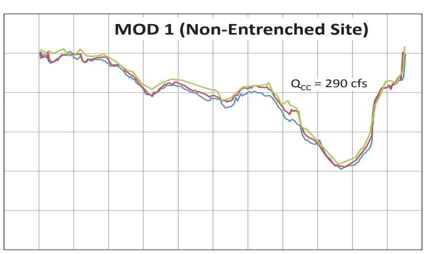
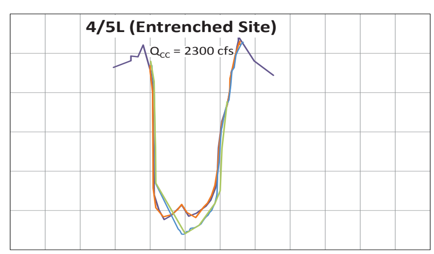
TECHNICAL REPORT

Methodology to Predict Fine Sediment Load Reductions as a Result of Floodplain Inundation in Lake Tahoe Streams

Upper Truckee River, California
Submitted to the USFS Lake Tahoe Basin Management Unit

February 2011





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The Upper Truckee River Fine Sediment Monitoring Technical Report has been developed by:

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LIST OF VARIABLES

ΔFSP	FSP Load Reduction resulting from Stream Restoration (MT)
$FSP(Q)$	FSP Concentration (mg/L) as a Function of Discharge
Q	Instantaneous Upper Truckee River Discharge (cfs)
Q_{CC}	Channel Capacity Discharge (cfs)
Q_{fp}	Instantaneous Floodplain Discharge (cfs)
Q_s	FSP Loading Rate (kg/s)
R_{FSP}	FSP Floodplain Retention Coefficient
S_{fp}	FSP Load Delivered to the Floodplain (MT)
S_{FSP}	Retained FSP Floodplain Load (MT)
$S_{FSP(post)}$	Post-Restoration Floodplain FSP Retention (MT)
$S_{FSP(post)}$	Pre-Restoration Floodplain FSP Retention (MT)
t	Time
V_{fp}	Inundated Floodplain Water Volume (ac-ft)
ΔFSP	FSP Load Reduction resulting from Stream Restoration (MT)

LIST OF ACRONYMS

FSP	Fine Sediment Particles (< 16μm)
SLRT	Stream Load Reduction Tool
TERC	Tahoe Environmental Research Center
TMDL	Total Maximum Daily Load
TSS	Total Suspended Sediment
UTR	Upper Truckee River

EXECUTIVE SUMMARY

Resource managers need tools to quantify the water quality benefits of stream environment zone (SEZ) restoration efforts in a manner comparable to and consistent with the stormwater quality load reduction tools that have been developed to support the Lake Tahoe TMDL (LRWQCB and NDEP 2010) and Lake Clarity Crediting Program (LRWQCB and NDEP 2009). It is assumed that SEZ restoration actions that increase the frequency and duration of overbank flow events may result in substantial removal of the pollutants of concern, particularly fine sediment particles (FSP <16 µm), yet to date an accepted method for estimation and supporting data do not exist. The research herein provides a cost-effective data collection and analysis technique that quantifies the fine sediment particle load reductions as a result of floodplain inundation, and this analysis shows that stream restoration is a potentially significant FSP load reduction opportunity.

Two stream reaches on the Upper Truckee River (UTR) were instrumented and monitored to obtain continuous site-specific hydrology, in-stream FSP vertical profiles, and floodplain FSP deposition for three consecutive snowmelt events (WY08-WY10). Overbank flow occurred in 2009 and 2010 at the non-entrenched (MOD1) site, which has a channel capacity (Q_{CC}) of 290 cfs. In contrast, at the entrenched site (4/5L) located 0.5 miles downstream of MOD1, the channel capacity (Q_{CC}= 2,300 cfs) was not exceeded by the peak discharge during the study, a 10-yr event (Q= 1,120 cfs on June 7 2010). Vertical profile sampling of in-stream FSP concentrations at both sites indicated a consistently well-mixed water column for the discharge range sampled. The average % of TSS finer than 16 µm of the in-stream samples collected when discharge (Q) was greater than 100 cfs was 40% (*n*= 134). The in-stream FSP data and site hydrology was used to calculate FSP loads delivered to the MOD1 floodplain (S_{fp}) of 29.3 MT and 120 MT in spring 2009 and 2010, respectively. The research team applied the FSP concentration data obtained from passive samplers deployed along the upper and lower boundary of the MOD1 floodplain to estimate an FSP retention coefficient (R_{FSP}) of 0.7 and an estimated FSP mass retained on the floodplain (S_{FSP}) at MOD1 of 20.5 MT and 84.0 MT as a result of the 2009 and 2010 spring snowmelt floods, respectively.

At the time of this report, California State Parks is completing the design and planning process to restore portions of the Upper Truckee River, including the entrenched 4/5L reach to an estimated restored channel capacity (Q_{CC}) of 525 cfs. Assuming that site 4/5L had been restored prior to 2009, the estimated FSP load reduction as a result of restoration (ΔFSP) is estimated to be 0.8 MT and 36.5 MT for spring snowmelts 2009 and 2010, respectively. A precipitation frequency analysis suggests WY09 and WY10 were average total precipitation years, yielding an estimated average annual FSP load reduction due to increased floodplain retention of 18 MT/yr, or 2.1 x 10^{18} particles/yr, if the 4/5L restoration plans are implemented.

This research provides evidence that FSP retention by floodplains does occur and may provide a significant FSP load reduction during overbank flow events. However, the load reduction estimates provided herein are not yet directly comparable to an estimate of load reductions achievable by stream restoration for Tahoe streams. The data from one floodplain over 3 water years is limited in both its spatial and temporal resolution; however it is a site-specific and representative dataset, which is very challenging to obtain given the infrequency of overbank flow events. This research only addressed the FSP retained on the floodplain, and does not include the expected FSP load reduction associated with reduced channel erosion. There are a number of critical components yet to be resolved, but the knowledge gained and lessons learned from this research will be applied to the continued development of a Stream Load Reduction Tool (SLRT; 2NDNATUE 2010a) by the 2NDNATURE team. Upcoming research will explore methods to integrate both site-specific and readily available regional data with critical geomorphic and FSP fate and transport principles and to provide resource managers with a reasonable approach to consistently predict the FSP load reduction expected from stream restoration actions in the Tahoe Basin.

RESEARCH OVERVIEW

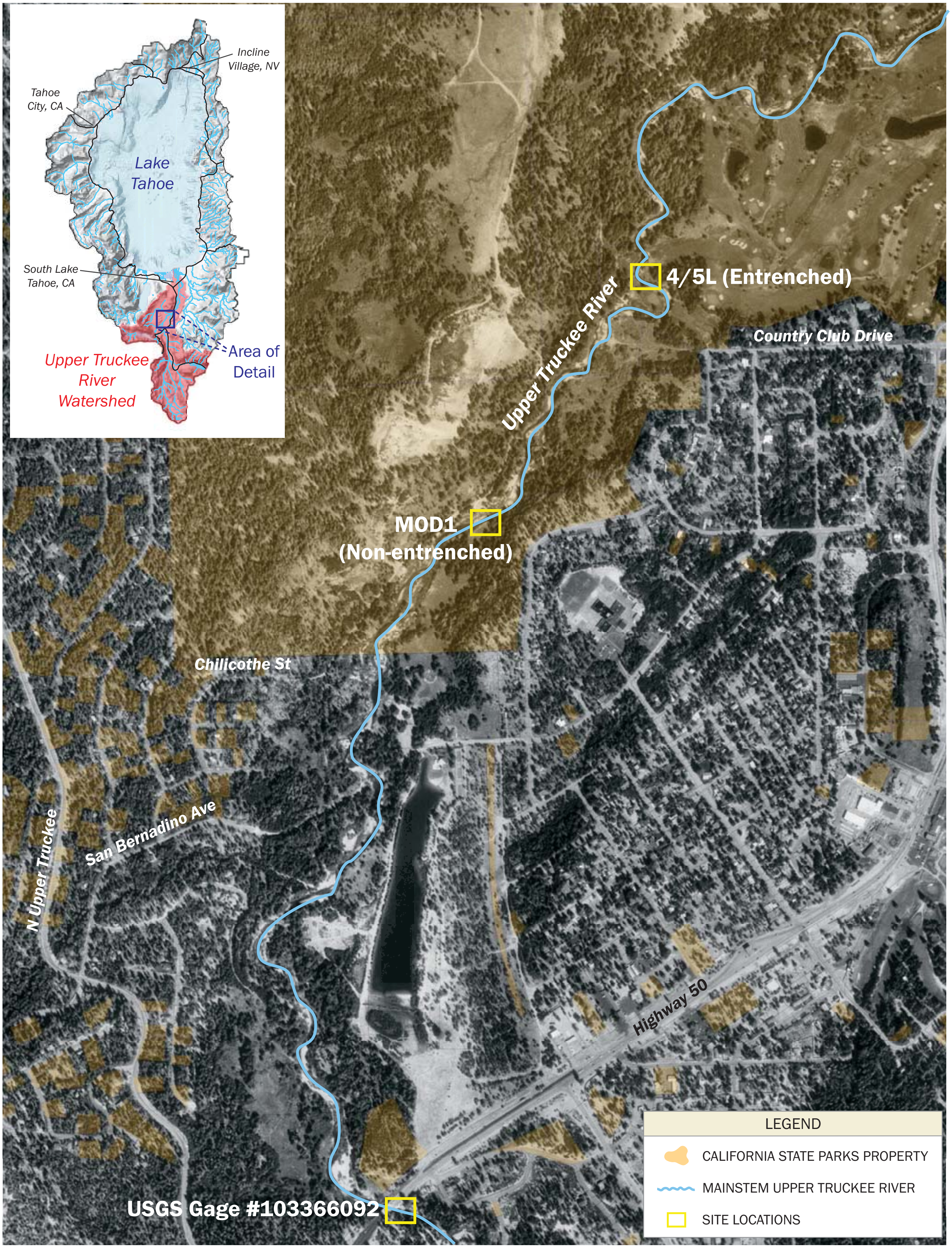
The *Methodology to Predict Fine Sediment Load Reductions as a Result of Floodplain Inundation in Lake Tahoe Streams* was funded by USFS SNPLMA Round 7 grant funds with a contract awarded to the 2NDNATURE team in November 2007. Dr. Catherine Riihimaki of Drew University is a valued partner and provided critical technical assistance throughout this research. The main goal of this research was to develop, verify and document data collection and data analysis protocols to quantify and predict the water quality improvement (i.e., sediment load reductions) as a result of stream restoration projects.

Specifically, the following initial objectives were defined to meet the project goal:

> *Objective 1.* Implement and evaluate cost-effective, robust and repeatable field techniques to compare the vertical and horizontal sediment load and grain size distribution within two existing stream reaches with differing width-to-depth ratios and floodplain connectivity.
>
> Objective 2. Utilize the site-specific hydrologic, morphologic and sediment data to identify simple data analysis techniques to quantify and predict the suspended sediment and fine-sediment particle (FSP <16 μm) loads[1] at two geomorphically different sites. This data can be used to evaluate the results of restoration efforts that increase the frequency and duration of floodplain interactions in Tahoe Basin streams.
>
> *Objective 3.* Provide empirical data and additional insight on improving the CONCEPTS or other empirical models' representation of the fate and transport of total suspended and fine-grained sediment loads in Lake Tahoe streams.

2NDNATURE, in collaboration with the California Department of State Parks, selected two sites within the Middle Reach of the Upper Truckee River (UTR) (Figure 1) to compare the floodplain dynamics at locations with entrenched and non-entrenched channel geometry. Evaluations were conducted concurrently at both sites between spring 2008 and spring 2010 over a range of 17 different stream discharge conditions. The original research schedule included data collection for two consecutive spring snowmelts (2008 and 2009). At significant cost to the project, the sites were instrumented and maintained in preparation for a number of potential overbank events, yet targeted events did not result in significant floodplain inundation. The research team decided to stretch the limited remaining resources and apply small contributions from a Round 9 SNPLMA grant award (*Quantification and Characterization of Trout Creek Restoration Effectiveness; Focused Development of a Stream Load Reduction Methodology (SLRT)*) to extend monitoring efforts

[1] Total suspended sediment (TSS) data is also available, but given the focus on FSP load reductions in Tahoe while this research was being conducted, the data analysis within this final report focuses on the Lake Tahoe TMDL primary pollutant of concern (LRWQCB and NDEP 2010).



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PROJECT LOCATION MAP

FIGURE 1

through the spring 2010. The majority of the valuable data was obtained from the 2010 snowmelt event.

This technical report summarizes the data collection and analysis methods, as well as provides a simple initial estimate of the FSP load reduction benefit for the Upper Truckee River golf course reach (site 4/5 L) where restoration actions are currently planned. However, due to the lack of resources remaining under this Round 7 research effort, the application of the data obtained from the Upper Truckee River to provide a standardized methodology and detailed guidance to quantify the water quality benefit of stream restoration in the Tahoe Basin (Objective 3 above) will be incorporated into the Round 9 final technical report to be released in 2012, following additional data collection and model development efforts.

DATA COLLECTION METHODS

2NDNATURE developed a detailed monitoring plan in preparation for this research, including research rationale, instrumentation selection, and field data collection protocols. Please see the Final Data Collection Sampling Plan for complete details (available for download at http://www.fs.fed.us/psw/partnerships/tahoescience/stream_sediment.shtml). Below we provide a brief summary for context when reviewing the data analysis results.

SITE SELECTION

The research team selected two reaches (1 entrenched, 1 non-entrenched) of the UTR on State Parks property that vary in floodplain connectivity while constraining as many other variables (hydrology, weather, watershed sediment loading, etc) influencing sediment transport dynamics as possible. The two sites selected, MOD1 (non-entrenched channel) and 4/5L (entrenched channel), are within 0.5 miles of each other to ensure discharge is nearly constant and sampling of both sites could occur within hours during specific discharge events (see Figure 1).

SITE INSTRUMENTATION

The instrumentation installed for this research at each of the two sites is provided in Table 1 and shown in Figures 2-3. The following provides the general concepts of the data collection techniques:

- Water Level Recorders (WLR) were installed to obtain continuous water surface elevations at the specific stream reaches. An In-Situ Level Troll 500 collected continuous (15-minute interval) stage data at each site to monitor the site hydrology. Staff plates were installed concurrently for data QA/QC, and an In-Situ BaroTroll was installed at the entrenched site to correct the unvented model for changes in barometric pressure. All instrument elevations were surveyed using existing State Parks benchmarks to translate stage data to water surface elevation. Water surface elevation data was correlated to the USGS

Table 1. Research Instrumentation Summary

Equipment	Purpose	# at MOD 1 (Non-entrenched)	# at 4/5L (Entrenched)	Install Date	Maintenance Frequency	Notes
In-Situ LevelTroll 500 (WLR)	Site-specific hydrology	1	1	MOD1: Existing State Parks gage 4/5L: 10/18/07	Every 4 months (battery check; data download; housing check)	Records on 15-minute intervals. Corrected for barometric pressure. Correlated to discharge measured at USGS #103366092.
Staff Plate	Verify In-Situ gage readings	1	1	10/18/07	Every 4 months (data QA/QC; housing check)	Used to visually verify and QA/QC the WLR readings.
In-Situ Barotroll	Barometric pressure changes	0	1	10/18/07	Every 4 months (battery check; data download; housing check)	Used to correct unvented WLR for changes in atmospheric pressure.
Vertical Profile Sediment Samplers (VPS)	In-stream vertical water sample collection	1 VPS holds 4 samplers	1 VPS holds 4 samplers	Spring 2008	Every Spring (equipment check)	Surface water sample is taken simultaneously resulting in 5 vertical points. Data analysis includes vertical grain-size distribution and TSS.
Floodplain Passive Samplers (PS)	Floodplain water sample collection	13 (8 at grade, 5 hanging)	1 (at grade)	12/13/07	Every Event (housing and supply check; bottle deployment/collection)	Water sample analysis includes grain-size distribution and TSS.
Sediment Pins (PIN)	Sediment deposition during overbank flow	18	1	4/29/08	Every Spring / Fall (equipment check)	Sediment accumulation measured over time.
Cross Sections (XS)	Channel morphology changes, intrument placement	2	1	12/13/07	Every Summer (monument check)	Data analysis includes changes in channel geometry over time.

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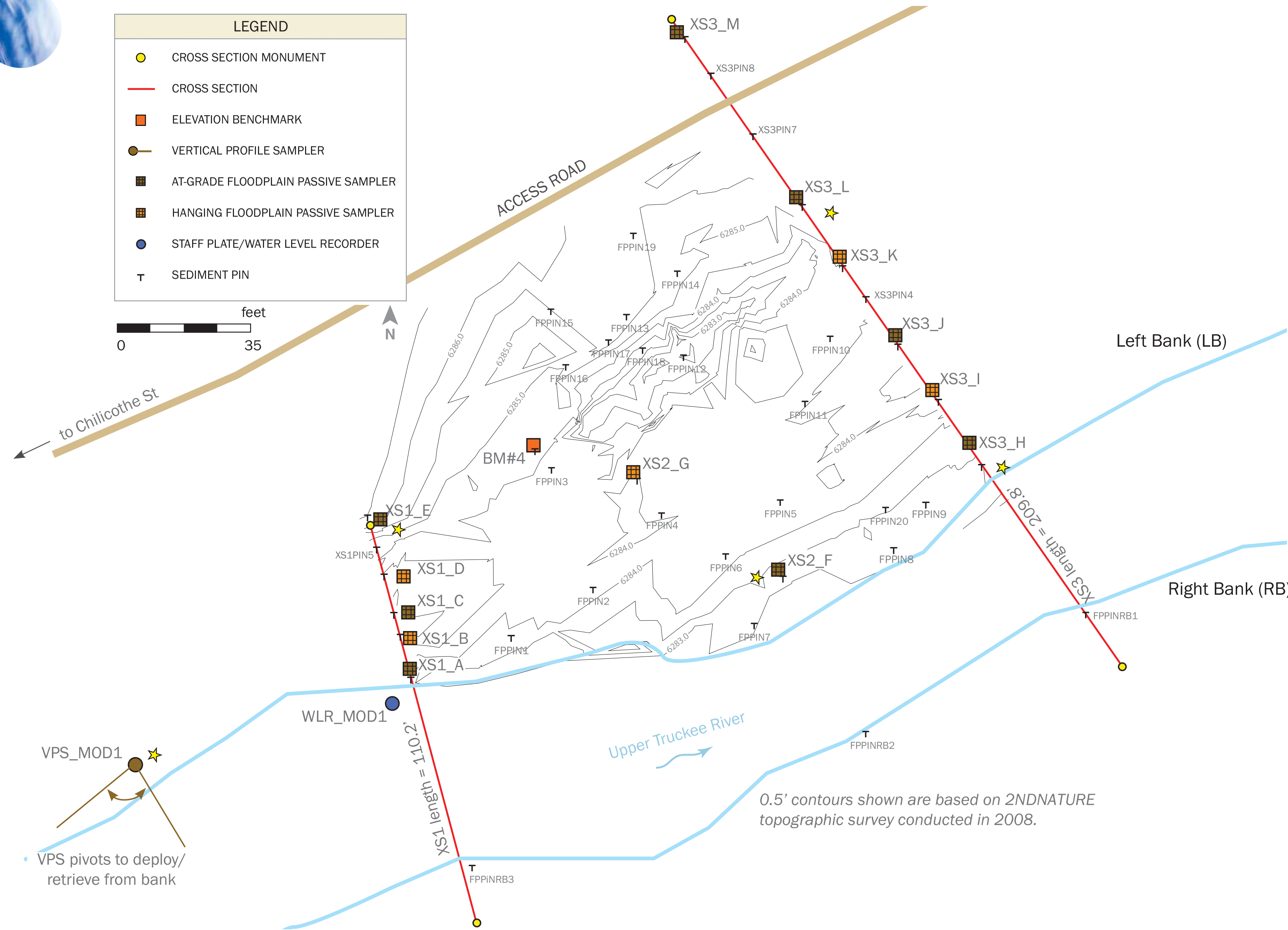
SITE MOD1 (NON-ENTRENCHED)



