (carried out by personnel from Keller-Bliesner Engineering), will possess some error due photograph clarity and human subjectivity. Suspended-sediment loads calculated using a single rating equation will not take into account seasonal effects and hysteresis. Additionally, the result of any trend with time is lost.

5 PROTOCOL AND SUMMARY

Deposition of excessive fine sediment in coarse-bed river channels can be detrimental to habitat conditions as it decreases rock surface area required for fish and macroinvertebrates for the purposes of shelter, spawning and egg incubation (Sylte and Fischenish, 2002) and reduces interparticle dissolved oxygen levels. This project was conducted to generate a standardized methodology for assessment of bed material conditions of large southwestern rivers, using the San Juan and Animas Rivers as a case study.

5.1 Bed Material Protocol

The following steps outline the recommended protocol for establishment of bed-material reference conditions in a given region:

- Complete Rapid Geomorphic Assessments (RGA) for all sites in the study area.
- Sample bed-material at all RGA locations. If bed-material consists of a mixture of coarse and fine material, this should consist of a particle count (PC) accompanied by bulk sample (BS). If the bed consists purely of sand and finer a bulk sample will be sufficient, and if bed-material is all coarse material a particle count alone will suffice.
- Determine sites considered to be stable from RGA results (Channel Evolution Model stage I or VI).
- Isolate percent finer than 2 mm for stable sites and calculate the median, and first and third quartiles of this dataset.
- The reference bed-material value for this dataset is defined as the median percent finer than 2 mm for stable sites.
- The median and interquartile range of percent finer that 2 mm for unstable sites should be calculated for comparison purposes. Generally corresponding quartile values will be higher for the unstable channels dataset.

5.2 Summary

The findings of this investigation can be summarized as follows:

- Reference percent fines values (defined as the mean percent of bed-material finer than 2 mm in stable coarse bed sites) for locations firstly in the San Juan and Animas Rivers, and secondly in Ecoregion 22, are **20.5%** and **15.5%** respectively.

- Cañon Largo is considered to be the dominant source of fine sediment in the study reach of the San Juan River. Evidence to substantiate this hypothesis include the sharp increase in percent fines in channel substrate on the long profile at the location of the mouth of this tributary (Figures 3.1 and 3.2), field observations made on this incised arroyo itself (such as failing banks and large sand deposits on the bed) and on the San Juan River downstream from this confluence (multiple bars and islands).

- The considerable fine sediment load emanating from Cañon Largo is attributed to mass failures from unstable banks in this arroyo, combined with contributions from the erodible surficial geology (windblown loess deposits), particularly in the west section of this watershed. The flow regime of Cañon Largo is extremely flashy, with colossal pulsed loads being delivered into the San Juan River during late summer high intensity storms.

- Reach 2, the section of the San Juan River between the Cañon Largo and Animas River confluences, is the least stable of the five designated reaches. This instability is attributed to sediment input from Cañon Largo. Flow regime modification by Navajo Dam has attenuated the spring snowmelt peak, meaning these high flows are rarely achieved in magnitude and duration, and subsequently an accumulation of sediment on the bed has occurred.

- Other major tributaries contributing fine sediment on the dominantly coarse-bed San Juan River include Gallegos Canyon, Kutz Canyon and La Plata River. Estes Arroyo inputs some fine sediment to the Animas River.

- Flow diversion structures in the form of low head dams crossing the channel complicate sediment transport through the system, causing some deposition of sediment upstream of the structure.

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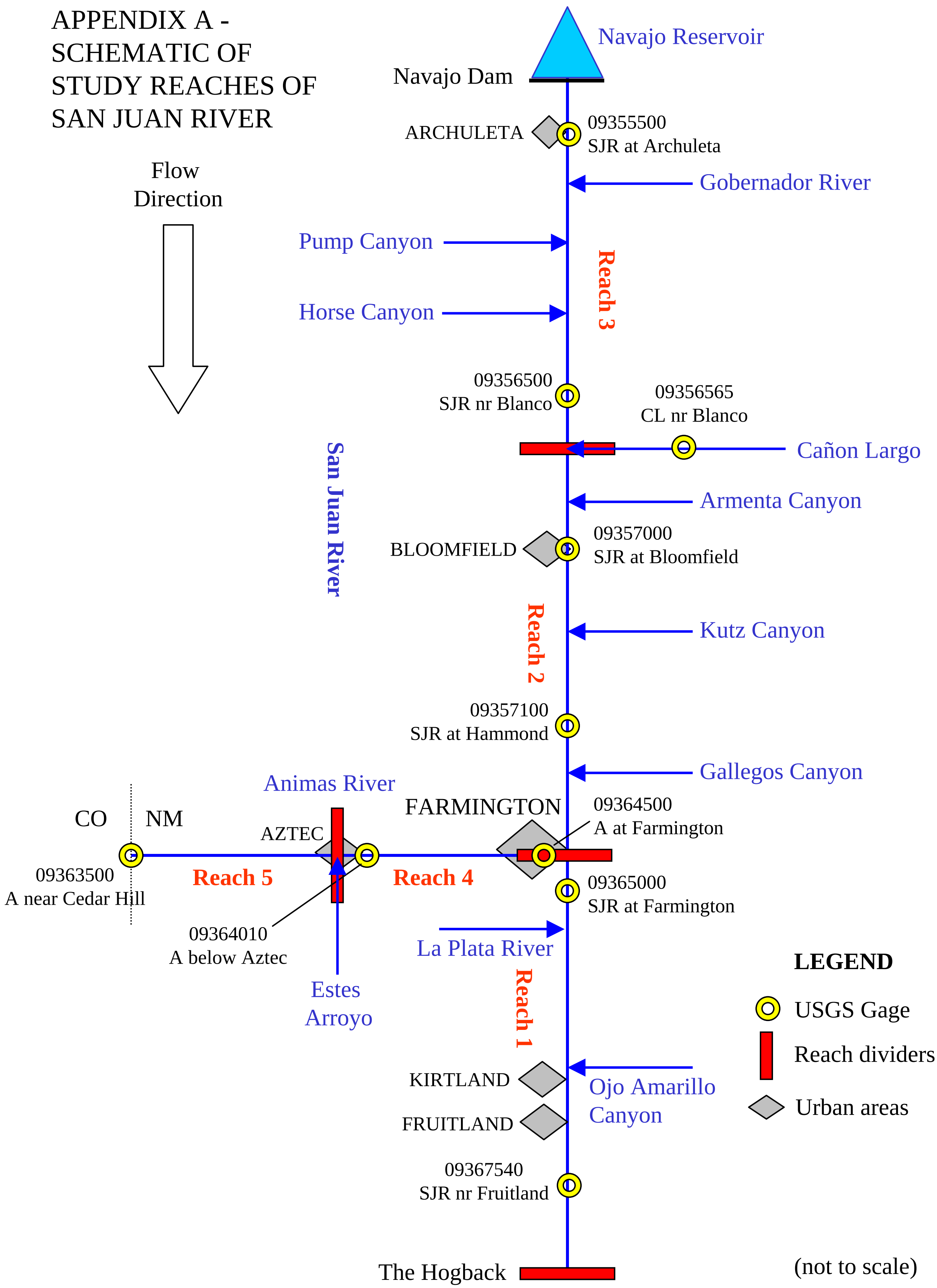
10.0 - APPENDICES

APPENDIX A –

SCHEMATIC DIAGRAM OF STUDY REACHES AND TRIBUTARIES

APPENDIX A - SCHEMATIC OF STUDY REACHES OF SAN JUAN RIVER



APPENDIX B -

RGA RESULTS FOR THE SAN JUAN RIVER, ANIMAS RIVER AND TRIBUTARIES

Appendix B1 - Rapid Geomorphic Assessments results: San Juan River

Site	River kilometer	Stage of channel evolution	Bed material	Bed or bank protection	Incision	Constriction	Stream bank erosion		Stream bank instability		Woody vegetative cover		Bank accretion		Channel stability index
							Left	Right	Left	Right	Left	Right	Left	Right	
SJ224a	365.92	VI	Cobble/Gravel/Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	11-25%	11-25%	7.5
SJ223a	364.79	VI	Boulder/Cobble	No	76-100%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	76-100%	0-10%	0-10%	9.5
SJ222a	363.04	VI	Gravel	No	76-100%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	76-100%	0-10%	0-10%	10.5
SJ222	361.55	VI	Cobble/Gravel/Sand	No	51-75%	0-10%	Fluvial	None	11-25%	0-10%	76-100%	76-100%	11-25%	26-50%	9.5
SJ221a	359.33	VI	Boulder/Cobble	No	76-100%	0-10%	Fluvial	None	0-10%	0-10%	76-100%	76-100%	0-10%	0-10%	8.5
SJ220	358.63	VI	Boulder/Cobble/Gravel	No	76-100%	0-10%	Mass Wasting	None	11-25%	0-10%	26-50%	51-75%	11-25%	11-25%	11.0
SJ119	356.44	VI	Boulder/Cobble	No	76-100%	0-10%	Fluvial	None	0-10%	0-10%	76-100%	76-100%	26-50%	0-10%	7.5
SJ218a	355.14	VI	Gravel	No	51-75%	0-10%	Fluvial	None	0-10%	0-10%	76-100%	51-75%	0-10%	0-10%	11.0
SJ217c	354.78	VI	Boulder/Cobble/Gravel	No	51-75%	0-10%	Fluvial	Fluvial	0-10%	0-10%	26-50%	51-75%	51-75%	0-10%	11.0
SJ217b	354.66	VI	Boulder/Cobble	No	76-100%	0-10%	None	Fluvial	0-10%	0-10%	76-100%	0-10%	0-10%	0-10%	10.5
SJ217a	354.16	VI	Boulder/Cobble	1 Bank	26-50%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	26-50%	26-50%	8.5
SJ216	351.56	VI	Gravel	No	76-100%	0-10%	Fluvial	Fluvial	0-10%	0-10%	51-75%	76-100%	11-25%	11-25%	10.0
SJ215b	351.04	VI	Gravel	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	26-50%	26-50%	6.5
SJ215a	350.62	VI	Boulder/Cobble	No	76-100%	0-10%	None	Fluvial	0-10%	0-10%	76-100%	76-100%	76-100%	11-25%	6.0
SJ214	348.83	VI	Gravel	No	76-100%	0-10%	Fluvial	None	0-10%	0-10%	76-100%	76-100%	51-75%	76-100%	6.0
SJ213	346.43	VI	Gravel	No	51-75%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	76-100%	11-25%	11-25%	10.5
SJ212	345.09	VI	Cobble/Gravel/Sand	No	51-75%	0-10%	None	Fluvial	0-10%	0-10%	51-75%	76-100%	26-50%	26-50%	9.0
SJ211a	343.81	VI	Sand	No	51-75%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	26-50%	26-50%	8.5

Site	River kilometer	Stage of channel evolution	Bed material	Bed or bank protection	Incision	Constriction	Stream bank erosion		Stream bank instability		Woody vegetative cover		Bank accretion		Channel stability index
							Left	Right	Left	Right	Left	Right	Left	Right	
SJ210a	342.45	VI	Sand	No	51-75%	0-10%	Fluvial	None	0-10%	0-10%	51-75%	76-100%	26-50%	76-100%	9.0
SJ209	340.53	VI	Sand	No	51-75%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	76-100%	26-50%	26-50%	10.5
SJ208	338.44	VI	Sand	No	76-100%	0-10%	Fluvial	Fluvial	0-10%	0-10%	51-75%	26-50%	26-50%	11-25%	11.5
SJ207a	337.51	VI	Boulder/Cobble/Gravel	1 Bank	51-75%	0-10%	None	None	0-10%	0-10%	0-10%	0-10%	11-25%	0-10%	13.5
SJ206d	336.76	VI	Silt/Clay	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	6.5
SJ206c	335.99	V	Sand	1 Bank	51-75%	0-10%	Mass Wasting	Fluvial	76-100%	0-10%	0-10%	26-50%	76-100%	51-75%	17.5
SJ206b	335.64	V	Sand	No	76-100%	0-10%	Mass Wasting	Fluvial	26-50%	0-10%	26-50%	26-50%	76-100%	76-100%	13.0
SJ206a	335.48	V	Cobble/sand	No	51-75%	0-10%	Mass Wasting	Fluvial	26-50%	0-10%	0-10%	11-25%	76-100%	76-100%	14.0
SJ206	335.27	V	Sand	No	26-50%	0-10%	Mass Wasting	Mass Wasting	51-75%	26-50%	76-100%	51-75%	26-50%	76-100%	17.0
SJ205	333.74	V	Sand	No	26-50%	0-10%	Mass Wasting	Fluvial	51-75%	0-10%	51-75%	76-100%	26-50%	76-100%	15.0
SJ204	332.12	V	Sand	No	26-50%	0-10%	Mass Wasting	Fluvial	51-75%	0-10%	26-50%	76-100%	76-100%	76-100%	14.5
SJ203a	330.88	V	Sand	No	51-75%	0-10%	Mass Wasting	Mass Wasting	76-100%	51-75%	76-100%	51-75%	76-100%	76-100%	16.0
SJ203	330.70	V	Sand	No	26-50%	0-10%	Mass Wasting	Mass Wasting	76-100%	76-100%	76-100%	0-10%	76-100%	76-100%	19.0
SJ202b	330.40	V	Sand	No	26-50%	0-10%	Mass Wasting	Mass Wasting	76-100%	26-50%	0-10%	26-50%	0-10%	26-50%	22.0
SJ202a	330.23	V	Sand	No	26-50%	0-10%	Mass Wasting	Mass Wasting	26-50%	26-50%	11-25%	11-25%	76-100%	0-10%	20.0
SJ202	329.07	V	Sand	No	11-25%	0-10%	Mass Wasting	Mass Wasting	51-75%	26-50%	11-25%	11-25%	11-25%	11-25%	22.5
SJ201	327.03	V	Sand	No	51-75%	0-10%	Mass Wasting	Mass Wasting	76-100%	51-75%	11-25%	51-75%	11-25%	11-25%	20.5
SJ199	323.09	V	Gravel/Sand	No	11-25%	0-10%	None	Mass Wasting	0-10%	76-100%	0-10%	0-10%	76-100%	0-10%	19.5
SJ198	321.52	V	Sand	No	11-25%	0-10%	Fluvial	Mass Wasting	0-10%	76-100%	11-25%	11-25%	26-50%	0-10%	21.0

Site	River kilometer	Stage of channel evolution	Bed material	Bed or bank protection	Incision	Constriction	Stream bank erosion		Stream bank instability		Woody vegetative cover		Bank accretion		Channel stability index
							Left	Right	Left	Right	Left	Right	Left	Right	
SJ197	319.40	V	Sand	No	11-25%	0-10%	None	Mass Wasting	0-10%	76-100%	0-10%	0-10%	76-100%	0-10%	20.0
SJ195	316.49	V	Sand	No	26-50%	0-10%	Fluvial	Fluvial	11-25%	0-10%	76-100%	76-100%	26-50%	51-75%	13.0
SJ194	313.44	V	Sand	1 Bank	26-50%	0-10%	Mass Wasting	Mass Wasting	51-75%	51-75%	51-75%	51-75%	51-75%	26-50%	19.5
SJ192c	313.08	V	Cobble/Sand	No	26-50%	0-10%	Mass Wasting	Fluvial	76-100%	26-50%	11-25%	76-100%	0-10%	76-100%	17.5
SJ192b	312.81	V	Sand/Silt Clay	No	0-10%	0-10%	Fluvial	Fluvial	0-10%	26-50%	76-100%	51-75%	76-100%	51-75%	15.5
SJ192d	312.43	V	Sand	No	11-25%	11-25%	Mass Wasting	Fluvial	51-75%	0-10%	26-50%	26-50%	26-50%	76-100%	18.5
SJ193a	312.16	V	Sand	No	0-10%	0-10%	Mass Wasting	None	76-100%	0-10%	76-100%	76-100%	0-10%	76-100%	17.0
SJ193b	309.97	V	Sand	No	11-25%	0-10%	Mass Wasting	Fluvial	76-100%	11-25%	11-25%	0-10%	11-25%	76-100%	20.5
SJ191a	309.79	V	Sand	No	26-50%	0-10%	Mass Wasting	Fluvial	51-75%	0-10%	26-50%	76-100%	11-25%	0-10%	18.0
SJ191	308.18	VI	Sand	No	26-50%	0-10%	Fluvial	None	0-10%	0-10%	76-100%	76-100%	26-50%	0-10%	11.5
SJ190	306.46	VI	Sand	No	26-50%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	7.5
SJ188a	303.64	V	Sand	1 Bank	51-75%	0-10%	Mass Wasting	Fluvial	76-100%	26-50%	76-100%	11-25%	11-25%	0-10%	20.0
SJ187d	303.22	VI	Sand	No	51-75%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	8.5
SJ187c	303.01	VI	Sand	No	51-75%	0-10%	None	Fluvial	0-10%	0-10%	76-100%	51-75%	76-100%	51-75%	8.5
SJ187b	302.67	VI	Sand	No	51-75%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	8.5
SJ187a	302.16	VI	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	5.5
SJ186a	300.92	V	Sand	No	51-75%	0-10%	Mass Wasting	None	51-75%	0-10%	11-25%	76-100%	0-10%	76-100%	15.0
SJ186	299.73	V	Boulder/Cobble	No	0-10%	0-10%	Fluvial	None	26-50%	0-10%	51-75%	76-100%	11-25%	76-100%	13.0
SJ185	298.52	V	Sand	No	51-75%	0-10%	Mass Wasting	Mass Wasting	26-50%	11-25%	26-50%	51-75%	0-10%	0-10%	19.0

