2019 TRINITY RIVER SEDIMENT TRANSPORT MONITORING REPORT

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TRINITY RIVER RESTORATION PROGRAM
WY 2019 SEDIMENT TRANSPORT MONITORING
FINAL REPORT

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EXECUTIVE SUMMARY

This report presents the results of Water Year (WY) 2019 sediment transport monitoring efforts on the Trinity River near Weaverville, California. As part of an ongoing study for the Trinity River Restoration Program (TRRP), GMA Hydrology (GMA, formerly Graham Matthews and Associates) conducted bedload and suspended sediment sampling at four monitoring locations. Secondary hydrologic and geomorphic data such as water surface slope, streamflow measurements, cross section surveys, pebble counts and turbidity were collected as part of the study. New for 2019 was: (1) scheduled times for crews to take bedload samples, (2) no suspended sediment at the Lewiston site, (3) pressure transducers installed at water surface elevation reference stations to acquire 15-minute continuous stage data, and (4) partitioned bedload data were provided for all sites to support hydroacoustic computations. WY2019 marks the 14th year (2004-2013, 2015-2017, 2019) of Trinity River sediment transport monitoring by GMA Hydrology for the TRRP.

Historic impacts to the Trinity River and their effects on anadromous fish habitat are described in the Introduction (Section 1.0) of this report and are documented extensively elsewhere (e.g. McBain and Trush, 1997). In short, physical changes in the channel resulting from mining, increased sediment loads related to logging and flow reduction due to impoundment resulted in a severely degraded channel in the mainstem while the Trinity and Lewiston dams cut off anadromous salmonids from the upper 700 square miles of the watershed.

TRRP's restoration strategy involves a combination of Spring Flow Releases, fine and coarse sediment management, and mechanical channel rehabilitation. This 2019 study is conducted as part a sediment budget approach to understanding sediment-related habitat issues. We provide sediment load estimates at four locations along the river: at Lewiston (TRAL), near Grass Valley Creek (TRGV), at Limekiln Gulch (TRLG), and near Douglas City (TRDC). The sediment load estimates inform gravel injection strategies (locations and volumes) and hydrograph development for Spring Flow Releases.

Suspended sediment and bedload sampling were conducted from cataraft platforms attached to temporary cableways. Samplers (US D-74 for suspended sediment and TR-2 with 0.5mm mesh for bedload) are lowered and raised using cranes equipped with winches. Each station is located near a stream gage operated by either US Geological Survey (USGS) or GMA. Continuous turbidity was collected for use as a surrogate for suspended sediment concentration (SSC) at three sites. Cross section surveys and pebble counts were conducted before and after the 2019 Spring Flow Release.

WY2019 was determined to be a "Wet" water year (TRRP 2019). The approved spring release hydrograph included three high flow peaks above 8,000 cfs during April and May and three additional smaller peaks, less than 5,000 cfs, as flows were dropping through May, June and July. All of the peaks were planned to be instantaneous and not contain a bench. The three high flow peaks were planned to have peak values of 9,850 cfs on April 17; 10,900 cfs

on April 29; and 9,000 cfs on May 19. The three smaller peaks were planned to be 4,500 cfs on May 24; 3,800 cfs on June 7; 2,450 cfs on June 23; and 3 3,200 on June 26. A gradual tailout started on June 27th, with the hydrograph dropping back to summer base flow (450 cfs) on August 5th.
GMA sampling crews collected suspended sediment and bedload measurements for eight days over the three large hydrograph peaks between April 17 and May 20, 2019. Crews collected one-pass bedload samples as scheduled and one suspended sediment sample each day. Bedload variability testing was performed at each site by sampling repeatedly at one location along the cross section for a period of time. Water surface slope was measured manually after each bedload sample and every 15-minutes with the pressure transducer. SSC samples were processed for three particle-size ranges (<0.063mm, 0.063 - <0.5mm and >0.5mm) and bedload samples were processed for total mass and grain size analysis. Sediment loads were computed using a variety of standard and modified methods (Sections 2.3.3, 2.3.4 and Appendix [Station Analyses]). Suspended sediment loads were computed for the three size classes mentioned and bedload was computed for 0.5 - <8mm (fine) and ≥8mm (coarse) loads. The computational period for sediment load estimates is April 1, 2019 to July 31, 2019.

Suspended sediment loads for all size classes increased in the downstream direction, with one exception (>0.5mm at TRLG). Loads for all size classes are provided in Table 16 of the report. Total suspended load (the sum of <0.063, 0.063-0.5mm and ≥0.5mm) is provided here:

- TRAL: NA
- TRGV: 8,530 tons
- TRLG: 9,850 tons
- TRDC: 21,250 tons

TRDC is at the downstream boundary and represents the combined contribution of all tributaries in the study reach.

Crews collected between 25 and 32 single-pass bedload samples during the 2019 Spring Flow Release. The fine (0.5 - <8mm) bedload for each station was:

- TRAL: 614 tons
- TRGV: 1,140 tons
- TRLG: 868 tons
- TRDC: 5,580 tons

The relative downstream increase in fine bedload is presumably due to the contribution of more tributaries and more channel bank length in the downstream direction. Changes in transport capacity between sites (not evaluated here) can also influence differences in sediment load magnitude.

Coarse bedload (≥8mm) is of particular interest as it is a critical geomorphic habitat component (e.g. spawning gravel, bar/riffle composition). TRAL and TRGV sites are influenced by gravel injection. 2019 coarse bedload for each station was:

- TRAL: 2,300 tons
- TRGV: 1,800 tons
- TRLG: 870 tons
- TRDC: 10,410 tons

TRLG and TRDC are less influenced by gravel injection.

Of particular interest in 2019, considering the triple-peak hydrograph, is the question of how the loads compare for each peak flow. We examined each site relative to its own hydrograph and summed the ≥8mm loads for each peak flow bench. Computational periods were defined as the time the hydrograph exceeded the low flow point between the flow peaks (Table 17). The peak flow (magnitude) of the second peak was the largest and it had the largest transport rates at all sites except for TRAL, where the first peak saw slightly more transport than the second peak. For TRAL, with a ≥8mm load of 2,300 tons, the first, second and third peaks transported 48%, 41% and 11% of the ≥8mm load, respectively. At TRGV, with a ≥8mm load of 1,800 tons, the first, second and third peaks transported 30%, 51% and 19% of the ≥8mm load, respectively. TRLG with a ≥8mm load of 870 tons, the first, second and third peaks transported 25%, 54% and 21% of the ≥8mm load, respectively.. TRDC with a ≥8mm load of 10,410 tons, the first, second and third peaks transported 36%, 36% and 19% of the ≥8mm load, respectively.

(Excerpted) Table 17. ≥8mm bedload totals for each peak flow bench, WY2019.

	Suspended Sediment				Bedload		
SEDIMENT MONITORING STATION	SS <0.063 mm (tons)	SS 0.063 mm - <0.50 mm (tons)	SS ≥0.50 mm (tons)	SS Total (tons)	Bedload 0.50-<8 mm (tons)	Bedload ≥8 mm (tons)	Total Bedload (tons)
Trinity River at Lewiston (TRAL)	NA	NA	NA	NA	614	2,300	2,910
Trinity River above Grass Valley Creek (TRGV)	3,120	3,920	1,490	8,530	1,140	1,800	2,950
Trinity River below Limekiln Gulch (TRLG)	3,450	5,100	1,310	9,850	868	870	1,760
Trinity River near Douglas City (TRDC)	5,770	11,300	4,080	21,160	5,580	10,410	16,000

All values rounded using methods by Porterfield (1972)

The magnitude of Spring Flow Release sediment loads is dependent upon numerous factors, including: peak flow magnitude, hydrograph shape, sediment augmentation efforts (e.g. location and augmentation volume), changes in transport capacity (e.g. from channel and floodplain restoration) and tributary sediment contributions. We examined potential trends in the coarse bedload (≥8mm) Spring Flow Release load totals from 2004 to 2019. In the previous 13 years of sediment sampling, there have been four "Dry" type releases (2007, 2009, 2013, 2015), five "Normal" releases (2004, 2005, 2008, 2010, and 2012), and four "Extremely Wet" releases (2006, 2011, 2016 and 2017). The distinction between water year type and Spring Flow release type is important because there were some variations (e.g. 2011 was a Wet water year type, but had an Extremely Wet release, 2004 was a wet year, but had a Normal Year release type). WY2019 was classified a Wet water year and had a modified Wet flow release type.

We examined coarse bedload transport at all stations over the 14 monitored flow releases dating back to 2004 (12 years at TRGV). 2006, 2011 and 2017 clearly dominated the coarse bedload transport at all stations although at TRGV, 2016 produced the third highest computed load. All stations exhibited an apparent downward trend in ≥8mm transport during Normal Release types. The trend among Dry Flow Release types is less clear (2007, 2009, 2013 and 2015), though 2015 clearly transported larger loads than the other three years. 2015 with its “Dry (modified)” release type (that is a dry year restoration total release [453,000 af] with an 8,500 cfs flow bench) showed an evident increase over preceding “Dry-type” flow releases at all stations. At TRGV, WY2015 exceeds some wet years and at TRAL and TRDC, WY2015 approximates the magnitude of “Normal” flow release types (Section 2.5.4).

WY 2019 bedload sample particle-size distributions were compared to examine general variations in grain size, both between stations and between peak flows. TRDC did not show a large change in particle size distribution over the three peaks. The three sites upstream of TRDC showed the first peak transported finer material than the following two peaks. The third peak at TRAL stands out being that it has the coarsest transport of all sites.

The D50 for each bedload sample collected during the 2019 SFR is provided by individual site-hydrograph in Figure 40. With the exception of the second peak at TRAL, the D50 increased at each site from Peak 1 to Peak 3 (Table 18). This trend indicates that with similar flows and, in the case of the third peak on May 19, with a decrease in discharge, the system is moving less fine material over the duration of the flow release.

Bedload discharge is highly variable across a sampling section. Sample data reveal that two to three stations (locations) can transport most of the bedload along a sampling section (which generally contain 11-14 stations). Bedload discharge is also temporally variable. In 2019, we sampled the highest-transport location along the sampling section (at each site) repeatedly for a period of time yielding 3-6 samples. We examined variability in fine, coarse and total bedload discharge (total is the sum of fine and coarse) over the period (though the units are transformed into tons per day).

At TRAL, the fine bedload had a range of 52.9 tons per day while the coarse load had a range of 214 tons per day. The relative contribution of the fine bedload ranges from 12 to 37 percent.

At TRGV, the fine bedload had a range of 20.2 tons per day while the coarse load had a range of 145 tons per day. The relative contribution of the fine bedload ranges from 15 to 40 percent. TRGV shows the highest average coarse percentage at 87%.

Unlike at TRAL and TRGV, TRLG reveals heterogeneity in fine and coarse bedload. Fine bedload ranges from 37 to 66 percent and the coarse bedload ranges from 34 to 63 percent. The fluctuation of both fine and coarse bedload from mid-30% to mid-60% illustrates the variability a bedload sample may contain. An interesting feature of the TRLG variability study is that the total transport range (11 tons/day) has very little variability.

At TRDC, the fine bedload varied over a range of 35.0 tons per day while the coarse load varied over a range of 84.7 tons per day. The total transport rate has a range of 116 tons/day. The relative contribution of the fine bedload ranges from 22 to 57 percent. The total transport range at TRDC is more typical with a 116 tons/day fluctuation between the three samples.

Crews have reported that most of the sediment load is typically generated at one to three stations. If we apply the spatial inference mentioned previously (most of the load is transported at 3 to 4 stations) to the bedload variability study, then we can assume that at TRDC for example, that loads computed from samples collected at slightly different times could vary widely.

While the variability study data are far from conclusive, they do suggest a need for more sampling at fewer stations (i.e., over a narrower width of the cross section where the most sediment load is being transported) in order to derive a more accurate estimate of average bedload discharge. These data also support the need for a better surrogate than discharge such as passive hydroacoustics. The 2019 findings from the USGS (and other researchers who deployed hydrophones during the Spring Flow Release) will be highly relevant for improving future monitoring efforts.

1.0 INTRODUCTION

The mainstem Trinity River drains a 2,036 square mile (mi^2) watershed (excluding the South Fork Trinity) joining the Klamath River at Weitchpec, some 43 miles above the Klamath's entry into the Pacific Ocean. The Trinity River is the largest tributary to the Klamath River and historically produced large runs of Chinook salmon (*Oncorhynchus tshawytscha),* Coho salmon (*Oncorhynchus kisutch*), and steelhead trout (*Oncorhynchus mykiss*). Impacts from industrial gold mining and logging in the early to mid-1900s substantially changed the mainstem and tributary channels. Placer mining overturned the streambeds and washed hillslopes into stream channels; while logging of highly erosive watersheds, such as Grass Valley Creek, introduced considerable quantities of sand into the mainstem. Following the start of construction and resulting flow regulation in November 1960, the Trinity River Diversion Project (TRD) was fully completed in 1964 to increase water supplies to the Central Valley Irrigation Project. The TRD, which included both Trinity and Lewiston dams, blocked the upper 700 square miles of the watershed to fish passage, eliminated upstream large wood and sediment contributions, and severely reduced streamflow; in all, TRD diverted nearly 90 percent of the streamflow; however, downstream of the TRD, tributaries continued to remain largely unregulated, contributing streamflow, sediment, and wood at their natural (pre-TRD) rates. Constant low flow releases below Lewiston Dam failed to transport the tributary sediment contributions, and formed large deltas, commonly containing significant quantities of granitic sand. The low flows and large quantities of fine sediment provided the optimum conditions for riparian encroachment and berm development along the low-flow channel margin. Combined, these essentially eliminated channel migration, rendered the larger pre-dam alluvial features immobile, and greatly simplified stream channel geometry (e.g., continuous rectangular channel). The subsequent habitat loss and aquatic species decline were documented in numerous studies by the U.S. Fish and Wildlife Service, the Hoopa Valley Tribe, and other agencies e.g., Trinity River Maintenance Flow Study (McBain and Trush, 1997).

In an effort to restore the Trinity River fish and wildlife, the U.S. Secretary of the Interior directed the U.S. Fish and Wildlife Service to prepare the Trinity River Flow Evaluation Study in 1981 (TRFE, U.S. Fish and Wildlife Service and Hoopa Valley Tribe, 1999). The TRFE produced recommendations "to fulfill fish and wildlife mandates" of the Congressional Act authorizing the Trinity River Diversion. The study also provided the basis for the Trinity River Mainstem Fishery Restoration Environmental Impact Statement/Environmental Impact Report (U.S. Fish and Wildlife Service [USFWS], 2000) and the Record of Decision signed in 2000 (ROD, U.S. Dept. of Interior, 2000). The ROD established the Trinity River Restoration Program (TRRP), which included minimum water volume allocations based annually on water year type. The TRRP's purpose is to restore and maintain the natural production of fish and wildlife populations in the Trinity River, downstream of Lewiston Dam. To achieve this goal, the TRFE and ROD provide the scientific framework and management strategy to reestablish natural physical processes that promote a dynamic alluvial system which, in turn, intend to enhance aquatic habitat conditions capable of restoring salmonid populations. Restoration efforts focus on the Trinity River mainstem from Lewiston Dam downstream to the confluence with the North Fork Trinity River (Figure 1). The restoration strategy requires a combination of Spring Flow Releases, fine and coarse sediment management, and mechanical channel rehabilitation. This monitoring report focuses on the sediment management component.

Managing dam releases to route fine and coarse sediment through a river system requires an accounting of the sediment inputs, outputs, and a change in stream channel storage (i.e., a sediment budget). The simplest form of a sediment budget is expressed by the mass balance relation:

Input – Output = Change in Storage

On the Trinity River, sediment inputs downstream from Trinity and Lewiston dams are delivered naturally into each cell (see Figure 2 for graphical description of cells) by tributaries, and by managed coarse sediment injections, which are necessary to supplement lost upstream supplies or disconnected tributary supplies (i.e. Grass Valley Creek). Sediment outputs are simply the sediment transported by the mainstem at the downstream end of each sediment budget cell in Figure 2. The study reach and sub-reaches (cells, bounded by sampling stations) are further described in Section 2.1.

Several sediment budgets have been computed for the Trinity River between Lewiston Dam and Douglas City, including: the Trinity River Maintenance Flow Study (TRMFS, McBain & Trush, 1997); the Sediment Source Analysis for the Mainstem Trinity River (GMA, 2001); the Draft Sediment Budget and Monitoring Plan (SBMP, Wilcock, 2004); and the 2010 Bed-Material Sediment Budget Update (Gaeuman and Krause, 2011). Each sediment budget used the most current streamflow data, sediment transport measurements, tributary delta volumetric estimates, particle-size distribution measurements, and streamflow and sediment transport models to estimate the inputs and outputs.

The TRFE, ROD, and subsequent scientific contributions (Wilcock, 2004; Gaeuman and Krause, 2011), specify monitoring actions to address sediment budgeting related hypotheses and questions, and evaluate specific sediment management objectives. “A sediment budget provides a consistent and comprehensive framework within which the sediment objectives of the TRRP may be evaluated” (Wilcock, 2004). The central TRRP *sediment budgeting* objectives outlined in the TRFE are to:

- Reduce fine sediment storage in the mainstem;
- Increase and maintain coarse sediment storage in the mainstem Trinity River;
- Route coarse sediment supply through all reaches of the mainstem; and
- Reduce fine sediment inputs to the Trinity River.

Sediment transport monitoring is intended to estimate the inputs and outputs to mainstem sediment budget cells, which support flow scheduling (e.g., determining flow magnitude and duration) and other related sediment management efforts.

1.1 Sediment Management Objectives

The following section focuses on the flow-induced geomorphic processes and partially explains the flow evaluation process described in the TRMFS and TRFE. The magnitude, duration, frequency, timing, and rate of change of the ROD hydrographs were developed based on:

- thresholds required to initiate specific geomorphic processes (e.g., the flow magnitude necessary to scour a certain depth),

- o the flow required to maintain a geomorphic process (e.g., flow duration required to transport various quantities of sediment), or
- o historical attributes of the flow regime (e.g. historically, snowmelt flows occurred annually from April to June).

Previous monitoring on the Trinity River indicates sediment transport rates vary considerably over time and space, and can span up to several orders of magnitude; based on this, GMA (2006b) and Wilcock (2004) conclude direct measurement (as opposed to historical transport curves or mathematical models), provides the best method for estimating continuous sediment transport and annual loads. Sediment load computations inform gravel injection strategies, flow release hydrograph development, restoration design and other management decisions.

1.2 Report Organization

This report presents the results of WY2019 mainstem sediment transport monitoring efforts. The scope, scale and historical context of sediment sampling on the Trinity River are detailed in Section 2.0. WY2019 Methods and Results are described in their respective sections (2.3 and 2.4). Results are compared to those from previous years to examine general trends, which may be of use by Trinity River managers for predictive purposes and to assess management actions such as gravel augmentation and channel/floodplain restoration. Explanatory figures and tables are included in the text, whereas larger datasets are included as appendices. All data and seminal report files are included in a digital format. Less relevant documents (staff certification and SLQA compliance) are included with the digital files.

Definitions useful for this report:

“Site” and “Station” are used interchangeably to refer to the sediment monitoring locations. “Station” may also refer to a sampling location along a cross section (aka “vertical”) – though in this case, we attempt to clarify in the associated text.

“Sediment discharge” is often used to describe both the instantaneous rate of sediment transport and/or the cumulated load over time. While others’ definitions may vary, in this report we attempt to distinguish between sediment discharge and sediment load as follows:

(1) Sediment discharge: an instantaneous sediment transport rate, expressed in mass or volume per unit time (tons/day). For example, “a bedload discharge of 105 tons/day was measured on the Trinity River below Limekiln Gulch, sample measurement #7, on 5/6/12 at 13:15;” and

(2) Sediment load: a mass or volume of sediment transported over a pre-defined unit of time (tons). This is the rate (sediment discharge) integrated over a period of time. For example, “674 tons of bedload were transported past the Trinity River below Limekiln Gulch monitoring station during the WY 2013 Spring Flow Release”.

In this report, *sediment discharge* describes sediment in transport, and *sediment load* describes the quantity that was accumulated over a longer time period. A useful comparison is with streamflow: discharge is the instantaneous rate (cfs, analogous to sediment discharge) and yield is the volume of water cumulated over time (acre feet, analogous to sediment load).

“Hysteresis” refers to varying concentration at a common discharge.

2.0 SEDIMENT TRANSPORT MONITORING

WY2019 marks the 14th year (2004-2013, 2015-2017, 2019) of mainstem Trinity River sediment transport monitoring by GMA Hydrology (GMA, formerly Graham Matthews and Associates) for TRRP. Sediment transport monitoring, in various forms, has periodically occurred at a range of sites in the TRRP study area during the last thirty years. For example, the U.S. Geological Survey (USGS) collected sediment data from 1976-1999 at the Grass Valley Creek at Fawn Lodge gaging station, and from 1981-1991 at the Trinity River below Limekiln Gulch gaging station. Most of these sediment-monitoring efforts supported the TRFE process, or were conducted for watershed restoration and fine sediment reduction efforts occurring in tributary basins such as Grass Valley Creek. Previous results and data collection methods were described in detail in other reports, including the TRMFS; the Sediment Source Analysis for the Mainstem Trinity River Report (GMA, 2001); and the Annual Sediment Transport Monitoring Reports from WY 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2013, 2014 (GMA, 2003, 2006a, 2006b, 2007, 2008, 2009, 2010, 2013, 2014, 2015, 2016, 2017, 2018).

In WY 2002, following recommendations from the ROD and TRFE, the Trinity River Restoration Program began operating several tributary and mainstem streamflow and sediment monitoring stations. Subsequent recommendations laid out in the SBMP (2004) focused the sediment transport monitoring efforts on three major tributaries and four mainstem sites (Figure 1). Sediment monitoring on the tributaries was discontinued after WY 2006.

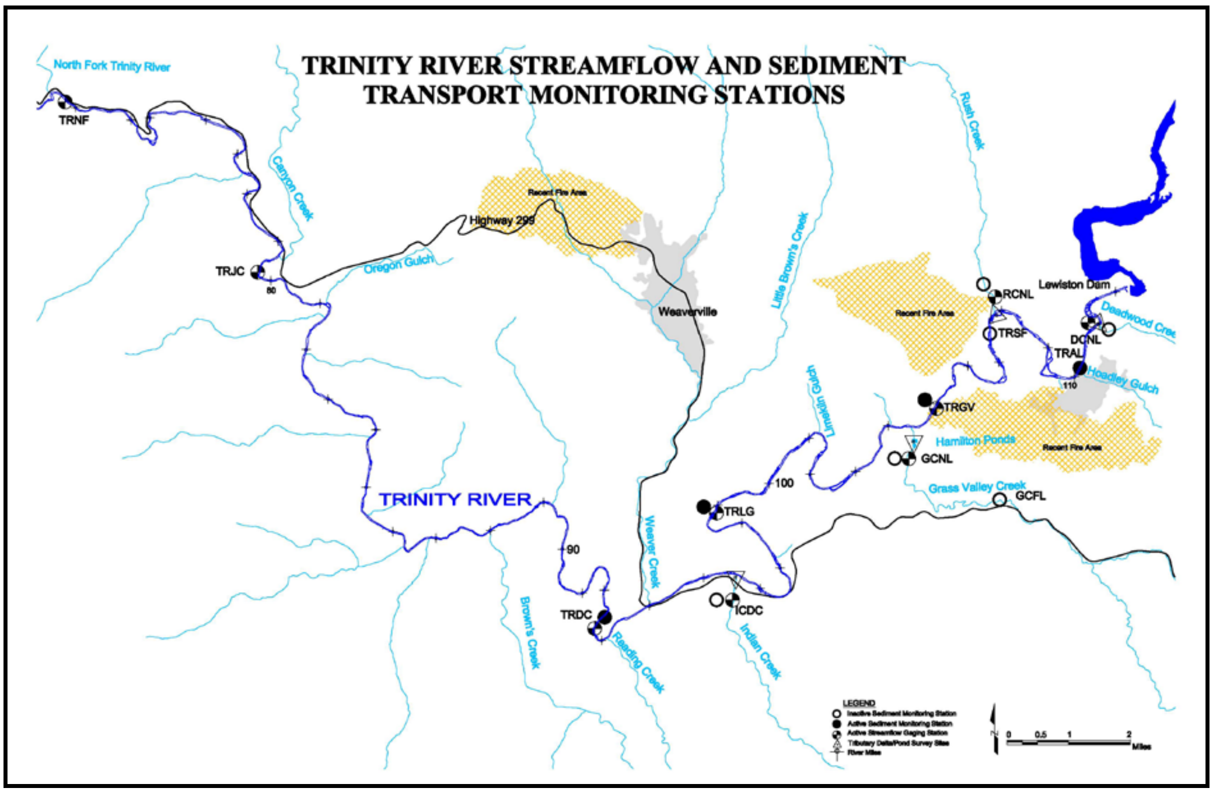


Figure 1. Location Map for the Trinity River Spring Flow Release Sediment Transport Monitoring. Black circles describe locations of the four mainstem sampling stations.

2.1 Sediment Transport Monitoring Locations

In WY 2019, sediment transport data were collected at four mainstem Trinity River monitoring stations during the Spring Flow Release: Trinity River at Lewiston (TRAL, USGS gage #11525500, approximate River Mile [distance upstream from confluence with Klamath River, RM] 109.95), Trinity River above Grass Valley Creek near Lewiston (TRGV, GMA gage #11525540, RM 104.5), Trinity River below Limekiln Gulch near Douglas City (TRLG, USGS gage #11525655, RM 98.7), and Trinity River at Douglas City (TRDC, USGS gage #11525670, RM 92.6) (Figure 1). These are the same stations used for previous annual GMA monitoring, with the exception of TRGV, which was relocated in 2006. The USGS operated the streamflow gages at the TRAL, TRLG, and TRDC stations. GMA operated the seasonal streamflow gaging station at TRGV.

The monitoring stations were designed to provide sediment flux data for the four mainstem sediment budget cells between Lewiston Dam and Douglas City (Figure 2). The larger tributaries (site name initials provided for reference in Figure 1), Deadwood (DCNL), Rush (RCNL), Grass Valley (GCFL, GCNL), Indian (ICDC), Weaver, and Reading Creeks, provide the majority of the natural sediment contributions for the mainstem within the study area. The downstream-most sediment budget boundary is located near Douglas City, where additional streamflow and sediment contributions (from Indian, Weaver, and Reading Creeks) significantly reduce the coarse sediment and streamflow deficits. Below Douglas City, dam releases and natural runoff events are generally capable of transporting sediment influxes (TRFE, 1999; GMA, 2007).

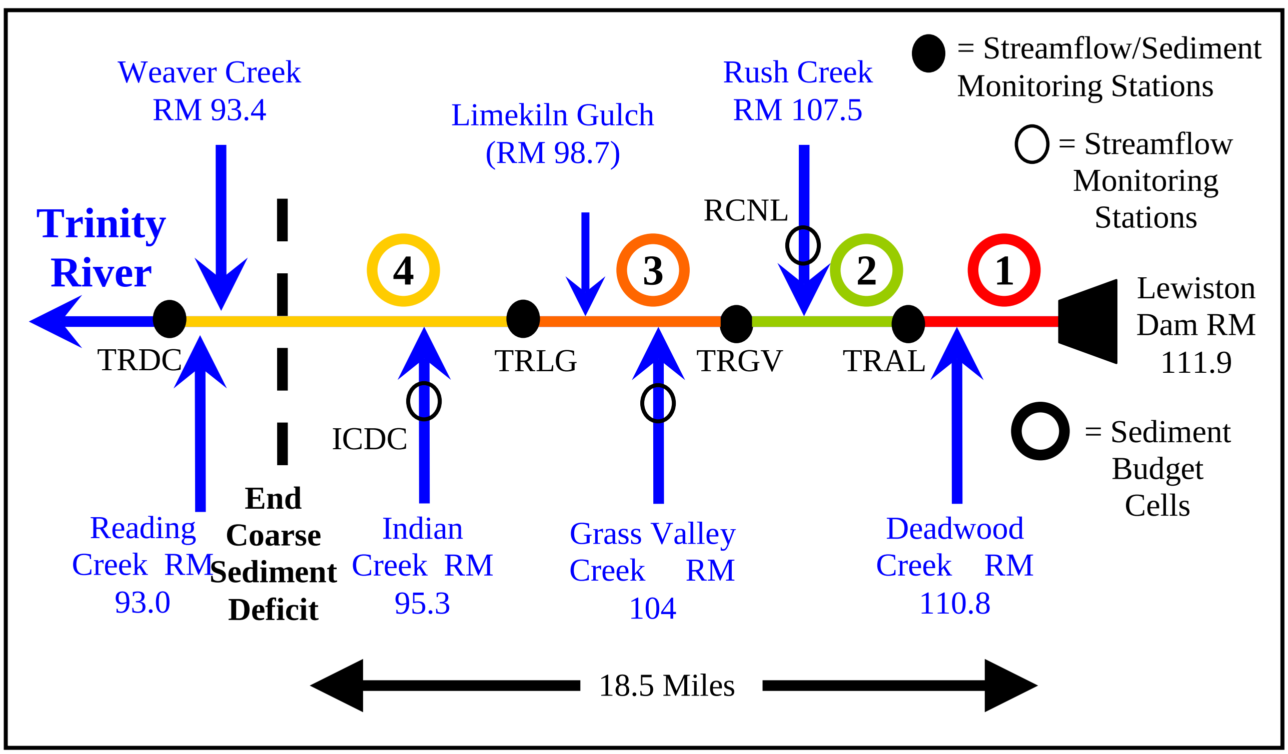


Figure 2. Schematic drawing of the Trinity River Sediment Budget, showing sediment sources and routing. The river has been divided into cells (1 through 4) bounded by stations, which are used for monitoring, measurement and analysis to compute sediment transport and storage.

2.2 Sediment Transport Monitoring: Objectives and Tasks

WY 2019 sediment transport monitoring occurred during the Spring Flow Release period. The overall WY 2019 objectives were to determine the rate, volume (load) and texture of total sediment load at the four monitoring locations.

Primary sediment monitoring tasks designed to accomplish these objectives included:

- Operating mainstem sediment transport monitoring stations at: the Old Lewiston Bridge (TRAL); above the Grass Valley Creek confluence (TRGV); at the USGS gaging station below Limekiln Gulch (TRLG); and just downstream of the USGS streamflow gaging station at the Bureau of Land Management (BLM) Douglas City Campground (TRDC);
- Collecting continuous turbidity at three of the four mainstem sampling stations TRGV, TRLG, TRDC;
- Collecting streamflow measurements and continuous stage data at TRGV during the Spring Flow Release period;
- Updating stage/discharge relationships and computing streamflow records for TRGV;
- Developing turbidity/suspended sediment concentration (SSC) relationships, discharge/SSC, and discharge/bedload relationships as required;
- Computing continuous bedload and suspended sediment discharge using sediment samples we collected and using methods developed by the USGS. Sediment sample analyses were performed to provide transport rates by size fraction: <0.063mm (suspended), 0.063-<0.5mm (suspended), ≥0.5mm (suspended), 0.5-<8.0mm (bedload), and ≥8.0mm (bedload); and
- Computing bedload and suspended sediment load estimates for these size classes for the Spring Flow release period.
- Additional data were collected to support sediment transport computations, and subsequent sediment budgeting efforts, including: water surface slope measurements (during the flow release), bed-surface particle size distributions and cross section surveys at the sediment transport monitoring stations (pre- and post-flow release) (Appendices A, B, C, D). We also conducted experimental "bedload variability testing" (repeat sampling at one location) to assess the potential range in magnitude of bedload transport.

New for 2019 (TRRP, personal communication):

- Bedload sampling sections were divided into halves to provide partition section transport for hydrophone calibration.
- Bedload samples were collected according to a schedule created by TRRP.
- Pressure transducers (PT) installed at each water surface monitoring reference area. PTs recorded 15-minute continuous data through the peak release.
- No suspended sediment data was collected at TRAL.
- ADCP velocity measurements were taken to pair with bedload measurements from TRGV.

2.3 Sediment Transport Monitoring Methods

Sampling protocols and methods, lab analysis, data entry, quality assurance, and sediment computation methods are described in detail in previous reports (e.g., GMA, 2006b); thus the following section provides only the absolutely essential descriptions.

