Annual Stormwater Monitoring Report

Water Year 2019

Prepared by

Tahoe Resource Conservation District

for the

Implementers' Monitoring Program

component of the

Regional Stormwater Monitoring Program

Submitted to the

Lahontan Regional Water Quality Control Board and the

Nevada Division of Environmental Protection

March 15, 2020

Annual Stormwater Monitoring Report

Implementers' Monitoring Program (IMP), component of the Regional Stormwater Monitoring Program (RSWMP)

Funding for this project is currently provided in full through agreements with the City of South Lake Tahoe, El Dorado County, Placer County, Douglas County, Washoe County, and the Nevada Department of Transportation.

Funding for this project has previously been provided in part by the USDA Forest Service Lake Tahoe Basin Management Unit through the Southern Nevada Public Lands Management Act and the Department of Conservation.

Funding has previously been provided in part through an agreement with the State Water Resources Control Board using funds from Proposition 84.

The contents of this document do not necessarily reflect the views and policies of the foregoing, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

Submitted by:

California

El Dorado County

Placer County

City of South Lake Tahoe

Nevada

Douglas County

Washoe County

Nevada Department of Transportation

TABLE OF CONTENTS

1. Monitoring Purpose 1
2. Study Design 1
   - 2.1 SR431 Catchment Description 3
   - 2.2 Elks Club Catchment Description 3
   - 2.3 Lakeshore Catchment Description 4
   - 2.4 Pasadena Catchment Description 5
   - 2.5 Speedboat Catchment Description 5
   - 2.6 Tahoe Valley Catchment Description 5
   - 2.7 Tahoma Catchment Description 6
   - 2.8 Upper Truckee Catchment Description 6
3. Data Collection Methods, Sampling Protocols, Analytic Methods 7
4. Data Management Procedure 8
5. Data Analysis 9
6. Catchment Outfall Monitoring 10
   - 6.1 Summary Data for All Monitoring Sites 10
   - 6.2 Summary Data for Individual Catchments 18
7. BMP Effectiveness Monitoring 63
   - 7.1 SR431 63
   - 7.2 Elks Club 70
8. Trends Analysis 73
   - 8.1 SR431 Contech MFS Inflow 74
   - 8.2 SR431 Jellyfish Inflow 77
   - 8.3 Elks Club 80
   - 8.4 Lakeshore 81
   - 8.5 Pasadena 82
   - 8.6 Speedboat 84
   - 8.7 Tahoe Valley 86
   - 8.8 Tahoma 88
   - 8.9 Upper Truckee 90
9. PLRM Modeling Results 92
10. Lessons Learned 93
11. Changes: Accepted and Proposed 95

References 96

Appendix A: Raw Analytical Data 97

Appendix B: Quality Assurance/Quality Control Summary 100

List of Acronyms

AC	Autosampler Composite Sample
Autosamplers	ISCO brand automated samplers
BMP	Best Management Practice
cf	cubic feet
cfs	cubic feet per second
CI	Contech MFS Inflow
CICU	Commercial, Industrial, Communications, Utilities
CMP	Corrugated Metal Pipe
CPP	Corrugated Plastic Pipe
CO	Contech MFS Outflow
CPC	Characteristic Pollutant Concentration
CRC	Characteristic Runoff Concentration
DMS	Data Management System
EC	Elks Club
EDCY	El Dorado County Yard meteorological station
EMC	Event Mean Concentration
FB	Field Blank
FIG	Framework and Implementation Guidance document for RSWMP
FSP	Fine Sediment Particles
GS	Grab Sample
IMP	Implementers' Monitoring Program
JI	Jellyfish Inflow
JO	Jellyfish Outflow
Lahontan	Lahontan Regional Water Quality Control Board
LS	Lakeshore
MS	Manual Sample
NDEP	Nevada Division of Environmental Protection
NDOT	Nevada Department of Transportation
NPDES	National Pollutant Discharge Elimination System
NTU	Nephlometric Turbidity Units
PD	Pasadena
PI	Pasadena Inflow
PO	Pasadena Outflow
PLRM	Pollutant Load Reduction Model
PSD	Particle Size Distribution
QAPP	Quality Assurance Project Plan
QAQC	Quality Assurance, Quality Control
ROW	Right-of-Way
RSWMP	Regional Stormwater Monitoring Program
SAP	Sampling and Analysis Protocol
SB	Speedboat
SR	State Route 431
TA	Tahoma
Tahoe RCD	Tahoe Resource Conservation District

TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
TV	Tahoe Valley
USDA	United States Department of Agriculture
UT	Upper Truckee
WY	Water Year

1. Monitoring Purpose

Stormwater monitoring began in 2013 under the Implementers' Monitoring Program (IMP) to collectively fulfill California National Pollutant Discharge Elimination System (NPDES) Permit requirements and Nevada Interlocal Agreement commitments. IMP is a partnership between the California and Nevada implementing jurisdictions and was inspired by permit language that encouraged jurisdictions to comply collaboratively with regulatory requirements to promote cost savings through economies of scale. IMP is a partnership between the City of South Lake Tahoe, El Dorado County, Placer County, Douglas County, Washoe County, and the Nevada Department of Transportation (NDOT). Regulations require that California and Nevada jurisdictions in the Lake Tahoe Basin take measures to decrease pollutant loading from stormwater runoff in urbanized areas by implementing pollutant controls to decrease fine sediment particles (FSP, particles less than 16 microns) and nutrient inputs to Lake Tahoe. The Regional Stormwater Monitoring Program (RSWMP) was developed by Tahoe Resource Conservation District (Tahoe RCD) in partnership with IMP in 2015. A new NPDES permit was issued to California jurisdictions on March 9, 2017 for the second five-year term and aligned all monitoring activities with the RSWMP Framework and Implementation Guidance Document (FIG, Tahoe RCD et al 2017). In the second permit term (water years 2017-2021), California jurisdictions are collectively required to monitor urban catchment outfalls at a minimum of six sites and Best Management Practices (BMPs) at a minimum of two sites for flow volumes and pollutant loads. The renewed Nevada Interlocal Agreements require participation in IMP. Monitoring provides empirical data that will be used to assess nutrient and sediment loading in chosen catchments and evaluate BMP effectiveness at chosen BMPs.

All data has been collected in a manner consistent with RSWMP monitoring protocols outlined in the RSWMP FIG designed to provide consistent data collection, management, analysis, and reporting approaches so that results can easily align with RSWMP objectives. Data collected for permit and agreement compliance initiate efforts to satisfy RSWMP's primary objective of establishing sites around the Lake Tahoe Basin for long-term stormwater monitoring. Long-term data are useful in identifying status and trends in the watershed.

2. Study Design

During Water Year 2019 (WY19), eight catchments (monitoring sites) were monitored for continuous flow and sampled for water quality at eleven monitoring stations. The monitoring stations were the outfalls of seven of the eight selected catchments (seven stations) and the inflows to, and outflows from, two BMPs both located in the eighth catchment (SR431 - four stations). One of the catchment outfalls, Elks Club, is also monitored as a BMP. This exceeds the minimum regulatory requirement of six monitored catchments and two monitored BMPs in the second term. The extra catchment outfall (Elks Club) is supported through additional funding from El Dorado County. Additionally, the two side-by-side BMPs at SR431 are supported through additional funding from the Nevada Department of Transportation. The catchments were chosen because of their direct hydrologic connectivity to Lake Tahoe, diversity of urban land uses, range of sizes, and a reasonably equitable distribution among the participating jurisdictions. BMP effectiveness sites were selected because of their potential efficacy in treating storm water runoff characteristic of the Lake Tahoe Basin, the broad interest in data regarding the efficiency of the selected BMPs in reducing runoff volumes and pollutant loads (especially FSP), and the importance of determining maintenance intervals required to retain effectiveness. See Figure 1 for stormwater monitoring sites and meteorological station locations.

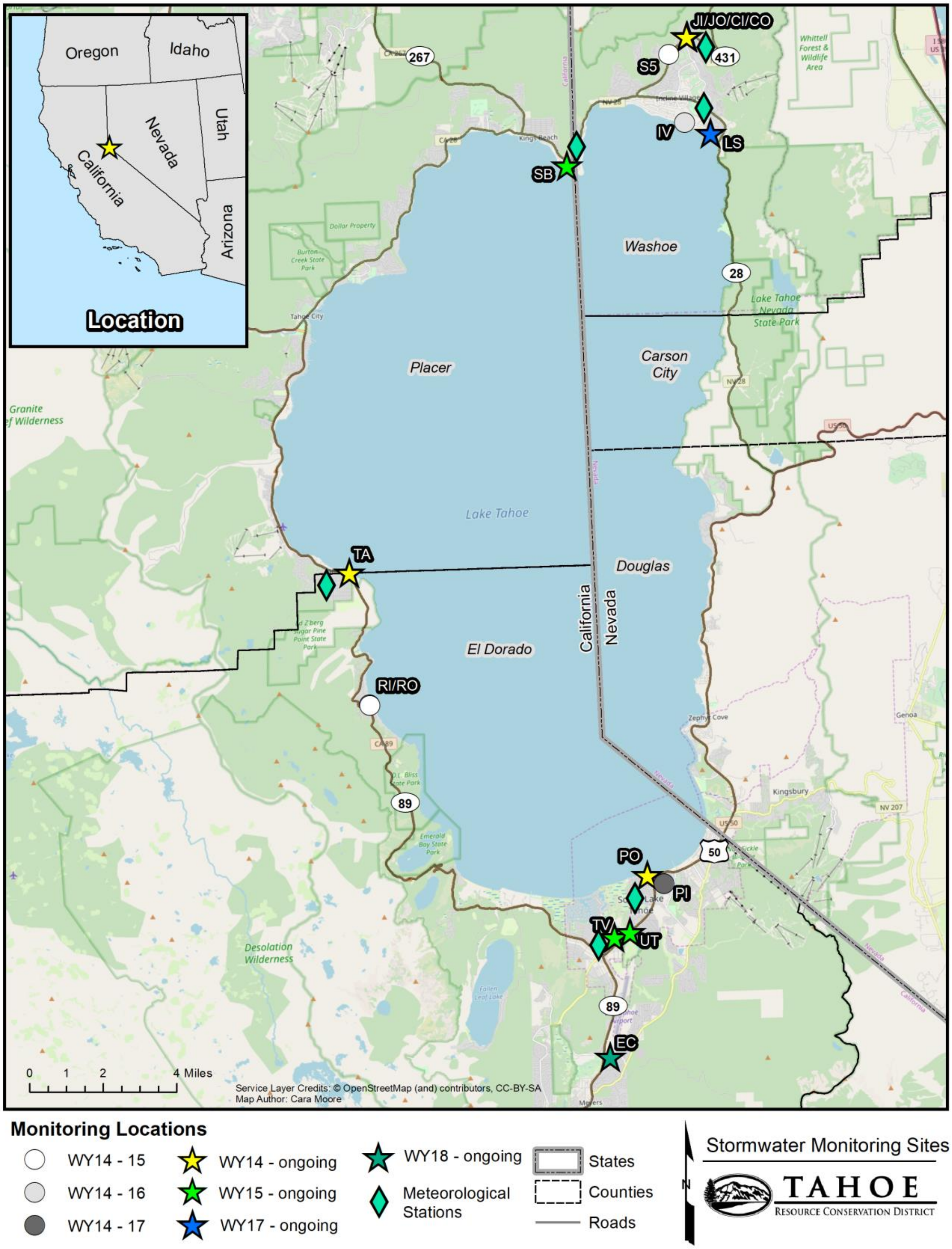

Figure 1 Past and current stormwater monitoring sites and ongoing meteorological stations. Jellyfish Inflow (JI), Jellyfish Outflow (JO), Contech MFS Inflow (CI), Contech MFS Outflow (CO), SR431 outfall (S5), Incline Village (IV), Lakeshore (LS), Speedboat (SB), Tahoma (TA), Rubicon Inflow (RI), Rubicon Outflow (RO), Tahoe Valley (TV), Upper Truckee (UT), Pasadena Inflow (PI), Pasadena Outflow (PO), and Elks Club (EC).

Table 1 summarizes the selected catchments and their corresponding designation as a catchment outfall monitoring site and/or BMP effectiveness monitoring site. Also included are the number of monitoring stations in the catchment, jurisdiction, total catchment area, percent impervious area, and dominant land uses in each catchment.

Table 1 Monitoring site specifics. Dominant urban land use is highlighted in dark pink, second most dominant in medium pink, and the third most dominant in light pink. The vegetated class was not considered in this ranking. SR431 has two checkmarks under BMP because there are two different cartridge filters at this site.

Catchment Name	Outfall	BMP	# Monitoring Stations	Jurisdiction	Total Acres	Impervious Area	Landuse: Single Family Residential	Multi-Family Residential	CICU*	Primary Roads	Secondary Roads	Vegetated
SR431		√√	4	NDOT	1.4	89%	0%	0%	0%	89%	0%	11%
Elks Club	√	√	1	El Dorado	14.4	29%	50%	0%	0%	9%	19%	22%
Lakeshore	√		1	Washoe	97.8	41%	2%	43%	31%	1%	10%	13%
Pasadena	√		1	CSLT	78.8	39%	52%	13%	5%	0%	16%	14%
Speedboat	√		1	Placer	29.0	30%	49%	3%	9%	4%	10%	25%
Tahoe Valley	√		1	CSLT, Caltrans	338.4	39%	19%	12%	20%	2%	13%	34%
Tahoma	√		1	Placer, El Dorado, Caltrans	49.5	30%	41%	4%	12%	3%	15%	25%
Upper Truckee	√		1	CSLT, Caltrans	10.5	72%	14%	7%	39%	14%	18%	8%

2.1 SR431 Catchment Description

The SR431 monitoring site is located on State Route 431 in Washoe County above Incline Village, Nevada. The 1.4-acre catchment encompasses NDOT right-of-way (ROW) of which approximately 89% is impervious. During winter months, when snow and ice may occasionally block stormwater infrastructure (like drop inlets) this catchment area may increase, though this is difficult to verify. This is the smallest catchment monitored and the outfall discharges directly into a perennial stream called Deer Creek which connects with Incline Creek and discharges into Lake Tahoe, giving this site the distinction of being directly connected to the lake despite being 2.5 miles away. SR431 was monitored as a catchment outfall site for two years (WY14-15), but is now only monitored for evaluating and comparing the effectiveness of two adjacent stormwater cartridge filter vaults, the Contech MFS and the Jellyfish, containing different types of cartridge filters (WY14 - ongoing). There are four monitoring stations at SR431: the inflow and outflow to the Contech MFS vault (CI, CO), and the inflow and outflow to the Jellyfish vault (JI, JO). Though located in a rural area with moderate highway traffic density, SR431 is the only site that isolates runoff from primary roads and can therefore be used to characterize runoff from one land use type. In addition, SR431 is the only site currently available where a true side-by-side comparison of stormwater cartridge filter types can be performed.

Runoff enters a transverse drain across a parking pull-out directly adjacent to SR431. It then flows through a pipe to a splitter chamber that should theoretically route equal amounts of flow through two inflow pipes, one to the Contech MFS inflow flume and then to the Contech MFS vault, and one to the Jellyfish inflow flume and then to the Jellyfish vault. This splitter chamber gets filled with accumulated sediment very quickly and without proper, consistent maintenance the volume often does not get split evenly. After the runoff has been treated in each vault, the flow exits the vaults through respective pipes that lead either to the Contech MFS outflow flume or the Jellyfish outflow flume and then to Deer Creek.

2.2 Elks Club Catchment Description

The Elks Club monitoring site is located on the northwest corner of Elks Club Drive and Bel Aire Circle in El Dorado County. It is monitored as a catchment outfall and a BMP at one monitoring station (EC). At 14.4 acres, it is a relatively small catchment comprised primarily of single family residential and secondary road land uses. Elks Club Drive is a fairly steep road that serves as the primary access road for this neighborhood. Runoff is channelized along the north side of the road and routed directly to the monitoring location adjacent to the roadside.

Prior to the summer of 2018, Elks Club Drive was in poor condition, covered in cracks and potholes. Visual observations and a pilot study on Pioneer Trail in El Dorado County from 2012-2014 suggested that the degraded road surface itself was contributing a substantial amount of fine sediment to stormwater runoff. The Elks Club monitoring site was established to determine if improving road condition would result in decreased FSP loads in stormwater runoff from this catchment. In the summer of 2018, El Dorado County completed an erosion control project in this catchment that included completely reconstructing Elks Club Drive and armoring the road shoulders and roadside channels with asphalt and rocks. A repaved road is more durable and less likely to deteriorate under the heavy equipment and plow blades used for snow removal operations. The smooth surface is easier to sweep and therefore more road abrasives can be recovered. New roads also look nicer and provide a better driving experience. The primary purpose of this monitoring site is to conduct pre and post project monitoring and perform source apportionment analyses on runoff samples to determine what portion of the fine sediment originates from native soil (road shoulder erosion), traction abrasives (road sand), and asphalt plus asphalt binder (the road itself).

Post project data collected at Elks Club indicates that repaving a road contributes to improved water quality (less sediment). Improved pavement condition should be recognized as a water quality BMP, not only to garner credits for the Lake Tahoe TMDL Clarity Crediting Program but also to potentially open up water quality improvement funds for road maintenance and vice versa. New roads would be beneficial for public safety, vehicle maintenance costs, aesthetic appeal, driving pleasure, road maintenance and sweeping operations, long term durability, snow removal operations, stormwater quality, and lake clarity.

2.3 Lakeshore Catchment Description

The Lakeshore monitoring site is located in the roadside channel on the northern side of Lakeshore Blvd., near Third Creek, replacing the old Incline Village site. It is monitored as a catchment outfall at one monitoring station (LS). At 97.8 acres, this is the second largest catchment monitored and includes runoff from Washoe County and NDOT jurisdictions. The catchment drains a relatively steep, highly urbanized area of Incline Village with dominant urban land uses consisting of moderate to high density residential, commercial, and secondary roads. Forty-one percent of the catchment area is impervious and there is a lack of any intervening natural dispersion and infiltration areas due to steep slopes and high-density development. Runoff discharges into Third Creek which discharges into Lake Tahoe.

As part of the Central Incline Village Phase II Water Quality Improvement Project, constructed during the summer of 2015, substantial improvements were made in the catchment upstream of the monitoring site. New infiltration features that reduce roadway runoff in the catchment include: (1) a series of three upstream infiltration basins that receive 1.8 cfs of low flow from the pipe network, (2) two small roadside infiltration pools, and (3) 450 linear feet of roadside infiltration channels. A Jellyfish cartridge filter similar to the one installed at SR431 (see section 2.4) was also installed downstream of the new infiltration features. A Vortechnics treatment vault routes low flow through the Jellyfish to be discharged to the lake through a 30-inch corrugated metal pipe (CMP) that passes through the old Incline Village monitoring site. High flows are routed through the roadside channel to the new Lakeshore monitoring site. The drainage area for this outfall is similar to the old Incline Village catchment but receives additional flow from Lakeshore Blvd. east of Village Blvd as well as some overland flow originating upslope of Lakeshore Blvd.

2.4 Pasadena Catchment Description

The Pasadena monitoring site is located at the northernmost end of Pasadena Ave. in the City of South Lake Tahoe (City). It was monitored as a catchment outfall and BMP effectiveness site. Beginning water year 2018 it was monitored as a catchment outfall only as inflow monitoring was suspended. A 36-inch outfall CMP emerging from the side of the steep slope at the end of Pasadena Avenue conveys runoff directly to Lake Tahoe. The pipe is the terminus of a 78.8-acre catchment designated the "G12" urban planning catchment by the City. The dominant land uses are moderate density single and multi-family residential and secondary roads. Thirty-nine percent of the catchment is impervious. In addition to the upstream permeable and porous road shoulders and perforated storm drain pipes, a pre-treatment Vortechnics storm vault and two Contech Stormfilter cartridge filter vaults were installed in parallel at the end of the catchment before discharge to the lake through the 36-inch CMP. Prior to WY14 monitoring, one of the Contech Stormfilters was not receiving any flow due to a missing orifice plate and the filter cartridges were therefore clean. The cartridges in the other Contech Stormfilter were replaced at the same time the missing orifice plate was installed (September 30, 2013). BMP RAM results and manufacturer's inspection method as of WY19 indicate that replacing the filters again is not yet necessary. However, the City has been sweeping streets and vactoring sediment traps annually to maintain the whole system. Pasadena Inflow (PI) was a monitoring station located at the inflow to the pre-treatment Vortechnics vault and two Stormfilter cartridge filter vaults (below the in-situ infiltration BMPs), and Pasadena Outflow (PO) is located in the 36-inch outfall CMP, the outflow from the pre-treatment vault and two Stormfilter cartridge filter vaults.

2.5 Speedboat Catchment Description

The Speedboat monitoring site is located midway along the western side of Speedboat Avenue just south of Dip Street in Kings Beach, California. The 29.0-acre catchment is monitored as a catchment outfall at a single monitoring station (SB). It receives co-mingled runoff from Placer County and Caltrans jurisdictions delivered by a 12-inch CMP. The catchment is comprised of thirty percent impervious surfaces and drains a steep area that is characterized predominately by single family residences, vegetation, and secondary road land uses. After passing through a Palmer-Bowlus flume at the monitoring station, runoff from the catchment drains untreated through a series of CMPs along a pedestrian footpath at the intersection of Lake Street and Harbor Avenue directly to Lake Tahoe.

This site was monitored from 2003 to 2012 by the University of California, Davis, Tahoe Environmental Research Center (UCD TERC) and the Desert Research Institute (DRI). Data collected from this site was included in the initial Total Maximum Daily Load (TMDL) study that ultimately populated the PLRM used to estimate pollutant loading from urban catchments.

2.6 Tahoe Valley Catchment Description

The Tahoe Valley monitoring site is located on the eastern side of Tahoe Keys Boulevard just south of the intersection with Sky Meadows Court in South Lake Tahoe, California near the entrance to the Sky Meadows Condominium Complex. With an area of 338.4 acres, this is the largest catchment monitored. It is a relatively flat, highly urbanized catchment consisting primarily of commercial/industrial/communications/utilities (CICU), single family residences, secondary roads, and vegetation land uses. Thirty-nine percent of the catchment is impervious. This site is monitored as a catchment outfall at a single monitoring site (TV). Runoff to the site is delivered by a 36-inch "squashed" CMP from the City of South Lake Tahoe jurisdiction. After passing by the TV monitoring station, runoff is conveyed through a vegetated swale along the northwest edge of the Sky Meadows Condominium Complex directly to the Upper Truckee River and eventually to Lake Tahoe.

Many water quality improvement projects have been implemented in this catchment in the last 25+ years. The existing Helen Basin and almost 3,200 linear feet of vegetated swales were built as part of the Tahoe Valley Erosion Control Project

(ECP) in 1989 to increase stormwater infiltration upstream of the current monitoring site. This area was maintained under a contract with the California Conservation Corps in 2014 and included removing sediment that was blocking pipes, excess vegetation in the basin and swales, drug paraphernalia, empty liquor bottles, and human waste. Additionally, Caltrans completed the $12 Million US Highway 50 water quality improvement project in 2012 which included curb, gutter, rock-lined swales, infiltration chambers and basins along Highways 50 and 89 to address highway runoff in the catchment. Lastly, to ensure high infiltration rates, the City of South Lake Tahoe removed accumulated sediment, excess vegetation, and trash in the Caltrans swales upstream of Tahoe Keys Boulevard near Council Rock Road and behind the storage units on Eloise in May and June of 2015, also under a contract with the California Conservation Corps. Nearby homeless camps littered with trash, human waste, empty liquor bottles, and used needles were also removed.

2.7 Tahoma Catchment Description

Tahoma is monitored as a catchment outfall at one monitoring station (TA). The 49.5-acre catchment straddles the Placer County/El Dorado County border and comingles runoff from both jurisdictions, plus waters from the Caltrans maintained Highway 89. The land uses in this catchment are primarily moderate density residential and secondary roads in the Tahoe Cedars subdivision, but also include some CICU and primary roads. Thirty percent of the catchment area is impervious. The runoff from this catchment discharges directly into Lake Tahoe via a 36-inch oval "squashed" CMP at the bottom of the Water's Edge North condominium complex driveway without infiltration or treatment. Because of the high direct connectivity between the catchment and Lake Tahoe, this storm drain system has great potential to deliver high FSP loads to the lake.

A water quality improvement project completed in the fall of 2014 installed nine sediment traps to decrease flow rates and capture coarse sediment, one new drop inlet to more effectively capture and route flow, and more than 80 feet of perforated infiltration pipe to decrease runoff volumes to the catchment outflow.

2.8 Upper Truckee Catchment Description

The Upper Truckee monitoring site is located on the eastern bank of the Upper Truckee River at the intersection of Highway 50 and River Drive a short distance upstream of the bridge on Highway 50 that crosses the Upper Truckee River in the City of South Lake Tahoe, California. The 10.5-acre catchment drains a highly urbanized area which is primarily composed of CICU, primary and secondary roads, and single-family residences. This is the second smallest catchment monitored, but with a high percentage of impervious coverage (72%) it receives relatively high volumes of co-mingled runoff from the City of South Lake Tahoe and Caltrans jurisdictions. The site is monitored as a catchment outfall site at a single location (UT).

Improvements were made in this catchment by the City of South Lake Tahoe in the summer of 2015 that included an 8,100 cubic foot infiltration gallery, 394 linear feet of perforated pipe and infiltration trenches, seven sediment traps/dry wells, and 3,340 linear feet of stabilized road shoulders. Any runoff that still remains gets discharged through a corrugated plastic pipe (CPP) to a small rock-lined basin installed by Caltrans in 2019. However, since the majority of runoff in this catchment originates from Highway 50, under Caltrans' jurisdiction, volume and pollutant reductions at this monitoring site have been hard to detect to date.

In the summer of 2019 Caltrans completed installation of a large underground concrete vault (dimensions: 54′ long x 11′7″ wide x 10′ deep) that captures and treats Caltrans Highway 50 runoff only. A 6′ wall about halfway down the 54′ chamber separates it into 2 parts (total volume capacity 3,753 cubic feet). The first half is for settling out the larger particles. Once the water reaches a depth of 6′ it spills over the wall into the second half which contains a sand filter to filter out FSP. It then goes over a weir and out the same CPP used by City runoff described above. The pipe discharges into the small rock-lined basin which overflows onto an unarmored slope that leads directly to the Upper Truckee River and eventually to Lake Tahoe. The vault was designed to be large enough to capture the estimated amount of flow that could enter the vault in any given storm. This site offers the unique opportunity to monitor pre and post project conditions. It is anticipated that this site will show significant load reductions between WY19 and WY20 now that Caltrans is treating Highway 50 runoff in the vault.

3. Data Collection Methods, Sampling Protocols, Analytic Methods

Continuous hydrology and stormwater samples are collected using ISCO brand automated samplers (autosamplers) per RSWMP protocols (RSWMP FIG 2015 section 10.2.1, Tahoe RCD et al 2017) at all eleven monitoring stations in WY19 to support seasonal [fall/winter (October 1-February 28), spring (March 1-May 31), and summer (June 1-September 30)] volume and load reporting. Autosamplers were installed and sites maintained according to protocols outlined in the RSWMP FIG sections 10.1.2.2 and 10.2.1.3 respectively. Continuous turbidity was collected at all sites with an FTS DTS-12 turbidimeter. Turbidimeters were installed and maintained as outlined in the RSWMP FIG sections 10.2.2.1 and 10.2.2.2. Equations that relate turbidity to FSP concentration have been developed specifically for the Tahoe Basin and were applied to estimate FSP loads (2NDNATURE et al 2014). Continuous meteorological data is recorded using a Davis Instruments Vantage Pro weather station or weather station equipment sold by Campbell Scientific. The weather stations are installed at seven locations in the vicinity of the eight monitored catchments and maintained following recommendations in the RSWMP FIG sections 10.2.3.1 and 10.2.3.2. All weather stations are maintained by Tahoe RCD, with the exception of Shakori, which is maintained by El Dorado County. Meteorological data is used to calculate seasonal and annual precipitation totals (RSWMP FIG section 10.2.3.5) and to estimate the amount of flow that can be expected in a particular catchment for a particular amount of precipitation to aid with autosampler programming for event-based sampling (RSWMP FIG section 10.2.1.4).

Continuous data (flow, turbidity, and meteorology) are logged at a constant time interval, generally every 5 minutes. Flow and turbidity data are QAQC'd with frequent stage and turbidity field measurements to ensure that no drift has occurred in the readings and sensors are performing optimally (RSWMP FIG sections 10.2.1.7 and 10.2.2.5). Visual observations are used to confirm when a flume or pipe is dry and stage and turbidity should read zero. Visual observations are also used to determine if ice in the flume or pipe is causing stage errors that need to be adjusted to zero. Visual observations and field measurements are made every two weeks at a minimum but more often during precipitation events. Recalibration of stage measuring equipment is done by adjusting the level measurement on the autosampler. Turbidimeter accuracy was verified on all in-situ turbidimeters with a solution of known turbidity in late September/early October 2016, June 2017, and May/June 2018. Starting in 2019, all turbidimeters are sent into the manufacturer for calibration on an annual basis.

Weather is monitored closely and autosamplers are programmed to sample at the beginning of each runoff event in accordance with RSWMP FIG sections 10.2.1.4 and 10.2.1.5. Individual aliquots from single samples are combined into flow-weighted composites (RSWMP FIG section 10.2.1.10) based on their occurrence in the hydrograph. Full event composites and quality control samples are analyzed for total nitrogen (TN) concentration, total phosphorus (TP) concentration, total suspended solid (TSS) concentration, turbidity, and particle size distribution (PSD) to determine fine sediment particle (FSP) concentration at the UC Davis Tahoe Environmental Research Center Laboratory in Incline Village, NV, the UC Davis Laboratory in Davis, CA, or the High Sierra Water Laboratory, Inc. in Tahoe City, CA. Table 2 summarizes the sample type acronyms and their meaning. Table 3 summarizes the analytical methods and detection limits for all analyses. Raw analytical data for all samples is presented in Appendix A.

Table 2 Sample types and acronyms.

Sample Acronym	Sample Type
AC	**A**uto-sampler **C**omposite, flow-weighted composite of whole or part of hydrograph
FB	**F**ield **B**lank (QA/QC)
GS	**G**rab **S**ample single (QA/QC)
MS	**M**anually triggered auto-**S**ampler single (QA/QC)

Table 3 Analytical methods and detection limits.