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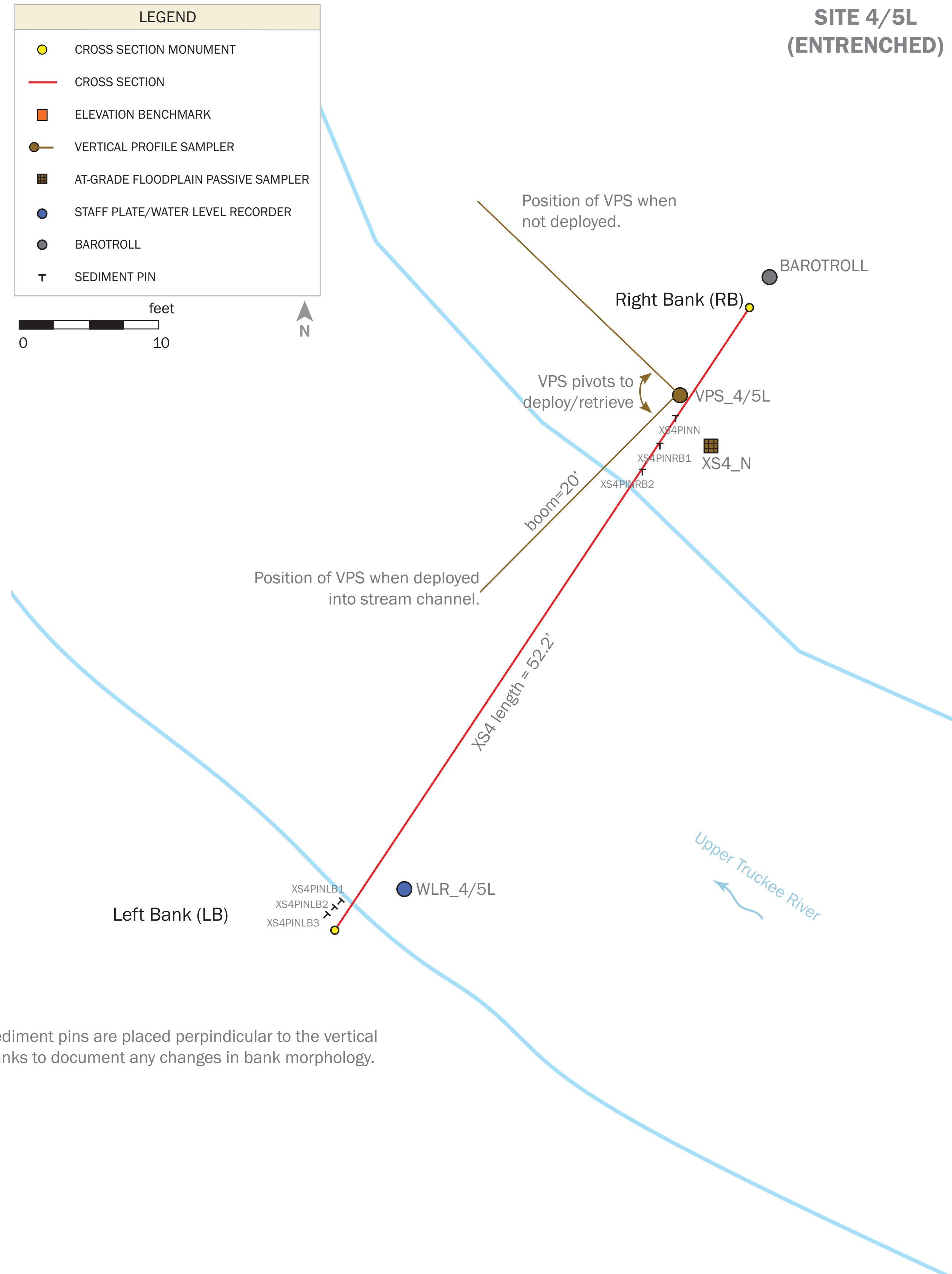
MOD1 (NON-ENTRENCHED) SITE SCHEMATIC

FIGURE 2



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4/5L (ENTRENCHED) SITE SCHEMATIC

FIGURE 3

streamflow gage (#103366092, Upper Truckee River at Highway 50 above Meyers, CA) to calculate the continuous stream discharge at each site.

- A Vertical Profile Sediment Sampler (VPS) was installed at each site and used to determine if FSP vertical distribution in the water column has any pattern or variability that may inform restoration design to maximize FSP floodplain delivery. Using a custom-built stainless steel boom (see photo on right), vertical profile sampling was conducted at evenly spaced intervals in the water column. During a monitoring event, four samples were collected using the boom and one grab sample was collected concurrently from the surface water.
- Custom-built floodplain Passive Samplers (PS) were installed at grade (see sampler in foreground of photo on right) and surveyed throughout the floodplain at MOD1 to collect samples at the onset of floodplain inundation to determine the sediment distribution in initial overbank flow. Passive samplers were also installed hanging at known elevations above the floodplain surface (see sampler in background of photo on right) to collect samples as the overbank flow continues and the floodplain is inundated to a greater depth. One passive sampler was installed at site 4/5L.

Vertical Profile Sediment Sampler

Passive samplers set at grade (forefront) and hanging at known elevation (background).

- Twelve-inch steel Sediment Pins (PIN) were installed throughout the floodplain surface as a cost-effective technique to calculate the volume of sediment deposition on the floodplain during an event. The elevations and locations of all pinheads were surveyed and measurements were taken from the top of the pin to the ground surface before and after flood events to measure sediment accumulation or degradation.
- Annual Cross-Section Surveys were conducted at both monitoring sites to document changes in channel and floodplain geometry following springtime snowmelt and floodplain inundation.

All water samples collected from either the VPS or PS units were collected and submitted for analysis following proper sample handling protocols detailed in the Sampling Plan. In 2008, samples were submitted to the Tahoe Environmental Research Center (TERC) laboratory for TSS concentration and particle size distribution. TERC provided the grain size distribution as # of particles to maintain consistency with the Tahoe Basin TMDL. However, the comparison of the sample particle counts (converted to mass per volume) to TSS concentrations was inconsistent (total concentrations based on particle analysis ranged from 10 to 159% of the TSS concentration provided by lab), and therefore could not be reliably used to calculate FSP concentration (mg/L) for the 2008 dataset. The 2009 and 2010 samples were submitted to Western Environmental Testing Laboratory (WETLAB) for TSS (mg/L) and grain size distribution (% TSS less than 1µm, 10µm, 16µm, 20µm, 63µm, 100µm by mass). FSP concentrations (mg/L) were calculated for each sample by multiplying the TSS concentration by the % TSS <16 µm. In spring 2010, all samples were also analyzed in the field for turbidity using a Hach 2100P portable turbidimeter.

DATA COLLECTION RESULTS

CHANNEL MORPHOLOGY

The results of cross section surveys conducted by State Parks and 2NDNATURE personnel from 2001-2010 are shown in Figure 4. There is some indication of sediment accumulation on the floodplain at the downstream end of the non-entrenched site, but generally little change in the cross-sectional geometry of the sites has been observed over the past 10 years.

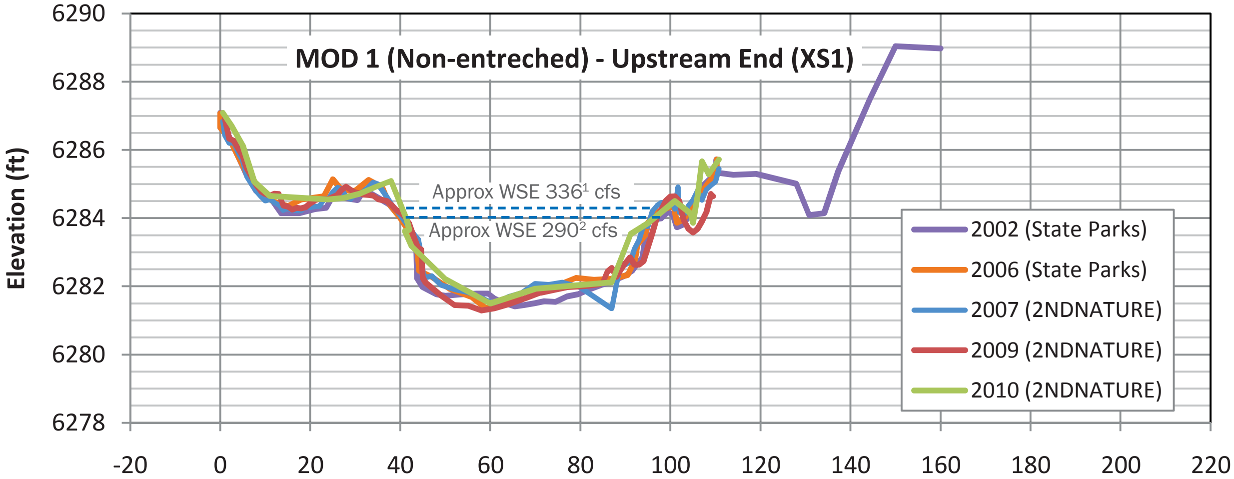
SH+G (2004) conducted a partial duration flood frequency analysis and estimated the bankfull discharge of the upper reach of the Upper Truckee River to be 336 cfs. The water surface elevation of the channel capacity for each reach is indicated on Figure 4 and the channel capacity is estimated to be 290 cfs at MOD1 and 2,300 cfs at 4/5L based on existing channel cross sections. The entrenchment ratio expresses the relative vertical containment of a stream channel; the lower the entrenchment ratio, the less frequently the floodplain is inundated. Site 4/5L has a very low entrenchment ratio of 1.1, which indicates that the channel width at both bankfull depth and 2 times bankfull depth are nearly the same and at flows equivalent to 2 times bankfull depth (~ 1800 cfs) water will still not get out of bank. In contrast, site MOD1 has an entrenchment ratio of 7.4 and will experience more frequent and longer floodplain inundation than the entrenched site, as observed over the duration of the study.

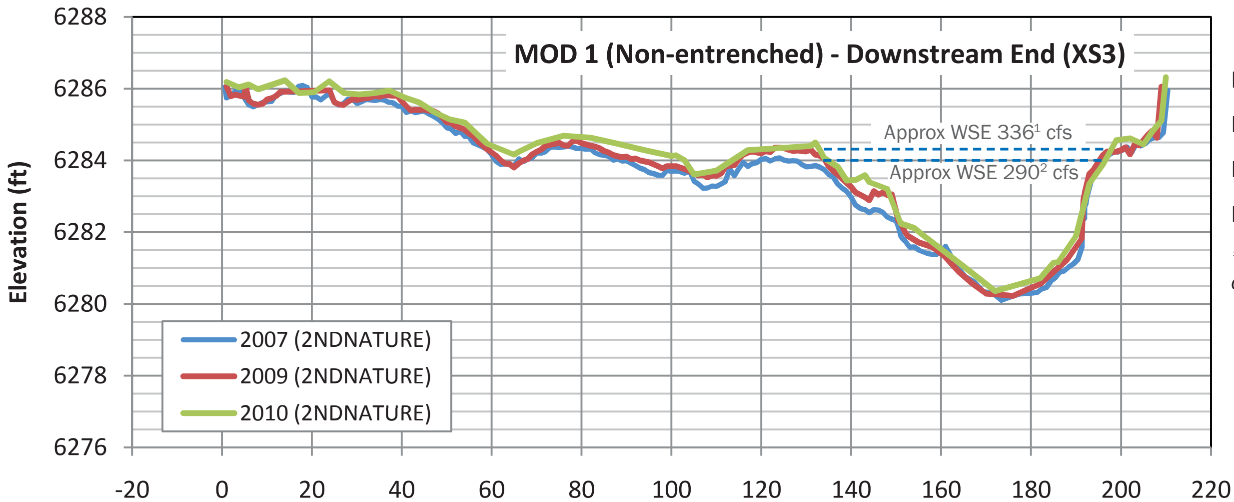
METEOROLOGY & HYDROLOGY

Figure 5 summarizes the key meteorological parameters for the three water years monitored. The precipitation, air temperature and snowpack data were obtained from the Echo Peak SNOTEL monitoring site (gage # 463; http://www.wcc.nrcs.usda.gov/snotel/California/california.html). Of the available data, this gage best represents the upper watershed meteorological conditions that have a strong influence on the hydrology observed at the research site.

The climatic differences between water years have a direct impact on the resulting UTR hydrology observed during the study. Providing climatic context for the monitored years assists the research team with interpretation of these results and will assist researchers with comparisons of these data to future water year observations. The Tahoe City gage, operated by Western Regional Climate Center (WRCC) (http://www.wrcc.dri.edu/), provides the longest period of record for climate data in the Tahoe Basin. A precipitation frequency analysis was conducted on the 100 years of Tahoe City precipitation data to

CHANNEL CROSS SECTIONS





MOD 1*

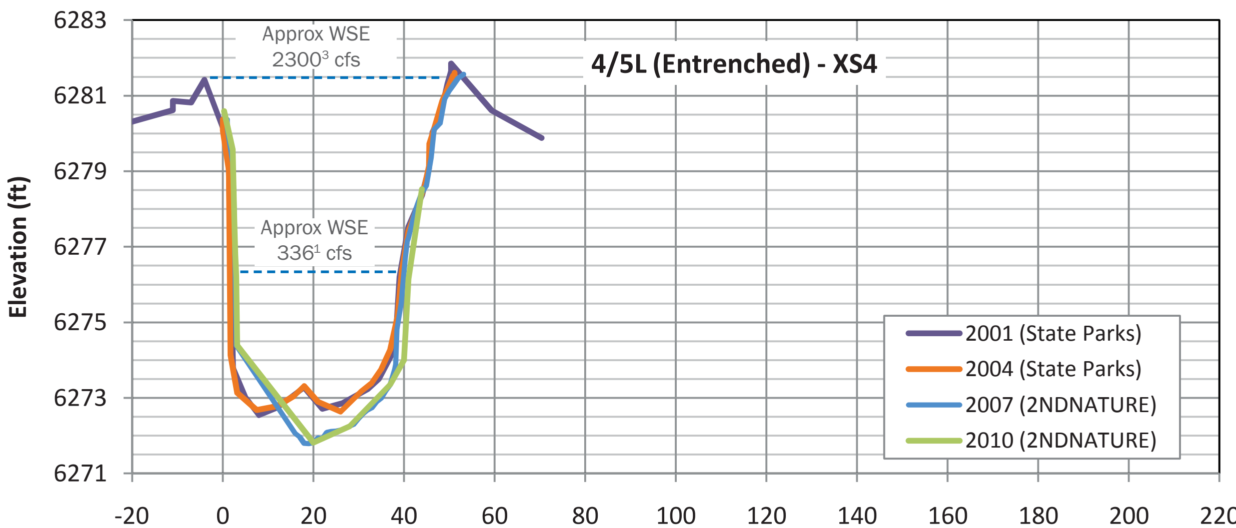
Bankfull[1] Depth = ~4.2'

Bankfull Width = ~68'

Floodprone Width = ~500'

Entrenchment Ratio = 7.4

**estimates based on downstream cross section*



4/5L

Bankfull[1] Depth = ~4.0'

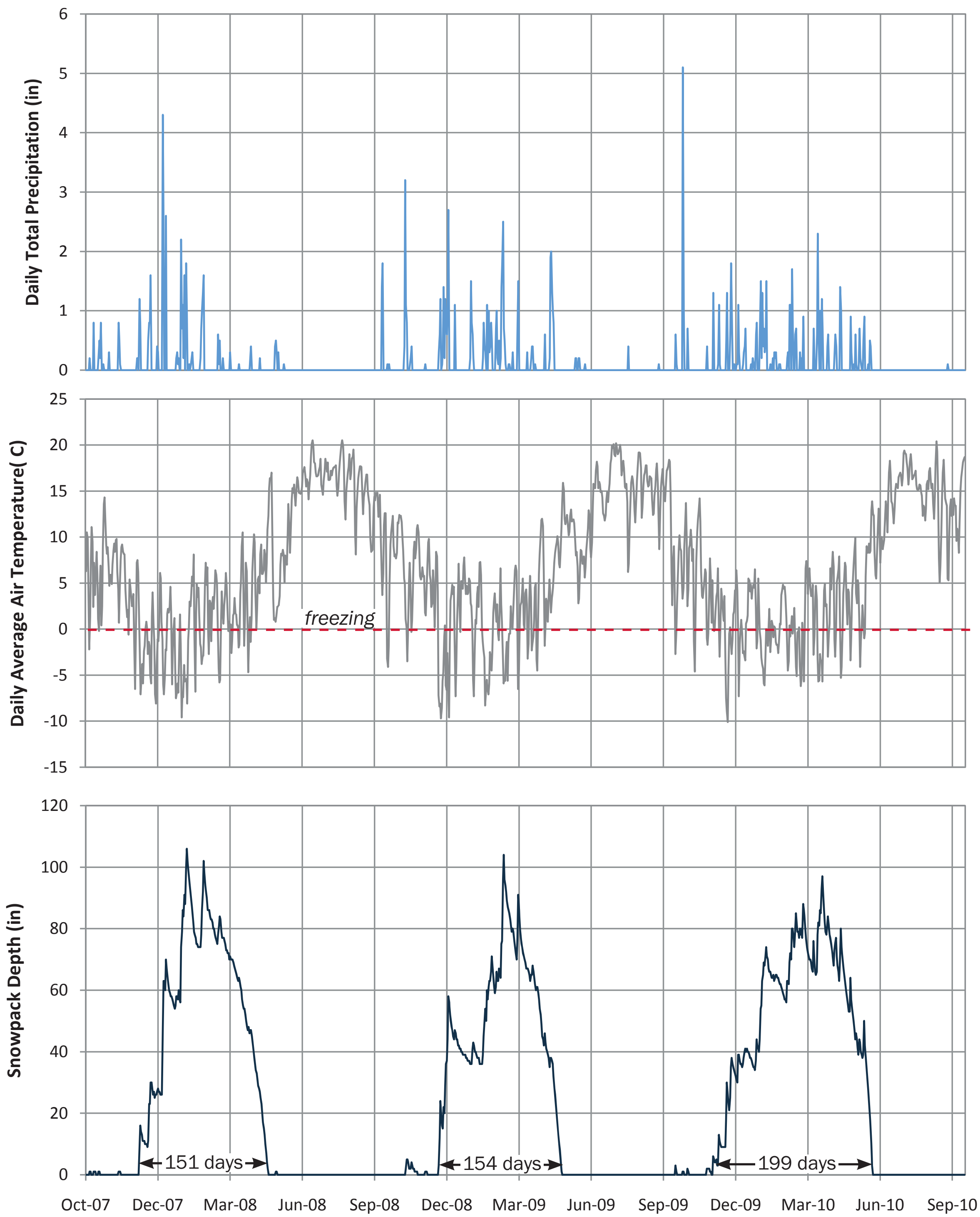
Bankfull Width = ~38'

Floodprone Width = ~42'

Entrenchment Ratio = 1.1

[1] Upper Truckee River bankfull discharge within the project reach is estimated to be 336 cfs (SH+G 2004).
[2] Channel capacity discharge is estimated to be 290 cfs at MOD1, based on the cross section surveys and the discharge to water surface elevation rating curves shown in Figure7.
[3] Channel capacity discharge at 4/5L is estimated to be 2300 cfs, based on the surveyed cross section surveys and the discharge to water surface elevation rating curves shown in Figure7.

METEOROLOGY TIME SERIES



All data are from the Echo Peak SNOTEL monitoring site (site number=463; http://www.wcc.nrcs.usda.gov/snotel/California/california.html,).

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METEOROLOGY TIME SERIES

FIGURE 5

determine the recurrence intervals of total annual precipitation totals. A regression analysis was conducted to extend the 30 years of record for the Echo Peak SNOTEL gage using the Tahoe City dataset. Water year precipitation totals were binned into one of 5 water year type categories (Table 2) based on the recurrence interval of the Tahoe City gage annual precipitation data and the corresponding Echo Peak precipitation using the empirical relationship between the two stations.

Table 2. Water year type definitions and annual precipitation statistics for select Tahoe Basin precipitation gages. The Tahoe City dataset was used to extrapolate the Echo Peak dataset to 100 years of data and define the water precipitation ranges for five water year types.