2.3.1 Streamflow Monitoring and Computational Methods at TRGV

Streamflow monitoring and continuous-discharge computation for the Trinity River above Grass Valley Creek were carried out using standard or modified USGS methods. Continuous stage was recorded using a Design Analysis H-310 pressure transducer. The H-310 has an accuracy of less than or equal to 0.025 percent of the full-scale output (FSO). Continuous stage readings were recorded in the data collection platform (DCP) at 15-minute intervals. Stage observations from staff plates were recorded on all site visits. All surface water data including electronic gage data, staff-height readings, the gage datum, and discharge measurements were entered and processed in the WISKI Suite (Water Information Management System Kisters), developed by KISTERS AG. WISKI is a Windows-based time-series hydrological data management package, based on a relational database client-server platform such as Microsoft Sequel Server. The WISKI Suite is comprised of three components: WISKI, BIBER, and SKED. The main WISKI shell is the hydrologic workbench where all data are organized and where computations on time-series data are carried out. BIBER is used to evaluate and manage discharge measurements as well as track current meters and personnel using those meters. SKED is a rating curve editor that uses a graphical user interface to assist the hydrologist in developing, maintaining, and applying rating curves. The U.S. version of WISKI uses standard hydrologic computations and techniques as set forth by the USGS. Full details of computations can be found in the station analyses contained in Appendix B.

2.3.2 Mainstem Sediment Sampling

All sediment sampling was conducted from cataraft-based sampling platforms as in previous years. The catarafts were attached to tensioned cableways (temporary cableways of 5/16" galvanized wire rope) securely attached to trees or other anchors on either side of the channel. Various types of equipment were deployed from the cataraft platforms, including 12 inch wide TR-2 bedload samplers with 0.5mm mesh (Figure 3) and US D-74 suspended sediment samplers. This was the 12th year that TR-2 bedload samplers were utilized at all four stations. In previous years, 6 inch Helley-Smith samplers were utilized.

GMA personnel at each site consisted of, at a minimum, two crew on the cataraft and one safety kayaker. All GMA staff have completed First Aid and CPR training and Swift Water Rescue Training courses. Each day crews, to the best of their abilities, followed the approved schedule and collected one-pass bedload samples, two-pass suspended sediment samples, and water surface slope measurements before and after each bedload measurement.

TRGV, TRLG, and TRDC were each fitted with a Forest Technology Systems DTS-12 in-situ turbidity probe and a Campbell CR200 data collection platform, set to record on 15-minute intervals. Articulating booms used in previous years were again used in 2019 to deploy the turbidity probes, whereas prior to 2011 the probes had been mounted in fixed locations. The articulated booms (Figure 4) allow turbidity probes to shed debris and produce much cleaner turbidity records. For all stations, Station Analyses, detailing sediment data collection and computational methods, were developed for each sampling station

(Appendices A, B, C, D). Quality Assurance plans for both laboratories are available to interested parties.

Suspended sediment measurements, were collected over a range of flows and at various positions on the hydrograph during the 2019 Spring Flow Release. Cross-sections were typically sampled at 11-15 verticals. Protocols followed standard USGS procedures (Edwards and Glysson, 1999) for Equal Width Increment (EWI) sampling. Information recorded for each sample included: time, date, site, stage, bottle #, pass #, method, equipment used, etc. All suspended sediment samples were transported to GMA's fine sediment laboratory in Arcata, CA, where they were processed and summarized for three particle-size ranges (<0.063mm, 0.063-<0.5mm or ≥0.5mm).

Bedload measurements were collected on 14 days within the release period. The sampling down-times (i.e., time the sampler rested on the bed actively collecting sediment) ranged from 15 to 600 seconds. Bedload samples were also transported to the GMA sediment lab in Arcata, CA where they were processed and the data were summarized (Figure 5).

Figure 3. A 200 lb twin-tube TR2 bedload sampler deployed from a cataraft at the TRLG sampling site in April, 2017.

Figure 4. An articulating turbidity boom and gage house box deployed at TRGV in 2019.

Figure 5. GMA Coarse Sediment Laboratory, Arcata, CA.

2.3.3 Continuous Suspended Sediment Discharge and Load Computations

The computational period for the mainstem stations was defined as April 1, 2019 00:00 to July 31, 2019 23:45. (encompassing the Spring Flow Release, as stipulated by TRRP). Computations were performed as follows: First, suspended sediment transport curves were generated in order to develop estimates of continuous suspended sediment concentration (SSC). Next, the curves were analyzed to investigate whether streamflow and/or turbidity provided reasonable surrogate measures for predicting continuous suspended sediment concentration. Then, SSC data points were obtained from depth-integrated suspended sediment samples and the corresponding streamflow or turbidity values and transport curves were developed from these data. Once sedigraphs of continuous concentration were generated using the transport curves, the plotted traces were adjusted to pass through the depth-integrated sample data points. Finally, continuous concentration was transformed into continuous suspended sediment discharge (SSD) using the standard equation:

$$Q \text{ (cfs)} * SSC \text{ (mg/l)} * 0.002697 = SSD \text{ (tons/day)}$$

Continuous suspended sediment discharge was summed over the computational period to compute the load for the following size classes (partial loads): < 0.063mm, 0.063mm - <0.5mm, and ≥ 0.5mm. Mainstem total suspended sediment load was computed by summing the partial loads. For detailed information on suspended sediment discharge computations see the individual Station Analyses in Appendices A, B, C, and D.

2.3.4 Continuous Bedload Discharge and Bedload Computations

The computational period for the mainstem stations was April 1, 2019 00:00 to July 31, 2019 23:45 (i.e. the Spring Flow Release, same as per the suspended sediment computations). Continuous partial-bedload discharge was computed for 0.5-<8mm and ≥ 8mm size classes. Single (or multiple) sediment transport curves were fitted through distinct groupings of measured bedload vs stream discharge points. Continuous bedload sediment discharge was estimated as a function of stream discharge for the two size classes. Bedload sedigraphs (graphical depictions of continuous sediment discharge) were constructed and were manually fitted through the measured sediment discharge points. This employs a combined approach (utilizing multiple temporal transport curves and sedigraph fitting through measured data points) which is more accurate for assessing the transport variability on the Trinity River (observed during previous flow releases) than the application of a single, general transport curve for the entire release period. While comparisons between the combined and single-curve approaches have shown minor differences in computed bedload discharge totals (GMA 2006b; 2007), the combined method highlights short term trends which the single regression method does not. In WY2019, the single general equation and multiple equation approaches were applied as appropriate.

The TR-2 samplers were equipped with 0.5mm mesh sampler bags, which allowed an unknown portion of the <0.5mm size sediment particles to pass through the samplers. Therefore, continuous bedload discharge was not computed for the <0.5mm size fraction. For simplicity, the 0.5-<8mm and ≥ 8mm size classes are hereafter referred to as “fine” and “coarse” bedload. Continuous total bedload discharge ≥ 0.5mm was computed by summing these partial bedload discharges. Bedload was estimated for the release period by summing the area under the respective sedigraph. For detailed information on bedload discharge and bedload computations see the individual Station Analyses in Appendices A, B, C, and D.

2.3.5 Cross Sections, Water Surface Slope and Pebble Counts

Water surface elevation (stage) data were recorded at each station. Stage references consisted of posts or staff plates which had their elevation established using leveling methods detailed in Harrelson et al. (1994). Manual measurements were taken before and after each bedload measurement. Continuous stage was recorded at 15-minute intervals at each reference section using a HOBO ONSET Water Level Logger. A barometer was installed in close proximity to correct the pressure transducers raw pressure file. The distance stage measurement posts was measured during peak flows and facilitated calculation of water surface slope.

One cross section at each sediment monitoring site was surveyed pre- and post-Spring Flow Release. Cross sections were surveyed per standard methods (Harrelson et al. 1994) to assess topographic changes at the sampling section. Topographic change along cross sections was calculated in MS Excel by creating a common 1-foot stationing between sequential surveys and interpolating surveyed elevations to these stations, resulting in both surveys having elevations for the same stationing. Topographic change was computed incrementally, (elevation difference multiplied by a 1 foot width), and then summed, to create cut/fill tables and calculate total pre- and post-release cross section area change.

In addition, pebble counts (n=100+ particles) were collected along the cross sections to examine textural changes related to the flow release (Wolman 1954). Pebble count results are used to describe the texture of the dominant bedload transport feature (e.g. a transverse gravel bar).

2.4 Sediment Transport Monitoring Results

2.4.1 Hydrology and Streamflow

The following is a description of the Water Year 2019 hydrologic setting and the resulting flow release hydrograph. WY2019 was determined to be a "Wet" water year (TRRP 2019).

The approved release hydrograph included three high flow peaks above 8,000 cfs during April and May and three additional smaller peaks, less than 5,000 cfs, as flows were dropping through May, June and July. All of the peaks were planned to be instantaneous and not contain a bench. The three high flow peaks were planned to have peak values of 9,850 cfs on April 17; 10,900 cfs on April 29; and 9,000 cfs on May 19. The three smaller peaks were planned to be 4,500 cfs on May 24; 3,800 cfs on June 7; 2,450 cfs on June 23; and 3,200 on June 26. A gradual tailout spanned ran from June 27th, with the hydrograph dropping back to summer base (450 cfs) on August 5th.

Examination of the 15-minute water discharge data at USGS gage near Lewiston (11525500, Figure 6) shows the flow release closely tracked the planned hydrograph. The first high flow peak rising limb, had an inflection at 4,190 cfs on April 15 17:30. It dropped to 2,720 cfs on April 16 22:00 then rose to a peak of 9,800 cfs on April 17 16:45. The falling limb started at 18:00 and continued until April 28 17:15 at 1,950 cfs when the hydrograph began to rise again. The second peak occurred on April 29 18:30 at 10,800 cfs. Flows fell to 3,500 cfs on May 1 12:00 at which point a bench occurred until May 4 03:30. Flow dropped to 2,600 cfs on May 15 13:30 and then began to rise. The third high flow peak occurred on May 19 07:15 at 8,920 cfs. Flows dropped to 2,350 cfs on May 24 07:45 then rose to a peak of 4,600 cfs on May 24 15:45. Flows dropped to 2,060 cfs on June 7 04:15, then rose to 3,970 cfs on June 7 04:15, dropped to 1,550 cfs on June 20 00:15, rose to 2,800 cfs on June 23 14:30, dropped to 1,900 cfs on June 25 06:45, rose to 3,450 cfs on June 26 13:30 then tailed off to 440 cfs on August 6, 2019 at 12:30.

2.4.2 Mainstem Sediment Transport Monitoring

Following the approved schedule, GMA sampling crews collected suspended sediment and bedload measurements during the three high flow peak events. Table 1 summarizes the number of bedload and suspended sediment samples collected by station. For 2019, experimental bedload-variability testing (repeated sampling at a high-transport location to examine short-term temporal variability) was performed for a 30-minute period at each site. Crews collected 14 discharge measurements during the release period and one after the release period, for computing continuous discharge at TRGV. Appendices A, B, C and D provide hydrographs displaying the timing of bedload and suspended sediment samples at each station.

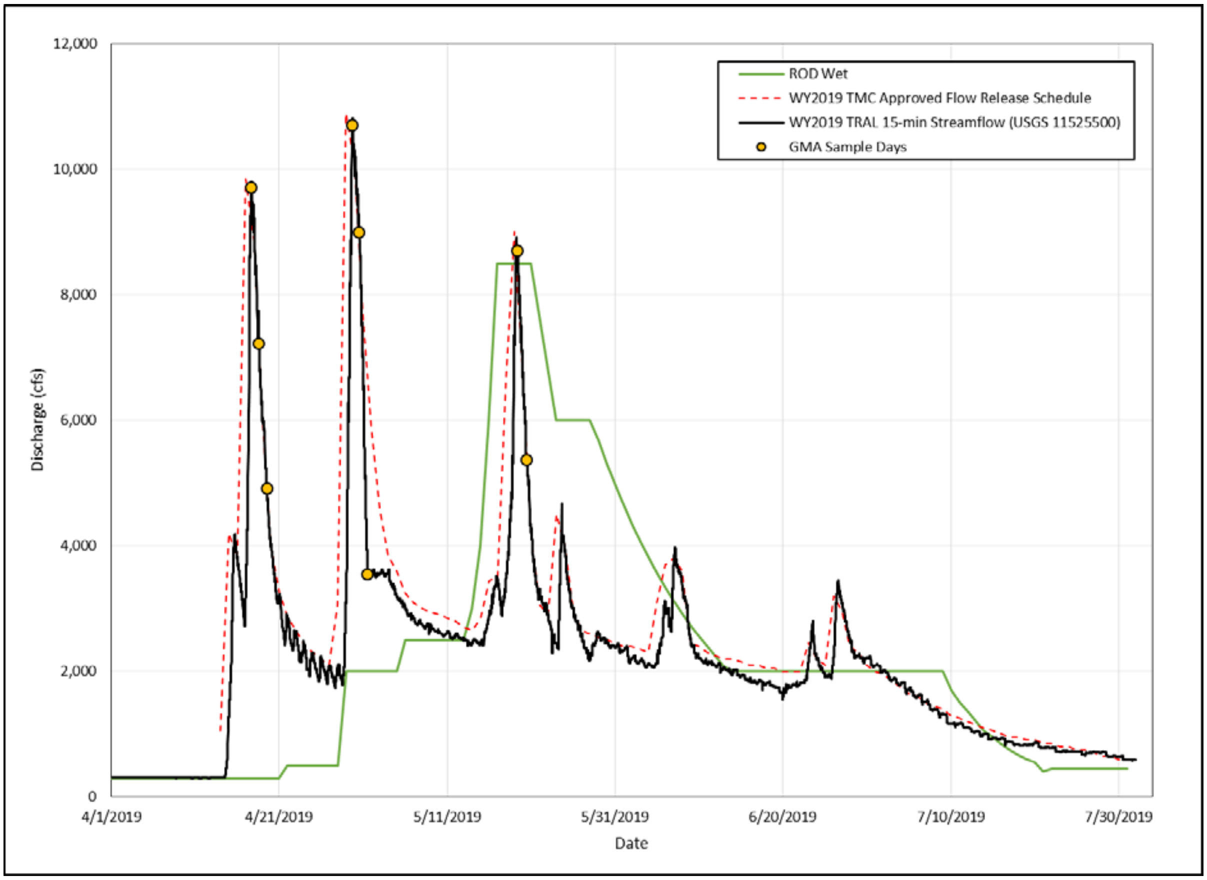


Figure 6. ROD Wet hydrograph, TMC Approved hydrograph, and recorded (actual) Streamflow for USGS Gage #11525500, Trinity River at Lewiston, CA for the WY2019 Spring Flow Release.

Table 1. WY 2019 Mainstem Sediment Sample Summary

SEDIMENT MONITORING STATION	SUSPENDED SEDIMENT SAMPLES (# collected)	BEDLOAD SAMPLES (# collected)
Trinity River at Lewiston (TRAL)	0	29
Trinity River above Grass Valley Creek (TRGV)	12	25
Trinity River below Limekiln Gulch (TRLG)	15	32
Trinity River near Douglas City (TRDC)	13	31

2.4.2.1 Trinity River at Lewiston

Station Description

The TRAL station defines the end of the first sediment budgeting cell which starts at Lewiston Dam (Figure 1, Figure 7). Since WY 2005, sediment transport monitoring has occurred directly beneath the old Lewiston Bridge. Previous sediment transport monitoring occurred 1,150 ft upstream, near the USGS Trinity River at Lewiston gaging station cableway. The USGS streamflow gaging station (#11525500) is located farther upstream, just below the old fish weir.

Suspended Sediment Transport Data

As directed by TRRP, no suspended sediment data were collected at TRAL in 2019.

Figure 7. Overhead view of TRAL Sampling Site looking upstream. Sampling cataraft visible under the Old Lewiston Bridge. Flow is approximately 11,500 cfs.

Bedload Data

Twenty-nine bedload samples were collected at TRAL during the Spring Flow Release. All samples were one-pass samples. Bedload sample data are displayed in Table 2. Bedload sample times were plotted on the hydrographs in Appendix A-3 and displayed in the Bedload Summary in Appendix A-5. WY 2019 fine, coarse, and total bedload discharge samples were plotted with historic data in Figures 8-10. Measured total bedload discharge (sum of fine and coarse bedload) ranged from a peak of 1,990 tons/day on April 17 to a minimum of 6.74 tons/day on April 19. The bedload transport curves used to compute continuous bedload discharge are provided in Appendix A-2.

Table 2. Trinity River at Lewiston -- USGS #11525500, Bedload Sampling Summary -- WY2019

Sample Number	Date & Mean Time	Average Discharge (cfs)	Total Bedload Discharge (tons/day)	≥ 8mm Bedload Discharge (tons/day)	0.5-<8 mm Bedload Discharge (tons/day)
TRAL-BLM2019-01	04/17/2019 11:12	7,120	377	250	121
TRAL-BLM2019-02	04/17/2019 12:14	8,550	586	414	164
TRAL-BLM2019-03	04/17/2019 14:24	9,190	1,990	1,640	336
TRAL-BLM2019-04	04/17/2019 16:07	9,710	999	792	203
TRAL-BLM2019-05	04/18/2019 08:46	7,900	771	686	82.4
TRAL-BLM2019-06	04/18/2019 12:18	7,230	431	301	129
TRAL-BLM2019-07	04/18/2019 16:25	6,810	353	321	31.6
TRAL-BLM2019-08	04/19/2019 08:25	5,260	136	84.7	51.4
TRAL-BLM2019-09	04/19/2019 12:28	4,920	25.1	13.5	11.5
TRAL-BLM2019-10	04/19/2019 16:04	4,600	15.4	8.26	7.10
TRAL-BLM2019-11	04/19/2019 17:55	4,440	6.74	2.32	4.38
TRAL-BLM2019-12	04/29/2019 09:11	7,010	316	182	132
TRAL-BLM2019-13	04/29/2019 10:16	8,010	484	356	126
TRAL-BLM2019-14	04/29/2019 12:28	8,540	786	544	239
TRAL-BLM2019-15	04/29/2019 14:22	9,570	629	391	236
TRAL-BLM2019-16	04/29/2019 16:28	10,700	1,030	784	247
TRAL-BLM2019-17	04/29/2019 17:54	10,600	1,400	1,130	224
TRAL-BLM2019-18	04/30/2019 09:04	9,360	567	420	146
TRAL-BLM2019-19	04/30/2019 12:19	9,000	291	192	98.9
TRAL-BLM2019-20	04/30/2019 16:23	8,550	526	391	134
TRAL-BLM2019-21	04/30/2019 17:47	8,180	289	256	32.5
TRAL-BLM2019-22	05/19/2019 08:53	8,710	405	321	82.8
TRAL-BLM2019-23	05/19/2019 10:12	8,600	272	219	52.2
TRAL-BLM2019-24	05/19/2019 14:18	8,000	236	184	51.3
TRAL-BLM2019-25	05/19/2019 18:02	7,480	174	144	29.9
TRAL-BLM2019-26	05/20/2019 08:17	5,760	26.5	23.0	3.53
TRAL-BLM2019-27	05/20/2019 10:22	5,380	15.6	13.9	1.69
TRAL-BLM2019-28	05/20/2019 14:33	5,120	32.0	29.5	2.42
TRAL-BLM2019-29	05/20/2019 17:32	5,010	21.5	20.0	1.39

Values Rounded According to Porterfield (1972)

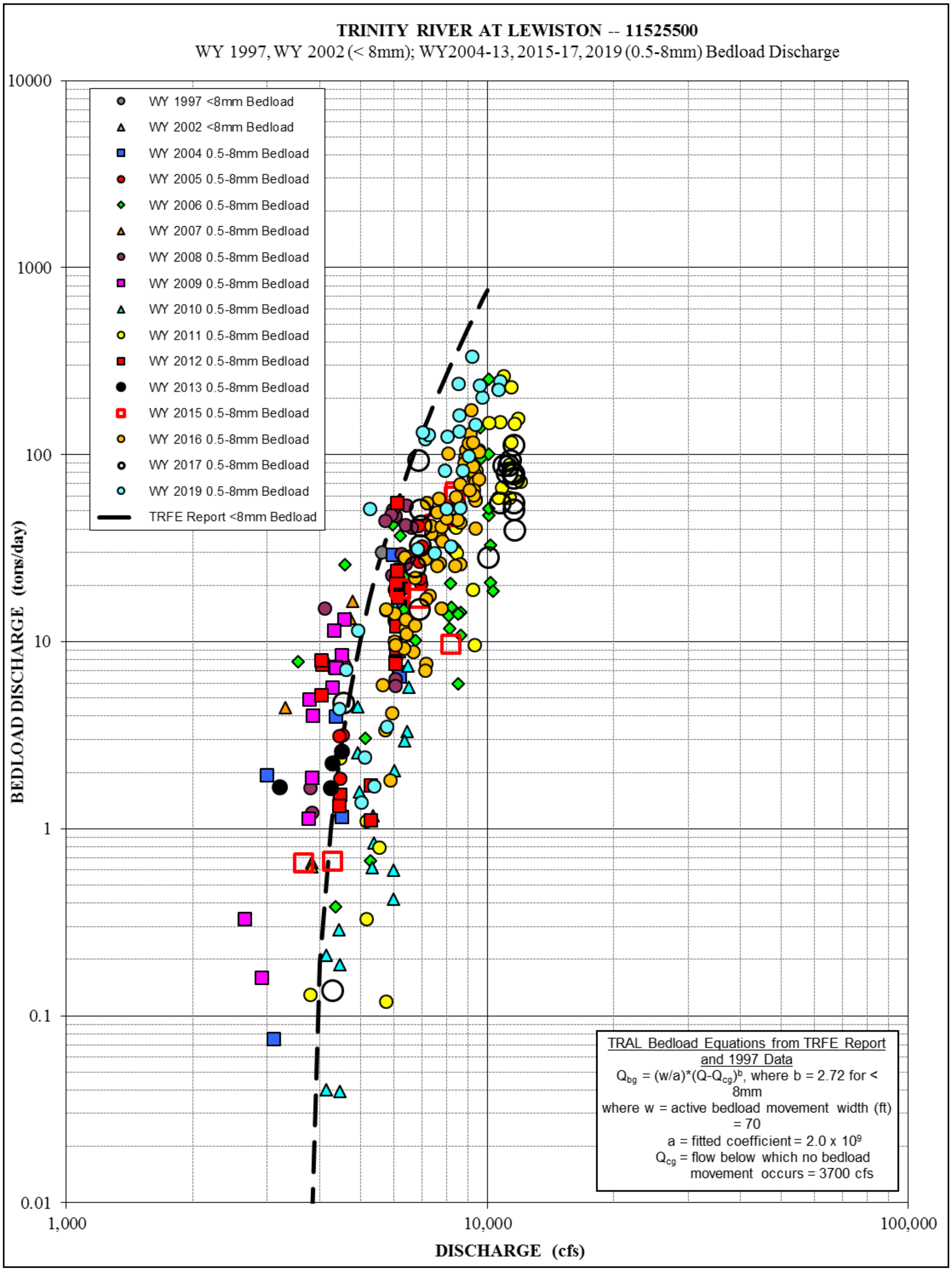


Figure 8. Fine Bedload Discharge (0.5-<8mm) at TRAL, WY1997-2019.

The 1999 TRFE bedload equations were used to develop flow recommendations based in part on bedload discharge predictions at TRAL and TRLG (shown in the inset box on chart). The equation is plotted and shown here as the dashed black line and is included for comparison with subsequent measured bedload transport rates.

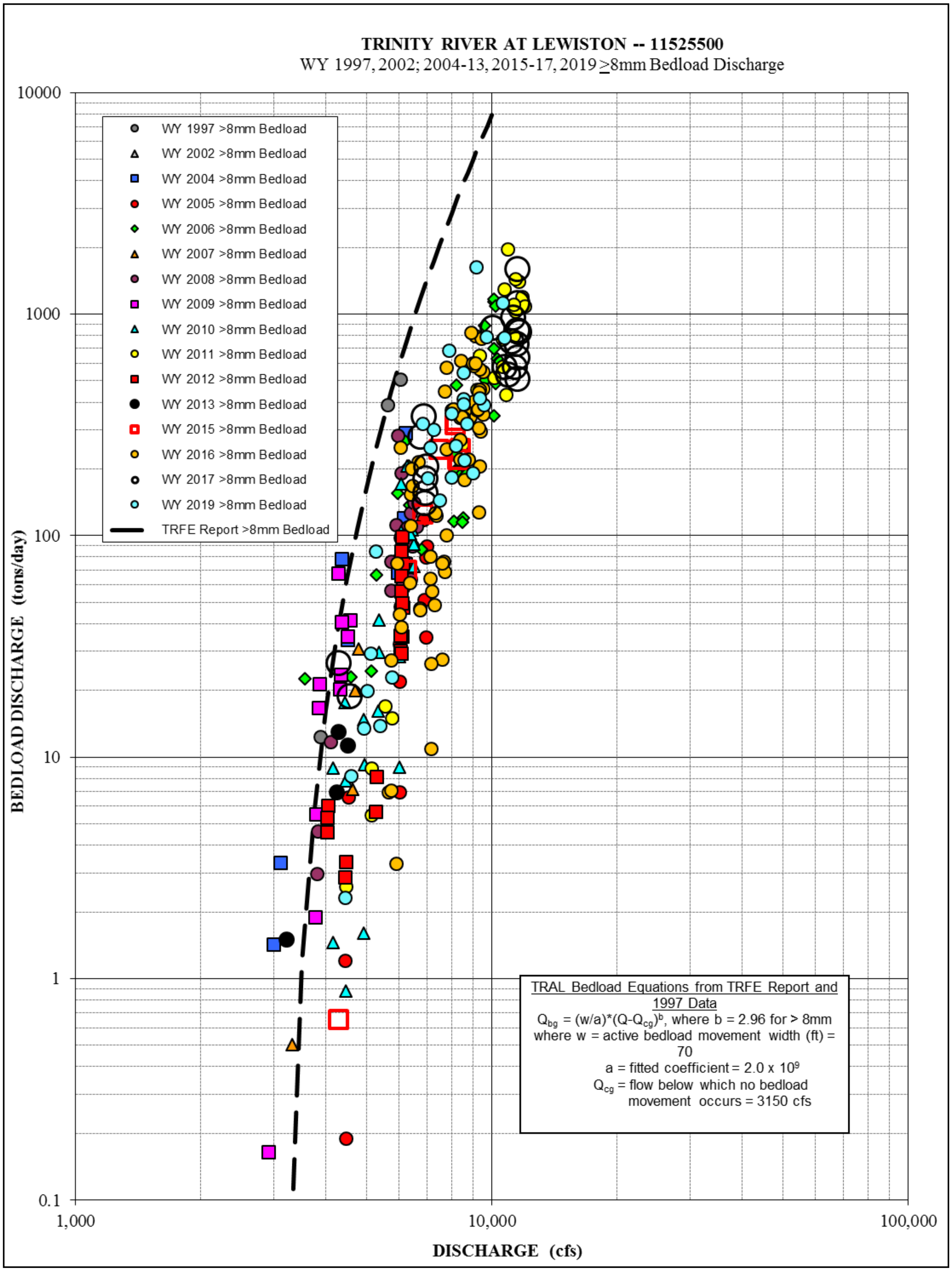


Figure 9. Coarse Bedload Discharge (≥8mm) at TRAL, WY1997-2019.

The 1999 TRFE bedload equations were used to develop flow recommendations based in part on bedload discharge predictions at TRAL and TRLG (shown in the inset box on chart). The equation is plotted and shown here as the dashed black line and is included for comparison with subsequent measured bedload transport rates.

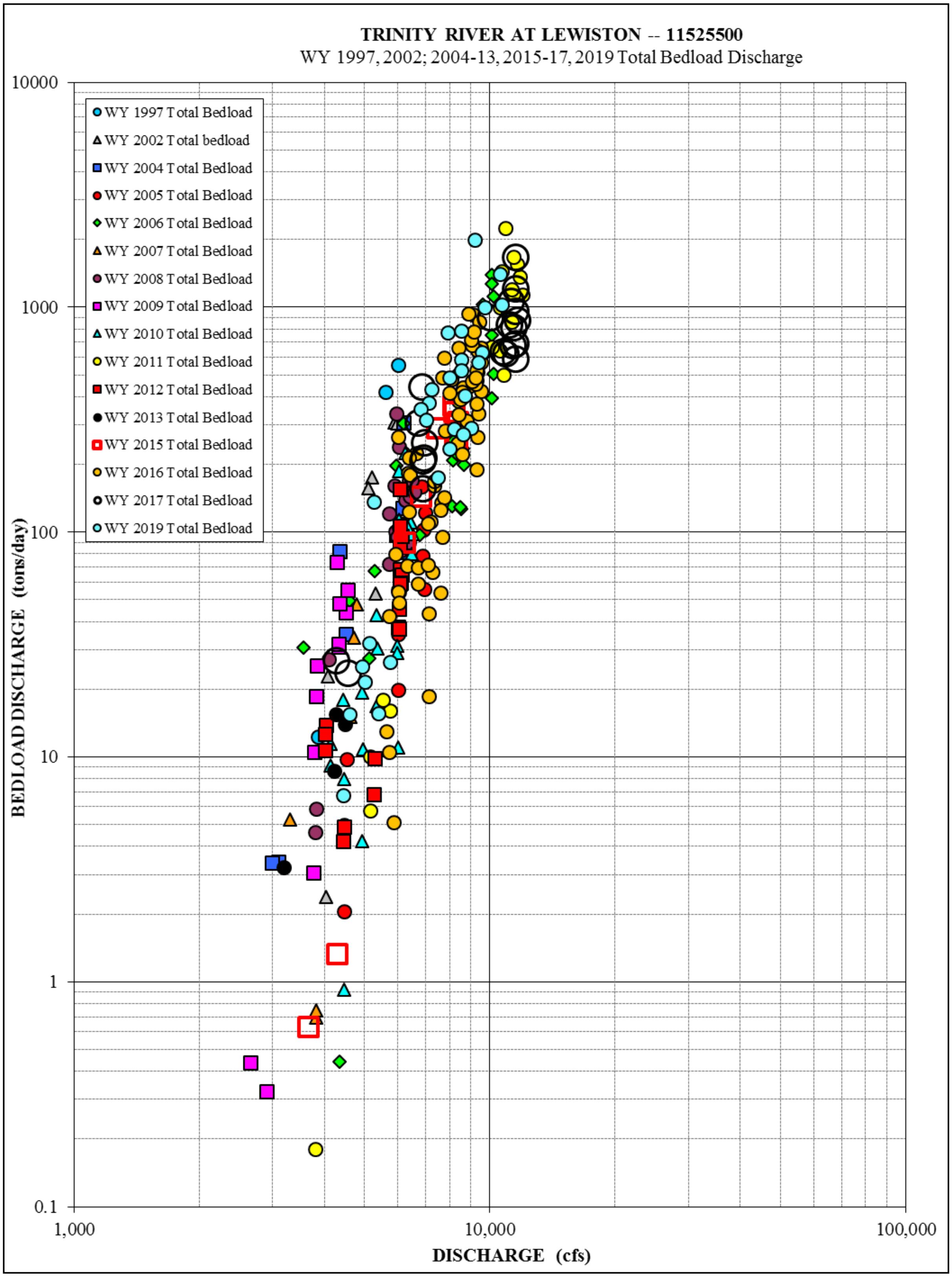


Figure 10. Total Bedload Discharge at TRAL, WY1997-2019.

Continuous bedload-discharge sedigraphs are displayed in Appendix A-3. Flow release estimates for fine, coarse, and total bedload in WY 2019 were 614, 2,300 and 2,910 tons, respectively (Table 3). Detailed explanations of the bedload discharge load computations are provided in the Station Analysis (Appendix A-1). Appendix A-5 contains the particle size distributions, sample data, (e.g. sample times, weights, computed transport rates) and bedload computation values. As discussed in section 2.3.4, the <0.5mm fraction is omitted from bedload data and computations; however, this fraction is included for graphical comparisons with historic values (e.g. Figure 10).

Bedload samples were partitioned to support hydrophone experiments conducted by USGS and NOAA. Partitioned sample results are included in Appendix A-5 in a sub-folder labeled 'SplitXS' in individual Excel spreadsheets. Sample numbers were split into an A and B sub-sample, representing the left or right side of the channel as indicated by the stations sampled with station zero being on the right bank. Results in the Excel spreadsheet contain pertinent metadata such as, but not limited to, date, start and end time, the begin and end stage height, bottom time, stations sampled, interval (distance between stations) and processing information.

Table 3. Trinity River at Lewiston, CA -- USGS Gage #11525500, Bedload -- WY2019

0.5-<8 mm (tons)	≥8 mm (tons)	Total Bedload (tons)
614	**2,300**	**2,910**

Values Rounded According to Porterfield (1972)

Water Surface Slope, Cross Section Changes and Pebble Count Changes

The WY2019 peak water surface slope through the reach was 0.0017. Cross section (Figure 11) and pebble count (Figure 12) data were collected at the TRAL sediment monitoring site pre- and post-Spring Flow Release to assess changes at the sampling section. Cross section analysis showed changes in the channel geometry with total computed scour of 11.7 ft^2, total computed fill of 3.0 ft^2 and a net change of 8.7 ft^2 of scour.