Analyte	Methods	Description	Detection Limit	Target Reporting Limit
Total Suspended Solids	EPA 160.2 or SM 2540-D	Gravimetric	0.4 mg/L	1 mg/L
Turbidity	EPA 180.1 or SM 2130-B	Nephelometric	0.05 NTU	0.1 NTU
Total Kjeldahl Nitrogen	EPA 351.1; or EPA 351.2	Colorimetric, block digestion, phenate	40 µg/L	100 µg/L
Nitrate + Nitrite	TERC Low Level Method	Colorimetric, NO3 + NO2 Hydrazine Method, low level	2 µg/L	10 µg/L
Total Nitrogen as N	N/A	Total Kjeldahl Nitrogen + Nitrate + Nitrite	40 µg/L	100 µg/L
Total Phosphorus as P	TERC Low Level Method	Colorimetric, Total Phosphorus, Persulfate digestion, low level	2 µg/L	10 µg/L
Particle Size Distribution	SM 2560 or RSWMP addendum SOP	Laser backscattering	0.5 mg/L	1 mg/L

Sample handling and processing includes proper labeling of samples in the field, transporting samples to a laboratory immediately after collection in a cooler with ice, compositing individual aliquots from single samples on a flow-weighted basis, taking turbidity measurements with a calibrated instrument, shipping to an analytical laboratory with proper chain-of-custody procedures, and filtering samples within a 24-hour period. A minimum of 10% of all samples analyzed were QAQC samples to identify any potential problems related to field sampling and sample processing (RSWMP FIG section 10.2.1.6). Analytical data for all QAQC samples is presented in Appendix B.

4. Data Management Procedure

Continuous data series and sample dates and times are collected through the RSWMP Data Management System (DMS) at the time samples are collected, when maintenance is required, or every two weeks during dry periods. All data are input into Excel workbooks for storing continuous parameters and sample dates and times. Any other field measurements and observations are recorded in a field notebook or the ArcGIS Survey123 app and transcribed into Excel workbooks. Samples are transported to a processing lab immediately after collection. The DMS automatically calculates the recipe for compositing individual aliquots from single samples into an event composite for each monitoring station. All composite samples are measured for turbidity using a Hach 2100N benchtop turbidimeter and values are recorded on standard data sheets in the laboratory and entered into an Excel workbook for storing nutrient and sediment data. All samples are sent to analytical laboratories within appropriate holding times for TSS, TN, TP, and PSD analysis. For a complete description of holding times for sampled parameters, see the RSWMP Quality Assurance Project Plan (QAPP) (DRI et al 2011a). Results from analytical laboratories are entered into the same Excel workbook for storing nutrient and sediment data. All Excel workbooks are housed on one central server (with backup device) and managed by Tahoe RCD staff. All data management procedures described above follow protocols outlined in the RSWMP FIG section 10.2.1.

5. Data Analysis

The raw hydrologic data set includes stage, velocity (at select sites), flow (determined by an equation relating stage in a weir, flume or pipe, or stage and velocity in a pipe to flow), and turbidity recorded every 5 minutes throughout the water year. Data gaps were short and rare. Erroneous readings are corrected and data gaps are filled following protocols outlined in the RSWMP FIG sections 10.2.1.7 for flow and 10.2.2.5 for turbidity.

Seasonal and annual volumes are calculated by the DMS in accordance with RSWMP FIG sections 10.2.1.8 and 10.2.1.9. Results from lab analysis are used by the DMS to calculate a flow-weighted event mean concentration (EMC) as outlined in section 10.2.1.10 of the RSWMP FIG. The DMS groups EMCs by season and calculates a seasonal characteristic pollutant concentration for each site; the DMS then applies these concentrations to each hydrologic measurement for that season. The DMS calculates loads by summing concentrations multiplied by runoff volumes over time as outlined in section 10.1.2.11 of the RSWMP FIG. Turbidity is converted to FSP concentration (in both mass per liter and number of particles per liter) using equations relating turbidity to FSP (2NDNATURE et al 2014) and integrated over time to calculate seasonal and annual load estimates in pounds and number of particles (RSWMP FIG sections 10.2.2.6 and 10.2.2.7). Rainfall normalized seasonal and annual trends are calculated for catchments with at least five years of continuous data according to protocols outlined in the RSWMP FIG section 10.4.3.

Raw meteorological data include a precipitation and a temperature reading every 5 or 10 minutes (depending on the station) throughout the water year. Precipitation occurring as snow is converted to inches of water by a heated tipping bucket at the meteorological station that melts falling snow upon contact with the device. Data is QAQC'd by comparing event, seasonal and annual totals to the closest neighboring meteorological station. Data gaps are rare, but are filled with data from a neighboring station when they occur (RSWMP FIG section 10.2.3.4). The DMS calculates seasonal and annual precipitation totals for reporting purposes.

6. Catchment Outfall Monitoring

6.1 Summary Data for All Monitoring Sites

A meteorological station at the Tahoe City Dam located in the northwest corner of the lake at an elevation of 6,235 feet is maintained under the Truckee River Operating Agreement (TROA). Per RSWMP protocols, this station is to be used as a reference station to determine if a particular water year is wet, average, or dry (assuming that a wet, average, or dry season in Tahoe City will be the same around the lake). Using an 87-year precipitation record (water years 1933-2019) from this station, WY19, at **43.74 total inches**, falls within the fourth quartile for this period of record and is therefore designated a very wet year (Table 4, Figure 2). In WY19 approximately 72% of the precipitation fell during the fall/winter season, approximately 24% fell during the spring season, and approximately 4% fell during the summer season. The summer season produced very little runoff, but Upper Truckee was the only site not sampled at least once during the summer season. The intention is to sample 6-12 events per year in each catchment, and this target was met in WY19.

Table 4 Annual precipitation statistics from the Tahoe City meteorological reference station, water years 1933-2019.

WY 1933-2019	Annual Precipitation (in)	Designation
1st quartile	8.8 - 21.9	very dry
2nd quartile	22.0 - 29.4	dry
Median	29.5	average
3rd quartile	29.6 - 39.5	wet
4th quartile	39.6 - 69.8	very wet

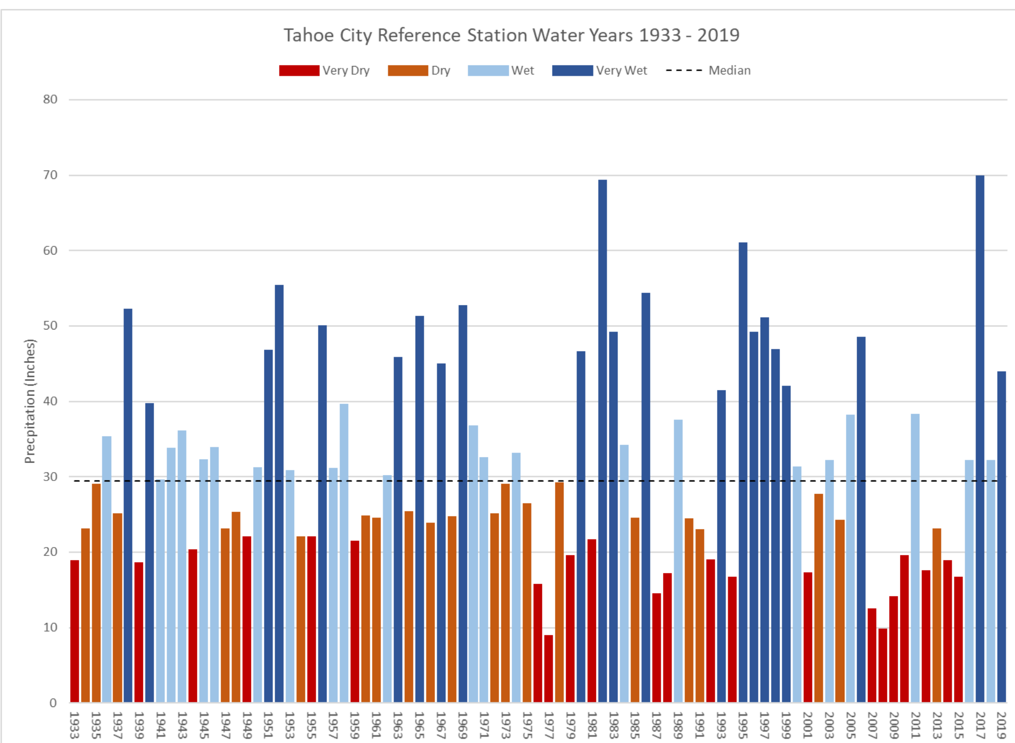

Figure 2 Long-term precipitation record at the Tahoe City meteorological station, water years 1933-2019.

Three primary "seasons" are defined by the NPDES permit; fall/winter (October 1 - February 28), spring (March 1 - May 31), and summer (June 1 - September 30). These are the seasons used by RSWMP and are defined as such to better fit with precipitation patterns and storm event types that occur in the Tahoe Basin. The primary event types in the fall/winter are frontal rain storms, rain on snow, mixed rain/snow, or event snowmelt. An event snowmelt occurs during and shortly after a snow event when enough snow melts (generally on the roads from the heat generated by automobile traffic) to produce runoff at a given monitoring site. Spring event types include the fall/winter event types plus non-event snowmelts. A non-event snowmelt event generally occurs in the spring when temperatures are greater than 50 degrees Fahrenheit and accumulated snowpack melts. Most monitoring sites do not receive sufficient spring non-event snowmelt to sample. Summer events are primarily thunderstorms and frontal rain storms.

Summary data for all sites are presented in Table 5. Figure 3 - Figure 12 illustrate Table 5 in graphical form. Runoff volumes are calculated from instantaneous flow rates (cubic feet per second) taken every 5 minutes by assuming the flow rate was constant for the 5 minute period. FSP loads are calculated from event sampling and estimated from continuous turbidity, and TN and TP loads are calculated from event sampling. As not every runoff event was sampled during the year; the seasonal and annual loads represent an average (volume weighted) load calculation for the respective period based on the events that were sampled in that period. FSP loads estimated from continuous turbidity include all periods of flow, not just those that were sampled. In Figure 3 - Figure 12, SR431 is represented by its four sites: Contech MFS Inflow (CI), Contech MFS Outflow (CO), Jellyfish Inflow (JI), and Jellyfish Outflow (JO), Elk's Club is EC, Lakeshore is LS, Pasadena is PO, Speedboat is SB, Tahoe Valley is TV, Tahoma is TA, and Upper Truckee is UT.

Table 5 Summary statistics for all catchments for WY19. Top table shows seasonal and annual precipitation and runoff volumes; middle table shows seasonal and annual FSP concentrations and loads based on samples and estimated from continuous turbidity; bottom table shows seasonal and annual TN and TP concentrations and loads based on samples.

Water Year 2019 (October 1, 2018 - September 30, 2019)			Seasonal Precipitation (in)			Total Annual Precip (in)	Seasonal Runoff Volumes (cf)			Total Annual Runoff Volumes (cf)
Catchment Name	Station Name	Station Acronym	Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)		Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)	
SR431	Contech In	CI	18.48	5.89	0.90	25.27	6,549	14,527	862	21,938
	Contech Out	CO	18.48	5.89	0.90	25.27	3,620	10,762	480	14,862
	Jellyfish In	JI	18.48	5.89	0.90	25.27	7,425	16,292	894	24,611
	Jellyfish Out	JO	18.48	5.89	0.90	25.27	6,465	16,969	798	24,231
Elk's Club	Elk's Club	EC	16.42	6.95	1.05	24.42	35,550	303,927	47,721	387,197
Lakeshore	Lakeshore	LS	17.19	4.96	0.55	22.70	74,828	4,151	223	79,202
Pasadena	Pasadena Out	PO	10.61	4.08	0.42	15.11	38,153	2,872	235	41,261
Speedboat	Speedboat	SB	11.35	4.58	1.24	17.17	572,772	339,503	20,294	932,570
Tahoe Valley	Tahoe Valley	TV	18.11	5.82	0.52	24.44	848,915	3,782,419	15,153	4,646,487
Tahoma	Tahoma	TA	25.30	8.16	1.02	34.48	203,932	1,338,823	1,192	1,543,946
Upper Truckee	Upper Truckee	UT	18.11	5.82	0.52	24.44	55,886	35,483	0	91,370

Water Year 2019 (October 1, 2018 - September 30, 2019)			Average Seasonal FSP Concentrations (mg/L)			Average Annual FSP Concen-trations (mg/L)	Seasonal FSP Loads (lbs)			Total Annual FSP Loads (lbs)	Average Estimated Seasonal FSP Concentrations (mg/L)			Average Estimated Annual FSP Concen-trations	Seasonal Estimated FSP Loads (lbs)			Total Annual Estimated FSP Loads (lbs)	Seasonal Estimated FSP Loads (#particles)			Total Annual Estimated FSP Loads (#particles)
Catchment Name	Station Name	Station Acronym	Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)		Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)		Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)		Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)		Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)	
SR431	Contech In	CI	366	699	100	576	150	634	5	789	155	57	121	89	63	52	7	122	6.76E+15	5.43E+15	5.94E+14	1.28E+16
	Contech Out	CO	285	344	197	325	64	231	6	301	41	48	121	49	9	32	4	45	8.58E+14	3.08E+15	3.14E+14	4.25E+15
	Jellyfish In	JI	338	808	104	641	157	822	6	985	143	59	122	87	66	60	7	134	7.02E+15	6.80E+15	6.18E+14	1.44E+16
	Jellyfish Out	JO	162	314	67	265	65	333	3	402	49	27	64	34	20	28	3	52	1.92E+15	2.71E+15	2.78E+14	4.90E+15
Elk's Club	Elk's Club	EC	11	10	63	17	24	189	187	400	7	3	1	3	17	65	2	84	1.32E+15	4.00E+15	1.30E+14	5.45E+15
Lakeshore	Lakeshore	LS	9	9	115	9	40	2	2	44	10	10	89	10	47	3	1	51	4.01E+15	1.92E+14	1.11E+14	4.31E+15
Pasadena	Pasadena Out	PO	26	5	89	25	62	1	1	64	32	47	53	33	77	8	1	86	6.78E+15	6.73E+14	6.13E+13	7.52E+15
Speedboat	Speedboat	SB	16	65	550	45	559	1,373	697	2,628	222	288	459	251	7,926	6,103	581	14,611	9.47E+17	6.89E+17	6.18E+16	1.70E+18
Tahoe Valley	Tahoe Valley	TV	13	15	174	15	691	3,516	165	4,371	15	5	5	7	803	1,095	5	1,903	7.12E+16	8.91E+16	3.41E+14	1.61E+17
Tahoma	Tahoma	TA	29	13	170	15	371	1,086	13	1,470	45	11	70	15	575	890	5	1,470	6.36E+16	7.40E+16	4.60E+14	1.38E+17
Upper Truckee	Upper Truckee	UT	228	182	0	210	796	403	0	1,199	218	107	0	175	762	237	0	1,000	8.18E+16	2.23E+16	0.00E+00	1.04E+17

Water Year 2019 (October 1, 2018 - September 30, 2019)			Average Seasonal TN Concentrations (ug/L)			Average Annual TN Concen-trations (ug/L)	Seasonal TN Loads (lbs)			Total Annual TN Loads (lbs)	Average Seasonal TP Concentrations (ug/L)			Average Annual TP Concen-trations (ug/L)	Seasonal TP Loads (lbs)			Total Annual TP Loads (lbs)
Catchment Name	Station Name	Station Acronym	Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)		Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)		Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)		Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)	
SR431	Contech In	CI	2,618	2,570	2,660	2,588	1.07	2.33	0.14	3.54	2,095	3,936	818	3,264	0.86	3.57	0.04	4.47
	Contech Out	CO	2,346	1,663	3,430	1,887	0.53	1.12	0.10	1.75	1,594	2,084	1,265	1,938	0.36	1.40	0.04	1.80
	Jellyfish In	JI	2,520	2,631	2,970	2,610	1.17	2.68	0.17	4.01	1,643	4,329	806	3,391	0.76	4.40	0.04	5.21
	Jellyfish Out	JO	2,600	1,649	3,790	1,973	1.05	1.75	0.19	2.99	617	1,982	541	1,571	0.25	2.10	0.03	2.38
Elk's Club	Elk's Club	EC	877	271	4,870	893	1.95	5.14	14.51	21.60	191	65	59	76	0.42	1.23	0.18	1.83
Lakeshore	Lakeshore	LS	577	431	5,840	584	2.70	0.11	0.08	2.89	115	95	71	113	0.54	0.02	0.00	0.56
Pasadena	Pasadena Out	PO	2,058	980	11,350	2,036	4.90	0.18	0.17	5.24	446	254	108	431	1.06	0.05	0.00	1.11
Speedboat	Speedboat	SB	2,363	902	6,012	1,910	84.50	19.11	7.62	111.22	556	453	2,626	564	20	10	3	33
Tahoe Valley	Tahoe Valley	TV	1,002	479	8,730	602	53.13	113.18	8.26	174.57	131	97	116	104	6.93	23.00	0.11	30.04
Tahoma	Tahoma	TA	1,534	300	9,850	470	19.53	25.07	0.73	45.34	494	92	134	145	6.30	7.67	0.01	13.98
Upper Truckee	Upper Truckee	UT	1,447	1,455	0	1,450	5.05	3.22	0.00	8.27	1,211	1,007	0	1,132	4.22	2.23	0.00	6.46

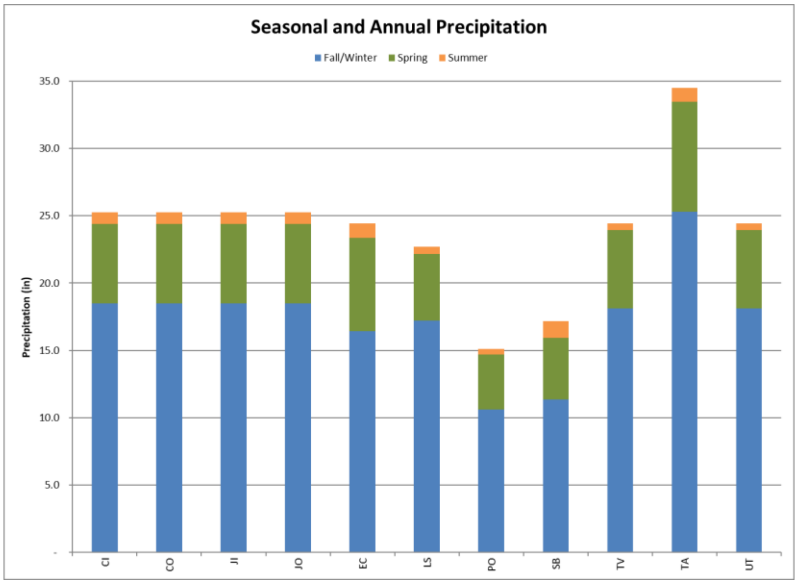

Figure 3 Precipitation totals at each monitoring station, WY19.

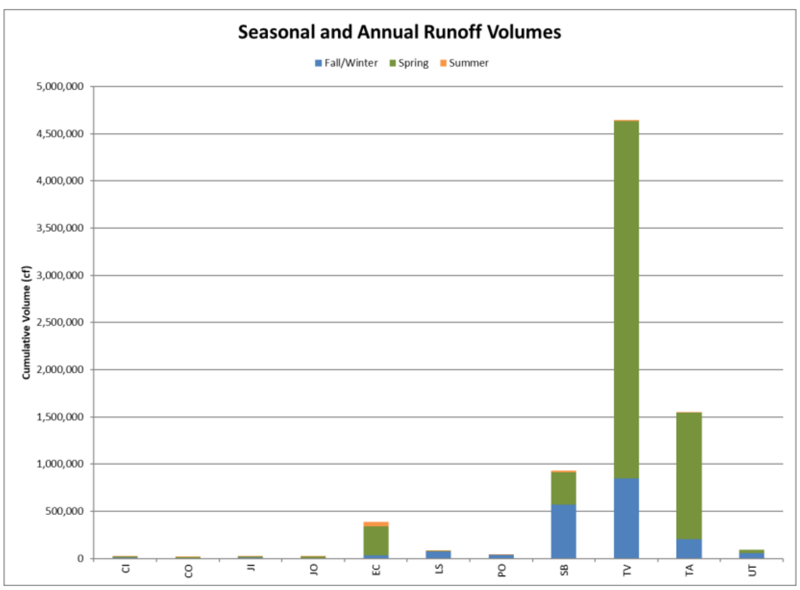

Figure 4 Runoff volumes at each monitoring station, WY19.

Precipitation

- The west shore received the most precipitation (TA)
- The eastern side of south shore (PO) received the least amount of precipitation.
- There are no stations on the east shore.
- All regions of the lake received the greatest amount of precipitation during the fall/winter season and least during the summer.

Runoff Volumes

- Catchment size influences runoff volume. Tahoe Valley is the largest catchment and had the greatest runoff volume. SR431 is the smallest catchment and had the smallest runoff volume.
- Infiltration features influence runoff volume. Though Tahoma is approximately half the size of Lakeshore, its runoff volume is two orders of magnitude greater. Lakeshore is downstream of numerous infiltration features.
- Impervious area influences runoff volumes. Pasadena and Upper Truckee have similar runoff volumes even though the Upper Truckee catchment area is about one eighth the size of Pasadena. Upper Truckee is 72% impervious and Pasadena is 39% impervious.
- Precipitation totals influence runoff volumes. All catchments had the most runoff in the fall/winter or spring and the least runoff in the summer.

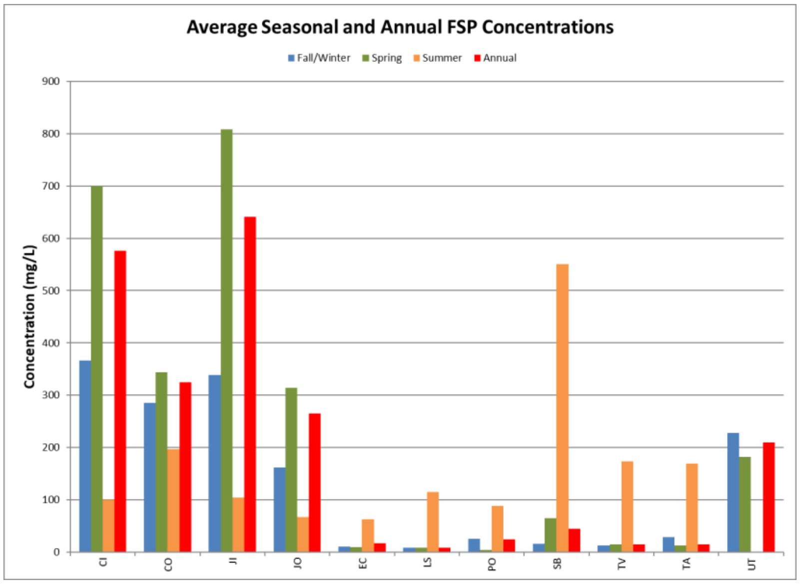

Figure 5 FSP concentrations based on samples at each monitoring station, WY19.

FSP Concentrations Based on Samples

- Average seasonal FSP concentrations were highest in the summer at all sites that received runoff in the summer except for SR431 (CI, CO, JI, JO).
- For SR431 the highest average seasonal FSP concentrations were in the spring and the lowest were in the summer.
- For Upper Truckee, that received no runoff in the summer, the highest average seasonal FSP concentrations were in the fall/winter (UT).
- The highest average seasonal FSP concentration was observed during the spring season at the SR431 inflows (CI, JI) and during the summer season at Speedboat (SB), all three of these sites are highly influenced by primary road.
- Average annual FSP concentrations were lowest at Elks Club (EC), Lakeshore (LS), Pasadena (PO), Tahoe Valley (TV), and Tahoma (TA).

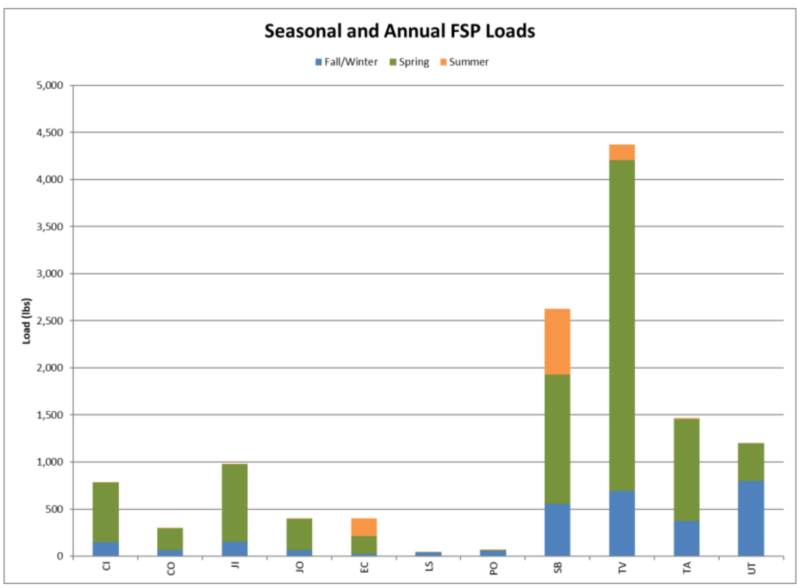

Figure 6 FSP loads at each monitoring station, WY19.

FSP Loads Based on Samples

- Runoff volume has the largest influence on loads. Tahoe Valley contributed the greatest FSP load to the lake, yet it had one of the lowest average seasonal FSP concentrations in all seasons except summer when volumes are relatively low.
- Concentrations influence loads. Upper Truckee had relatively low runoff volumes, relatively high FSP concentrations, and relatively high FSP loads. Speedboat summer volumes were very low, but very high summer concentrations resulted in the highest summer load.

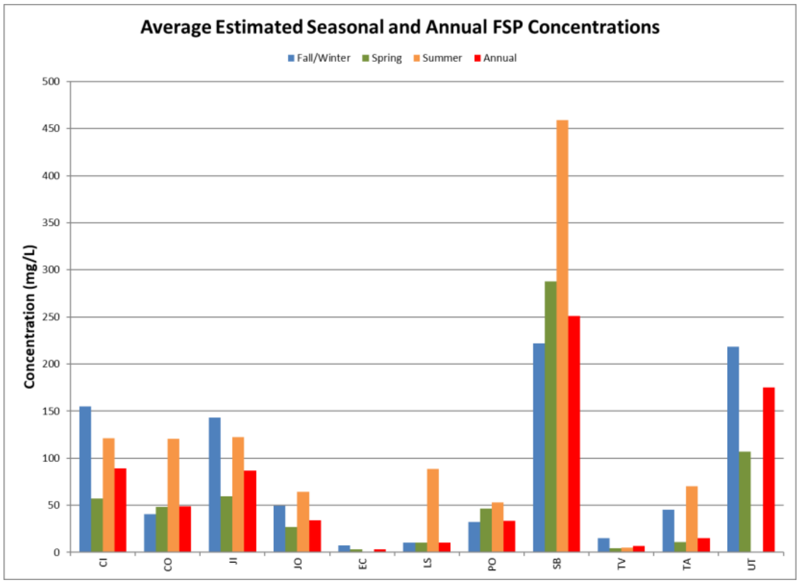

Figure 7 FSP concentrations estimated from turbidity at each monitoring station, WY19.

FSP Concentrations Estimated from Turbidity

- Average estimated seasonal FSP concentrations were highest in the summer at all sites that received runoff in the summer except for SR431 inflows (CI, JI) and Tahoe Valley (TV).
- For SR431 inflows, Tahoe Valley, and Upper Truckee, the highest average estimated seasonal FSP concentrations were in the fall/winter (UT).
- The highest average estimated seasonal FSP concentrations were observed at Speedboat.
- Average estimated annual FSP concentrations were highest at Upper Truckee (UT), Speedboat (SB), Jellyfish Inflow (JI), and Contech MFS inflow (CI) - four sites highly influenced by primary road.
- Average estimated annual FSP concentrations were lowest at Elk's Club (EC), Lakeshore (LS), Tahoe Valley (TV), and Tahoma (TA).

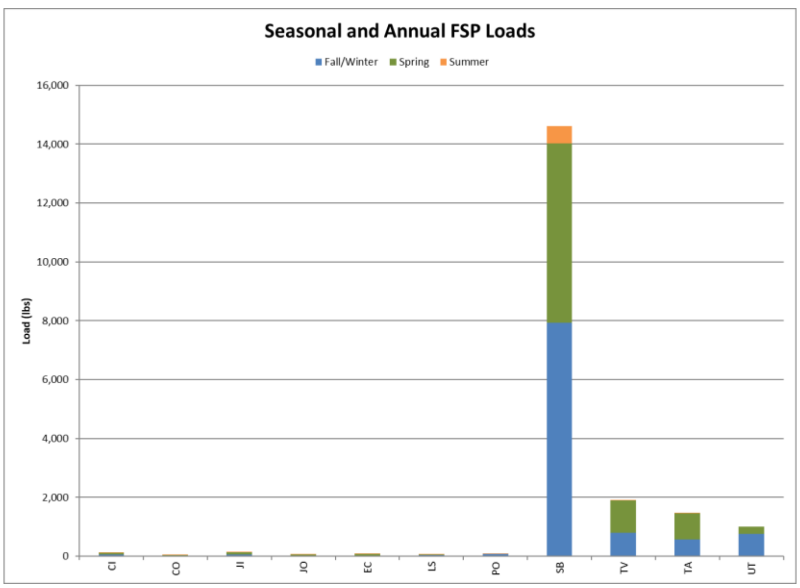

Figure 8 FSP loads at each monitoring station, WY19.

FSP Loads Estimated from Turbidity

- Runoff volume has the largest influence on loads. Tahoe Valley contributed the second highest estimated FSP load to the lake, yet it had one of the lowest estimated average seasonal FSP concentrations in all seasons.
- Concentrations influence loads. Speedboat had the third highest flows, but the largest estimated concentrations and therefore the largest estimated loads.

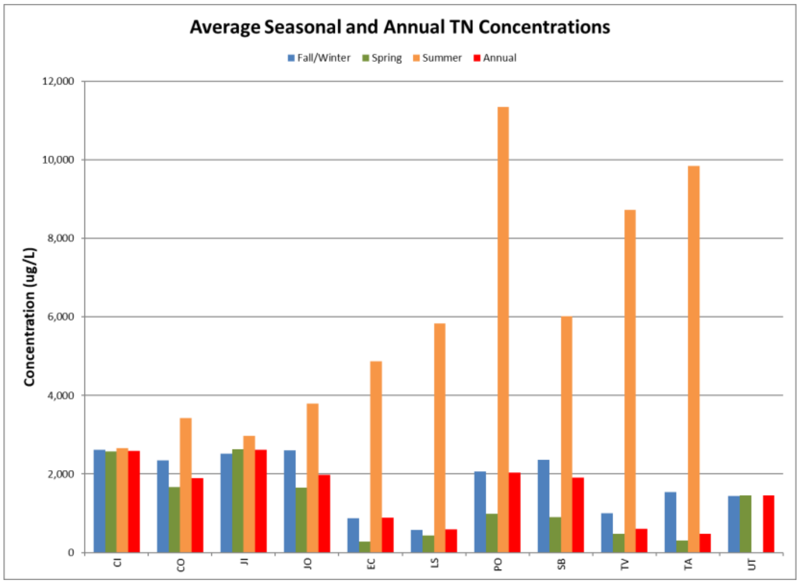

Figure 9 TN concentrations at each monitoring station, WY19.