Site	River kilometer	Stage of channel evolution	Bed material	Bed or bank protection	Incision	Constriction	Stream bank erosion		Stream bank instability		Woody vegetative cover		Bank accretion		Channel stability index
							Left	Right	Left	Right	Left	Right	Left	Right	
SJ184	296.93	III	Boulder/Cobble	No	0-10%	0-10%	None	Fluvial	0-10%	0-10%	51-75%	76-100%	76-100%	11-25%	11.0
SJ183	295.00	V	Boulder/Cobble	1 Bank	51-75%	0-10%	None	Mass Wasting	0-10%	26-50%	0-10%	76-100%	76-100%	26-50%	13.0
SJ182	293.10	VI	Boulder/Cobble	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	3.5
SJ181	291.82	VI	Boulder/Cobble	No	51-75%	0-10%	Fluvial	None	11-25%	0-10%	76-100%	76-100%	76-100%	76-100%	6.0
SJ180c	291.44	V	Boulder/Cobble	No	11-25%	0-10%	Mass Wasting	Fluvial	11-25%	0-10%	0-10%	76-100%	51-75%	51-75%	14.5
SJ180b	291.31	VI	Sand	No	76-100%	26-50%	None	Fluvial	0-10%	0-10%	76-100%	51-75%	11-25%	76-100%	10.5
SJ180a	290.76	VI	Sand	No	51-75%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	6.5
SJ180	290.14	VI	Sand	No	51-75%	0-10%	None	Fluvial	0-10%	0-10%	51-75%	76-100%	51-75%	26-50%	9.5
SJ179	288.56	VI	Sand	No	51-75%	11-25%	None	Fluvial	26-50%	0-10%	76-100%	76-100%	76-100%	51-75%	10.0
SJ178a	287.61	VI	Boulder/Cobble	No	76-100%	0-10%	None	None	0-10%	0-10%	51-75%	76-100%	76-100%	76-100%	4.0
SJ177c	286.93	VI	Cobble	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	26-50%	4.5
SJ177b	286.33	V	Sand	No	51-75%	0-10%	Mass Wasting	None	11-25%	0-10%	51-75%	76-100%	26-50%	76-100%	12.0
SJ177a	286.18	VI	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	51-75%	76-100%	76-100%	76-100%	6.0
SJ177a1	286.01	VI	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	51-75%	6.0
SJ177aa	285.68	VI	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	5.5
SJ177	284.54	VI	Sand	No	76-100%	0-10%	None	Fluvial	0-10%	0-10%	76-100%	51-75%	76-100%	51-75%	7.5
SJ176	283.28	VI	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	5.5
SJ175	282.38	VI	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	51-75%	6.0
SJ174	281.11	VI	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	5.5

Site	River kilometer	Stage of channel evolution	Bed material	Bed or bank protection	Incision	Constriction	Stream bank erosion		Stream bank instability		Woody vegetative cover		Bank accretion		Channel stability index
							Left	Right	Left	Right	Left	Right	Left	Right	
SJ173	278.54	V	Boulder/Cobble	No	51-75%	0-10%	Mass Wasting	Fluvial	26-50%	0-10%	51-75%	76-100%	51-75%	76-100%	11.0
SJ172	277.28	V	Sand	1 Bank	0-10%	0-10%	None	Mass Wasting	0-10%	11-25%	76-100%	51-75%	51-75%	26-50%	16.5
SJ171	275.24	VI	Sand	No	76-100%	0-10%	None	None	0-10%	11-25%	76-100%	51-75%	76-100%	51-75%	7.0
SJ170	274.23	VI	Boulder/Cobble/Sand	No	76-100%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	76-100%	51-75%	51-75%	7.5
SJ169	272.39	V	Boulder/Cobble	No	26-50%	0-10%	Mass Wasting	Mass Wasting	51-75%	51-75%	76-100%	76-100%	0-10%	0-10%	18.0
SJ167a	270.28	VI	Cobble	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	51-75%	51-75%	4.5
SJ167	269.13	VI	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	5.5
SJ166a	267.72	VI	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	5.5
SJ165	265.92	VI	Cobble/Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	4.5
SJ164	263.86	VI	Boulder/Cobble/Gravel	No	51-75%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	5.0
SJ162a	261.09	VI	Cobble/Sand	No	51-75%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	7.5
SJ161a	259.77	VI	Sand	No	51-75%	0-10%	Fluvial	Fluvial	11-25%	11-25%	51-75%	51-75%	76-100%	51-75%	11.0
SJ160	258.12	V	Sand	No	76-100%	0-10%	None	Mass Wasting	26-50%	51-75%	76-100%	76-100%	76-100%	0-10%	13.5
SJ159	255.88	VI	Sand	1 Bank	51-75%	0-10%	None	Fluvial	0-10%	0-10%	76-100%	76-100%	76-100%	51-75%	9.0

Appendix B2 - Rapid Geomorphic Assessments results: Animas River

Site	River kilometer	Stage of channel evolution	Bed material	Bed or bank protection	Incision	Constriction	Stream bank erosion		Stream bank instability		Woody vegetative cover		Bank accretion		Channel stability index
							Left	Right	Left	Right	Left	Right	Left	Right	
A31	55.89	VI	Boulder/Cobble/Sand	No	51-75%	0-10%	Fluvial	None	26-50%	11-25%	76-100%	26-50%	0-10%	0-10%	13.0
A29	51.71	V	Boulder/Cobble/Sand	No	51-75%	0-10%	Mass Wasting	Fluvial	51-75%	11-25%	76-100%	76-100%	11-25%	0-10%	15.5
A27	47.77	VI	Boulder/Cobble	No	76-100%	0-10%	Fluvial	None	11-25%	0-10%	51-75%	26-50%	11-25%	0-10%	10.0
A25	45.43	V	Boulder/Cobble	1 Bank	11-25%	0-10%	Mass Wasting	None	51-75%	0-10%	26-50%	76-100%	26-50%	0-10%	16.5
A23	41.48	VI	Boulder/Cobble	No	51-75%	0-10%	None	Fluvial	11-25%	0-10%	51-75%	76-100%	76-100%	11-25%	8.0
A21	37.98	V	Boulder/Cobble	1 Bank	26-50%	0-10%	None	None	11-25%	0-10%	11-25%	51-75%	51-75%	11-25%	12.5
A19	34.42	VI	Cobble	No	76-100%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	51-75%	76-100%	26-50%	7.0
A17	29.71	VI	Sand	No	51-75%	0-10%	None	None	0-10%	0-10%	51-75%	76-100%	51-75%	51-75%	8.0
A15	27.19	VI	Cobble	No	76-100%	0-10%	Fluvial	None	26-50%	0-10%	76-100%	76-100%	26-50%	51-75%	7.0
A14d	26.85	VI	Cobble	1 Bank	11-25%	0-10%	Fluvial	None	11-25%	0-10%	76-100%	76-100%	76-100%	51-75%	9.5
A14b	26.37	VI	Sand	No	26-50%	0-10%	Fluvial	Fluvial	0-10%	0-10%	51-75%	51-75%	26-50%	26-50%	12.5
A14a	26.04	VI	Boulder/Cobble	No	51-75%	0-10%	None	Fluvial	0-10%	0-10%	76-100%	76-100%	76-100%	26-50%	6.5
A13a	24.42	V	Boulder/Cobble	No	51-75%	0-10%	Fluvial	Mass Wasting	11-25%	26-50%	11-25%	76-100%	76-100%	26-50%	13.0
A11	19.57	V	Boulder/Cobble/Sand	No	11-25%	0-10%	None	Mass Wasting	11-25%	76-100%	11-25%	76-100%	76-100%	11-25%	16.5
A10a	17.39	VI	Boulder/Cobble	No	51-75%	0-10%	Mass Wasting	None	26-50%	11-25%	76-100%	76-100%	26-50%	51-75%	9.5
A7	12.69	VI	Boulder/Cobble	No	51-75%	0-10%	None	None	0-10%	0-10%	51-75%	76-100%	26-50%	11-25%	7.5
A5	8.73	VI	Cobble	1 Bank	26-50%	0-10%	Mass Wasting	None	26-50%	0-10%	76-100%	76-100%	26-50%	76-100%	10.5

Site	River kilometer	Stage of channel evolution	Bed material	Bed or bank protection	Incision	Constriction	Stream bank erosion		Stream bank instability		Woody vegetative cover		Bank accretion		Channel stability index
							Left	Right	Left	Right	Left	Right	Left	Right	
A4	3.76	VI	Boulder/Cobble	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	26-50%	26-50%	5.5
A3	2.22	VI	Boulder/Cobble	1 Bank	51-75%	0-10%	None	Fluvial	0-10%	0-10%	76-100%	51-75%	76-100%	51-75%	7.5
A2	0.51	VI	Cobble	No	76-100%	0-10%	None	Fluvial	0-10%	0-10%	76-100%	76-100%	51-75%	0-10%	7.0
A1	0.19	V	Boulder/Cobble/Gravel	No	76-100%	0-10%	Mass Wasting	None	11-25%	0-10%	0-10%	51-75%	76-100%	51-75%	11.0

Appendix B3 - Rapid Geomorphic Assessments results: tributaries of the San Juan and Animas Rivers

Tributary name	Site	Stage of channel evolution	Bed material	Bed or bank protection	Incision	Constriction	Stream bank erosion		Stream bank instability		Woody vegetative cover		Bank accretion		Channel stability index
							Left	Right	Left	Right	Left	Right	Left	Right	
Gobenador Canyon	GOB#1	VI	Sand	No	76-100%	0-10%	None	Fluvial	0-10%	0-10%	51-75%	76-100%	76-100%	76-100%	5.0
Gobenador Canyon	GOB#2	VI	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	51-75%	51-75%	76-100%	76-100%	6.5
Pump Canyon	PC#2	VI	Sand	No	51-75%	0-10%	Fluvial	Fluvial	26-50%	11-25%	51-75%	51-75%	51-75%	51-75%	12.0
Horse Canyon	HC#1	V	Sand	Yes	0-10%	0-10%	Fluvial	Mass Wasting	11-25%	76-100%	51-75%	11-25%	51-75%	0-10%	20.0
Canyon Largo	CL#1	V	Sand	No	51-75%	0-10%	Mass Wasting	Fluvial	11-25%	26-50%	26-50%	26-50%	51-75%	51-75%	15.5
Canyon Largo	CL#2a	V	Sand	No	0-10%	0-10%	Mass Wasting	Mass Wasting	51-75%	76-100%	0-10%	0-10%	51-75%	51-75%	23.5
Canyon Largo	CL#2	V	Sand	1 Bank	11-25%	0-10%	Mass Wasting	Fluvial	76-100%	26-50%	11-25%	26-50%	11-25%	26-50%	22.0
Canyon Largo	CL#3	V	Sand	No	0-10%	26-50%	Fluvial	Mass Wasting	11-25%	76-100%	26-50%	0-10%	76-100%	0-10%	23.5
Armenta Canyon	AC#1	V	Sand	No	0-10%	0-10%	Mass Wasting	Mass Wasting	76-100%	76-100%	76-100%	51-75%	76-100%	26-50%	20.5
Armenta Canyon	AC#2	V	Sand	No	0-10%	0-10%	Mass Wasting	Mass Wasting	76-100%	76-100%	76-100%	76-100%	76-100%	76-100%	19.0
Kutz Canyon	KC#0	IV	Sand	No	11-25%	0-10%	Mass Wasting	Mass Wasting	51-75%	76-100%	0-10%	11-25%	11-25%	11-25%	25.0
Kutz Canyon	KC#1	V	Sand	1 Bank	11-25%	0-10%	Fluvial	None	26-50%	11-25%	26-50%	26-50%	51-75%	51-75%	16.5
Kutz Canyon	KC#2	IV	Sand	No	11-25%	0-10%	Mass Wasting	Mass Wasting	76-100%	76-100%	0-10%	0-10%	11-25%	76-100%	24.5
Gallegos Canyon	GC#1	VI	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	51-75%	76-100%	51-75%	6.5
Gallegos Canyon	GC#2	V	Sand	No	76-100%	0-10%	Mass Wasting	None	26-50%	0-10%	26-50%	76-100%	26-50%	76-100%	12.0
La Plata Canyon	LP#2	VI	Sand	1 Bank	26-50%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	11-25%	10.0
La Plata Canyon	Gage, LP#3	V	Sand	1 Bank	11-25%	11-25%	Fluvial	Mass Wasting	0-10%	26-50%	76-100%	26-50%	11-25%	26-50%	19.5
La Plata Canyon	LP#4	V	Cobble/Gravel	No	0-10%	0-10%	None	Fluvial	0-10%	0-10%	11-25%	51-75%	11-25%	76-100%	14.0

Tributary name	Site	Stage of channel evolution	Bed material	Bed or bank protection	Incision	Constriction	Stream bank erosion		Stream bank instability		Woody vegetative cover		Bank accretion		Channel stability index
							Left	Right	Left	Right	Left	Right	Left	Right	
La Plata Canyon	LP#5	VI	Cobble/Gravel	No	51-75%	0-10%	None	None	0-10%	0-10%	51-75%	51-75%	51-75%	26-50%	7.5
Miller Arroyo	100 m U/S	IV	Sand	1 Bank	0-10%	0-10%	None	Fluvial	26-50%	0-10%	0-10%	26-50%	0-10%	0-10%	22.0
Estes Arroyo	EA#1	VI	Sand	No	76-100%	0-10%	Fluvial	Fluvial	0-10%	0-10%	26-50%	11-25%	76-100%	76-100%	10.0
Estes Arroyo	EA#2	VI	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	51-75%	76-100%	76-100%	76-100%	6.0