The particle size distribution derived from the pebble count data are provided in Figure 12. The deeper, coarser left side of the channel is not included in the annual pebble count, which represents the right half of the low flow channel. Overall the channel became finer The coarse (upper) half of the particle size distribution grew somewhat finer, with the D50 (grain size for which 50 percent of the sample is smaller) changing from 38.7 to 32.6 mm. Above the 90^{th} percentile, the distribution shows more fining with the D90 decreasing from 63.6 to 60.3 mm.

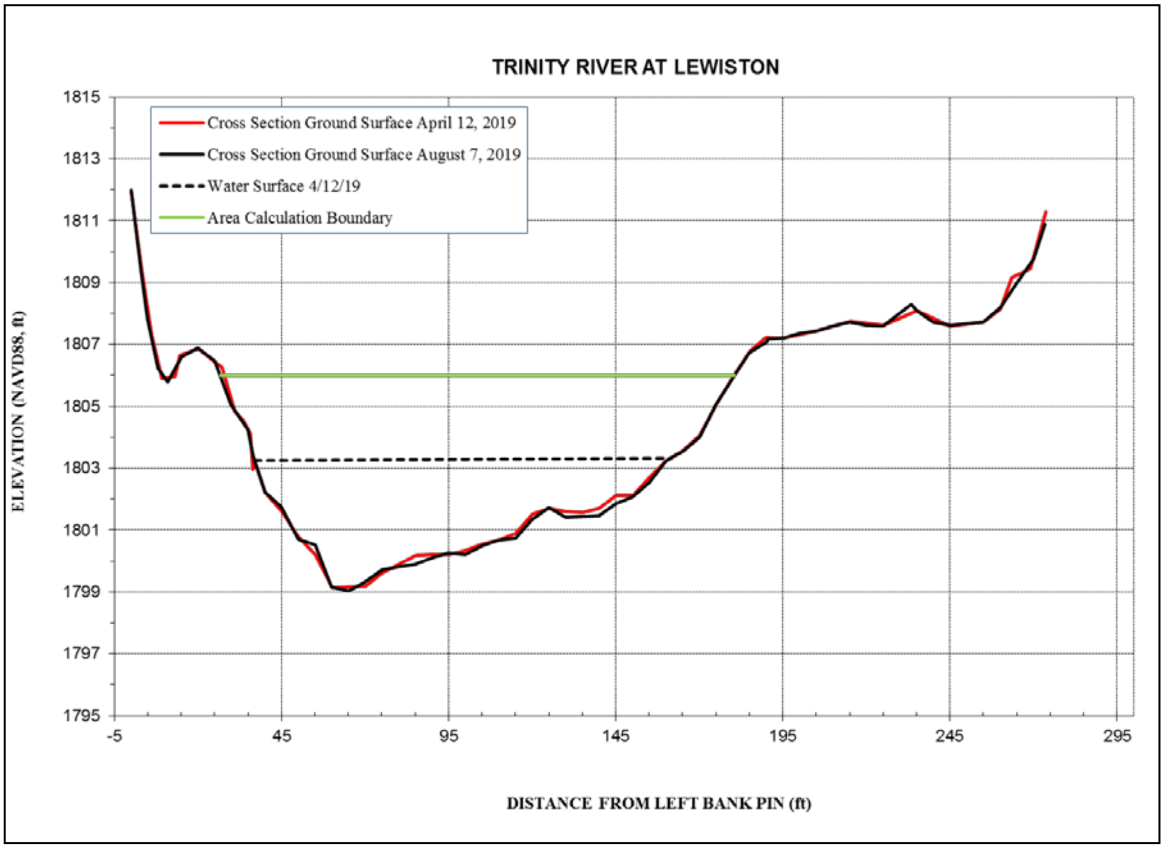


Figure 11. Cross Section changes at TRAL, pre/post Spring Flow Release 2019. Downstream view.

Figure 12. Changes in bed texture at TRAL, pre/post Spring Flow Release 2019.

2.4.2.2 Trinity River above Grass Valley Creek

Station Description

The TRGV sediment transport monitoring station is located approximately 1,800 feet upstream of the Grass Valley Creek confluence on the BLM Lowden Ranch property (Figure 1). A seasonal streamflow and turbidity gaging station was established at TRGV (Appendix B-1) just prior to the WY 2006 Spring Flow Release. The station was originally located in a relatively straight and uniformly-shaped low-gradient section of the Trinity River. The station was relocated about 200 feet downstream in WY 2011 as a result of restoration construction activities in 2010 which created a forced meander only a short distance upstream from the original gage site.

The gage was operated from April 11 to August 6. Streamflow data from April 1 through April 11 were estimated by proportionally fitting Trinity River at Lewiston streamflow record to the TRGV streamflow record. The TRGV gage defines the downstream end of the second sediment budget cell (Figures 1 and 2). A cable was strung between two large conifers above the active channel to allow cataraft sampling. The TRGV site provided an excellent sediment sampling location and a fair streamflow gaging site, despite upstream gravel injection which causes deposition at the gaging site resulting in shifts in the stage-discharge relation.

Streamflow Gaging

The relatively straight, uniform channel created by the riparian berms and old mining activities provided an ideal streamflow gaging reach for the 2006-2010 period. The reach was modified substantially during construction of the restoration project in 2010. Removal of the left bank riparian berm and tailing piles and construction of a floodplain resulted in a channel with a substantial floodplain flow component at the higher discharges. Continuous stage height readings were recorded from April 11 through August 6, but streamflow records were computed (or estimated) for the Spring Flow Release period (April 1 through July 31). Fifteen discharge measurements were collected during the computation period (Appendix B-1; B-5). Measured discharge for the period ranged from 401 cfs to 9,080 cfs. Computed instantaneous discharge ranged from 405 cfs to 10,200 cfs.

The stage-discharge relationship, Rating 6.1 (Appendix B-2), used during Water Year 2017 was used from April 11 to 17 with a stage variable shift (SV19-01). A new stage-discharge relationship, Rating 7.0, was developed for use in Water Year 2019. A detailed explanation of the methods and assumptions used to compute the discharge record are provided in the Streamflow Station Analysis (Appendix B-1a).

Suspended Sediment Transport Data

Twelve two-pass suspended sediment samples were collected between April 17 and May 20, 2019 at TRGV (Table 4). Measured SSC fluctuated from a peak of 198 mg/l on April 17 at 7,590 cfs, to a low of 6.05 mg/l on May 20 at 5,330 cfs. The associated transport rates were 4,040 and 87 tons/day respectively. WY 2019 suspended sediment discharge values are plotted in Figure 13 along with sample data from WY 2006-2017.

Table 4. Trinity River above Grass Valley Creek -- GMA Gage #11525540, Suspended Sediment Sampling Summary -- WY2019

Sample Number	Date & Mean Time	Average Discharge (cfs)	Average SSC (mg/l)	Average SSD (tons/day)
TRGV-SSCT2019-01	4/17/2019 13:15	7,590	198	4,040
TRGV-SSCT2019-02	4/18/2019 9:24	8,210	168	3,710
TRGV-SSCT2019-03	4/18/2019 16:12	7,270	27.8	545
TRGV-SSCT2019-04	4/19/2019 9:38	5,640	13.4	203
TRGV-SSCT2019-05	4/19/2019 17:34	4,660	9.9	124
TRGV-SSCT2019-06	4/29/2019 12:16	7,540	111	2,270
TRGV-SSCT2019-07	4/29/2019 18:08	9,690	48.1	1,260
TRGV-SSCT2019-08	4/30/2019 10:10	9,140	22.3	550
TRGV-SSCT2019-09	5/19/2019 10:09	8,490	21.5	492
TRGV-SSCT2019-10	5/19/2019 16:00	7,870	18.6	394
TRGV-SSCT2019-11	5/20/2019 11:01	5,730	8.51	132
TRGV-SSCT2019-12	5/20/2019 14:46	5,330	6.05	87.0

Values Rounded According to Porterfield (1972)

Using turbidity as a surrogate for SSC proved suitable in WY2019, unlike 2016 when recent gravel augmentation activities at the site sporadically affected turbidity values at the turbidity probe, which is located along the left bank. The turbidity record was faulty from May 26 to July 31 necessitating the development of discharge versus SSC relationships. Continuous suspended sediment discharge for the three size classes were computed using the applicable SSC relationships (Appendix B-1; B-4). Partial and total suspended sediment load for the Spring Flow Release were 3,120; 3,920; 1,490 and 8,530 tons for the <0.063mm, 0.063-<0.50mm, ≥0.50mm size classes and total load respectively (Table 5). The Sediment Station Analysis (Appendix B-1b) details the relationships and periods of record for which the transport curves were applied. Appendix B-11 contains the sample data and SSC computations.

Table 5. Trinity River above Grass Valley Creek -- GMA Gage #11525540, Suspended Sediment Loads -- WY2019

< 0.063 mm (tons)	0.063 mm-<0.50 mm (tons)	≥0.50 mm (tons)	Total Load (tons)
3,120	3,920	1,490	8,530

Values Rounded According to Porterfield (1972)

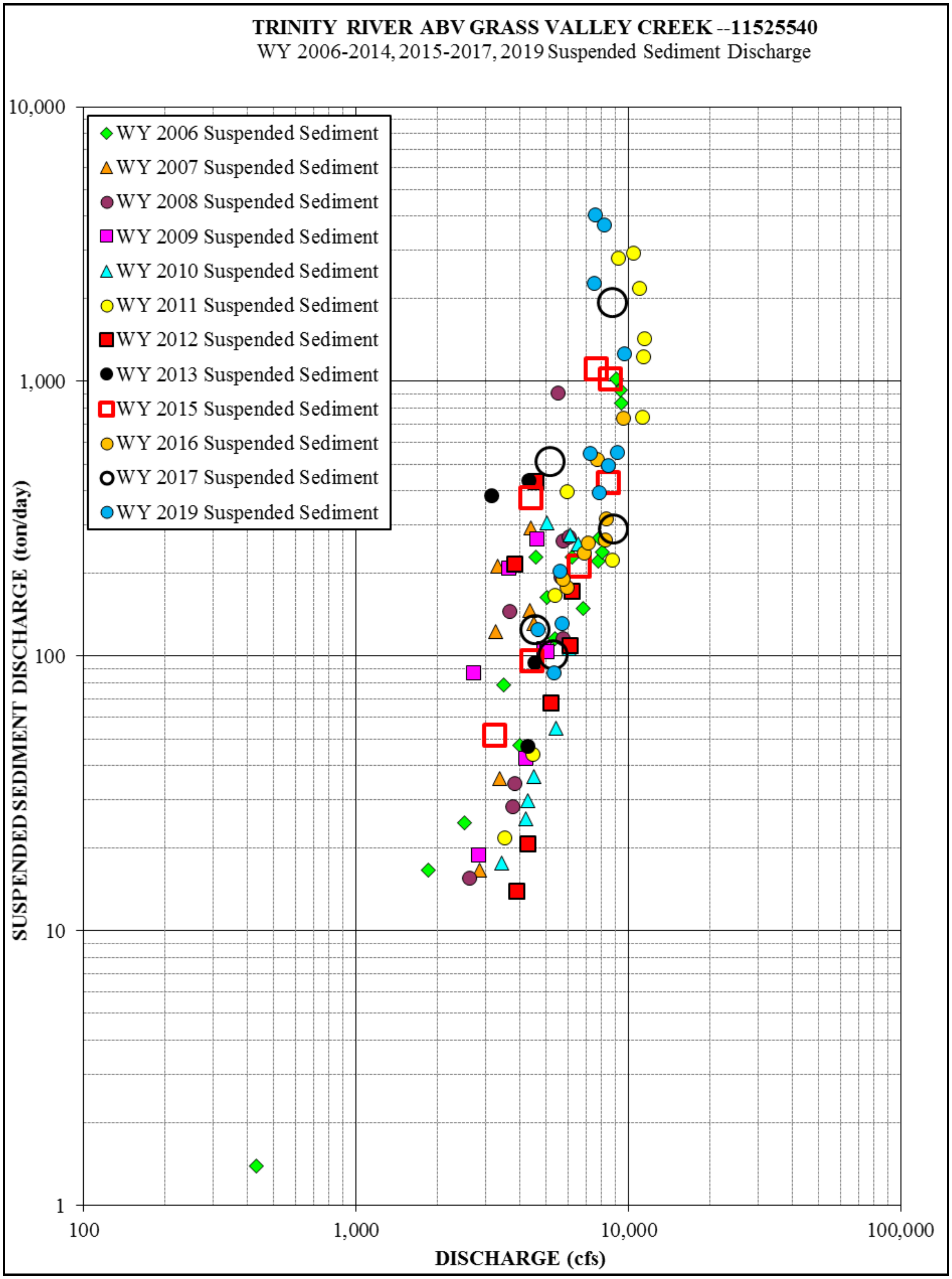


Figure 13. Suspended Sediment Discharge at TRGV, WY2006-2013, 2015-2017, 2019.

Bedload Data

Twenty five one-pass bedload samples were collected at TRGV between April 17 and May 20, 2019. Bedload sampling times were plotted on hydrographs in Appendix B-6. Bedload sample data and bedload discharge computations are summarized in Table 6. Fine, coarse, and total bedload discharge rates for WY 2006-19 are plotted in Figures 21-23. As discussed in section 2.3.4, the <0.5mm fraction is omitted from bedload data and computations; however, this fraction is included for graphical comparisons with historic values (e.g. Figure 16).

The measured (Total) transport rates varied from 46.4 tons/day at 5,280 cfs on April 19, to 1,050 tons/day at 8,290 cfs on April 29 (Table 6). The Sediment Station Analysis (Appendix B-1) describes the development of the bedload transport curves. The transport curves and bedload measurements were used to compute continuous bedload discharge and load estimates (Appendix B-10). Appendix B-3 contains the bedload transport curves and Appendix B-6 contains the bedload sedigraphs. Fine, coarse, and total bedload estimates for the period April 1 to July 31, 2019 were 1,140; 1,800 and 2,950 tons (Table 7). Appendix B-10 contains the sample data (weights and computed transport rates) and bedload computation values.

Bedload samples were partitioned to support hydrophone experiments conducted by USGS and NOAA. Partitioned sample results are included in Appendix B-10 in a sub-folder labeled 'SplitXS' in individual Excel spreadsheets. Sample numbers were split into an A and B sub-sample, representing the left or right side of the channel as indicated by the stations sampled with station zero being on the left bank. Results in the Excel spreadsheet contain pertinent metadata such as, but not limited to, date, start and end time, the begin and end stage height, bottom time, stations sampled, interval (distance between stations) and processing information.

Table 6. Trinity River above Grass Valley Creek -- GMA Gage #11525540, Bedload Sediment Sampling Summary -- WY2019

Sample Number	Date & Mean Time	Average Discharge (cfs)	Total Bedload Discharge (tons/day)	≥ 8mm Bedload Discharge (tons/day)	0.5-<8 mm Bedload Discharge (tons/day)
TRGV-BLM2019-01	04/17/2019 11:36	6,570	127	64.0	56.5
TRGV-BLM2019-02	04/18/2019 10:49	7,950	202	157	43.5
TRGV-BLM2019-03	04/18/2019 13:35	7,490	202	160	40.8
TRGV-BLM2019-04	04/18/2019 17:10	7,110	167	104	61.2
TRGV-BLM2019-05	04/19/2019 08:41	5,710	47.2	19.8	26.8
TRGV-BLM2019-06	04/19/2019 12:27	5,280	46.4	7.56	38.1
TRGV-BLM2019-07	04/19/2019 16:04	4,750	52.2	17.5	33.8
TRGV-BLM2019-08	04/19/2019 18:25	4,550	58.8	9.7	48.3
TRGV-BLM2019-09	04/29/2019 11:00	6,770	310	121	177
TRGV-BLM2019-10	04/29/2019 13:09	7,870	433	236	188
TRGV-BLM2019-11	04/29/2019 14:53	8,290	1,050	686	354
TRGV-BLM2019-12	04/29/2019 16:47	9,090	812	622	180
TRGV-BLM2019-13	04/29/2019 18:57	10,000	901	643	246
TRGV-BLM2019-14	04/30/2019 09:13	9,280	761	608	149
TRGV-BLM2019-15	04/30/2019 12:25	8,900	375	233	139
TRGV-BLM2019-16	04/30/2019 16:48	8,460	764	535	225
TRGV-BLM2019-17	04/30/2019 17:58	8,380	527	377	146
TRGV-BLM2019-18	05/01/2019 09:30	5,050	65.2	6.84	57.5
TRGV-BLM2019-19	05/19/2019 10:58	8,430	635	544	87.8
TRGV-BLM2019-20	05/19/2019 14:58	8,040	255	169	84.1
TRGV-BLM2019-21	05/19/2019 18:20	7,650	262	187	74.0
TRGV-BLM2019-22	05/20/2019 09:16	5,970	228	142	84.1
TRGV-BLM2019-23	05/20/2019 12:30	5,420	167	93	71.8
TRGV-BLM2019-24	05/20/2019 16:04	5,270	331	197	133
TRGV-BLM2019-25	05/20/2019 18:11	4,990	118	39.7	76.6

Values Rounded According to Porterfield (1972)

Table 7. Trinity River above Grass Valley Creek -- GMA Gage #11525540, Bedload -- WY2019

0.5-<8 mm (tons)	≥8 mm (tons)	Total Bedload (tons)
1,140	1,800	2,950

Values Rounded According to Porterfield (1972)

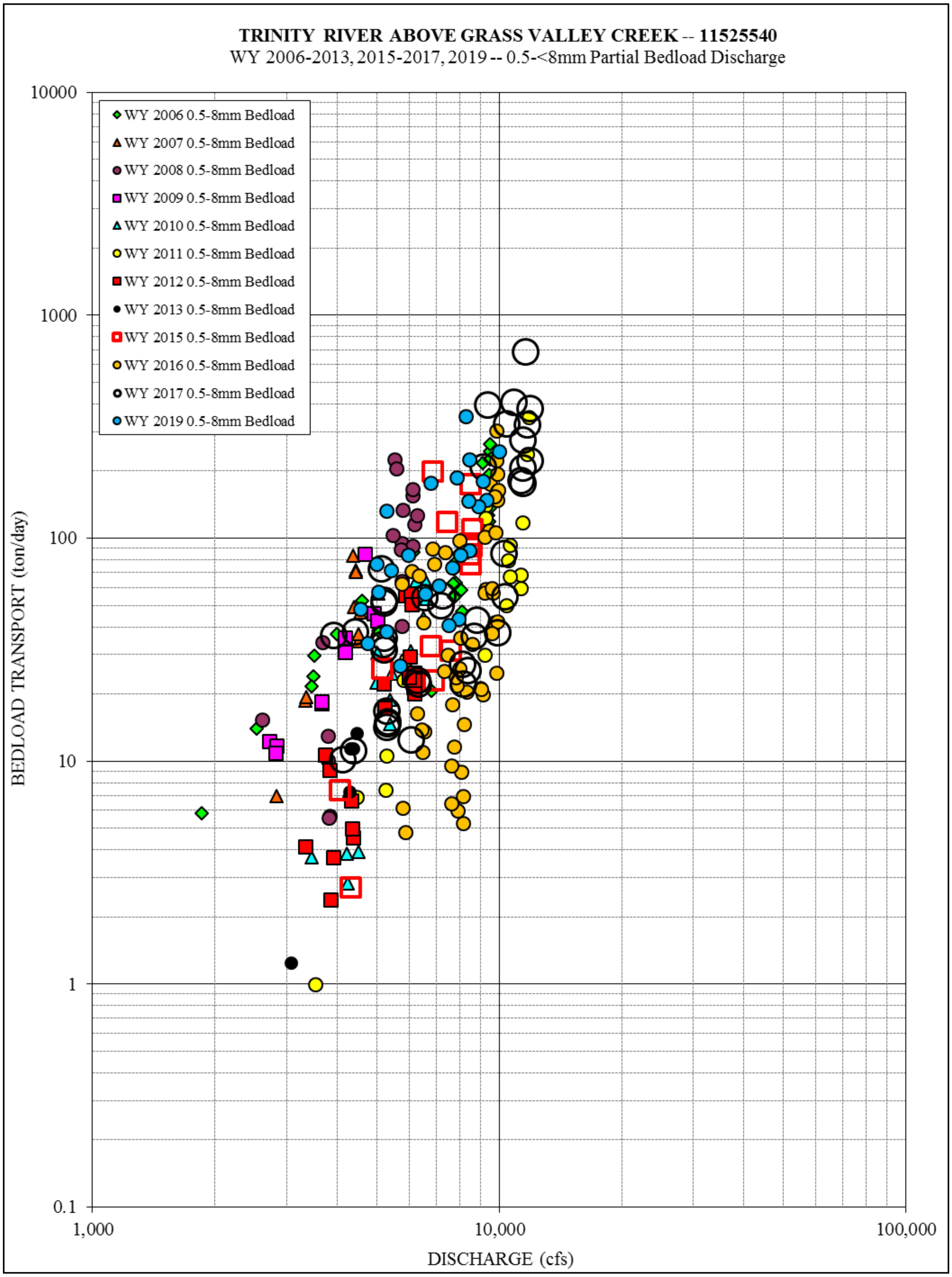


Figure 14. Fine Bedload Discharge (0.5-8mm) at TRGV, WY2006-2013, 2015-2017, 2019.
The 1999 TRFE bedload equations that were used to develop flow recommendations did not include this site.

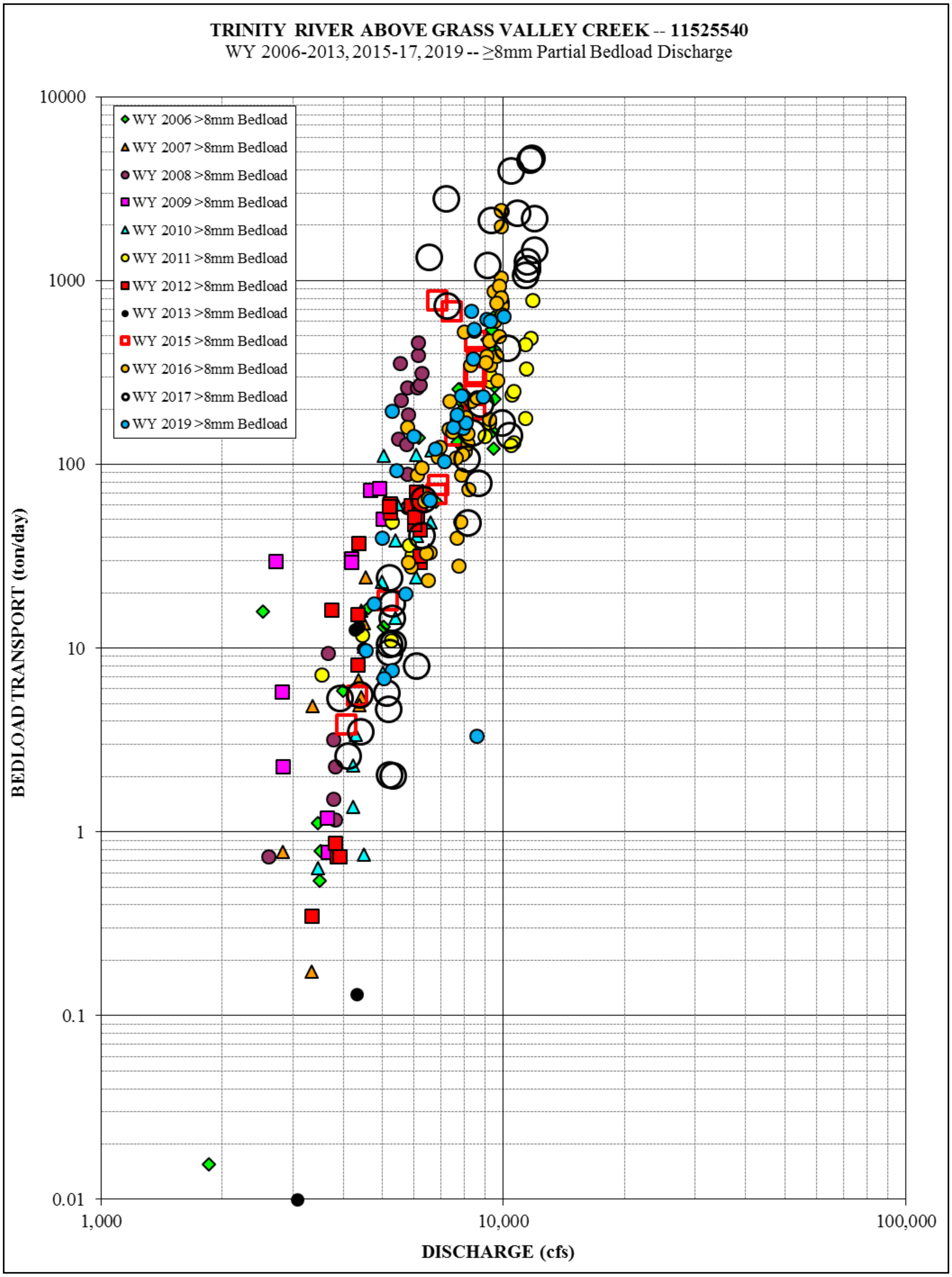


Figure 15. Coarse Bedload Discharge (≥8mm) at TRGV, WY2006-2013, 2015-2017, 2019.
The 1999 TRFE bedload equations that were used to develop flow recommendations did not include this site.

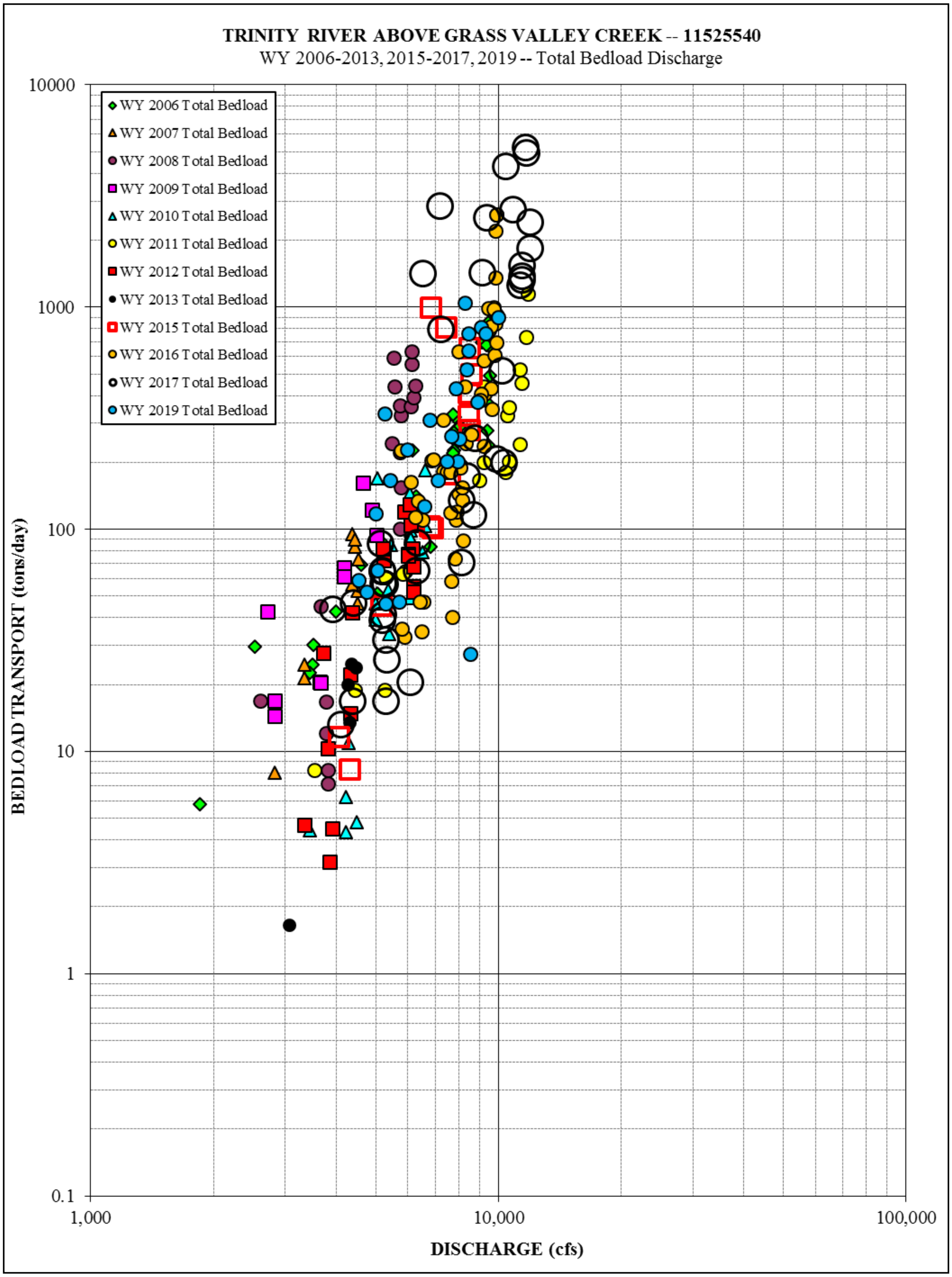


Figure 16. Total Bedload Discharge at TRGV, WY2006-2013, 2015-2017, 2019.

Water Surface Slope, Cross Section Changes and Pebble Count Changes
The 2019 water surface slope for 10,100 cfs was 0.000994. The average water surface slope, using four measurements ranging from 4,640 cfs to 10,100 cfs, was 0.000916.

Cross section (Figure 17) and pebble count (Figure 18) data were collected at the TRGV sediment monitoring site pre- and post-Spring Flow Release to assess changes at the sampling section. The toe of the far right side of the channel (stations 306-313) scoured approximately 1.1 ft. The left side of the active channel scoured 0.5 ft while the right side of the active channel aggraded 0.5 ft. The area change calculation for the cross section below the 1,746 foot elevation revealed 15.9 ft^2 of scour and 20.0 ft^2 of fill for a net change of 4.0 ft^2 of fill.

The particle size distribution derived from the pebble count data is provided in Figure 18. The channel saw very little change in pebble size. Below D16 material got finer and above D75 material got coarser. The D50 had very little change going from 30.4 to 28.9 mm while the D90 increased from 55.7 to 63.0 mm.

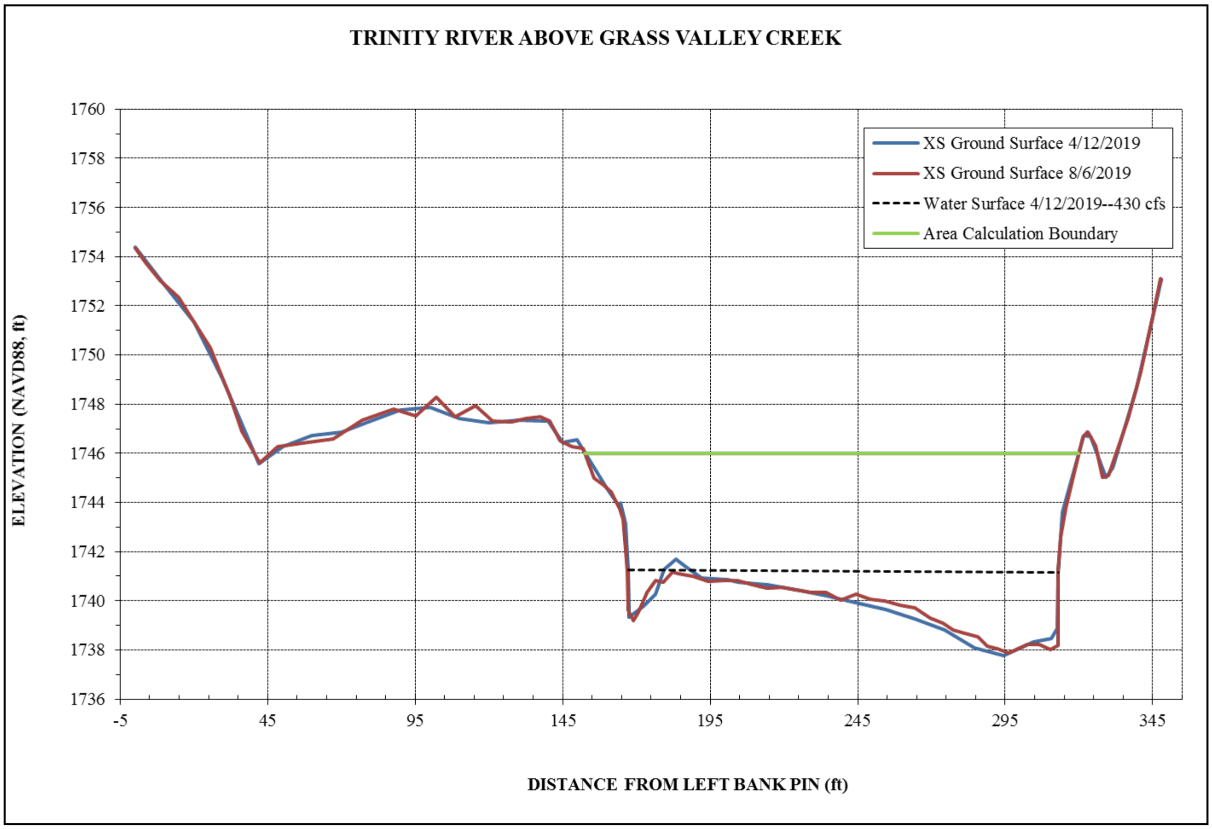


Figure 17. Cross Section Changes at TRGV, pre and post-Spring Flow Release 2019.