Water Year Type	Recurrence Interval (years)	Tahoe City[1] WY Precipitation (in)	Echo Peak[2] Water Year Precipitation (in)
Very Dry	< 1.2	<20.5	<41.4
Dry	1.2 - 1.5	20.5 - 24.4	41.4 - 46.9
Average	1.5 - 3.0	24.5 - 33.0	47.0 - 59.5
Wet	3.0 - 10.0	34.0 - 49.0	59.6 -79.0
Very Wet	> 10.0	> 49.0	> 79.0
Gage Elevation (ft)		6,230	7,670
Minimum Annual Precipitation (in)		9.34	27.9
Maximum Annual Precipitation (in)		66.4	91.1
Average Annual Precipitation (in)		31.6	58.9
Number of Years Monitored		100	30
Relationship to Tahoe City Gage Data: R^2 value			0.89

[1] Tahoe City (1911-present) gage operated by WRCC.
[2] Echo Peak (1981-present) gage operated by SNOTEL.

The extension of this research into WY2010 proved to be extremely beneficial when the relatively average WY08 and WY09 snowmelts were followed by a 10-yr flood event in the spring of 2010 (Table 3). Based on total precipitation, WY08 was very dry and both WY09 and WY10 were average. While the total precipitation between WY09 and WY10 were similar, the spring climate and snowmelt dynamics yielded very different spring discharge responses. In WY2010 precipitation events occurred during periods of cooler air temperatures and resulted in the snowpack persisting much later in the year; the peak discharge occurred on June 7, compared to early to mid May during the two previous years. The snowpack persisted longer and melted much faster in the increasing air temperatures of the later spring and early summer, resulting in a relatively larger streamflow event on the UTR (see Table 3).

Table 3. Snowpack and precipitation metrics, WY08-WY10.

Metric	WY08	WY09	WY10
Snowpack Duration (days)	151	154	199
Peak Melt Rate (in/day)	1.4	2.5	4.6
Date of Peak Snowmelt Discharge[1]	May 18	May 3	June 7
Peak WY Discharge (cfs)[1]	548	603	1,120
Peak discharge RI (yr)[2]	3	3	10
WY precipitation (in)	39.8	53.6	54.4
Water year type[3]	Very Dry	Average	Average

[1] Upper Truckee River at Meyers (USGS #103366092), snowmelt peak was annual peak for each WY.
[2] The recurrence interval (RI) is estimated based on the partial duration flood frequency analysis for the Meyers USGS gage by SH+G (2004).
[3] Water year type as defined by this research and presented in Table 2.

Figure 6 presents the discharge time series for the USGS Upper Truckee River at Meyers gage and the water surface elevation (WSE) time series for the two monitoring sites. Due to the close proximity of the USGS gage to the monitoring sites (less than 1.5 miles upstream; see Figure 1) and the lack of significant stream inputs between the sites, the discharge from the Meyers gage is assumed to be representative. The water level time series for each site, the dates of vertical profile sampling and the channel capacity are also indicated. The floodplain at the non-entrenched site (MOD1) was inundated each spring snowmelt with the largest flooding occurring in 2010 (see photo at right). The channel capacity of the entrenched site (4/5L; approximately 2,300 cfs) was never exceeded during the study.

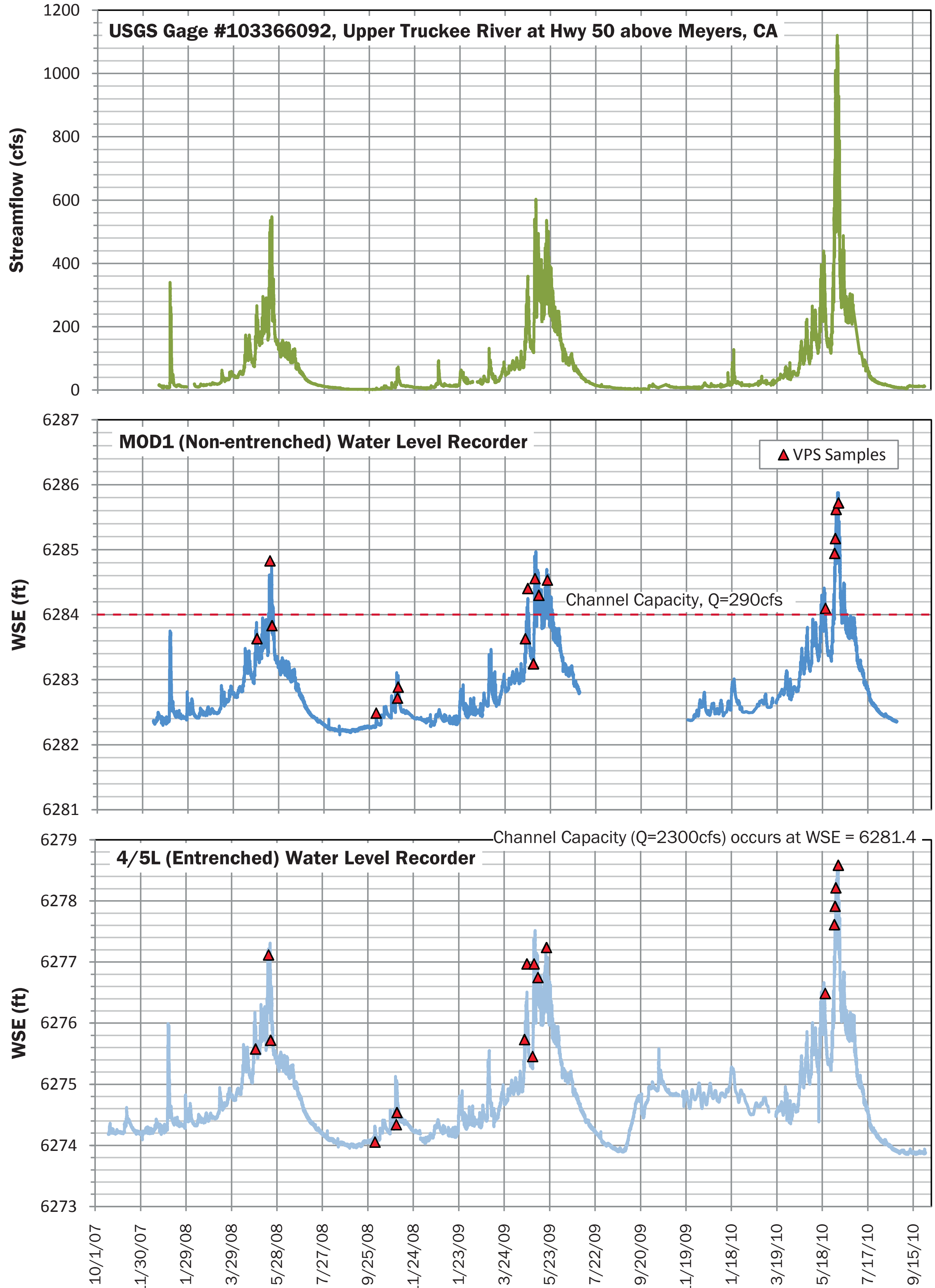
MOD1 Floodplain Inundation – June 2010

Simultaneous discharge from the Upper Truckee River at Meyers (USGS #103366092) and the site-specific water surface elevation time series were correlated to create a discharge to water surface elevation rating curve for both MOD1 and 4/5L (Figure 7) and used to convert the continuous water stage data to annual hydrographs for each site.

WATER SAMPLE COLLECTION

A total of 168 in-stream and 17 passive sampler samples (Table 4) were collected from WY08- WY10 at the two sites. Seventeen events with flows ranging from 5.8 to 960 cfs were sampled, with the majority of the sampling occurring during the spring snowmelts (Table 5; see Figure 6). Field personnel sampled the upstream site first during each event and the elapsed time between sampling of the 2 sites was approximately 70 minutes and never more than 2 hours. The average percent difference in the discharge sampled at the two sites for an event was 6%. The water quality results (TSS concentration, FSP concentration, field turbidity) for all in-stream and passive sampler samples collected during this research are provided in Appendix A. Ninety-two in-stream samples from both the Upper Truckee River

HYDROLOGY TIME SERIES



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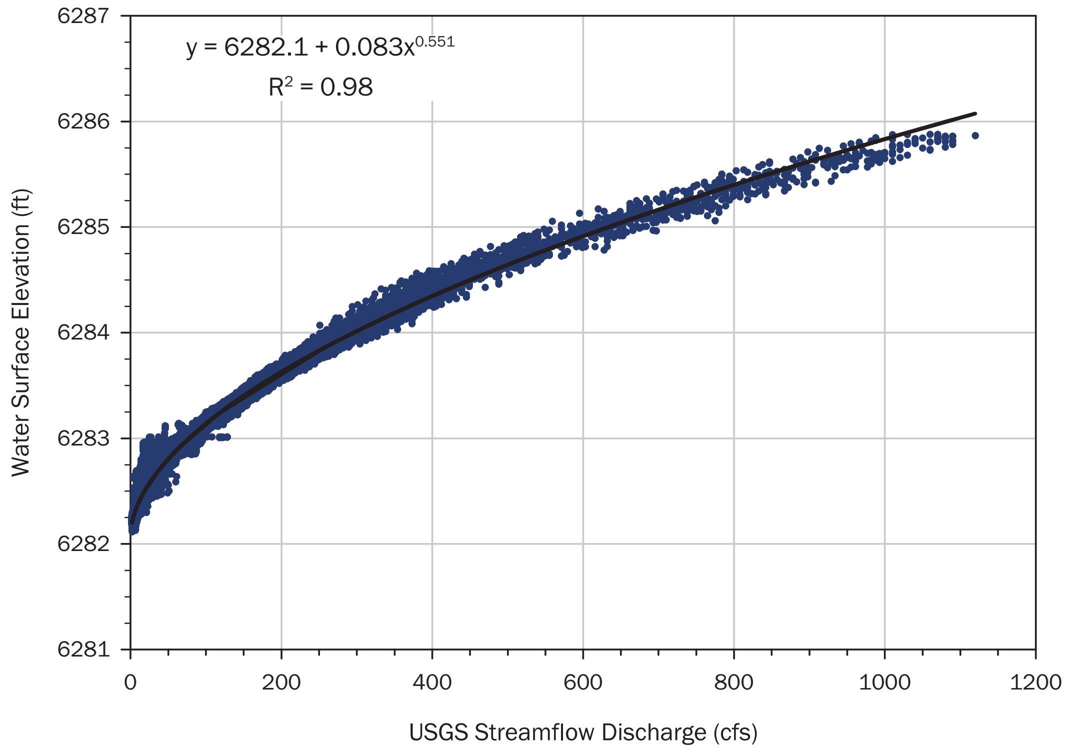
HYDROLOGY DATA TIME SERIES

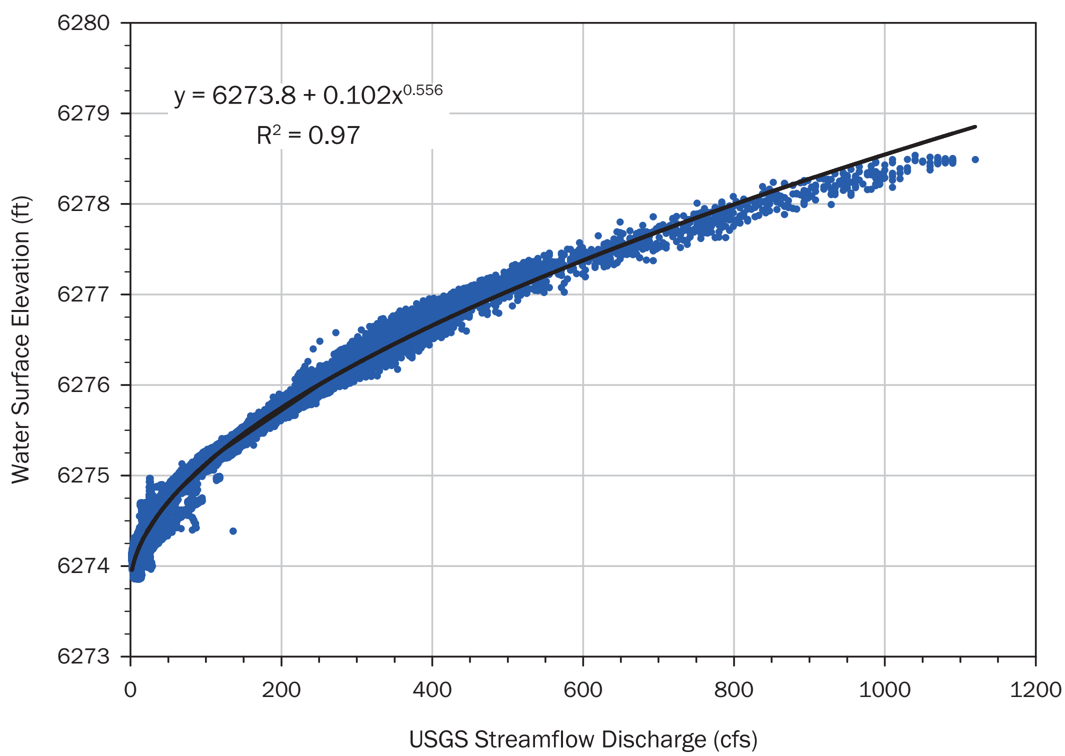
FIGURE 6

DISCHARGE TO WATER SURFACE ELEVATION RATING CURVES

MOD1 (Non-entrenched)



4/5L (Entrenched)



Relationship between instanteneous USGS streamflow discharge data from gage #103366092 (Upper Truckee River at Highway 50 above Meyers, CA) and continuous water surface elevation data measured by In-Situ water level recorders at each site. Data is collected on the same 15-minute time interval for ease of comparison.

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and Trout Creek (SNPLMA Round 9 research) were compiled to create the rating curve shown in Figure 8. This initial data collection indicates that turbidity can be a cost-effective proxy for FSP concentrations in the stream systems and data will continue to be collected to validate these findings and improve the rating curve dataset (2NDNATURE 2010b).

Table 4. Summary of water quality samples by water year.

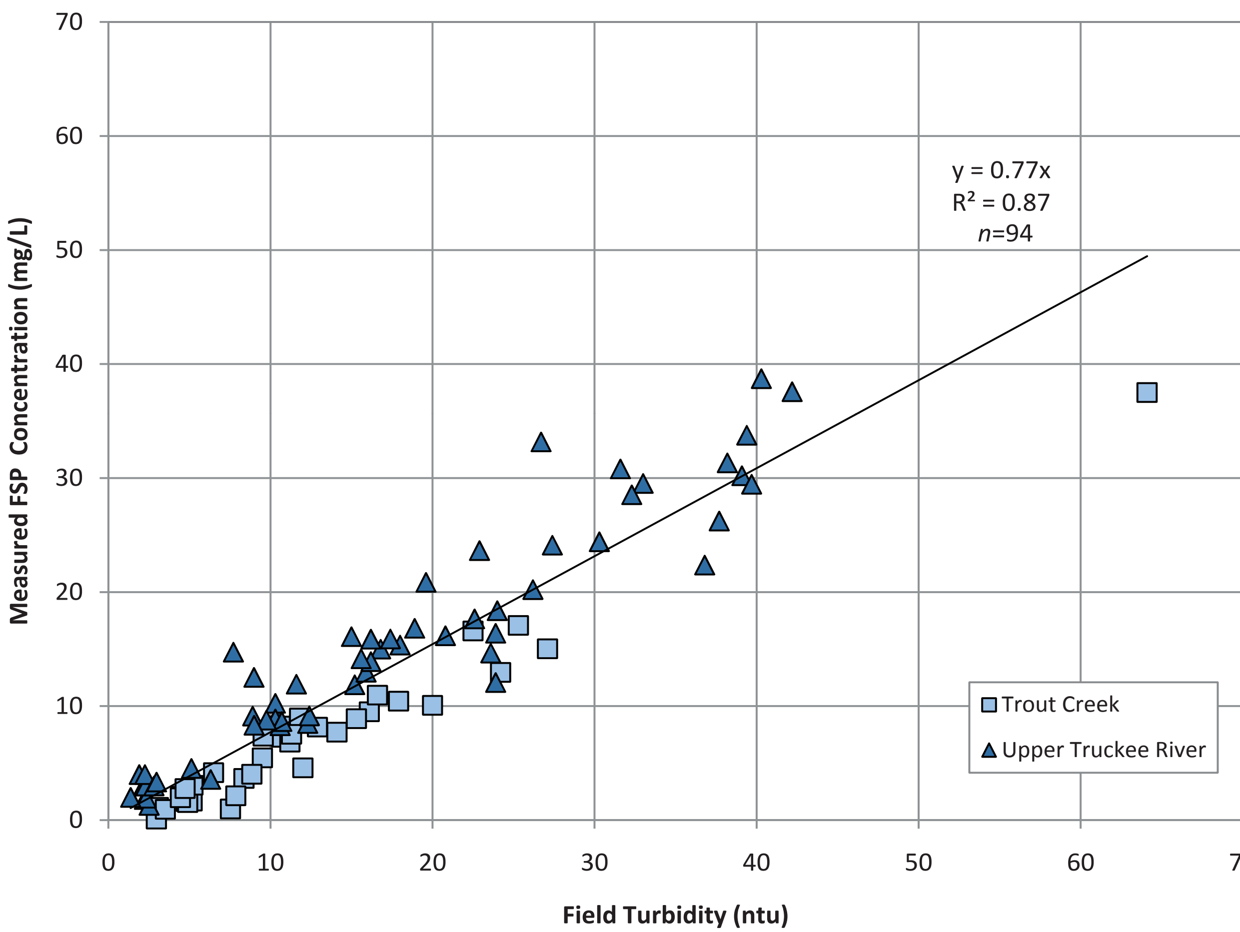
Sample Type	2008[1]		2009		2010		Site Totals		Grand Total
	MOD1	*4/5L*	*MOD1*	*4/5L*	*MOD1*	*4/5L*	*MOD1*	*4/5L*	
Vertical Profile Samples (VPS)	15	15	44	44	25	25	84	84	168
Passive Samplers (PS)	0	0	9	0	7	1	16	1	17
Totals by Year	**15**	**15**	**53**	**44**	**32**	**26**	**100**	**85**	**185**

[1] 2008 data – FSP concentrations unreliable because TERC provided data as # particles and conversion to mass yielded unverifiable results.

Table 5. Summary of vertical profile sampling (VPS) by date and discharge. Number of passive samplers (PS) collected also provided.

Date	Discharge (cfs) when VPS were sample		# PS Samples
	MOD1 (Non-entrenched)	4/5L (Entrenched)	
4/29/2008	183	217	0
5/16/2008	480	533	0
5/19/2008	240	263	0
10/4/2008	5.8	5.8	0
11/1/2008	39	38	0
11/2/2008	64	61	0
4/19/2009	129	152	0
4/22/2009	345	345	1
4/30/2009	116	122	0
5/2/2009	427	380	6
5/7/2009	359	348	0
5/18/2009	420	438	2
5/21/2010	270	256	0
6/2/2010	474	518	0
6/3/2010	620	606	6
6/4/2010	890	878	0
6/7/2010	960	890	2

TURBIDITY TO FSP RATING CURVE



Correlation plot of turbidity versus FSP concentration based on 94 samples collected in Upper Truckee River and Trout Creek in 2010.