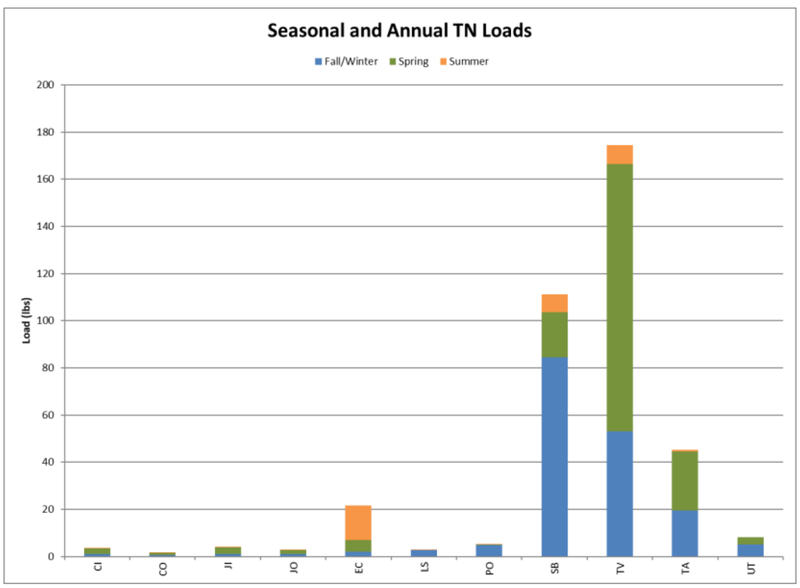

Figure 10 TN loads at each monitoring station, WY19.

TN Concentrations

- Average seasonal TN concentrations were substantially higher in the summer than any other season at all sites that were sampled during the summer except SR431. Average seasonal TN concentrations at SR431 were higher in the summer, but not substantially.
- Average seasonal TN concentrations at Pasadena during the summer were higher than at any other site.
- Average seasonal TN concentrations were lowest in the spring at all sites except UT and JI.
- Average annual TN concentrations were highest at the SR431 inflows (CI, JI) and lowest at Tahoma and Lakeshore.
- TN concentrations at CO were higher than CI in the summer, indicating TN flushing from the Contech MFS vault.
- Upper Truckee has no summer data due to no measured runoff during the summer.

TN Loads

- Runoff volume has the largest influence on loads. Tahoe Valley contributed substantially more TN to the lake than any other site, yet it had average seasonal TN concentrations similar to other sites in all seasons.
- Summer runoff volume at Elks Club was more than twice as high as the next highest summer runoff volume and resulted in the largest summer TN load.
- Concentrations influence loads. Though runoff volumes are universally low in the summer, high average seasonal TN concentrations resulted in proportionally higher summer TN loads at Speedboat and Tahoe Valley.
- Upper Truckee has no summer data due to no measured runoff during the summer.

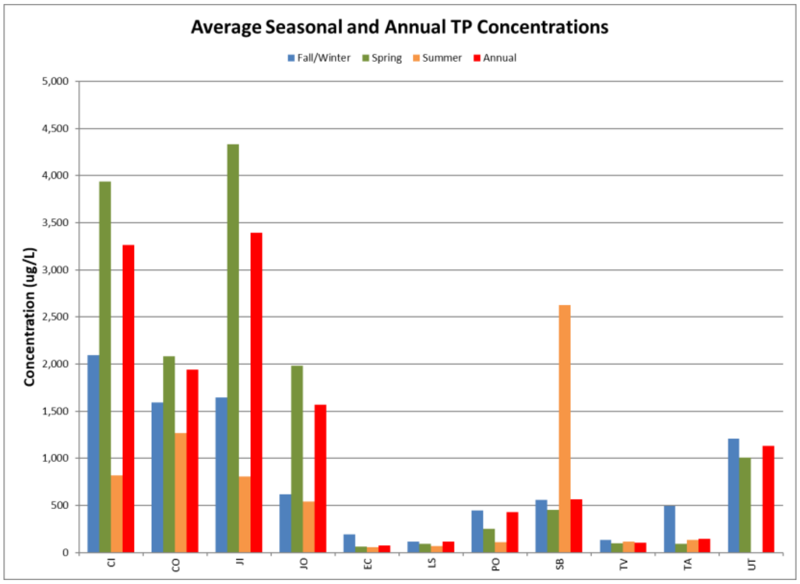

Figure 11 TP concentrations at each monitoring station, WY19.

TP Concentrations

- Average seasonal TP concentrations were highest in the spring at the SR431 sites (CI, CO, JI, JO) and highest in the winter at the remaining sites except Speedboat where summer concentrations were highest.
- Average annual TP concentrations were highest at SR431 inflows (CI, JI).
- Average annual TP concentrations were lowest at Elks Club, Lakeshore, Tahoe Valley, and Tahoma.
- Upper Truckee has no summer data due to no measured runoff during the summer.

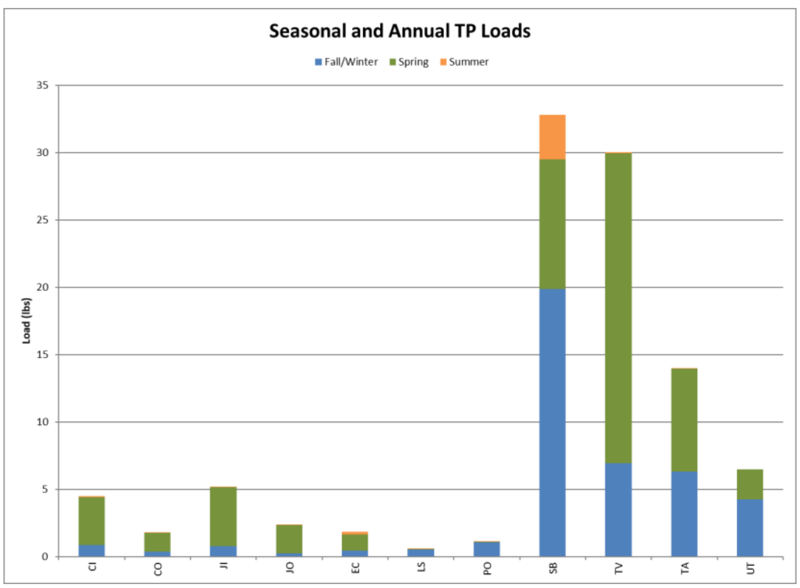

Figure 12 TP loads at each monitoring station, WY19.

TP Loads

- Runoff volume has the largest influence on loads. Tahoe Valley contributed the second most TP to the lake, yet it had low average seasonal TP concentrations.
- Concentrations influence loads. Though runoff volumes were universally low in the summer, high average seasonal TP concentrations resulted in proportionally higher summer TP loads at Speedboat.
- High runoff volumes coupled with high average seasonal TP concentrations resulted in high spring TP loads at most sites.
- Upper Truckee has no summer data due to no measured runoff during the summer.

6.2 Summary Data for Individual Catchments

6.2.1 SR431

Figure 13 shows the average daily inflow and cumulative precipitation for WY19 at the SR431 treatment vaults. The treatment vaults are not designed to reduce flows so outflows are roughly equal to inflows for the Jellyfish. However, the Contech MFS vault has a capacity of about 3,000 cf. This results in a substantial amount of runoff evaporating from the vault instead of passing through the outflow and accounts for the large difference between inflow and outflow volumes in Table 5 (compare CI annual volume to CO annual volume in Table 5).

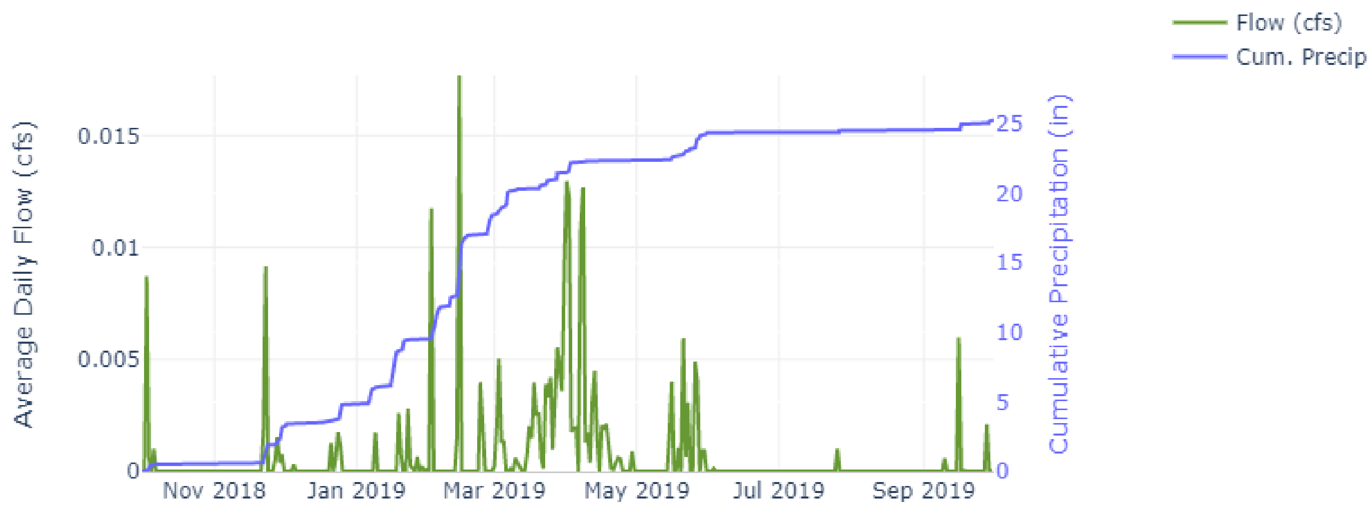

Figure 13 Average daily inflow and cumulative precipitation at the SR431 treatment vaults, WY19.

- Average daily flow in Figure 13 is from CI, but JI is similar so it is not shown. The occasional difference in inflow volume between CI and JI is attributable to unequal split of the flow in the splitter chamber when sediment accumulates.
- 25.27 inches of total precipitation (18.48 in the fall/winter, 5.89 in the spring, and 0.90 in the summer) were recorded at the NDOT weather station.
- 54 precipitation events occurred (22 fall/winter events, 23 spring events, 9 summer events).
- The largest storm event produced over 4 inches of precipitation and occurred during an atmospheric river rain on snow event February 13-17, 2019.
- 69% of storms were less than half an inch.
- Highest average daily flows occurred in during the atmospheric river rain on snow event from February 13-17, 2019.
- 58 days of snowmelt occurred in the fall/winter and spring seasons.
- The highest instantaneous peak precipitation was 0.13 inches in 5 minutes during an atmospheric river rain on snow event from January 14-18, 2019.
- The highest instantaneous peak flow was 0.19 cfs during the rain and snow event on September 16, 2019.
- The April 1-2, 2019 mixed precipitation event produced the most runoff (1,998 cf).

Contech MFS

Daily flow and FSP EMC summaries for the Contech MFS inflow and outflow are presented in Figure 14 and Figure 15, respectively. Table 6 presents this data in tabular form. Table 6 also presents the load data referenced in some bullet points below.

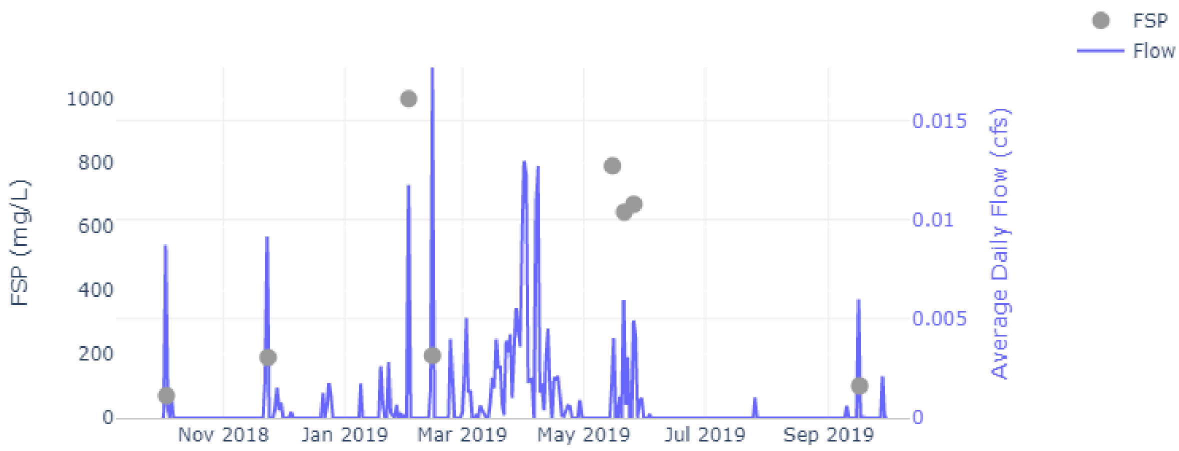

Figure 14 Daily inflow and FSP EMC summary at the Contech MFS, WY19.

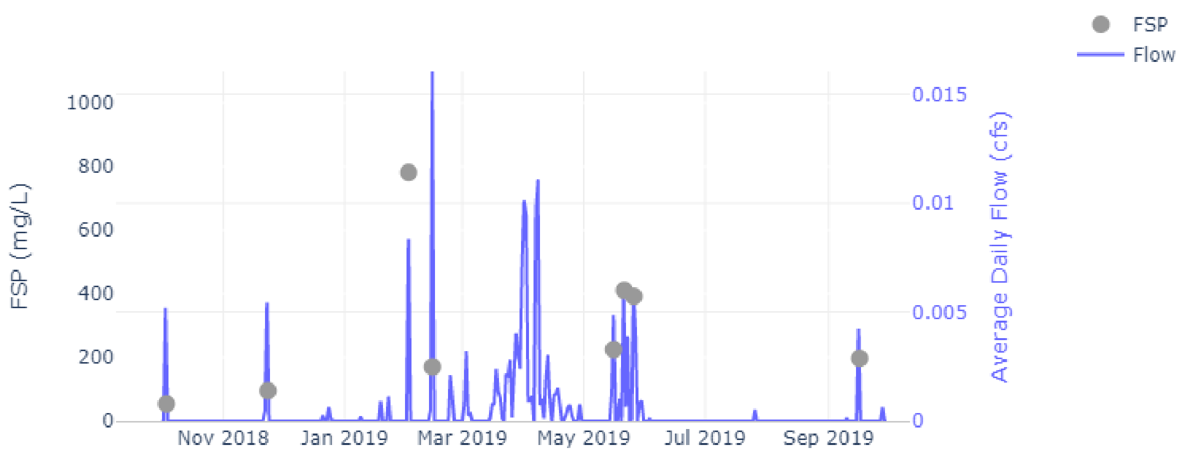

Figure 15 Daily outflow and FSP EMC summary at the Contech MFS, WY19.

- Eight events were sampled for FSP (four in the fall/winter, three in the spring, one in the summer).
- In 7 out of 8 events, FSP EMCs were lower at the outflow than the inflow indicating treatment occurred in the Contech MFS vault.
- The highest FSP EMC and loads at the inflow and outflow occurred during the rain on snow event on February 1-2, 2019.
- The lowest FSP EMCs occurred at the inflow during the October 3, 2018 thunderstorm event and the September 16, 2019 rain and snow event. The lowest FSP load at the outflow occurred during the October 3, 2018 thunderstorm event.

Daily flow and TN EMC summaries for the Contech MFS inflow and outflow are presented in Figure 16 and Figure 17, respectively. Table 6 presents this data in tabular form. Table 6 also presents the load data referenced in some bullet points below.

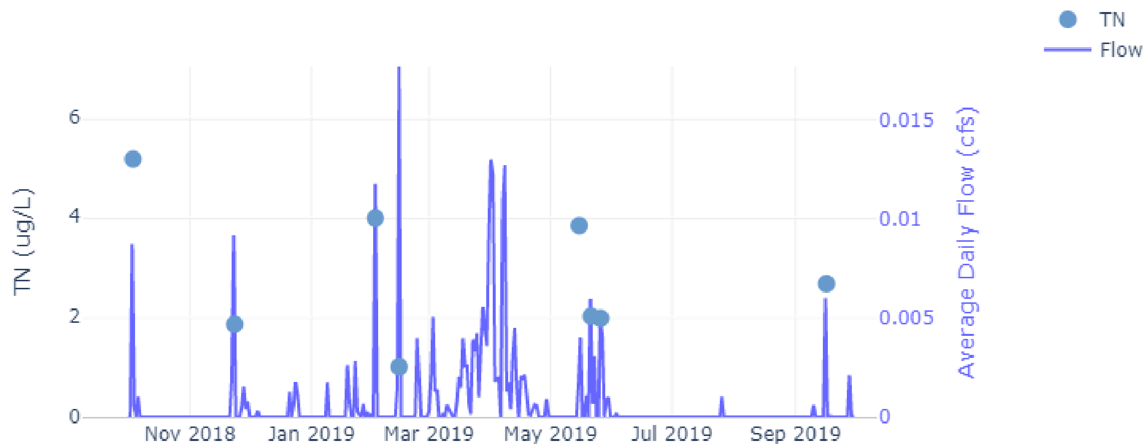

Figure 16 Daily inflow and TN EMC summary at the Contech MFS, WY19.

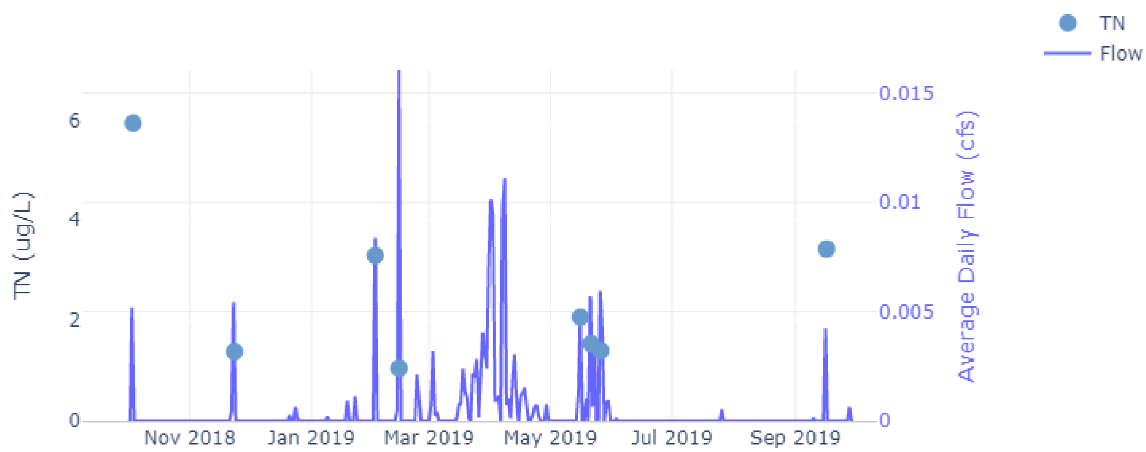

Figure 17 Daily outflow and TN EMC summary at the Contech MFS, WY19.

- Eight events were sampled for TN (four in the fall/winter, three in the spring, one in the summer).
- In 5 of 8 events, TN EMCs were lower at the outflow than the inflow indicating treatment occurred in the Contech MFS.
- The highest TN EMCs occurred during the thunderstorm event on October 3, 2018.
- The highest TN load at the inflow and outflow occurred during the rain on snow event on February 1-2, 2019.
- The lowest TN EMCs occurred during the atmospheric river rain on snow event from February 13-14, 2019.
- The lowest TN load at the inflow occurred during the May 26, 2019 rain on snow event. The lowest TN load at the outflow occurred during the May 15-16, 2019 rain on snow event.

Daily flow and TP EMC summaries for the Contech MFS inflow and outflow are presented in Figure 18 and Figure 19, respectively. Table 6 presents this data in tabular form. Table 6 also presents the load data referenced in some bullet points below.

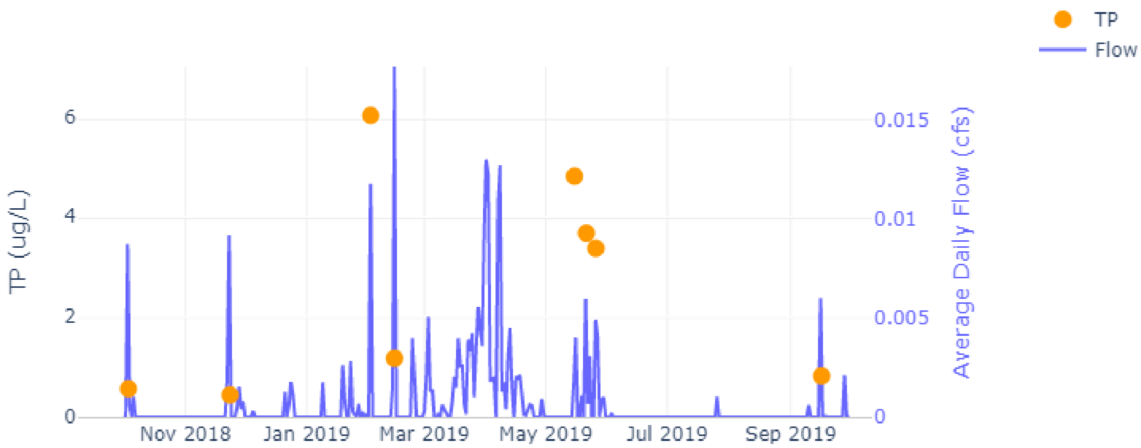

Figure 18 Daily inflow and TP EMC summary at the Contech MFS, WY19.

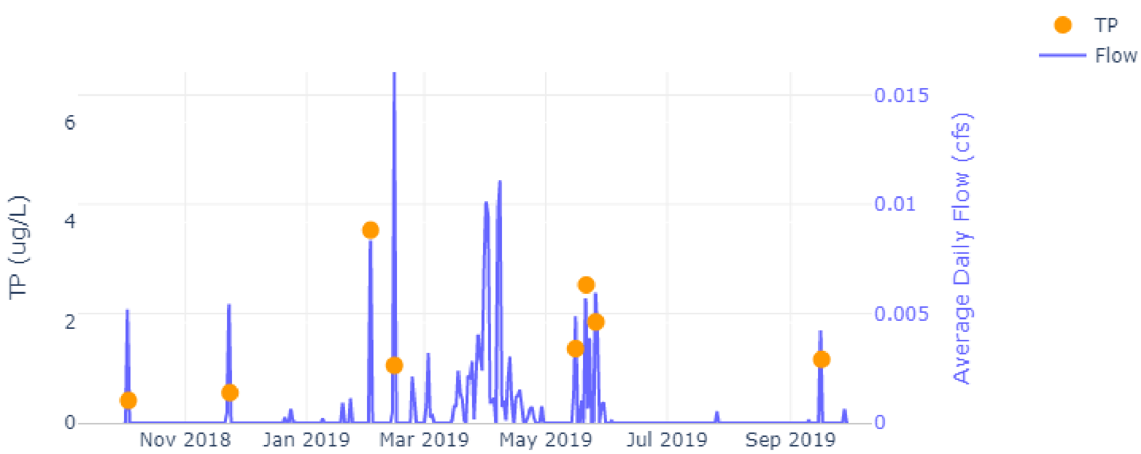

Figure 19 Daily outflow and TP EMC summary at the Contech MFS, WY19.

- Eight events were sampled for TP (four in the fall/winter, three in the spring, one in the summer).
- In 6 of 8 events, TP EMCs were lower at the outflow than the inflow indicating treatment occurred in the Contech MFS.
- The highest TP EMCs and loads at the inflow and outflow occurred during the rain on snow event from February 1-2, 2019.
- The lowest TP EMC at the inflow occurred during the rain event on November 23, 2018.
- The lowest TP EMC at the outflow occurred during the thunderstorm event on October 3, 2018.
- The lowest TP load at the inflow occurred during the rain event on November 23, 2018, and the lowest TP load at the outflow occurred during the thunderstorm event on October 3, 2018.

Seasonal load as a fraction of the water year load for the Contech MFS inflow and outflow are presented in Figure 20 and Figure 21, respectively. Event loads are presented in tabular form in Table 6.

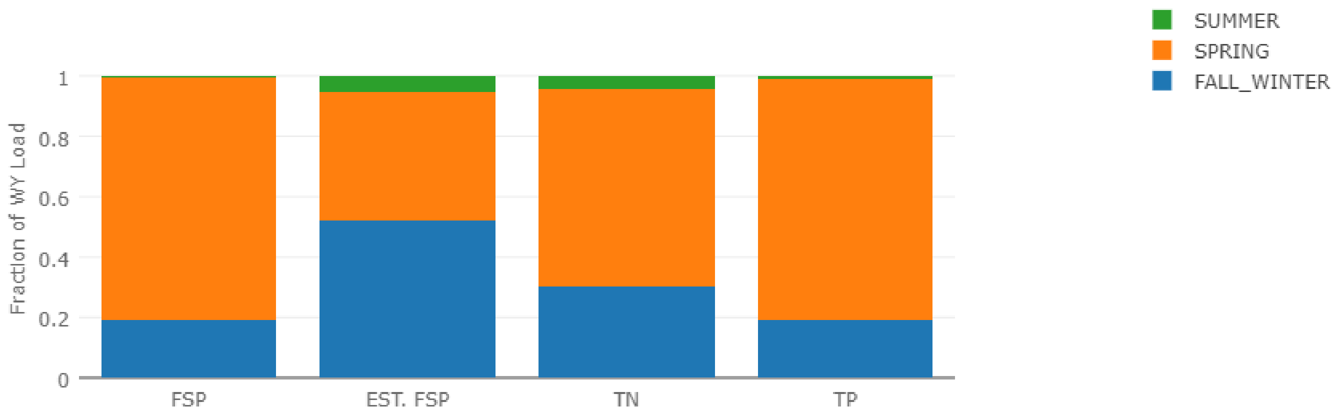

Figure 20 Seasonal load as a fraction of the water year load at the Contech MFS inflow, WY19. The first FSP column represents the FSP load calculated using event mean concentrations and the second FSP column (EST. FSP) represents the FSP load estimated using continuous turbidity data.

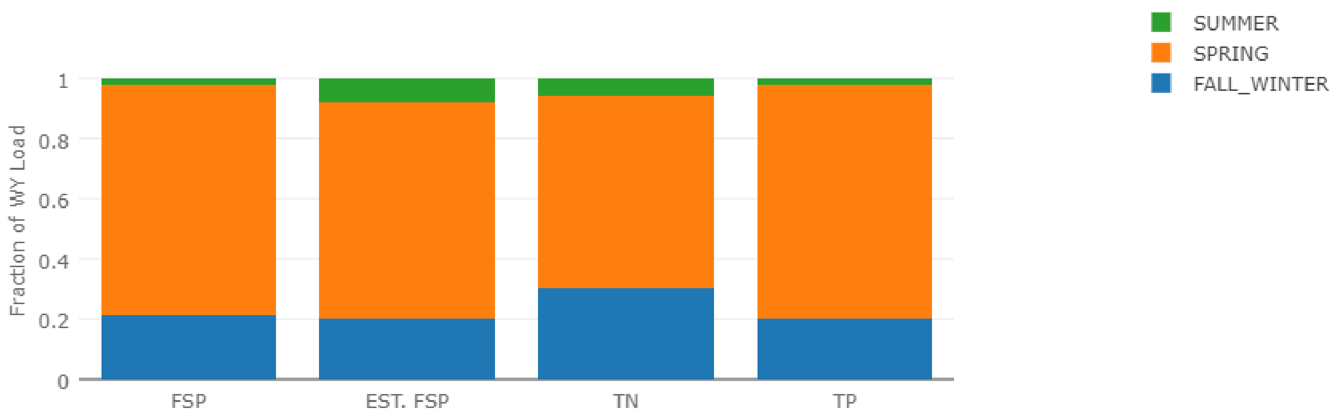

Figure 21 Seasonal load as a fraction of the water year load at the Contech MFS outflow, WY19. The first FSP column represents the FSP load calculated using event mean concentrations and the second FSP column (EST. FSP) represents the FSP load estimated using continuous turbidity data.

- The largest fraction of FSP loads (based on samples) at the inflow was generated in the spring.
- The largest fraction of FSP loads (based on continuous turbidity) at the inflow was generated in the fall/winter.
- The largest fraction of FSP loads (based on samples and continuous turbidity) at the outflow was generated in the spring.
- The discrepancy between FSP loads based on samples and based on continuous turbidity is likely a result of the turbidimeters being buried in sediment during the fall/winter. This would cause an overestimation of fall/winter FSP load based on continuous turbidity.
- The largest fraction of TN loads at the inflow was generated in the spring.
- The largest fraction of TN loads at the outflow was generated in the spring.
- The largest fraction of TP loads at the inflow was generated in the spring.
- The largest fraction of TP loads at the outflow was generated in the spring.

Jellyfish

Daily flow and FSP EMC summaries for the Jellyfish inflow and outflow are presented in Figure 22 and Figure 23, respectively. Table 7 presents this data in tabular form. Table 7 also presents the load data referenced in some bullet points below.

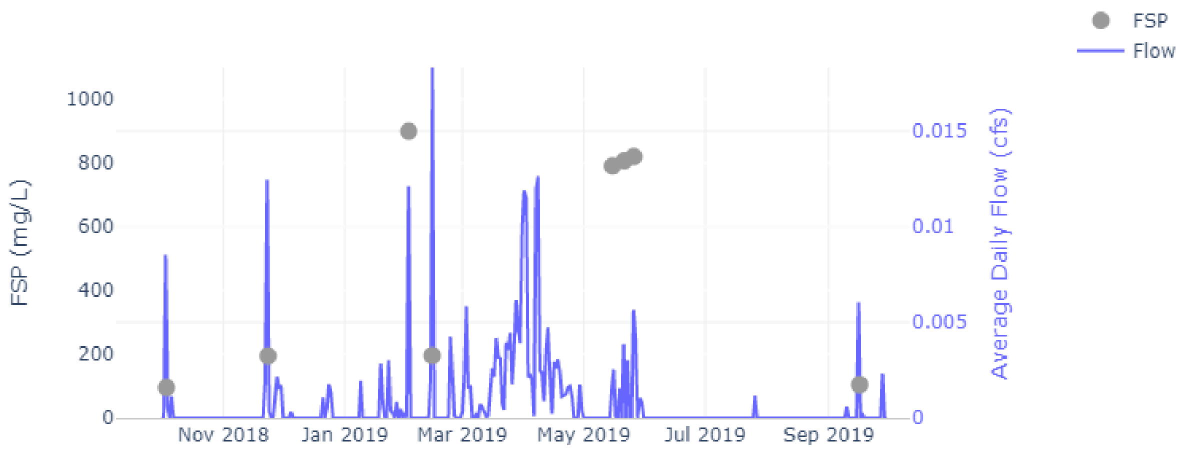

Figure 22 Daily inflow and FSP EMC summary at the Jellyfish, WY19. (February 13-14 and May 15-16 data is from CI.)