APPENDIX C –

BED MATERIAL FIELD-SHEET RESULTS FOR THE SAN JUAN RIVER, ANIMAS RIVER AND TRIBUTARIES

Appendix C1 - Bed material data: San Juan River

Site	River kilometer	Planform	Reach classification in percent			Bed material	Maximum depth in meters (estimated)	Channel width in meters	Particle size sample	Whole channel		Wetted perimeter		Surface fines			Date
			Riffle	Pool	Run					Particle count	Percent bulk sample/ percent particle count	Particle count	Percent bulk sample/ percent particle count	Percent	Grid	Plexiglas cylinder	
SJ224a	365.92	Braided	0	35	65	Cobble	3.00	-	Yes	Yes	26/74	-	-	21.8	Yes	-	10/21/03
SJ223a	364.79	Braided	35	30	35	Cobble	2.20	71	Yes	Yes	0/100	-	-	16.3	-	Yes	10/24/03
SJ222a	363.04	Sinuous	5	25	70	Gravel	0.60	71	Yes	Yes	12/88	-	-	18.3	-	Yes	10/24/03
SJ222	361.55	Sinuous	30	0	70	Cobble/Boulder	1.50	40	Yes	Yes	30/70	-	-	36.1	Yes	-	10/21/03
SJ221a	359.33	Braided	30	10	60	Cobble	0.80	226	Yes	Yes	0/100	-	-	6.80	Yes	-	10/24/03
SJ220	358.63	Braided	25	0	75	Cobble	1.50	37	Yes	Yes	0/100	-	-	6.50	-	Yes	10/30/03
SJ119	356.44	Sinuous	60	0	40	Cobble/Boulder	1.75	70	Yes	Yes	40/60	-	-	12.2	Yes	-	10/21/03
SJ218a	355.14	Straight	0	0	100	Gravel	1.00	80	Yes	Yes	17/83	-	-	58.2	-	Yes	10/21/03
SJ217c	354.78	Straight	28	0	72	-	0.75	60	Yes	Yes	17/83	-	-	11.1	-	Yes	10/21/03
SJ217b	354.66	Straight/Braided	25	0	75	Cobble/Boulder	1.50	86	No	Yes	0/100	-	-	2.6	-	Yes	10/28/03
SJ217a	354.16	Straight/Braided	60	0	40	Cobble/Boulder	0.50	40	No	Yes	0/100	-	-	7.8	-	Yes	10/28/03
SJ216	351.56	Braided	90	0	10	Gravel	0.40	30	No	Yes	0/100	-	-	25.5	-	Yes	10/28/03
SJ215b	351.04	Sinuous	30	0	70	Cobble/Gravel	0.70	80	Yes	Yes	10/90	-	-	11.8	-	Yes	10/28/03
SJ215a	350.62	Straight	10	20	70	Cobble/Gravel	1.00	40	Yes	Yes	15/85	-	-	39.9	-	Yes	10/28/03
SJ215	350.37	Straight/Braided	100	0	0	Cobble	0.60	84	Yes	Yes	5/95	-	-	21.6	-	Yes	10/28/03
SJ214	348.83	Straight	35	0	65	Cobble/Boulder	1.00	45	Yes	Yes	9/91	-	-	22.9	-	Yes	10/28/03
SJ213	346.43	Straight	30	0	70	Cobble/Boulder	1.00	65	Yes	Yes	6/94	-	-	13.1	-	Yes	10/28/03
SJ212	345.09	Straight	25	0	75	Cobble	0.70	44	Yes	Yes	9/91	-	-	15.7	-	Yes	10/29/03

Site	River kilometer	Planform	Reach classification in percent			Bed material	Maximum depth in meters (estimated)	Channel width in meters	Particle size sample	Whole channel		Wetted perimeter		Surface fines			Date
			Riffle	Pool	Run					Particle count	Percent bulk sample/ percent particle count	Particle count	Percent bulk sample/ percent particle count	Percent	Grid	Plexiglas cylinder	
SJ211a	343.81	Straight	20	0	80	Cobble	1.00	68	Yes	Yes	20/80	-	-	19.6	-	Yes	10/28/03
SJ210a	342.45	Straight	20	0	80	Cobble	0.50	39	Yes	Yes	27/73	-	-	47.1	-	Yes	10/29/03
SJ209	340.53	Braided	20	0	80	Cobble	1.00	25	Yes	Yes	7/93	-	-	27.5	-	Yes	10/29/03
SJ208	338.44	Straight	20	0	80	Cobble	0.50	58	Yes	Yes	12/88	-	-	28.8	-	Yes	10/29/03
SJ207a	337.51	Straight	40	60	0	Cobble/Boulder	1.00	43	Yes	Yes	28/72	-	-	28.1	-	Yes	10/29/03
SJ206d	336.76	Straight	20	45	35	Cobble/Boulder	0.75	56	Yes	Yes	16/84	-	-	26.1	-	Yes	10/22/03
SJ206c	335.99	Straight	0	0	100	Sand	1.30	40	Yes (2)	Yes	78/22	-	-	-	-	-	10/22/03
SJ206b	335.64	Braided	35	0	65	Sand	1.20	100	Yes (2)	Yes	30/70	Yes	29/71	22.9	-	Yes	10/22/03
SJ206a	335.48	Braided	90	0	10	Cobble	0.80	91	Yes (2)	Yes	45/55	Yes	32/68	21.6	-	Yes	10/22/03
SJ206	335.27	Straight/Braided	65	0	35	Sand	0.30	54	Yes	Yes	40/60	-	-	85.6	-	Yes	10/29/03
SJ205	333.74	Straight	25	0	75	Sand	1.00	67	Yes	Yes	52/48	-	-	70.6	-	Yes	10/29/03
SJ204	332.12	Straight	0	0	100	Sand	0.70	78	Yes	No	100/0	-	-	100	Yes	-	10/29/03
SJ203a	330.88	Straight	0	0	100	Sand	0.70	47	Yes	No	100/0	-	-	100	Yes	-	10/29/03
SJ203	330.70	Straight	0	0	100	Sand	1.00	48	Yes	No	100/0	-	-	100	Yes	-	10/29/03
SJ202b	330.40	Sinuous	25	0	75	Sand	0.70	64	Yes	No	100/0	-	-	100	Yes	-	10/29/03
SJ202a	330.23	Braided	10	0	90	Cobble/Sand	-	39	Yes	Yes	74/26	-	-	88.2	-	Yes	10/30/03
SJ202	329.07	Straight	25	0	75	Cobble/Sand	0.50	64	Yes	Yes	36/64	-	-	30.7	-	Yes	10/30/03
SJ201	327.03	Straight	0	0	100	Sand	0.70	47	Yes	Yes	90/10	-	-	97.4	-	Yes	10/30/03
SJ200	324.45	Straight	0	0	100	Sand	0.60	34	Yes	Yes	92/8	-	-	98.7	-	Yes	10/28/03

Site	River kilometer	Planform	Reach classification in percent			Bed material	Maximum depth in meters (estimated)	Channel width in meters	Particle size sample	Whole channel		Wetted perimeter		Surface fines			Date
			Riffle	Pool	Run					Particle count	Percent bulk sample/ percent particle count	Particle count	Percent bulk sample/ percent particle count	Percent	Grid	Plexiglas cylinder	
SJ199	323.09	Straight	15	0	75	Cobble/Sand	0.70	60	Yes	Yes	38/62	-	-	49.0	-	Yes	10/30/03
SJ198	321.52	Braided	20	0	80	Cobble/Sand	0.70	68	Yes	Yes	44/56	-	-	41.8	-	Yes	10/30/03
SJ197	319.40	Straight	25	0	75	Cobble/Sand	0.70	68	Yes	Yes	24/76	-	-	29.4	-	Yes	10/30/03
SJ196	317.96	Straight	100	0	0	Sand	0.60	55	Yes	Yes	92/8	-	-	100	-	Yes	10/28/03
SJ195	316.49	Sinuous	0	0	100	Sand	0.60	38	Yes	No	100/0	-	-	100	Yes	-	10/30/03
SJ194	313.44	Sinuous	20	0	80	Cobble/Sand	0.50	37	Yes	Yes	20/80	-	-	17.0	-	Yes	10/30/03
SJ192c	313.08	Sinuous	25	1	74	Cobble	0.50	20	Yes	Yes	40/60	-	-	62.1	-	Yes	11/16/03
SJ192b	312.81	Sinuous	10	0	90	Cobble/Sand	0.20	15	Yes	Yes	51/49	-	-	63.4	Yes	-	11/16/03
SJ192d	312.43	Straight	20	50	30	Gravel	0.30	45	Yes	Yes	53/47	Yes	10/90	6.10	Yes	-	10/24/03
SJ193a	312.16	Sinuous	0	0	100	Sand	0.30	37	Yes	Yes	80/20	-	-	100	-	Yes	10/30/03
SJ193b	309.97	Sinuous	20	0	80	Cobble/Sand	0.30	19	Yes	Yes	39/61	-	-	23.5	-	Yes	10/30/03
SJ191a	309.79	Braided	20	0	80	Cobble/Sand	0.70	55	Yes	Yes	62/38	-	-	70.6	-	Yes	10/30/03
SJ191	308.18	Sinuous	0	0	100	Sand	2.00	29	Yes	No	100/0	-	-	100	Yes	-	10/30/03
SJ190	306.46	Straight	30	0	70	Cobble/Sand	0.80	42	Yes	Yes	32/68	-	-	44.1	-	Yes	10/30/03
SJ189	304.94	Straight	60	0	40	Sand	0.40	60	Yes	Yes	71/29	-	-	88.9	-	Yes	10/29/03
SJ188a	303.64	Sinuous	20	0	80	Cobble/Sand	0.80	70	Yes	Yes	52/48		-	60.8	-	Yes	11/16/03
SJ187d	303.22	Braided	0	0	100	Sand	1.00	73	Yes	No	100/0	-	-	100	Yes	-	10/21/03
SJ187c	303.01	Sinuous	0	0	100	Sand	1.00	85	Yes	No	100/0	-	-	100	Yes	-	10/21/03
SJ187b	302.67	Sinuous	20	0	80	Sand	1.00	73	Yes	Yes	71/29	-	-	51.6	-	Yes	10/21/03

Site	River kilometer	Planform	Reach classification in percent			Bed material	Maximum depth in meters (estimated)	Channel width in meters	Particle size sample	Whole channel		Wetted perimeter		Surface fines			Date
			Riffle	Pool	Run					Particle count	Percent bulk sample/ percent particle count	Particle count	Percent bulk sample/ percent particle count	Percent	Grid	Plexiglas cylinder	
SJ187a	302.16	Braided	40	0	60	-	1.00	77	Yes	Yes	76/24	-	-	54.2	-	Yes	10/21/03
SJ186a	300.92	Sinuous	30	0	70	Sand	1.25	49	Yes	Yes	73/27	Yes	35/65	71.2	-	Yes	10/23/03
SJ186	299.73	Straight	25	0	75	Cobble	0.50	52	Yes (2)	Yes	35/65	Yes	15/85	18.3	-	Yes	10/23/03
SJ185	298.52	Straight	0	0	100	Sand	1.20	33	Yes	No	100/0	-	-	96.1	-	Yes	10/23/03
SJ184	296.93	Straight/Braided	50	0	50	Cobble	-	68	Yes	Yes	25/75	-	-	34.6	-	Yes	10/23/03
SJ183	295.00	Straight	30	0	70	Cobble	0.80	78	Yes	Yes	26/74	-	-	10.5	-	Yes	10/23/03
SJ182	293.10	Straight/Braided	80	0	20	Cobble	0.50	53	Yes	Yes	26/74	-	-	18.3	-	Yes	10/23/03
SJ181	291.82	Straight	35	0	65	Cobble	0.70	38	Yes (2)	Yes	56/44	Yes	33/67	29.4	-	Yes	10/25/03
SJ180c	291.44	Straight	40	0	60	Gravel/Cobble	0.50	54	No	Yes	0/100	-	-	17.6	-	Yes	10/23/03
SJ180b	291.31	Sinuous	0	0	100	Sand	2.00	28	Yes (2)	Yes	33/67	No	100/0	63.3	Yes	-	10/23/03
SJ180a	290.76	Sinuous	15	20	65	Sand	1.00	54	Yes	Yes	14/86	-	-	26.1	-	Yes	10/23/03
SJ180	290.14	Straight	20	80	0	Sand	1.00	40	Yes	Yes	8/92	Yes	8/92	7.20	-	Yes	10/20/03
SJ179	288.56	Straight/braided	0	0	100	Estimate sand	-	-	No	No	-	-	-	-	-	-	11/17/03
SJ178a	287.61	Straight	35	0	65	Cobble/Boulder	1.00	40	Yes (2)	Yes	55/45	Yes	14/86	27.5	-	Yes	10/25/03
SJ177c	286.93	Braided	80	0	20	Cobble/Boulder	1.00	59	Yes	Yes	22/78	-	-	74.5	-	Yes	10/23/03
SJ177b	286.33	Braided	20	40	40	Cobble/Sand	1.00	105	No	Yes	0/100	-	-	33.8	-	Yes	10/20/03
SJ177a	286.18	Braided	70	0	30	Sand	1.00	50	Yes	Yes	35/65	-	-	51.6	-	Yes	10/24/03
SJ177a1	286.01	Straight	0	0	100	Sand	1.00	41	Yes	Yes	100/0	-	-	100	-	Yes	10/23/03
SJ177aa	285.68	Straight	30	0	70	Cobble/Boulder/Sand	1.00	50	Yes	Yes	13/87	-	-	30.7	-	Yes	10/23/03

Site	River kilometer	Planform	Reach classification in percent			Bed material	Maximum depth in meters (estimated)	Channel width in meters	Particle size sample	Whole channel		Wetted perimeter		Surface fines			Date
			Riffle	Pool	Run					Particle count	Percent bulk sample/ percent particle count	Particle count	Percent bulk sample/ percent particle count	Percent	Grid	Plexiglas cylinder	
SJ177	284.54	Straight	10	0	90	Sand	1.30	72	Yes	Yes	21/79	-	-	43.8	-	Yes	10/23/03
SJ176	283.28	Straight/Braided	40	0	60	Sand	1.00	53	Yes	-	-	Yes	18/82	39.9	-	Yes	10/23/03
SJ175	282.38	Straight	0	0	100	Sand	1.00	48	Yes	Yes	48/52	-	-	60.8	-	Yes	10/23/03
SJ174	281.11	Straight	15	0	85	Sand	1.30	30	Yes (2)	Yes	42/58	Yes	15/85	46.4	-	Yes	10/23/03
SJ173	278.54	Sinuous	40	0	60	Cobble/Boulder	0.70	40	Yes (2)	Yes	5/95	Yes	7/93	12.4	-	Yes	10/25/03
SJ172	277.28	Braided	30	0	70	Cobble/Boulder	1.20	36	Yes	-	-	Yes	16/84	18.3	-	Yes	10/23/03
SJ171	275.24	Braided	20	30	50	Sand	0.70	57	Yes	Yes	33/67	-	-	45.1	-	Yes	10/23/03
SJ170	274.23	Braided	20	0	80	Cobble/Boulder	1.20	59	Yes	Yes	46/54	-	-	41.2	-	Yes	10/24/03
SJ169	272.39	Braided	30	1	69	Cobble/Sand	0.80	81	Yes	Yes	9/91	-	-	66.7	Yes	-	11/16/03
SJ167a	270.28	Braided	30	0	70	Cobble/Boulder	1.20	50	Yes	Yes	33/67	-	-	26.8	-	Yes	10/24/03
SJ167	269.13	Straight	0	0	100	Sand	1.20	56	Yes	Yes	56/44	-	-	77.1	-	Yes	10/24/03
SJ166a	267.72	Straight	25	0	75	Cobble/Sand	1.00	77	Yes	Yes	28/72	-	-	-	-	-	11/15/03
SJ165	265.92	Straight	0	0	100	Cobble	-	57	Yes	Yes	21/79	-	-	-	-	-	11/15/03
SJ164	263.86	Straight	20	0	80	Cobble/Boulder	1.20	58	Yes (2)	Yes	24/76	Yes	18/82	-	-	-	10/24/03
SJ162a	261.09	Straight/Braided	30	0	70	Cobble	0.50	59	Yes	Yes	20/80	-	-	-	-	-	11/15/03
SJ161a	259.77	Sinuous	65	0	35	Cobble/Sand	0.50	54	Yes	Yes	12/88	-	-	-	-	-	11/15/03
SJ160	258.12	Braided	30	0	70	Sand	-	91	Yes	Yes	17/83	-	-	-	-	-	11/15/03
SJ159	255.88	Straight	0	100	0	Sand	1.20	88	Yes	Yes	95/5	-	-	100	-	Yes	10/24/03