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STREAM FIELD TURBIDITY TO FSP CONCENTRATION RELATIONSHIP

FIGURE 8

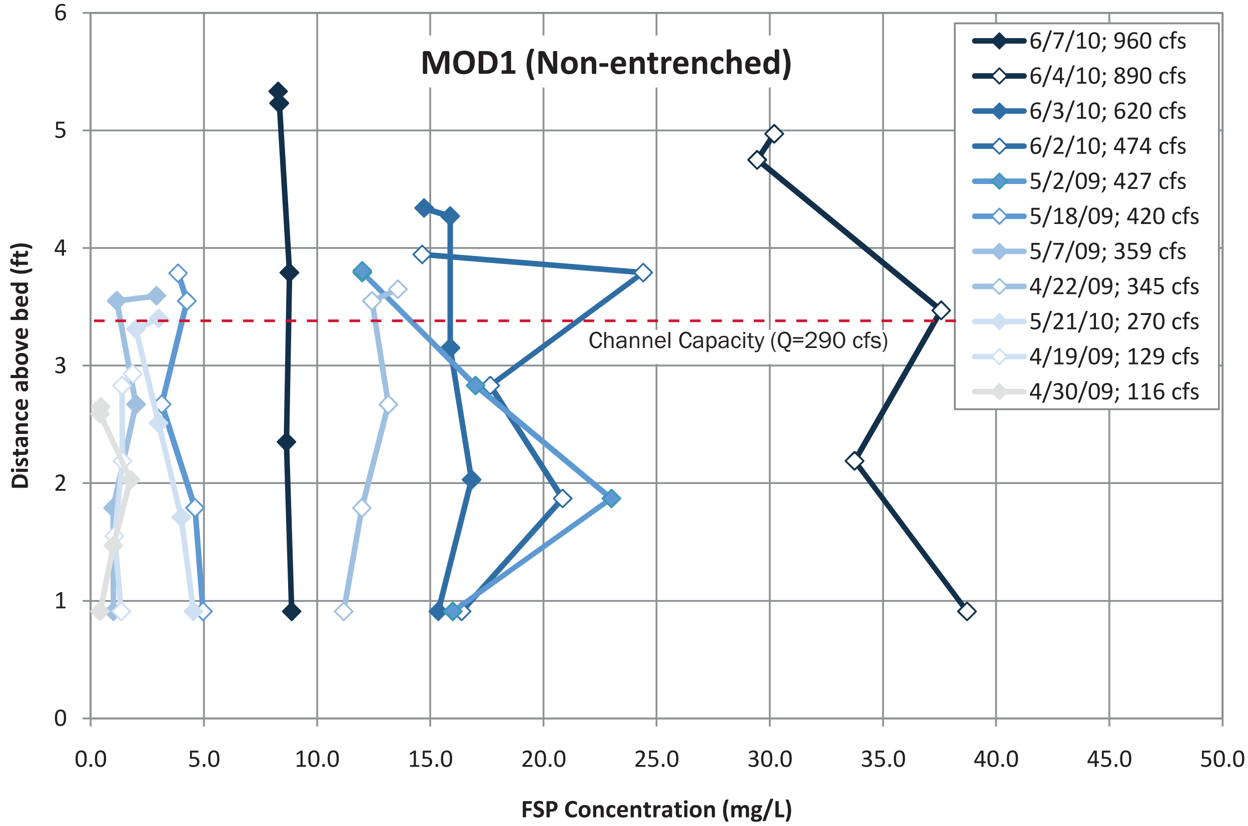
VERTICAL FSP SAMPLING RESULTS

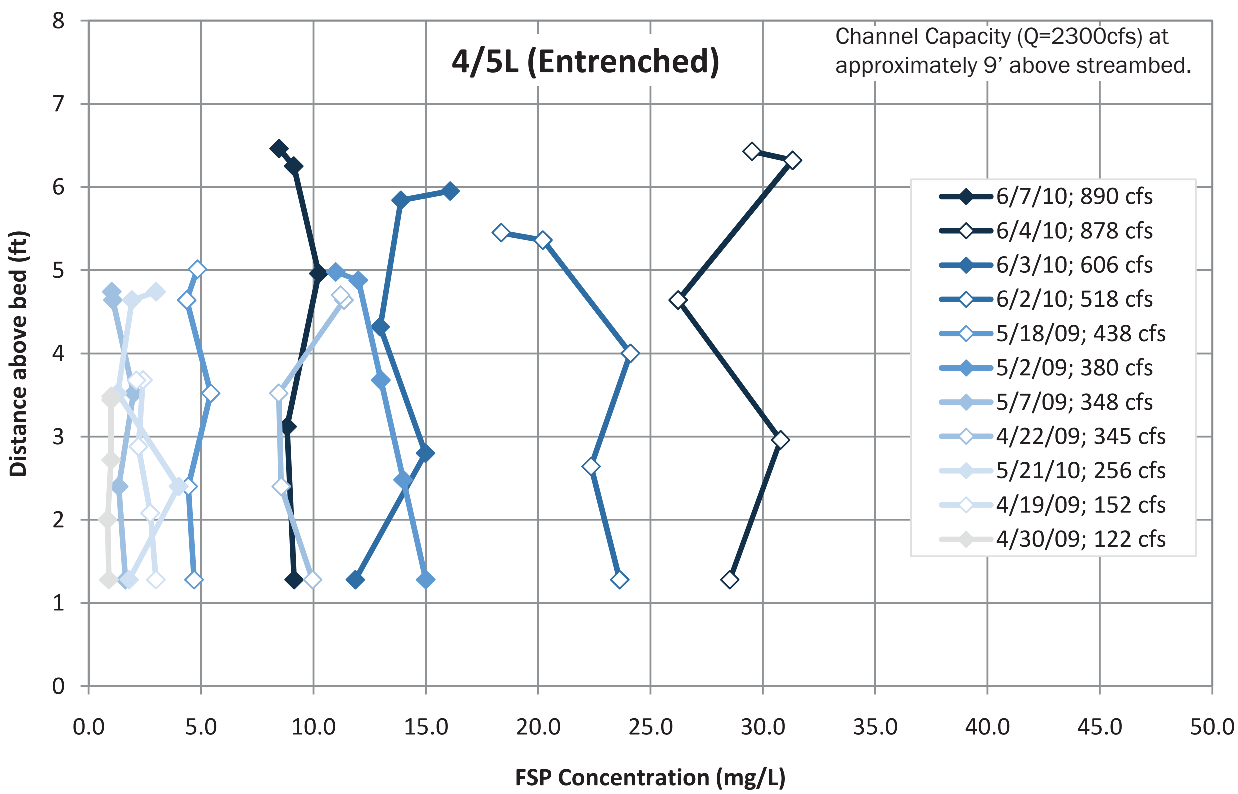
The FSP concentrations for the 168 in-stream samples collected using the vertical profile sediment sampler at MOD1 (non-entrenched channel, top graph) and 4/5L (entrenched channel, bottom graph) during 2009 and 2010 are displayed in Figure 9. FSP concentration (x-axis) is plotted against the location in the water column where the sample was collected, measured as height above the stream bed (y-axis). All samples collected during the same event are denoted in the same symbology, and events are organized from highest (darkest blue) to lowest (light grey) discharge at time of sampling. The water column height at which the channel reaches capacity and floodplain inundation begins is indicated by the dashed red line.

The vertical FSP sampling results indicate that the water column is well-mixed with respect to FSP concentrations and there is no discernable vertical structure to FSP concentrations within the water column. The average % of TSS finer than 16 μm of the in-stream samples collected when discharge (Q) was greater than 100 cfs is 40% (n=134). In future sampling, surface grab samples would be a cost-effective proxy to reasonably represent FSP concentrations in the entire water column. This finding also suggests that high resolution monitoring for sediment loading rate using automated turbidity probes installed at a fixed elevation within the water column may provide a representative measure of the FSP concentration for a given discharge. However, it must be noted that the vertical FSP sampling only captured discharges up to 960 cfs (see Table 5) at two locations and predominantly during spring snowmelt events. SH+G (2004) flow frequency analysis determined 1120 cfs is approximately the 10-yr reoccurrence interval for this section of the Upper Truckee River.

The average water column FSP concentration was correlated to discharge at the time of sampling for all vertical profile samples collected at MOD1 and 4/5L in spring 2009 and 2010 (Figure 10). Samples are plotted by site (color and shape) and by location on the hydrograph (fill). Three power regressions are provided (all samples, samples collected on the rising limb, and samples collected on the falling limb) to calculate the FSP concentration as a function of discharge (FSP(Q)). As Figure 10 indicates, knowing the location of the sample collection on the event hydrograph is critical to interpreting water quality results, with the rising limb of large events transporting a significant fraction of the overall event FSP load. These findings are similar to the expected pollutagraphs of other pollutants and well observed in Tahoe Basin stream systems (Stubblefield et al. 2006). The data suggest that if grab sampling techniques are used to estimate of the potential FSP event loading, collection during both the rising and falling limb will provide a reasonable bound on the potential concentrations to be extrapolated throughout the hydrograph to estimate the total event load.

IN-STREAM FSP CONCENTRATIONS





Samples collected by in-stream vertical sampler with simultaneous surface water grab.

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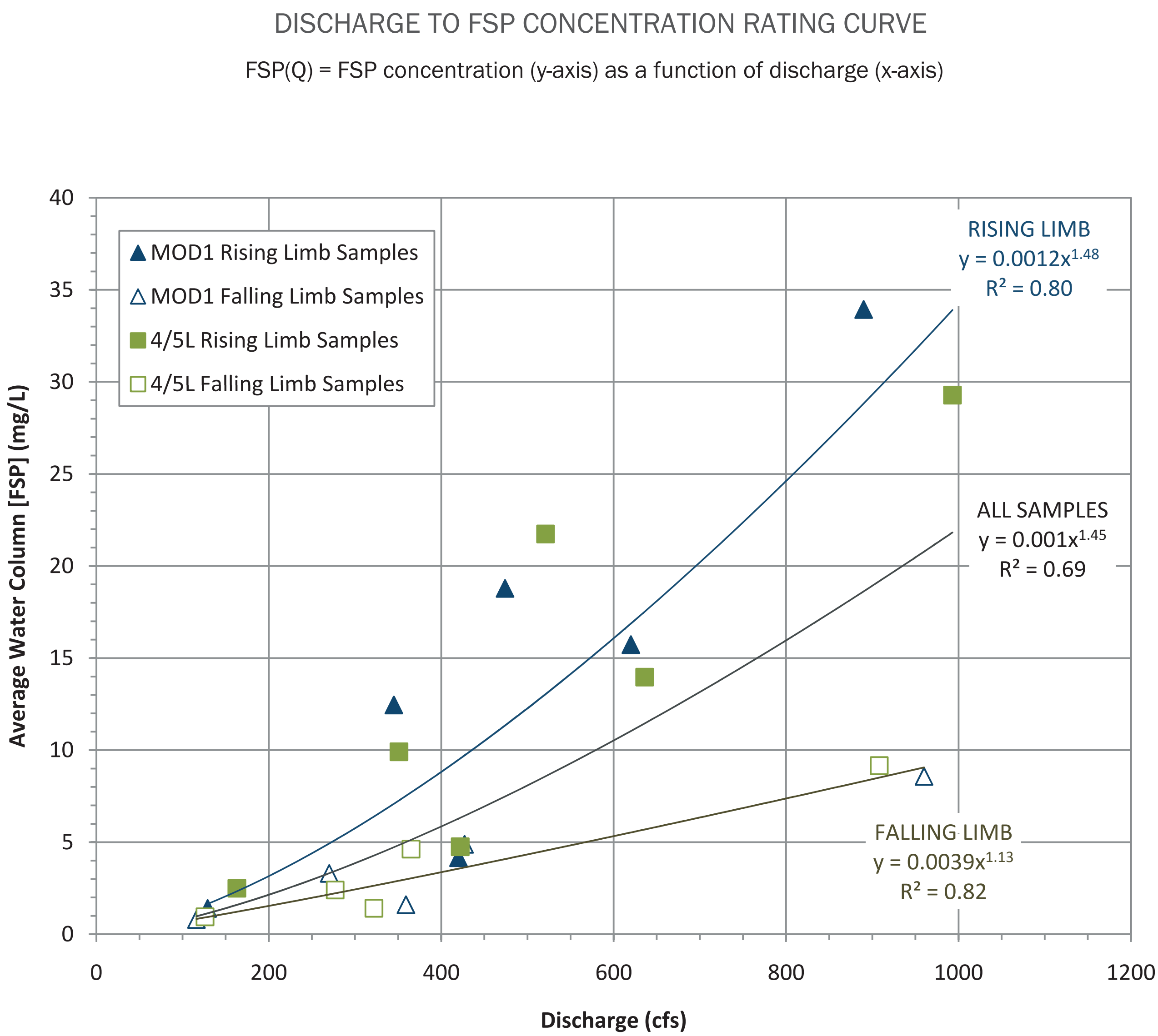


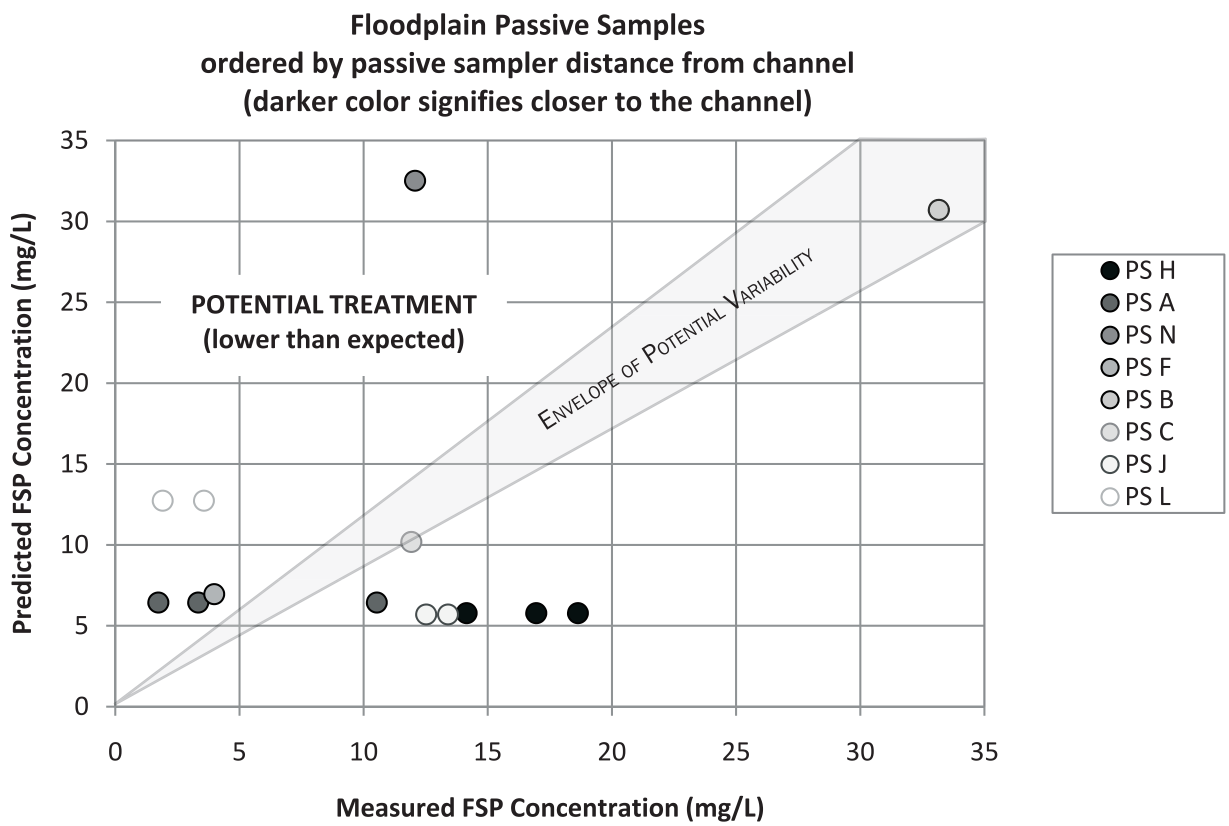
Relationship between USGS streamflow discharge data from gage #103366092 (Upper Truckee River at Highway 50 above Meyers, CA) and the average water column FSP concentration, as measured by in-stream vertical sampler (see Figure 9). Location on the hydrograph is determined based on the site hydrology time series (see Figure 6) and the time of sample collection as noted by field personnel.

FLOODPLAIN FSP SAMPLING RESULTS

Sixteen of the seventeen floodplain samples were collected from the non-entrenched MOD1 site, which is expected given its morphology and hydrologic connection with the stream. The continuous stage dataset from site 4/5L and site visits during peak flows suggest discharge did not exceed the channel capacity this study. However, the passive sampler at the site was inundated during the June 2010 event because the sampler is located approximately 2.5ft below the top of bank (see Figure 4) and thus does not represent out of bank conditions.

The floodplain passive samplers capture a sample at a known elevation and discharge during the rising limb of each respective event. Figure 11 compares the measured FSP concentrations for each sample collected by the passive samplers to the predicted concentrations of the floodwaters for the given discharge. The predicted concentrations were determined using the rising limb FSP(Q) rating curve (see Figure 10) because the samplers are designed to sample water and sediment from their first inundation. The data points are ordered from dark to light by increasing distance of the passive sampler from the thalweg. The 1:1 line with confidence bounds indicates where measured and predicted values are equal. Samples above the line suggest potential treatment (particle retention) by the floodplain. Notice that measured FSP values at PS H are consistently higher than the predicted values, perhaps due to greater proportion of FSP settling out at locations on the floodplain closest to the channel. Additional explanations include potential contamination, sediment entrainment from the upstream floodplain, or uncertainty in predicted values. The capture of FSP at distributed locations on the floodplain and at different elevations provides promising data that FSP retention during floodplain inundation does occur and some load reduction during overbank events is expected.

The floodplain passive sampler FSP concentrations distribution is plotted for the WY09 and WY10 snowmelt events for the MOD1 floodplain in Figures 12A and 12B. Sample concentration ranges are presented by increasing FSP concentration, from light tan to dark brown. As expected, Figure 12 indicates a decreasing FSP concentration as water flows across the floodplain from the upper to lower transect and as the distance from the channel increases. While the dataset is limited to two events on one floodplain, the data displayed in Figure 12 is used to estimate retention coefficients (R_{FSP}: the relative fraction of the FSP load delivered that is retained on the floodplain) in the FSP load retention calculations below.



Measured concentrations are from analytical laboratory results of samples collected by each floodplain passive sampler over the course of the study. Predicted concentrations are based on the discharge at which each sampler is inundated and converted to FSP concentration using the rising limb rating curve in Figure 10.

The 1:1 line and an envelope of potential variability is provided. Samples above the envelope have measured values well below predicted and provide potential evidence of floodplain FSP retention. Samples below the line indicate measured values are higher than predicted. The majority of passive samplers below the line are closer to the thalweg and may provide potential evidence of preferential deposition as flows initiate overbank interactions.

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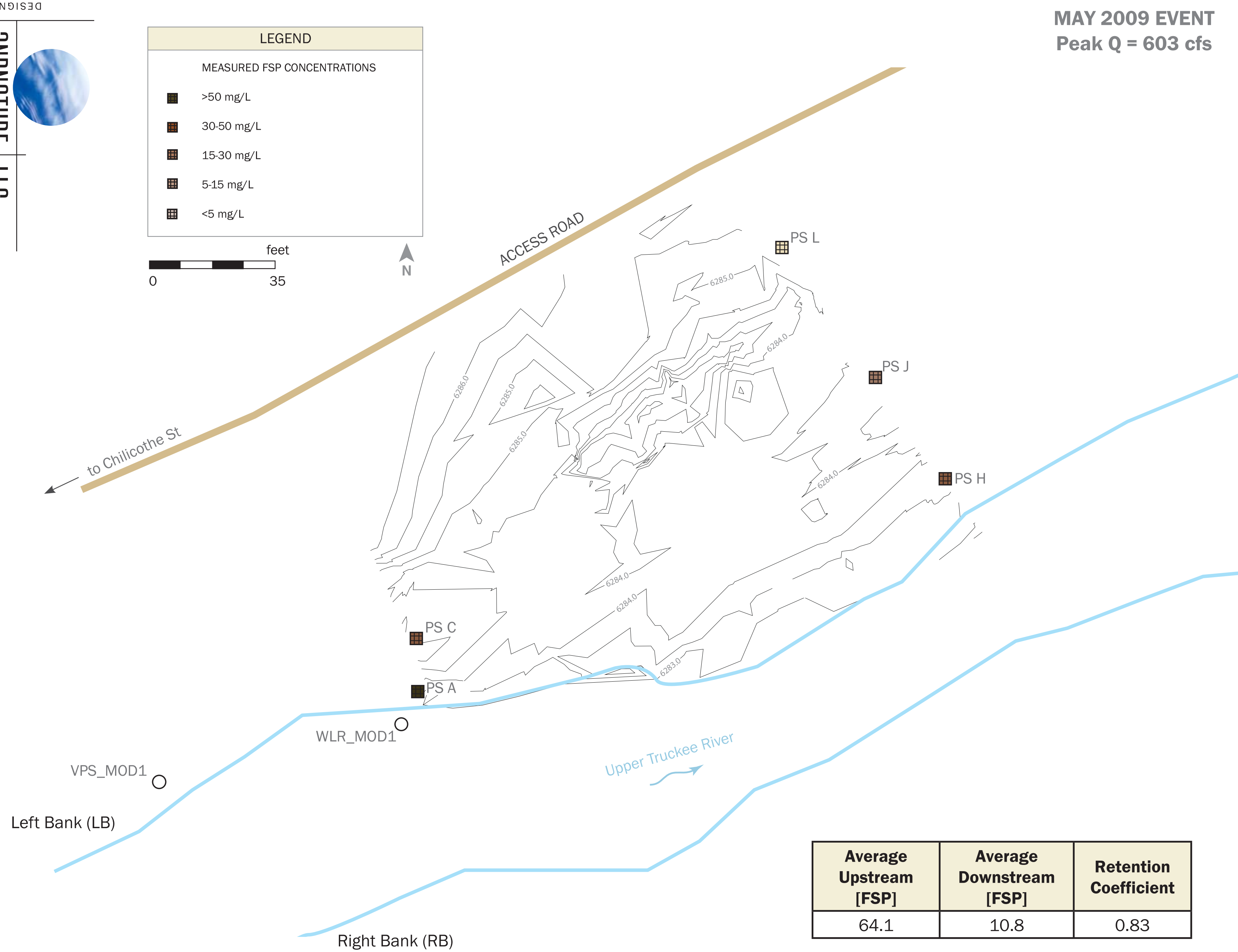
MAY 2009 EVENT
Peak Q = 603 cfs



Average Upstream [FSP]	Average Downstream [FSP]	Retention Coefficient
64.1	10.8	0.83

0.5' contours shown are based on 2NDNATURE topographic survey conducted in 2008.