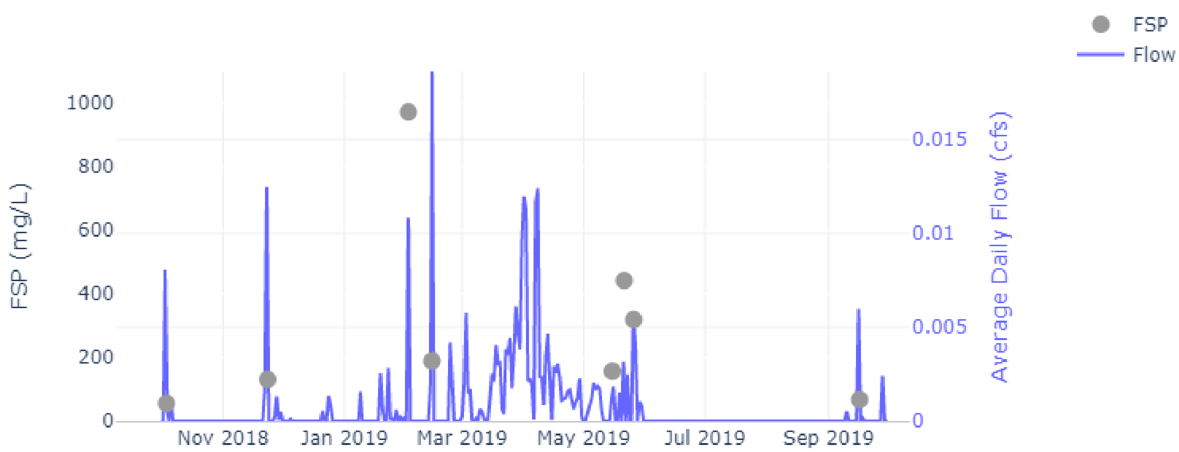

Figure 23 Daily outflow and FSP EMC summary at the Jellyfish, WY19.

- Eight events were sampled for FSP (four in the fall/winter, three in the spring, one in the summer). Sampling at JI failed on February 13-14, 2019 and May 15-16, 2019, so CI data values were used for JI.
- In 7 of 8 events, FSP EMCs were lower at the outflow than the inflow indicating treatment occurred.
- The highest FSP EMCs and load occurred during the rain on snow event on February 1-2, 2019.
- The lowest FSP EMCs occurred on the October 3, 2018 thunderstorm event.
- The lowest FSP loads occurred at the inflow and outflow during rain and snow event on September 16, 2019.

Daily flow and TN EMC summaries for the Jellyfish inflow and outflow are presented in Figure 24 and Figure 25, respectively. Table 7 presents this data in tabular form. Table 7 also presents the load data referenced in some bullet points below.

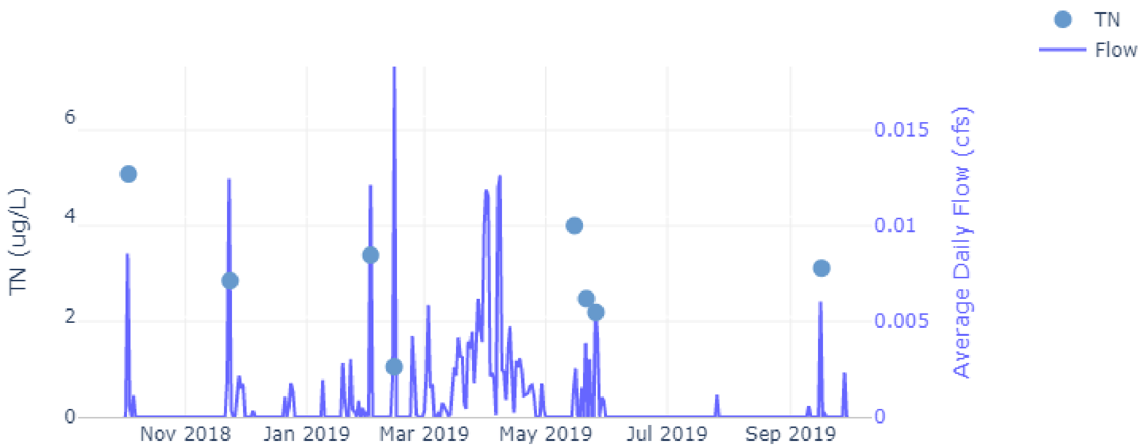

Figure 24 Daily inflow and TN EMC summary at the Jellyfish, WY19. (February 13-14 and May 15-16 data is from CI.)

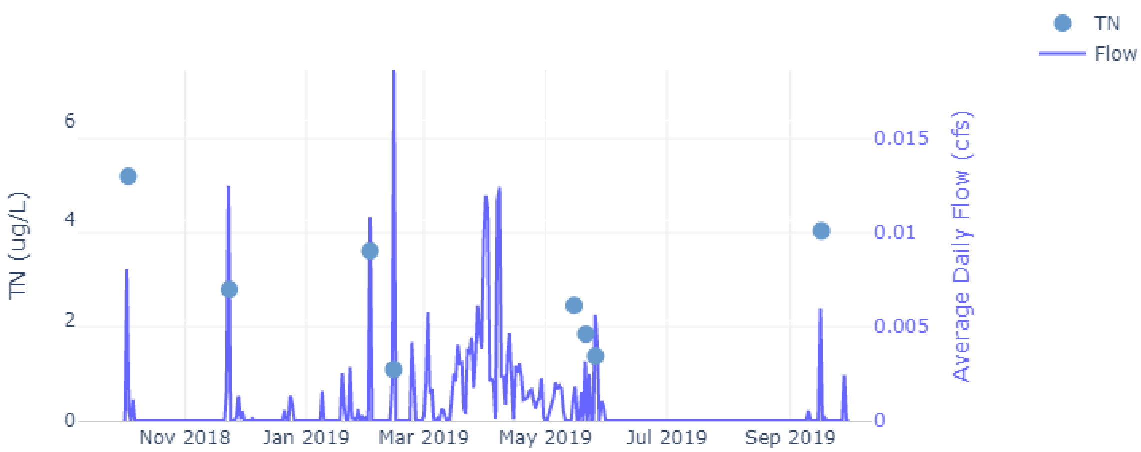

Figure 25 Daily outflow and TN EMC summary at the Jellyfish, WY19.

- Eight events were sampled for TN (four in the fall/winter, three in the spring, one in the summer). Sampling at JI failed on February 13-14, 2019 and May 15-16, 2019, so CI data values were used for JI.
- Half of the TN EMCs were higher at the outflow than the inflow, and half were lower at the outflow than the inflow, indicating minimal treatment from the Jellyfish.
- The highest TN EMC and load at the inflow and outflow occurred during the thunderstorm on October 3, 2018.
- The lowest TN EMCs at the inflow (data from CI) and outflow occurred during the atmospheric river rain on snow event from February 13-14, 2019.
- The lowest TN loads at the inflow occurred during the rain on snow event on May 21, 2019 and at the outflow the lowest TN loads occurred during the rain on snow event from May 15-16, 2019 and during the rain on snow event on May 21, 2019.

Daily flow and TP EMC summaries for the Jellyfish inflow and outflow are presented in Figure 26 and Figure 27, respectively. Table 7 presents this data in tabular form. Table 7 also presents the load data referenced in some bullet points below.

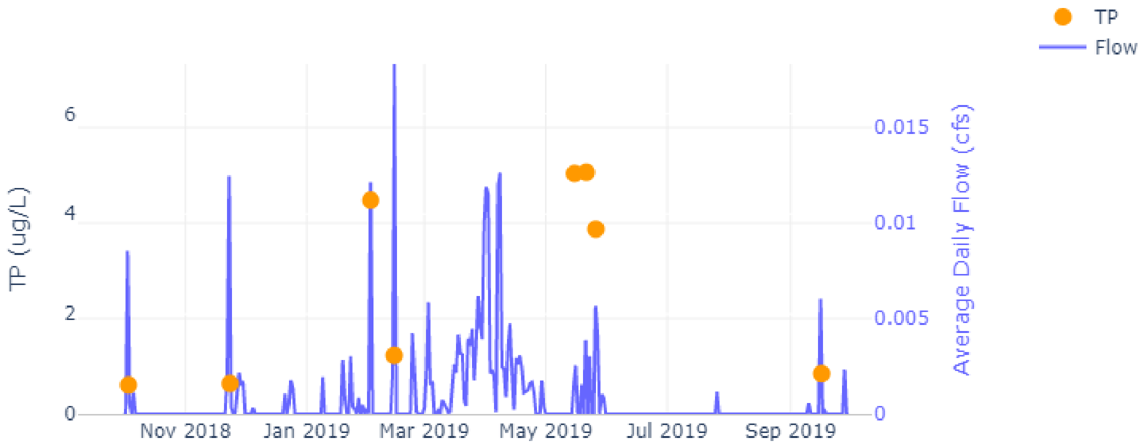

Figure 26 Daily inflow and TP EMC summary at the Jellyfish, WY19. (February 13-14 and May 15-16 data is from CI.)

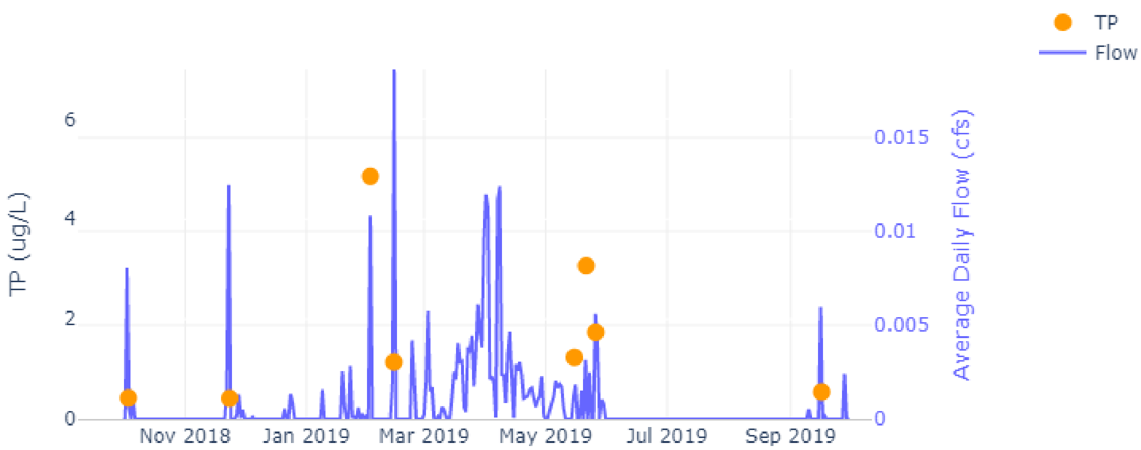

Figure 27 Daily outflow and TP EMC summary at the Jellyfish, WY19.

- Eight events were sampled for TP (four in the fall/winter, three in the spring, one in the summer). Sampling at JI failed on February 13-14, 2019 and May 15-16, 2019, so CI data values were used for JI.
- In 7 of 8 events, TP EMCs were higher at the inflow than the outflow indicating treatment occurred in the Jellyfish.
- The highest TP EMCs at the inflow occurred during the rain on snow event on May 21, 2019.
- The highest TP EMC at the outflow occurred during the rain on snow event on February 1-2, 2019.
- The highest TP loads occurred at the inflow and outflow during the February 1-2, 2019 rain on snow event.
- The lowest TP EMCs at the inflow and outflow occurred during the October 3, 2018 thunderstorm event and the November 23, 2018 rain event.
- The lowest TP loads at the inflow and outflow occurred during the October 3, 2018 thunderstorm event and the rain and snow event on September 16, 2019.

Seasonal load as a fraction of the water year load for the Jellyfish inflow and outflow are presented in Figure 28 and Figure 29, respectively. Event loads are presented in tabular form in Table 7.

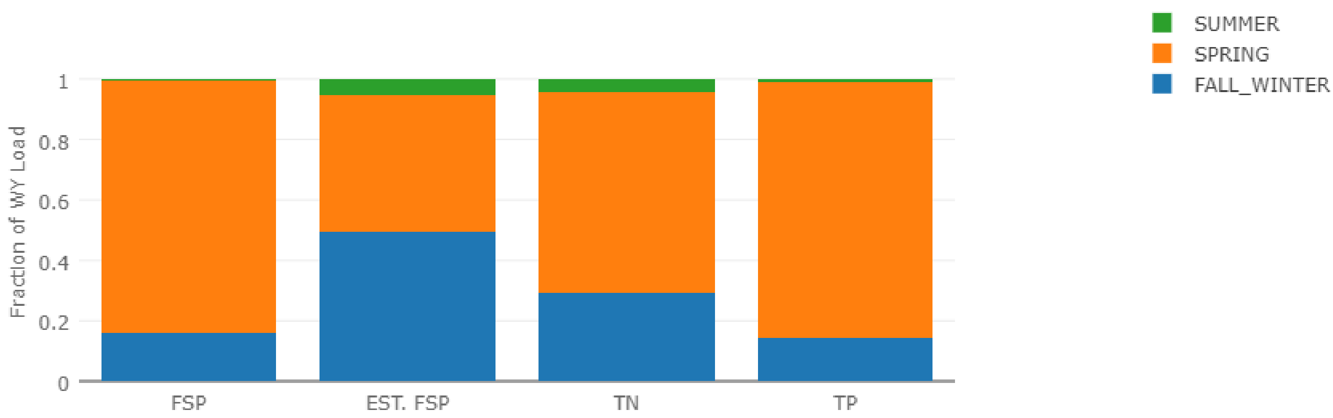

Figure 28 Seasonal load as a fraction of the water year load at the Jellyfish inflow, WY19. The first FSP column represents the FSP load calculated using event mean concentrations, while the second FSP column (EST. FSP) represents the FSP load estimated using continuous turbidity data.

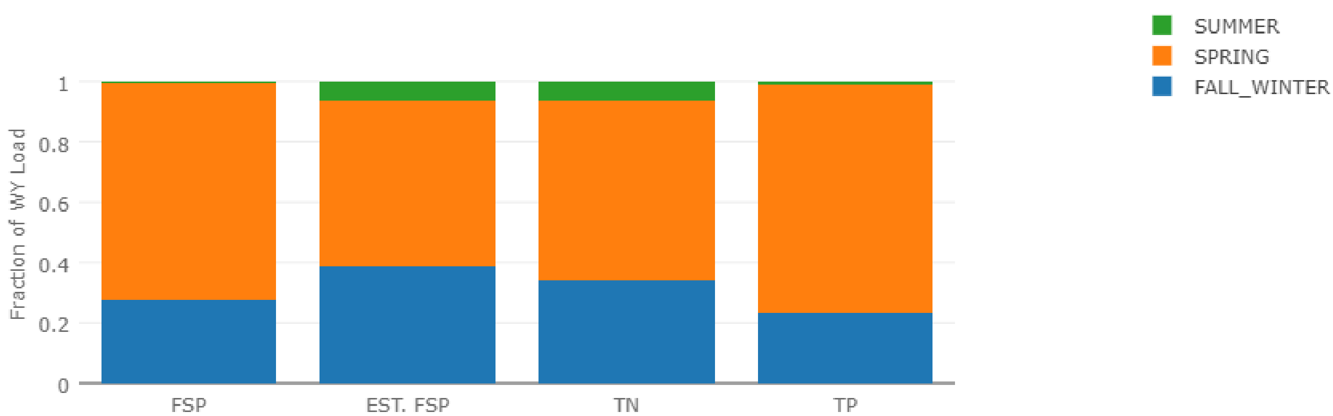

Figure 29 Seasonal load as a fraction of the water year load at the Jellyfish outflow, WY19. The first FSP column represents the FSP load calculated using event mean concentrations, while the second FSP column (EST. FSP) represents the FSP load estimated using continuous turbidity data.

- The largest fraction of FSP loads (based on samples) at the inflow was generated in the spring.
- The largest fraction of FSP loads (based on continuous turbidity) at the inflow was generated in the fall/winter.
- The largest fraction of FSP loads (based on samples and continuous turbidity) at the outflow was generated in the spring.
- The discrepancy between FSP loads based on samples and based on continuous turbidity is likely a result of the turbidimeters being buried in sediment during the fall/winter. This would cause an overestimation of fall/winter FSP load based on continuous turbidity.
- The largest fraction of TN loads at the inflow was generated in the spring.
- The largest fraction of TN loads at the outflow was generated in the spring.
- The largest fraction of TP loads at the inflow was generated in the spring.
- The largest fraction of TP loads at the outflow was generated in spring.

Eight events were sampled at SR431 in WY19. Event summary data for the Contech MFS and Jellyfish treatment vaults is presented in Table 6 and Table 7 respectively. CI data values were used for JI for 2/13/19 and 5/15/19 events because sampling failed at JI during those two events. This is a valid approach because the runoff that is measured at both these monitoring stations should be the same. They should be the same because incoming flow off the highway is roughly equally split between the two treatment vaults in a chamber directly above the monitoring stations.

Table 6 Event summary data at the Contech MFS treatment vault, WY19

Station Acronym	Season	Runoff Start (Date Time)	Runoff End (Date Time)	Runoff Duration (hh:mm)	Runoff Volume (cf)	Peak Flow (cfs)	Peak Turb (NTU)	Storm Total (in)	Event Type	% of Storm Sampled	FSP EMC (mg/L)	FSP event load (lbs)	TN EMC (ug/L)	TN event load (lbs)	TP EMC (ug/L)	TP event load (lbs)
CI	Fall/Winter	10/3/2018 10:05	10/3/2018 19:00	8:55	754	0.16	564	0.41	Thunderstorm	100%	70	3	5,150	0.2	562	<0.1
CO	Fall/Winter	10/3/2018 11:55	10/3/2018 19:05	7:10	450	0.05	184	0.41	Thunderstorm	100%	54	2	5,940	0.2	446	<0.1
CI	Fall/Winter	11/23/2018 10:10	11/23/2018 18:10	8:00	791	0.09	1,287	1.38	Rain	100%	190	9	1,850	<0.1	438	<0.1
CO	Fall/Winter	11/23/2018 10:30	11/23/2018 18:30	8:00	469	0.06	493	1.38	Rain	100%	95	3	1,380	<0.1	601	<0.1
CI	Fall/Winter	2/1/2019 23:50	2/2/2019 16:00	16:10	1,018	0.08	498	0.73	Rain on snow	100%	1,001	64	3,970	0.3	6,020	<0.1
CO	Fall/Winter	2/2/2019 0:55	2/2/2019 16:30	15:35	722	0.07	89	0.73	Rain on snow	100%	782	35	3,300	0.1	3,844	<0.1
CI	Fall/Winter	2/13/2019 18:25	2/14/2019 10:20	15:55	1,657	0.08	385	3.06	Rain on snow	100%	196	20	1,000	0.1	1,170	<0.1
CO	Fall/Winter	2/13/2019 21:05	2/14/2019 11:10	14:05	1,431	0.08	36	3.06	Rain on snow	100%	170	15	1,050	0.1	1,145	<0.1
CI	Spring	5/15/2019 9:35	5/16/2019 6:00	20:25	433	0.09	200	0.24	Rain	100%	791	21	3,820	0.1	4,807	0.1
CO	Spring	5/15/2019 9:55	5/16/2019 6:20	20:25	269	0.08	150	0.24	Rain	100%	225	4	2,070	<0.1	1,479	<0.1
CI	Spring	5/21/2019 8:10	5/21/2019 21:45	13:35	668	0.12	590	0.28	Rain on snow	100%	646	27	2,010	0.1	3,670	0.2
CO	Spring	5/21/2019 8:10	5/21/2019 21:25	13:15	492	0.08	666	0.28	Rain on snow	100%	411	13	1,540	<0.1	2,753	0.1
CI	Spring	5/26/2019 1:40	5/26/2019 14:10	12:30	424	0.07	905	0.64	Rain on snow	100%	671	18	1,970	0.1	3,368	0.1
CO	Spring	5/26/2019 2:05	5/26/2019 13:50	11:45	514	0.10	396	0.64	Rain on snow	100%	392	13	1,400	<0.1	2,012	0.1
CI	Summer	9/16/2019 11:10	9/16/2019 12:50	1:40	517	0.19	386	0.38	Rain	100%	100	3	2,660	0.1	818	<0.1
CO	Summer	9/16/2019 11:15	9/16/2019 12:55	1:40	366	0.15	405	0.38	Rain	100%	197	4	3,430	0.1	1,265	<0.1

Table 7 Event summary data at the Jellyfish treatment vault, WY19

Station Acronym	Season	Runoff Start (Date Time)	Runoff End (Date Time)	Runoff Duration (hh:mm)	Runoff Volume (cf)	Peak Flow (cfs)	Peak Turb (NTU)	Storm Total (in)	Event Type	% of Storm Sampled	FSP EMC (mg/L)	FSP event load (lbs)	TN EMC (ug/L)	TN event load (lbs)	TP EMC (ug/L)	TP event load (lbs)
JI	Fall/Winter	10/3/2018 10:05	10/3/2018 18:45	8:40	738	0.20	416	0.41	Thunderstorm	100%	95	4	4,850	0.2	578	<0.1
JO	Fall/Winter	10/3/2018 13:05	10/3/2018 19:15	6:10	696	0.11	168	0.41	Thunderstorm	100%	55	2	4,880	0.2	421	<0.1
JI	Fall/Winter	11/23/2018 10:05	11/24/2018 3:40	17:35	1,104	0.10	1,287	1.38	Rain	100%	194	13	2,720	0.2	607	<0.1
JO	Fall/Winter	11/23/2018 10:10	11/23/2018 23:40	13:30	1,078	0.11	455	1.38	Rain	100%	131	9	2,620	0.2	413	<0.1
JI	Fall/Winter	2/1/2019 23:45	2/2/2019 16:05	16:20	1,051	0.07	538	0.73	Rain on snow	100%	900	59	3,230	0.2	4,273	0.3
JO	Fall/Winter	2/2/2019 0:00	2/2/2019 16:05	16:05	935	0.07	43	0.73	Rain on snow	100%	972	57	3,390	0.2	4,858	0.3
JI	Fall/Winter	2/13/2019 18:25	2/14/2019 11:10	16:45	1,764	0.08	385	3.06	Rain on snow	100%	196	22	1,000	0.1	1,170	<0.1
JO	Fall/Winter	2/13/2019 20:05	2/14/2019 10:45	14:40	1,762	0.09	41	3.06	Rain on snow	100%	189	21	1,020	0.1	1,139	<0.1
JI	Spring	5/15/2019 8:30	5/16/2019 6:30	22:00	298	0.07	200	0.24	Rain	100%	791	15	3,820	0.1	4,807	0.1
JO	Spring	5/15/2019 8:55	5/16/2019 6:30	21:35	235	0.04	150	0.24	Rain	100%	156	2	2,300	<0.1	1,233	<0.1
JI	Spring	5/21/2019 8:10	5/21/2019 20:30	12:20	332	0.16	507	0.28	Rain on snow	100%	807	17	2,360	<0.1	4,831	0.1
JO	Spring	5/21/2019 8:10	5/21/2019 20:45	12:35	272	0.05	687	0.28	Rain on snow	100%	442	7	1,730	<0.1	3,067	0.1
JI	Spring	5/26/2019 1:40	5/26/2019 14:55	13:15	487	0.08	905	0.64	Rain on snow	100%	820	25	2,090	0.1	3,695	0.1
JO	Spring	5/26/2019 1:50	5/26/2019 14:55	13:05	485	0.08	375	0.64	Rain on snow	100%	319	10	1,290	<0.1	1,736	0.1
JI	Summer	9/16/2019 11:10	9/16/2019 12:50	1:40	522	0.19	386	0.38	Rain	100%	104	3	2,970	0.1	806	<0.1
JO	Summer	9/16/2019 11:10	9/16/2019 13:00	1:50	516	0.17	343	0.38	Rain	100%	67	2	3,790	0.1	541	<0.1

*CI data values were used for JI for 2/13/19 and 5/15/19 events because sampling failed at JI during those two events.

6.2.2 Elks Club

Figure 30 shows the average daily flow and cumulative precipitation for WY19 at the Elks Club catchment outfall.

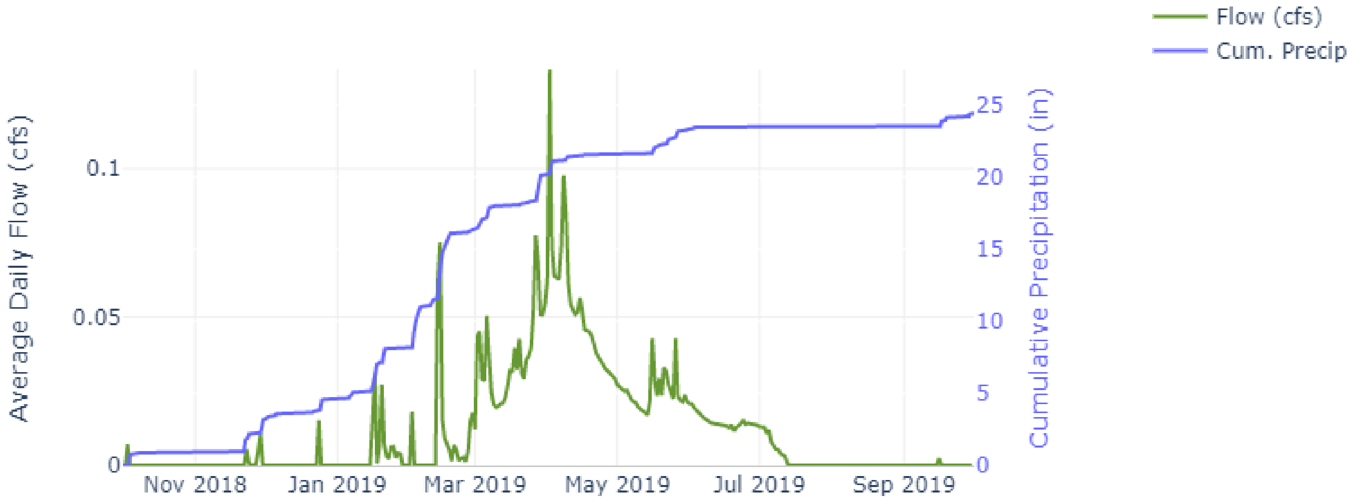

Figure 30 Average daily flow and cumulative precipitation at the Elks Club catchment outfall, WY19.

- 24.4 inches of total precipitation (16.42 in the fall/winter, 6.96 in the spring, 1.04 in the summer) were recorded at the Shakori (SHK) weather station.
- 46 precipitation events occurred (22 fall/winter events, 20 spring events, 4 summer events).
- The largest storm, with over 4 inches of precipitation, occurred during an atmospheric river rain and snow event from February 13-17, 2019.
- 70% of storms were less than half an inch.
- Highest average daily flows occurred in April of the spring season.
- 136 days of snowmelt runoff occurred in the fall/winter, spring, *and* summer.
- The highest instantaneous peak precipitation was 0.112 inches in 5 minutes during a thunderstorm event on October 3, 2018.
- The highest instantaneous peak flow was 0.39 cfs during a rain and snow event on April 2, 2019.
- The most runoff was produced by *snowmelt*, which occurred in the fall/winter, spring, *and* summer (274,632 cf). The most runoff caused by a precipitation event occurred during the February 13-17, 2019 atmospheric river rain and snow event (14,959 cf).

Daily flow and the FSP EMC summary at Elks Club are presented in Figure 31. Table 8 presents this data in tabular form. Table 8 also presents the load data referenced in some bullet points below.

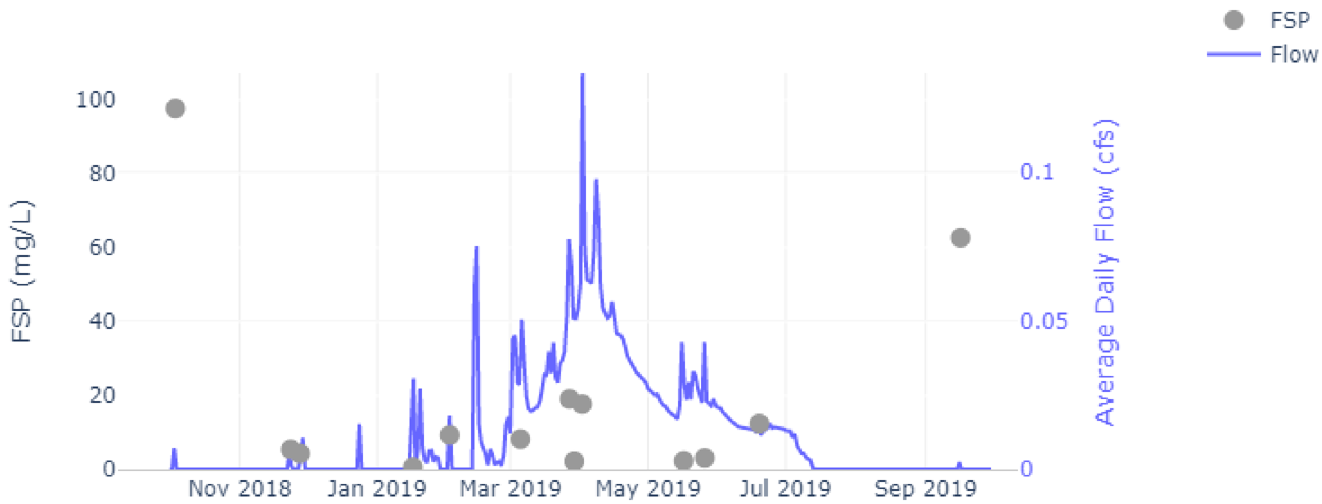

Figure 31 Daily flow and FSP EMC summary at the Elks Club catchment outfall, WY19.

- Thirteen events were sampled for FSP (five in the fall/winter, six in the spring, and two in the summer).
- The highest FSP EMC occurred during the thunderstorm event on October 3, 2018.
- The highest FSP load occurred during the rain on snow event on April 1-3, 2019.
- The lowest FSP EMCs and load occurred during a rain on snow event on January 16-17, 2019.

Daily flow and the TN EMC summary at Elks Club are presented in Figure 32. Table 8 presents this data in tabular form. Table 8 also presents the load data referenced in some bullet points below.