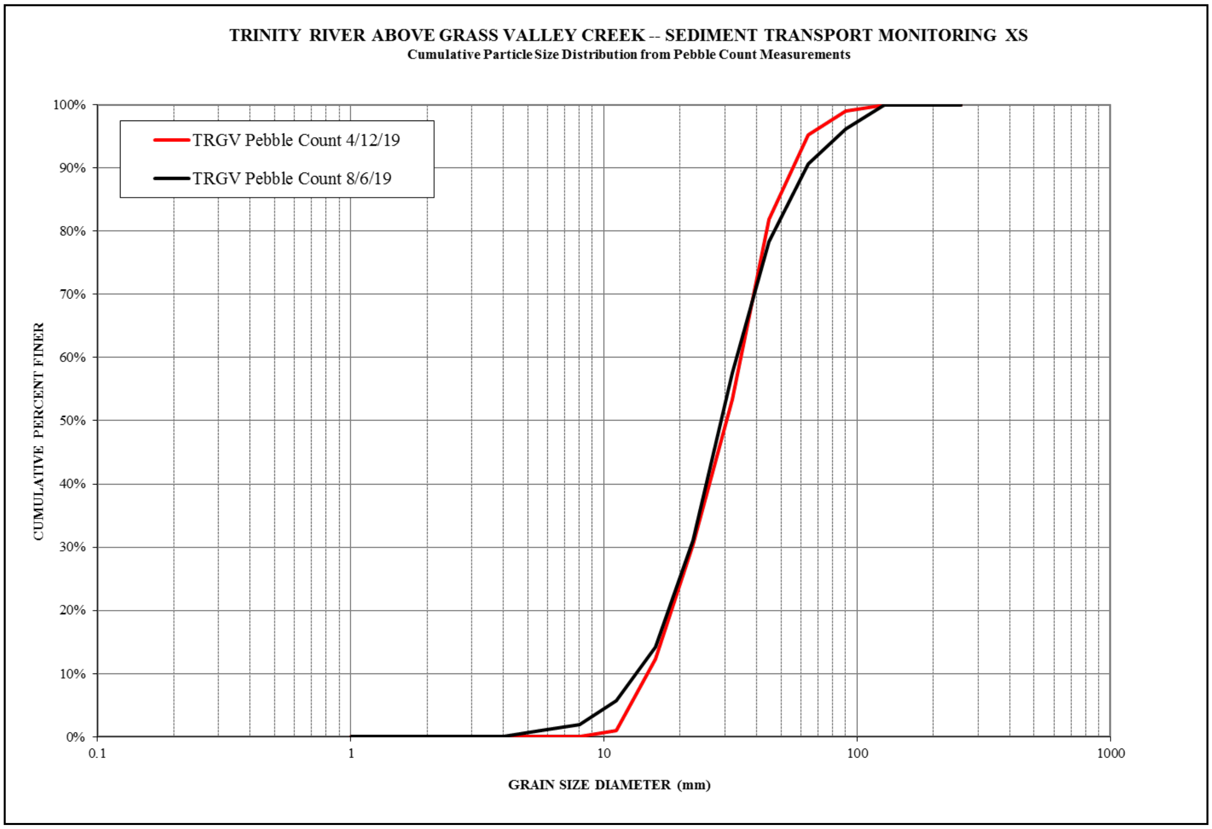


Figure 18. Changes in bed texture at TRGV, Spring Flow Release 2019.

2.4.2.3 Trinity River below Limekiln Gulch

Station Description

The station is located 60 feet downstream of the USGS streamflow gaging station (#11525655) and 250 feet downstream of the GMA turbidimeter. The section is located upstream of a heavily wooded island with a side channel flowing around the left side (Figure 19). Sampling has occurred at the current sampling location or approximately 30 ft upstream since WY 1998. A two-person cataraft crew collected 32 bedload and 15 suspended sediment samples at TRLG during the 2019 Spring Flow Release.

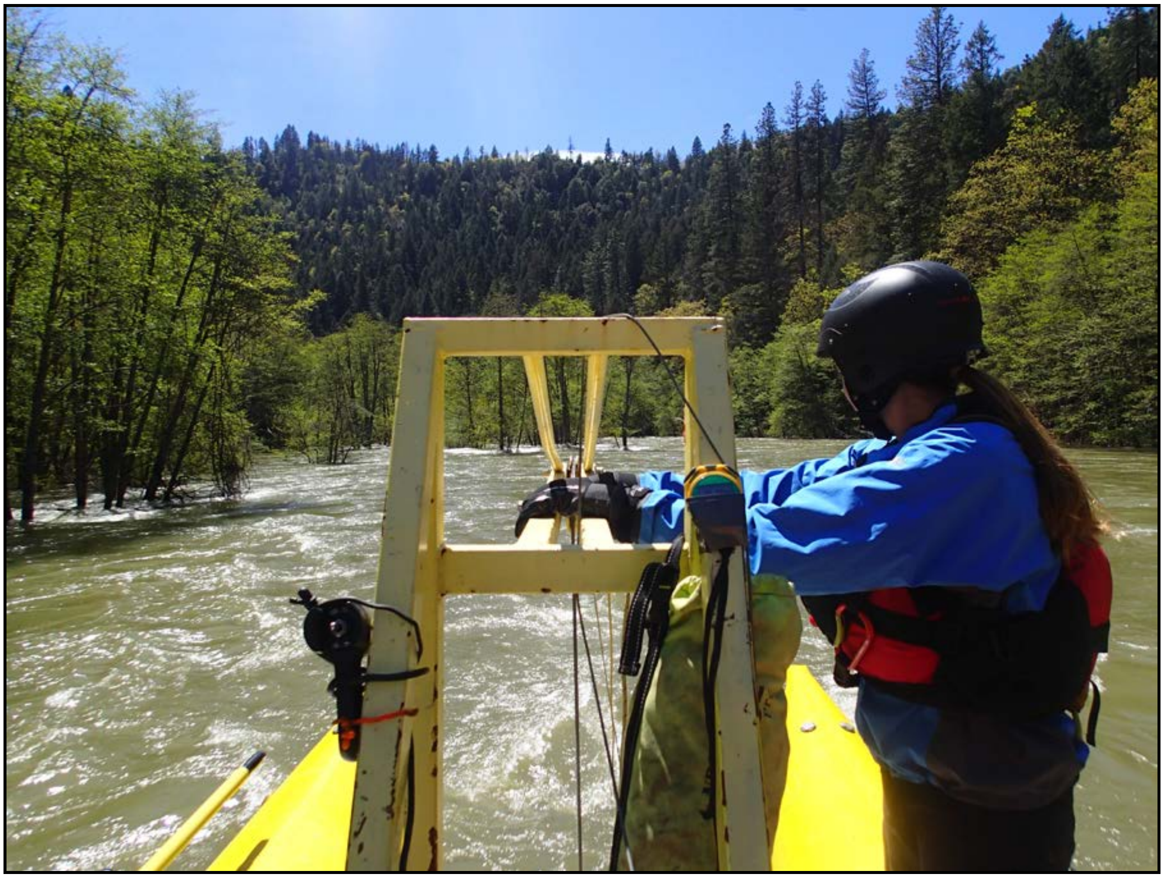


Figure 19. Photograph: downstream view of TRLG sampling site at 12,500 cfs.

Suspended Sediment Transport Data

Fifteen two-pass suspended sediment samples were collected during the Spring Flow Release (Table 8). Measured SSC ranged from 6.93 mg/l to 156 mg/l. The computed suspended sediment discharge for the highest measurement was 4,010 tons/day at 9,550 cfs (Table 8). Continuous suspended sediment discharge for the three size classes was computed using the turbidity versus SSC relationships (Appendix C-3). Partial discharges were computed for all three size classes and then summed to compute total SS discharge (Appendix C-1). Partial and total suspended sediment load for the Spring Flow Release were 3,450; 5,100; 1,310 and 9,850 tons for the <0.063mm, 0.063-<0.50mm, ≥0.50mm size classes and total load respectively (Table 9). The computational methods, assumptions, surrogate relationships, and period of records for which they were applied are described in detail in the Station Analysis (Appendix C-1). Appendix C-10 contains the sample data and SSC computations.

Table 8. Trinity River below Limekiln Gulch -- USGS Gage #11525655, Suspended Sediment Sampling Summary -- WY2019

Sample Number	Date & Mean Time	Average Discharge (cfs)	Average SSC (mg/l)	Average SSD (tons/day)
TRLG-SSCT2019-01	4/17/2019 11:05	5,750	151	2,330
TRLG-SSCT2019-02	4/17/2019 18:12	9,550	156	4,010
TRLG-SSCT2019-03	4/18/2019 12:31	8,160	30.9	679
TRLG-SSCT2019-04	4/18/2019 17:41	7,510	26.3	533
TRLG-SSCT2019-05	4/19/2019 9:33	5,910	22.8	363
TRLG-SSCT2019-06	4/19/2019 17:39	4,950	13.7	183
TRLG-SSCT2019-07	4/29/2019 12:15	6,860	45.6	843
TRLG-SSCT2019-08	4/29/2019 18:01	9,700	59.7	1,560
TRLG-SSCT2019-09	4/30/2019 9:38	10,000	29.7	801
TRLG-SSCT2019-10	4/30/2019 17:47	9,100	22.0	539
TRLG-SSCT2019-11	5/1/2019 10:16	5,260	10.0	141
TRLG-SSCT2019-12	5/19/2019 10:40	9,100	34.5	847
TRLG-SSCT2019-13	5/19/2019 18:54	8,100	15.7	343
TRLG-SSCT2019-14	5/20/2019 9:53	6,210	14.3	239
TRLG-SSCT2019-15	5/20/2019 18:27	6,210	6.93	98.6

Values Rounded According to Porterfield (1972)

Table 9. Trinity River below Limekiln Gulch-- USGS Gage #11525655, Suspended Sediment Loads -- WY2019

< 0.063 mm (tons)	0.063 mm-<0.50 mm (tons)	≥0.50 mm (tons)	Total Load (tons)
3,450	5,100	1,310	9,850

Values Rounded According to Porterfield (1972)

Total suspended sediment discharge values were plotted in Figure 20 along with all historic transport data collected at TRLG, including the historic USGS data from multiple natural winter storm events.

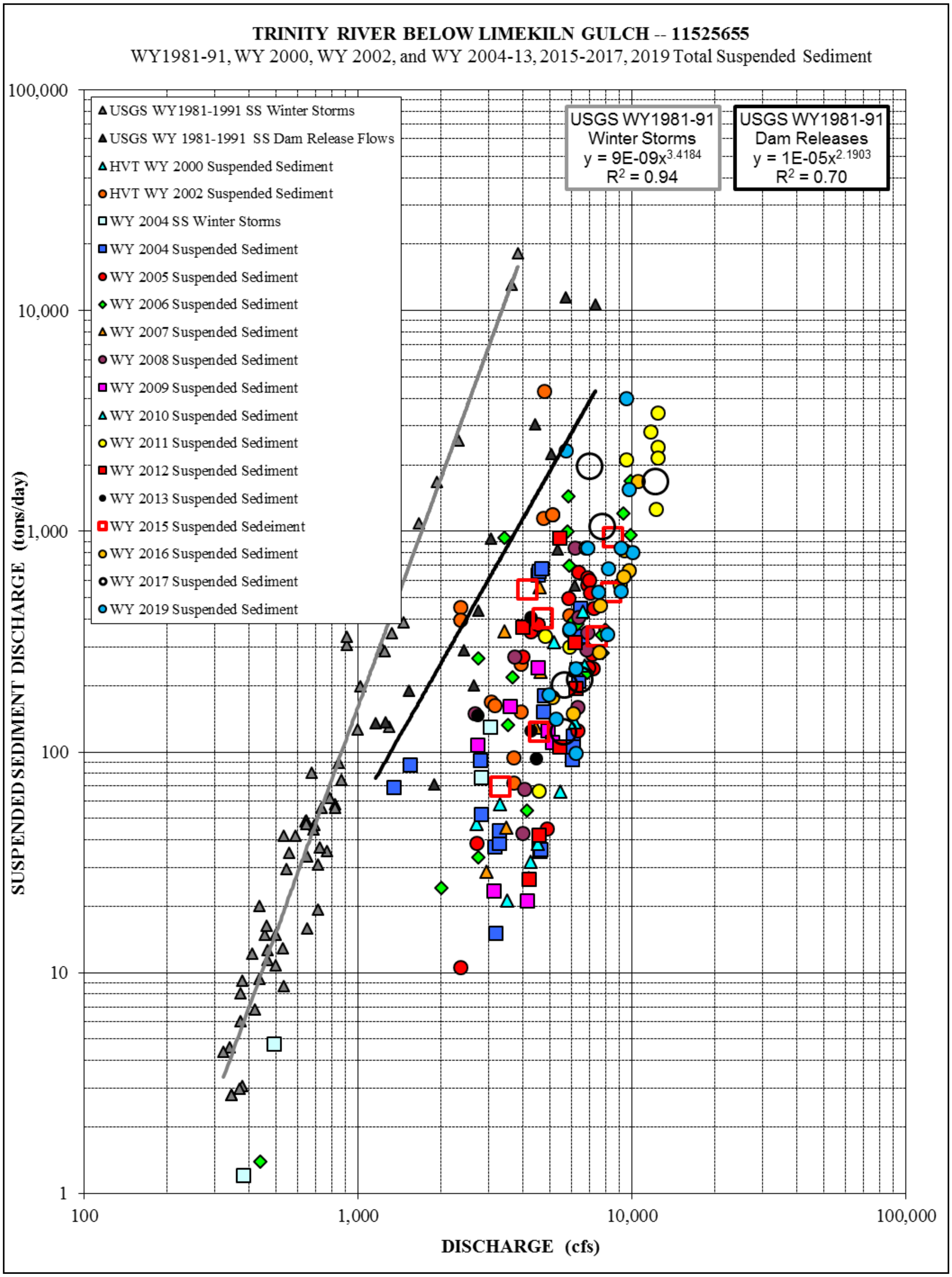


Figure 20. Suspended Sediment Discharge at TRLG, WY1981-1991, 2000, 2002, 2004-2013, 2015-2017, 2019.

Bedload Transport Data

Thirty-two one-pass bedload samples were collected during the Spring Flow Release (Table 10). Appendix C-5 displays the bedload sample collection times on the Spring Flow Release hydrograph. The highest bedload transport rate of 562 tons/day was measured at 10,400 cfs on April 30, while the lowest, 22.2 tons/day was measured at 5,490 cfs on May 20. All measured fine, coarse, and total bedload discharge rates were plotted in Figures 21-23 along with historic data from WY 1981-2016. Details regarding the samples and the sediment discharge computations are provided in the Station Analysis (Appendix C-1).

Bedload transport curves were fit to the WY 2019 bedload discharge data in WISKI. For both fine and coarse bedload, no obvious patterns of hysteresis or changes in rate between flow peaks were observed, therefore, a single generalized transport curve was developed (Appendix C-2). Detailed explanations of assumptions and relationships developed for computing continuous bedload discharge are provided in the Station Analysis (Appendix C-1).

The fine, coarse, and total bedload computed estimates for WY 2019 were 868, 870 and 1,760 tons, respectively (Table 11). As discussed in section 2.3.4, the <0.5mm fraction is omitted from bedload data and computations; however, this fraction is included for graphical comparisons with historic values (e.g. Figure 31).

Bedload samples were partitioned to support hydrophone experiments conducted by USGS and NOAA. Partitioned sample results are included in Appendix C-9 in a sub-folder labeled ‘SplitXS’ in individual Excel spreadsheets. Sample numbers were split into an A and B sub-sample, representing the left or right side of the channel as indicated by the stations sampled with station zero being on the left bank. Results in the Excel spreadsheet contain pertinent metadata such as, but not limited to, date, start and end time, the begin and end stage height, bottom time, stations sampled, interval (distance between stations) and processing information.

Table 10. Trinity River below Limekiln Gulch -- USGS Gage #11525655, Bedload Sediment Sampling Summary -- WY2019.

Sample Number	Date & Mean Time	Average Discharge (cfs)	Total Bedload Discharge (tons/day)	≥ 8mm Bedload Discharge (tons/day)	0.5-<8 mm Bedload Discharge (tons/day)
TRLG-BLM2016-01	4/17/19 12:40	6,360	26.2	1.32	19.7
TRLG-BLM2016-02	4/17/19 14:40	7,460	138	29.4	101
TRLG-BLM2016-03	4/17/19 16:45	8,950	311	166	133
TRLG-BLM2016-04	4/17/19 19:02	9,880	322	175	139
TRLG-BLM2016-05	4/18/19 10:47	8,390	194	118	73.8
TRLG-BLM2016-06	4/18/19 14:26	7,850	258	157	99.2
TRLG-BLM2016-07	4/18/19 18:20	7,420	131	58.5	71.0
TRLG-BLM2016-08	4/19/19 8:23	6,020	81.8	13.4	67.6
TRLG-BLM2016-09	4/19/19 12:29	5,520	67.1	9.49	56.8
TRLG-BLM2016-10	4/19/19 15:35	5,190	42.0	10.3	31.2
TRLG-BLM2016-11	4/19/19 18:34	4,910	38.3	7.87	29.9
TRLG-BLM2016-12	4/29/19 9:38	6,010	113	35.3	74.9
TRLG-BLM2016-13	4/29/19 11:15	6,400	170	692	101
TRLG-BLM2016-14	4/29/19 13:07	7,380	155	54.1	97.7
TRLG-BLM2016-15	4/29/19 15:01	8,490	305	178	124
TRLG-BLM2016-16	4/29/19 16:49	8,890	250	124	122
TRLG-BLM2016-17	4/29/19 19:12	10,400	562	431	124
TRLG-BLM2016-18	4/30/19 8:50	10,100	218	142	74.2
TRLG-BLM2016-19	4/30/19 13:45	9,630	354	206	145
TRLG-BLM2016-20	4/30/19 16:36	9,160	474	345	127
TRLG-BLM2016-21	4/30/19 18:39	8,940	372	244	126
TRLG-BLM2016-22	5/1/19 9:02	5,390	38.6	18.2	20.1
TRLG-BLM2016-23	5/1/19 11:48	4,790	35.1	7.97	26.8
TRLG-BLM2016-24	5/19/19 8:30	8,830	305	196	106
TRLG-BLM2016-25	5/19/19 9:40	9,030	356	260	92.4
TRLG-BLM2016-26	5/19/19 12:44	8,980	312	213	96.1
TRLG-BLM2016-27	5/19/19 14:56	8,760	376	273	101
TRLG-BLM2016-28	5/19/19 17:36	8,190	295	195	97.5
TRLG-BLM2016-29	5/19/19 19:42	8,010	135	68.1	65.6
TRLG-BLM2016-30	5/20/19 8:25	6,440	93.9	51.9	41.5
TRLG-BLM2016-31	5/20/19 12:01	5,960	70.0	32.2	370
TRLG-BLM2016-32	5/20/19 16:53	5,490	22.2	13.9	16.1

Values Rounded According to Porterfield (1972)

Table 11. Trinity River below Limekiln Gulch -- USGS Gage #11525655, Bedload -- WY2019

0.5-<8 mm (tons)	≥8 mm (tons)	Total Bedload (tons)
868	870	1,760

Values Rounded According to Porterfield (1972)

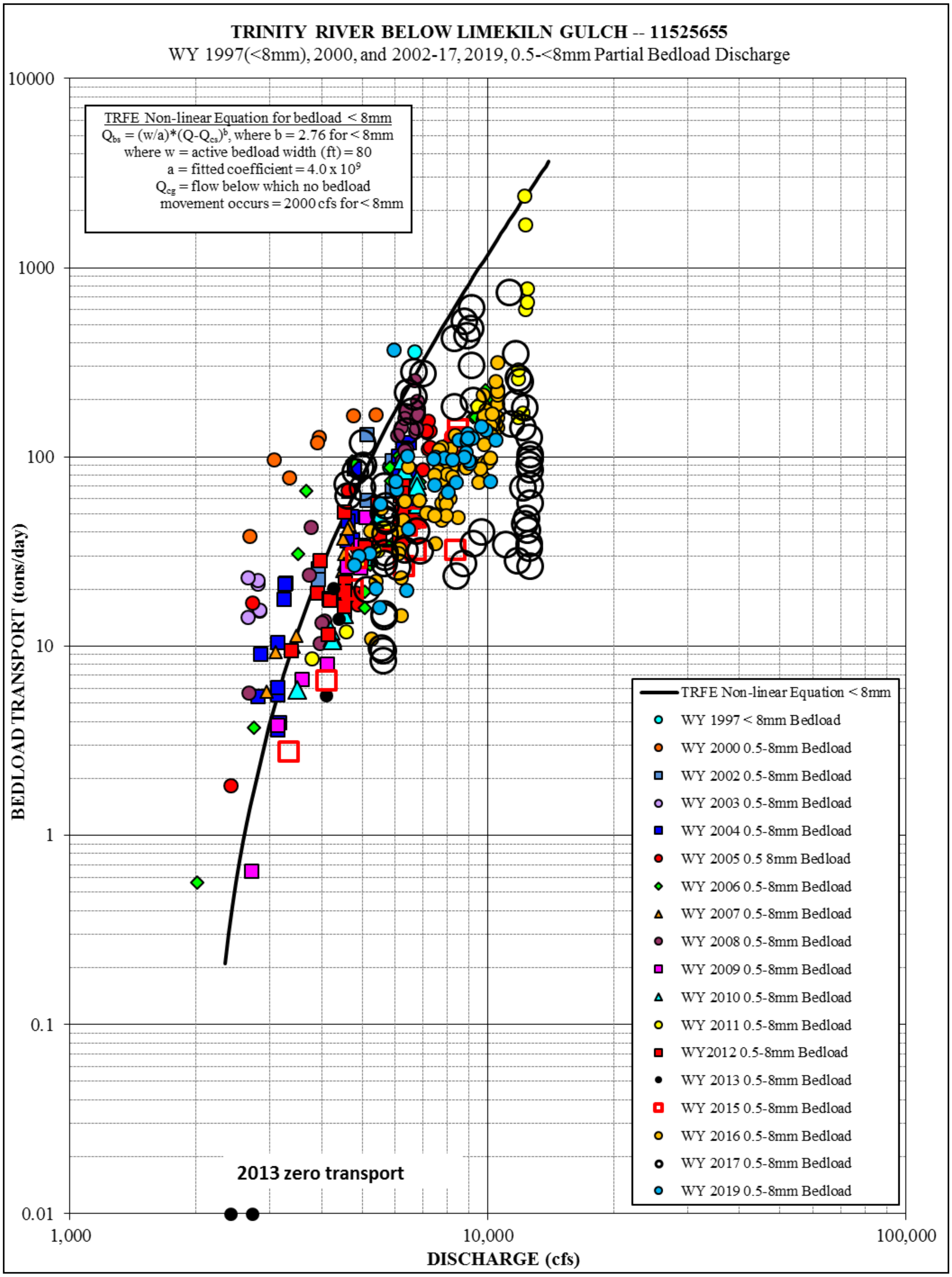


Figure 21. Fine Bedload Discharge (0.5-<8mm) at TRLG, WY1997-2013, 2015-2017, 2019.

The 1999 TRFE bedload equations were used to develop flow recommendations based in part on bedload discharge predictions at TRAL and TRLG (shown in the inset box on chart). The equation is plotted and shown here as the dashed black line and is included for comparison with subsequent measured bedload transport rates.

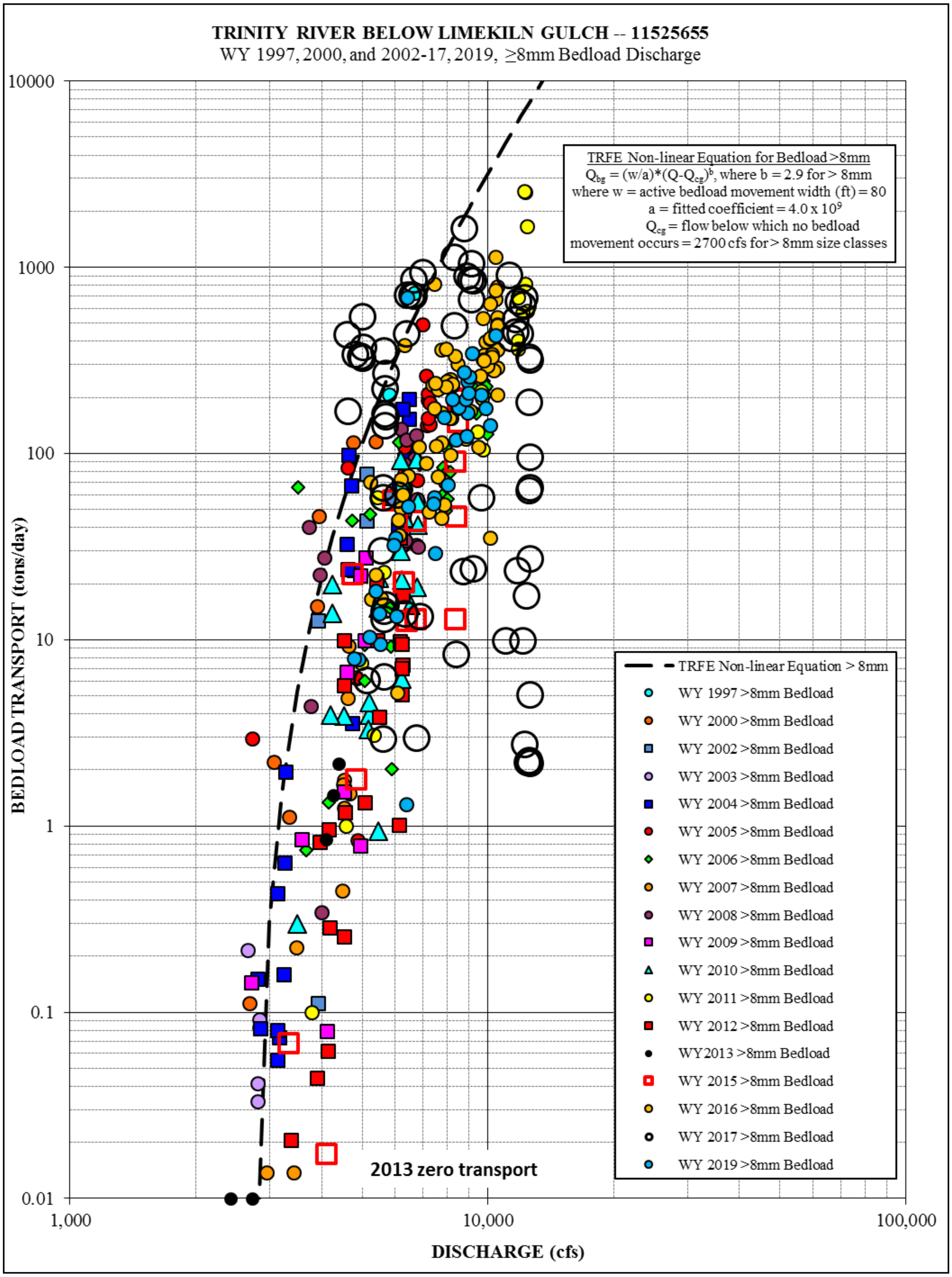


Figure 22. Coarse Bedload Discharge (≥8mm) at TRLG, WY1997-2013, 2015-2017, 2019.

The 1999 TRFE bedload equations were used to develop flow recommendations based in part on bedload discharge predictions at TRAL and TRLG (shown in the inset box on chart). The equation is plotted and shown here as the dashed black line and is included for comparison with subsequent measured bedload transport rates.

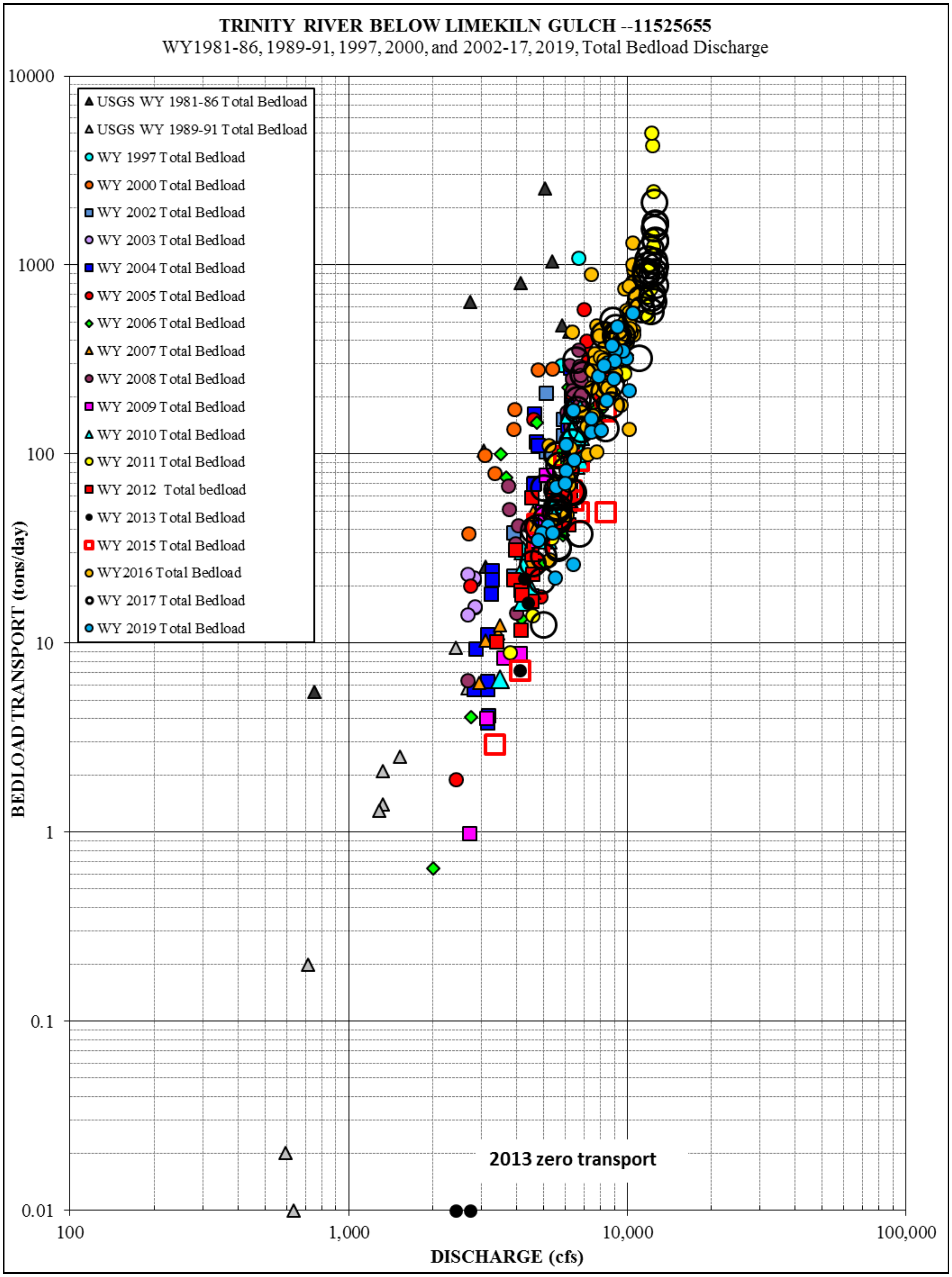


Figure 23. Total Bedload Discharge at TRLG, WY1997-2013, 2015-2017, 2019.