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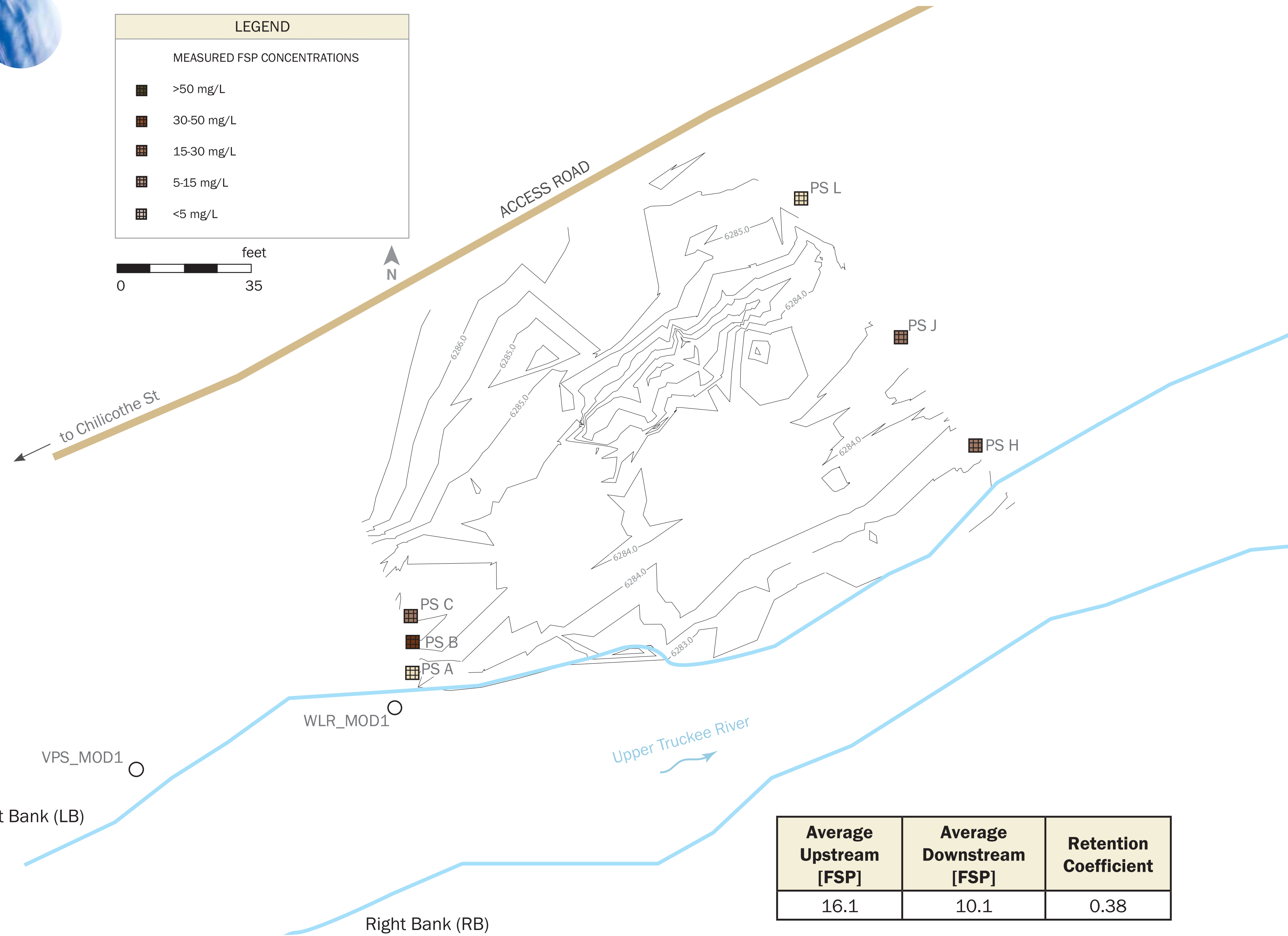
MAY 2009 MOD1 FLOODPLAIN PASSIVE SAMPLER RESULTS

FIGURE 12A

JUNE 2010 EVENT
Peak Q = 1,120 cfs



Average Upstream [FSP]	Average Downstream [FSP]	Retention Coefficient
16.1	10.1	0.38

0.5' contours shown are based on 2NDNATURE topographic survey conducted in 2008.

JUNE 2010 MOD1 FLOODPLAIN PASSIVE SAMPLER RESULTS

FIGURE 12B

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QUANTIFICATION OF FINE SEDIMENT RETENTION BY FLOODPLAIN

Below we apply the existing data to estimate the potential FSP load deposited on the floodplain during sustained inundation from the WY09 and WY10 spring snowmelt events at the non-entrenched (MOD1) site. While the entrenched (4/5L) channel capacity was not exceeded during this study, we apply the planned restoration design channel capacity (C. Walck, CA State Parks, pers. com.) to estimate the potential FSP load reduction if the channel had been in restored conditions during the WY09 and WY10 snowmelt events. Due to laboratory miscommunications and a relatively low peak snowmelt discharge, no retention calculations are made for WY08. The data and estimation approaches presented herein will continue to be applied and refined under the research team's continued SNPLMA Round 9 work on the SLRT development (2NDNATURE 2010a).

FLOODPLAIN FSP LOAD RETENTION ESTIMATES

FSP loads retained on the floodplain (i.e., floodplain deposition) can be calculated as:

$$S_{FSP} = S_{fp} * R_{FSP} \qquad \text{(EQ 1)}$$

where S_{FSP} is the retained FSP floodplain load (MT); S_{fp} is the FSP load delivered to the floodplain for a given event, season, or year; and R_{FSP} is the FSP retention coefficient of the floodplain due to particle settling, vegetation interaction, etc. for the time interval of interest. R_{FSP} is expressed as a fraction (0-1) of the total S_{fp} introduced to the floodplain. Below we apply the existing dataset to estimate spring 2009 and 2010 S_{FSP} for the existing MOD1 and the hypothetical restored 4/5L site.

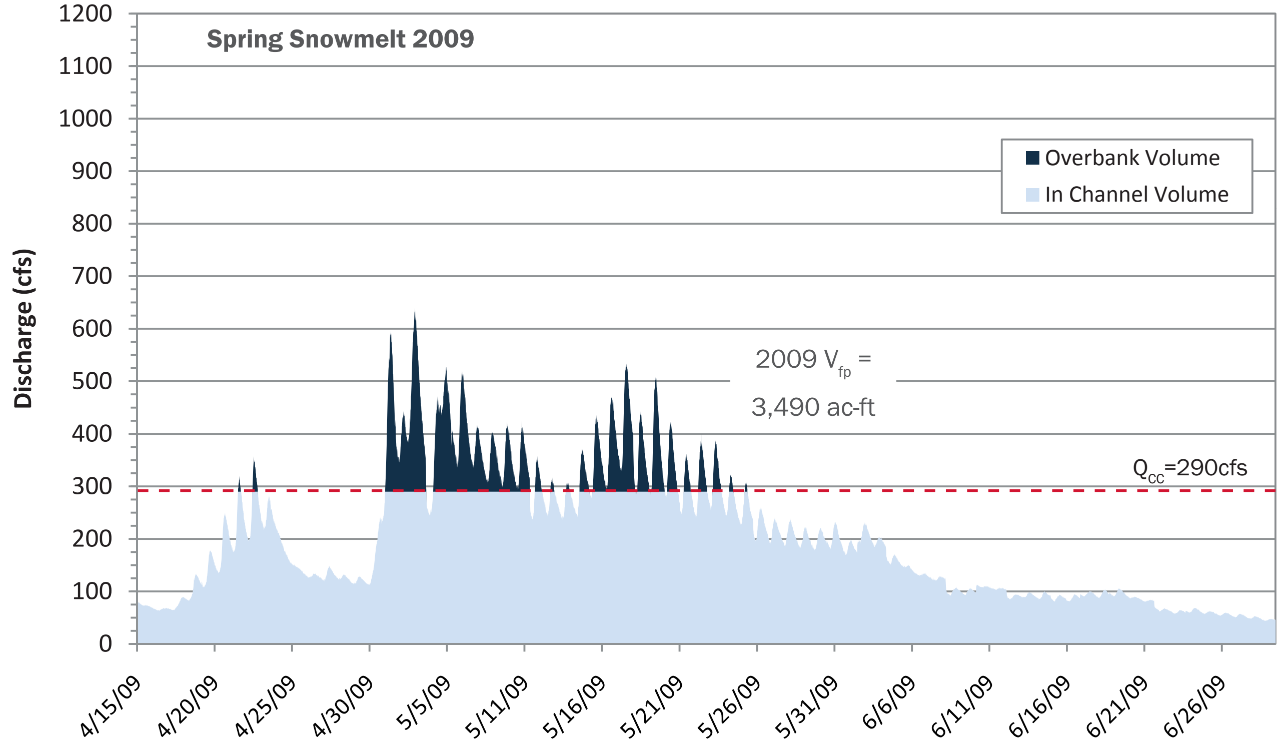
FLOODPLAIN VOLUME (V_{fp}) CALCULATIONS

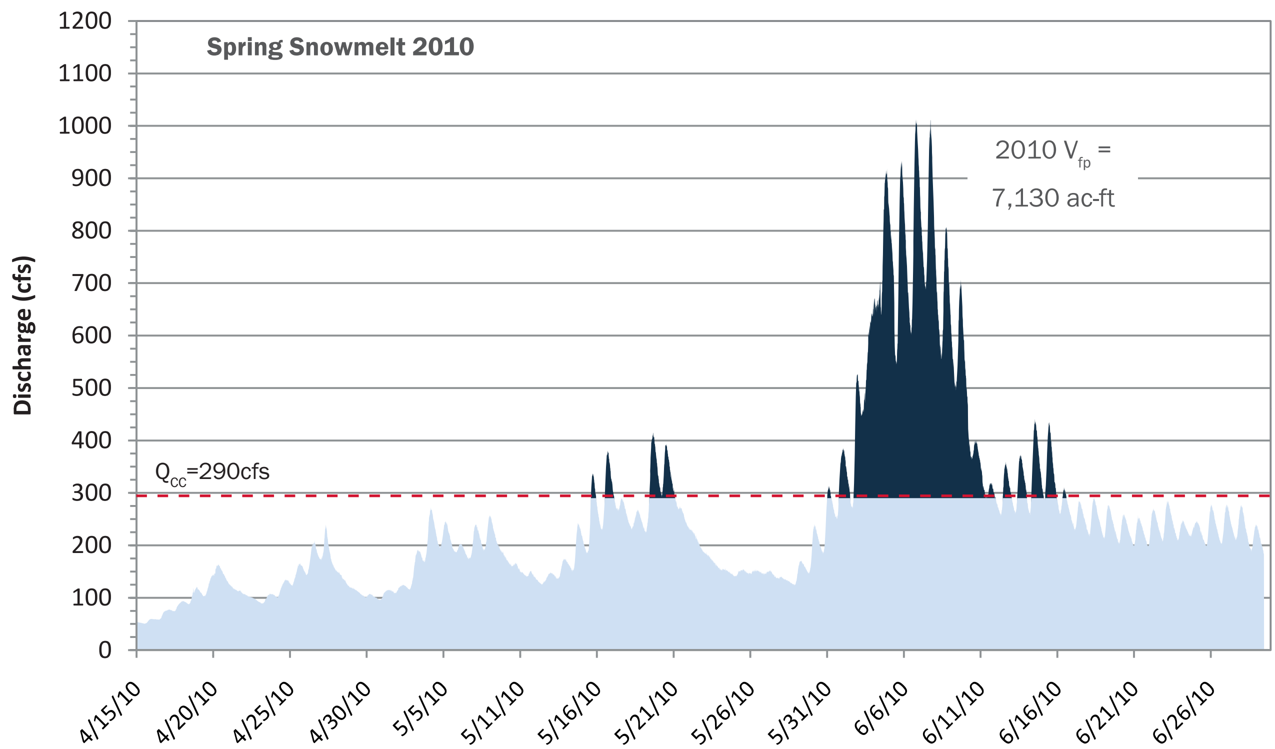
To quantify the volume of water on the inundated floodplain, we convert the measured water surface elevation time series (see Figure 6) to discharge using the rating curves shown in Figure 7. The MOD1 spring 2009 and 2010 hydrographs are shown in Figure 13 and the channel capacity is noted. The fraction of the stream discharge that is assumed to access the floodplain is simply calculated as:

$$Q_{fp} = \max\begin{cases} Q - Q_{cc} \\ 0 \end{cases} \qquad \text{(EQ 2)}$$

where Q_{fp} is the instantaneous discharge on the floodplain (cfs); Q is the UTR instantaneous discharge (cfs); and Q_{CC} is the discharge at channel capacity (cfs). Q_{CC} at MOD1 (non-entrenched) is 290 cfs (see Figure 4) and the linear relationship of instantaneous discharge to floodplain discharge for MOD1 is shown in the top half of Figure 14.

MOD1 (NON-ENTRENCHED) SPRING HYDROGRAPHS

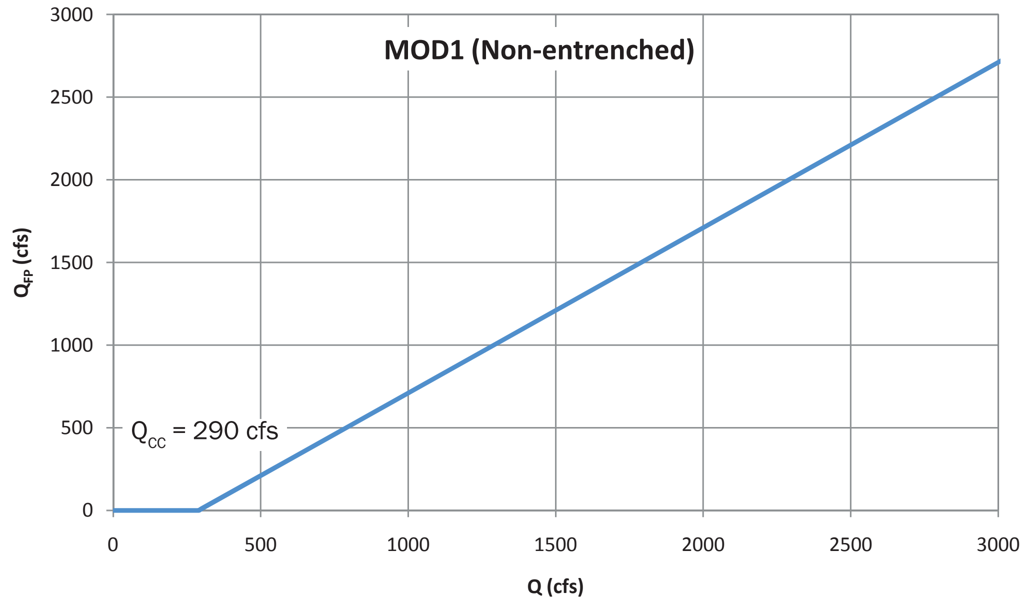


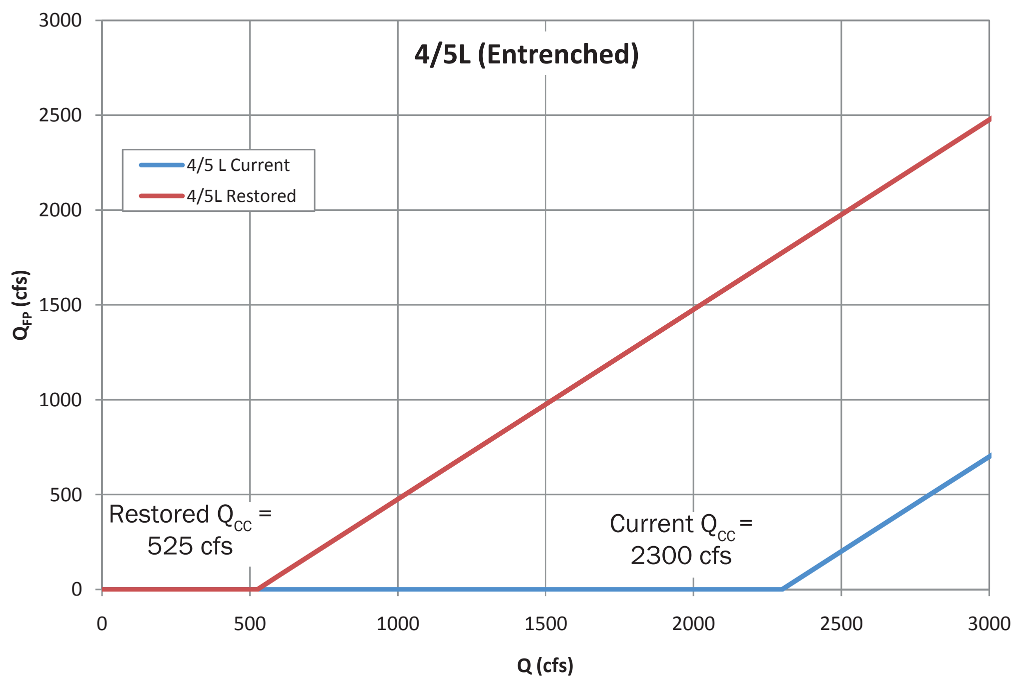


Q_{CC} = Discharge at channel capacity (cfs)

V_{fp} = Inundated floodplain water volume (ac-ft)

DISCHARGE TO FLOODPLAIN DISCHARGE RELATIONSHIP





Q_{fp} = Floodplain discharge (cfs)

Q = Instantaneous discharge (cfs)

Q_{CC} = Discharge at channel capacity (cfs)

The cumulative volume of water that reaches the floodplain can then be calculated as:

$$V_{fp} = \sum Q_{fp} t \quad \text{(EQ 3)}$$

where V_{fp} is the inundated floodplain water volume (ac-ft) and t is the time interval of each measurement (typically 15 minutes). The total floodplain inundation volumes at MOD1 during spring 2009 and 2010 snowmelt events were calculated to be 3,490 ac-ft and 7,130 ac-ft, respectively (see Figure 13).

Table 6 provides the frequency and duration of overbank flow statistics for MOD1 for WY08, WY09 and WY10, as well as the duration of the peak floodplain discharge event, which was the spring snowmelt for each year evaluated (see Figure 6). Consistent with the water year weather patterns (see Figure 5), the frequency and magnitude of overbank flow increased with each subsequent year, as did the duration and maximum discharge of the peak spring snowmelt discharge event.

Table 6. Summary of overbank flow conditions at the MOD1 site for each spring snowmelt.