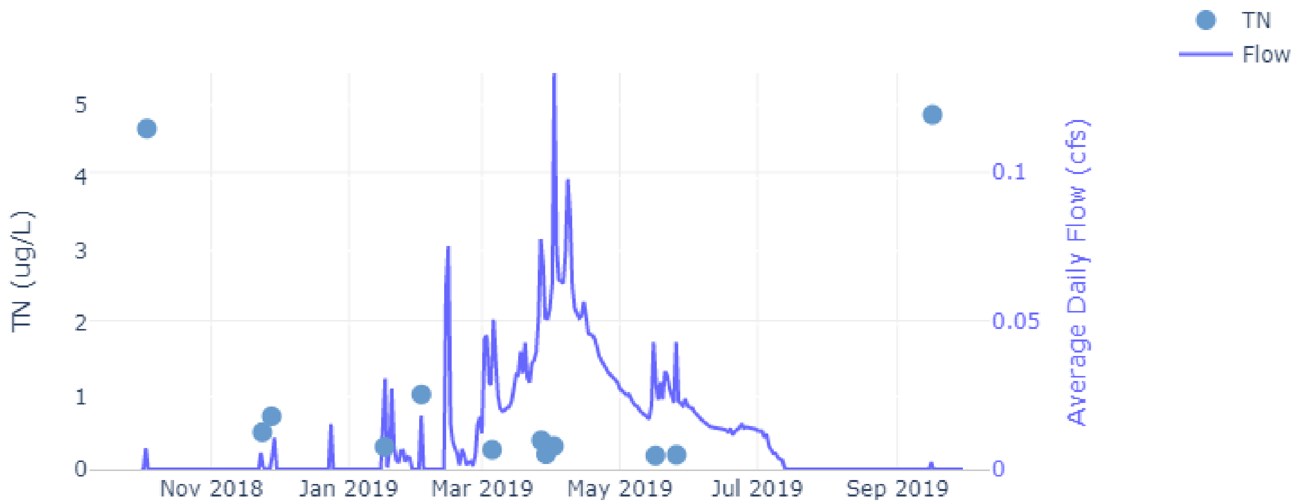

Figure 32 Daily flow and TN EMC summary at the Elks Club catchment outfall, WY19.

- Thirteen events were sampled for TN (five in the fall/winter, six in the spring, and two in the summer).
- The highest TN EMC occurred during the rain and snow event on September 16, 2019.
- The highest TN load occurred during the rain on snow event April 1-3, 2019.
- The lowest TN EMC occurred during a rain and snow event from May 16-17, 2019.
- The lowest TN load occurred during the rain event on November 23-24, 2018 and the event snowmelt on May 16-17, 2019.

Daily flow and the TP EMC summary at Elks Club are presented in Figure 33. Table 8 presents this data in tabular form. Table 8 also presents the load data referenced in some bullet points below.

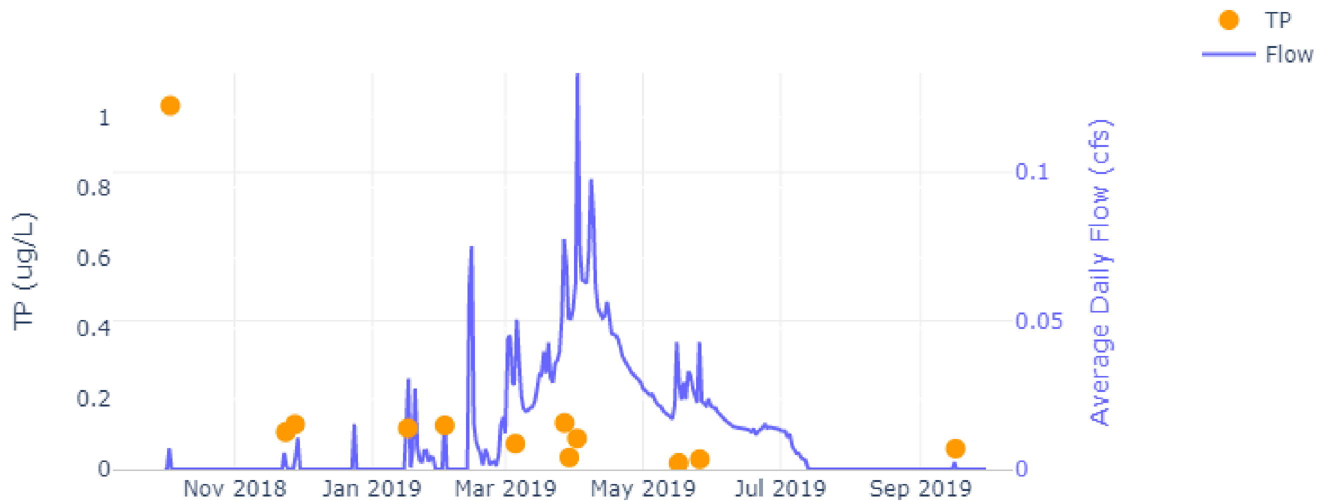

Figure 33 Daily flow and TP EMC summary at the Elks Club catchment outfall, WY19.

- Thirteen events were sampled for TP (five in the fall/winter, six in the spring, and two in the summer).
- The highest TP EMC occurred during the thunderstorm event on October 3, 2018.
- The highest TP load occurred during the rain on snow event from April 1-3, 2019.
- The lowest TP EMC occurred during the rain and snow from May 16-17, 2019.
- The lowest TP load occurred during the rain and snow event on September 16, 2019.

Seasonal load as a fraction of the water year load at Elks Club is presented in Figure 34. Event loads are presented in tabular form in Table 8.

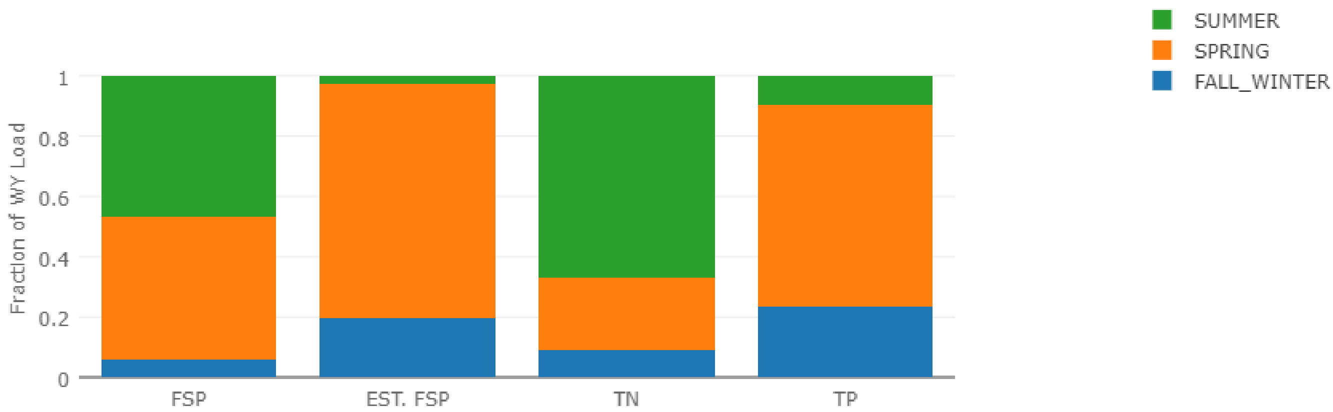

Figure 34 Seasonal load as a fraction of the water year load at the Elks Club catchment outfall, WY19. The first FSP column represents the FSP load calculated using event mean concentrations, while the second FSP column (EST. FSP) represents the FSP load estimated using continuous turbidity data.

- The largest fraction of FSP loads (based on samples) was split between the spring and summer.
- The largest fraction of FSP loads (based on continuous turbidity) was generated in the spring.
- The largest fraction of TN loads was generated in the summer.
- The largest fraction of TP loads was generated in the spring.

Thirteen events were sampled at Elks Club in WY19. Event summary data is presented in Table 8.

Table 8 Event summary data at the Elks Club catchment outfall, WY19

Station Acronym	Season	Runoff Start (Date Time)	Runoff End (Date Time)	Runoff Duration (hh:mm)	Runoff Volume (cf)	Peak Flow (cfs)	Peak Turb (NTU)	Storm Total (in)	Event Type	% of Storm Sampled	FSP EMC (mg/L)	FSP event load (lbs)	TN EMC (ug/L)	TN event load (lbs)	TP EMC (ug/L)	TP event load (lbs)
EC	Fall/Winter	10/3/2018 11:05	10/3/2018 16:30	5:25	623	0.16	319	0.76	Thunderstorm	100%	98	4	4,680	0.2	1,032	<0.1
EC	Fall/Winter	11/23/2018 13:35	11/24/2018 2:10	12:35	540	0.02	29	1.22	Rain	100%	5	<1	510	<0.1	106	<0.1
EC	Fall/Winter	11/27/2018 16:50	11/29/2018 5:30	36:40	1,354	0.23	56	0.40	Rain on snow	100%	4	<1	730	0.1	128	<0.1
EC	Fall/Winter	1/16/2019 18:30	1/17/2019 18:30	24:00	3,895	0.24	40	1.43	Rain on snow	100%	1	<1	310	0.1	117	<0.1
EC	Fall/Winter	2/2/2019 1:25	2/2/2019 13:40	12:15	1,565	0.10	44	0.75	Rain on snow	100%	9	1	1,030	0.1	125	<0.1
EC	Spring	3/5/2019 9:40	3/6/2019 9:10	23:30	2,879	0.09	32	0.38	Rain on snow	100%	8	1	270	<0.1	73	<0.1
EC	Spring	3/27/2019 2:50	3/27/2019 12:55	10:05	3,632	0.20	72	0.37	Rain on snow	100%	19	4	400	0.1	132	<0.1
EC	Spring	3/29/2019 6:00	4/1/2019 6:00	72:00	13,471	0.10	9	0.00	Non-event Snowmelt	100%	2	2	210	0.2	34	<0.1
EC	Spring	4/1/2019 16:15	4/3/2019 0:15	32:00	14,240	0.39	49	0.99	Rain on snow	100%	18	16	320	0.3	88	0.1
EC	Spring	5/16/2019 17:15	5/17/2019 6:25	13:10	1,926	0.06	11	0.55	Event Snowmelt	100%	2	<1	190	<0.1	18	<0.1
EC	Spring	5/26/2019 1:10	5/26/2019 12:50	11:40	2,603	0.24	15	0.48	Rain	100%	3	1	200	<0.1	29	<0.1
EC	Summer	6/19/2019 7:51	6/19/2019 9:12	1:21	241	0.22	509	0.00	Washoff Study	100%	12	<1	na	na	na	na
EC	Summer	9/16/2019 12:00	9/16/2019 14:20	2:20	212	0.08	120	0.41	Rain	100%	63	1	4,870	0.1	59	<0.1

6.2.3 Lakeshore

Figure 35 shows the average daily flow and cumulative precipitation for WY19 at the Lakeshore catchment outfall.

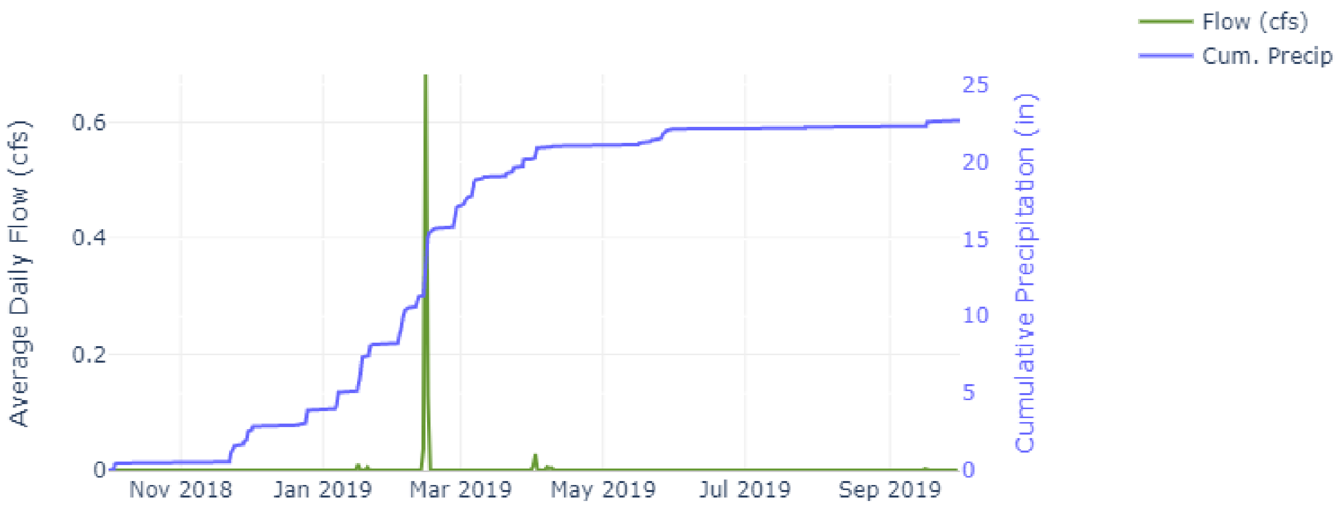

Figure 35 Average daily flow and cumulative precipitation at the Lakeshore catchment outfall, WY19.

- 22.64 inches of total precipitation (17.19 in the fall/winter, 4.96 in the spring, and 0.50 in the summer) were recorded at the TERC weather station.
- 47 precipitation events occurred (21 fall/winter events, 20 spring events, 6 summer events).
- The largest storm, with over 4 inches of precipitation, was an atmospheric river rain on snow event that occurred from February 13-15, 2019.
- 66% of storms were less than half an inch.
- Highest average daily flows occurred during the February 13-15, 2019 atmospheric river rain on snow event.
- There was one day of snowmelt on April 7, 2019.
- The highest instantaneous peak precipitation was 0.035 inches in 5 minutes during the thunderstorm event on October 3, 2018 and during a thunderstorm on July 26, 2019.
- The highest instantaneous peak flow was 1.55 cfs during the rain on snow event on February 14, 2019.
- The February 13-15, 2019 atmospheric river rain on snow event produced the most runoff by far (73,161 cf). The next largest runoff event was approximately 3,000cf, and all of the others were under 1,000 cf.

Daily flow and the FSP EMC summary at Lakeshore are presented in Figure 36. Table 9 presents this data in tabular form. Table 9 also presents the load data referenced in some bullet points below.

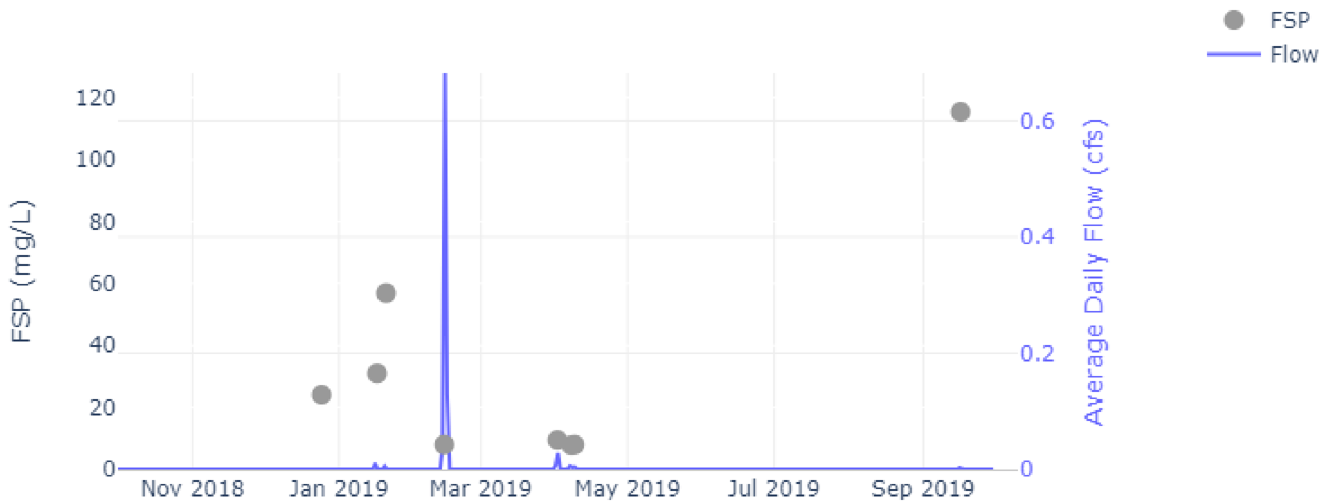

Figure 36 Daily flow and FSP EMC summary at the Lakeshore catchment outfall, WY19.

- Eight events were sampled for FSP (four in the fall/winter, three in the spring, one in the summer).
- The highest FSP EMC occurred during the rain and snow event on September 16, 2019.
- The highest FSP loads occurred during the atmospheric river rain on snow event from February 13-15, 2019.
- The lowest FSP EMC occurred during the non-event snowmelt sampled on April 7, 2019. FSP was also low during the February 13-15, 2019 atmospheric river rain on snow event, the April 1-2, 2019 rain on snow event, and the April 8, 2019 rain on snow event.
- The lowest FSP load occurred during the non-event snowmelt on April 7, 2019.

Daily flow and the TN EMC summary at Lakeshore are presented in Figure 37. Table 9 presents this data in tabular form. Table 9 also presents the load data referenced in some bullet points below.

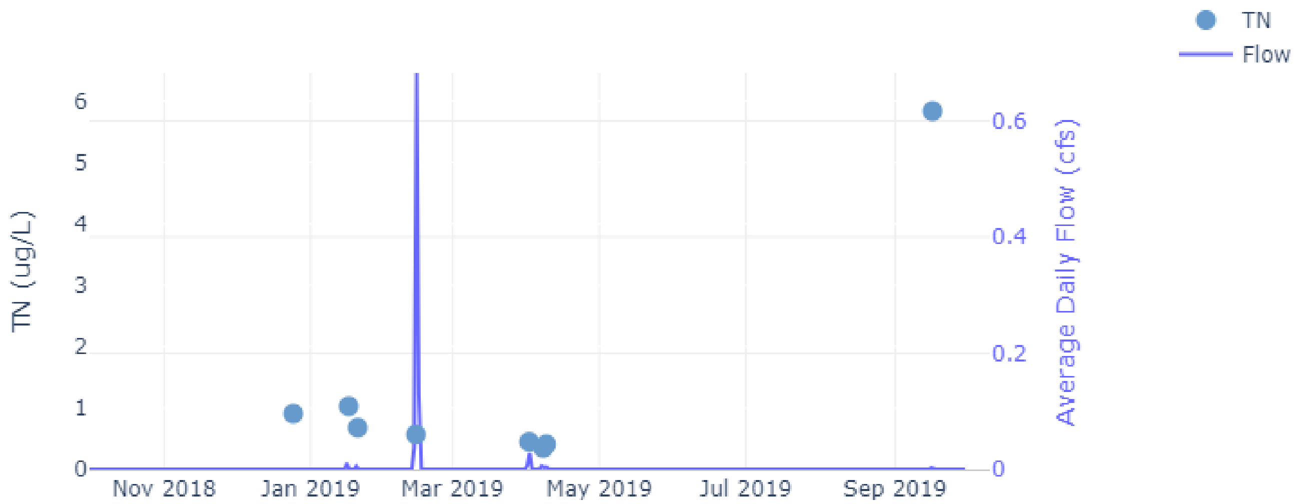

Figure 37 Daily flow and TN EMC summary at the Lakeshore catchment outfall, WY19.

- Eight events were sampled for TN (four in the fall/winter, three in the spring, one in the summer).
- The highest TN EMC occurred during the rain and snow event on September 16, 2019.
- The highest TN load occurred during the atmospheric river rain event from February 13-15, 2019.
- The lowest TN EMC occurred during the non-event snowmelt on April 7, 2019.
- The lowest TN load occurred during the non-event snowmelt on April 7, 2019 and the rain on snow event on December 24, 2018.

Daily flow and the TP EMC summary at Lakeshore are presented in Figure 38. Table 9 presents this data in tabular form. Table 9 also presents the load data referenced in some bullet points below.

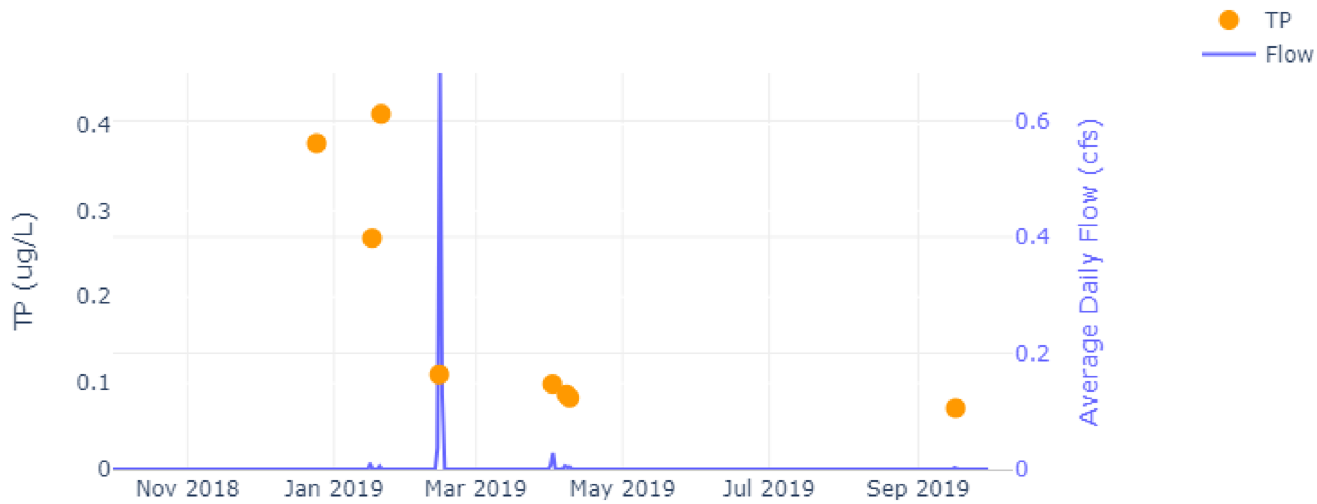

Figure 38 Daily flow and TP EMC summary at the Lakeshore catchment outfall, WY19.

- Eight events were sampled for TP (four in the fall/winter, three in the spring, one in the summer).
- The highest TP EMCs occurred during the rain on snow on January 20, 2019.
- The highest TP load occurred during the atmospheric river rain event from February 13-15, 2019.
- The lowest TP EMC occurred during the rain and snow event on September 16, 2019.
- The lowest TP load occurred during the rain and snow event on September 16, 2019.

Seasonal load as a fraction of the water year load at Lakeshore is presented in Figure 39. Event loads are presented in tabular form in Table 9.

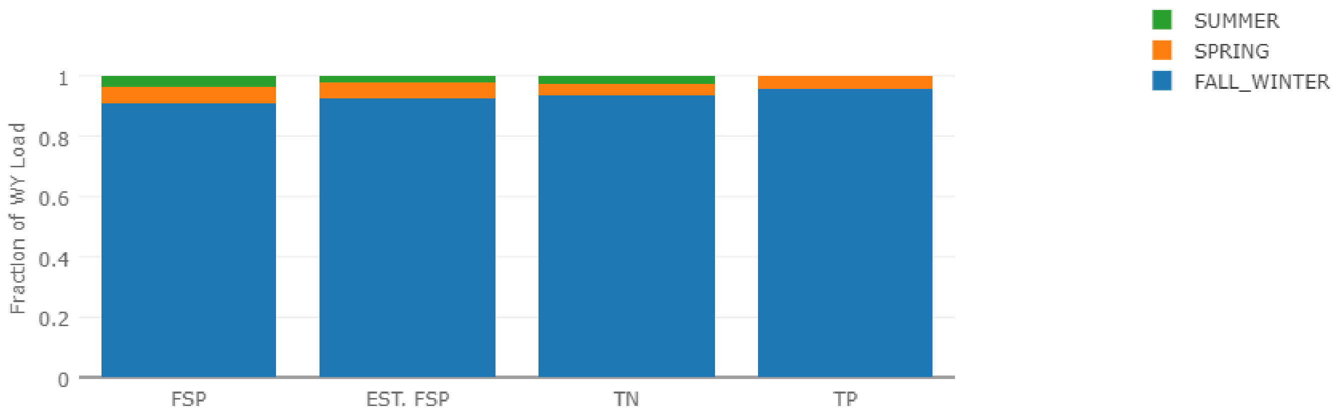

Figure 39 Seasonal load as a fraction of the water year load at the Lakeshore catchment outfall, WY19. The first FSP column represents the FSP load calculated using event mean concentrations, while the second FSP column (EST. FSP) represents the FSP load estimated using continuous turbidity data.

- The largest fraction of the FSP load was generated in the fall/winter.
- The largest fraction of the TN load was generated in the fall/winter
- The largest fraction of the TP load was generated in the fall/winter.
- The fraction of TP generated in the summer was negligible and is not visible.

Eight events were sampled at Lakeshore in WY19. Event summary data is presented in Table 9.

Table 9 Event summary data at the Lakeshore catchment outfall, WY19

Station Acronym	Season	Runoff Start (Date Time)	Runoff End (Date Time)	Runoff Duration (hh:mm)	Runoff Volume (cf)	Peak Flow (cfs)	Peak Turb (NTU)	Storm Total (in)	Event Type	% of Storm Sampled	FSP EMC (mg/L)	FSP event load (lbs)	TN EMC (ug/L)	TN event load (lbs)	TP EMC (ug/L)	TP event load (lbs)
LS	Fall/Winter	12/24/2018 15:30	12/24/2018 18:15	2:45	190	0.16	96	0.94	Rain on snow	100%	24	<1	910	<0.1	378	<0.1
LS	Fall/Winter	1/16/2019 18:45	1/17/2019 0:15	5:30	901	0.26	1,064	1.02	Rain on snow	100%	31	2	1,030	0.1	268	<0.1
LS	Fall/Winter	1/20/2019 12:30	1/20/2019 17:45	5:15	484	0.15	1,527	0.71	Rain on snow	100%	57	2	680	<0.1	412	<0.1
LS	Fall/Winter	2/13/2019 16:20	2/15/2019 16:40	48:20	73,161	1.55	44	4.20	Rain on snow	100%	8	37	570	2.6	110	0.5
LS	Spring	4/1/2019 19:25	4/2/2019 18:10	22:45	2,981	0.39	29	0.73	Rain on snow	100%	10	2	450	0.1	99	<0.1
LS	Spring	4/7/2019 14:40	4/7/2019 21:15	6:35	503	0.05	48	0.00	Non-event Snowmelt	100%	8	<1	350	<0.1	87	<0.1
LS	Spring	4/8/2019 14:13	4/9/2019 2:40	12:27	668	0.10	131	0.11	Rain on snow	100%	8	<1	410	<0.1	83	<0.1
LS	Summer	9/16/2019 12:20	9/16/2019 13:10	0:50	212	0.18	341	0.31	Rain	100%	115	2	5,840	0.1	71	<0.1

6.2.4 Pasadena

Figure 40 shows the average daily flow and cumulative precipitation for WY19 at the Pasadena outfall.

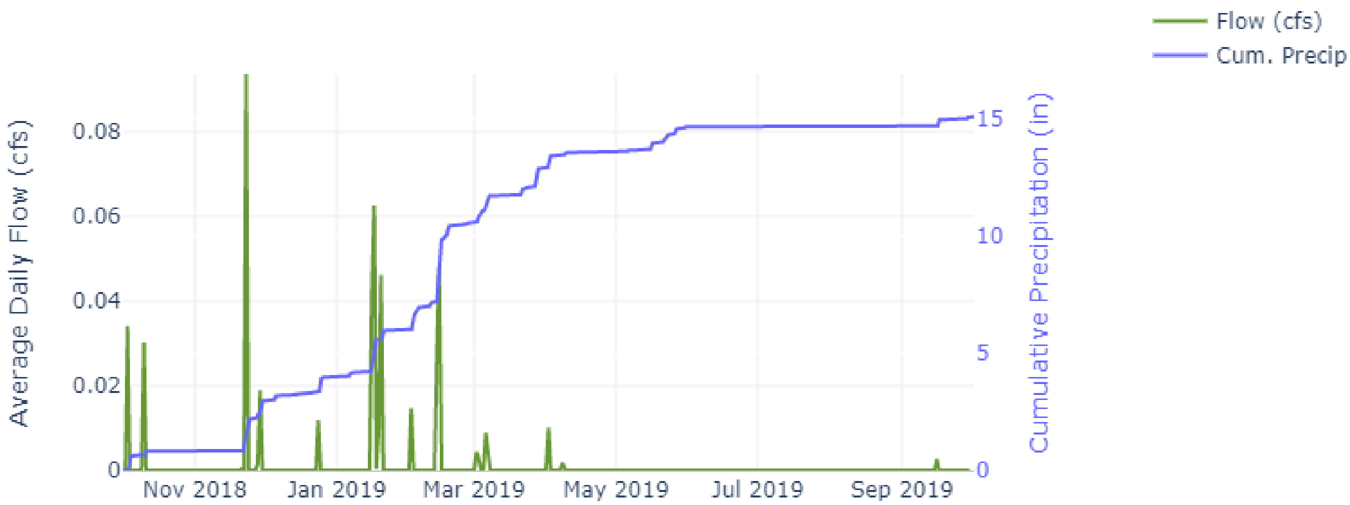

Figure 40 Average daily flow and cumulative precipitation at the Pasadena outfall, WY19.

- 15.11 inches of total precipitation (10.61 in the fall/winter, 4.16 in the spring, and 0.42 in the summer) were recorded at the Bellevue (BV) weather station. The Bellevue weather station is located at the edge of a meadow and likely gets high winds during precipitation events, and therefore may be subject to undercatch.
- 46 precipitation events occurred (24 fall/winter events, 17 spring events, 5 summer events).
- The largest storm, with 2.6 inches of precipitation, was an atmospheric river rain on snow event that occurred from February 13-14, 2019.
- 76% of storms were less than half an inch.
- Highest average daily flows occurred in November of the fall/winter season.
- There were zero days of snowmelt during the spring.
- The highest instantaneous peak precipitation was 0. 047 inches in 5 minutes during the rain event on October 3, 2018.
- The highest instantaneous peak flow was 1.3 cfs during the rain event on October 10, 2018.
- The January 16-17, 2019 atmospheric river rain event produced the most runoff (8,966 cf).

Daily flow and FSP EMC summaries at the Pasadena outfall are presented in Figure 41. Table 10 presents this data in tabular form. Table 10 also presents the load data referenced in some bullet points below.