Water Surface Slope, Cross Section Changes and Pebble Count Changes

The 2019 water surface slope at 10,400 cfs was 0.0033. Cross section data were collected at the TRLG sediment monitoring site pre- and post-Spring Flow Release to assess changes at the sampling section. Changes in the cross section are shown in Figure 24. The area change calculation for the cross section below the 1,673.50 foot elevation revealed 21.1 ft^2 of scour and 5.9 ft^2 of fill for a net scour of 15.1 ft^2.

Pebble count data were collected at the TRLG sediment monitoring site post-Spring Flow Release (SFR), however, a pebble count was not preformed prior to the SFR. The pebble count at this site describes the transverse riffle intersecting the right quarter (near station 200) of the sampling section. The left half of the section is deeper with bedrock fins and coarser boulder elements. Even though no pre-SFR pebble count data were collected the graphical representation of the particle size distribution for the post-SFR has been included (Figure 25).

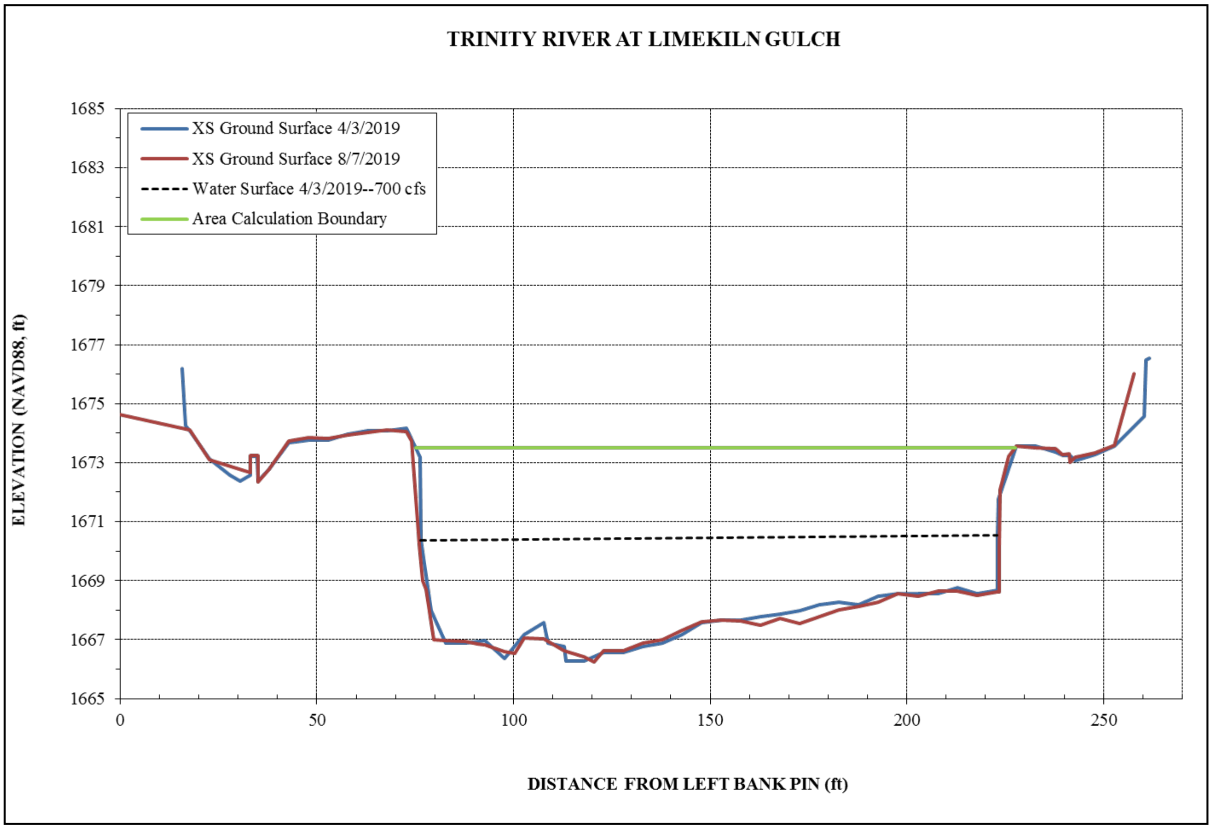


Figure 24. Cross Section Changes, pre and post-Spring Flow Release 2019.

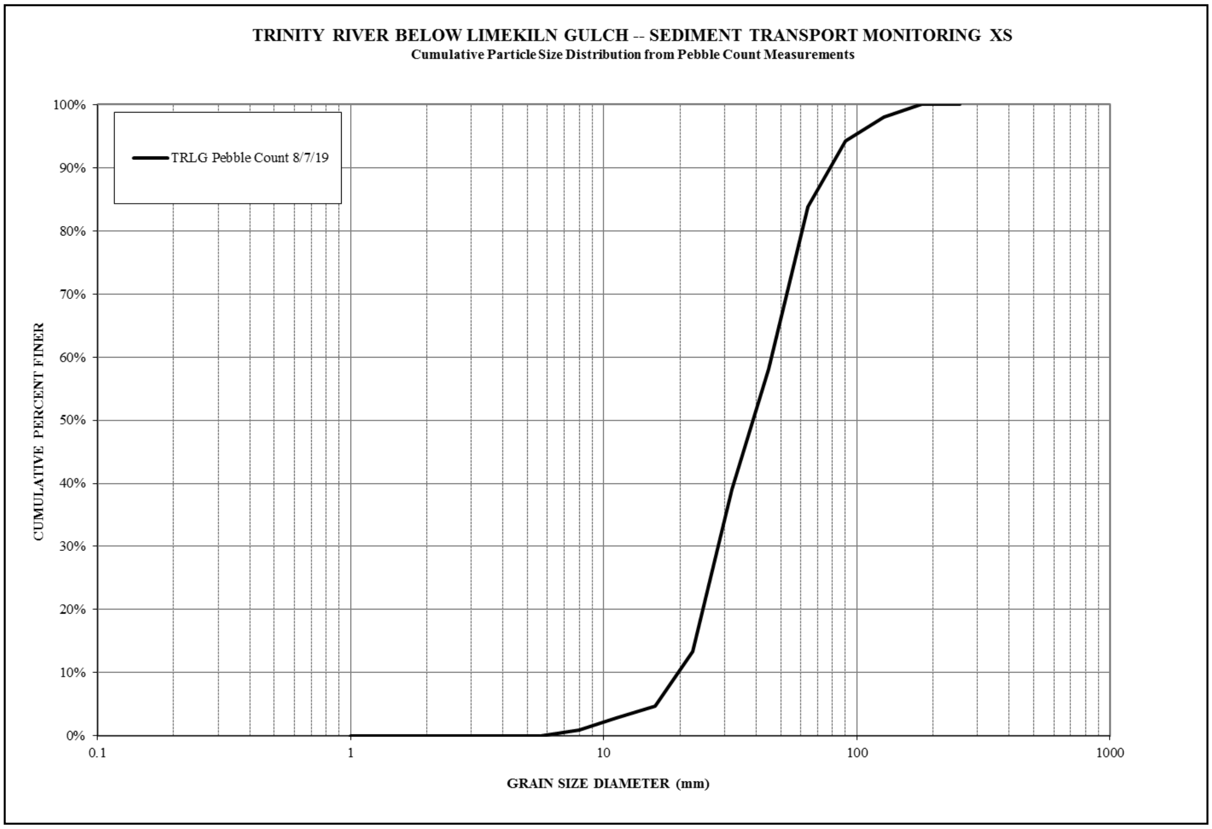


Figure 25. Changes in bed texture at TRLG, pre and post Spring Flow Release 2019.

<u>2.4.2.4 Trinity River near Douglas City</u>

Station Description

The TRDC sediment monitoring cross-section (Figure 26) was relocated approximately 200 feet downstream in 2012 from its 2011 location due to hydraulic complexity and bedrock elements at and upstream of the sampling section. The more favorable hydraulic conditions at the new sampling location facilitate better sampling coverage and presumably results in higher quality sediment transport data. The water surface slope is the highest of all the mainstem stations at 0.003 (2019 at 11,500 cfs). Sediment transport monitoring has occurred at TRDC since WY 2004. The USGS gaging station is now located at the upstream end of the BLM Douglas City Campground, and the sediment transport monitoring station is located approximately two hundred and forty feet downstream of the gaging station.

As is typical during very high flow releases, TRDC presented numerous challenges to the sampling crew. Similar to TRGV, TRDC was tasked with collecting velocity data to correspond with bedload samples. After a few attempts, the velocity data were considered not useable and velocity data collection was aborted. On the night of April 29, 2019, woody debris destroyed water surface elevation station ‘C2”, which was a new reference station that had not yet been surveyed, thus making all data collected on C2 prior to April 29th not useable. A new reference post was installed and remained through the rest of the release.

Figure 26. View from right bank at TRDC on April 26, 2017 at 11,000 cfs.

Suspended Sediment Transport Data

Thirteen two-pass suspended sediment samples were collected during the Spring Flow Release at TRDC (Table 12). Measured SSC ranged from a high of 556 mg/l on April 17, to 18.8 mg/l on May 20, the last day of suspended sediment sampling. The associated computed suspended sediment discharges were 14,040 and 344 tons/day which were measured at 9,370 and 6,780 cfs. Total suspended sediment discharge values are plotted in Figure 27, with transport data from WY 2004-2019.

Continuous turbidity was measured beginning April 12, 2019 at 14:15 (Appendix D-4). The turbidity record was faulty from May 28 to July 31 necessitating the development of discharge versus SSC relationships. Continuous suspended sediment discharge for the three size classes was computed using the applicable SSC relationships (Appendix D-1; D-4). Partial and total suspended sediment load for the Spring Flow Release were 5,770; 11,300; 4,080 and 21,160 tons for the <0.063mm, 0.063-<0.50mm, ≥0.50mm size classes and total load respectively (Table 13). The Sediment Station Analysis (Appendix D-1) details the relationships and periods of record for which the transport curves were applied. Appendix D-10 contains the sample data and SSC computations.

Table 12. Trinity River at Douglas City-- USGS Gage #11525854, Suspended Sediment Sampling Summary -- WY2019

Sample Number	Date & Mean Time	Average Discharge (cfs)	Average SSC (mg/l)	Average SSD (tons/day)
TRDC-SSCT2019-01	4/17/2019 11:11	6,000	221	3,580
TRDC-SSCT2019-02	4/17/2019 17:22	9,370	556	14,040
TRDC-SSCT2019-03	4/18/2019 12:15	9,820	78.2	2,070
TRDC-SSCT2019-04	4/19/2019 15:16	6,640	34.8	623
TRDC-SSCT2019-05	4/29/2019 10:28	6,720	89.4	1,620
TRDC-SSCT2019-06	4/29/2019 16:35	9,630	108	2,790
TRDC-SSCT2019-07	4/30/2019 8:30	11,600	73.1	2,285
TRDC-SSCT2019-08	4/30/2019 18:01	10,200	46.9	1,290
TRDC-SSCT2019-09	5/1/2019 9:49	6,630	25.0	446
TRDC-SSCT2019-10	5/19/2019 11:35	10,400	66.9	1,880
TRDC-SSCT2019-11	5/19/2019 15:43	10,400	46.2	1,290
TRDC-SSCT2019-12	5/20/2019 9:40	7,820	31.5	664
TRDC-SSCT2019-13	5/20/2019 16:37	6,780	18.8	344

Values Rounded According to Porterfield (1972)

Table 13. Trinity River at Douglas City-- USGS Gage #11525854, Suspended Sediment Loads -- WY2019

< 0.063 mm (tons)	0.063 mm-<0.50 mm (tons)	≥0.50 mm (tons)	Total Load (tons)
5,770	11,300	4,080	21,160

Values Rounded According to Porterfield (1972)

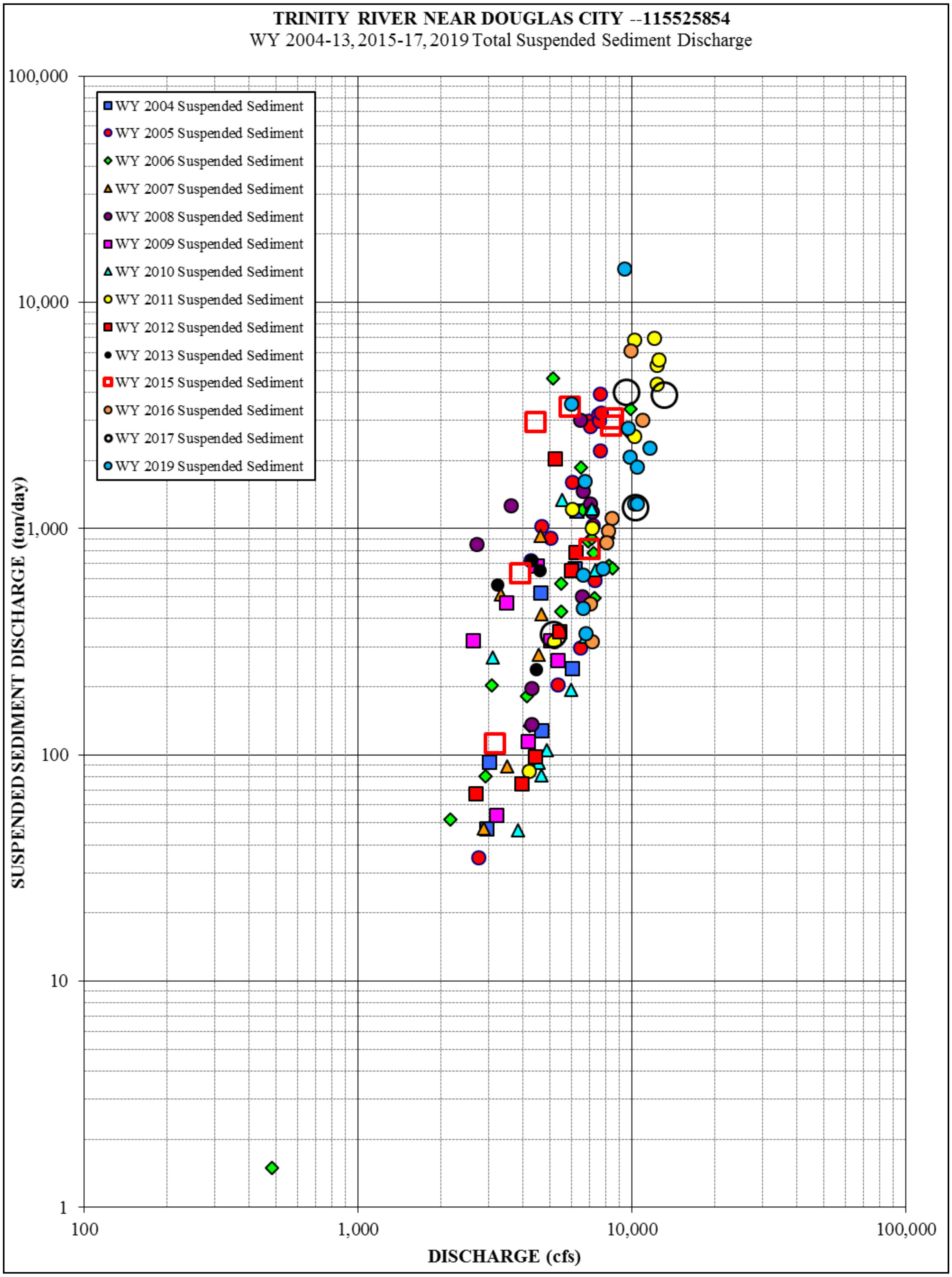


Figure 27.Total Suspended Sediment Discharge at TRDC, WY2004-2013, 2015-2017, 2019.

Bedload Transport Data

Thirty-one bedload samples were collected during the 2019 Spring Flow Release. Table 14 summarizes the sample bedload discharge data. Measured bedload discharge for Total bedload peaked on April 30 at 4,600 tons/day at 11,500 cfs (Table 14). Appendix D-9 contains the sample data (e.g. weights and computed transport rates) and bedload computation values. Bedload discharge rates were plotted in Figures 28-30 with the previous nine years of data. Bedload transport rates for fine and coarse sediment were computed using generalized equations developed from WY 2019 bedload samples (Appendix D-2). Fine, coarse, and total bedload estimates were 5,580; 10,410 and 16,000 tons, respectively (Table 15). As discussed in section 2.3.4, the <0.5mm fraction is omitted from bedload data and computations; however, this fraction is included for graphical comparisons with historic values.

The partial transport curves used to compute continuous bedload discharge are included in Appendix D-2. A complete explanation of assumptions and techniques employed in the continuous bedload discharge and load computation process is provided in the Station Analysis (Appendix D-1). The bedload sedigraphs are shown in Appendix D-5.

Bedload samples were partitioned to support hydrophone experiments conducted by USGS and NOAA. Partitioned sample results are included in Appendix D-9 in a sub-folder labeled 'SplitXS' in individual Excel spreadsheets. Sample numbers were split into an A and B sub-sample, representing the left or right side of the channel as indicated by the stations sampled with station zero being on the left bank. Results in the Excel spreadsheet contain pertinent metadata such as, but not limited to, date, start and end time, the begin and end stage height, bottom time, stations sampled, interval (distance between stations) and processing information.

Table 14. Trinity River at Douglas City -- USGS Gage #11525854, Bedload Sediment Sampling Summary -- WY2019

Sample Number	Date & Mean Time	Average Discharge (cfs)	Total Bedload Discharge (tons/day)	≥ 8mm Bedload Discharge (tons/day)	0.5-<8 mm Bedload Discharge (tons/day)
TRDC-BLM2019-01	04/17/2019 12:39	6,650	1,790	1,540	220
TRDC-BLM2019-02	04/17/2019 14:27	7,190	2,930	2,240	614
TRDC-BLM2019-03	04/17/2019 16:17	8,490	2,790	1,760	916
TRDC-BLM2019-04	04/18/2019 11:14	9,870	1,780	1,350	399
TRDC-BLM2019-05	04/18/2019 14:04	9,460	2,490	732	1,720
TRDC-BLM2019-06	04/18/2019 15:48	9,260	1,640	1,100	514
TRDC-BLM2019-07	04/19/2019 10:02	7,320	1,340	869	460
TRDC-BLM2019-08	04/19/2019 12:18	7,090	685	441	240
TRDC-BLM2019-09	04/19/2019 14:29	6,710	1,870	818	1,030
TRDC-BLM2019-10	04/29/2019 09:42	6,240	405	262	139
TRDC-BLM2019-11	04/29/2019 12:37	7,540	670	423	236
TRDC-BLM2019-12	04/29/2019 14:37	8,650	1,890	1,200	649
TRDC-BLM2019-13	04/29/2019 15:53	9,350	2,430	1,730	659
TRDC-BLM2019-14	04/29/2019 17:42	9,870	2,880	2,270	580
TRDC-BLM2019-15	04/30/2019 09:16	11,500	4,600	2,860	1,710
TRDC-BLM2019-16	04/30/2019 12:03	11,100	1,910	1,520	372
TRDC-BLM2019-17	04/30/2019 14:07	10,900	1,070	665	388
TRDC-BLM2019-18	04/30/2019 17:23	10,600	1,970	924	1,020
TRDC-BLM2019-19	04/30/2019 18:38	10,300	1,090	510	573
TRDC-BLM2019-20	05/01/2019 08:40	7,030	706	359	340
TRDC-BLM2019-21	05/01/2019 10:26	6,460	529	270	255
TRDC-BLM2019-22	05/01/2019 12:18	6,060	189	66.7	120
TRDC-BLM2019-23	05/19/2019 09:07	9,670	1,900	1,720	170
TRDC-BLM2019-24	05/19/2019 10:30	10,300	2,370	1,850	499
TRDC-BLM2019-25	05/19/2019 14:11	10,400	1,550	1,150	392
TRDC-BLM2019-26	05/19/2019 16:21	10,200	2,140	1,680	435
TRDC-BLM2019-27	05/19/2019 18:18	9,850	1,850	1,570	278
TRDC-BLM2019-28	05/20/2019 08:38	7,890	353	229	122
TRDC-BLM2019-29	05/20/2019 12:15	7,420	448	179	266
TRDC-BLM2019-30	05/20/2019 15:14	6,890	255	138	115
TRDC-BLM2019-31	05/20/2019 17:24	6,690	105	70.5	33.6

Values Rounded According to Porterfield (1972)

Table 15. Trinity River at Douglas City -- USGS Gage #11525854, Bedload -- WY2019

0.5-<8 mm (tons)	≥8 mm (tons)	Total Bedload (tons)
5,580	10,410	16,000

Values Rounded According to Porterfield (1972)

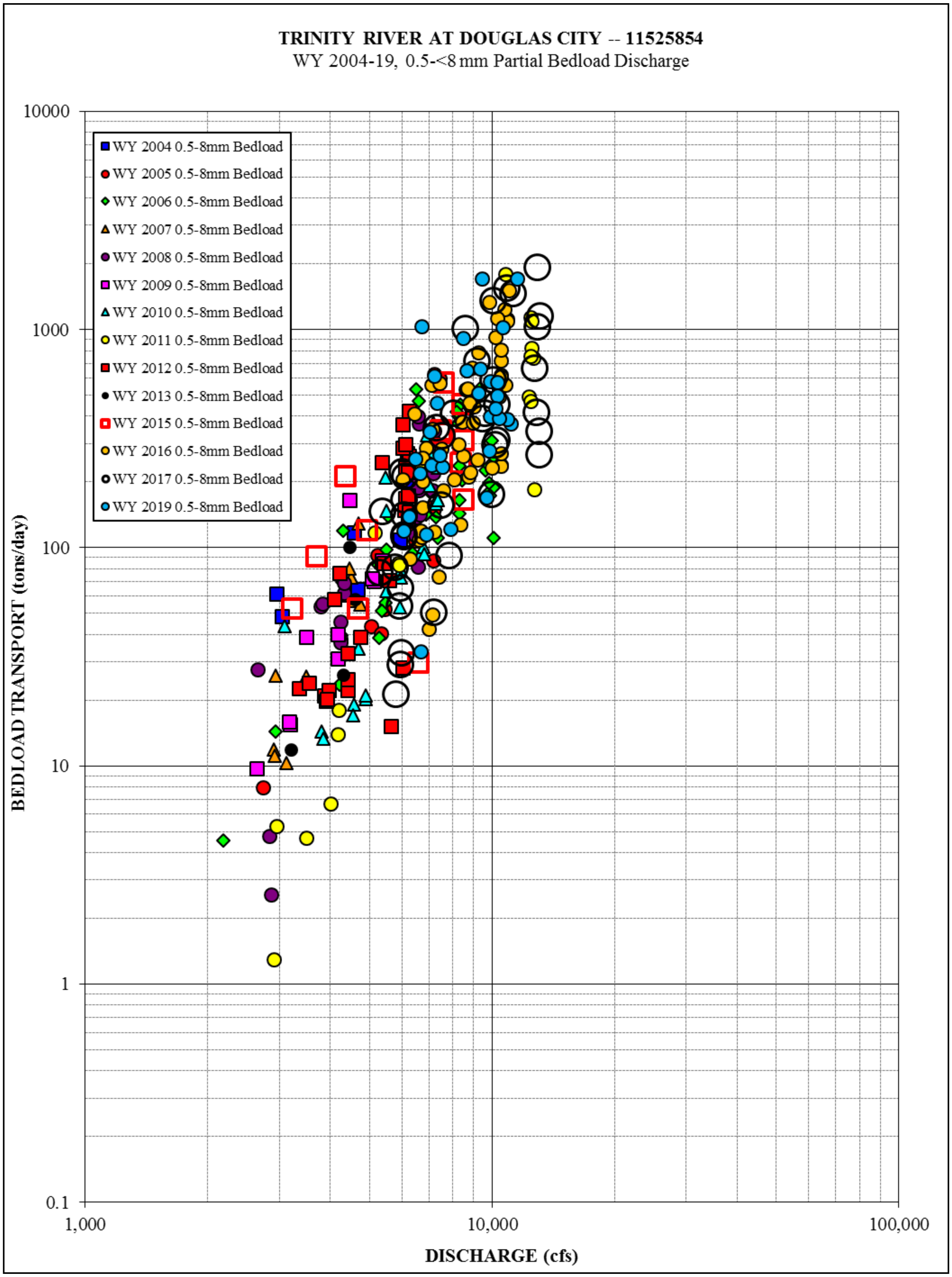


Figure 28. Fine Bedload Discharge at TRDC, WY2004-2013, 2015-2017, 2019.

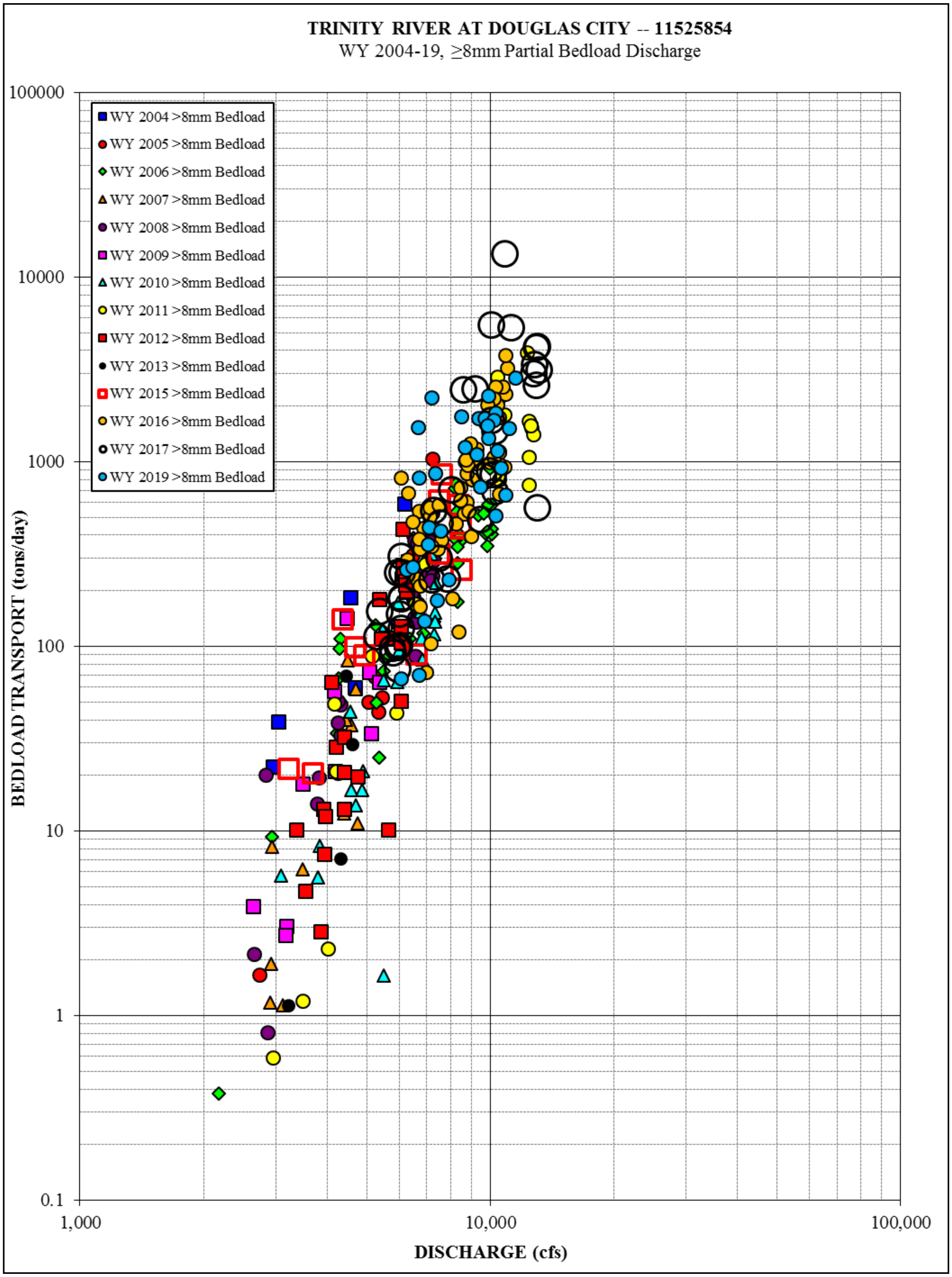


Figure 29. Coarse Bedload Discharge at TRDC, WY2004-2013, 2015-2017, 2019.

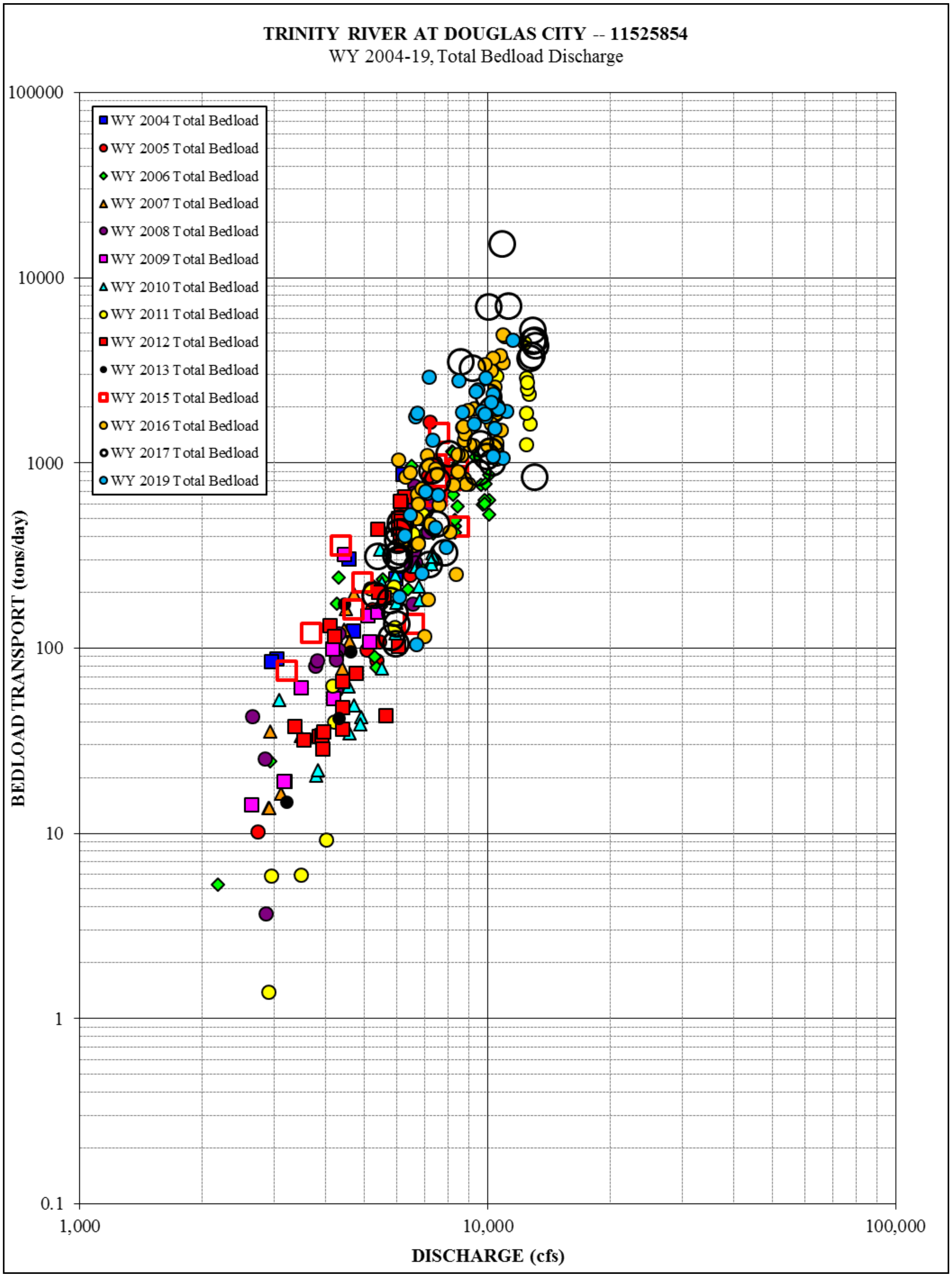


Figure 30. Total Bedload Discharge at TRDC, WY2004-2013, 2015-2017, 2019.

Water Surface Slope, Cross Section Changes and Pebble Count Changes
The 2019 water surface slope was 0.0027 at 11,500 cfs. Cross section data were collected at the TRDC sediment monitoring station pre- and post-Spring Flow Release to assess changes at the sampling section. Changes in the cross section are shown in Figure 31. The area change calculation for the cross section below the 1,606.49 foot elevation revealed 31.4 ft^2 of scour and 26.0 ft^2 of fill for a net scour of 5.4 ft^2. The stream bed, stations 37 to 192, saw an overall fill of 13.5 ft^2, while the right bank, stations 192 to 204 received a net scour of 18.9 ft^2 of bank material.