	WY08	**WY09**	**WY10**
Q_{fp} (cfs)	**# Days Q_{CC} Equaled or Exceeded**		
0	5.2	19.4	16.7
100	2.5	7.3	8.9
200	0.7	1.8	7.1
300	0	0.3	5.7
400	0	0	3.6
500	0	0	2.2
600	0	0	1.1
700	0	0	0.2
800	0	0	0
Peak Annual Event			
Peak Q_{fp} (cfs)	260	350	722
# of continuous days Q> Q_{CC}	3.9	2.8	9.6

FLOODPLAIN FSP LOAD (S_{fp}) CALCULATIONS

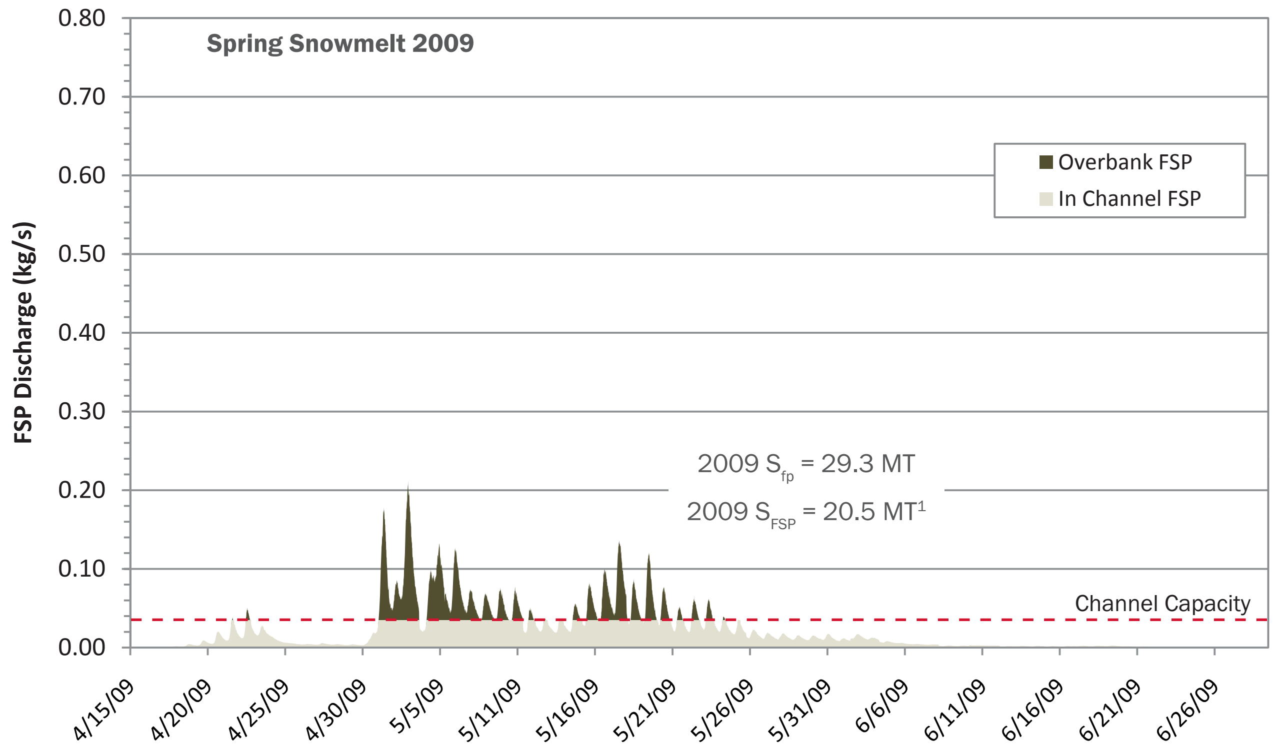
The discharge to average FSP concentration rating curve developed from *all samples* (see Figure 10) is used to convert the MOD1 spring snowmelt hydrograph (see Figure 13) to the FSP pollutagraph shown in Figure 15. The rating curve for all samples was used to reduce the calculation complexity, and while this equation likely underestimates the FSP loading rate (kg/sec) on the rising limb and overestimates on the falling limb, it is assumed the net difference is negligible given the comparable rate changes on the rising and falling limbs of the hydrographs. The FSP loading rate is calculated as:

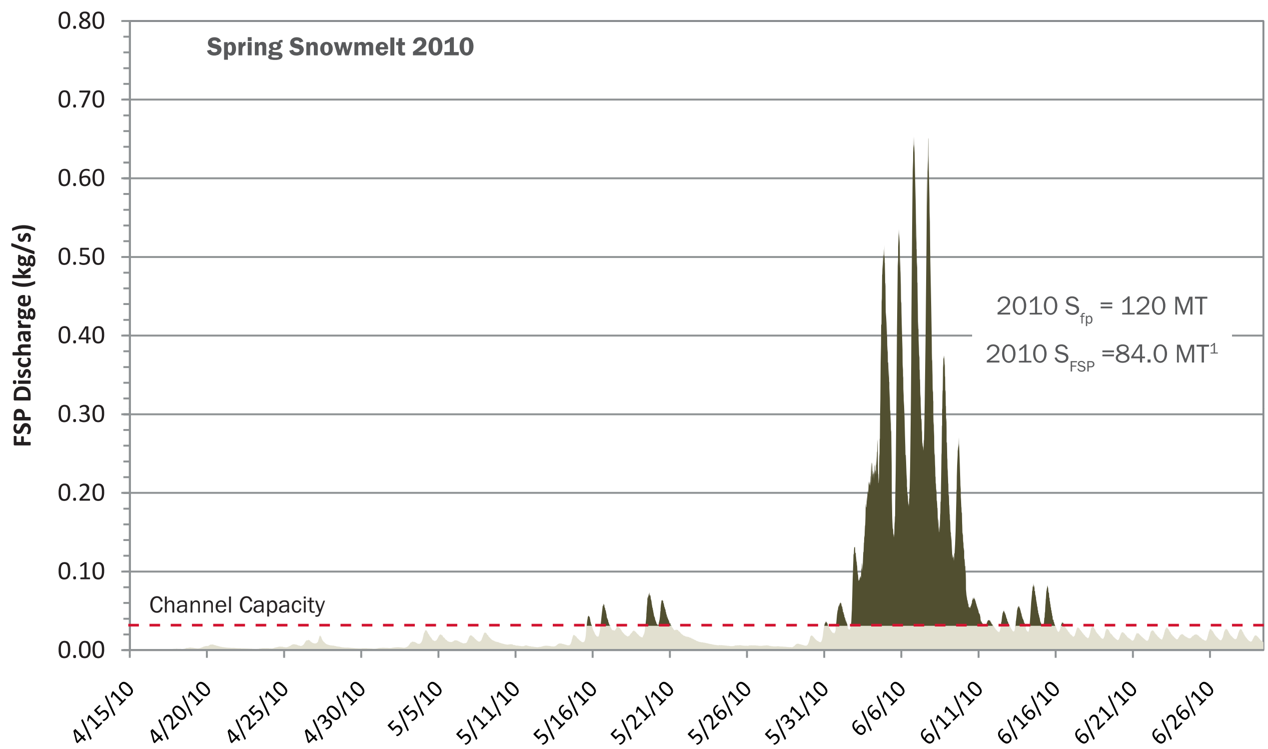
$$Q_s = FSP(Q) * Q_{fp} \quad \text{(EQ 4)}$$

where Q_S is the FSP loading rate (kg/s) and FSP(Q) is the FSP concentration (mg/L) as a function of discharge.

MOD1 (NON-ENTRENCHED) SPRING FSP DISCHARGE TIME SERIES

$S_{FSP} = S_{fp} * R_{FSP}$





S_{FSP}: FSP load retained on floodplain

S_{fp}: FSP load delivered to the floodplain

R_{FSP}: FSP floodplain retention coefficient

[1] Assumes $R_{FSP} = 0.7$.

Similar to the floodplain volume calculations, the FSP discharge time series is integrated when $Q>Q_{CC}$ to calculate the total FSP event load delivered to the floodplain (S_{fp}):

$$S_{fp} = \sum Q_s t \quad \text{(EQ 5)}$$

During the continuous inundation of the spring snowmelts of WY09 and WY10, the estimated total FSP loads delivered to the MOD1 floodplain were 29.3 MT and 120 MT, respectively (see Figure 15).

FSP FLOODPLAIN RETENTION COEFFICIENT (R_{FSP})

The retention coefficient (R_{FSP}) expresses the fraction of FSP delivered to the floodplain that is retained. TERC researchers have conducted a large amount of Tahoe-specific data collection and model development to define and quantify R_{FSP} (Andrews and Schladow 2010a; 2010b). TERC researchers identify 3 processes by which FSP loads contained in streamflow could be retained on a floodplain: direct settling from the water column, biofilms (adherence to vegetation), and flocculation (coagulation of smaller particles into larger ones capable of settling). Building upon TERC concepts and the processes likely influencing FSP retention on a floodplain, we expect both discharge conditions and floodplain characteristics to influence actual R_{FSP} values. When depth of water on the floodplain is relatively shallow, velocity will be relatively lower and soil and vegetation interactions will increase and enhance FSP retention. Because floodplain water depth and the velocity of the water on the floodplain increase as a function of stream discharge, larger floods are expected to have a lower R_{FSP} than during a smaller inundation event on the same floodplain. In addition, vegetation structure, density and distribution as well as the topographic complexity of the floodplain surface likely influence R_{FSP}, with retention efficiency increasing as vegetation and topographic complexity increase. The relative influence of each of these factors will continue to be evaluated as a methodology to consistently estimate R_{FSP} is a critical component in the development of standardized methods to quantify stream load reductions (2NDNATURE 2010a).

R_{FSP} CALCUATIONS

The simple approach is to assume the entire FSP load delivered to the floodplain (S_{fp}) is retained, or $R_{FSP} = 1$. This approach would ensure consistent results across users, but it likely overestimates the FSP load reductions, ignores hydrologic influences on FSP retention, and fails to consider the presence of floodplain characteristics, such as vegetation and topographic complexity, that are expected to enhance FSP retention and can be components of restoration designs.

A more complex approach is to apply the data obtained from the floodplain passive samplers distributed on the MOD1 floodplain to estimate R_{FSP}. Using the distribution and FSP passive sampler concentration data from the WY09 and WY10 events, we estimate the average reduction in the FSP concentrations as flood water is transported in both a longitudinal and cross-sectional direction on the floodplain. Figures 12A and 12B visually present the data and respective locations of the passive sampler. The cross section that contains the passive samplers PS A, PS B, and PS C is located at the upper boundary of the MOD1 floodplain and above this location the stream has much lower entrenchment ratio than 7.4 (i.e., the floodplain is less frequently inundated). If we assume that the upstream passives samplers (US) are inundated as water enters the floodplain at the site and the downstream passive samplers (DS) collect samples after water has travelled across the floodplain, we can compare the data to infer FSP retention (Table 7). Similarly, horizontal floodplain retention estimates are made using the passive samplers within the downstream transect (PS H, PS J and PS L) and the results are presented in Table 8.

Table 7. Comparison of the US passive sample average (PS A, PS B, PS C) to the DS samples (PS H, PS J, PS L) for WY09 and WY10 peak snowmelt events. The retention coefficient is the reduction in the measured average concentrations between the two locations. The average longitudinal distance between the cross sections is 150ft, yielding an estimate of the potential retention per linear foot of floodplain inundated.

US [PS A, PS B, PS C] to DS [PS H, PS J, PS L] (separation distance = 150 ft)				
Event	**Avg US FSP (mg/L)**	**Avg DS FSP (mg/L)**	**Retention coefficient**	
5/2/2009	64.1	10.8	0.83	
6/7/2010	16.1	10.1	0.38	
		Longitudinal Average	**0.6**	

Table 8. Summary of the horizontal differences in passive sampler FSP concentrations with increasing distance from thalweg (see Figure 12) and observed total and per linear foot floodplain reduction for the WY09 and WY10 peak snowmelt events.

Event	**PS H to PS L (separation distance = 84 ft)**		**PS H to PS J (separation distance = 40 ft)**		**PS J to PS L (separation distance =44 ft)**	
	[FSP] difference	**Retention coefficient**	**[FSP] difference**	**Retention coefficient**	**[FSP] difference**	**Retention coefficient**
5/2/2009	- 15.0	0.89	- 3.6	0.21	- 11.5	0.86
6/7/2010	- 10.6	0.75	- 1.6	0.11	- 9.0	0.72
Horizontal Average		**0.8**		**0.16**		**0.79**

Tables 7 and 8 indicate a consistent FSP concentration decrease from upstream to downstream as well as with increasing distance from the thalweg. The dataset above can be used to estimate an average longitudinal retention coefficient of 0.6 and a horizontal retention coefficient of approximately 0.8 for MOD1 for these two events. This limited floodplain sampling data suggests an observed R_{FSP} of 0.7. This R_{FSP} values seems reasonable for the MOD1 floodplain and the event magnitudes evaluated. The floodplain does possess a fairly irregular topography rich with low spots, woody debris and floodplain vegetation. In addition, the maximum water depths during the larger spring 2010 flooding event did not exceed 2 ft, and given the topographic irregularity the average maximum water depth on the floodplain is estimated to be 0.5 ft. The actual floodplain does extend slightly downstream beyond our downstream transect making it reasonable to assume that additional FSP may still be deposited prior to the water reentry into the channel. This suggests that for the entire contiguous MOD1 floodplain a R_{FSP} = 0.7 may be an underestimate.

MOD1 FSP LOAD RETENTION CALCULATIONS

Using EQ1 [$S_{FSP} = S_{fp}*R_{FSP}$] and R_{FSP}=0.7, the total floodplain FSP loads retained on the MOD1 floodplain during spring 2009 and 2010 are 20.5 MT and 84.0 MT, respectively (see Figure 15). Table 9 presents the calculation results for MOD1 (non-entrenched) load reduction estimates as a result of floodplain inundation during 2009 and 2010 spring snowmelts

Table 9. Summary of MOD1 WY09 and WY10 floodplain volume and FSP load calculations.

Spring Snowmelt	Q_{CC}	V_{FP} (ac-ft)	S_{fp} (MT)	S_{FSP} (MT), where R_{FSP}=0.7
WY2009	290	3,490	29.3	20.5
WY2010		7,130	120	84.0

WATER QUALITY BENEFIT OF STREAM RESTORATION

The expected water quality benefit as a result of the planned stream restoration at 4/5L can be estimated by applying the methods and data available. Stream restoration actions that are expected to result in FSP load reductions include a reduction in the channel capacity to increase the frequency and duration of overbank flow, as well as floodplain improvements that would enhance the retention of FSP delivered (i.e., increase R_{FSP}). Only the planned channel capacity reduction of 4/5L is incorporated into the estimates below, but future methods (2NDNATURE 2010a) will include methods to estimate R_{FSP} as a function of floodplain and discharge characteristics. In general, the FSP load reduction associated with stream restoration (ΔFSP) can be calculated as:

$$\Delta FSP = S_{FSP\ (post\ restoration)} - S_{FSP\ (pre\ restoration)} \qquad \text{(EQ 6)}$$

where the FSP load reduction (ΔFSP) for a specific event, season, or year is calculated as the difference between the floodplain FSP retention post-restoration ($S_{FSP\ (pre\text{-}restoration)}$) and FSP retention pre-restoration ($S_{FSP\ (pre\text{-}restoration)}$). In this instance the ΔFSP calculation for 4/5L is easy as no floodplain inundation occurred during spring 2009 and 2010 (see Figure 6) and therefore $S_{FSP(pre\text{-}restoration)}$ is equal to 0 MT. Below we provide a preliminary estimate of ΔFSP as result of increased floodplain FSP retention if the 4/5L reach had been restored prior to 2009. The calculations herein do not incorporate the additional expected FSP load reduction associated with decreased channel erosion due to increased floodplain connectivity.

PROPOSED STREAM CHANNEL RESTORATION AT SITE 4/5L

A stream channel restoration project is planned for the Upper Truckee River in the area of site 4/5L. While the specific restoration designs are still in the planning stage, conversations with California State Parks (Cyndie Walck, pers. comm.) indicate that the designed channel capacity (Q_{cc}) will be reduced from the current Q_{CC}= 2,300 cfs to approximately 525 cfs. Figure 14 illustrates the change in the floodplain discharge (Q_{fp}) as function of stream discharge as a result of this restoration at 4/5L.

Figure 16 presents WY09 and WY10 spring hydrographs, illustrating the increased frequency and duration of overbank flow as a result of the channel capacity reduction. Table 10 compares the frequency and duration of overbank flow statistics for the current and restored 4/5L channels for water years 2008, 2009 and 2010, as well as the duration of the peak floodplain discharge event. The reduction of the channel capacity as a result of stream restoration actions, a critical design component of geomorphic modifications, would result in an increased Q_{fp} for any given Q in the specific reach.

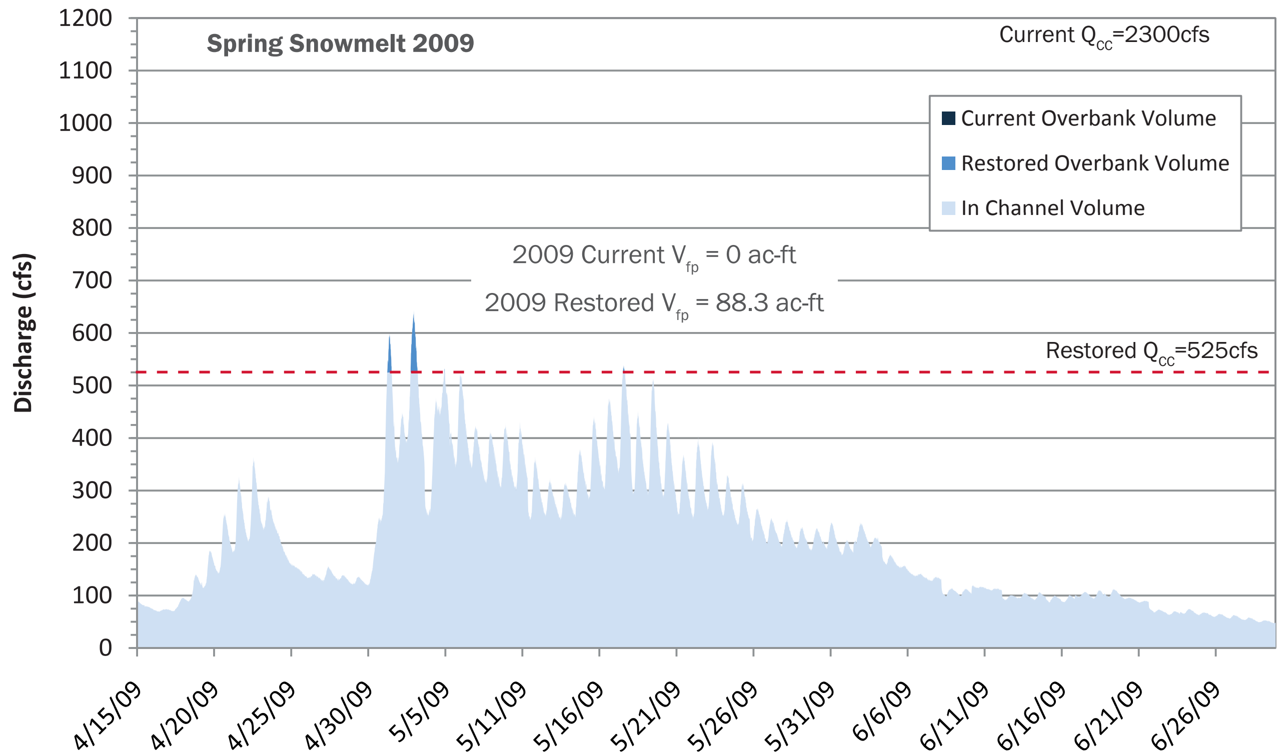
Table 10. Comparison of overbank flow conditions for 2009 and 2010 spring snowmelts for existing and restored 4/5L conditions.