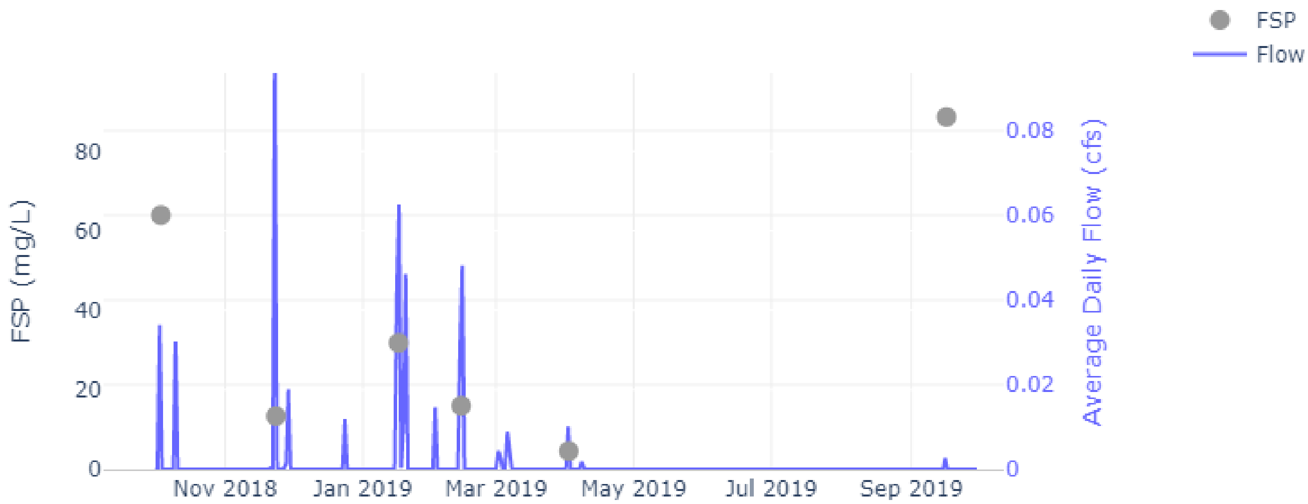

Figure 41 Daily outflow and FSP EMC summary at the Pasadena outfall, WY19.

- Six events were sampled for FSP (four in the fall/winter, one in the spring, one in the summer).
- The highest FSP EMC occurred during the rain and snow event on September 16, 2019.
- The highest FSP loads occurred during the atmospheric river rain event from January 16-17, 2019.
- The lowest FSP EMCs and load occurred during the rain on snow event from April 1-2, 2019.

The daily flow and TN EMC summaries for the Pasadena outfall are presented in Figure 42Table 10 presents this data in tabular form. Table 10 also presents the load data referenced in some bullet points below.

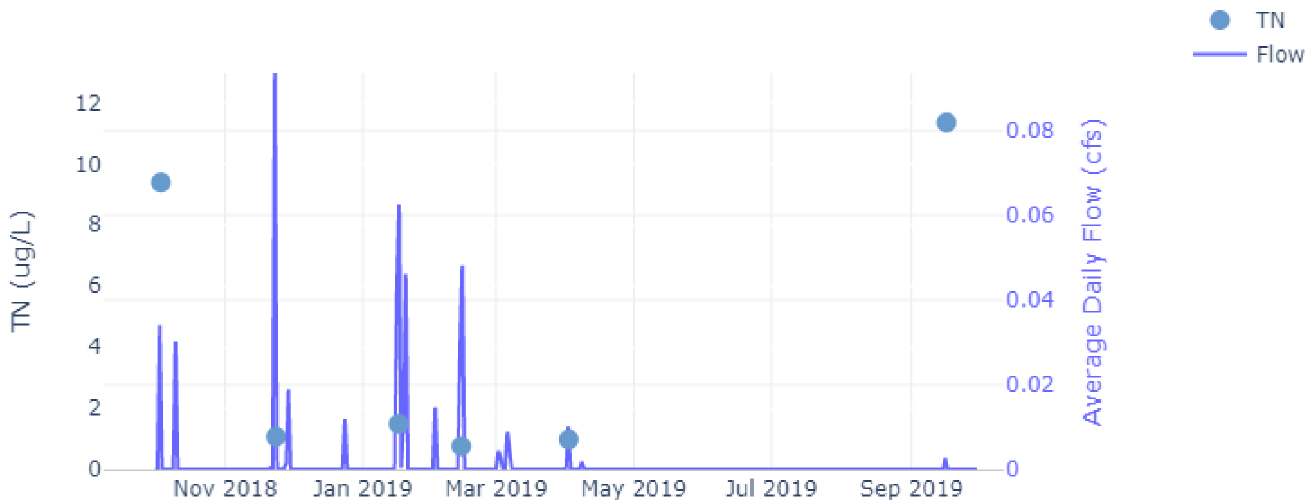

Figure 42 Daily outflow and TN EMC summary at the Pasadena outfall, WY19.

- Six events were sampled for FSP (four in the fall/winter, one in the spring, one in the summer).
- The highest TN EMC occurred during the rain and snow event on September 16, 2019.
- The highest TN loads occurred during the thunderstorm event on October 3, 2018.
- The lowest TN EMC occurred during the February 12-13, 2019 atmospheric river rain event.
- The lowest TN load occurred during the rain on snow event on April 1-2, 2019.

The daily flow and TP EMC summary for the Pasadena outflow are presented Figure 43. Table 10 presents this data in tabular form. Table 10 also presents the load data referenced in some bullet points below.

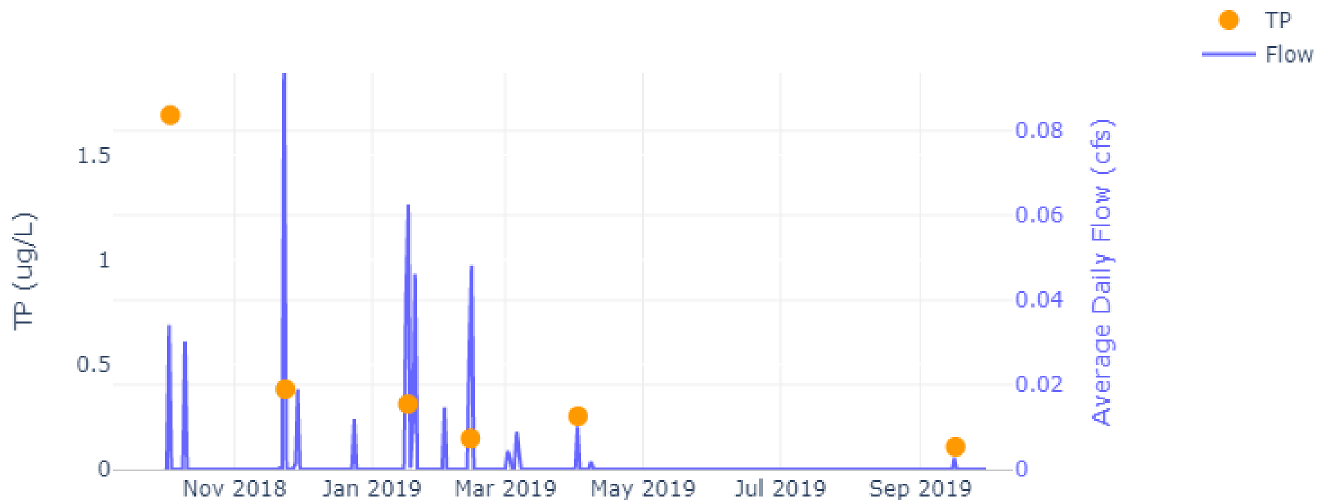

Figure 43 Daily outflow and TP EMC summary at the Pasadena outfall, WY19.

- Six events were sampled for FSP (four in the fall/winter, one in the spring, one in the summer).
- The highest TP EMC and load occurred during the thunderstorm event on October 3, 2018.
- The lowest TP EMC and load occurred during the rain and snow event on September 16, 2019.

Seasonal load as a fraction of the water year load for the Pasadena outflow are presented in Figure 44. Event loads are presented in tabular form in Table 10.

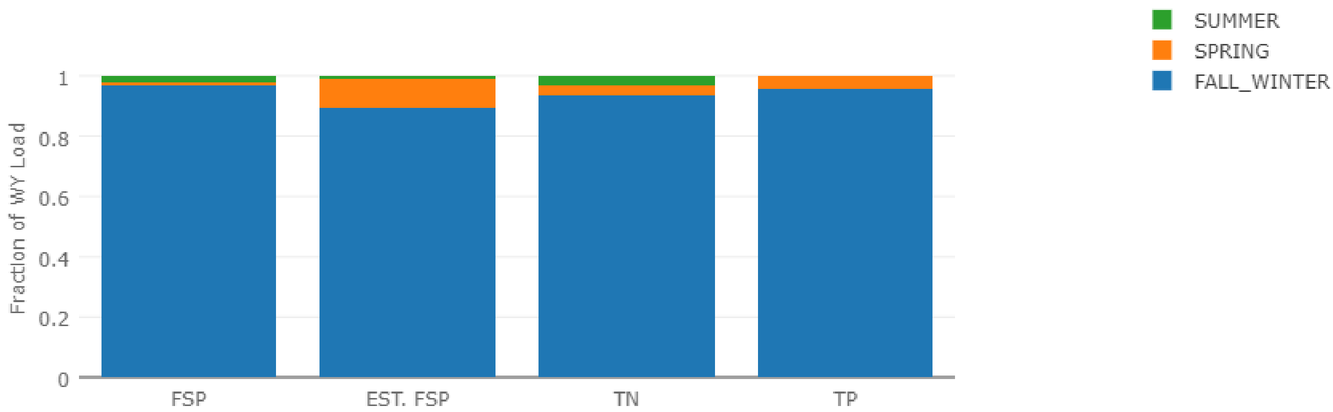

Figure 44 Seasonal load as a fraction of the water year load at the Pasadena outfall, WY19. The first FSP column represents the FSP load calculated using event mean concentrations, while the second FSP column (EST. FSP) represents the FSP load estimated using continuous turbidity data.

- The largest fraction of FSP load was generated in the fall/winter.
- The largest fraction of TN was generated in the fall/winter.
- The largest fraction of TP was generated in the fall/winter.
- Very small fractions of FSP and TN loads were generated in the spring and summer. The fraction of TP generated in the summer was negligible and is not visible.

Six events were sampled at Pasadena in WY19. Event summary data for the Pasadena outfall is presented in Table 10.

Table 10 Event summary data at the Pasadena outfall, WY19

Station Acronym	Season	Runoff Start (Date Time)	Runoff End (Date Time)	Runoff Duration (hh:mm)	Runoff Volume (cf)	Peak Flow (cfs)	Peak Turb (NTU)	Storm Total (in)	Event Type	% of Storm Sampled	FSP EMC (mg/L)	FSP event load (lbs)	TN EMC (ug/L)	TN event load (lbs)	TP EMC (ug/L)	TP event load (lbs)
PO	Fall/Winter	10/3/2018 12:20	10/3/2018 19:05	6:45	2,945	0.70	187	0.65	Thunderstorm	100%	64	12	9,390	1.7	1,691	0.3
PO	Fall/Winter	11/23/2018 11:00	11/24/2018 1:10	14:10	8,120	0.68	84	1.37	Rain	100%	13	7	1,070	0.5	383	0.2
PO	Fall/Winter	1/16/2019 18:50	1/17/2019 8:00	13:10	8,966	0.63	182	0.82	Rain on snow	100%	32	18	1,490	0.8	312	0.2
PO	Fall/Winter	2/13/2019 12:50	2/14/2019 11:50	23:00	6,528	0.56	143	2.64	Rain on snow	100%	16	7	760	0.3	148	0.1
PO	Spring	4/1/2019 17:20	4/2/2019 16:05	22:45	911	0.10	176	0.52	Rain on snow	100%	5	<1	980	0.1	254	<0.1
PO	Summer	9/16/2019 13:55	9/16/2019 14:15	0:20	235	0.10	174	0.28	Rain	100%	89	1	11,350	0.2	108	<0.1

6.2.5 Speedboat

Figure 45 shows the average daily flow and cumulative precipitation for WY19 at the Speedboat catchment outfall.

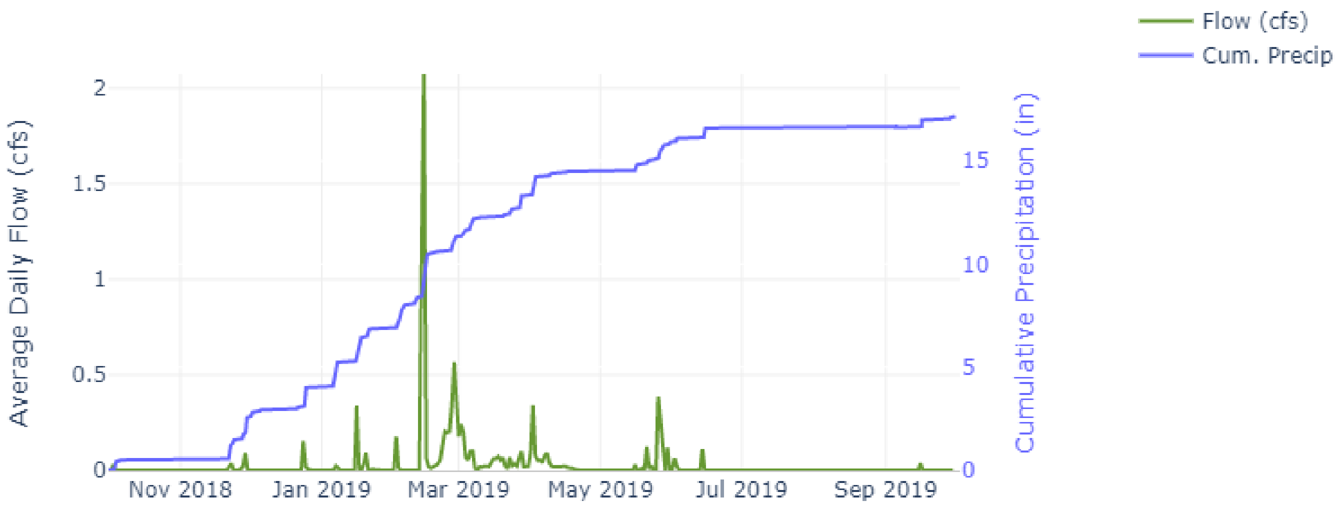

Figure 45 Average daily flow and cumulative precipitation at the Speedboat catchment outfall, WY19.

- 17.32 inches of total precipitation (11.35 in the fall/winter, 4.58 in the spring, and 1.38 in the summer) were recorded at the Nugget (NG) weather station.
- 52 precipitation events (20 fall/winter events, 21 spring events, 11 summer events).
- The largest storm, with over 2 inches of precipitation, was an atmospheric river rain on snow event that occurred from February 13-17, 2019.
- 79% of storms were less than half an inch.
- Highest average daily flows occurred during the February 13-17, 2019 atmospheric river rain on snow event.
- 82 days of intermittent snowmelt occurred in the fall/winter and spring.
- The highest instantaneous peak precipitation was 0.20 inches in 5 minutes during a thunderstorm on June 14, 2019.
- The highest instantaneous peak flow was 8.9 cfs during the thunderstorm event on June 14, 2019.
- The February 13-17, 2019 atmospheric river rain on snow event produced the most runoff (289,586 cf).

Daily flow and the FSP EMC summary at Speedboat are presented in Figure 46. Table 11 presents this data in tabular form. Table 11 also presents the load data referenced in some bullet points below.

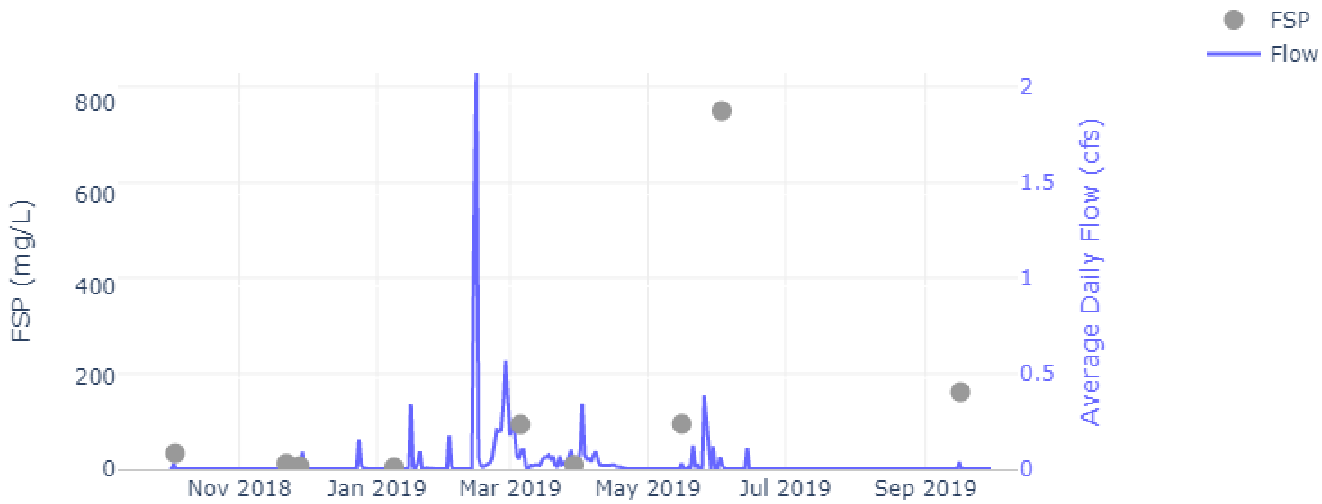

Figure 46 Daily flow and FSP EMC summary at the Speedboat catchment outfall, WY19.

- Nine events were sampled for FSP (four in the fall/winter, three in the spring, and two in the summer).
- The highest FSP EMC and load occurred during the thunderstorm on June 2, 2019.
- The lowest FSP EMC and load occurred during the rain on snow event from January 8-9, 2019.

Daily flow and the TN EMC summary are presented in Figure 47. Table 11 presents this data in tabular form. Table 11 also presents the load data referenced in some bullet points below.

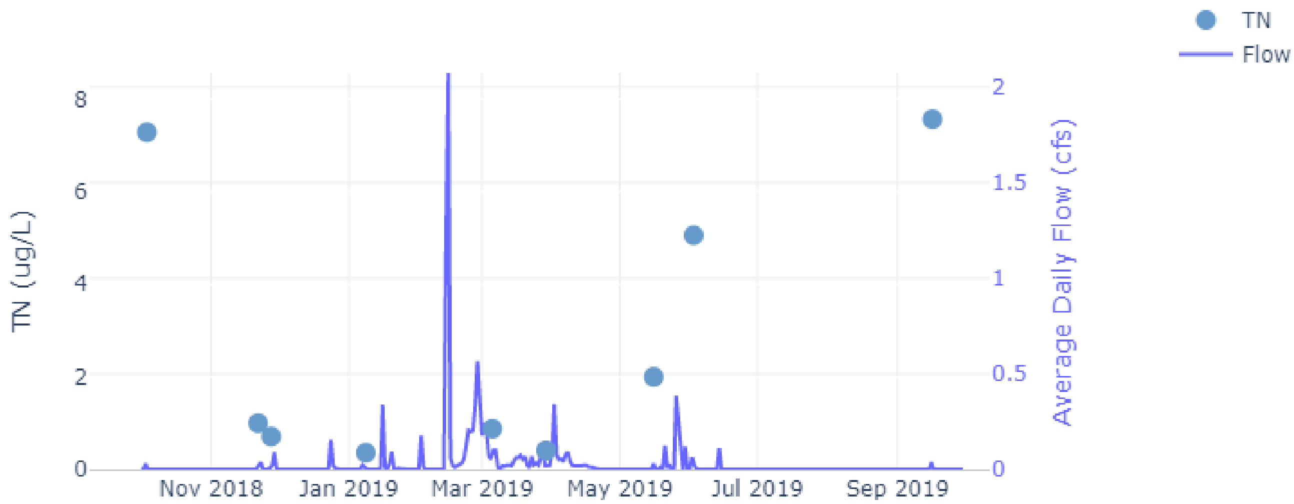

Figure 47 Daily flow and TN EMC summary at the Speedboat catchment outfall, WY19.

- Nine events were sampled for TN (four in the fall/winter, three in the spring, and two in the summer).
- The highest TN EMC occurred during the rain and snow event on September 16, 2019.
- The highest TN load occurred during the thunderstorm event on June 2, 2019.
- The lowest TN EMC and load occurred during the rain on snow event from January 8-9, 2019.

Daily flow and the TP EMC summary are presented in Figure 48. Table 11 presents this data in tabular form. Table 11 also presents the load data referenced in some bullet points below.

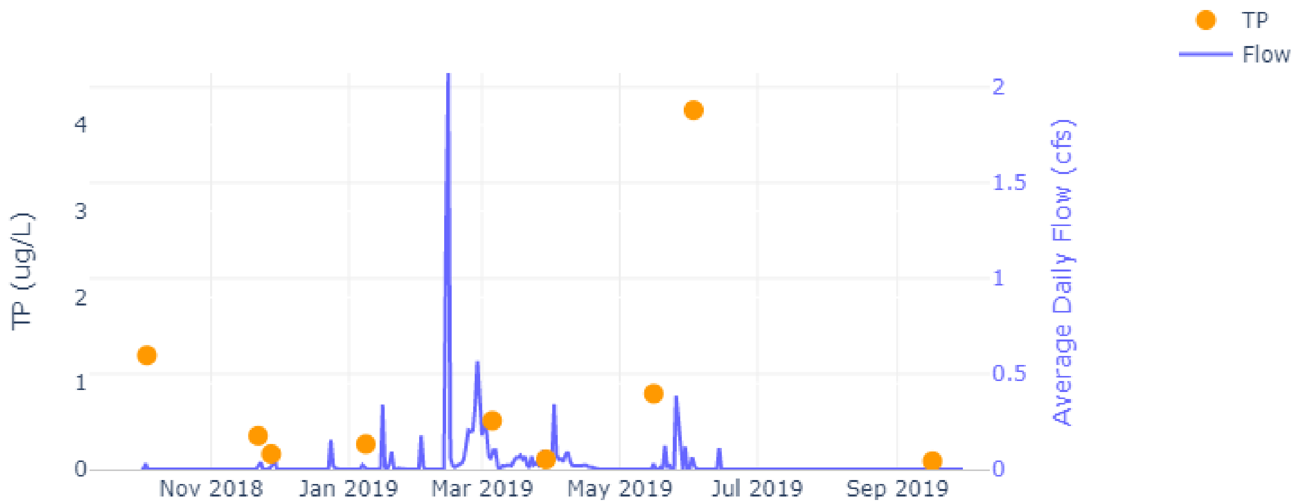

Figure 48 Daily flow and TP EMC summary at the Speedboat catchment outfall, WY19.

- Nine events were sampled for TP (four in the fall/winter, three in the spring, and two in the summer).
- The highest TP EMC and load occurred during the thunderstorm event on June 2, 2019.
- The lowest TP EMC and load occurred during the rain and snow event on September 16, 2019.

Seasonal load as a fraction of the water year load is presented in Figure 49. Event loads are presented in tabular form in Table 11.

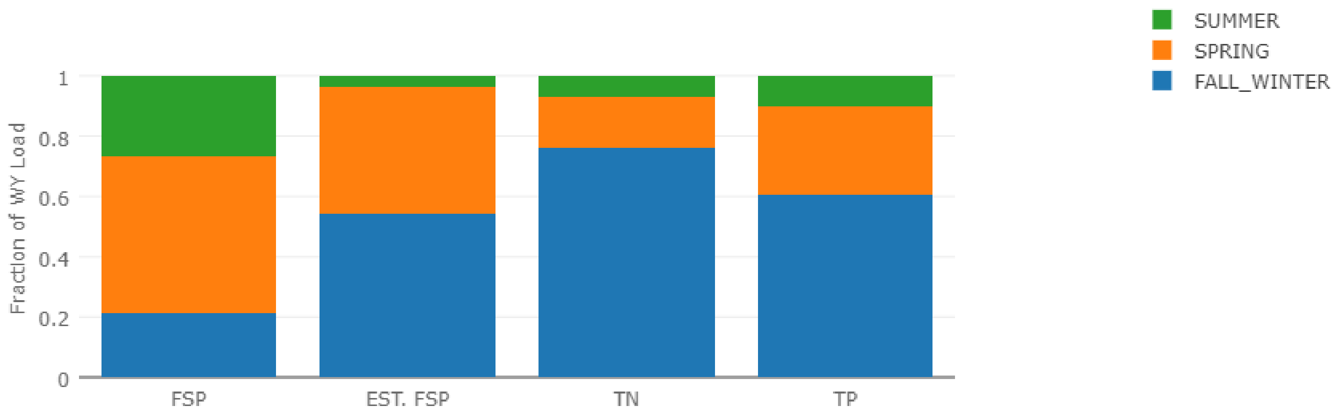

Figure 49 Seasonal load as a fraction of the water year load at the Speedboat catchment outfall, WY19. The first FSP column represents the FSP load calculated using event mean concentrations, while the second FSP column (FSP EST) represents the FSP load estimated using continuous turbidity data.

- The largest fraction of FSP loads (based on samples) was generated in the spring.
- The largest fraction of FSP loads (based on continuous turbidity) was generated in the fall/winter.
- The largest fraction of TN loads was generated in the fall/winter.
- The largest fraction of TP loads was generated in the fall/winter.

Nine events were sampled at Speedboat in WY19. Event summary data is presented in Table 11.

Table 11 Event summary data at the Speedboat catchment outfall, WY19.

Station Acronym	Season	Runoff Start (Date Time)	Runoff End (Date Time)	Runoff Duration (hh:mm)	Runoff Volume (cf)	Peak Flow (cfs)	Peak Turb (NTU)	Storm Total (in)	Event Type	% of Storm Sampled	FSP EMC (mg/L)	FSP event load (lbs)	TN EMC (ug/L)	TN event load (lbs)	TP EMC (ug/L)	TP event load (lbs)
SB	Fall/Winter	10/3/2018 13:15	10/4/2018 2:50	13:35	2,599	0.61	2,362	0.42	Thunderstorm	100%	35	6	7,290	1.2	1,324	0.2
SB	Fall/Winter	11/21/2018 19:50	11/24/2019 11:30	8823:40	4,821	0.45	2,617	0.94	Rain	100%	12	4	1,000	0.3	390	0.1
SB	Fall/Winter	11/27/2018 13:10	11/28/2018 8:45	19:35	2,366	0.40	2,354	0.28	Rain on snow	100%	7	1	710	0.1	179	<0.1
SB	Fall/Winter	1/8/2019 11:55	1/9/2019 17:50	29:55	1,158	0.12	35	1.26	Rain on snow	100%	4	<1	360	<0.1	294	<0.1
SB	Spring	3/5/2019 13:05	3/6/2019 9:50	20:45	6,643	0.37	2,578	0.33	Rain on snow	100%	98	41	880	0.4	566	0.2
SB	Spring	3/29/2019 4:30	4/1/2019 15:30	83:00	5,562	0.10	25	0.00	Non-event Snowmelt	100%	9	3	410	0.1	117	<0.1
SB	Spring	5/16/2019 0:20	5/16/2019 5:30	5:10	2,623	0.50	140	0.28	Rain	100%	99	16	2,000	0.3	880	0.1
SB	Summer	6/2/2019 16:35	6/2/2019 21:10	4:35	7,408	6.01	1,899	0.15	Thunderstorm	100%	783	362	5,060	2.3	4,172	1.9
SB	Summer	9/16/2019 11:20	9/16/2019 13:00	1:40	3,127	1.63	1,985	0.37	Rain	100%	169	33	7,570	1.5	96	<0.1

6.2.6 Tahoe Valley

Figure 50 shows the average daily flow and cumulative precipitation for WY19 at the Tahoe Valley catchment outfall.

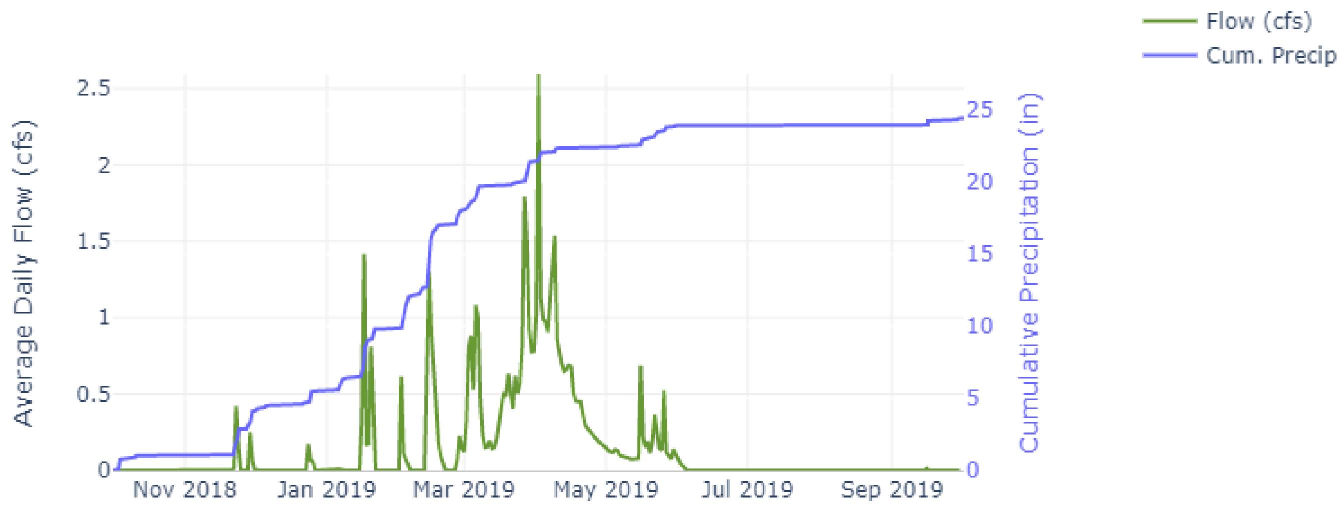

Figure 50 Average daily flow and cumulative precipitation at the Tahoe Valley catchment outfall, WY19.

- 24.44 inches of total precipitation (18.11 in the fall/winter, 5.82 in the spring, 0.52 in the summer) were recorded at the Raph's Shop (RAPH) weather station.
- 48 precipitation events occurred (22 fall/winter events, 22 spring events, 4 summer events).
- The largest storm, with over 4 inches of precipitation, occurred during an atmospheric river rain on snow event from February 13-20, 2019.
- 67% of storms were less than half an inch.
- Highest average daily flows occurred in the spring season (March -April).
- 82 days of continuous snowmelt runoff occurred in the spring.
- The highest instantaneous peak precipitation was 0.07 inches in 5 minutes during the rain event October 3, 2018.
- The highest instantaneous peak flow was 5.2 cfs during a rain on snow event on January 17, 2019.
- The most runoff was generated by *snowmelt* (2,493,917 cf); for runoff generated by precipitation events, the most runoff was generated by the February 13-20, 2019 atmospheric river rain on snow event (357,616 cf).