Pebble count data were collected at the TRDC sediment monitoring site post-Spring Flow Release (SFR), however, a pebble count was not preformed before the SFR. The pebble count represents the mid-channel portion of the transverse riffle. The left half of the section is deeper with bedrock protrusions and coarser boulder elements. Even though no pre-SFR pebble count data were collected the graphical representation of the particle size distribution for the post-SFR has been included (Figure 32).

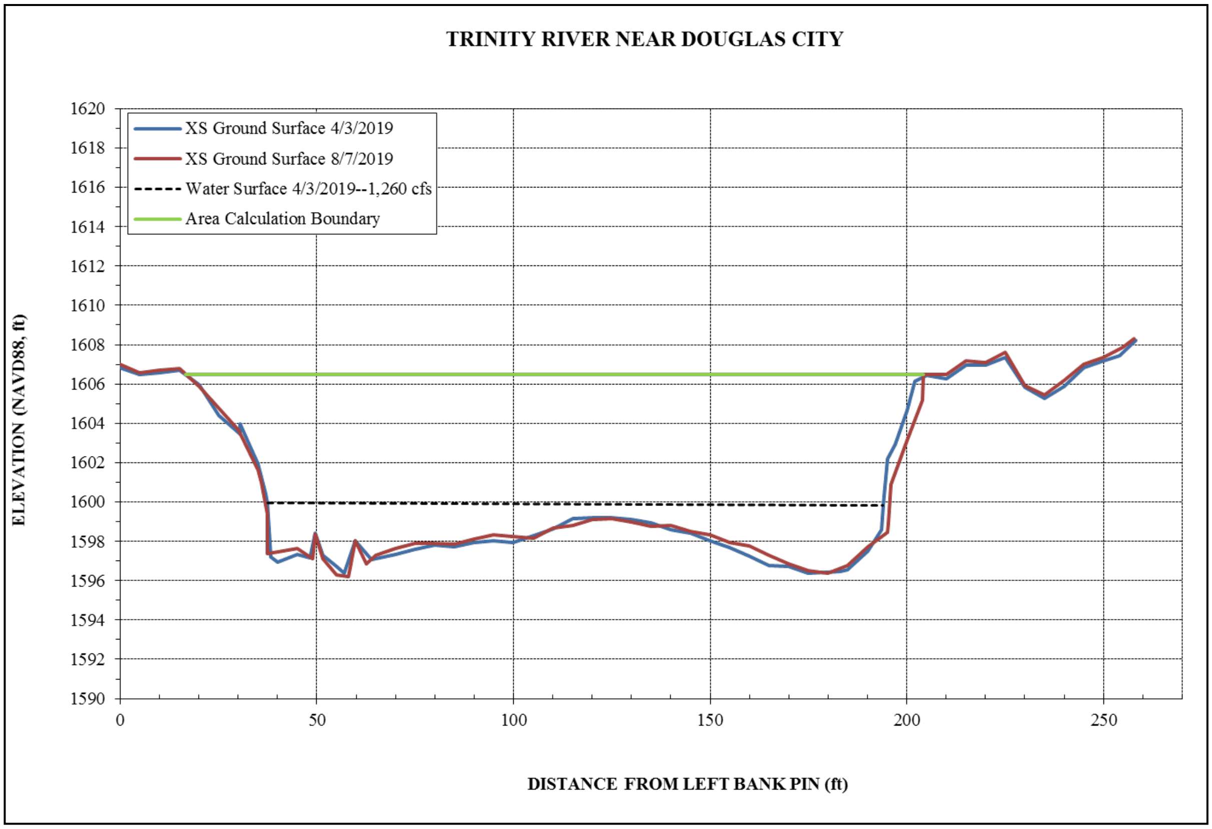


Figure 31. Cross section changes at TRDC, pre and post Spring Flow Release 2019.

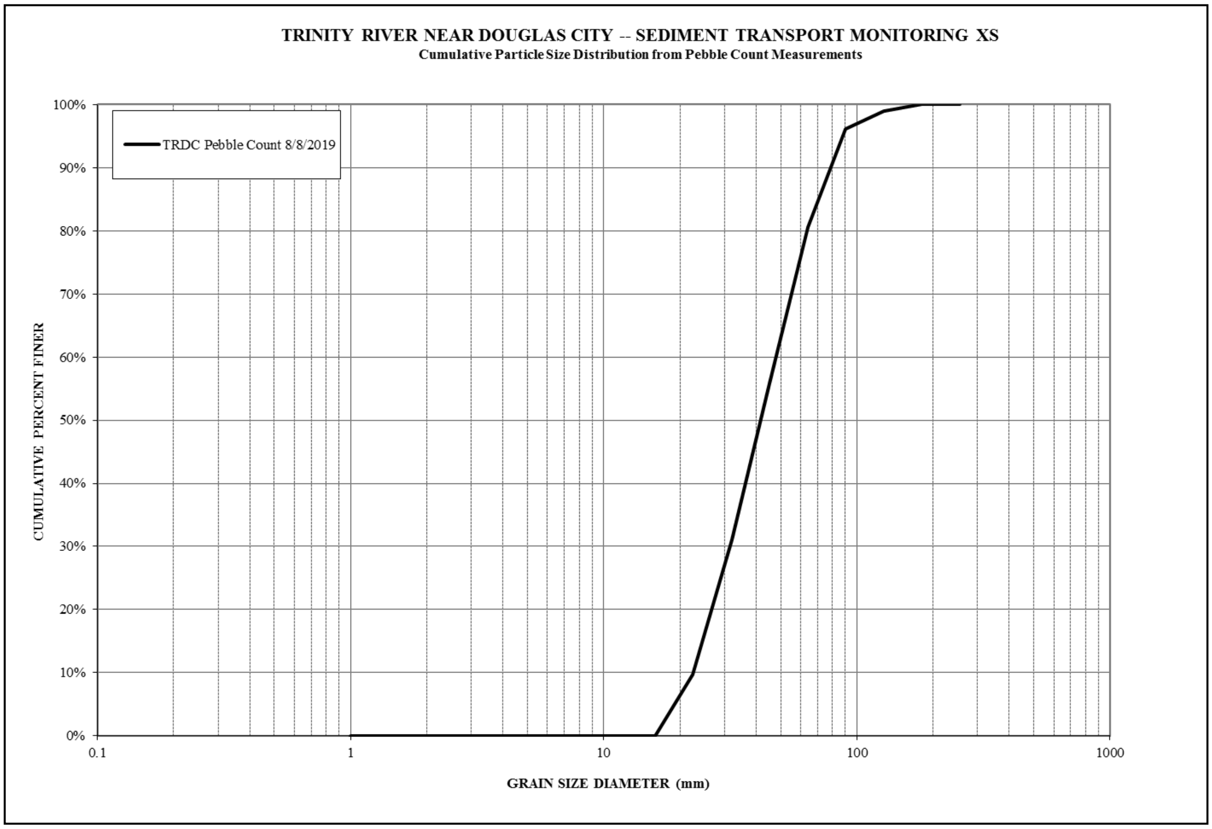


Figure 32. Changes in bed texture at TRDC, Spring Flow Release 2019.

2.5 Focused Results and Discussion

Sediment transport rates derived from field samples display considerable inter- and intra-annual variability. For example, the bedload transport rates at long-term sediment transport monitoring stations TRAL and TRLG show over an order of magnitude variation for a given discharge for a given year (Figures 8-10; 21-23). The suspended sediment data display less variation (Figure 20). The need to accurately estimate sediment transport rates for sediment load computations and to differentiate periods of higher or lower sediment transport (via transport curve comparison) provides the impetus for repeat annual sampling efforts.

The sediment budgeting objectives outlined in the TRFE and SBMP require an accounting of sediment inputs and outputs to sediment budget cells. These values are used to determine the dam release flow duration required to transport sediment, the sediment quantities, and the particle sizes needed to augment various reaches. Monitoring results which inform sediment budgets, and are ultimately used to help explain the linkages between management actions and desired restoration outcomes (e.g. as described in TRFE, 1999) include:

- Differences in sediment discharge (transport rates) between stations;
- Differences in sediment loads between stations;
- Differences in bedload sediment particle sizes;
- Changes in sediment loads at a station over time;
- Changes in sediment discharge (transport rates) at a station over time.

We focus on each of these topics in the following sections. We also explore uncertainty in some of the sediment load calculations as implied by temporal bedload discharge variation (also done previously in 2015, 2016 and 2017); the results of this pilot study are presented in section 2.5.5.

Data evaluations in this section are based on visual estimates of data trends and no statistical analyses were performed (with exception of Sec 2.5.6 -- Table 18). Although data may suggest clear trends, we do not provide statistical inference.

2.5.1 Differences in Sediment Discharge between Stations

2.5.1.1 Mainstem Suspended Sediment

WY 2019 suspended sediment discharge data for three mainstem stations were plotted together (Figure 33) to highlight downstream transport variation. Mainstem suspended sediment transport rates increase (shift upward) with distance downstream from the dam. Assuming all stations are transporting below their potential SSD transport capacity, the progressive downstream increase in transport rate indicates that fine sediment supply increases with distance downstream. This is likely due to both tributary contributions and cumulative increase in channel bank (e.g. sandy lateral berms) available to recruit fine material. The USGS dam release data from1981-1991sits to the left of the WY2019 data, which suggests that the mainstem produced more fine sediment at TRLG than it does today (Figure 33). A regression line extrapolated beyond the upper end of the WY2019 data would suggest a possible convergence at higher flows.

The WY 2019 sedigraphs for total and partial suspended sediment discharge were plotted with their respective site hydrographs to highlight sediment discharge variation across the hydrograph (at a station) and in the downstream direction (between stations) (Figures 34, 35). The first peak, April 17, experienced the highest SSD even though discharge was around 1,000 cfs lower than the highest peak on April 29. The second peak (April 29), which had the highest discharge, had SSD values that were 60-80% lower than the first peak.

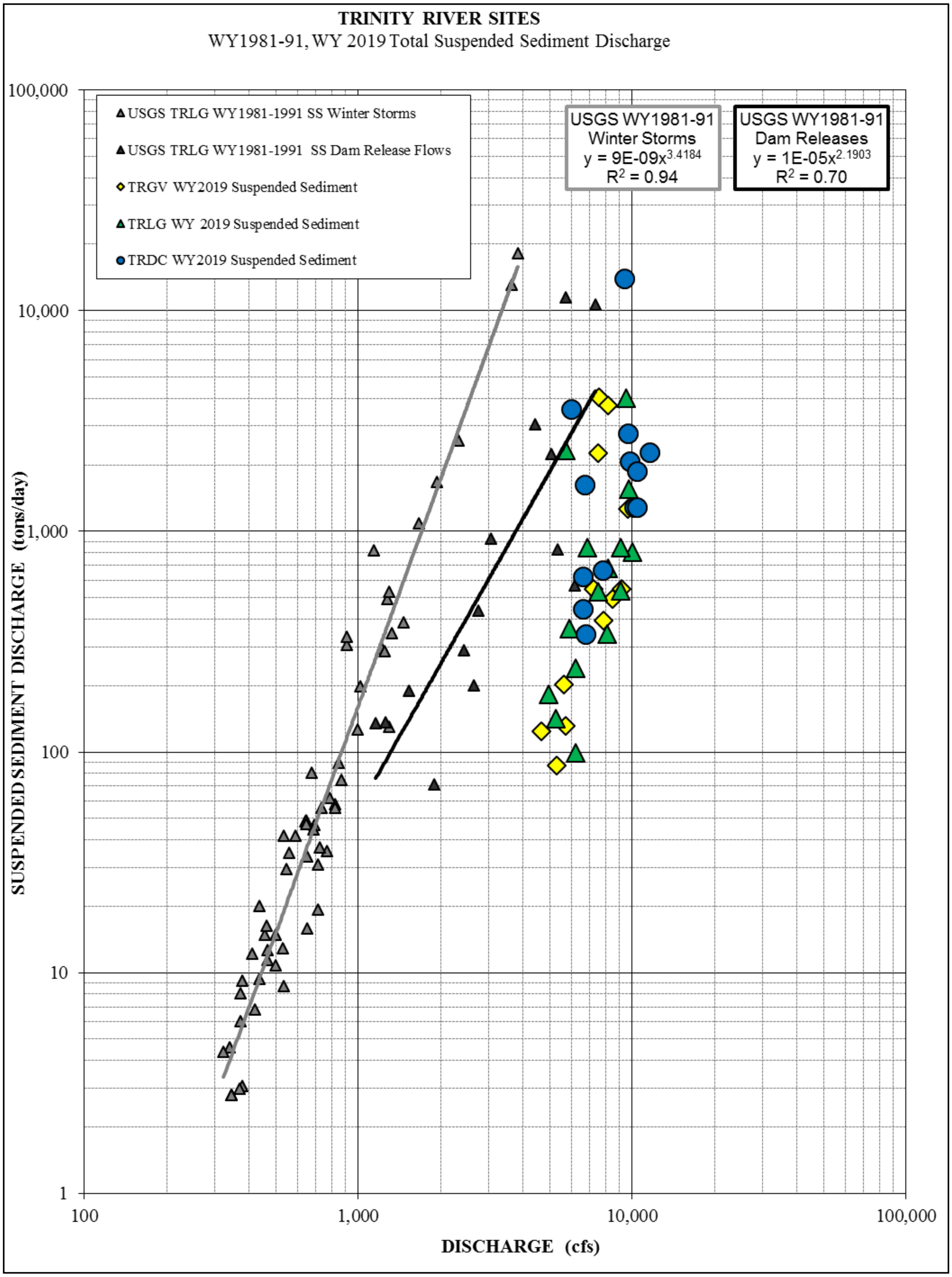
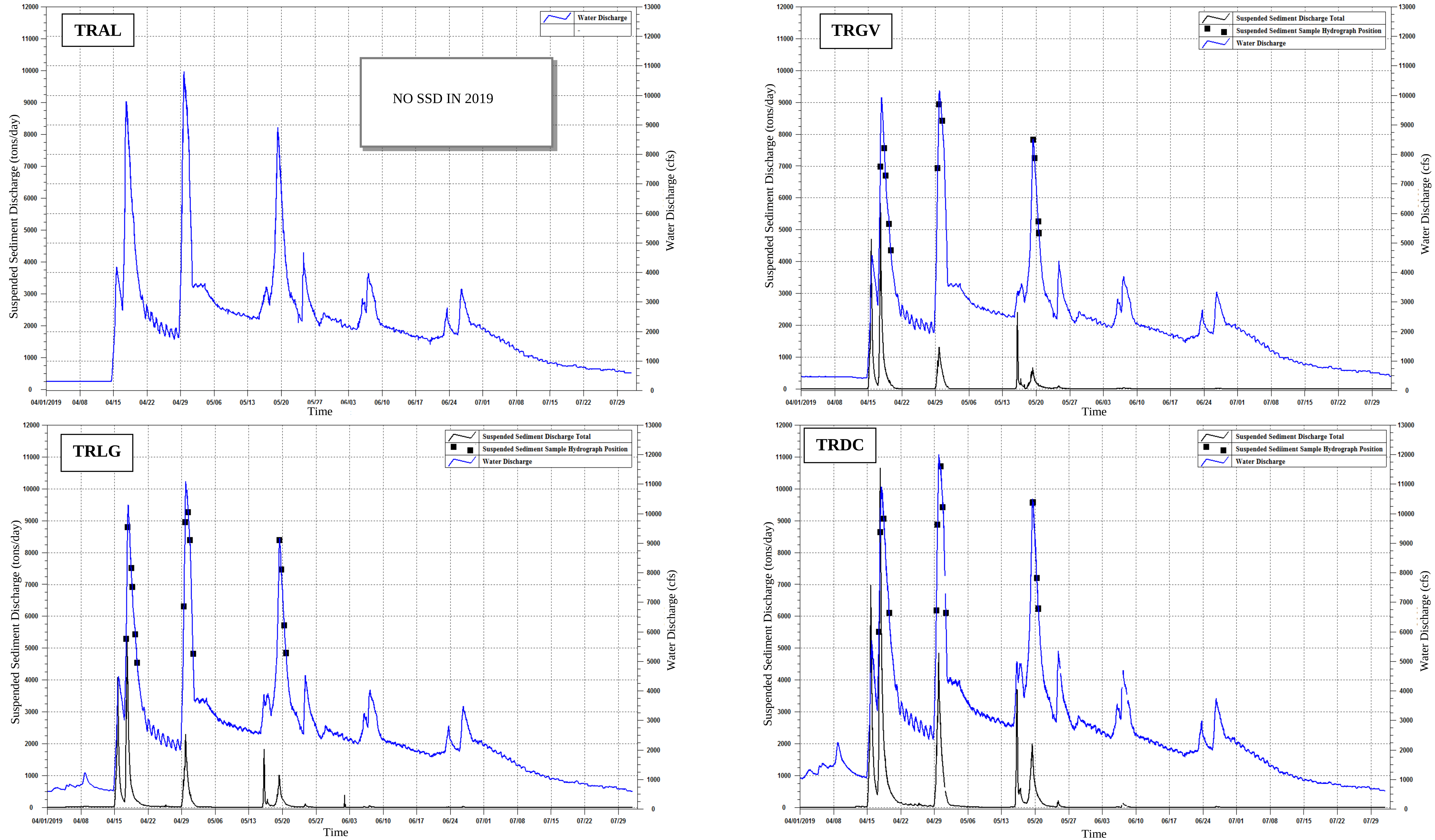


Figure 33. Suspended Sediment Discharge, Mainstem Trinity River Monitoring Stations, WY 2019 with TRLG Data from 1981-1991 for comparison.

See Figures 1 and 2 for sampling site locations.

TRINITY RIVER MAINSTEM STATIONS

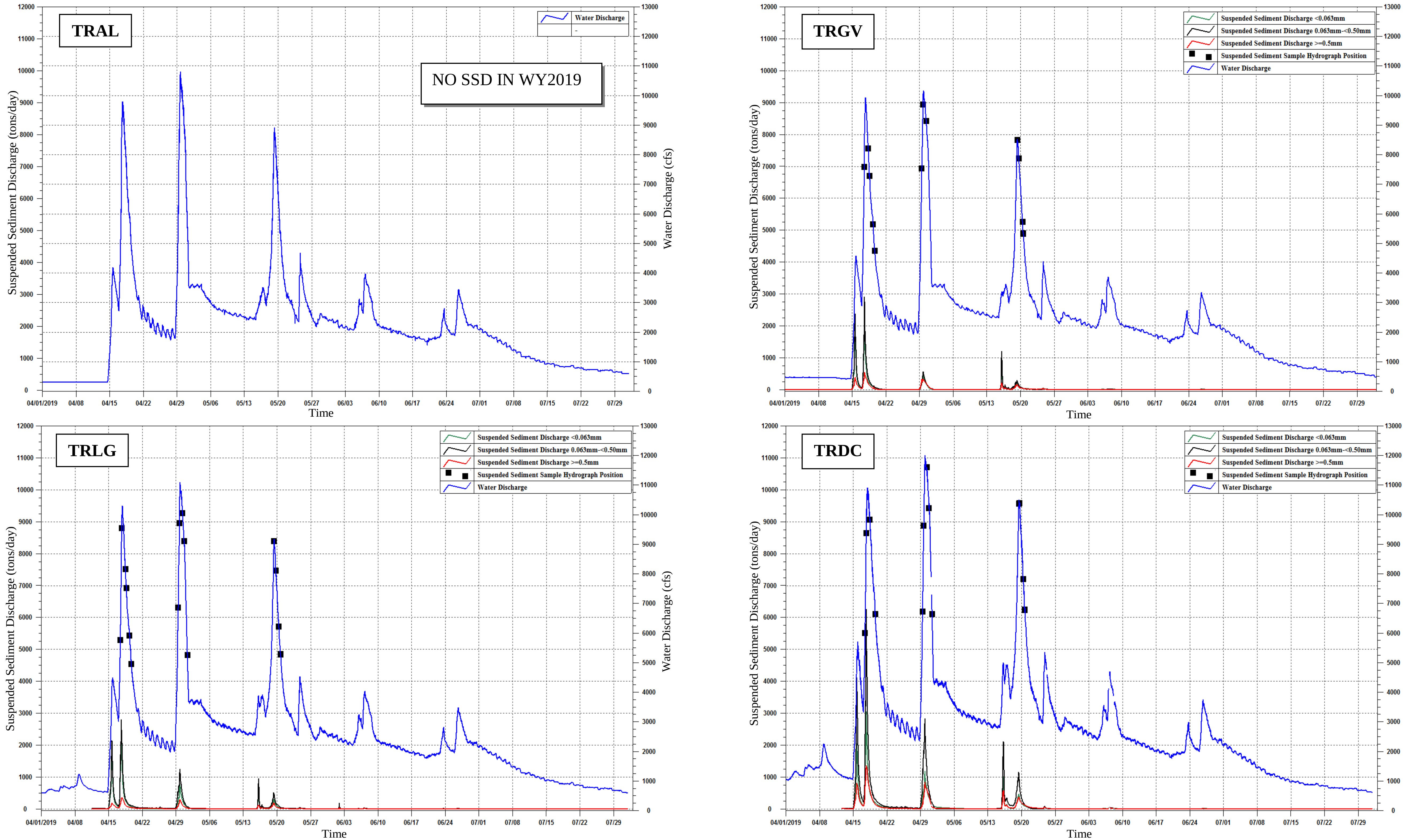
Suspended Sediment Discharge -- Spring Flow Release WY 2019



WY2019 SEDIMENT TRANSPORT MONITORING REPORT	TRINITY RIVER RESTORATION PROGRAM	GMA Hydrology | Geomorphology | Stream Restoration	FIGURE 34

TRINITY RIVER MAINSTEM STATIONS

Suspended Sediment Discharge -- Spring Flow Release WY 2019



WY2019 SEDIMENT TRANSPORT MONITORING REPORT	TRINITY RIVER RESTORATION PROGRAM	GMA Hydrology | Geomorphology | Stream Restoration	FIGURE 35

2.5.1.2 Mainstem Bedload

The WY 2019 total bedload discharge (BLD) measurements for all stations were plotted together in Figure 36. Trend lines were added strictly to aid in distinguishing relative trends. We attribute data-point scatter to: the hysteresis that often occurs on the rising and falling limb of the hydrograph, the inherent variability in sample particle-size distributions (e.g. periodic large particles biasing the sample), and the inherent temporal variability in bedload transport.

TRAL bedload shows the highest rate of increase (exponent = 5.44 in the power function). TRGV, TRLG and TRDC all have similar rates of increase (exponents of 3.01 to 3.62). At TRDC, bedload discharge magnitudes for individual samples plot higher than the other three stations and the curve sits to the left of the others. Of the three sites upstream of TRDC, TRAL collected the lowest bedload discharge sample (2019-27) and also collected the two highest samples (2019-03 & 2019-17). The range of the TRAL samples creates a trend line that traverses the other sites generalized transport curves (Figure 36).

The four mainstem total bedload sedigraphs and partial-bedload sedigraphs for fine (0.5-<8mm) and coarse (≥ 8mm) bedload size fraction (Figures 37, 38) illustrate bedload discharge variation across the Spring Flow Release hydrograph and in the downstream direction. All sites show higher transport on the first peak of the hydrograph and all sites show the coarser fraction to constitute most of the bedload (Figure 37). At TRDC, the fine fraction of bedload is greater than at the other three sites, again presumably due to its position lower in the watershed (fine sediment supply increases with distance downstream).

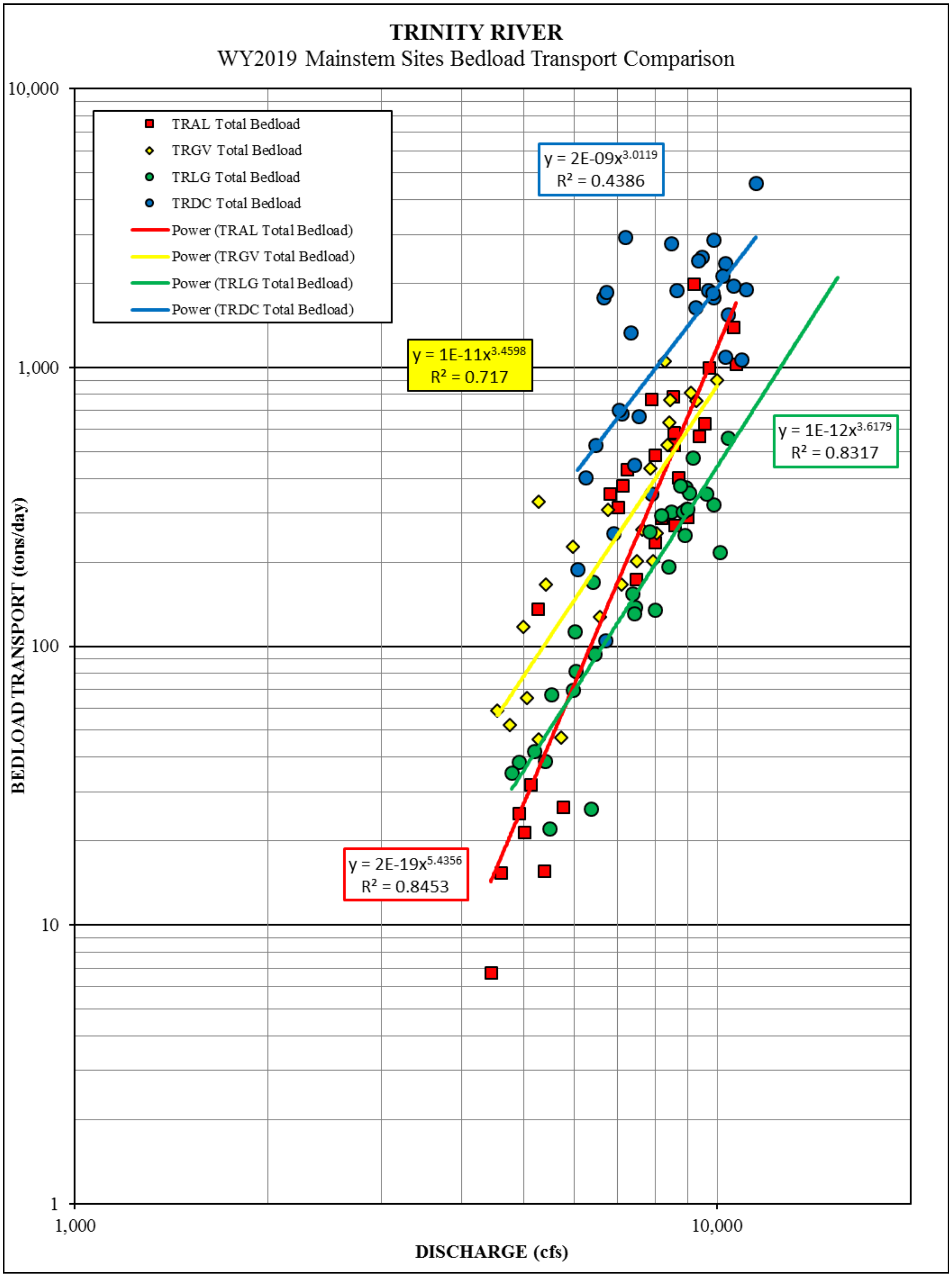
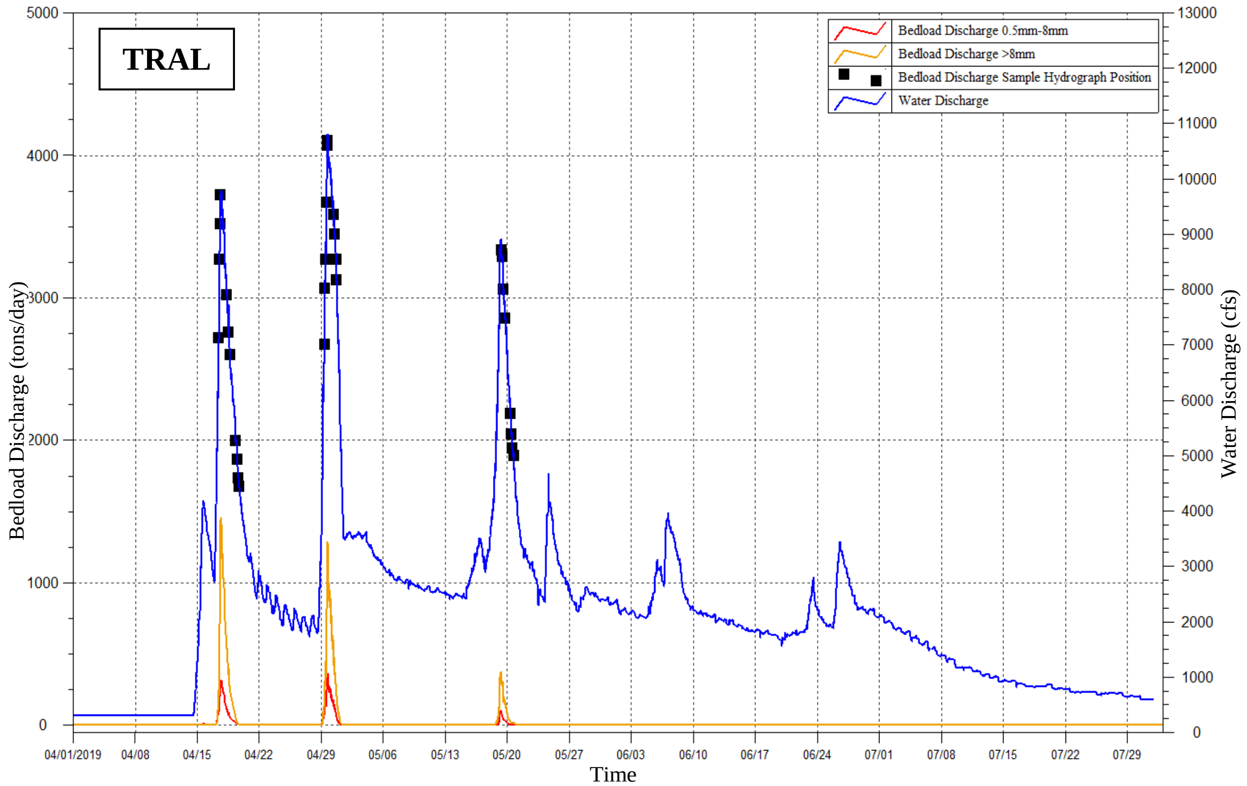
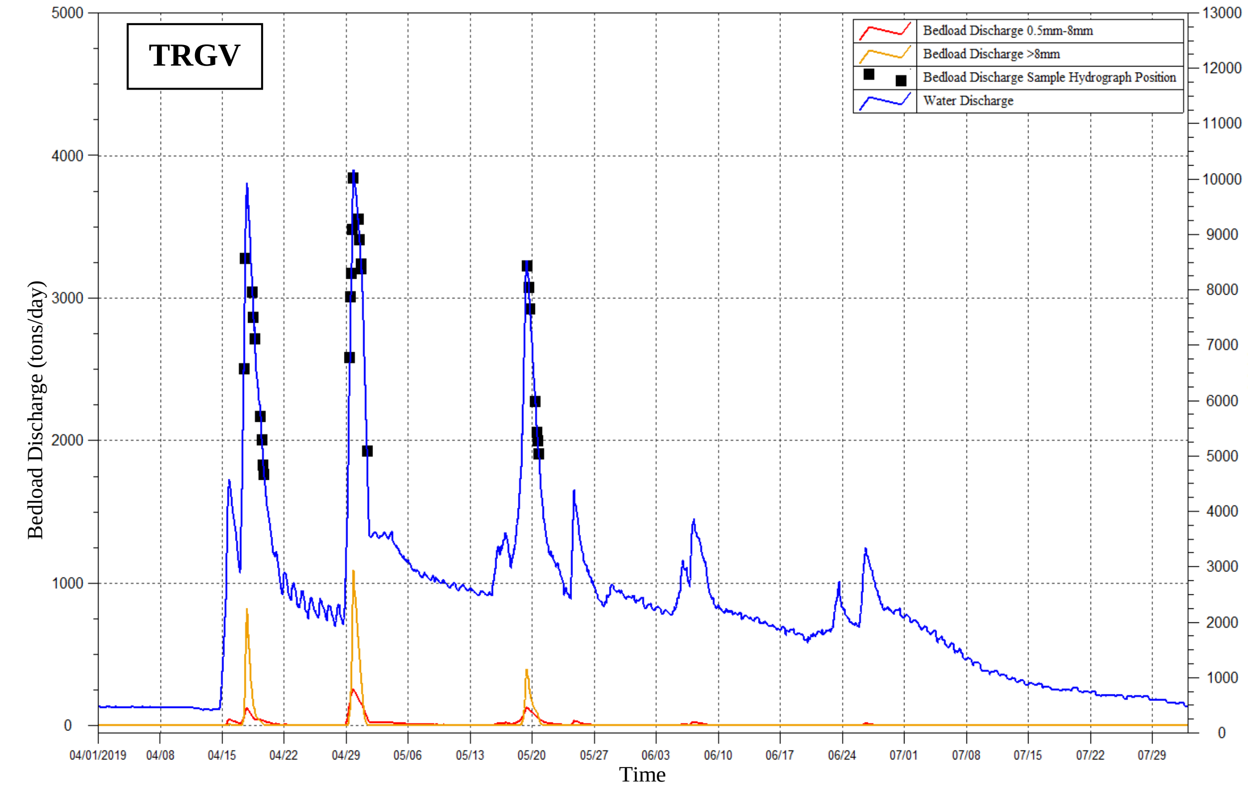


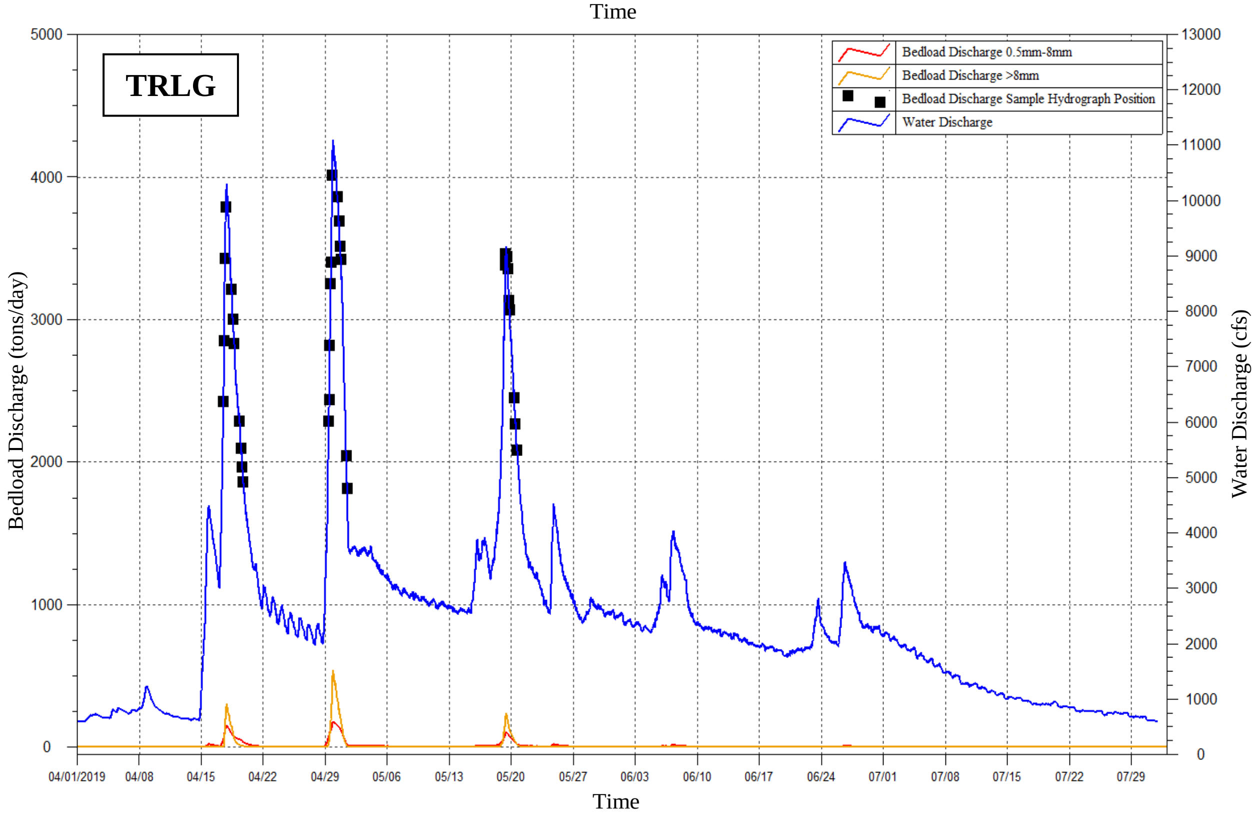
Figure 36. Total Bedload Discharge, Mainstem Trinity River Monitoring Stations, WY2019.
See Figures 1 and 2 for sampling station locations.