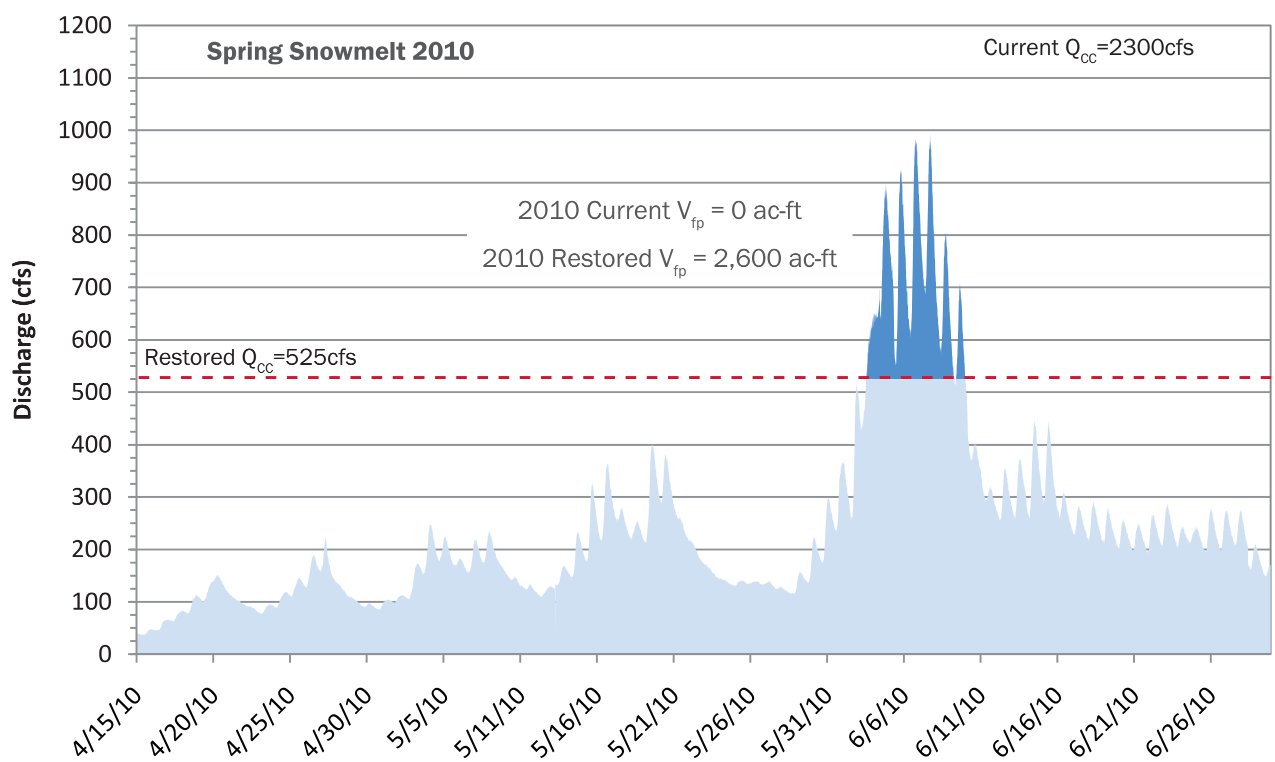
	WY08		WY09		WY10	
	Current	**Restored**	**Current**	**Restored**	**Current**	**Restored**
Q_{fp} (cfs)	**# Days Q_{CC} Equaled or Exceeded**					
0	0	0.6	0	1.0	0	6.6
100	0	0	0	0.1	0	5.0
200	0	0	0	0	0	2.9
300	0	0	0	0	0	1.5
400	0	0	0	0	0	0.5
500	0	0	0	0	0	0
Peak Annual Event						
Peak Q_{fp} (cfs)	0	55	0	118	0	469
# of continuous days Q> Q_{CC}	0	0.3	0	0.5	0	5.9

Using the concepts and equations described above, we estimate the FSP load reduction potential of a reduced channel capacity along the 4/5L stream reach. As indicated in Table 10, with the current channel geometry, overbank flow did not occur during the three water years of data collection. By reducing the Q_{CC} from 2,300 cfs to 525 cfs, the total floodplain inundation volume under the restored conditions would have been 88.3 ac-ft in 2009 and 2,600 ac-ft in 2010 (see Figure 16). Figure 17 shows the spring FSP discharge time series for 4/5L under current and restored conditions. Using EQ6, the estimated FSP load reduction (ΔFSP) under the restoration scenario at site 4/5L is 0.8 MT in 2009 and 36.5 MT in 2010 (see Figure 17), assuming a retention coefficient (R_{FSP}) of 0.7. The R_{FSP} of 0.7 assumes that the restoration design includes floodplain characteristics that optimize FSP retention similar to MOD1.

Table 11 summarizes the calculation results for both the current and restored 4/5L channels. WY09 and WY10 were average water years (see Table 3) and therefore expected to represent an average annual load reduction estimate. WY09 and WY10 S_{FSP} values are averaged to estimate an average annual FSP load reduction of 18 MT/yr associated with Upper Truckee River stream restoration at the entrenched site. The average annual FSP load reduction of 18 MT can be converted to 2.1 x 10^{18} particles using the particle conversion of 1 .1 kg FSP = 1.1x10^{14} particles (LRWQCB and NDEP 2009).

4/5L (ENTRENCHED) SPRING HYDROGRAPHS





Q_{CC} = Discharge at channel capacity (cfs)

V_{fp} = Inundated floodplain water volume (ac-ft)

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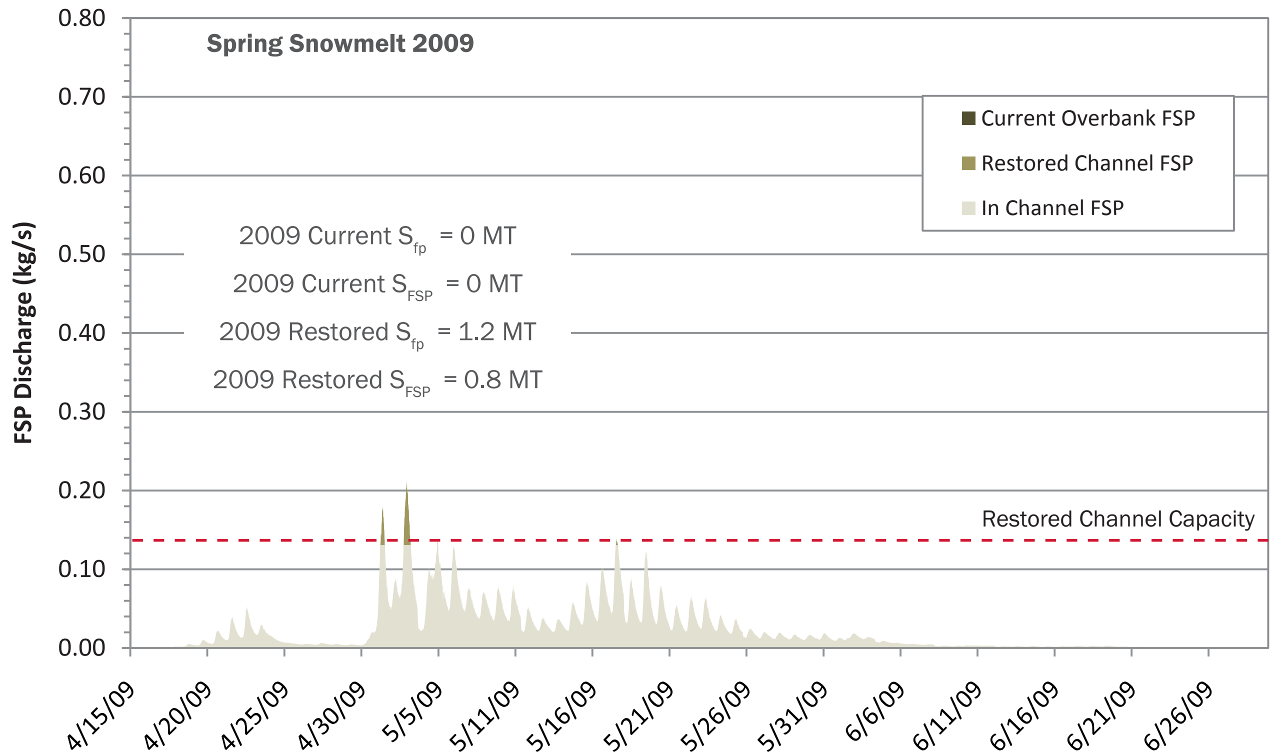
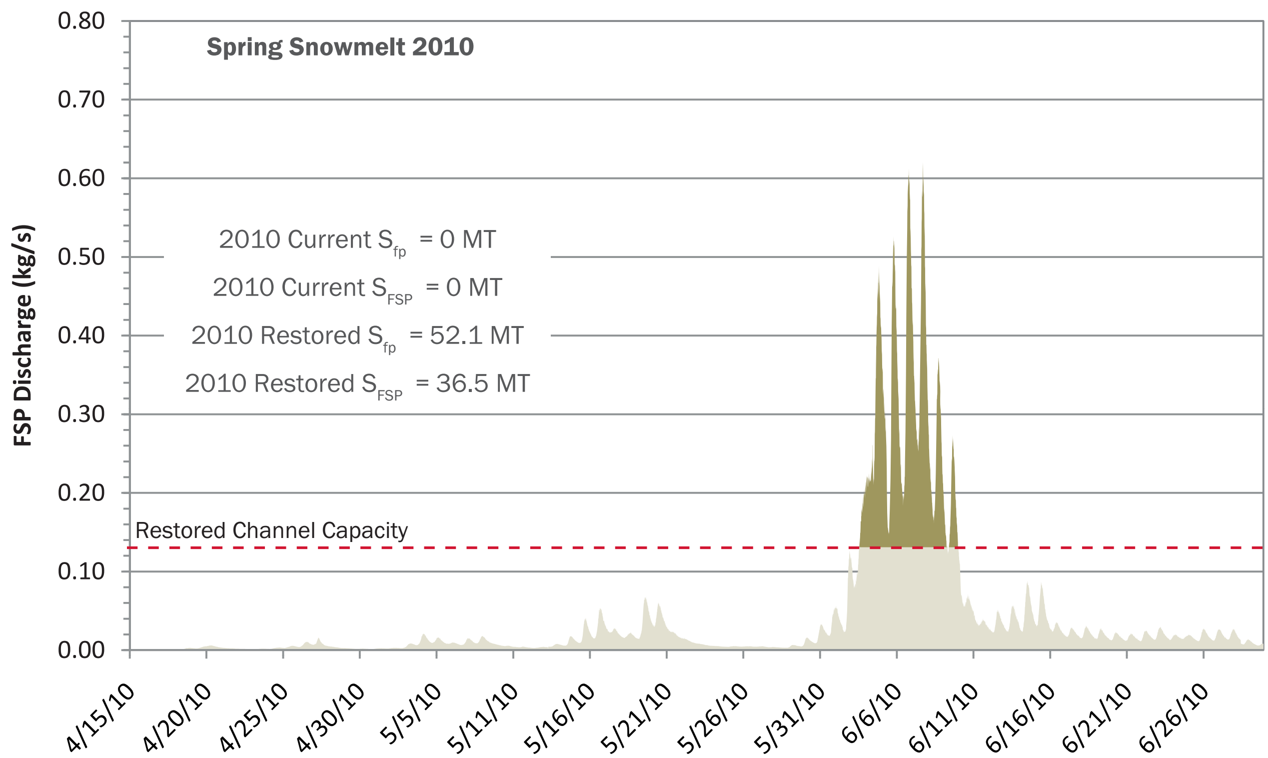
WY09 AMD WY10 4/5L SPRING HYDROGRAPHS

FIGURE 16

4/5L (ENTRENCHED) SPRING FLOODPLAIN FSP LOADS

$S_{FSP} = S_{fp} * R_{FSP}$





[1] Assumes $R_{FSP} = 0.7$.

S_{FSP}: FSP load retained on floodplain

S_{fp}: FSP load delivered to the floodplain

R_{FSP}: FSP floodplain retention coefficient

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Table 11. Comparison of current and restored 4/5L floodplain volume and FSP load calculations.

Spring Snowmelt	Q_{CC}		V_{FP} (ac-ft)		S_{fp} (MT)		S_{FSP} (MT), where R_{FSP}= 0.7		ΔFSP (MT)
	Current	Restored	Current	Restored	Current	Restored	Current	Restored	
WY2009	2,300	525	0	88.3	0	1.2	0	0.8	0.8
WY2010			0	2,600	0	52.1	0	36.5	36.5

The ΔFSP of 18 MT/yr is limited to the predicted FSP mass retained on the floodplain and does not include the additional expected FSP load reduction associated with decreased channel erosion. It is reasonable to assume that this average value is representative of an average annual FSP load reduced with the knowledge that there are many years when either no floodplain inundation occurs or events are much greater than those evaluated. However, in future analyses FSP load reduction estimates will include a more representative distribution of discharge conditions by leveraging the extensive USGS LTIMP datasets. The estimate of 18 MT/yr is consistent with initial estimates of 22 MT/year FSP reduction as a result increased floodplain retention calculated for the Trout Creek restoration project using a simple method that did leverage the existing local USGS datasets (2NDNATURE 2010a)[2].

There is a wide range of average annual total suspended sediment loading estimates for the mouth of the Upper Truckee River using the USGS long-term data sets (Table 12), but little to no FSP data available prior to this study. Applying the FSP:TSS ratio measured in the Upper Truckee for this study of 0.4, the average annual FSP loading of Upper Truckee River to Lake Tahoe is estimated to be 1,380 MT/yr. The average annual FSP load reduction estimated for the restoration of reach 4/5L would therefore be on the order of 1% of the total annual FSP load to the lake from UTR.

Table 12. Comparison of Upper Truckee River annual loading rates.

Reference	Notes	# years of data	TSS (MT/year)	FSP[1] (MT/year)
Reuter and Miller (2000)	WY1989-WY1996; LTIMP monitoring	8	3,305	1,322
Simon et al. (2003)	WY1977-WY2002; based on mean daily discharge and suspended sediment concentrations	24	2,200	880
LTIMP[2]	Monitoring results with standard deviation of 2,572 MT	24	3,189	1,276
LSPC (Tetra Tech 2007)[2]	Lake Tahoe Watershed Model results; Model calibration/validation period from 1994-2004	11	5,091	2,036
		Average	**3,446**	**1,379**

[1] TSS loading rate is converted to FSP based on 2NDNATURE water quality results suggesting the average % TSS <16 μm is 40%.
[2] As reported in Table 4-41 of the Lake Tahoe TMDL Technical Report (LRWQCB and NDEP 2010).

[2] Value of 22 MT/yr obtained from Table 7 (2NDNATURE 2010a) where the increased floodplain retention estimate of 110 MT/yr of fine sediment (<63μm) * 20% of < 63 μm as < 16 μm = 22 MT/yr.

ANALYSIS LIMITATIONS

This approach is limited for the following reasons:

- It relies upon the data from two events on a single floodplain.
- The quantification of floodplain volume assumes that all water in overbank conditions ($Q>Q_{CC}$) reaches the floodplain. This likely leads to a small overestimate in load reductions because, in reality, a portion of the water may remain vertically above the stream channel without interacting with the floodplain.
- The floodplain loading rate uses the discharge versus FSP concentration rating curve for all samples (the middle curve in Figure 10), which means the FSP concentrations are likely overestimated during the falling limb and underestimated during the rising limb. We assume the trade off is negligible, but SNPLMA Round 9 research has included continuous turbidity measurements to refine the FSP(Q) values. Future analyses will determine the relative difference in event load calculations by separating the rising and falling limb instead of applying the combined rating curve.
- The R_{FSP} calculations assume a uniform FSP retention coefficient, irrespective of the depth, velocity or area of inundation on the floodplain or the density, distribution and characteristics of the floodplain vegetation. However, all of these factors are assumed to play an important role in the deposition of sediment (i.e., retention will increase with increased distance from channel and decrease with increased water depth due to turbulent flow and less interaction with vegetation). Tahoe-specific research is currently being conducted by both TERC (Andrews and Schladow 2010a; 2010b) and the 2NDNATURE team (2NDNATURE 2010a) to continue to improve our understanding of the characteristics to which R_{FSP} is most sensitive.
- A large number of assumptions have been made to extrapolate available meteorologic and hydrologic datasets, as well as in the interpretation of the data collected during this research. However, all assumptions are clearly documented and are assumed reasonable by the researchers.
- The prediction of FSP load reduction for the "hypothetical" restoration of site 4/5L provided above does not incorporate the linear feet of stream restored nor the area of active floodplain created. This will be a critical component of the SLRT development (2NDNATURE 2010a) due to the need to correlate the extent of restored floodplain to the expected water quality benefit.
- This research does provide evidence that FSP retention by floodplains does occur and may provide a significant FSP load reduction during overbank flow events. However, the load reduction estimates provided herein are not yet directly comparable to an estimate of load reductions achievable by stream restoration. First, this estimate only includes the FSP load reduction associated with floodplain retention and does not include the potential FSP load reduction associated with the decreased channel erosion as a result of a reduced wetted

perimeter. Although, based on available data, it is expected that floodplain retention due to changes in channel capacity will be a greater fraction of the overall FSP load reduction (2NDNATURE 2010a). Secondly, the FSP load retained on the MOD1 floodplain is from some combination of urban, upland and stream sediment sources and the disassociation of these relative contributions may be necessary prior to incorporating FSP load reduction estimates into the Lake Clarity Crediting Program (LRWQCB and NDEP 2009).

FINDINGS AND FUTURE RESEARCH

DATA COLLECTION

One of the key objectives of the 2NDNATURE research was to develop cost-effective, repeatable data collection protocols to inform our understanding of FSP fate and transport in fluvial systems and obtain data that could inform methods to predict the FSP load reductions as a result of stream restoration actions. 2NDNATURE installed a number of data collection devices to evaluate the effectiveness of these techniques:

- The vertical profile sampler (VPS) is an innovative technique to collect water quality samples throughout the water column during a range of stream discharge events. The results indicate the water column is well-mixed with respect to FSP concentrations (see Figure 9) and therefore this data validates that surface grab samples can be collected as a cost-effective proxy for water column FSP concentrations to reduce sampling and analytical costs. This finding also suggests that high resolution turbidity sampling within a stream channel, where the location of the probe is vertically fixed in the water column, can be reasonably assumed to be representative of the overall vertical turbidity for a given discharge. This is a valuable finding that improves our confidence in the continuous turbidity datasets being obtained on Trout Creek for WY10 and WY11 (2NDNATURE 2010a) and may be a recommended approach to long-term FSP monitoring in Tahoe Basin streams.
- The vertical profile FSP dataset validates that FSP follows the delivery patterns of other pollutants in streams (Stubblefield et al. 2006) with the bulk of the FSP event load being delivered during the rising limb of the hydrograph. Future quantification of FSP loads in Tahoe Basin streams that rely upon grab samples must consider the location of sample collection on the hydrograph in event, seasonal and annual load calculations.
- The compilation of existing field turbidity and FSP concentration data from this research (Upper Truckee River) and Trout Creek (2NDNATURE 2010b) provide promising evidence that field turbidity is a consistent and reliable proxy for laboratory analyses for grain size distribution. Figure 8 does suggest slightly different rating curves for each stream and therefore the temporal and spatial range of data collection should continue to be expanded to validate these preliminary curves. However, this finding significantly increases the amount of FSP loading data

that can be obtained from Tahoe Basin streams using very cost-effective, yet reliable, techniques.

- Passive samplers have shown to be a reliable and cost effective method to sample the sediment concentrations of waters inundating a floodplain. Strategic placement of the samplers at the upstream and downstream boundary of a floodplain can provide valuable FSP data to inform estimates of actual retention coefficient (R_{FSP}). However, the logistics associated with site maintenance were greater than originally anticipated and the cost-effectiveness of passive samplers is decreased as a result of the intensive deployment requirements. Seasonal maintenance is necessary to protect housing from vandalism and damage, and there is a continued need for field personnel to be on-site immediately prior to and following targeted events, yet not all targeted events yield samples if no overbank flow occurs.
- The 12" steel pins installed within the MOD1 floodplain were too small to effectively measure changes in floodplain sediment volumes. Despite orange flagging, the sediment pins were difficult to relocate and many pins were disturbed and/or removed between field-personnel visits to the site. Protocols have been improved for SNPLMA Round 9 research and 3-foot rebar stakes were installed and surveyed on the Trout Creek floodplain in Spring 2010 (2NDNATURE 2010a).
- In 2008, ten 1-ft^2 artificial turf plots were installed on the MOD1 floodplain to estimate the mass of suspended sediment removed by vegetation during floodplain inundation. However, contamination of the plots by airborne sediment was common, variable and nearly impossible to control. The elevated and variable sediment mass accumulated on control plots reduced researchers' confidence that exposed turf plots could be used to reliably quantify the FSP retention associated with vegetation interaction on the floodplain. Floodplain transect protocols have been modified for the SNPLMA Round 9 research (2NDNATURE 2010a), and include visual observations of sediment indicator height on floodplain vegetation by dominant vegetation class before and following spring floodplain inundation.
- This research obtains and presents fine sediment particle data by mass, rather than number of particles. While the Lake Tahoe TMDL identifies the number of particles <16 μm as the primary pollutant impairing Lake Tahoe clarity (LRWQCB and NDEP 2010), the data analysis and data management of particle count data is laborious and complicated. During the first year of data collection, stream samples were submitted to TERC for both TSS and particle grain size distribution analysis. TERC provided the grain size distribution as # of particles to maintain consistency with the Lake Tahoe TMDL. However, the comparison of the sample particle counts (converted to mass per volume) to TSS concentrations was inconsistent. The total concentrations based on particle analysis ranged from 10 to 159% of the TSS concentration provided by lab, and therefore could not be reliably used to calculate FSP concentration (mg/L). At that time, it was apparent that the QA/QC procedures for particle counts had not been fully developed. As an alternative, water samples were submitted to an analytical laboratory for TSS

analysis and particle grain size distribution expressed as a % of sample less than 16 μm. The FSP concentration is easily calculated and provides a common water quality unit of measure to simplify data interpretation and analysis. The Lake Tahoe TMDL (LRWQCB and NDEP 2010) and Lake Clarity Crediting Program (LRWQCB and NDEP 2009) include a linear conversion factor to simply convert mass to # of particles and this relationship should continue to be developed, tested and refined by the local academics who have access to the required analytical instrumentation.