Daily flow and the FSP EMC summary at Tahoe Valley are presented in Figure 51. Table 12 presents this data in tabular form. Table 12 also presents the load data referenced in some bullet points below.

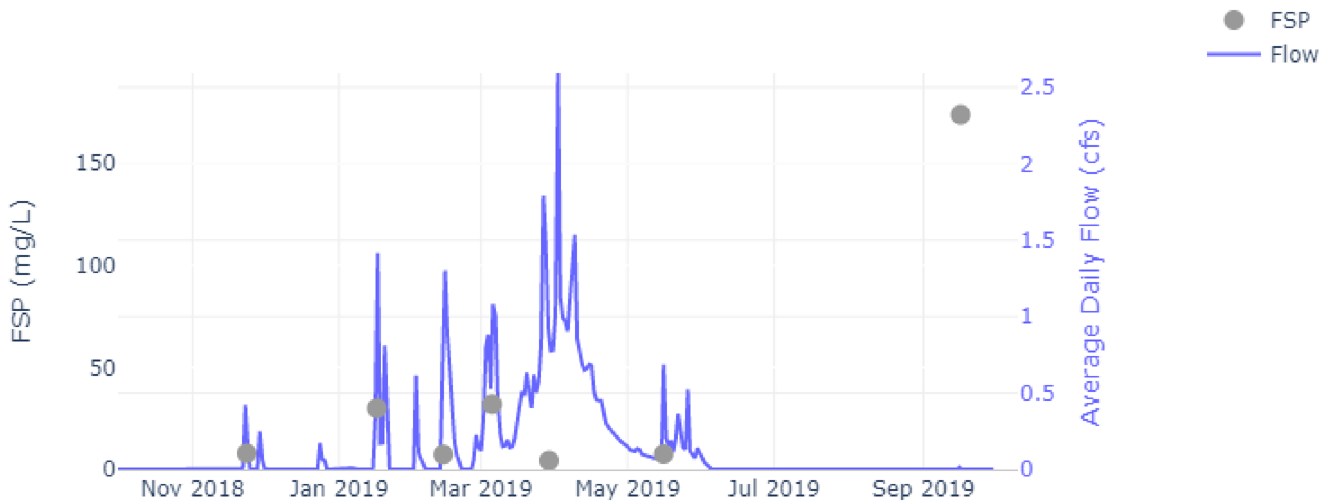

Figure 51 Daily flow and FSP EMC summary at the Tahoe Valley catchment outfall, WY19.

- Seven events were sampled for FSP (three in the fall/winter, three in the spring, and one in the summer).
- The highest FSP EMC occurred during the rain and snow event on September 16, 2019.
- The highest FSP load occurred during the rain on snow event from March 5-7, 2019.
- The lowest FSP EMC occurred during the spring snowmelt event from March 29, 2019 to April 1, 2019.
- The lowest FSP load occurred during the rain and snow event on September 16, 2019.

Daily flow and the TN EMC summary at Tahoe Valley are presented in Figure 52. Table 12 presents this data in tabular form. Table 12 also presents the load data referenced in some bullet points below.

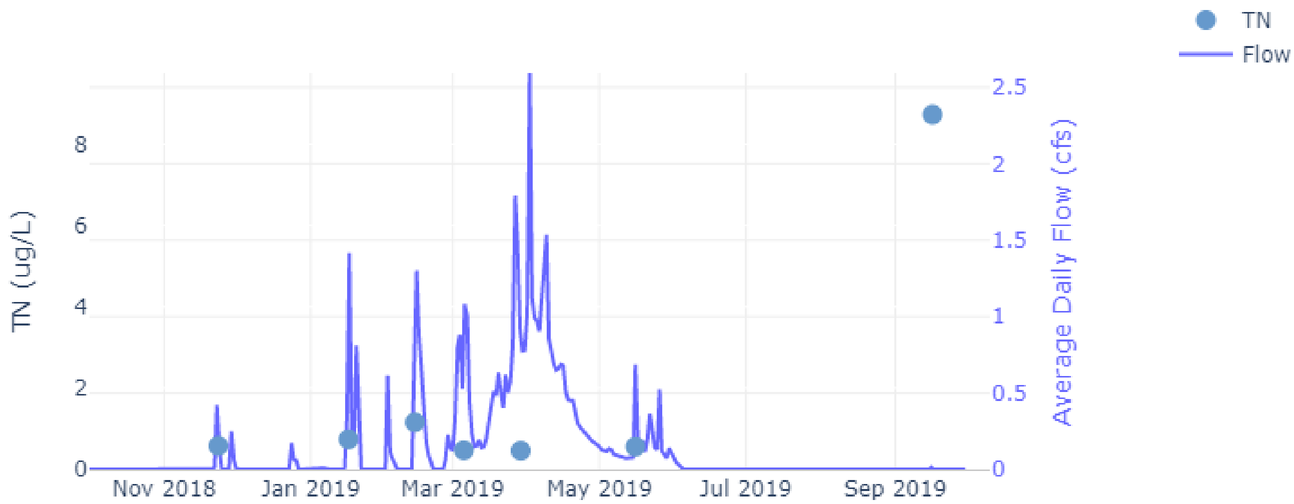

Figure 52 Daily flow and TN EMC summary at the Tahoe Valley catchment outfall, WY19.

- Seven events were sampled for FSP (three in the fall/winter, three in the spring, and one in the summer).
- The highest TN EMC occurred during the summer rain and snow event on September 16, 2019.
- The highest TN load occurred during the atmospheric river rain on snow event from February 13-20, 2019.
- The lowest TN EMC occurred during the spring snowmelt event from March 29, 2019 to April 1, 2019 and during the spring rain on snow event from March 5-7, 2019.
- The lowest TN load occurred during the rain and snow event on September 16, 2019.

Daily flow and the TP EMC summary at Tahoe Valley are presented in Figure 53. Table 12 presents this data in tabular form. Table 12 also presents the load data referenced in some bullet points below.

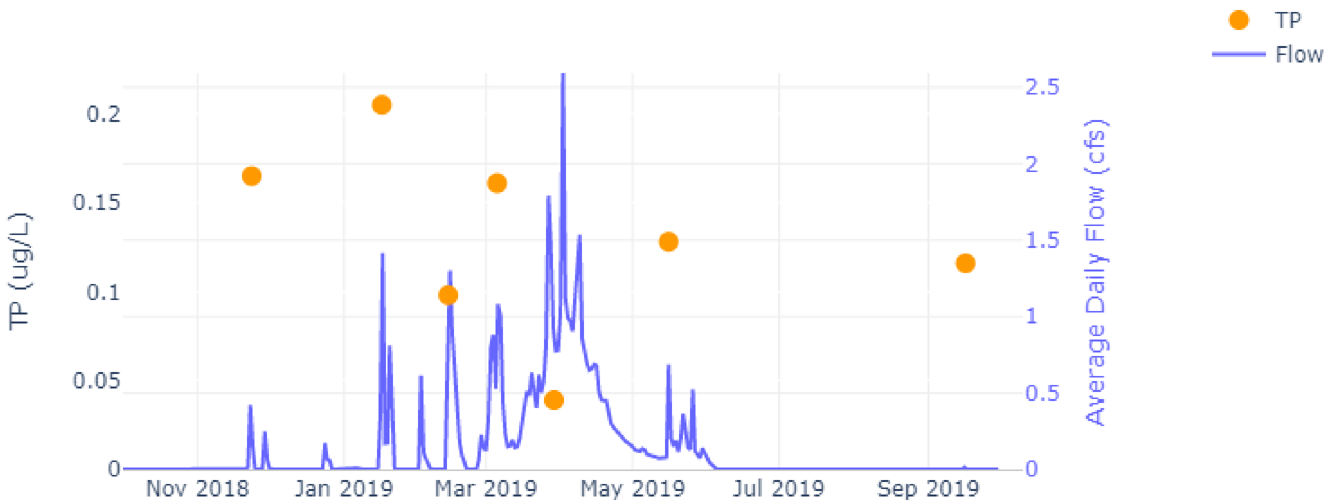

Figure 53 Daily flow and TP EMC summary at the Tahoe Valley catchment outfall, WY19.

- Seven events were sampled for FSP (three in the fall/winter, three in the spring, and one in the summer).
- The highest TP EMC occurred during the atmospheric river rain on snow event on January 16-17, 2019.
- The highest TP load occurred during the atmospheric river rain on snow event from February 13-20, 2019.
- The lowest TP EMC occurred during the spring snowmelt from March 29, 2019 to April 1, 2019.
- The lowest TP load occurred during the rain and snow event on September 16, 2019.

Seasonal load as a fraction of the water year load at Tahoe Valley is presented in Figure 54. Event loads are presented in tabular form in Table 12.

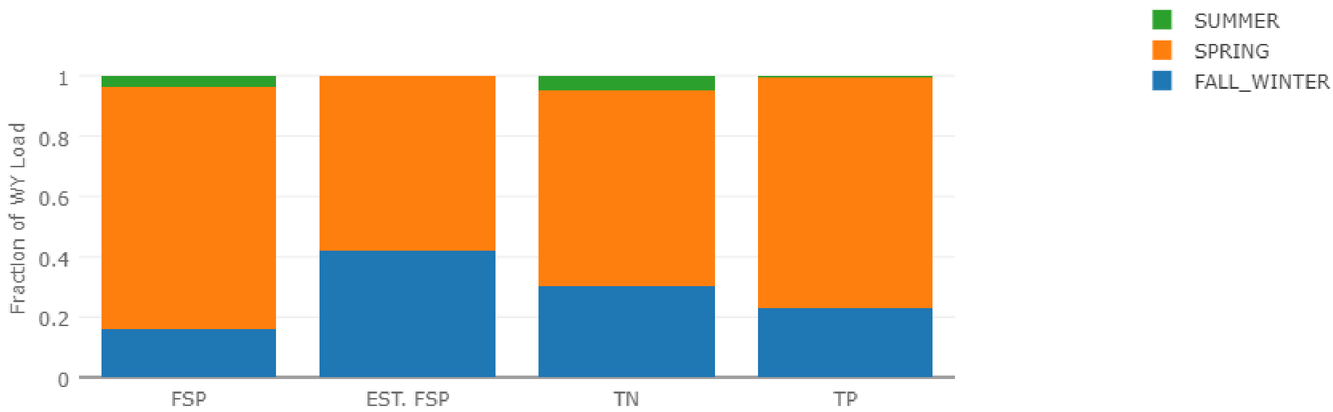

Figure 54 Seasonal load as a fraction of the water year load at the Tahoe Valley catchment outfall, WY19. The first FSP column represents the FSP load calculated using event mean concentrations, while the second FSP column (EST. FSP) represents the FSP load estimated using continuous turbidity data.

- The largest fraction of FSP loads was generated in the spring.
- The largest fraction of TN loads was generated in the spring
- The largest fraction of TP loads was generated in the spring.

Seven events were sampled at Tahoe Valley in WY19. Event summary data is presented in Table 12.

Table 12 Event summary data at the Tahoe Valley catchment outfall, WY19

Station Acronym	Season	Runoff Start (Date Time)	Runoff End (Date Time)	Runoff Duration (hh:mm)	Runoff Volume (cf)	Peak Flow (cfs)	Peak Turb (NTU)	Storm Total (in)	Event Type	% of Storm Sampled	FSP EMC (mg/L)	FSP event load (lbs)	TN EMC (ug/L)	TN event load (lbs)	TP EMC (ug/L)	TP event load (lbs)
TV	Fall/Winter	11/23/2018 8:30	11/24/2018 14:35	30:05	48,997	1.67	20	1.85	Rain	100%	8	24	580	1.8	165	0.5
TV	Fall/Winter	1/16/2019 10:45	1/17/2019 14:20	27:35	135,587	5.20	800	1.86	Rain on snow	100%	30	254	740	6.3	205	1.7
TV	Fall/Winter	2/13/2019 5:25	2/20/2019 17:20	179:55	357,616	1.91	658	4.40	Rain on snow	100%	7	163	1,160	26	98	2.2
TV	Spring	3/5/2019 12:20	3/7/2019 9:45	45:25	157,476	1.68	360	1.03	Rain on snow	100%	32	315	470	4.6	161	1.6
TV	Spring	3/29/2019 6:00	4/1/2019 6:00	72:00	209,327	1.15	8	0.00	Non-event Snowmelt	100%	4	56	460	6.0	39	0.5
TV	Spring	5/15/2019 22:55	5/17/2019 9:35	34:40	68,715	1.86	246	0.48	Rain	100%	8	32	560	2.4	128	0.5
TV	Summer	9/16/2019 11:25	9/16/2019 13:25	2:00	1,202	0.34	316	0.32	Rain	100%	174	13	8,730	0.7	116	<0.1

6.2.7 Tahoma

Figure 55 shows the average daily flow and cumulative precipitation for WY19 at the Tahoma catchment outfall.

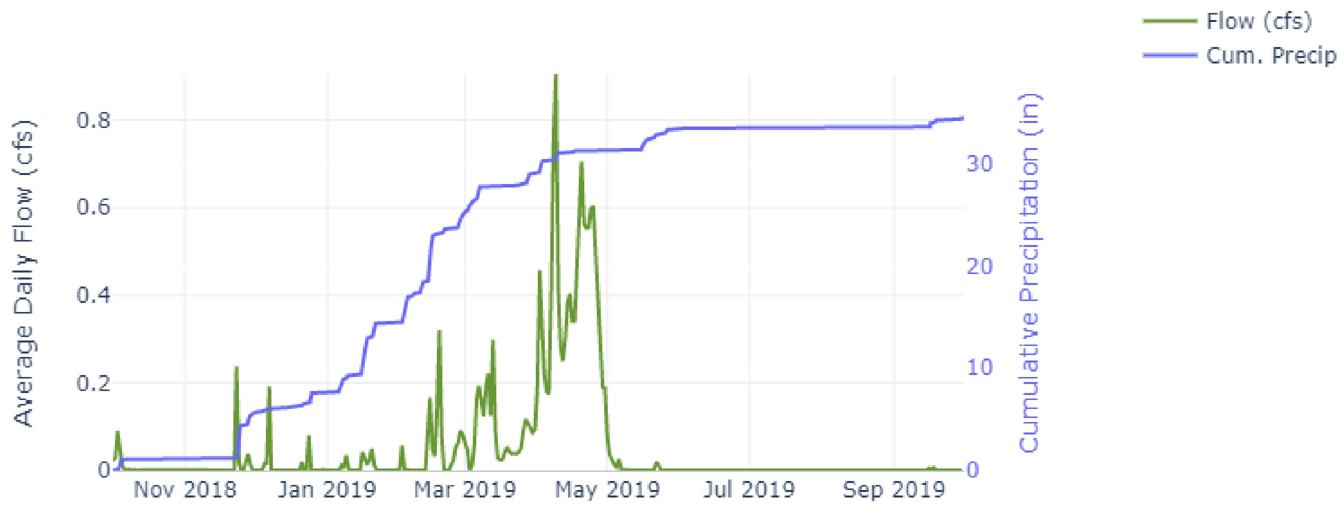

Figure 55 Average daily flow and cumulative precipitation at the Tahoma catchment outfall, WY19.

- 34.47 inches of total precipitation (25.30 in the fall/winter, 8.16 in the spring, 1.02 in the summer) were recorded at the El Dorado County Yard (EDCY) weather station.
- 54 precipitation events occurred (24 fall/winter events, 22 spring events, 8 summer events).
- The largest storm, with almost 5 inches of precipitation, occurred during an atmospheric river rain on snow event from February 13-17, 2019.
- 65% of storms were less than half an inch.
- Highest average daily flows occurred in April of the spring season.
- 96 days of continuous snowmelt runoff occurred in the spring.
- The highest instantaneous peak precipitation was 0.09 inches in 5 minutes during the rain event on October 3, 2018.
- The highest instantaneous peak flow was 2.53 cfs during the rain on snow event on April 8, 2019.
- The most runoff was produced by snowmelt (1,136,663cf). The February 13-20, 2019 atmospheric river rain on snow event produced the most runoff in a single event (75,520 cf).

Tahoma was backwatered beginning in late April through early September due to high lake levels and could not be sampled during that time.

Daily flow and the FSP EMC summary at Tahoma are presented in Figure 56. Table 13 presents this data in tabular form. Table 13 also presents the load data referenced in some bullet points below.

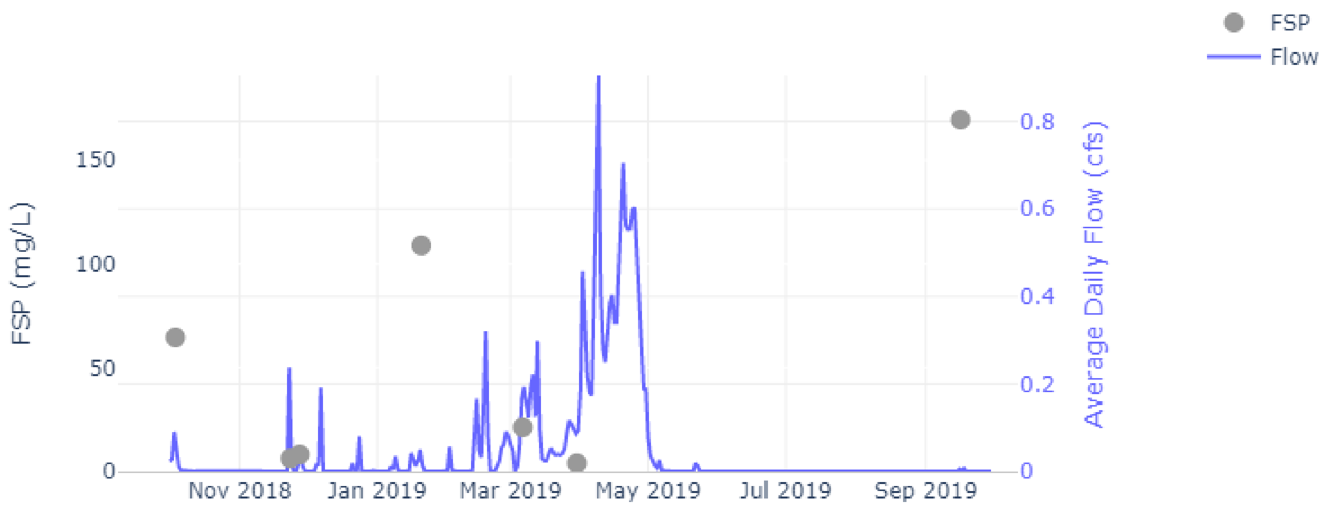

Figure 56 Daily flow and FSP EMC summary at the Tahoma catchment outfall, WY19.

- Seven events were sampled for FSP (four in the fall/winter, two in the spring, and one in the summer).
- The highest FSP EMC occurred during the rain and snow event on September 16, 2019.
- The highest FSP load occurred during the rain on snow event from January 20-21, 2019.
- The lowest FSP EMC occurred during the snowmelt event from March 30, 2019 to April 1, 2019.
- The lowest FSP load occurred during the rain on snow event from November 27-28, 2018.

Daily flow and the TN EMC summary at Tahoma are presented in Figure 57. Table 13 presents this data in tabular form. Table 13 also presents the load data referenced in some bullet points below.

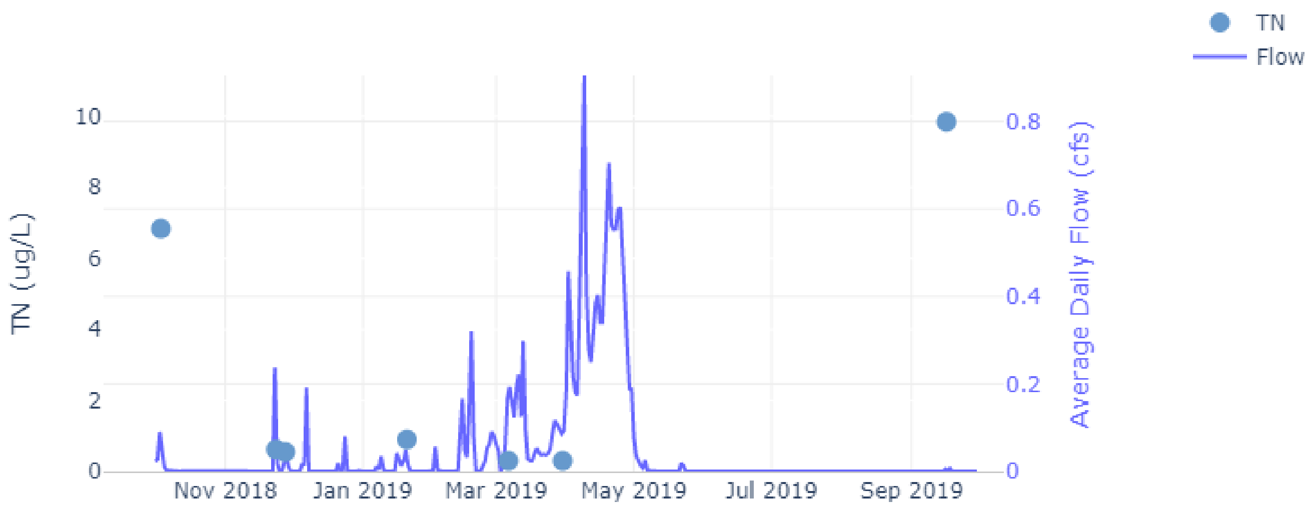

Figure 57 Daily flow and TN EMC summary at the Tahoma catchment outfall, WY19.

- Seven events were sampled for TN (four in the fall/winter, two in the spring, and one in the summer).
- The highest TN EMC occurred during the rain and snow event on September 16, 2019.
- The highest TN load occurred during the thunderstorm event on October 3, 2018.
- The lowest TN EMC occurred during the rain on snow event from March 6-7, 2019 and the snowmelt event from March 30, 2019 to April 1, 2019.
- The lowest TN load occurred during the rain on snow event from November 27-28, 2018.

Daily flow and the TP EMC summary at Tahoma are presented in Figure 58. Table 13 presents this data in tabular form. Table 13 also presents the load data referenced in some bullet points below.

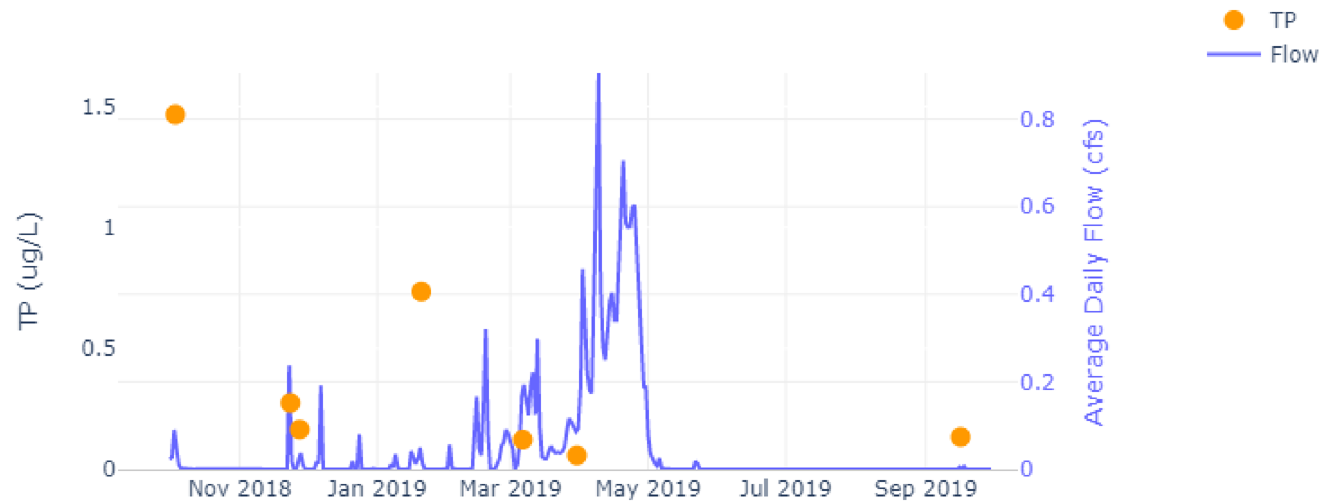

Figure 58 Daily flow and TP EMC summary at the Tahoma catchment outfall, WY19.

- Seven events were sampled for TP (four in the fall/winter, two in the spring, and one in the summer).
- The highest TP EMC and load occurred during the rain event on October 3, 2018.
- The lowest TP EMC occurred during the snowmelt event from March 30, 2019 to April 1, 2019.
- The lowest TP load occurred during the rain and snow event on September 16, 2019.

Seasonal load as a fraction of the water year load at Tahoma is presented in Figure 59. Event loads are presented in tabular form in Table 13.

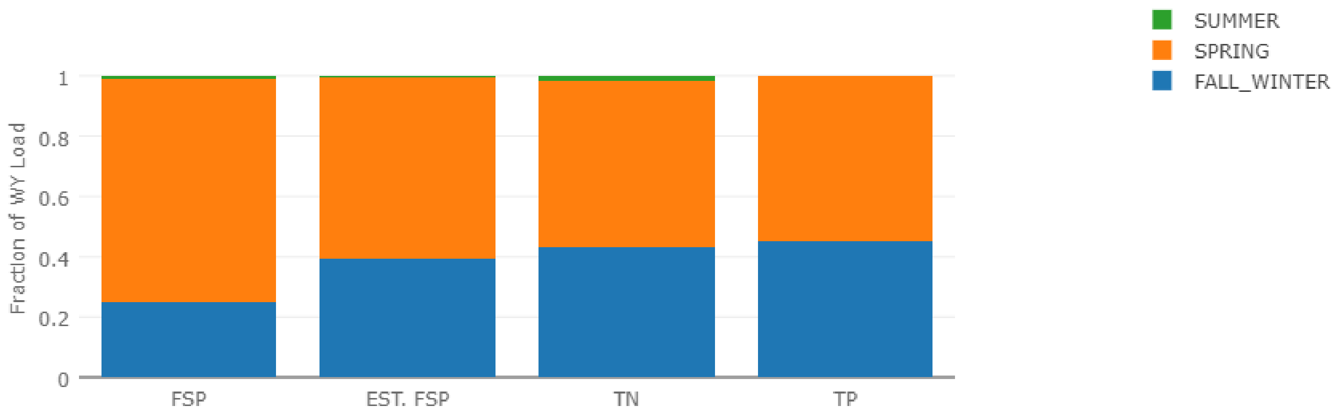

Figure 59 Seasonal load as a fraction of the water year load at the Tahoma catchment outfall, WY19. The first FSP column represents the FSP load calculated using event mean concentrations, while the second FSP column (EST. FSP) represents the FSP load estimated using continuous turbidity data.

- The largest fraction of FSP loads was generated in the spring.
- The largest fraction of TN loads was generated in the spring.
- The largest fraction of TP loads was generated in the spring.
- Very small fractions of FSP and TN were generated in the summer.
- The fraction of TP generated in the summer was negligible and is not visible.

Seven events were sampled at Tahoma in WY19. Event summary data is presented in **Error! Reference source not found.**

Table 13 Event summary data at the Tahoma catchment outfall, WY19.

Station Acronym	Season	Runoff Start (Date Time)	Runoff End (Date Time)	Runoff Duration (hh:mm)	Runoff Volume (cf)	Peak Flow (cfs)	Peak Turb (NTU)	Storm Total (in)	Event Type	% of Storm Sampled	FSP EMC (mg/L)	FSP event load (lbs)	TN EMC (ug/L)	TN event load (lbs)	TP EMC (ug/L)	TP event load (lbs)
TA	Fall/Winter	10/3/2018 11:20	10/3/2018 20:20	9:00	5,314	0.97	722	1.09	Thunderstorm	100%	65	21	6,840	2.3	1,467	0.5
TA	Fall/Winter	11/23/2018 9:55	11/24/2018 21:40	35:45	22,088	1.23	1,219	3.26	Rain	100%	6	9	620	0.9	275	0.4
TA	Fall/Winter	11/27/2018 13:00	11/28/2018 14:30	25:30	4,837	0.70	1,305	0.87	Rain on snow	100%	8	2	550	0.2	165	<0.1
TA	Fall/Winter	1/20/2019 8:25	1/21/2019 15:45	31:20	5,230	0.30	1,883	1.31	Rain on snow	100%	109	36	900	0.3	735	0.2
TA	Spring	3/6/2019 9:30	3/7/2019 9:30	24:00	17,620	0.36	209	1.09	Rain on snow	100%	21	23	300	0.3	123	0.1
TA	Spring	3/30/2019 8:00	4/1/2019 8:00	48:00	16,278	0.20	22	0.00	Non-event Snowmelt	100%	4	4	300	0.3	58	0.1
TA	Summer	9/16/2019 10:45	9/16/2019 13:05	2:20	458	0.13	324	0.39	Rain	100%	170	5	9,850	0.3	134	<0.1

6.2.8 Upper Truckee

Figure 60 shows the average daily flow and cumulative precipitation for WY19 at the Upper Truckee catchment outfall.

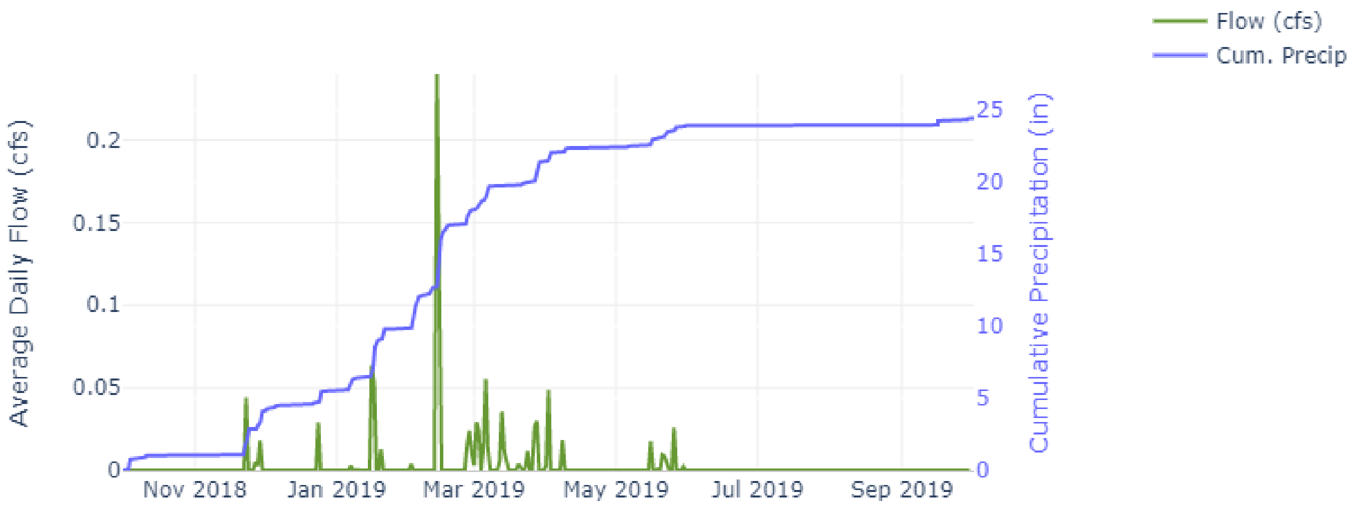

Figure 60 Average daily flow and cumulative precipitation at the Upper Truckee catchment outfall, WY19.