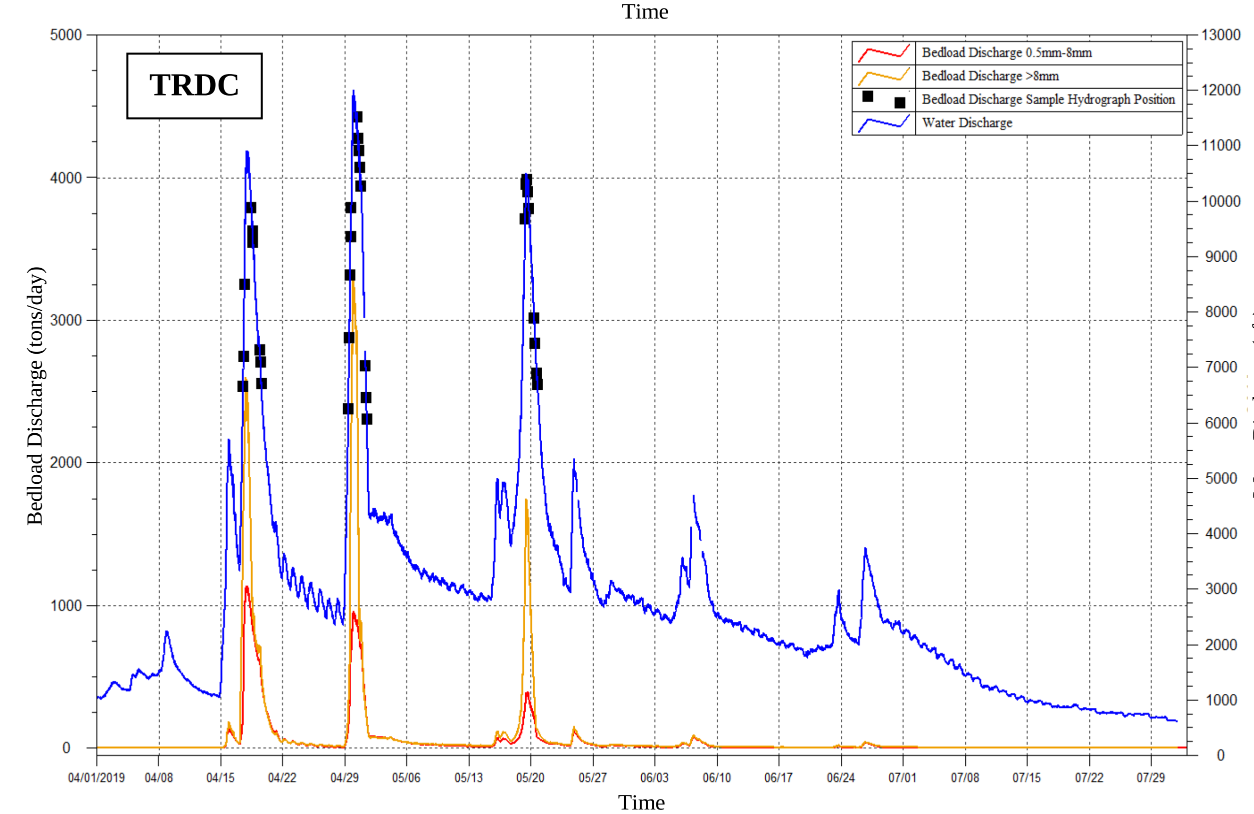
TRINITY RIVER MAINSTEM STATIONS

Partial Bedload Discharge -- Spring Flow Release WY 2019





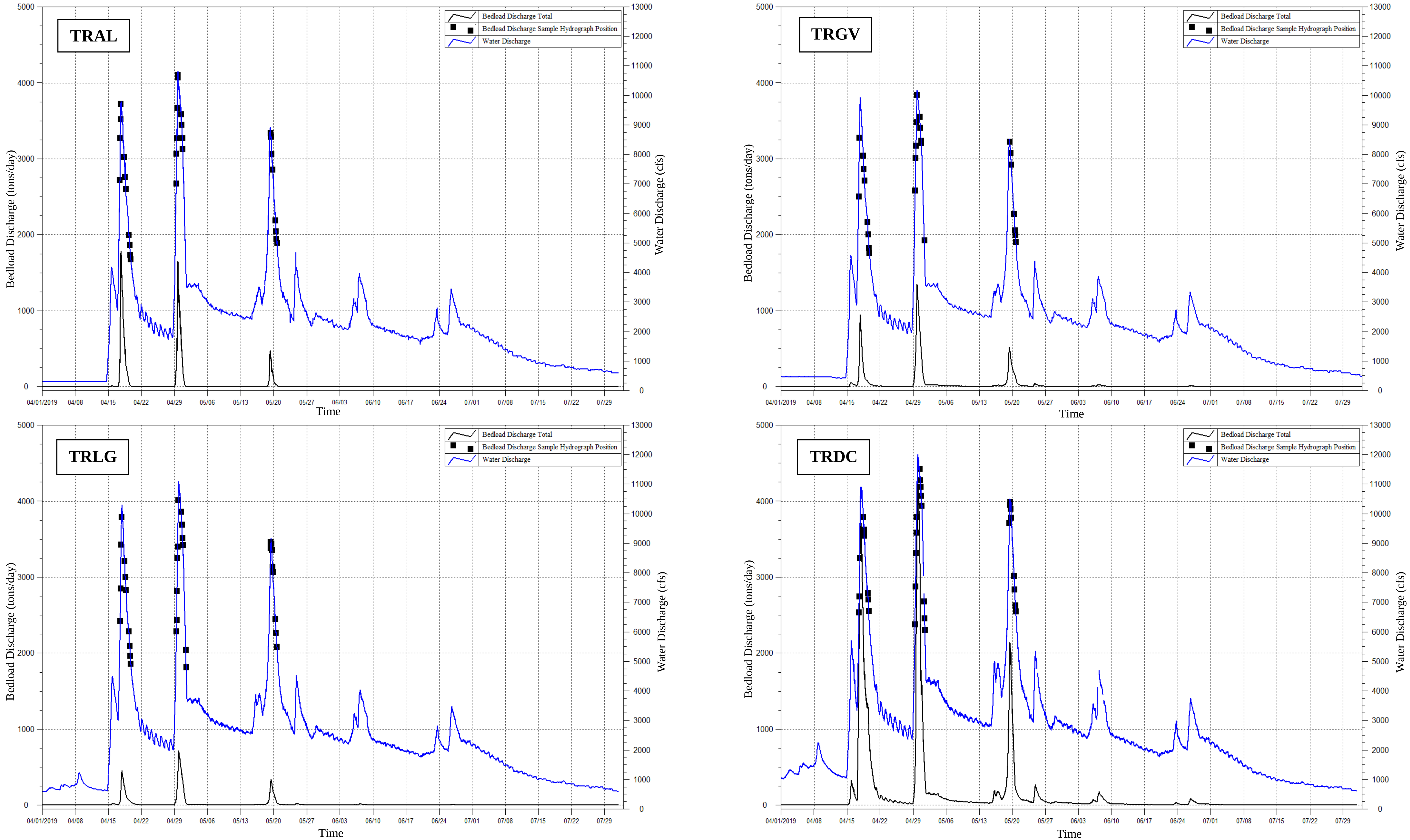




WY2019 SEDIMENT TRANSPORT MONITORING REPORT	TRINITY RIVER RESTORATION PROGRAM	GMA Hydrology | Geomorphology | Stream Restoration	FIGURE 37

TRINITY RIVER MAINSTEM STATIONS

Bedload Discharge -- Spring Flow Release WY 2019



WY2019 SEDIMENT TRANSPORT MONITORING REPORT	TRINITY RIVER RESTORATION PROGRAM	GMA Hydrology | Geomorphology | Stream Restoration	FIGURE 38

2.5.2 Differences in Sediment Load between Stations

2.5.2.1 Mainstem Suspended Sediment Loads

The computed partial and total suspended sediment loads for the WY2019 Spring Flow Release are presented in Table 16. Suspended sediment loads increased in the downstream direction: from 8,530 tons at TRGV, to 9,850 tons at TRLG, and 21,160 tons at TRDC.

2.5.2.2 Mainstem Bedload

Bedload does not show the same downstream increase as was observed for suspended load. Total bedload estimates for TRAL, TRGV, TRLG, and TRDC in WY2019 were 2,910; 2,950; 1,760 and 16,000 tons, respectively (Table 16).

Table 16. WY 2019 Mainstem Sediment Loads

	Suspended Sediment				Bedload		
SEDIMENT MONITORING STATION	SS <0.063 mm (tons)	SS 0.063 mm - <0.50 mm (tons)	SS ≥0.50 mm (tons)	SS Total (tons)	Bedload 0.50-<8 mm (tons)	Bedload ≥8 mm (tons)	Total Bedload (tons)
Trinity River at Lewiston (TRAL)	NA	NA	NA	NA	614	2,300	2,910
Trinity River above Grass Valley Creek (TRGV)	3,120	3,920	1,490	8,530	1,140	1,800	2,950
Trinity River below Limekiln Gulch (TRLG)	3,450	5,100	1,310	9,850	868	870	1,760
Trinity River near Douglas City (TRDC)	5,770	11,300	4,080	21,160	5,580	10,410	16,000

All values rounded using methods by Porterfield (1972)

The relative percentage of fine and coarse bedload varied between stations. TRAL had 21 percent fine, TRGV was 39 percent, TRLG was 49 percent and TRDC was 35 percent. Comparison of the ratio of suspended load or bedload to total load at the various mainstem sites can provide additional insight into transport dynamics. For WY2019, TRGV bedload was 66 percent of the total, TRLG was 58 percent and TRDC was 43 percent.

Of particular interest in 2019, considering the multi-peak hydrograph, is the question of how do the loads compare for each peak? We examined each site relative to its own hydrograph and summed the ≥8mm loads for each of the three largest peaks (Table 17). Computational periods were defined as the time the hydrograph exceeded the low flow point between the two flow peaks or when bedload mobility started to occur.

Table 17. ≥8mm bedload totals for each peak WY2019

SEDIMENT MONITORING STATION	Total BL ≥ 8mm (Tons)	Peak #1 - April 18 Bedload ≥ 8mm (Tons)	Q Peak (cfs)	% of Total ≥ 8mm	Peak #2 - April 29 Bedload ≥ 8mm (Tons)	Q Peak (cfs)	% of Total ≥ 8mm	Peak #3 - May 19 Bedload ≥ 8mm (Tons)	Q Peak (cfs)	% of Total ≥ 8mm
Trinity River at Lewiston (TRAL)	2,300	1,110	9,800	48%	935	10,800	41%	248	8,920	11%
Trinity River above Grass Valley Creek (TRGV)	1,800	542	9,930	30%	916	10,200	51%	345	8,520	19%
Trinity River below Limekiln Gulch (TRLG)	870	227	10,300	26%	484	11,100	56%	185	9,160	21%
Trinity River near Douglas City (TRDC)	10,410	3,775	10,900	36%	3,707	12,000	36%	1,979	10,500	19%

All values rounded using methods by Porterfield (1972)

2.5.3 Differences in Bedload Sample Particle Size Distributions

The bedload sample particle-size distributions for the mainstem stations were compared to examine general variations in grain size, both between stations and between peak flow benches. Particle-size distributions were averaged for all samples collected during each 2019 peak flow event (Figure 39). TRDC did not show a large change in particle size distribution over the three peaks. The three sites upstream of TRDC showed the first peak transported finer material than the following two peaks. The third peak at TRAL stands out being that it has the coarsest transport of all sites.

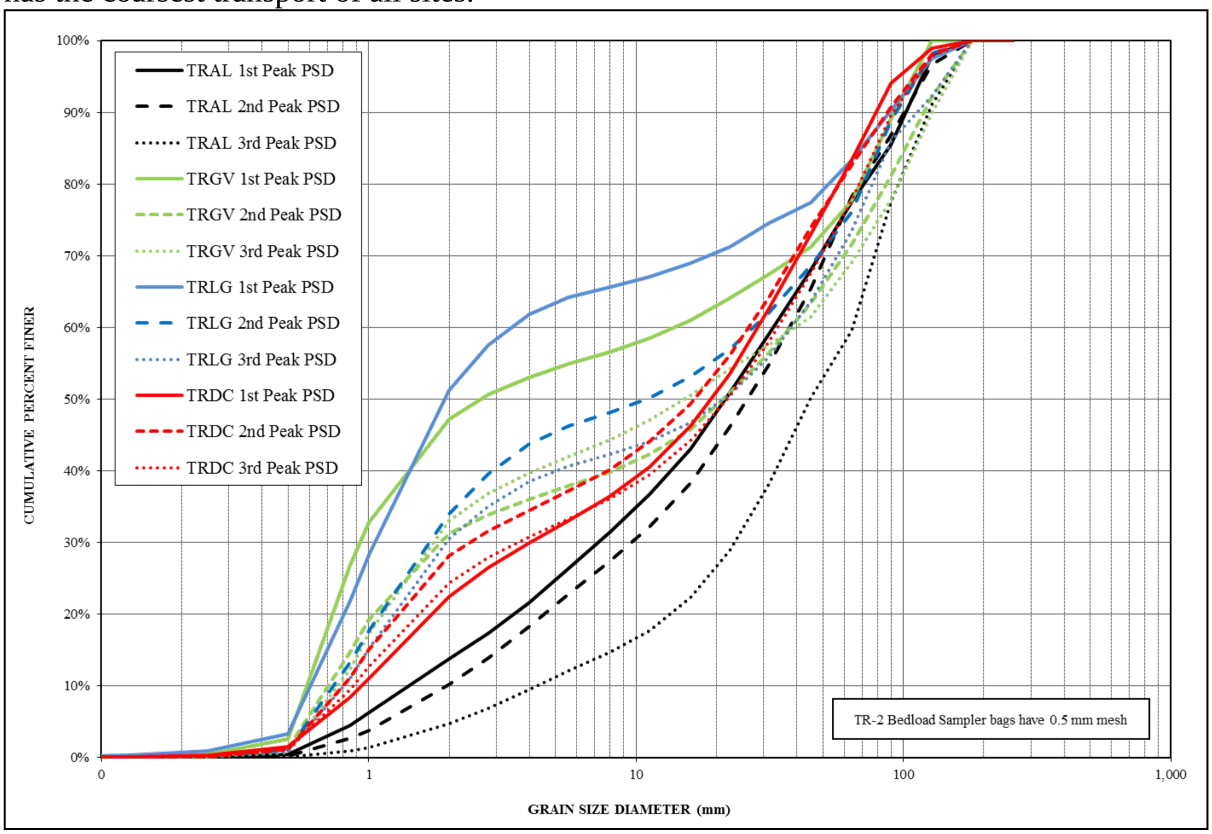


Figure 39. Peak Flow Bench Averaged Bedload Particle Size Distributions from the WY2019 Spring Flow Release.

The D50 for each bedload sample collected during the 2019 SFR is provided by individual site-hydrograph in Figure 40. With the exception of the second peak at TRAL, the D50 increased at each site from Peak 1 to Peak 3 (Table 18). This trend indicates that with similar flows and, in the case of the third peak on May 19, with a decrease in discharge, the system is moving less fine material over the duration of the flow release.

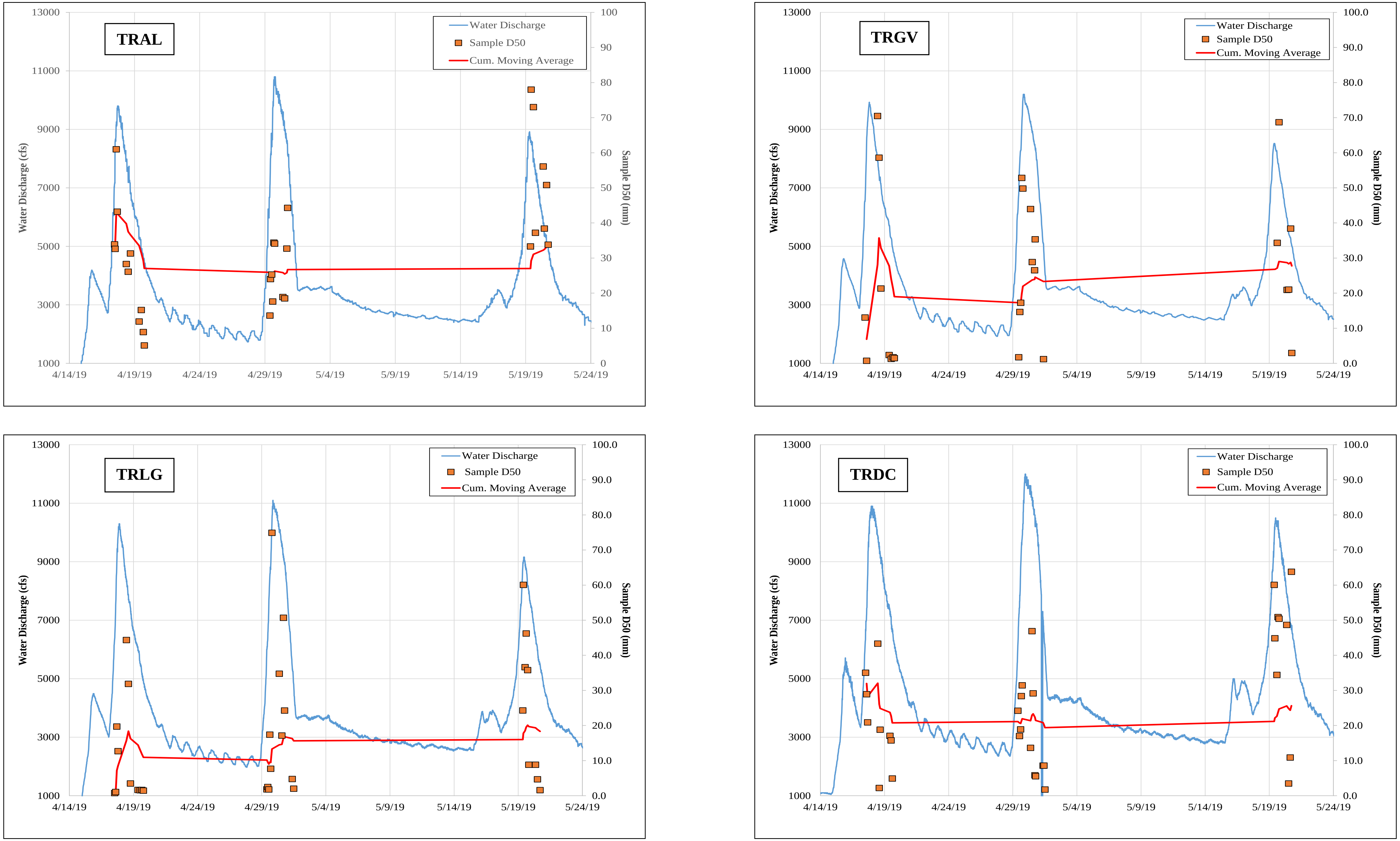
Table 18: Average D50 for each site for each peak event

	Peak #1 - April 18		Peak #2 - April 29		Peak #3 - May 19	
SEDIMENT MONITORING STATION	Average D50 mm	Q Peak (cfs)	Average D50 mm	Q Peak (cfs)	Average D50 mm	Q Peak (cfs)
Trinity River at Lewiston (TRAL)	27.0	9,800	26.3	10,800	50.1	8,920
Trinity River above Grass Valley Creek (TRGV)	21.3	9,930	30.1	10,200	35.0	8,520
Trinity River below Limekiln Gulch (TRLG)	10.9	10,300	23.3	11,100	25.2	9,160
Trinity River near Douglas City (TRDC)	20.8	10,900	22.1	12,000	40.8	10,500

All values rounded using methods by Porterfield (1972)

TRINITY RIVER MAINSTEM STATIONS

Bedload Sample D50 -- Spring Flow Release WY 2019



WY2019 SEDIMENT TRANSPORT MONITORING REPORT	TRINITY RIVER RESTORATION PROGRAM	GMA Hydrology | Geomorphology | Stream Restoration	FIGURE 40

2.5.4 Changes in Sediment Loads Over Time

The magnitude of Spring Flow Release sediment loads is dependent upon numerous factors, including: peak flow magnitude, hydrograph shape, sediment augmentation efforts, changes in transport capacity (e.g. from channel and floodplain restoration) and tributary sediment contributions. Here, we examine potential trends in the coarse bedload (≥8mm) Spring Flow Release load totals from 2004 to 2019. Table 19 provides water year types, release volumes and peak flow magnitudes for WY2004-2019. In addition, Table 19 also provides the Spring Flow Release type (as described in the TRFE recommendations). In the previous years of sediment sampling, there have been four "Dry" type releases (2007, 2009, 2013, 2015), five "Normal" releases (2004, 2005, 2008, 2010, and 2012), and four "Extremely Wet" releases (2006, 2011, 2016 and 2017). The distinction between water year type and Spring Flow release type is important because there were some variations (e.g. 2011 was a Wet water year type, but had an Extremely Wet release, 2004 was a Wet year, but had a Normal Year release type). WY2019 was classified a Wet water year and had a modified Wet flow release type.

Table 19. Water Year Types, Restoration Release Volumes, Flow Release Type and Peak Flow Release Magnitudes: 2004-2019 (source: TRRP 2019)

Water Year	Forecast Water Year Type	Actual Restoration Release (acre feet)	Spring Flow Release Type	Peak Release Magnitude (cfs)*
2004	Wet	651,000	Normal	6,200
2005	Normal	647,600	Normal	6,970
2006	Ex. Wet	809,900	Ex Wet	10,100
2007	Dry	453,700	Dry	4,750
2008	Normal	648,700	Normal	6,470
2009	Dry	445,500	Dry	4,410
2010	Normal	656,700	Normal	6,840
2011	Wet	721,800	Ex wet	11,600
2012	Normal	647,100	Normal	6,080
2013	Dry	451,900	Dry	4,420
2014	Critically Dry	370,500	Crit. Dry	3,410
2015	Dry	450,700	Dry (modified)	8,500
2016	Wet	708,800	Ex Wet (modified)	10,000
2017	Ex. Wet	821,266	Ex Wet (modified)	12,000
2018	Critically Dry	377,072	Critically Dry	2,040
2019	Wet	703,093	Wet (modified)	10,800

**Mean daily discharge at Trinity River at Lewiston (USGS 11525500)*

Figures 41-44 compare the computed ≥8mm bedload at all stations for the 14 years of monitoring (10 years at TRGV). The ≥8mm component of bedload is of primary interest for creating beneficial channel and habitat characteristics (alternate bars, spawning riffles etc, TRRP 2011). Evaluating the ≥8mm component also removes much of the tributary influence, because the <8mm component is not included in gravel injections, and therefore it must be either delivered by tributaries or derived from in-channel sources, adjacent banks or hillslopes.

Other than water years 2006, 2011 and 2017, which clearly dominate the ≥8mm bedload transport at TRAL, 2019 had the highest ≥8mm transport (Figure 41). At TRGV, 2017 produced by far the largest load, more than twice the magnitude of the next highest year, 2006 (Figure 42). Water year 2019 at TRGV was slightly larger than 2008, a “Normal” water year, and sat between 2008 and 2011. At TRLG, 2019 had less bedload transport than 2004 and 2005 which were both “Normal” water years, and 2019 was very similar to 2008 (Figure 43). At TRDC, 2019 saw the most transport with the exception of the extremely wet water years (Figure 44).

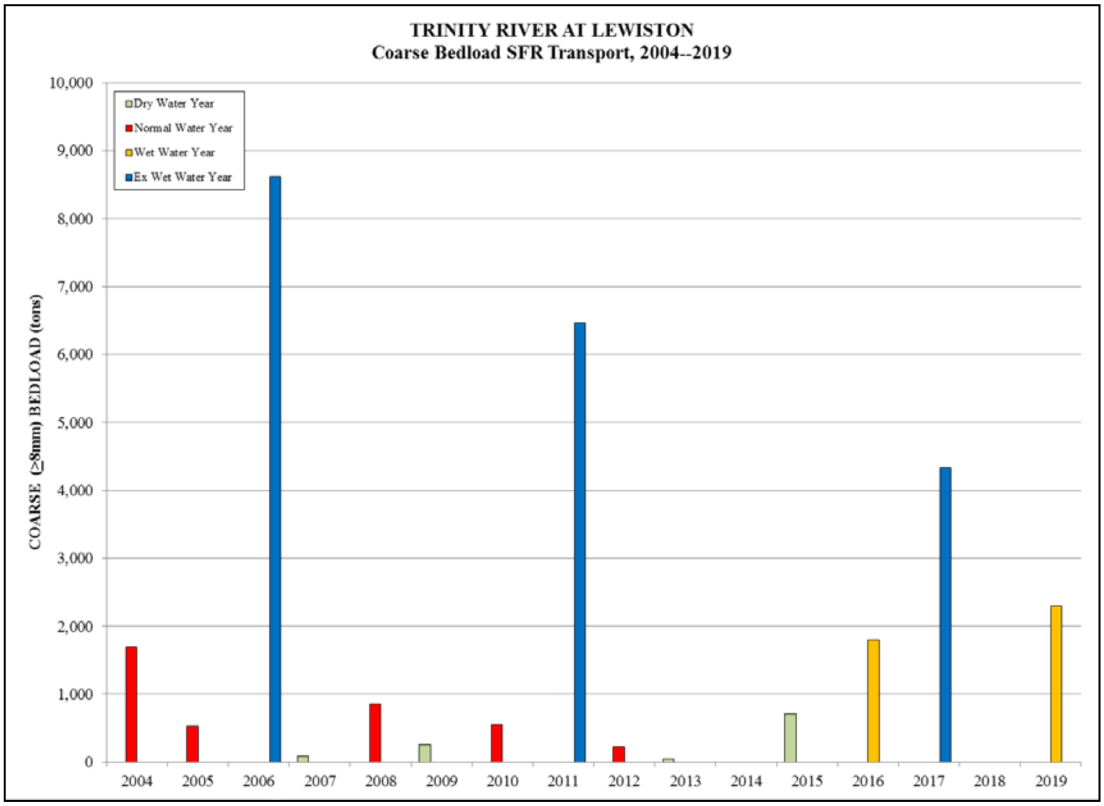


Figure 41. Trinity River at Lewiston, ≥8mm Bedload 2004-2019.

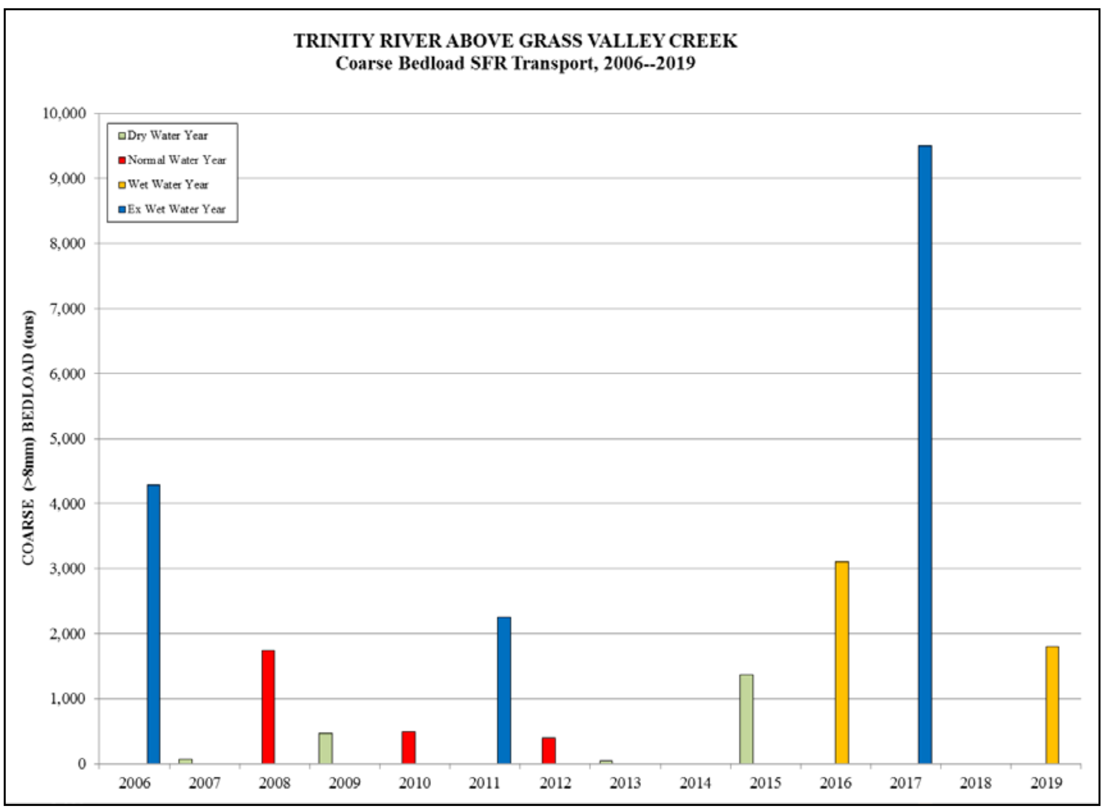


Figure 42. Trinity River above Grass Valley Creek, ≥8mm Bedload 2006-2019.