Appendix C2 - Bed material data: Animas River

Site	River kilometer	Planform	Reach classification in percent			Bed material	Maximum depth in meters (estimated)	Channel width in meters	Particle size sample	Particle count	Percent bulk sample/ percent particle count	Surface fines		Date
			Riffle	Pool	Run							Percent	Plexiglas cylinder	
A31	55.89	Straight	10	0	90	Cobble/Sand	0.60	40	Yes	Yes	20/80	47.06	Yes	11/17/03
A29	51.71	Straight	30	0	70	Cobble/Sand	1.00	54	Yes	Yes	43/57	31.37	Yes	11/17/03
A27	47.77	Straight	35	0	65	Cobble/Boulder	0.80	51	Yes	Yes	24/76	33.99	Yes	10/31/03
A25	45.43	Straight	30	0	70	Cobble/Boulder	0.60	32	Yes	Yes	11/89	-	-	11/14/03
A23	41.48	Straight	50	0	50	Cobble/Sand	0.80	68	Yes	Yes	18/82	-	-	11/14/03
A21	37.98	Straight	80	0	20	Cobble	0.50	41	Yes	Yes	23/77	-	-	11/14/03
A19	34.42	Straight	20	0	80	Cobble	-	55	Yes	Yes	24/76	52.94	Yes	10/31/03
A17	29.71	Straight	20	0	80	Cobble	0.40	54	Yes	Yes	23/77	83.01	Yes	10/31/03
A15	27.19	Straight	60	0	40	Cobble	0.60	48	Yes	Yes	21/79	30.72	Yes	10/31/03
A14d	26.85	Sinuous	25	0	75	Cobble	0.30	30	Yes	Yes	32/68	45.10	Yes	10/31/03
A14b	26.37	Straight	60	0	40	Sand	0.70	50	Yes	Yes	30/70	88.89	Yes	10/31/03
A14a	26.04	Straight	10	0	90	Cobble	0.70	40	Yes	Yes	41/59	62.09	Yes	10/31/03
A13a	24.42	Sinuous	80	0	20	Cobble	0.30	88	Yes	Yes	31/69	-	-	11/14/03
A11	19.57	Sinuous	90	0	10	Cobble/Sand	0.20	50	Yes	Yes	17/83	-	-	11/14/03
A10a	17.39	Straight	50	0	50	Cobble	0.50	50	Yes	Yes	26/74	-	-	11/14/03
A7	12.69	Sinuous	25	5	70	Cobble	1.30	37	Yes	Yes	28/72	26.80	Yes	11/14/03
A5	8.73	Sinuous	80	0	20	Cobble	0.40	22	Yes	Yes	11/89	16.99	Yes	10/27/03
A4	3.76	Straight	10	0	90	Cobble	0.70	38	Yes	Yes	10/90	30.07	Yes	10/27/03
A3	2.22	Straight	20	70	10	Cobble/Boulder	-	18	Yes	Yes	29/71	15.03	Yes	10/20/03
A2	0.51	Straight	40	25	35	Cobble	0.60	54	Yes	Yes	18/82	36.60	Yes	10/22/03
A1	0.19	Straight	15	5	80	Cobble/Boulder	0.60	26	Yes	Yes	22/88	13.73	Yes	10/22/03

APPENDIX D –

PARTICLE-SIZE DATA FOR THE SAN JUAN RIVER, ANIMAS RIVER AND TRIBUTARIES

Appendix D1 - Bed material data using particle count and bulk sample method: San Juan River

i Whole Channel

Site	River kilometer	Percent bulk sample / percent particle count	Percentiles in millimeters				Percent classified grain size in millimeters							
			D_{16}	D_{50}	D_{84}	D_{95}	Boulder / cobble > 64.0	Gravel 2.00 - 64.0	Sand 0.062 - 2.00	Silt and clay < 0.062	Silt 0.016 - 0.002	Clay < 0.002	Fine material ≤ 2.00	Coarse material > 2.00
SJ224a	365.92	26/74	0.490	17.0	90.0	135	26.0	48.0	26.0	0.00	-	-	26.0	74.0
SJ223a	364.79	0/100	17.0	72.0	160	Bedrock	56.0	41.0	3.00	0.00	-	-	3.00	97.0
SJ222a	363.04	12/88	8.00	40.0	104	188	27.0	61.0	9.81	2.19	1.94	0.246	12.0	88.0
SJ222	361.55	30/70	12.0	40.0	110	170	26.6	43.4	29.7	0.300	-	-	30.0	70.0
SJ221a	359.33	0/100	22.0	67.0	140	200	53.0	41.0	0.00	6.00	-	-	6.00	94.0
SJ220	358.63	0/100	25.0	45.0	85.0	140	26.0	74.0	0.00	0.00	-	-	0.00	100
SJ219	356.44	40/60	0.300	20.0	92.0	170	25.4	34.6	38.8	1.17	-	-	40.0	60.0
SJ218a	355.14	17/83	0.0160	18.0	32.0	43.0	0.00	83.0	13.6	3.45	3.04	0.409	17.0	83.0
SJ217c	354.78	17/83	1.80	42.0	90.0	140	32.0	51.0	16.4	0.611	-	-	17.0	83.0
SJ217b	354.66	0/100	11.0	57.0	130	150	0.00	95.0	5.00	0.00	-	-	5.00	95.0
SJ217a	354.16	0/100	25.0	60.0	120	160	42.0	50.0	8.00	0.00	-	-	8.00	92.0
SJ216	351.56	0/100	12.0	37.0	90.0	130	34.0	59.0	1.00	6.00	-	-	7.00	93.0
SJ215b	351.04	10/90	12.0	45.0	120	180	39.0	51.0	8.49	1.50	1.40	0.100	10.0	90.0
SJ215a	350.62	15/85	4.00	53.0	110	160	43.0	42.0	14.9	0.101	-	-	15.0	85.0
SJ215	350.37	5/95	20.0	95.0	170	200	68.0	27.0	4.90	0.103	-	-	5.00	95.0
SJ214	348.83	9/91	20.0	70.0	160	200	56.0	35.0	8.79	0.213	-	-	9.00	91.0

Site	River kilometer	Percent bulk sample / percent particle count	Percentiles in millimeters				Percent classified grain size in millimeters							
			D_{16}	D_{50}	D_{84}	D_{95}	Boulder / cobble > 64.0	Gravel 2.00 - 64.0	Sand 0.062 - 2.00	Silt and clay < 0.062	Silt 0.016 - 0.002	Clay < 0.002	Fine material ≤ 2.00	Coarse material > 2.00
SJ213	346.43	6/94	40.0	90.0	140	160	71.0	23.0	5.98	0.02	-	-	6.00	94.0
SJ212	345.09	9/91	19.0	58.0	115	140	48.0	43.0	8.95	0.0546	-	-	9.00	91.0
SJ211a	343.81	20/80	0.850	50.0	110	130	39.0	41.0	19.9	0.102	-	-	20.0	80.0
SJ210a	342.45	27/73	0.610	55.0	150	200	46.0	27.0	26.9	0.0907	-	-	27.0	73.0
SJ209	340.53	7/93	20.0	95.0	160	200	71.0	22.0	5.10	1.86	1.74	0.126	7.00	93.0
SJ208	338.44	12/88	10.0	50.0	87.0	115	37.0	51.0	9.0	3.03	2.74	0.290	12.0	88.0
SJ207a	337.51	28/72	0.650	43.0	110	150	36.0	36.0	27.6	0.374	-	-	28.0	72.0
SJ206d	336.76	16/84	3.00	45.0	120	170	35.0	49.0	12.4	3.60	3.13	0.472	16.0	84.0
SJ206c	335.99	78/22	0.201	0.435	15.0	61.0	5.00	17.0	77.7	0.297	0.271	0.026	78.0	22.0
SJ206b	335.64	30/70	0.130	35.0	120	160	41.2	28.8	21.5	8.55	7.78	0.767	30.0	70.0
SJ206a	335.48	45/55	0.170	11.0	57.0	97.0	11.0	44.0	41.4	3.62	-	-	45.0	55.0
SJ206	335.27	40/60	1.10	12.0	112	175	24.0	36.0	39.9	0.071	0.0587	0.0118	40.0	60.0
SJ205	333.74	52/48	0.200	0.570	90.0	150	18.0	34.0	47.0	0.966	-	-	48.0	52.0
SJ204	332.12	100/0	0.150	0.280	0.440	0.600	0.00	0.0141	99.3	0.676	-	-	100	0.0141
SJ203a	330.88	100/0	0.111	0.260	0.421	0.500	0.00	0.00	92.0	7.99	-	-	100	0.00
SJ202b	330.40	100/0	0.110	0.239	0.410	0.500	0.00	0.00	94.4	5.56	-	-	100	0.00
SJ202a	330.23	74/26	0.089	0.250	117	170	23.0	3.00	66.0	8.03	7.54	0.486	74.0	26.0
SJ202	329.07	36/64	0.230	44.0	150	180	46.7	17.3	35.3	0.722	-	-	36.0	64.0

Site	River kilometer	Percent bulk sample / percent particle count	Percentiles in millimeters				Percent classified grain size in millimeters							
			D_{16}	D_{50}	D_{84}	D_{95}	Boulder / cobble > 64.0	Gravel 2.00 - 64.0	Sand 0.062 - 2.00	Silt and clay < 0.062	Silt 0.016 - 0.002	Clay < 0.002	Fine material ≤ 2.00	Coarse material > 2.00
SJ201	327.03	90/10	0.160	0.201	0.699	205	5.50	4.50	89.4	0.608	-	-	90.0	10.0
SJ200	324.45	92/8	0.0650	0.200	0.450	100	7.00	1.00	75.9	16.1	15.6	0.441	92.0	8.00
SJ199	323.09	38/62	0.240	43.0	160	185	45.0	17.0	37.9	0.129	-	-	38.0	62.0
SJ198	321.52	44/56	0.870	35.0	110	180	35.0	21.0	38.3	5.74	5.49	0.244	44.0	56.0
SJ197	319.40	24/76	0.170	50.0	130	160	44.6	31.4	21.0	3.03	2.88	0.148	24.0	76.0
SJ196	317.96	92/8	0.0950	0.180	0.352	65.0	6.00	2.00	88.0	4.03	-	-	92.0	8.00
SJ195	316.49	100/0	0.115	0.208	0.400	0.485	0.00	0.482	96.8	2.70	-	-	99.5	0.482
SJ194	313.44	20/80	0.330	80.0	150	180	58.0	22.0	15.9	4.15	3.88	0.266	20.0	80.0
SJ192c	313.08	40/60	0.0820	33.0	140	205	38.0	22.0	30.9	9.12	8.62	0.498	40.0	60.0
SJ192b	312.81	51/49	0.0160	0.300	115	160	35.0	14.0	40.1	10.9	10.3	0.598	51.0	49.0
SJ192d	312.43	53/47	0.160	0.498	77.0	122	19.0	28.0	50.5	2.51	-	-	53.0	47.0
SJ193a	312.16	80/20	0.0780	0.130	85.0	140	19.0	1.00	74.8	5.15	-	-	80.0	20.0
SJ193b	309.97	39/61	0.210	14.0	110	170	28.0	33.0	35.2	3.82	3.30	0.523	39.0	61.0
SJ191a	309.79	62/38	0.290	55.0	90.0	140	38.5	23.46	37.2	0.774	-	-	38.0	62.0
SJ191	308.18	100/0	0.112	0.280	0.560	0.836	0.00	0.0659	94.8	5.10	-	-	99.9	0.0659
SJ190	306.46	32/68	0.120	60.0	120	160	55.1	12.9	27.0	4.97	4.70	0.273	32.0	68.0
SJ189	304.94	71/29	0.0670	0.159	95.0	160	22.0	7.00	56.9	14.1	13.5	0.653	71.0	29.0
SJ188a	303.64	52/48	0.140	0.600	160	190	40.0	8.00	46.6	5.36	5.01	0.353	52.0	48.0

Site	River kilometer	Percent bulk sample / percent particle count	Percentiles in millimeters				Percent classified grain size in millimeters							
			D_{16}	D_{50}	D_{84}	D_{95}	Boulder / cobble > 64.0	Gravel 2.00 - 64.0	Sand 0.062 - 2.00	Silt and clay < 0.062	Silt 0.016 - 0.002	Clay < 0.002	Fine material ≤ 2.00	Coarse material > 2.00
SJ187d	303.22	100/0	0.113	0.200	0.400	0.600	0.00	0.00	98.0	2.04	-	-	100	0.00
SJ187c	303.01	100/0	0.116	0.200	0.350	0.480	0.00	0.00	99.0	0.997	-	-	100	0.00
SJ187b	302.67	71/29	0.160	0.308	110	130	14.1	14.9	70.5	0.467	-	-	71.0	29.0
SJ187a	302.16	76/24	0.120	0.280	60.0	155	16.7	7.30	71.1	4.89	-	-	76.0	24.0
SJ186a	300.92	73/27	0.072	0.160	85.0	150	19.0	8.00	63.0	10.0	9.64	0.401	73.0	27.0
SJ186	299.73	35/65	0.0900	45.0	115	135	40.0	25.0	26.5	8.54	8.07	0.471	35.0	65.0
SJ185	298.52	100/0	0.0501	0.0849	0.110	0.197	0.00	0.00	78.5	21.5	20.5	0.999	100	0.00
SJ184	296.93	25/75	0.160	15.0	20.0	175	47.0	28.0	23.0	2.03	-	-	25.0	75.0
SJ183	295.00	26/74	0.130	52.0	45.0	56.0	0.00	74.0	22.8	3.24	3.01	0.232	26.0	74.0
SJ182	293.10	26/74	0.160	27.0	95.0	155	29.0	45.0	23.2	2.80	2.66	0.132	26.0	74.0
SJ181	291.82	56/44	0.140	25.0	85.0	110	26.7	29.3	41.5	2.53	-	-	44.0	56.0
SJ180c	291.44	0/100	21.0	73.0	115	130	58.0	37.0	5.00	0.00	-	-	5.00	95.0
SJ180b	291.31	33/67	0.250	20.0	77.0	95.0	29.6	37.4	29.5	3.53	3.32	0.213	33.0	67.0
SJ180a	290.76	14/86	80.0	160	250	300	86.0	0.00	9.17	4.83	4.52	0.301	14.0	86.0
SJ180	290.14	8/92	34.0	95.0	160	200	72.7	19.3	5.5	2.5	2.42	0.079	8.00	92.0
SJ178a	287.61	55/45	0.120	0.710	135	215	36.0	9.0	50.7	4.31	-	-	55.0	45.0
SJ177c	286.93	22/78	0.400	80.0	150	205	56.0	22.0	21.5	0.523	-	-	22.0	78.0
SJ177b	286.33	0/100	1.00	580	2080	3000	0.00	64.0	28.0	8.00	-	-	36.0	64.0

Site	River kilometer	Percent bulk sample / percent particle count	Percentiles in millimeters				Percent classified grain size in millimeters							
			D_{16}	D_{50}	D_{84}	D_{95}	Boulder / cobble > 64.0	Gravel 2.00 - 64.0	Sand 0.062 - 2.00	Silt and clay < 0.062	Silt 0.016 - 0.002	Clay < 0.002	Fine material ≤ 2.00	Coarse material > 2.00
SJ177a	286.18	35/65	0.0950	80.0	200	260	55.0	10.0	29.1	5.87	5.53	0.340	35.0	65.0
SJ177a1	286.01	100/0	0.200	0.310	0.438	0.514	0.04	0.00	100	0.00	-	-	100	0.04
SJ177aa	285.68	13/87	9.00	75.0	180	260	53.0	34.0	10.0	3.01	2.82	0.189	13.0	87.0
SJ177	284.54	21/79	0.210	40.0	120	170	43.0	36.0	17.3	3.75	3.51	0.239	21.0	79.0
SJ176	283.28	18/82	0.350	80.0	170	250	58.7	23.3	15.7	2.28	2.21	0.070	18.0	82.0
SJ175	282.38	48/52	0.300	3.00	95.0	130	24.5	27.5	48.0	0.00	-	-	48.0	52.0
SJ174	281.11	42/58	0.110	27.0	38.0	135	24.0	34.0	35.1	6.88	6.27	0.611	42.0	58.0
SJ173	278.54	5/95	35.0	80.0	190	270	60.0	35.0	2.90	2.10	1.97	0.133	5.00	95.0
SJ172	277.28	16/84	0.604	70.0	135	175	57.0	27.0	15.5	0.541	-	-	16.0	84.0
SJ171	275.24	33/67	0.220	45.0	160	200	41.6	25.4	28.2	4.79	4.47	0.320	33.0	67.0
SJ170	274.23	46/54	0.0850	10.0	95.0	125	30.0	24.0	35.4	10.6	10.0	0.628	46.0	54.0
SJ169	272.39	9/91	43.0	90.0	150	200	67.0	24.0	7.7	1.31	1.25	0.057	9.00	91.0
SJ167a	270.28	33/67	0.140	44.0	115	162	39.0	28.0	28.0	5.02	4.66	0.359	33.0	67.0
SJ167	269.13	56/44	0.490	1.00	85.0	103	20.0	24.0	56.0	0.00	-	-	56.0	44.0
SJ166a	267.72	28/72	0.260	40.0	145	180	45.0	27.0	25.5	2.49	2.45	0.041	28.0	72.0
SJ165	265.92	21/79	0.130	120	205	265	67.0	12.0	16.9	4.07	3.83	0.246	21.0	79.0
SJ164	263.86	24/76	0.450	80.0	140	165	57.0	19.0	18.0	6.00	5.63	0.365	24.0	76.0
SJ162a	261.09	20/80	0.190	80.0	140	190	60.8	19.2	14.7	5.27	4.73	0.538	20.0	80.0