DATA ANALYSIS AND MODELLING APPLICATIONS

The second objective was to develop analysis protocols to apply the data obtained to quantify the fine-sediment load retention associated with floodplain inundation for either existing or future restored channel morphology. The third and final objective was the incorporation of these data into future methods and models to predict the water quality benefit of stream restoration actions. The following summarizes the data analysis and applications of the data:

- A reasonable quantification method is provided that integrates site-specific channel capacity with stream FSP loading rate curves to estimate the mass of FSP delivered to a floodplain (S_{fp}) over spring snowmelt events. The data analysis approach can be applied to any particular site or time interval of interest. The passive sample datasets do provide applicable data to estimate the fraction of the FSP load retained on the floodplain (R_{FSP}) for the events evaluated. The method is then applied to estimate the fine sediment load reduction (ΔFSP) as a result increased frequency of floodplain deposition that may have been expected if the entrenched site had been restored prior to WY09 and WY10 to demonstrate the initial predictive utility of such an approach.
- The researchers leverage a wide array of existing datasets to extrapolate and estimate the meteorologic, hydrologic and floodplain FSP retention characteristics for the sites in question. In addition, the existing data from one site for two events is extrapolated to provide a prediction of the average annual FSP load reduction as a result of a planned restoration effort on the Upper Truckee River. Data accuracy and completeness must continually be balanced by costs to obtain, manage, and analyze the data and the end use of the datasets. While absolute accuracy and representativeness of the existing datasets is below what can be expected if all measurements were obtained at the best possible locations and intervals, all assumptions are documented and the findings are expected to be relatively accurate. Additional work is still necessary to spatially extrapolate the data to other stream channels within the Tahoe Basin. However, this applied research provides invaluable progress towards identifying cost-effective data collection techniques and a standardized estimation method to predict the FSP load retention on a floodplain as a result of stream restoration and adequately inform management decisions in the Tahoe Basin.

- The combined efforts of this research and the interim products from the SLRT development work (2NDNATURE 2010a; 2010b) provide complementary progress towards a stream load reduction methodology. The research presented herein relies upon available data with a long list of assumptions to predict an average annual FSP load reduction from the entrenched site (4/5L) of 18 MT/yr (2.1 $x10^{18}$ particles/yr). This estimate aligns with the 22 MT/yr FSP retention estimated as a result of Trout Creek restoration using a simple probability analysis of the available USGS hydrology and sediment dataset (2NDNATURE 2010a). The site-specific floodplain retention data from the UTR non-entrenched site (MOD1) fill key data gaps and will be incorporated into the SLRT development and estimates on Trout Creek to be completed over the next year.
- The development of a repeatable methodology to predict the FSP load reduction as a result of stream restoration will have to be developed based on application of fluvial and pollutant fate and transport principles, existing and readily obtainable datasets, and well-documented hypotheses. There are a number of critical concepts that will need to be considered and potentially incorporated into a standardized tool:
    - Additional data and understanding is necessary to develop a reasonable approach to estimate the FSP floodplain retention coefficient as a function of hydrologic and floodplain characteristics that are hypothesized to directly influence FSP retention. The greatest challenge in validating assumptions and empirical relationships is the infrequency of the overbank flows necessary to obtain the needed data.
    - An acceptable stream load reduction tool will need to incorporate the expected FSP load reduction as a function of linear feet of stream restored and floodplain area created. In concept, we know there is some critical area of floodplain necessary to optimize FSP retention given the frequency and magnitude of overbank flow events: too small a floodplain area will fail to achieve retention because more frequent overbank flows (recurrence interval < 10 yrs) are too deep and velocities too high and too extensive floodplains may not be inundated frequently enough to justify the additional cost. This concept can be constrained by limiting the estimate of FSP floodplain retention to the discharge range as defined by the pre- and post-restoration channel capacity. Flows lower than the restored (post) channel capacity will never access the floodplain and flows greater than the existing (pre-restoration) channel capacity would access the floodplain regardless of restoration actions.
    - The 2NDNATURE team will continue to develop specific components of the SLRT with existing funding (2NDNATURE 2010a 2010b) such that the methodology will provide stream restoration practitioners with a tool to evaluate alternatives of critical design components with respect to predicted water quality benefits.

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APPENDIX A. WATER QUALITY RESULTS

Table A. Water quality results.

Date	Time	Site	Sample Type (PS, VPS, SF)	TSS (mg/L)	FSP Conc (mg/L)	Field Turb (ntu)
4/29/08	16:10	MDVPSF	SF	4.8	-	-
4/29/08	16:10	MDVP02	VPS	4.0	-	-
4/29/08	16:10	MDVP09	VPS	4.4	-	-
4/29/08	16:10	MDVP16	VPS	4.0	-	-
4/29/08	16:10	MDVP23	VPS	4.0	-	-
4/29/08	18:00	H6VPSF	SF	10.0	-	-
4/29/08	18:00	H6VP03	VPS	8.7	-	-
4/29/08	18:00	H6VP13	VPS	10.7	-	-
4/29/08	18:00	H6VP23	VPS	5.6	-	-
4/29/08	18:00	H6VP33	VPS	5.2	-	-
5/16/08	18:59	MDVPSF	SF	26.0	-	-
5/16/08	18:59	MDVP02	VPS	32.8	-	-
5/16/08	18:59	MDVP13	VPS	28.4	-	-
5/16/08	18:59	MDVP24	VPS	26.8	-	-
5/16/08	18:59	MDVP35	VPS	21.6	-	-
5/16/08	20:14	H6VPSF	SF	38.0	-	-
5/16/08	20:14	H6VP03	VPS	34.4	-	-
5/16/08	20:14	H6VP17	VPS	42.8	-	-
5/16/08	20:14	H6VP31	VPS	36.4	-	-
5/16/08	20:14	H6VP45	VPS	43.2	-	-
5/19/08	13:45	MDVPSF	SF	8.0	-	-
5/19/08	13:45	MDVP02	VPS	7.2	-	-
5/19/08	13:45	MDVP08	VPS	8.4	-	-
5/19/08	13:45	MDVP16	VPS	10.0	-	-
5/19/08	13:45	MDVP24	VPS	9.6	-	-
5/19/08	15:45	H6VPSF	SF	4.8	-	-
5/19/08	15:45	H6VP03	VPS	5.6	-	-
5/19/08	15:45	H6VP13	VPS	5.2	-	-
5/19/08	15:45	H6VP21	VPS	6.0	-	-
5/19/08	15:45	H6VP31	VPS	6.4	-	-
10/4/08	8:00	MDVPSF	SF	5.6	-	-
10/4/08	8:00	MDVP02	VPS	3.6	-	-
10/4/08	8:00	MDVP07	VPS	3.6	-	-
10/4/08	8:00	MDVP12	VPS	5.6	-	-
10/4/08	8:35	H6VPSF	SF	2.0	-	-
10/4/08	8:35	H6VP03	VPS	0.8	-	-
10/4/08	8:35	H6VP10	VPS	1.2	-	-
10/4/08	8:35	H6VP17	VPS	3.2	-	-
11/1/08	13:22	MDVPSF	SF	4.0	-	-
11/1/08	13:22	MDVP02	VPS	2.8	-	-
11/1/08	13:22	MDVP07	VPS	4.4	-	-
11/1/08	13:22	MDVP12	VPS	7.6	-	-
11/1/08	13:22	MDVP17	VPS	2.0	-	-
11/1/08	14:10	H6VPSF	SF	1.2	-	-
11/1/08	14:10	H6VP03	VPS	6.8	-	-
11/1/08	14:10	H6VP10	VPS	3.2	-	-
11/1/08	14:10	H6VP17	VPS	4.4	-	-
11/1/08	14:10	H6VP24	VPS	5.6	-	-

- denotes no available data. 2008 particle size distribution results could not be reliably converted to FSP concentration. Field turbidity was not collected until Spring 2010.

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Table A (continued). Water quality results.

Date	Time	Site	Sample Type (PS, VPS, SF)	TSS (mg/L)	FSP Conc (mg/L)	Field Turb (ntu)
11/2/08	9:30	MDVPSF	SF	6.4	-	-
11/2/08	9:30	MDVP02	VPS	9.2	-	-
11/2/08	9:30	MDVP07	VPS	7.2	-	-
11/2/08	9:30	MDVP12	VPS	4.0	-	-
11/2/08	9:30	MDVP17	VPS	10.4	-	-
11/2/08	10:20	H6VPSF	SF	5.6	-	-
11/2/08	10:20	H6VP03	VPS	2.4	-	-
11/2/08	10:20	H6VP10	VPS	6.4	-	-
11/2/08	10:20	H6VP17	VPS	5.2	-	-
11/2/08	10:20	H6VP24	VPS	7.2	-	-
4/19/09	17:40	MDVPSF	SF	5.0	1.9	-
4/19/09	17:40	MDVP02	VPS	4.0	1.3	-
4/19/09	17:40	MDVP10	VPS	3.0	1.1	-
4/19/09	17:40	MDVP18	VPS	4.0	1.4	-
4/19/09	17:40	MDVP26	VPS	4.0	1.4	-
4/19/09	19:30	H6VPSF	SF	6.0	2.1	-
4/19/09	19:30	H6VP03	VPS	8.0	3.0	-
4/19/09	19:30	H6VP13	VPS	7.0	2.7	-
4/19/09	19:30	H6VP23	VPS	6.0	2.2	-
4/19/09	19:30	H6VP33	VPS	7.0	2.4	-
4/22/09	12:00	XS1A	PS	27.0	10.5	-
4/22/09	22:56	MDVPSF	SF	38.0	13.6	-
4/22/09	22:56	MDVP02	VPS	37.0	11.2	-
4/22/09	22:56	MDVP13	VPS	39.0	12.0	-
4/22/09	22:56	MDVP24	VPS	39.0	13.1	-
4/22/09	22:56	MDVP35	VPS	36.0	12.4	-
4/22/09	23:53	H6VPSF	SF	37.0	11.2	-
4/22/09	23:53	H6VP03	VPS	34.0	10.0	-
4/22/09	23:53	H6VP17	VPS	28.0	8.6	-
4/22/09	23:53	H6VP31	VPS	28.0	8.5	-
4/22/09	23:53	H6VP45	VPS	37.0	11.4	-
4/30/09	9:23	MDVPSF	SF	1.0	0.4	-
4/30/09	9:23	MDVP02	VPS	1.0	0.4	-
4/30/09	9:23	MDVP09	VPS	1.0	1.0	-
4/30/09	9:23	MDVP16	VPS	2.0	1.8	-
4/30/09	9:23	MDVP23	VPS	1.0	0.4	-
4/30/09	11:00	H6VPSF	SF	1.0	1.0	-
4/30/09	11:00	H6VP03	VPS	1.0	0.9	-
4/30/09	11:00	H6VP12	VPS	1.0	0.8	-
4/30/09	11:00	H6VP21	VPS	1.0	1.0	-
4/30/09	11:00	H6VP30	VPS	1.0	1.0	-

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Table A (continued). Water quality results.

Date	Time	Site	Sample Type (PS, VPS, SF)	TSS (mg/L)	FSP Conc (mg/L)	Field Turb (ntu)
5/2/09	9:47	MDVPSF	SF	12.0	3.9	-
5/2/09	9:47	MDVP02	VPS	16.0	4.5	-
5/2/09	9:47	MDVP14	VPS	23.0	6.8	-
5/2/09	9:47	MDVP26	VPS	17.0	5.2	-
5/2/09	9:47	MDVP38	VPS	12.0	4.0	-
5/2/09	11:27	H6VPSF	SF	11.0	3.4	-
5/2/09	11:27	H6VP03	VPS	15.0	6.0	-
5/2/09	11:27	H6VP18	VPS	14.0	5.7	-
5/2/09	11:27	H6VP33	VPS	13.0	4.4	-
5/2/09	11:27	H6VP48	VPS	12.0	3.7	-
5/2/09	12:00	XS1A	PS	370.0	99.2	-
5/2/09	12:00	XS1C	PS	140.0	29.0	-
5/2/09	12:00	XS2F	PS	22.0	4.0	-
5/2/09	12:00	XS3H	PS	75.0	17.0	-
5/2/09	12:00	XS3J	PS	42.0	13.4	-
5/2/09	12:00	XS3L	PS	12.0	1.9	-
5/7/09	11:33	MDVPSF	SF	3.0	2.9	-
5/7/09	11:33	MDVP02	VPS	2.0	1.0	-
5/7/09	11:33	MDVP13	VPS	2.0	1.0	-
5/7/09	11:33	MDVP24	VPS	2.0	2.0	-
5/7/09	11:33	MDVP35	VPS	2.0	1.1	-
5/7/09	12:55	H6VPSF	SF	3.0	1.0	-
5/7/09	12:55	H6VP03	VPS	5.0	1.6	-
5/7/09	12:55	H6VP17	VPS	4.0	1.3	-
5/7/09	12:55	H6VP31	VPS	2.0	2.0	-
5/7/09	12:55	H6VP45	VPS	3.0	1.1	-
5/18/09	12:00	XS1A	PS	5.0	1.7	-
5/18/09	12:00	XS3H	PS	54.0	18.6	-
5/18/09	19:30	MDVPSF	SF	9.0	3.9	-
5/18/09	19:30	MDVP02	VPS	11.0	5.0	-
5/18/09	19:30	MDVP13	VPS	12.0	4.6	-
5/18/09	19:30	MDVP24	VPS	9.0	3.1	-
5/18/09	19:30	MDVP35	VPS	10.0	4.3	-
5/18/09	20:45	H6VPSF	SF	13.0	4.8	-
5/18/09	20:45	H6VP03	VPS	14.0	4.7	-
5/18/09	20:45	H6VP17	VPS	13.0	4.4	-
5/18/09	20:45	H6VP31	VPS	13.0	5.4	-
5/18/09	20:45	H6VP45	VPS	11.0	4.4	-
5/21/10	18:31	MDVPSF	SF	3.0	3.0	2.3
5/21/10	18:31	MOD 1 VPS 2	VPS	11.0	4.5	5.12
5/21/10	18:31	MOD 1 VPS 12	VPS	4.0	4.0	2.25
5/21/10	18:31	MOD 1 VPS 22	VPS	3.0	3.0	2.81
5/21/10	18:31	MOD 1 VPS 32	VPS	2.0	2.0	1.37
5/21/10	19:32	H6VPSF	SF	3.0	3.0	2.17
5/21/10	19:32	Hole 6 VPS 3	VPS	5.0	1.8	2.22
5/21/10	19:32	Hole 6 VPS 17	VPS	4.0	4.0	1.9
5/21/10	19:32	Hole 6 VPS 31	VPS	4.0	1.3	2.51
5/21/10	19:32	Hole 6 VPS 45	VPS	2.0	1.9	2.33

Table A (continued). Water quality results.

Date	Time	Site	Sample Type (PS, VPS, SF)	TSS (mg/L)	FSP Conc (mg/L)	Field Turb (ntu)
6/2/10	19:30	MDVPSF	SF	52.0	14.6	23.6
6/2/10	19:30	MOD1VPS2	VPS	60.0	16.4	23.9
6/2/10	19:30	MOD1VPS14	VPS	69.0	20.9	19.6
6/2/10	19:30	MOD1VPS26	VPS	65.0	17.6	22.6
6/2/10	19:30	MOD1VPS38	VPS	93.0	24.4	30.3
6/2/10	20:46	HOLE6VPS3	VPS	81.0	23.6	22.9
6/2/10	20:46	HOLE6VPS20	VPS	74.0	22.4	36.8
6/2/10	20:46	HOLE6VPS37	VPS	74.0	24.1	27.4
6/2/10	20:46	H6VPSF	SF	66.0	18.4	24
6/2/10	20:46	HOLE6VPS54	VPS	70.0	20.2	26.2
6/3/10	12:00	XS1A	PS	10.0	3.3	2.97
6/3/10	12:00	XS1C	PS	74.0	11.9	11.6
6/3/10	12:00	XS2G	PS	53.0	16.2	20.8
6/3/10	12:00	XS3H	PS	56.0	14.1	15.6
6/3/10	12:00	XS3J	PS	85.0	12.5	8.98
6/3/10	12:00	XS3L	PS	10.0	3.6	6.31
6/3/10	18:34	MOD1VPS2	VPS	52.0	15.4	18
6/3/10	18:34	MOD1VPS16	VPS	55.0	16.8	18.9
6/3/10	18:34	MOD1VPS30	VPS	50.0	15.9	17.4
6/3/10	18:34	MDVPSF	SF	46.0	14.7	7.71
6/3/10	18:34	MOD1VPS44	VPS	49.0	15.9	16.2
6/3/10	19:30	H6VPSF	SF	50.0	16.1	15
6/3/10	19:30	HOLE6VPS3	VPS	43.0	11.9	15.2
6/3/10	19:30	HOLE6VPS22	VPS	51.0	15.0	16.8
6/3/10	19:30	HOLE6VPS41	VPS	44.0	13.0	15.9
6/3/10	19:30	HOLE6VPS60	VPS	49.0	13.9	16.2
6/4/10	18:40	MDVPSF	SF	96.0	30.2	39.1
6/4/10	18:40	MOD1VPS2	VPS	120.0	38.7	40.3
6/4/10	18:40	MOD1VPS18	VPS	110.0	33.7	39.4
6/4/10	18:40	MOD1VPS34	VPS	120.0	37.6	42.2
6/4/10	18:40	MOD1VPS50	VPS	94.0	29.5	39.7
6/4/10	19:35	HOLE6VPS3	VPS	93.0	28.5	32.3
6/4/10	19:35	HOLE6VPS24	VPS	100.0	30.8	31.6
6/4/10	19:35	HOLE6VPS45	VPS	82.0	26.2	37.7
6/4/10	19:35	H6VPSF	SF	90.0	29.5	33
6/4/10	19:35	HOLE6VPS66	VPS	91.0	31.3	38.2
6/7/10	12:00	XS1B	PS	140.0	33.2	26.7
6/7/10	12:00	XS4PSN	PS	37.0	12.1	23.9
6/7/10	23:39	MDVPSF	SF	23.0	8.3	10.6
6/7/10	23:39	MOD1VPS2	VPS	28.0	8.9	10.3
6/7/10	23:39	MOD1VPS20	VPS	28.0	8.6	10.7
6/7/10	23:39	MOD1VPS38	VPS	29.0	8.8	9.75
6/7/10	23:39	MOD1VPS56	VPS	23.0	8.3	8.99
6/8/10	0:21	H6VPSF	SF	22.0	8.5	12.3
6/8/10	0:21	HOLE6VPS49	VPS	31.0	10.2	10.3
6/8/10	0:21	HOLE6VPS72	VPS	24.0	9.1	8.9
6/8/10	0:21	HOLE6VPS3	VPS	29.0	9.1	12.4
6/8/10	0:21	HOLE6VPS26	VPS	27.0	8.8	10.5