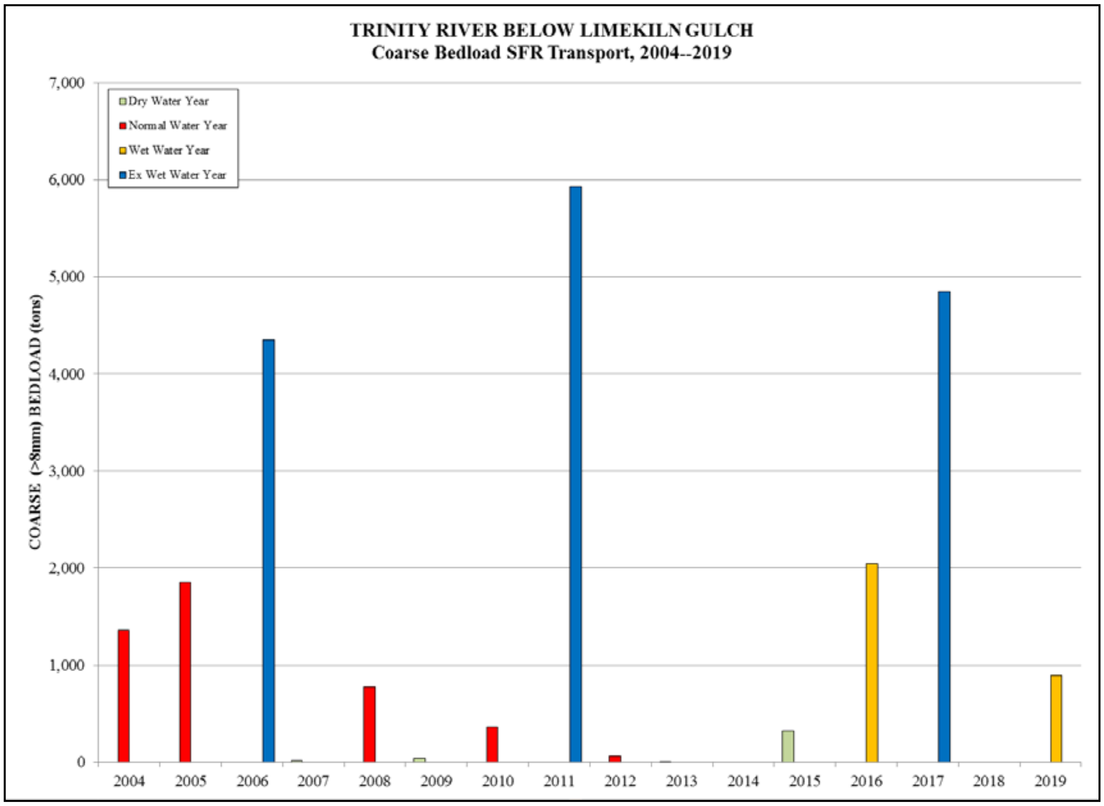


Figure 43. Trinity River below Limekiln Gulch, ≥8mm Bedload 2004-2019.

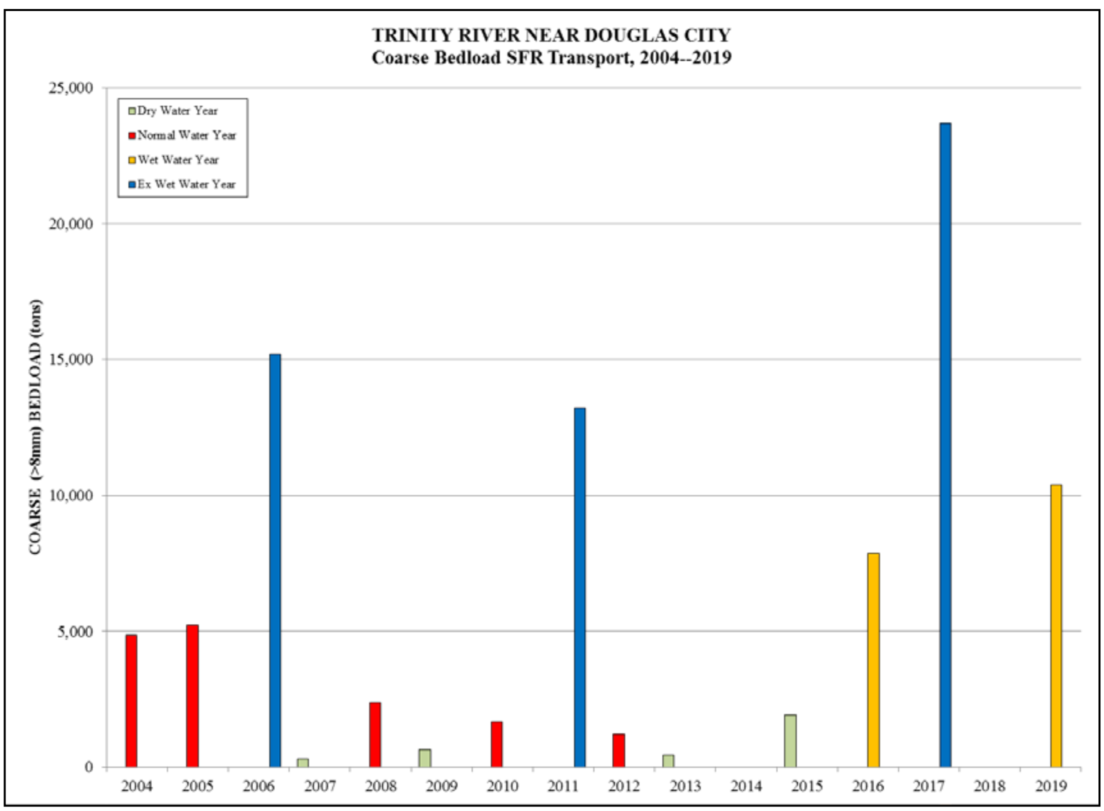


Figure 44. Trinity River below Limekiln Gulch, ≥8mm Bedload 2004-2019.

2.5.5 Changes in Sediment Transport Rate Over Time

This discussion is limited to the long-term mainstem monitoring stations used in the TRFE to predict the fine and coarse fractions of bedload transport: TRAL and TRLG.

2.5.4.1 Trinity River at Lewiston, CA

The total bedload transport rates for Water Years 1997 2002, 2004-2013, 2015-2017 and 2019 appear in Figure 10. The WY2019 data plotted within the overall cloud of points. Due to the wide range of variability within each year (e.g. WY2016 data spans a full order of magnitude at around 6,000 cfs), it is difficult to discern changes over time. Intra year comparisons are further compounded at TRAL by: changes in sampling location, the use of different types of samplers and winter storm samples lumped with flow release samples. The 2009 data sit to the left of most of the data, suggesting total bedload transport rates were higher in that year.

For the 0.5-<8mm bedload class (Figure 8), most of the 2019 samples fell to the right of the TRFE curve but a number of samples gravitated close to the line with a few falling on the left side of the TRFE curve. The ≥8mm bedload class (Figure 9) saw all of the 2019 samples fall to the right of the TRFE curve. This suggests that today's measured transport rates are lower than those used in the TRFE.

2.5.4.2 Trinity River below Limekiln Gulch

Partial and total bedload discharge data are available for TRLG during Water Years 1981-86, 1989-91, 1997, 2000, 2002-2014, 2015-2017 and 2019 (Figures 21-23). The WY 2019 ≥8mm data fall generally within the cloud of historic data points but sit to the right of the TRFE curve (Figure 22). The 0.5-<8mm class follows the same pattern and sit even further right of the TRFE curve at the highest flows (Figure 21). This suggests that today's measured transport rates are lower than those used in the TRFE.

2.5.6 Spatial and Temporal Variation in Bedload Discharge

Variation across a sampling section

We provide this description from 2006 in order to illustrate how bedload varies across a section and to illustrate how we choose high transport zones for the experiment described in the next section. In 2006, between May 25 and June 12, at flows in the 5,000-10,000 cfs range, GMA conducted a number of experiments at the TRDC station (GMA 2007). Bedload samples were collected at 11 sampling locations (stations) along the cross section and were processed separately to examine the variability in bedload transport across the section (Figure 45). Samples are typically composited. These data clearly indicate where most of the transport is occurring (station 75 and from 105-125). Note that while peak transport shifts among stations within the 105-125 range on different days, the peak always remains within this range. Figure 45 is intended to provide context for the next section, where samples are repeated at a high-transport location along a sampling section.

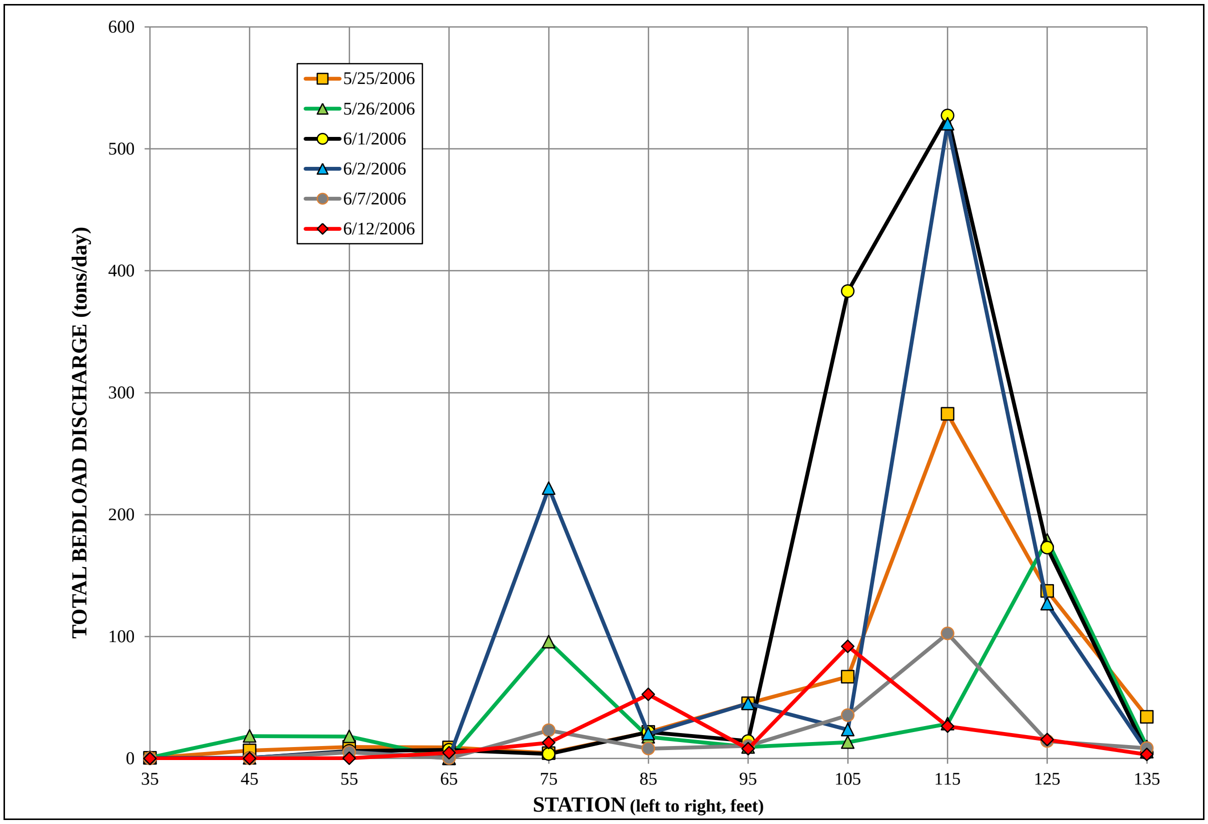


Figure 45. Spatial variation at a sampling section - total bedload discharge at TRDC in WY2006. Downstream view.

Bedload Sample Variation

In 2019 for the fourth year, GMA assessed the potential temporal variation in bedload measurements by sampling repeatedly at a single vertical over period of time. Crews were instructed to sample a high transport location on a high transport day. Down-times were held constant (e.g. 60 seconds) and since sample handling time was relatively constant, the method allowed for a systematic sample over the time period. Bedload discharge was computed over a 10 foot width, equivalent to a single computational cell in the SEWI computational method. Total bedload is the sum of the fine and coarse loads. Sample sizes are relatively small (n=3-6) and only very basic summary statistics were computed from the data (Table 20).

Table 20. 2019 Bedload Variability Sampling Summary

	TRAL			TRGV			TRLG			TRDC		
Sample	Total Transport Rate (tons/day)	Transport ≥ 8mm (tons/day)	Transport 0.5-8 mm (tons/day)	Total Transport Rate (tons/day)	Transport ≥ 8mm (tons/day)	Transport 0.5-8 mm (tons/day)	Total Transport Rate (tons/day)	Transport ≥ 8mm (tons/day)	Transport 0.5-8 mm (tons/day)	Total Transport Rate (tons/day)	Transport ≥ 8mm (tons/day)	Transport 0.5-8 mm (tons/day)
#1	354	274	80.1	175	152	23.0	104	66.1	38.3	57.0	24.3	32.7
#2	95.0	60.2	34.8	64.0	53.0	10.9	101	52.7	48.4	173	109	64.5
#3	227	199	27.2	9.8	7.00	2.77	109	58.2	51.3	134	105	29.4
#4							112	68.8	43.4			
#5							111	60.6	50.8			
#6							108	36.4	71.9			
mean	225	178	47.4	82.8	70.6	12.2	108	57.1	50.7	122	79.4	42.2
SD	129	108	28.6	84.0	73.9	10.2	4.27	11.6	11.5	59.3	47.8	19.4
min	95.0	60.2	27.2	9.8	7.00	2.77	101	36.4	38.3	57.0	24.3	29.4
max	354	274	80.1	175	152	23.0	112	68.8	71.9	173	109	64.5
range	259	214	52.9	165	145	20.2	11.0	32.4	33.7	116	84.7	35.0
Values are not rounded as per Porterfield 1972												

Figures 46-49 are provided as visual representation of WY 2019 bedload variability for individual stations (sites) within the study and Figure 50 portrays all four stations together.

At TRAL, the fine bedload varied over a range of 52.9 tons per day while the coarse load varied over a range of 214 tons per day (Table 20). The relative contribution of the fine bedload ranges from 12 to 37 percent.

At TRGV, the fine bedload varied over a range of 20.2 tons per day while the coarse load varied over a range of 145 tons per day (Table 20). The relative contribution of the fine bedload ranges from 15 to 40 percent. TRGV shows the highest average coarse percentage at 87%.

Unlike at TRAL and TRGV, TRLG reveals heterogeneity in the relative contribution of fine and coarse bedload. The relative contribution of fine bedload ranges from 37 to 66 percent and the coarse bedload ranges from 34 to 63 percent. The fluctuation of both fine and coarse bedload from mid-30% to mid-60% illustrates the variability a bedload sample may contain. An interesting feature of the TRLG variability study is that the total transport range (11 tons/day) has very little variability (Table 20).

At TRDC, the fine bedload varied over a range of 35.0 tons per day while the coarse load varied over a range of 84.7 tons per day (Table 20). The total transport rate has a range of 116 tons/day. The relative contribution of the fine bedload ranges from 22 to 57 percent. The total transport range at TRDC is more typical with a 116 tons/day fluctuation between the three samples.

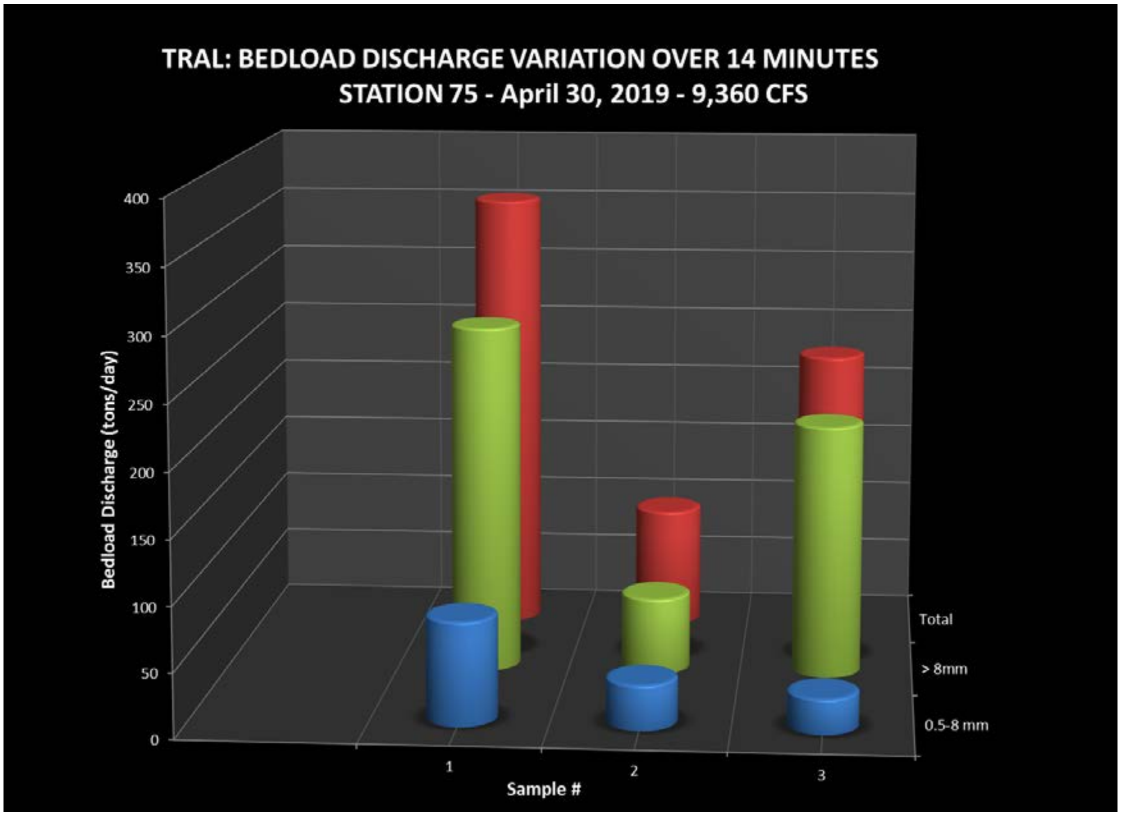


Figure 46. Bedload discharge at TRAL over 14 minutes at 90 second downtimes.

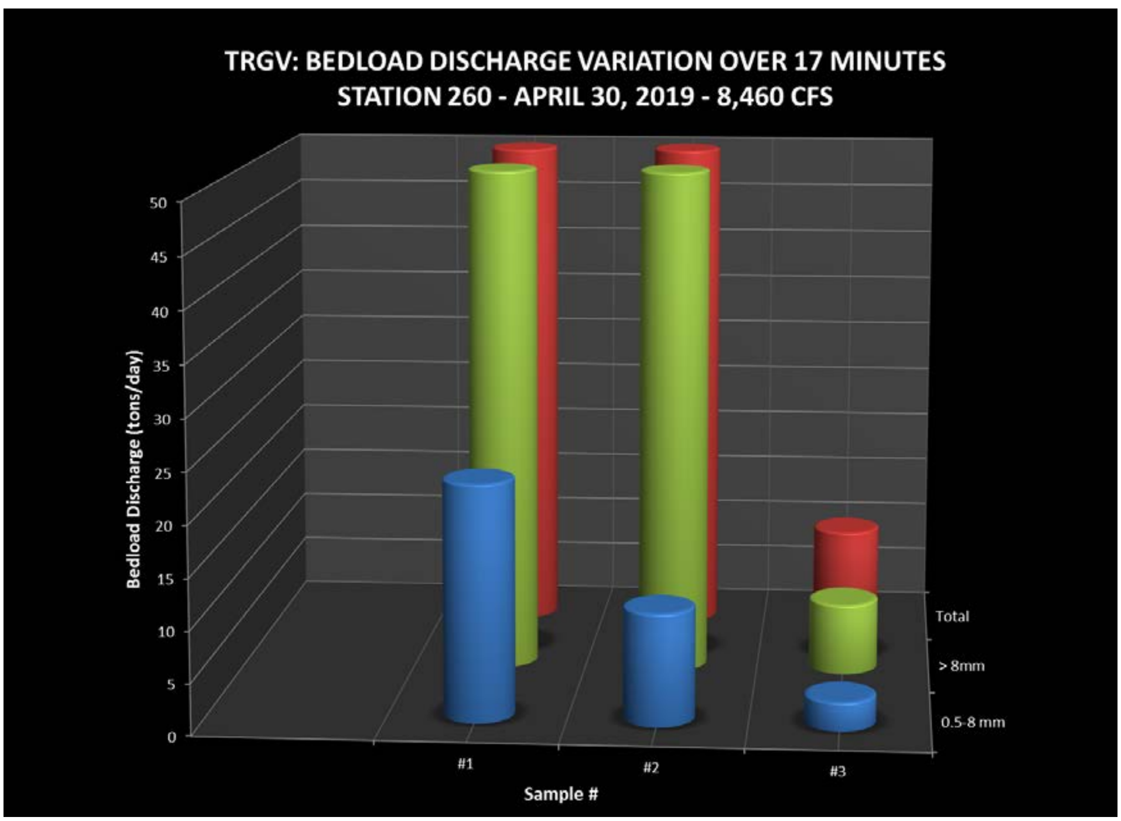


Figure 47. Bedload discharge at TRGV over 17 minutes at 120 second downtimes.

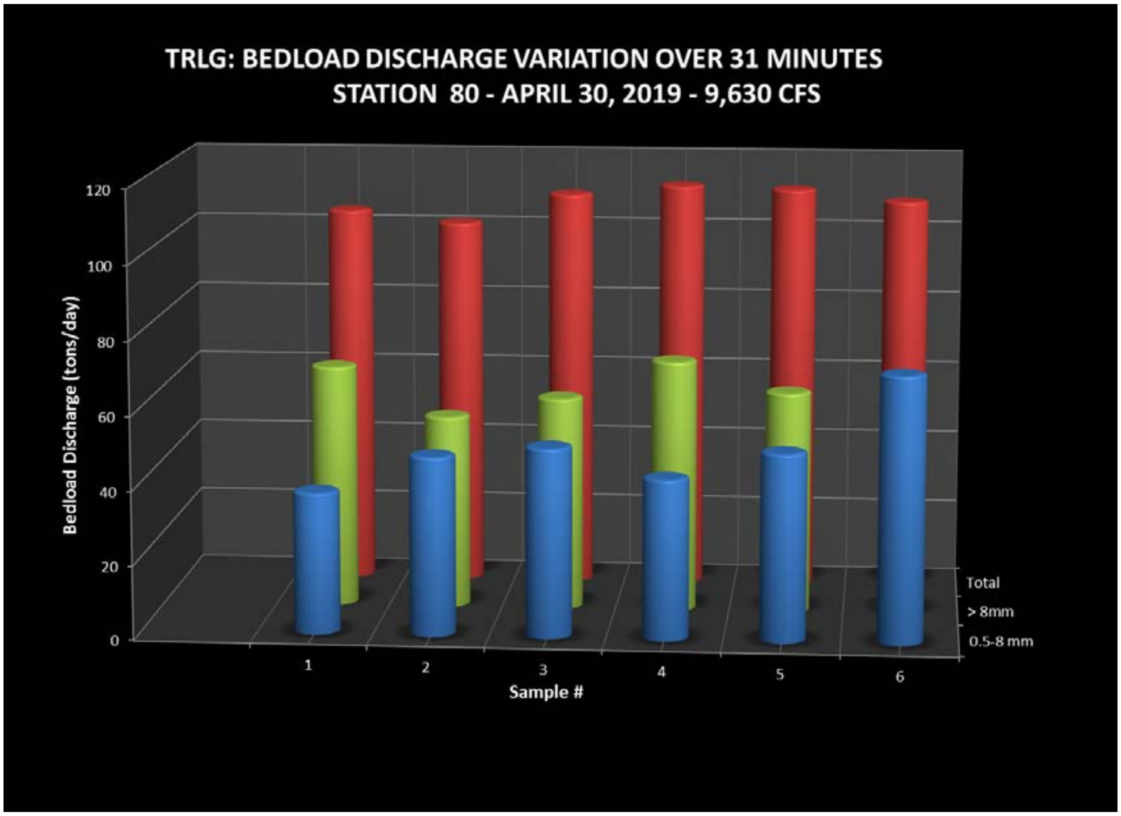


Figure 48. Bedload discharge at TRLG over 31 minutes at 180 second downtimes.

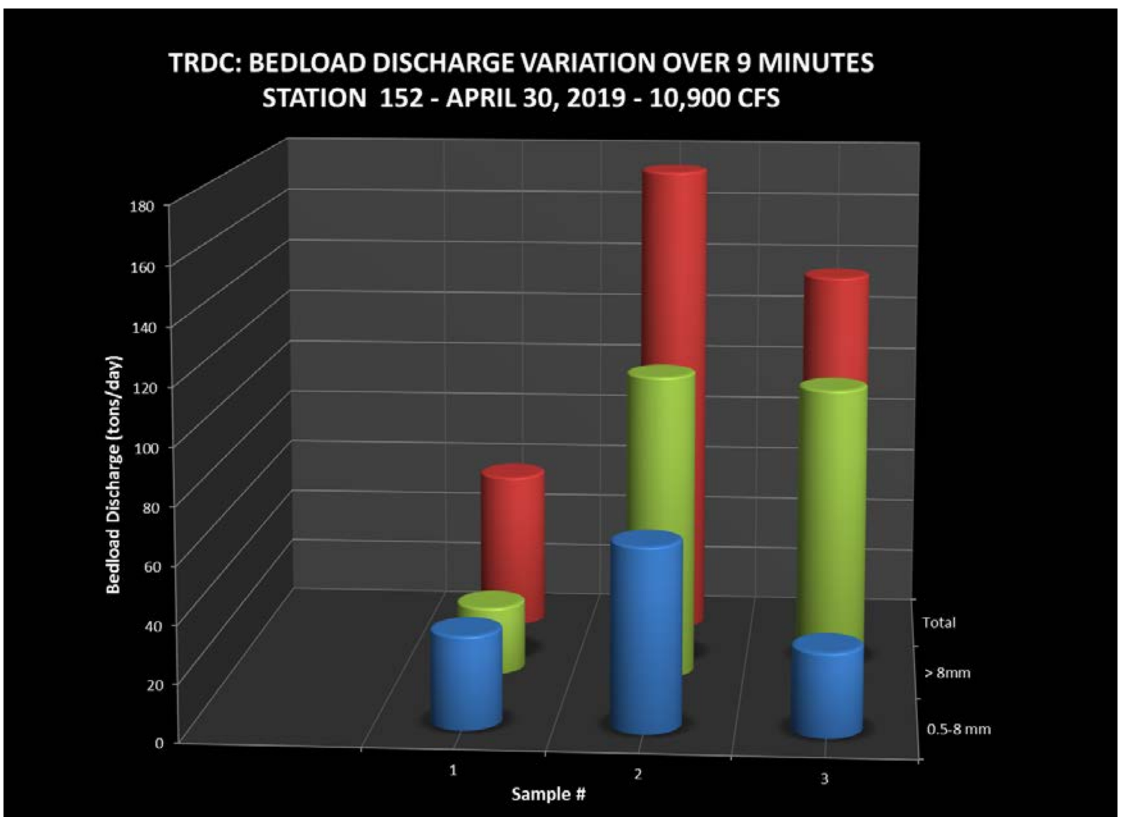


Figure 49. Bedload discharge at TRDC over 9 minutes at 60 second downtimes.

Since TRAL is starved of fines (located so close to the dam) and since both TRAL and TRGV are so strongly influenced by coarse-gravel injection, TRLG and TRDC results are likely more representative of temporal variability in magnitude and composition of bedload transport in the Trinity River. While all sites are highly variable, TRAL demonstrated the greatest range in 2019 total bedload discharge (Figure 50).

WY2019 crews reported most of the sediment load is typically generated at one to three stations. If we apply the 2006 spatial inference (most of the load is transported at 3 to 4 stations) to the bedload variability study, then we can assume that at TRDC, a full cross section total load computed from data collected on 6/1 will differ greatly (>80 percent) from a load computed from on 6/7 (Figure 45).

While the variability study data are far from conclusive, they do suggest a need for more sampling at fewer stations (i.e., over a narrower width of the cross section where the most sediment is being transported) in order to derive a more accurate estimate of average bedload discharge. These data also support the need for a better surrogate than discharge such as passive hydroacoustics. The 2019 findings from the USGS (and other researchers who deployed hydrophones during the Spring Flow Release) will be highly relevant for improving future monitoring efforts.

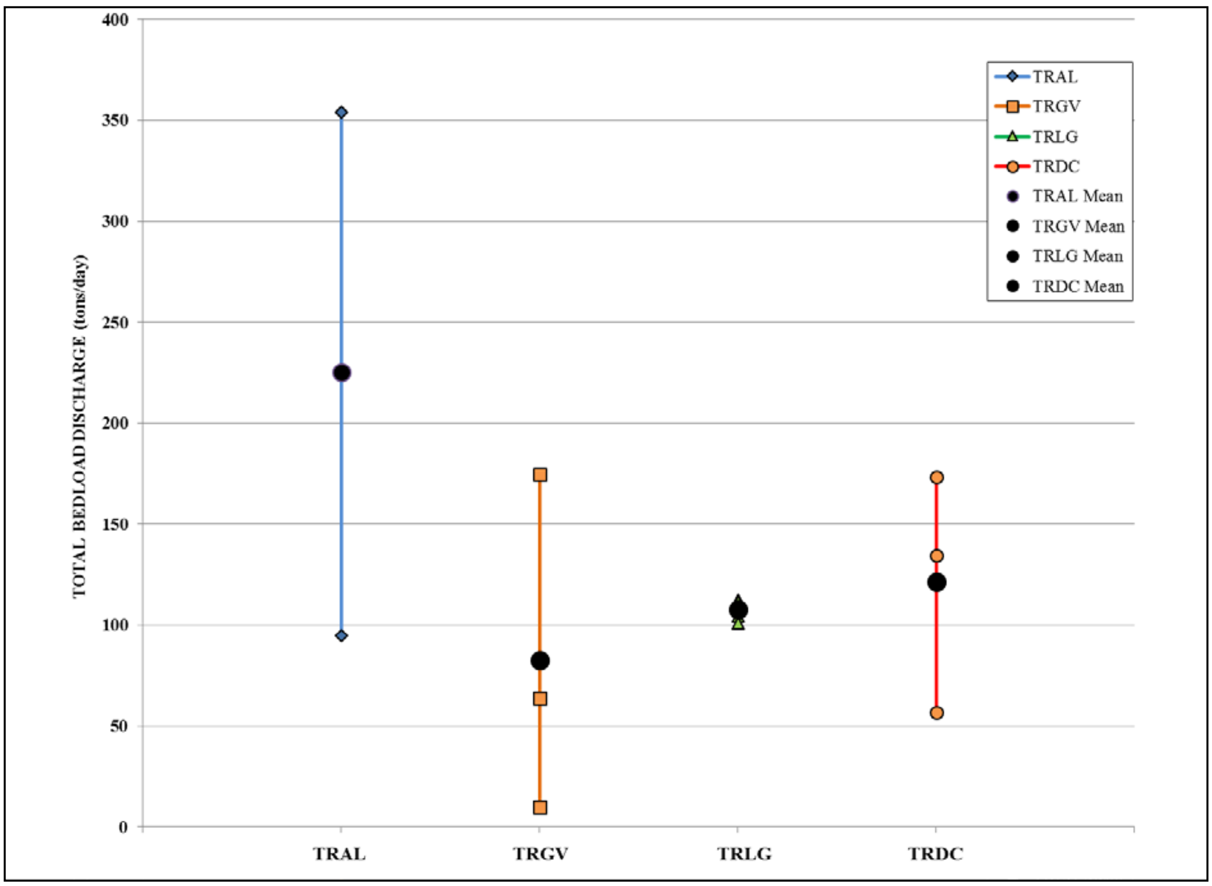


Figure 50. Total bedload discharge (range and mean values) during the variability pilot study at the four Trinity River sampling locations.

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