Site	River kilometer	Percent bulk sample / percent particle count	Percentiles in millimeters				Percent classified grain size in millimeters							
			D_{16}	D_{50}	D_{84}	D_{95}	Boulder / cobble > 64.0	Gravel 2.00 - 64.0	Sand 0.062 - 2.00	Silt and clay < 0.062	Silt 0.016 - 0.002	Clay < 0.002	Fine material ≤ 2.00	Coarse material > 2.00
SJ161a	259.77	12/88	16.0	115	205	260	74.0	14.0	9.87	2.13	2.03	0.103	12.0	88.0
SJ160	258.12	17/83	0.330	80.0	160	190	57.0	26.0	12.9	4.08	3.86	0.219	17.0	83.0
SJ159	255.88	95/5	0.170	0.340	0.470	6.00	2.00	3.00	88.6	6.38	-	-	95.0	5.00

ii. Wetted Perimeter

Site	River kilometer	Percent bulk sample / percent particle count	Percentiles in millimeters				Percent classified grain size in millimeters							
			D_{16}	D_{50}	D_{84}	D_{95}	Boulder / cobble > 64.0	Gravel 2.00 - 64.0	Sand 0.062 - 2.00	Silt and clay < 0.062	Silt 0.016 - 0.002	Clay < 0.002	Fine material ≤ 2.00	Coarse material > 2.00
SJ222a	363.04	100/0	0.148	0.315	0.510	0.940	0.00	0.300	94.7	5.00	-	-	99.7	0.300
SJ206b	335.64	29/71	1.13	45.0	120	170	29.6	41.4	28.9	0.148	-	-	29.0	71.0
SJ206a	335.48	32/68	0.190	18.0	80.0	105	17.0	51.0	31.5	0.486	-	-	32.0	68.0
SJ192d	312.43	10/90	7.00	27.0	68.0	105	20.0	70.0	7.26	2.74	2.56	0.172	10.0	90.0
SJ186a	300.92	35/65	0.200	15.0	180	240	40.0	25.0	34.5	0.471	-	-	35.0	65.0
SJ186	299.73	15/85	6.00	64.0	116	135	50.0	35.0	14.0	1.05	-	-	15.0	85.0
SJ181	291.82	33/67	0.190	25.0	85	130	28.0	39.0	32.6	0.445	-	-	33.0	67.0
SJ180b	291.31	100/0	0.208	0.400	0.790	1.00	0.00	0.161	99.5	0.338	-	-	99.8	0.161
SJ180	290.14	8/92	19.0	95.0	160	200	4.38	87.6	5.41	2.59	2.48	0.107	8.00	92.0
SJ178a	287.61	14/86	14.0	90.0	150	250	60.3	25.7	13.1	0.902	-	-	14.0	86.0
SJ174	281.11	15/85	5.50	80.0	180	210	58.7	26.3	11.8	3.16	2.99	0.171	15.0	85.0
SJ173	278.54	7/93	25.0	65.0	200	290	53.0	40.0	4.13	2.87	2.65	0.221	7.00	93.0
SJ164	263.86	18/82	0.200	70.0	145	180	55.0	27.0	13.2	4.80	4.65	0.152	18.0	82.0

Appendix D2 - Bed material data using particle count and bulk sample method: Animas River (whole channel)

Site	River kilometer	Percent bulk sample / percent particle count	Percentiles in millimeters				Percent classified grain size in millimeters							
			D_{16}	D_{50}	D_{84}	D_{95}	Boulder / cobble > 64.0	Gravel 2.00 - 64.0	Sand 0.062 - 2.00	Silt and clay < 0.062	Silt 0.016 - 0.002	Clay < 0.002	Fine material < 2.00	Coarse material > 2.00
09363500		34/66	0.180	43.0	95.0	135	35.0	31.0	27.8	6.19	5.79	0.405	34.0	66.0
A31	55.89	20/80	0.190	80.0	125	150	58.0	22.0	16.3	3.67	3.52	0.153	20.0	80.0
A29	51.71	44/56	0.210	50.0	105	130	43.0	13.0	41.9	2.09	-	-	44.0	56.0
A27	47.77	24/76	0.200	80.0	140	300	64.0	12.0	21.3	2.68	2.44	0.232	24.0	76.0
A25	45.43	11/89	27.0	140	245	370	79.0	10.0	7.70	3.30	3.05	0.252	11.0	89.0
A23	41.48	18/82	1.00	75.0	145	300	58.0	24.0	16.3	1.74	1.70	0.0475	18.0	82.0
A21	37.98	23/77	0.390	80.0	133	175	61.0	16.0	21.0	2.02	1.92	0.104	23.0	77.0
A19	34.42	24/76	0.450	80.0	130	170	63.0	13.0	22.9	1.13	-	-	24.0	76.0
A17	29.71	20/80	0.760	70.0	195	260	57.0	23.0	18.2	1.83	1.69	0.144	20.0	80.0
A15	27.19	21/79	0.560	90.0	160	200	63.8	15.2	19.4	1.60	-	-	21.0	79.0
A14d	26.85	32/68	0.250	60.0	150	210	48.0	20.0	28.3	3.69	3.49	0.194	32.0	68.0
A14b	26.37	30/70	0.400	48.0	120	170	39.6	30.4	29.0	1.01	-	-	30.0	70.0
A14a	26.04	41/59	0.320	65.0	170	220	51.0	8.00	40.0	0.973	-	-	41.0	59.0
A13a	24.42	31/69	0.280	62.0	92.0	106	49.0	20.0	28.4	2.62	2.46	0.154	31.0	69.0
A11	19.57	18/82	0.450	64.0	105	160	50.0	32.0	16.0	1.97	1.83	0.141	18.0	82.0
A10a	17.39	26/74	0.110	74.0	120	235	58.0	16.0	23.0	3.00	2.79	0.207	26.0	74.0
A7	12.69	28/72	0.170	60.0	135	175	49.0	23.0	25.4	2.56	2.42	0.145	28.0	72.0
A5	8.73	13/87	30.0	75.0	140	160	67.0	20.0	10.5	2.53	2.34	0.189	13.0	87.0

Site	River kilometer	Percent bulk sample / percent particle count	Percentiles in millimeters				Percent classified grain size in millimeters							
			D_{16}	D_{50}	D_{84}	D_{95}	Boulder / cobble > 64.0	Gravel 2.00 - 64.0	Sand 0.062 - 2.00	Silt and clay < 0.062	Silt 0.016 - 0.002	Clay < 0.002	Fine material < 2.00	Coarse material > 2.00
A4	3.76	10/90	41.0	120	170	290	79.0	11.0	9.36	0.638	-	-	10.0	90.0
A3	2.22	31/69	0.260	37.0	106	200	32.0	37.0	29.1	1.89	-	-	31.0	69.0
A2	0.51	19/81	1.80	57.0	160	220	41.0	40.0	18.4	0.554	0.484	0.0700	19.0	81.0
A1	0.19	22/78	0.190	85.0	210	240	54.0	24.0	19.4	2.62	2.24	0.375	22.0	78.0

Appendix D3 - Bed material data using particle count and bulk sample method: tributaries of the San Juan and Animas Rivers

Tributary	Site	Percent bulk sample / percent particle count	Percentiles in millimeters				Per cent classified grain size in millimeters							
			D_{16}	D_{50}	D_{84}	D_{95}	Boulder / cobble > 64.0	Gravel 2.00 - 64.0	Sand 0.062 - 2.00	Silt and clay < 0.062	Silt 0.016 - 0.002	Clay < 0.002	Fine material ≤ 2.00	Coarse material > 2.00
Gobernador Canyon	#1	100/0	0.303	0.589	1.00	1.69	0.00	1.54	98.5	0.00	-	-	98.5	1.54
Gobernador Canyon	#1 Right Channel	100/0	0.272	0.509	0.901	1.37	0.00	0.112	96.8	3.09	-	-	99.9	0.112
Gobernador Canyon	#2 Left Channel	100/0	0.302	0.702	7.03	10.0	0.00	26.1	72.4	1.50	-	-	73.9	26.1
Gobernador Canyon	#2 Main Channel	100/0	0.280	0.470	0.860	1.19	0.00	1.32	98.0	0.669	-	-	98.7	1.32
Gobernador Canyon	#2 Bar	100/0	0.180	0.339	0.628	0.900	0.00	0.113	98.2	1.70	-	-	99.9	0.113
Pump Canyon	PC2	100/0	0.249	0.411	0.816	1.17	0.00	0.601	98.0	1.35	-	-	99.4	0.601
Horse Canyon	HC1	100/0	0.260	0.510	1.080	1.88	0.00	2.42	95.9	1.66	-	-	97.6	2.42
Canyon Largo	#0 at Confluence	100/0	0.163	0.385	0.800	1.09	0.00	0.00	94.9	5.10	-	-	100	0.00
Canyon Largo	#1	100/0	0.180	0.233	0.890	1.48	0.00	0.394	93.9	5.68	-	-	99.6	0.394
Canyon Largo	#2	100/0	0.188	0.300	0.660	0.907	0.00	0.113	95.5	4.34	-	-	99.9	0.113
Canyon Largo	#2a	100/0	0.132	0.297	0.468	0.798	0.00	0.00	98.3	1.69	-	-	100	0.00
Canyon Largo	#3	100/0	0.0813	0.205	0.449	0.797	0.00	0.0134	90.6	9.43	8.82	0.604	100	0.0134
Armenta Canyon	AC1	80/20	0.213	0.460	12.2	34.1	0.400	19.6	77.6	2.44	-	-	80.0	20.0
Armenta Canyon	AC2	100/0	0.248	0.439	0.860	1.36	0.00	0.781	98.5	0.673	-	-	99.2	0.781
Kutz Canyon	#0 at Confluence	100/0	0.399	0.760	2.28	5.13	0.00	19.7	80.3	0.00	-	-	80.3	19.7
Kutz Canyon	KC1	100/0	0.287	0.611	1.96	7.89	0.00	15.2	83.7	1.13	-	-	84.8	15.2
Kutz Canyon	#2	100/0	0.298	0.629	1.31	6.00	0.00	10.9	86.7	2.42	-	-	89.1	10.9
Gallegos Canyon	#1 300 m abv mouth	100/0	0.149	0.308	0.610	0.9	0.00	0.00	97.3	2.69	-	-	100	0.00

Tributary	Site	Percent bulk sample / percent particle count	Percentiles in millimeters				Per cent classified grain size in millimeters							
			D_{16}	D_{50}	D_{84}	D_{95}	Boulder / cobble > 64.0	Gravel 2.00 - 64.0	Sand 0.062 - 2.00	Silt and clay < 0.062	Silt 0.016 - 0.002	Clay < 0.002	Fine material ≤ 2.00	Coarse material > 2.00
Gallegos Canyon	#2	100/0	0.128	0.354	0.791	1.00	0.00	0.127	95.9	4.02	-	-	99.9	0.127
La Plata River	US of HWY #2	0/100	0.355	32.0	104	210	0.00	84.0	16.0	0.00	-	-	16.0	84.0
La Plata River	#3 Wetted	30/70	0.390	12.0	45.0	120	14.0	56.0	29.9	0.104	-	-	30.0	70.0
La Plata River	#3 Whole	75/25	0.313	1.070	30.0	110	10.0	14.0	74.1	1.94	1.94	0.00	76.0	24.0
La Plata River	#3 Silt layer only	100/0	0.0148	0.0538	0.67	1.40	0.00	0.00	45.5	54.5	48.1	6.39	100	0.00
La Plata River	#4	0/100	12.0	27.0	52.0	74.0	8.00	89.0	1.00	2.00	-	-	3.00	97.0
La Plata River	#5	0/100	18.0	34.0	62.0	92.0	13.0	85.0	2.00	0.00	-	-	2.00	98.0
Estes Arroyo	#1	100/0	0.305	0.620	1.09	1.83	0.00	2.02	97.3	0.662	-	-	98.0	2.02
Estes Arroyo	#2	100/0	0.128	0.370	0.800	1.11	0.00	0.59	96.3	3.06	-	-	99.4	0.586

APPENDIX E –

ECOREGION 22 GAGING-STATION SUMMARY DATA

Appendix E – Ecoregion 22 USGS gaging station summary information

Gage number	Gage name	State	Area in square kilometers	Period of record for daily stream flow	Suspended sediment data		Date visited by USDA-ARS
					Period of record	Number of samples	
08220000	Rio Grande near del Norte	CO	3419	01/01/1890 - 02/05/2003	04/13/1993 - 08/15/1995	30	11/14/2003
08251500	Rio Grande near Lobatos	CO	19943	07/01/1899 - 02/07/2003	04/23/1975 - 09/15/1999	123	11/14/2003
08255500	Costilla Creek near Costilla	NM	505	03/07/1936 - 09/30/2003	07/12/1973 - 07/08/1976	36	11/14/2003
08263500	Rio Grande near Cerro	NM	21859	10/01/1948 - 09/30/2002	10/18/1978 - 06/15/1994	32	6/6/2001
08265000	Red River near Questa	NM	293	10/01/1924 - 0930/2002	10/17/1978 - 10/29/1985	48	6/6/2001
08266500	Red River below Questa	NM	-	-	-	-	6/6/2001
08266790	Red River above State Fish Hatchery near Questa	NM	-	-	-	-	6/6/2001
08266800	Red River at Fish Hatch near Questa	NM	479	-	-	-	6/6/2001
08266820	Red River below Fish Hatchery, near Questa	NM	479	08/09/1978 - 09/30/2002	12/27/1977 - 07/12/1985	69	6/6/2001
08267400	Rio Grande above Rio Hondo at Dunn Bridge	NM	-	-	-	-	11/13/2003
08267500	Rio Hondo near Valdez	NM	94	10/01/1934 - 09/30/2002	10/30/1985 - 08/30/1995	47	6/6/2001
08276300	Rio Puebelowo de Taos below Los Cordovas	NM	984	08/01/1957 - 09/30/2002	10/31/1985 - 08/26/1998	67	6/6/2001
08276500	Rio Grande below Taos Junction Bridge near Taos	NM	25201	10/01/1925 - 09/30/2002	10/16/1978 - 08/30/1999	126	6/6/2001
08286500	Rio Chama above Abiquiu Re	NM	4144	08/01/1961 - 09/30/2002	02/23/1972 - 10/16/1985	113	6/5/2001
08287000	Rio Chama below Abiquiu Dam	NM	5561	11/01/1961 - 09/30/2002	02/22/1972 - 10/16/1985	93	6/5/2001
08290000	Rio Chama near Chamita	NM	8143	10/01/1919 - 09/30/2002	03/30/1972 - 09/16/1999	-	6/5/2001
08313000	Rio Grande at Otowi Bridge	NM	37037	02/01/1895 - 09/30/2002	01/01/1972 - 09/16/1999	357	6/5/2001

Gage number	Gage name	State	Area in square kilometers	Period of record for daily stream flow	Suspended sediment data		Date visited by USDA-ARS
					Period of record	Number of samples	
08317200	Santa Fe River above Cochiti Lake	NM	598	03/20/1970 - 09/30/1999	04/06/1981 - 08/18/1999	72	6/4/2001
08317400	Rio Grande below Cochiti Dam	NM	38591	10/01/1970 - 09/30/2002	11/12/1974 - 07/18/1996	52	6/4/2001
08317950	Galisteo Creek below Galisteo Dam	NM	1546	03/20/1970 - 09/30/2002	06/16/1972 - 08/17/1979	58	6/4/2001
08319000	Rio Grande at San Felipe	NM	41699	01/01/1927 - 09/30/2002	05/19/1970 - 09/15/1999	184	11/11/2003
08324000	Jemez River near Jemez	NM	1217	10/01/1936 - 09/30/2002	12/3/1980 - 06/16/1999	33	11/11/2003
08329900	North Floodway Channel near Alameda	NM	228	07/01/1968 - 09/30/2002	05/22/1982 - 08/10/1999	334	11/11/2003
08330000	Rio Grande at Albuquerque	NM	45169	03/01/1942 - 09/30/2002	05/04/1970 - 09/29/1999	536	11/10/2003
08331000	Rio Grande at Isleta	NM	46361	10/01/1995 - 09/30/1996	07/28/1975 - 10/31/1997	186	11/19/2003
08331990	Rio Grande Conveyance Channel near Bernardo	NM	-	10/01/1952 - 09/30/2002	-	-	11/11/2003
08332010	Rio Grande Floodway near Bernardo	NM	49805	10/01/1957 - 09/30/2002	03/05/1972 - 09/21/1999	408	11/11/2003
08334000	Rio Puerco above Arroyo Chico near Guadalupe	NM	1088	10/01/1951 - 09/30/2002	02/28/1948 - 04/13/1995	273	11/19/2003
08340500	Arroyo Chico near Guadalupe	NM	3600	10/01/1943 - 09/30/1986	02/25/1948 - 10/15/1986	332	11/18/2003
08343500	Rio San Jose near Grants	NM	5957	10/01/1936 - 09/30/2002	04/22/1980 - 04/18/1996	52	11/18/2003
08352500	Rio Puerco at Rio Puerco	NM	17068	03/01/1934 - 12/31/1976	02/18/1948 - 08/28/1955	155	11/2/2001
08353000	Rio Puerco near Bernardo	NM	19036	11/01/1939 - 09/30/2002	10/18/1947 - 09/03/1999	613	11/11/2003
08354000	Rio Salado near San Acacia	NM	3574	10/01/1947 - 09/30/1984	06/18/1972 - 08/06/1984	51	11/10/2003
08379500	Pecos River near Anton Chico	NM	2719	10/01/1910 - 09/30/2002	07/30/1974 - 06/20/1977	33	11/10/2003
08382650	Pecos River above Santa Rosa Lake	NM	6061	02/28/1976 - 09/30/2002	02/06/1981 - 03/18/1997	84	11/10/2003

Gage number	Gage name	State	Area in square kilometers	Period of record for daily stream flow	Suspended sediment data		Date visited by USDA-ARS
					Period of record	Number of samples	
08383000	Pecos River at Santa Rosa	NM	6863	10/01/1912 - 09/30/1992	06/17/1972 - 04/24/1998	177	11/10/2003
08383500	Pecos River near Puerto De Luna	NM	10282	05/01/1938 - 09/30/2002	07/24/1975 - 08/26/1999	139	11/10/2003
09356565	Canon Largo near Blanco Bridge	NM	-	10/01/1977 - 10/09/1981	12/16/1977 - 09/09/1981	47	11/1/2001
09357100	San Juan River at Hammond bridge near Bloomfield	NM	-	10/01/1977 - 10/09/1981	12/09/1997 - 09/21/1981	67	11/1/2001
09363500	Animas River near Cedar Hill	CO	2823	11/12/1933 - 09/30/2002	02/14/1972 - 05/05/1998	46	11/17/2003
09364500	Animas River at Farmington	NM	3522	10/01/1913 - 09/30/2002	01/25/1972 - 08/05-1999	253	11/1/2001
09366500	La Plata River at Colorado-New Mexico State Line	CO	857	10/01/1920 - 09/30/2002	11/29/1977 - 08/04/1981	41	11/17/2003
09367500	La Plata River near Farmington	NM	1510	03/01/1938 - 09/30/2002	12/12/1977 - 02/07/1991	55	11/1/2001
09367540	San Juan River near Fruitland	NM	-	10/01/1977 - 09/30/1980	12/14/1977 - 10/05/1995	83	11/1/2001
09367561	Shumway Arroyo near Waterflow	NM	191	09/12/1974 - 05/09/1990	10/24/1974 - 04/04/1984	294	11/1/2001
09367660	Chaco Wash near Starlake Trading Post	NM	-	10/01/1977 - 10/20/1982	11/07/1977 - 08/26/1982	72	10/31/2001
09367680	Chaco Wash at Chaco Canyon National Monument,	NM	1497	04/08/1976 -05/10/1990	08/06/1976 - 10/06/1983	584	10/31/2001
09367683	Chaco Wash near PB at Bridge At Chaco national Monument	NM	-	03/27/1980 - 09/30/1983	07/01/1981 - 10/06/1983	53	10/31/2001
09367685	Ah-Shi-Sle-Pah Wash near Kimbeto	NM	21	3/18/1977 - 11/28/1984	07/18/1977 - 08/11/1983	134	-
09367710	De-Na-Zin Wash near Bisti Trading Post	NM	474	01/01/1976 - 09/30/1982	07/10/1975 - 08/24/1982	119	11/15/2003
09367930	Hunter Wash at Bisti Trading Post	NM	118	03/20/1975 - 09/30/1982	09/11/1974 - 09/11/1982	164	11/15/2003
09367938	Chaco River near Burnham	NM	-	10/01/1977 - 10/14/1982	07/20/1977 - 08/25/1982	45	11/15/2003
09367950	Chaco River near Waterflow	NM	11266	11/01/1975 - 10/11/1994	11/13/1975 - 08/10/1989	429	11/17/2003

Gage number	Gage name	State	Area in square kilometers	Period of record for daily stream flow	Suspended sediment data		Date visited by USDA-ARS
					Period of record	Number of samples	
09368000	San Juan River at Shiprock	NM	33411	10/01/1934 - 09/30/2002	01/02/1972 - 08/04/1999	319	11/1/2001
09386950	Zuni River above Black Rock Reservoir	NM	2196	10/01/1969 - 09/30/2002	06/20/1979 - 03/01/1994	107	11/17/2003
09394500	Little Colorado River at Woodruff	AZ	20906	03/16/1905 - 09/30/2002	10/10/1954 - 08/28/1991	91	11/17/2003
09396100	Puerco River near Chambers	AZ	5584	02/07/1973 - 09/11/2002	07/29/1982 - 08/08-1991	30	11/17/2003
09397300	Little Colorado River near Joseph City.	AZ	32074	03/01/1970 - 09/23/2002	12/20/1978 - 09/15/1999	381	11/17/2003
09401000	Little Colorado. River at Grand Falls	AZ	54566	11/15/1925 - 09/30/1994	02/24/1992 - 09/21/1994	113	11/17/2003
09401200	Little Colorado River at Cameron.	AZ	59878	-	-	-	11/16/2003
09402000	Little Colorado River near Cameron.	AZ	68528	06/01/1947 - 09/30/2002	09/01/1988 - 12/04/1998	135	-
09402500	Colorado River. near Grand Canyon	AZ	366742	10/01/1922 - 09/30/2002	01/02/1951 - 04/12/1993	126	-
09403000	Bright Angel Creek near Grand Canyon	AZ	262	10/01/1923 - 04/12/1993	10/27/1990 - 04/13/1993	100	-
09403850	Kanab Creek above Mouth near Supai	AZ	-	11/02/1990 - 04/15/1993	01/06/1991 - 03/28/1993	64	-
09404120	Colorado River above National Canyon near Supai	AZ	383140	07/31/1983 - 04/25/1996	10/07/1989 - 02/02/1993	80	-

APPENDIX F

RGA RESULTS FOR ECOREGION 22

Appendix F - Rapid Geomorphic Assessment results: carried out in Arizona and the New Mexico Plateau, Ecoregion 22

Gage number	Stage of channel evolution	Bed material	Bed or bank protection	Incision	Constriction	Stream bank erosion		Stream bank instability		Woody vegetative cover		Bank accretion		Channel stability index
						Left	Right	Left	Right	Left	Right	Left	Right	
08220000	VI	Cobble/gravel	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	4.0
08251500	VI	Gravel	No	51-75%	0-10%	None	None	0-10%	0-10%	76-100%	51-75%	76-100%	76-100%	6.0
08255500	I	Gravel	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	51-75%	51-75%	4.0
08265000	VI	Boulder/cobble	Yes	51-75%	11-25%	Fluvial	Fluvial	26-50%	0-10%	51-75%	51-75%	26-50%	26-50%	10.5
08266500	VI	Boulder/cobble	No	26-50%	0-10%	None	Mass Wasting	0-10%	51-75%	76-100%	26-50%	26-50%	0-10%	13.0
08266790	I	Boulder/cobble	No	76-100%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	26-50%	26-50%	26-50%	7.0
08266800	VI	Boulder/cobble	No	51-75%	0-10%	Fluvial	Fluvial	0-10%	0-10%	26-50%	76-100%	26-50%	11-25%	10.0
08266820	I	Boulder/cobble	No	76-100%	0-10%	Fluvial	None	0-10%	0-10%	76-100%	11-25%	0-10%	11-25%	8.0
08267400	VI	Boulder/cobble	No	51-75%	0-10%	None	None	0-10%	0-10%	76-100%	51-75%	76-100%	76-100%	5.0
08267500	I	Boulder/cobble	Yes	51-75%	0-10%	Fluvial	Fluvial	0-10%	0-10%	76-100%	76-100%	0-10%	11-25%	7.5
08276300	V	Gravel	No	76-100%	0-10%	Mass Wasting	Mass Wasting	26-50%	26-50%	0-10%	11-25%	11-25%	76-100%	17.0
08276500	I	Boulder/cobble	No	51-75%	0-10%	Fluvial	Fluvial	0-10%	0-10%	26-50%	26-50%	51-75%	51-75%	8.0
08286500	VI	Boulder/cobble	No	51-75%	0-10%	Fluvial	None	0-10%	0-10%	26-50%	11-25%	51-75%	51-75%	9.0
08287000	V	Boulder/cobble	Yes	51-75%	0-10%	Fluvial/Mass Wasting	Fluvial	11-25%	0-10%	0-10%	26-50%	26-50%	26-50%	13.0
08290000	VI	Gravel	Yes	51-75%	0-10%	Fluvial	Fluvial	0-10%	0-10%	51-75%	51-75%	51-75%	51-75%	8.5
08313000	I	Gravel	Yes	26-75%	0-10%	Fluvial	None	0-10%	0-10%	51-75%	51-75%	26-50%	26-50%	7.5
08317200	VI	Gravel	Yes	26-50%	0-10%	Fluvial	Fluvial	0-10%	0-10%	51-75%	76-100%	76-100%	76-100%	8.0
08317400	II	Cobble/gravel	Yes	26-50%	0-10%	None	None	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	12.5

Gage number	Stage of channel evolution	Bed material	Bed or bank protection	Incision	Constriction	Stream bank erosion		Stream bank instability		Woody vegetative cover		Bank accretion		Channel stability index
						Left	Right	Left	Right	Left	Right	Left	Right	
08317950	VI	Sand	No	0-10%	0-10%	Fluvial	Fluvial	0-10%	0-10%	51-75%	26-50%	51-75%	51-75%	14.0
08319000	VI	Cobble/gravel	No	76-100%	11-25%	Fluvial	None	0-10%	0-10%	76-100%	51-75%	76-100%	51-75%	7.0
08324000	VI	Gravel	No	76-100%	0-10%	None	None	0-10%	0-10%	26-50%	51-75%	51-75%	51-75%	7.0
08330000	VI	Gravel/sand	No	26-50%	0-10%	None	Fluvial	0-10%	0-10%	76-100%	76-100%	76-100%	51-75%	8.5
08331000	VI	Sand	Yes	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	4.5
08331990	VI	Silt/clay	Yes	51-75%	0-10%	None	None	0-10%	0-10%	51-75%	76-100%	76-100%	76-100%	7.0
08332010	VI	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	5.5
08340500	V	Sand	No	0-10%	0-10%	Mass Wasting	Mass Wasting	76-100%	76-100%	0-10%	0-10%	51-75%	51-75%	24.0
08343500	VI	Silt/clay	Yes	76-100%	0-10%	None	None	0-10%	0-10%	51-75%	26-50%	76-100%	76-100%	7.0
08352500	V	Sand/silt/clay	No	0-10%	11-25%	None	Fluvial	0-10%	11-25%	26-50%	26-50%	76-100%	11-25%	17.5
08353000	III	Silt/clay	No	0-10%	0-10%	None	None	0-10%	0-10%	0-10%	0-10%	11-25%	11-25%	18.0
08354000	V	Sand	No	0-25%	0-10%	Mass Wasting	None	26-50%	0-10%	26-50%	26-50%	26-50%	76-100%	16.5
08379500	VI	Cobble/gravel	No	51-75%	0-10%	None	None	0-10%	0-10%	26-50%	26-50%	76-100%	51-75%	7.5
08383000	VI	Bedrock	No	26-50%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	4.5
08383500	V	Sand	No	26-50%	0-10%	Mass Wasting	None	51-75%	0-10%	11-25%	11-25%	76-100%	11-25%	17.0
09356565	V	Sand/silt/clay	No	0-10%	11-25%	Fluvial	Mass Wasting	0-10%	76-100%	76-100%	26-50%	76-100%	76-100%	18.5
09357100	VI	Sand	No	26-50%	0-10%	Fluvial	Fluvial	11-25%	11-25%	11-25%	26-50%	76-100%	76-100%	13.0
09363500	VI	Boulder/cobble	No	76-100%	0-10%	Fluvial	Fluvial	26-50%	0-10%	76-100%	11-25%	51-75%	11-25%	10.0

Gage number	Stage of channel evolution	Bed material	Bed or bank protection	Incision	Constriction	Stream bank erosion		Stream bank instability		Woody vegetative cover		Bank accretion		Channel stability index
						Left	Right	Left	Right	Left	Right	Left	Right	
09364500	VI	Gravel	One bank	26-50%	0-10%	None	Fluvial	0-10%	11-25%	76-100%	76-100%	76-100%	51-75%	9.5
09366500	V	Gravel	Yes	51-75%	0-10%	Mass Wasting	Fluvial	51-75%	11-25%	76-100%	76-100%	11-25%	11-25%	14.0
09367500	VI	Gravel/sand	Yes	26-50%	0-10%	Fluvial	Fluvial	0-10%	0-10%	51-75%	51-75%	76-100%	51-75%	9.5
09367540	VI	Gravel	No	26-50%	0-10%	Fluvial	None	11-25%	0-10%	76-100%	76-100%	11-25%	76-100%	9.5
09367561	VI	Sand	No	26-50%	0-10%	Mass Wasting	None	26-50%	0-10%	76-100%	76-100%	51-75%	76-100%	11.0
09367660	I	Sand/silt/clay	Yes	76-100%	11-25%	Fluvial	Fluvial	0-10%	0-10%	11-25%	11-25%	26-50%	26-50%	11.5
09367680	VI	Gravel/sand	No	0-10%	0-10%	Fluvial	None	0-10%	0-10%	11-25%	11-25%	51-75%	51-75%	14.0
09367683	VI	Gravel/sand	No	0-10%	11-25%	None	None	0-10%	0-10%	11-25%	11-25%	76-100%	76-100%	13.0
09367710	V	Sand	No	76-100%	0-10%	Mass Wasting	Mass Wasting	26-50%	26-50%	11-25%	11-25%	76-100%	76-100%	16.0
09367930	VI	Sand	No	51-75%	0-10%	Fluvial	None	0-10%	0-10%	26-50%	26-50%	76-100%	76-100%	9.5
09367938	V	Sand	No	51-75%	0-10%	Mass Wasting	Mass Wasting	51-75%	51-75%	11-25%	11-25%	76-100%	76-100%	18.0
09367950	VI	Sand	No	51-75%	0-10%	Fluvial	Fluvial	26-50%	11-25%	26-50%	26-50%	76-100%	76-100%	12.0
09368000	VI	Gravel	No	26-50%	0-10%	None	Fluvial	0-10%	0-10%	51-75%	51-75%	51-75%	26-50%	10.0
09386950	VI	Boulder/cobble	No	51-75%	0-10%	None	None	0-10%	0-10%	51-75%	51-75%	51-75%	51-75%	6.5
09394500	IV	Bedrock/boulders	No	26-50%	0-10%	None	Mass Wasting	0-10%	26-50%	51-75%	11-25%	51-75%	11-25%	14.5
09396100	V	Sand	No	26-50%	0-10%	Mass Wasting	Mass Wasting	51-75%	51-75%	26-50%	26-50%	76-100%	76-100%	18.0
09397300	VI	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	51-75%	76-100%	76-100%	6.0
09401000	VI	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	76-100%	76-100%	76-100%	76-100%	5.5

Gage number	Stage of channel evolution	Bed material	Bed or bank protection	Incision	Constriction	Stream bank erosion		Stream bank instability		Woody vegetative cover		Bank accretion		Channel stability index
						Left	Right	Left	Right	Left	Right	Left	Right	
09401200	VI	Sand	No	76-100%	0-10%	None	None	0-10%	0-10%	51-75%	51-75%	76-100%	76-100%	6.5
09402000	VI	Sand	-	-	-	-	-	-	-	-	-	-	-	-
09402500	VI	Sand	-	-	-	-	-	-	-	-	-	-	-	-
09403000	VI	Cobble/gravel	-	-	-	-	-	-	-	-	-	-	-	-
09403850	VI	Cobble/gravel	-	-	-	-	-	-	-	-	-	-	-	-
09404120	VI	Sand	-	-	-	-	-	-	-	-	-	-	-	-

APPENDIX G -

PARTICLE SIZE DATA (FIELD COLLECTED AND HISTORICAL) FOR ECOREGION 22

Appendix G - Bed material data for Arizona and the New Mexico Plateau, Ecoregion 22

Gage number	Historical USGS data					USDA-ARS Field data 2001-2003								
	Dominant bed material	D_{50} in millimeters	Percent grain size in millimeters			Percent bulk sample / percent particle count	Dominant bed material	Percentiles in millimeters				Percent grain size in millimeters		
			Coarse material > 2.00	Sand 0.062 - 2.00	Silt and clay < 0.062			D_{16}	D_{50}	D_{84}	D_{95}	Coarse material > 2.00	Sand 0.062 - 2.00	Silt and clay < 0.062
08220000	-	-	-	-	-	0/100	Gravel	43.0	101	173	215	100	0.00	0.00
08251500	-	-	-	-	-	20/80	Gravel	0.800	14.0	57.0	140	80.0	19.2	0.752
08255500	Sand	0.389	1.00	82.5	5.00	0/100	Gravel	24.0	75.0	135	234	100	0.00	0.00
08263500	-	-	-	-	-	-	-	-	-	-	-	-	-	-
08265000	-	-	-	-	-	0/100	Gravel	30.0	91.0	151	220	99.0	1.00	0.00
08266500	-	-	-	-	-	0/100	Gravel	44.0	94.0	140	170	98.0	2.00	0.00
08266790	-	-	-	-	-	0/100	Gravel	21.0	57.0	127	200	99.0	1.00	0.00
08266800	-	-	-	-	-	0/100	Gravel	12.0	46.0	121	178	100	0.00	0.00
08266820	-	-	-	-	-	0/100	Gravel	18.0	40.0	115	164	100	0.00	0.00
08267400	-	-	-	-	-	-	-	-	-	-	-	-	-	-
08267500	-	-	-	-	-	0/100	Gravel	30.0	81.0	185	390	100	0.00	0.00
08276300	Fines	-	0.00	17.0	83.0	0/100	Gravel	0.0160	19.0	132	170	70.0	10.0	20.0
08276500	-	-	-	-	-	-	Boulder/cobble	-	-	-	-	-	-	-
08286500	-	-	-	-	-	-	Boulder/cobble	-	-	-	-	-	-	-
08287000	-	-	-	-	-	0/100	Gravel	16.0	33.0	58.0	82.0	98.0	0.00	2.00
08290000	Sand	0.0828	0.00	73.0	27.0	67/33	Sand	0.110	0.230	30.0	88.0	33.0	62.5	4.53
08313000	Sand	0.641	16.0	84.0	0.00	10/90	Boulder/cobble	32.0	105	260	390	90.0	6.39	3.61

Gage number	Historical USGS data					USDA-ARS Field data 2001-2003								
	Dominant bed material	D_{50} in millimeters	Percent grain size in millimeters			Percent bulk sample / percent particle count	Dominant bed material	Percentiles in millimeters				Percent grain size in millimeters		
			Coarse material > 2.00	Sand 0.062 - 2.00	Silt and clay < 0.062			D_{16}	D_{50}	D_{84}	D_{95}	Coarse material > 2.00	Sand 0.062 - 2.00	Silt and clay < 0.062
08317200	Fines	-	0.00	12.0	88.0	57/43	Sand	0.610	1.65	11.0	61.0	43.0	56.8	0.194
08317400	-	-	-	-	-	-	Boulder/cobble	-	-	-	-	-	-	-
08317950	-	-	-	-	-	100/0	Sand	0.277	0.500	1.23	3.10	8.37	91.6	0.00
08319000	Sand	0.394	4.00	91.5	1.00	-	Boulder/cobble	-	-	-	-	-	-	-
08324000	Sand	0.0755	0.00	63.0	37.0	20/80	Gravel	1.20	42.0	120	170	80.0	19.8	0.160
08329900	-	-	-	-	-	-	Concrete	-	-	-	-	-	-	-
08330000	Sand	0.331	2.00	96.0	1.00	-	Gravel/sand	-	-	-	-	-	-	-
08331000	Fines	0.0621	0.00	50.0	50.0	-	Sand	-	-	-	-	-	-	-
08331990	Sand	0.197	0.00	100	0.00	100/0	Sand	0.0400	0.0680	0.240	0.900	0.00	52.2	47.8
08332010	Sand	0.221	0.00	98.0	1.00	100/0	Sand	0.250	0.390	0.680	0.920	0.850	99.1	0.00
08334000	Sand	0.133	0.00	62.0	38.0	-	-	-	-	-	-	-	-	-
08340500	Sand	0.133	0.00	62.0	38.0	100/0	Sand	0.150	0.201	0.350	0.460	0.280	98.7	1.01
08343500	-	-	-	-	-	100/0	Sand	0.240	0.890	1.50	1.90	0.00	94.3	5.72
08352500	-	-	-	-	-	-	Fines	-	-	-	-	-	-	-
08353000	Sand	1.62	34.0	51.0	22.0	100/0	Sand	0.201	0.410	0.990	3.50	8.82	89.0	2.16
08354000	-	-	-	-	-	100/0	Sand	0.0980	0.197	0.398	2.60	5.75	90.1	4.15
08379500	-	-	-	-	-	15/85	Gravel	10.0	57.5	152	189	85.0	14.9	0.0508
08382650	-	-	-	-	-	-	-	-	-	-	-	-	-	-

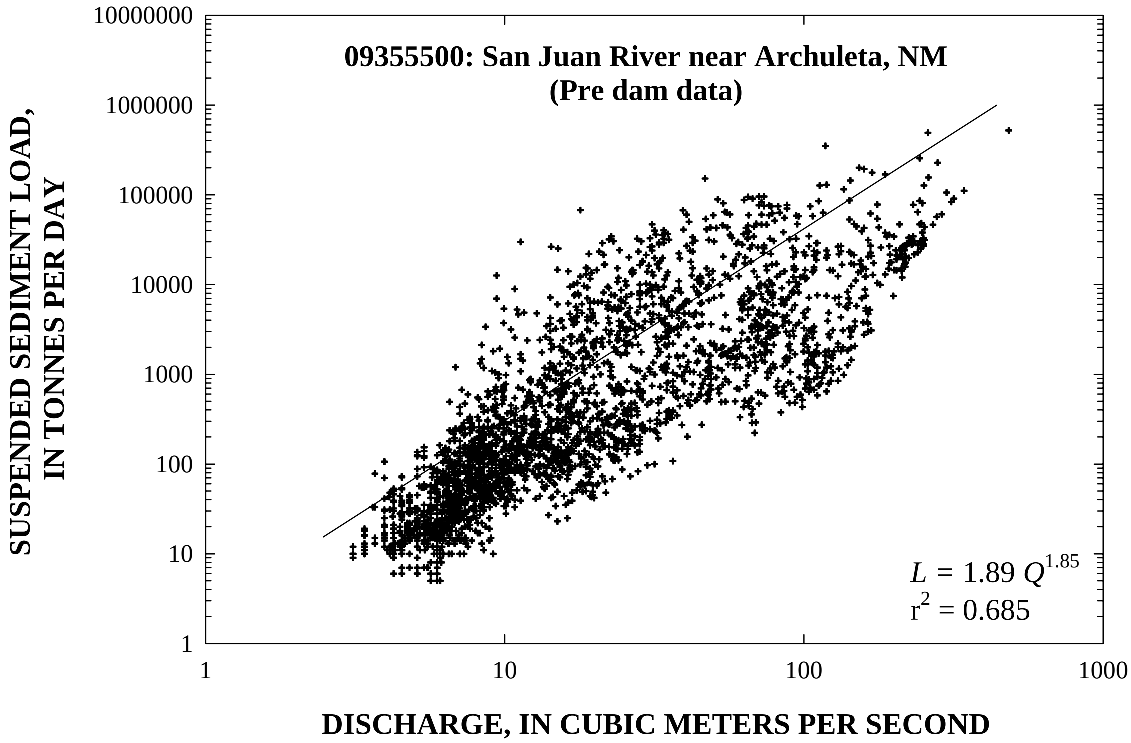
Gage number	Historical USGS data					USDA-ARS Field data 2001-2003								
	Dominant bed material	D_{50} in millimeters	Percent grain size in millimeters			Percent bulk sample / percent particle count	Dominant bed material	Percentiles in millimeters				Percent grain size in millimeters		
			Coarse material > 2.00	Sand 0.062 - 2.00	Silt and clay < 0.062			D_{16}	D_{50}	D_{84}	D_{95}	Coarse material > 2.00	Sand 0.062 - 2.00	Silt and clay < 0.062
08383000	Sand	0.260	0.00	100	0.00	-	Bedrock	-	-	-	-	-	-	-
08383500	-	-	-	-	-	100/0	Sand	0.195	0.499	0.950	4.90	8.60	91.1	0.313
09356565	Sand	0.202	0.00	83.0	17.0	100/0	Sand	0.0813	0.205	0.449	0.797	0.00	90.6	9.40
09357100	Sand	0.317	0.00	99.0	1.00		Sand	0.0670	0.159	95.0	160	29.0	56.9	14.1
09363500	-	-	-	-	-	34/66	Gravel	0.180	43.0	95.0	135	34.0	27.8	6.19
09364500	-	-	-	-	-	31/69	Boulder/cobble	0.260	37.0	106	200	31.0	29.1	1.89
09366500	-	-	-	-	-	0/100	Gravel	22.0	36.0	55.0	70.0	3.00	100.0	0.00
09367500	Sand	0.396	0.00	93.0	3.00	75/25	Gravel	0.313	1.07	30.0	110	76.0	74.1	1.94
09367540	Sand	0.354	0.00	95.0	1.00	56/44	Gravel	0.490	1.000	85.0	103	56.0	56.0	0.00
09367561	Fines/Sand	0.179	3.00	63.0	34.0	-	Sand	-	-	-	-	-	-	-
09367660	Sand	0.201	0.00	82.0	18.0	100/0	Fines	-	0.002	-	-	100	23.9	76.1
09367680	Sand	1.52	0.00	65.0	35.0	100/0	Fines	-	0.0079	-	-	90.0	2.00	88.0
09367683	Sand	0.0890	0.00	67.0	33.0	77/23	Sand	0.109	0.199	8.00	28.0	23.0	72.7	4.26
09367685	-	-	-	-	-	-	-	-	-	-	-	-	-	-
09367710	Sand	0.267	0.00	84.0	16.0	100/0	Sand	0.248	0.370	0.630	0.900	0.0660	99.2	0.687
09367930	Sand	0.147	0.00	82.5	17.5	100/0	Sand	0.135	0.300	0.480	0.800	0.657	97.0	2.37
09367938	Sand	0.203	0.00	95.0	5.00	100/0	Sand	0.120	0.208	0.398	0.492	0.00	98.5	1.53
09367950	Sand	0.279	5.00	92.5	2.50	100/0	Sand	0.180	0.615	1.19	1.76	0.00	93.9	6.14

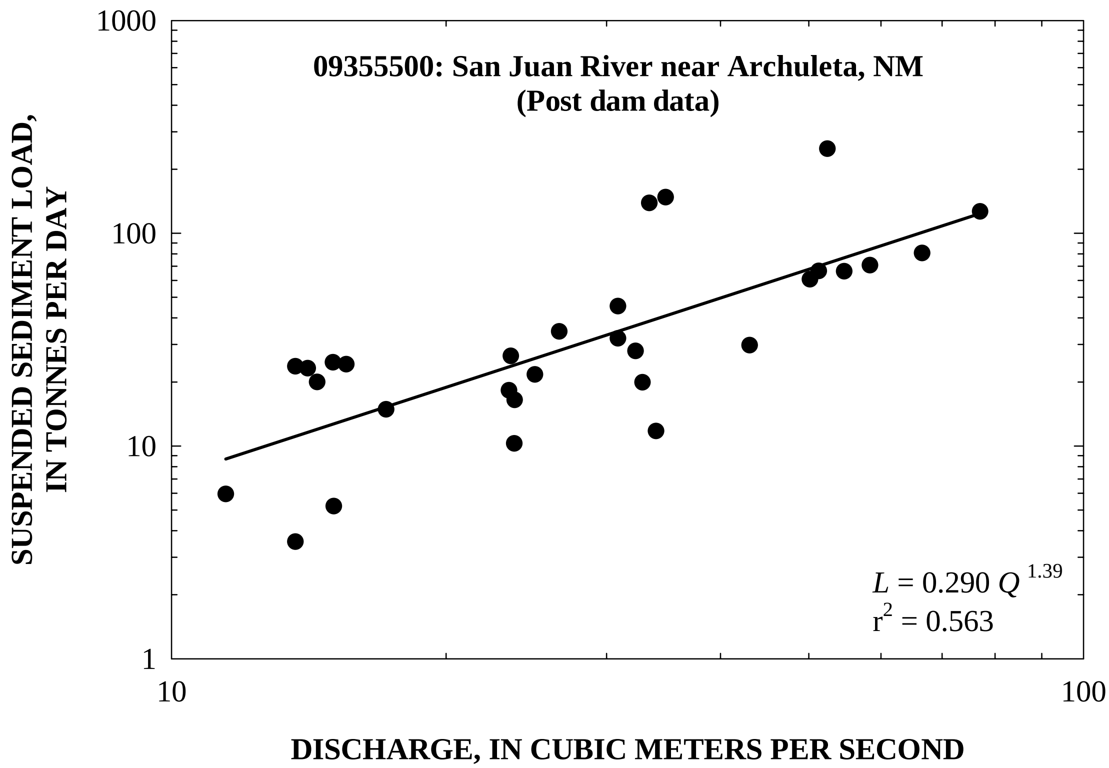
Gage number	Historical USGS data					USDA-ARS Field data 2001-2003								
	Dominant bed material	D_{50} in millimeters	Percent grain size in millimeters			Percent bulk sample / percent particle count	Dominant bed material	Percentiles in millimeters				Percent grain size in millimeters		
			Coarse material > 2.00	Sand 0.062 - 2.00	Silt and clay < 0.062			D_{16}	D_{50}	D_{84}	D_{95}	Coarse material > 2.00	Sand 0.062 - 2.00	Silt and clay < 0.062
09368000	-	-	-	-	-	-	Boulder/cobble	-	-	-	-	-	-	-
09386950	-	-	-	-	-		Sand	-	-	-	-	-	-	-
09394500	-	-	-	-	-	-	Bedrock/boulder/cobble	-	-	-	-	-	-	-
09396100	Fines	-	0.00	12.9	87.1	100/0	Sand	0.0701	0.110	0.385	0.499	0.00	86.4	13.6
09397300	-	-	-	-	-	100/0	Sand	0.0820	0.199	0.70	1.39	0.00	87.7	12.3
09401000	-	-	-	-	-	-	Sand	-	-	-	-	-	-	-
09401200	Sand	0.213	1.00	97.0	2.00	-	Sand	-	-	-	-	-	-	-
09402000	-	-	-	-	-	-	Sand	-	-	-	-	-	-	-
09402500	Sand	0.363	0.00	100	0.00	-	Sand	-	-	-	-	-	-	-
09403000	-	-	-	-	-	-	Boulder/cobble/gravel	-	-	-	-	-	-	-
09403850	-	-	-	-	-	-	Boulder/cobble/gravel	-	-	-	-	-	-	-
09404120	-	-	-	-	-	-	Sand	-	0.500	-	-	0.00	100	0.00

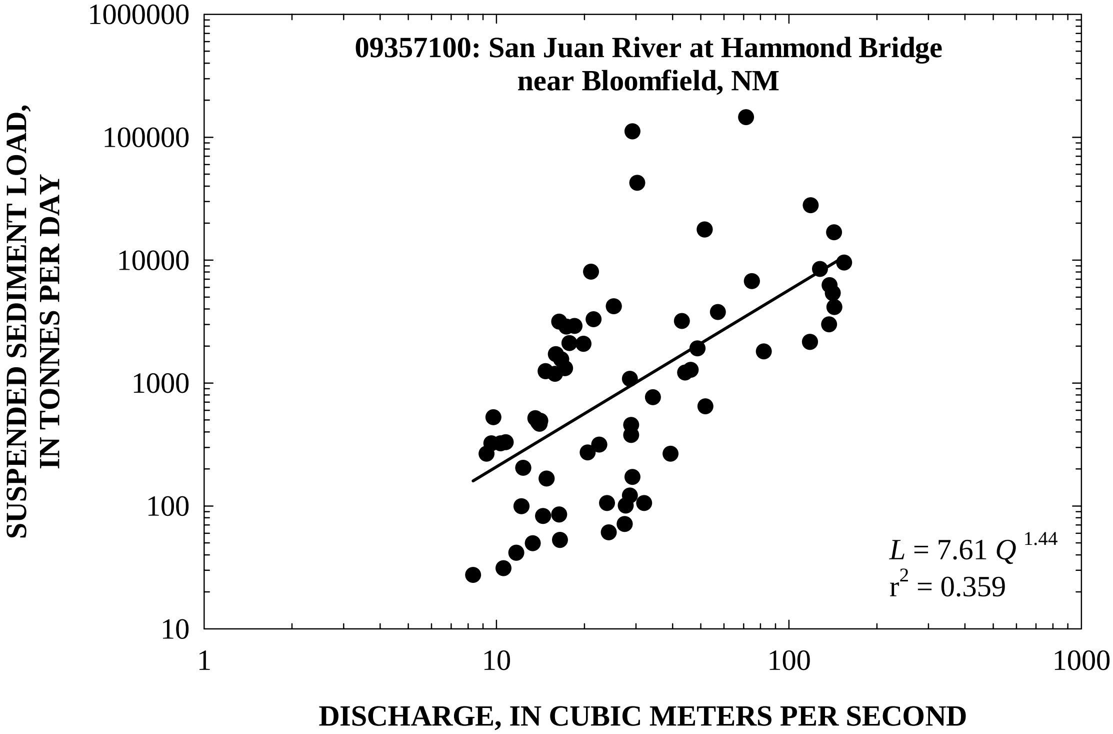
APPENDIX H –

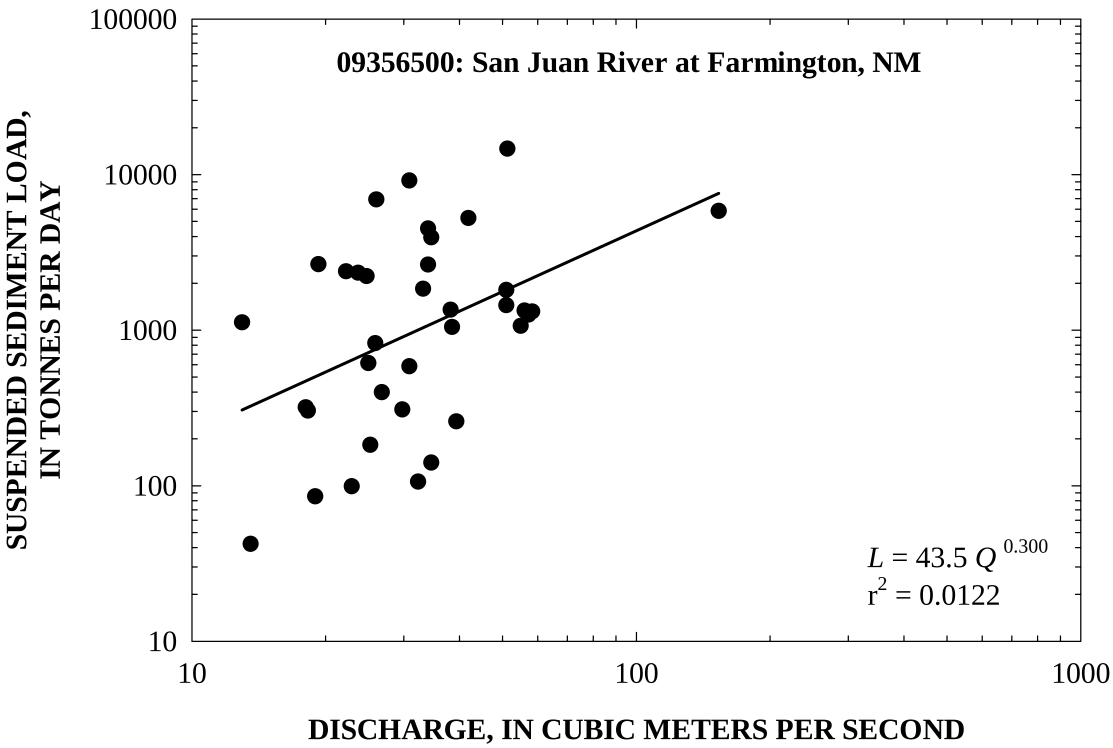
SUSPENDED-SEDIMENT RATING CURVES FOR USGS GAGES IN THE STUDY AREA

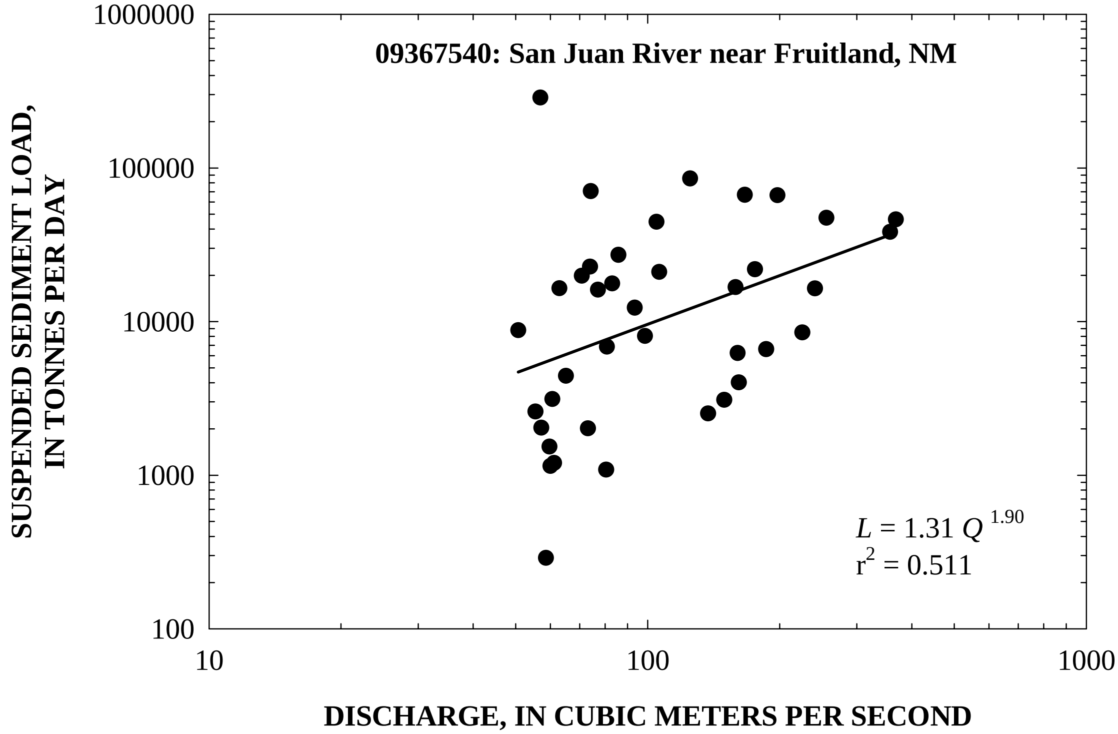
i – San Juan River Gaging Stations





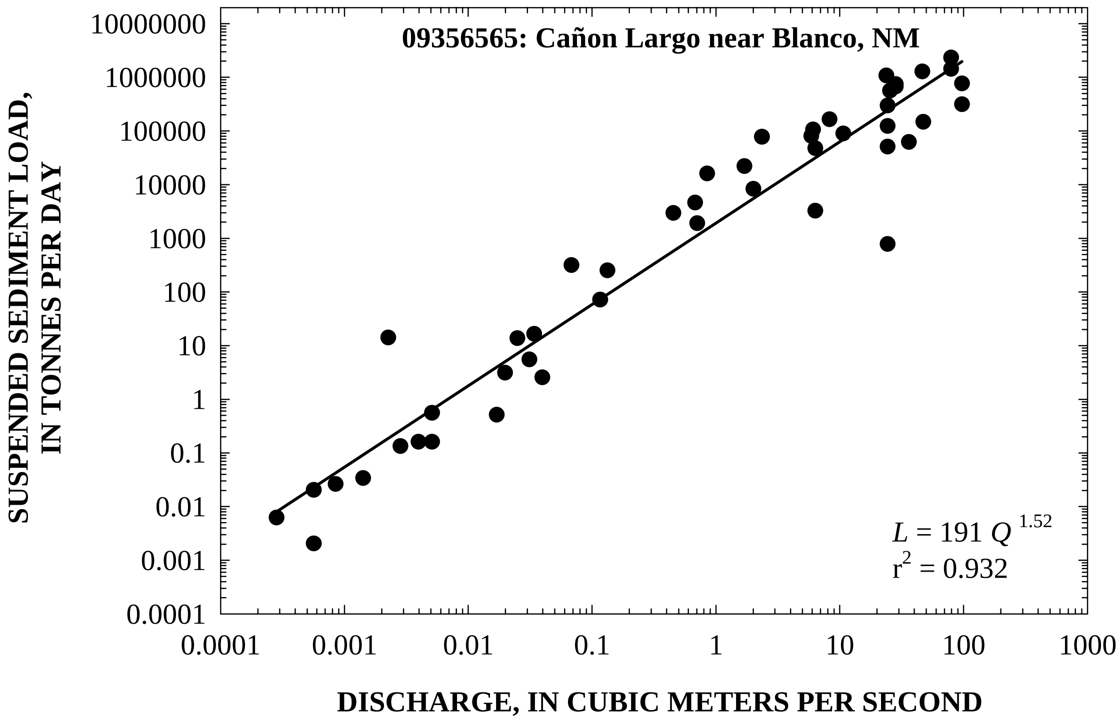

09357100: San Juan River at Hammond Bridge
near Bloomfield, NM
SUSPENDED SEDIMENT LOAD,
IN TONNES PER DAY
DISCHARGE, IN CUBIC METERS PER SECOND
L = 7.61 Q 1.44
r2 = 0.359
1000000
100000
10000
1000
100
10
1
10
100
1000


09356500: San Juan River at Farmington, NM
SUSPENDED SEDIMENT LOAD,
IN TONNES PER DAY
DISCHARGE, IN CUBIC METERS PER SECOND
L = 43.5 Q 0.300
r2 = 0.0122
100000
10000
1000
100
10
10
100
1000

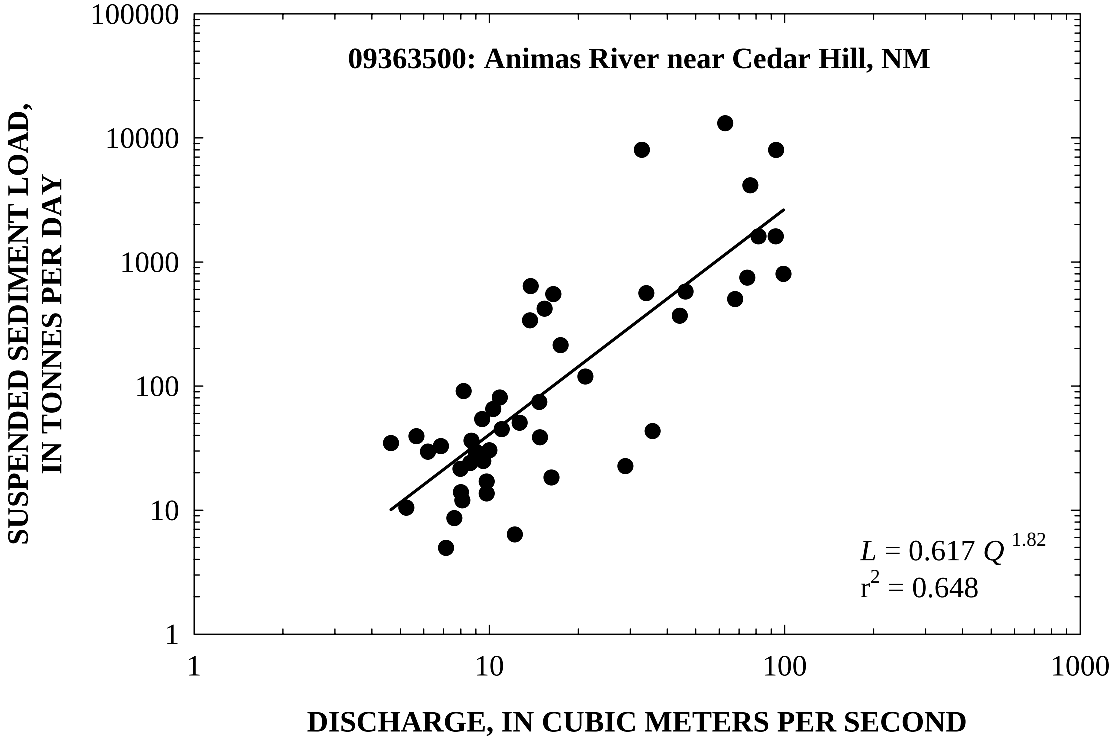


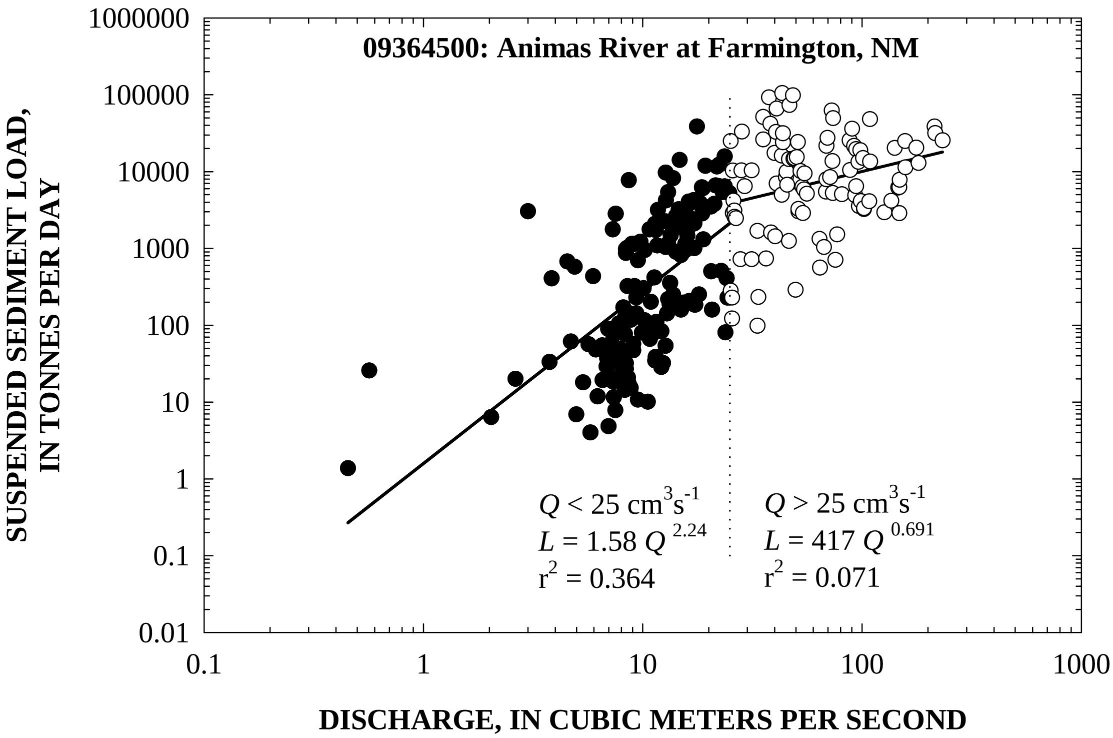
09367540: San Juan River near Fruitland, NM
SUSPENDED SEDIMENT LOAD, IN TONNES PER DAY
1000000
100000
10000
1000
100
10
100
1000
DISCHARGE, IN CUBIC METERS PER SECOND
L = 1.31 Q 1.90
r2 = 0.511

ii – Cañon Largo Gaging Stations



iii – Animas River Gaging Stations





iv – La Plata River gaging Station