- 24.44 inches of total precipitation (18.11 in the fall/winter, 5.82 in the spring, 0.52 in the summer) were recorded at the RAPH weather station.
- 48 precipitation events occurred (22 fall/winter events, 22 spring events, 4 summer events).
- The largest storm, with over 3 inches of precipitation, occurred during an atmospheric river rain on snow event from February 13-14, 2019.
- 67% of storms were less than half an inch.
- Highest average daily flows occurred in February of the fall/winter season.
- 13 days of intermittent snowmelt runoff occurred in the fall/winter and spring.
- The highest instantaneous peak precipitation was 0.07 inches in 5 minutes during the rain event October 3, 2018.
- The highest instantaneous peak flow was 2.10 cfs during the atmospheric rain on snow event on February 13, 2019.
- The February 13-14, 2019 atmospheric river rain on snow event produced the most runoff (31,046 cf).

Daily flow and the FSP EMC summary at Upper Truckee are presented in Figure 61. Table 14 presents this data in tabular form. Table 14 also presents the load data referenced in some bullet points below.

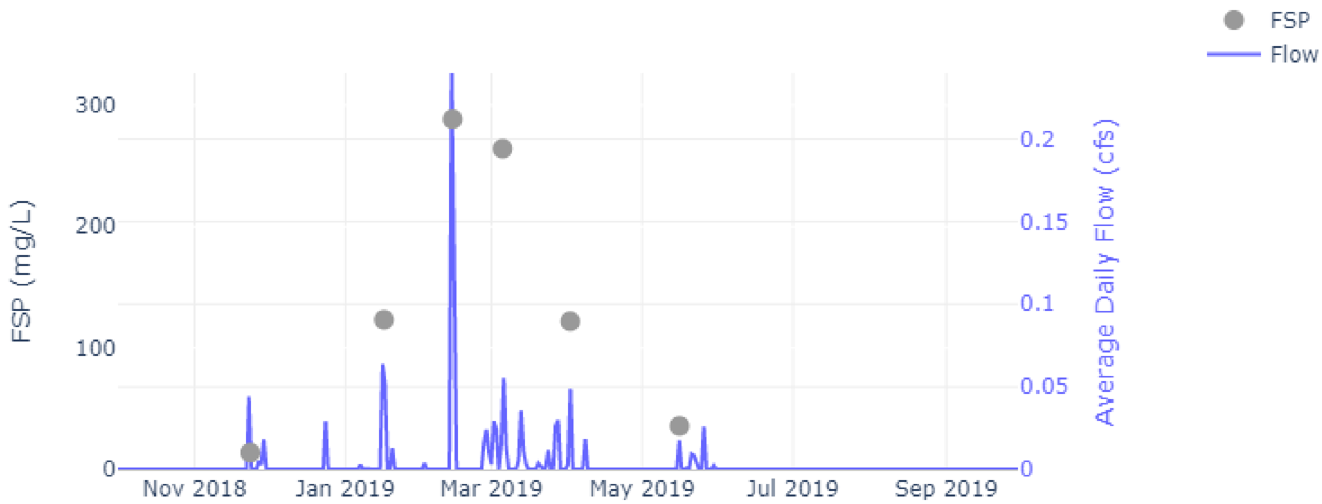

Figure 61 Daily flow and FSP EMC summary at the Upper Truckee catchment outfall, WY19.

- Six events were sampled for FSP (three in the fall/winter, three in the spring, and zero in the summer).
- The highest FSP EMC and load occurred during the atmospheric river rain on snow event on February 13-14, 2019.
- The lowest FSP EMC and load occurred during the rain event on November 23, 2018.

Daily flow and the TN EMC summary at Upper Truckee are presented in Figure 62. Table 14 presents this data in tabular form. Table 14 also presents the load data referenced in some bullet points below.

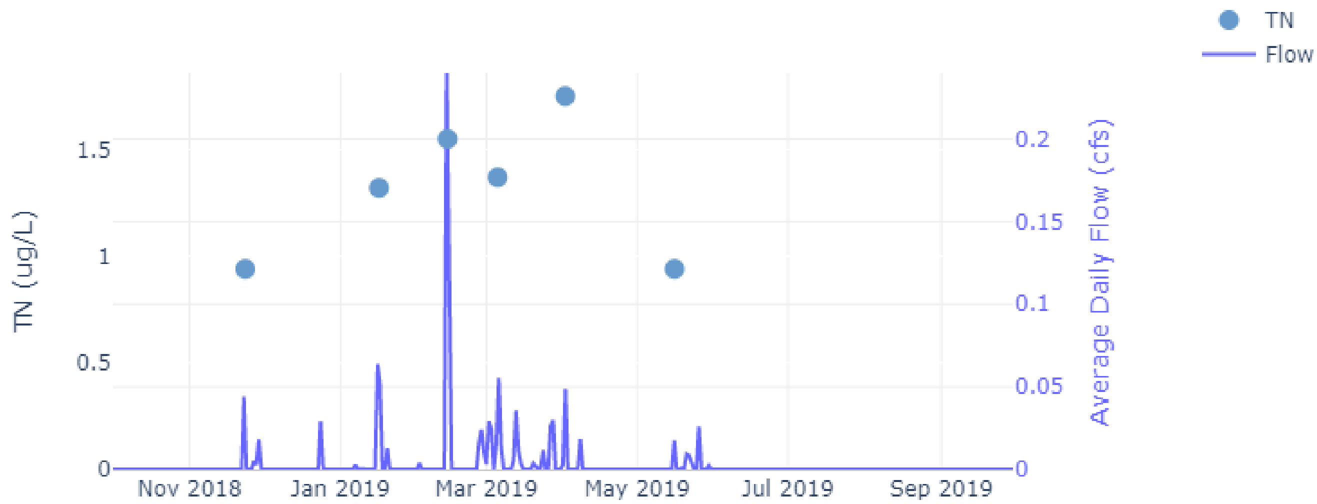

Figure 62 Daily flow and TN EMC summary at the Upper Truckee catchment outfall, WY19.

- Six events were sampled for TN (three in the fall/winter, three in the spring, and zero in the summer).
- The highest TN EMC occurred during a rain on snow event on April 1-2, 2019.
- The highest TN load occurred during the atmospheric river rain on snow event on February 13-14, 2019.
- The lowest TN EMC occurred during the rain event on November 23, 2018 and during an event snowmelt on May 16-17, 2019.
- The lowest TN load occurred during an event snowmelt on May 16-17, 2019.

Daily flow and the TN EMC summary at Upper Truckee are presented in Figure 63. Table 14 presents this data in tabular form. Table 14 also presents the load data referenced in some bullet points below.

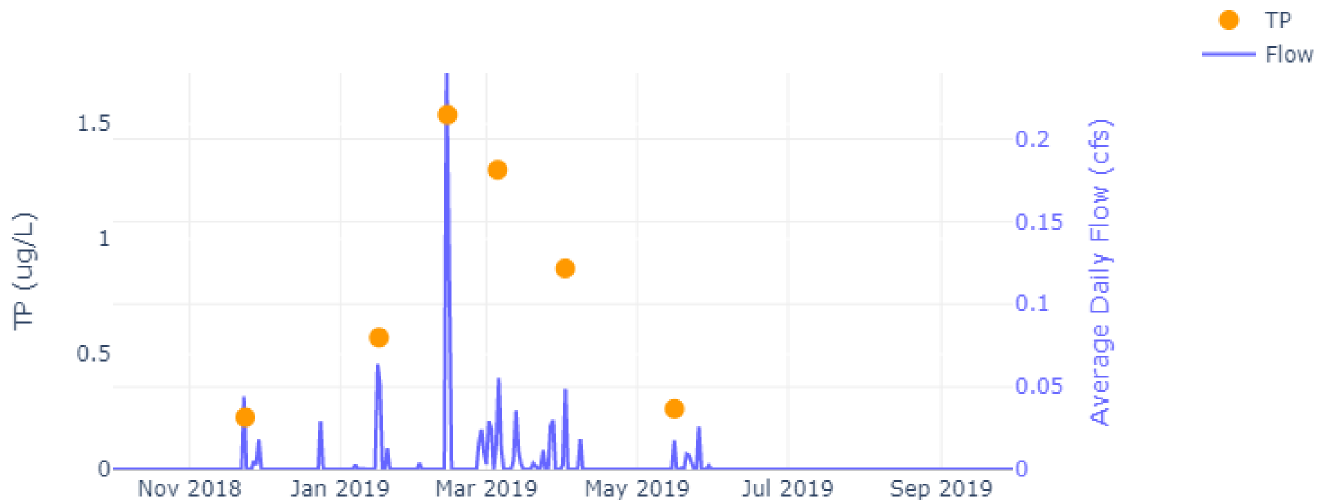

Figure 63 Daily flow and TP EMC summary at the Upper Truckee catchment outfall, WY19.

- Six events were sampled for TP (three in the fall/winter, three in the spring, and zero in the summer).
- The highest TP EMC and load occurred during the atmospheric river rain on snow event from February 13-14, 2019.
- The lowest TP EMC occurred during the rain event on November 23, 2018.
- The lowest TP load occurred during an event snowmelt on May 16-17, 2019.

Seasonal load as a fraction of the water year load at Upper Truckee is presented in Figure 64. Event loads are presented in tabular form in Table 14.

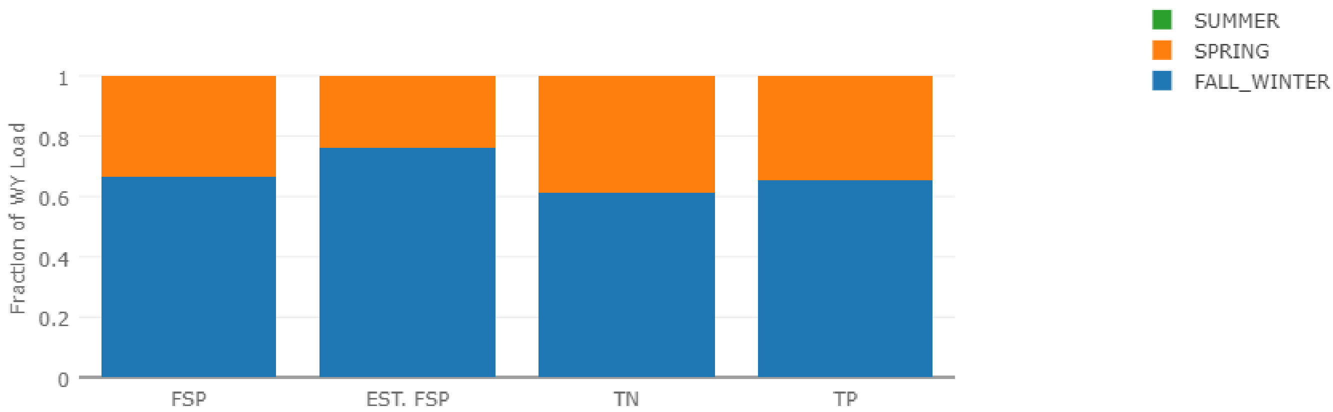

Figure 64 Seasonal load as a fraction of the water year load at the Upper Truckee catchment outfall, WY19. The first FSP column represents the FSP load calculated using event mean concentrations, while the second FSP column (EST. FSP) represents the FSP load estimated using continuous turbidity data.

- The largest fraction of FSP loads was generated fall/winter.
- The largest fraction of TN loads was generated in the fall/winter.
- The largest fraction of TP loads was generated in the fall/winter.
- Summer produced no loads for FSP, TN, or TP because there was no runoff to sample.

Six events were sampled at Upper Truckee in WY19. Event summary data is presented in Table 14.

Table 14 Event summary data at the Upper Truckee catchment outfall, WY19.

Station Acronym	Season	Runoff Start (Date Time)	Runoff End (Date Time)	Runoff Duration (hh:mm)	Runoff Volume (cf)	Peak Flow (cfs)	Peak Turb (NTU)	Storm Total (in)	Event Type	% of Storm Sampled	FSP EMC (mg/L)	FSP event load (lbs)	TN EMC (ug/L)	TN event load (lbs)	TP EMC (ug/L)	TP event load (lbs)
UT	Fall/Winter	11/23/2018 11:35	11/23/2018 22:55	11:20	3,821	0.37	98	1.85	Rain	100%	14	3	940	0.2	226	0.1
UT	Fall/Winter	1/16/2019 14:05	1/17/2019 10:10	20:05	9,853	0.34	315	1.86	Rain on snow	100%	123	76	1,320	0.8	572	0.4
UT	Fall/Winter	2/13/2019 6:45	2/14/2019 11:45	29:00	31,046	2.10	686	3.05	Rain on snow	100%	289	559	1,550	3.0	1,539	3.0
UT	Spring	3/5/2019 13:35	3/6/2019 18:25	28:50	6,034	0.41	378	0.83	Rain on snow	100%	264	100	1,370	0.5	1,300	0.5
UT	Spring	4/1/2019 17:20	4/2/2019 15:10	21:50	4,475	0.34	49	0.64	Rain on snow	100%	122	34	1,750	0.5	872	0.2
UT	Spring	5/16/2019 2:20	5/17/2019 2:20	24:00	1,568	0.32	126	0.43	Event Snowmelt	100%	36	4	940	0.1	263	<0.1

7. BMP Effectiveness Monitoring

7.1 SR431

Data collected from matched inflow and outflow sampling at the Contech MFS stormwater cartridge filter vault and at the Jellyfish stormwater cartridge filter vault at SR431 during WY19 show variable removal efficiencies for sediment and nutrients. Contech MFS and Jellyfish vaults were maintained to the same condition this year, so comparing annual (Table 15) and event by event (Table 16 and Table 17) removal efficiencies is valid. Below is a summary of the maintenance that occurred.

- On September 13, 2018 three weeks prior to the beginning of WY19, the entire system was vactored (splitter chamber, inflow pipes, Contech MFS vault, and Jellyfish vault) and the Contech MFS cartridges and Jellyfish tentacles were rinsed with high pressure water.
- On June 25, 2019, after the fall/winter and spring seasons, the entire system was vactored again (splitter chamber, inflow pipes, Contech MFS vault, and Jellyfish vault). However, the Contech MFS cartridges and Jellyfish tentacles were not rinsed.
- One month later, on July 25, 2019, the Contech MFS cartridges and Jellyfish tentacles were replaced.

Table 15 presents the seasonal and annual summary data on removal efficiency for each treatment vault at SR431 in WY19 based on samples taken during sampled events.

Table 15 Seasonal and annual efficiency data from the Contech MFS and Jellyfish vaults at SR431, WY19.

Water Year 2019 (October 1, 2018 - September 30, 2019)			Seasonal FSP Loads (lbs)			Total Annual FSP Loads (lbs)	Estimated Seasonal FSP Loads (lbs)			Estimated Total Annual FSP Loads (lbs)	Seasonal TN Loads (lbs)			Total Annual TN Loads (lbs)	Seasonal TP Loads (lbs)			Total Annual TP Loads (lbs)
Catchment Name	Station Name	Station Acronym	Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)		Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)		Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)		Fall/Winter (Oct1-Feb28)	Spring (Mar1-May31)	Summer (Jun1-Sep30)	
SR431	Contech In	CI	149.8	634.2	5.4	789.4	63.4	51.9	6.5	121.8	1.07	2.33	0.14	3.54	0.86	3.57	0.04	4.47
	Contech Out	CO	64.5	231.1	5.9	301.5	9.2	32.5	3.6	45.3	0.53	1.12	0.10	1.75	0.36	1.40	0.04	1.80
		Load Reduction	85.3	403.1	-0.5	487.9	54.2	19.4	2.9	76.5	0.54	1.21	0.04	1.79	0.50	2.17	0.01	2.67
		% Change	-57%	-64%	9%	-62%	-85%	-37%	-45%	-63%	-50%	-52%	-28%	-51%	-58%	-61%	-14%	-60%
SR431	Jellyfish In	JI	156.8	822.2	5.8	984.8	66.3	60.4	6.8	133.6	1.17	2.68	0.17	4.01	0.76	4.40	0.04	5.21
	Jellyfish Out	JO	65.4	332.8	3.3	401.5	20.0	28.4	3.2	51.6	1.05	1.75	0.19	2.99	0.25	2.10	0.03	2.38
		Load Reduction	91.4	489.5	2.5	583.3	46.4	32.0	3.6	82.0	0.12	0.93	-0.02	1.02	0.51	2.30	0.02	2.83
		% Change	-58%	-60%	-42%	-59%	-70%	-53%	-53%	-61%	-10%	-35%	14%	-26%	-67%	-52%	-40%	-54%

- The Contech MFS reduced annual FSP loads by 62% and 63% (based on samples and estimated from continuous turbidity respectively). The greatest FSP reduction efficiency occurred in the fall/winter at 85% according to loads estimated from turbidity.
- The Contech MFS released FSP during the summer season according to loads based on samples.
- The Jellyfish reduced annual FSP loads by 59% and 61% (based on samples and estimated from continuous turbidity respectively). The greatest FSP reduction efficiency occurred in the fall/winter at 70% according to loads estimated from turbidity.
- The Contech MFS reduced annual TN loads by 51%. The greatest TN reduction efficiency occurred in the spring at 52%.
- The Jellyfish reduced annual TN loads by 26%. The greatest TN reduction efficiency occurred in the spring at 35%. In the summer the Jellyfish released TN and increased loads by 14%.
- The Contech MFS reduced annual TP loads by 60%. The greatest TP reduction efficiency occurred in the spring at 61%.
- The Jellyfish reduced annual TP loads by 54%. The greatest TP reduction efficiency occurred in the fall/winter at 67%.
- The Contech MFS and Jellyfish were similar in their abilities to reduce FSP and TP. However, the Contech MFS was more efficient at reducing TN in all seasons than the Jellyfish.
- The Contech MFS reduced volumes substantially in all seasons (see Table 5) due to evaporation in the vault. This positively affects load reduction since concentration times volume equals load. The load reductions are only realized if the vault is maintained regularly to remove accumulated sediment before it is washed out as appears to have happened in the summer. The Jellyfish does not reduce volumes substantially, but must also be maintained regularly to avoid release of sediment or nutrients (like the summer release of TN).

Table 16 presents the efficiency of the Contech MFS at reducing concentrations and loads of all three pollutants for the individual events sampled in WY19.

Table 16 Event efficiency data from the Contech MFS vault at SR431, WY19.

Event Start Date	Event Volume as a % of Total Annual Volume (cf)	FSP Concentration			FSP Load (lbs)			TN Concentration			TN Load (lbs)			TP Concentration			TP Load (lbs)		
		in-flow	out-flow	% change	in-flow	out-flow	% change	in-flow	out-flow	% change	in-flow	out-flow	% change	in-flow	out-flow	% change	in-flow	out-flow	% change
10/3/2018	3%	70	54	-23%	3	2	-54%	5,150	5,940	15%	0.24	0.17	-31%	562	446	-21%	0.03	0.01	-53%
11/23/2018	4%	190	95	-50%	9	3	-70%	1,850	1,380	-25%	0.09	0.04	-56%	438	601	37%	0.022	0.018	-19%
2/1/2019	5%	1,001	782	-22%	64	35.3	-45%	3,970	3,300	-17%	0.25	0.15	-41%	6,020	3,844	-36%	0.38	0.17	-55%
2/13/2019	8%	196	170	-13%	20.2	15.2	-25%	1,000	1,050	5%	0.10	0.09	-9%	1,170	1,145	-2%	0.12	0.102	-15%
5/15/2019	2%	791	225	-72%	21.4	3.8	-82%	3,820	2,070	-46%	0.10	0.03	-66%	4,807	1,479	-69%	0.13	0.02	-81%
5/21/2019	3%	646	411	-36%	26.9	12.6	-53%	2,010	1,540	-23%	0.08	0.05	-44%	3,670	2,753	-25%	0.15	0.08	-45%
5/26/2019	2%	671	392	-42%	17.8	12.6	-29%	1,970	1,400	-29%	0.05	0.04	-14%	3,368	2,012	-40%	0.09	0.06	-28%
9/16/2019	2%	100	197	96%	3.2	4.5	39%	2,660	3,430	29%	0.09	0.08	-9%	818	1,265	55%	0.03	0.03	9%

- The highest FSP concentration and load reductions occurred during the rain on snow event beginning May 15, 2019 when inflow concentrations were the second highest.
- The lowest FSP concentration and load reductions occurred during the mixed rain and snow event beginning September 16, 2019 when the Contech MFS released FSP.
- The highest TN concentration and load reductions occurred during the rain on snow event beginning May 15, 2019 when inflow concentrations were relatively high when inflow concentrations were the second highest.
- The lowest TN concentration and load reductions occurred during the mixed rain and snow event beginning September 16, 2019 when inflow concentrations were relatively high. The Contech MFS released TN during this event as indicated by greater outflow concentrations than inflow concentrations. Despite this, there was still a small load reduction due to the fact that some water is retained in the vault so outflow volumes are lower than inflow volumes. The same situation occurred on October 3, 2018 and February 13, 2019.
- The highest TP concentration and load reductions occurred during the rain on snow event beginning May 15, 2019 when inflow concentrations were the second highest.
- The lowest TP concentration and load reductions occurred during the mixed rain and snow event beginning September 16, 2019.

Contech MFS vault water level and bypass flow are presented in Figure 65. When bypass occurs, untreated flow comingles with treated flow in the outflow from the Contech MFS vault, resulting in reduced overall treatment efficiency.

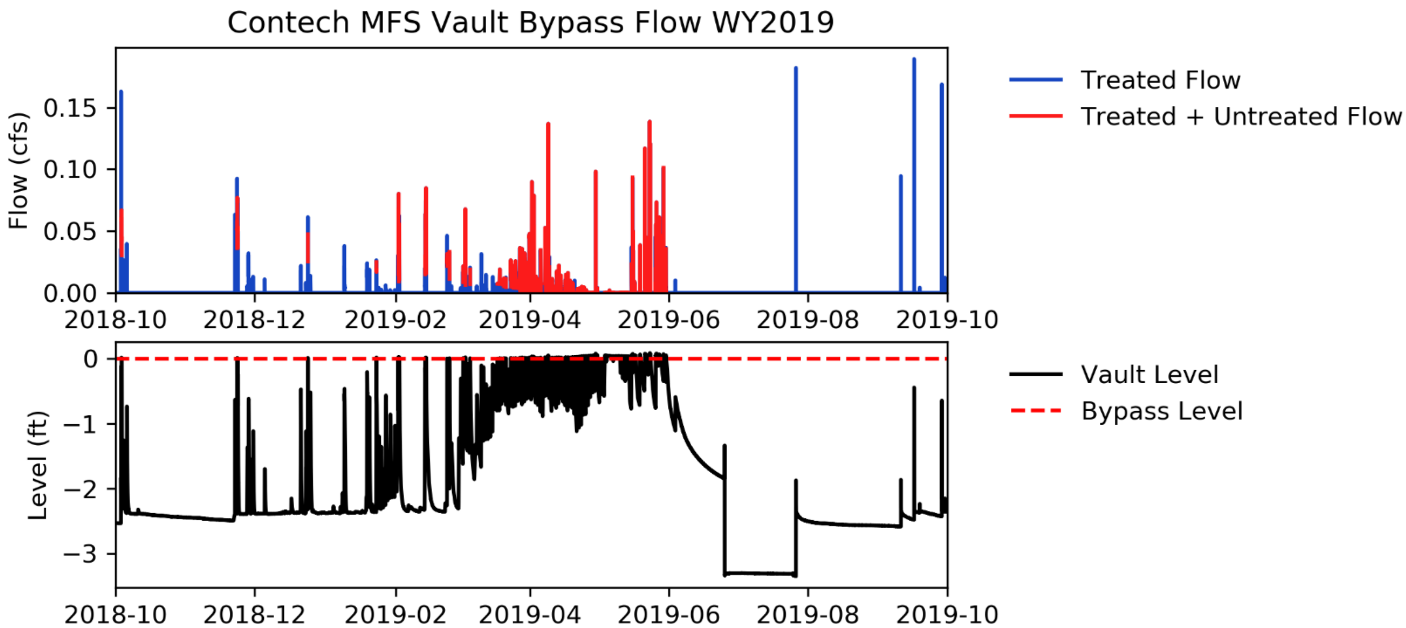

Figure 65 Contech MFS vault level at SR431, WY19 (bottom). Contech MFS outflow shown at top for reference. Vault level greater than 0 indicates bypass flow.

- During periods of flow, the Contech MFS filter was in bypass mode 79% of the time in WY19 which represents up to 88% of the flow volume (13,134 cf). The majority of this bypass flow occurred during the spring, when there was a consistent source of water flowing into the vaults from the large snowpack. During bypass mode treated flow is co-mingled with untreated (bypass) flow, so the exact amount of untreated flow is difficult to determine.
- Bypass occurred during 24 runoff events:
    - October 3, 2018 during a rain event that produced less than half an inch of rain.
    - November 23, 2018 during a rain on snow event that produced over an inch of precipitation.
    - December 24, 2018 during a rain on snow event that produced over an inch of precipitation.
    - January 23, 2019 during a snowmelt event.
    - February 2, 2019 during a rain event that produced 0.73 inches of rain.
    - February 14, 2019 during an atmospheric river rain on snow event that produced over 4 inches of rain.
    - February 23-24, 2019 during a snowmelt event.
    - March 2-3, 2019 during a mixed precipitation event that produced half an inch of water equivalent.
    - March 5, 2019 during a mixed precipitation event that produced half an inch of water equivalent.
    - March 17-19, 2019 during a snowmelt event.
    - March 20-21, 2019 during a mixed precipitation event that produced a quarter an inch of water equivalent.
    - March 23-March 26, 2019 during a snowmelt event.
    - March 27-28, 2019 during a mixed precipitation event that produced half an inch of water equivalent.
    - March 29-31, 2019 during a snowmelt event.
    - April 1-2, 2019 during a mixed precipitation event that produced close to three quarters of an inch of water equivalent.
    - April 3-April 5, 2019 during a snowmelt event.
    - April 7-14, 2019 during a snowmelt event.

- April 16-29, 2019 during a snowmelt event.
- May 15-17, 2019 during a rain on snow event that produced a quarter an inch of water equivalent.
- May 19, 2019 during a rain on snow event that produced less than a quarter an inch of water equivalent.
- May 21-23, 2019 during a rain and snow event that produced less than a half an inch of water equivalent.
- May 26-27, 2019 during a rain on snow event that produced about an inch of water equivalent.
- May 29, 2019 during a thunderstorm event.
- May 30, 2019 during a thunderstorm event.

- Seven of the eight sampled events had untreated (bypass) flow (every event except for the September 16, 2019 rain and snow event).

Table 17 presents the efficiency of the Jellyfish at reducing concentrations and loads of all three pollutants for the individual events sampled in WY19. Sampling at JI failed on February 13-14, 2019 and May 15-16, 2019, so CI data values were used for JI.

Table 17 Event efficiency data from the Jellyfish vault at SR431, WY19.

Event Start Date	Event Volume as a % of Total Annual Volume (cf)	FSP Concentration			FSP Load (lbs)			TN Concentration			TN Load (lbs)			TP Concentration			TP Load (lbs)		
		in-flow	out-flow	% change	in-flow	out-flow	% change	in-flow	out-flow	% change	in-flow	out-flow	% change	in-flow	out-flow	% change	in-flow	out-flow	% change
10/3/2018	3%	95	55	-42%	4	2	-45%	4,850	4,880	1%	0.22	0.21	-5%	578	421	-27%	0.03	0.02	-31%
11/23/2018	4%	194	131	-33%	13	9	-34%	2,720	2,620	-4%	0.19	0.18	-6%	607	413	-32%	0.042	0.028	-34%
2/1/2019	4%	900	972	8%	59	57	-4%	3,230	3,390	5%	0.21	0.20	-7%	4,273	4,858	14%	0.28	0.28	1%
2/13/2019	7%	196	189	-3%	21.5	20.8	-4%	1,000	1,020	2%	0.11	0.11	2%	1,170	1,139	-3%	0.13	0.13	-3%
5/15/2019	1%	791	156	-80%	14.71	2.29	-84%	3,820	2,300	-40%	0.07	0.03	-53%	4,807	1,233	-74%	0.09	0.02	-80%
5/21/2019	1%	807	442	-45%	16.73	7.50	-55%	2,360	1,730	-27%	0.05	0.03	-40%	4,831	3,067	-37%	0.10	0.05	-48%
5/26/2019	1%	820	319	-61%	24.93	9.66	-61%	2,090	1,290	-38%	0.06	0.04	-39%	3,695	1,736	-53%	0.11	0.05	-53%
9/16/2019	1%	104	67	-35%	3.39	2.16	-36%	2,970	3,790	28%	0.10	0.12	26%	806	541	-33%	0.03	0.02	-34%

- The highest FSP concentration and load reductions occurred during the rain on snow event beginning May 15, 2019 when inflow concentrations were relatively high.
- The lowest FSP concentration and load reductions occurred during the rain on snow event on February 1, 2019 when the Jellyfish released FSP as indicated by greater outflow concentrations than inflow concentrations. Despite this, there was still a small load reduction due to the fact that some water is retained in the vault so outflow volumes are lower than inflow volumes.
- The highest TN concentration and load reductions occurred during the rain on snow event beginning May 15, 2019 when inflow concentrations were the second highest.
- The lowest TN concentration and load reductions occurred during the mixed rain and snow event beginning September 16, 2019 when inflow concentrations were relatively high. The Jellyfish released TN during this event. It also released TN during the rain on snow event beginning February 13, 2019.
- The highest TP concentration and load reductions occurred during the rain on snow event beginning May 15, 2019 when inflow concentrations were the second highest.
- The lowest TP concentration and load reductions occurred during the rain on snow event beginning February 1, 2019 when inflow concentrations were relatively high. The Jellyfish released TP during this event.

Jellyfish vault water level and bypass flow are presented in Figure 66. When bypass occurs, untreated flow comingles with treated flow in the outflow from the Jellyfish vault, resulting in reduced overall treatment efficiency.

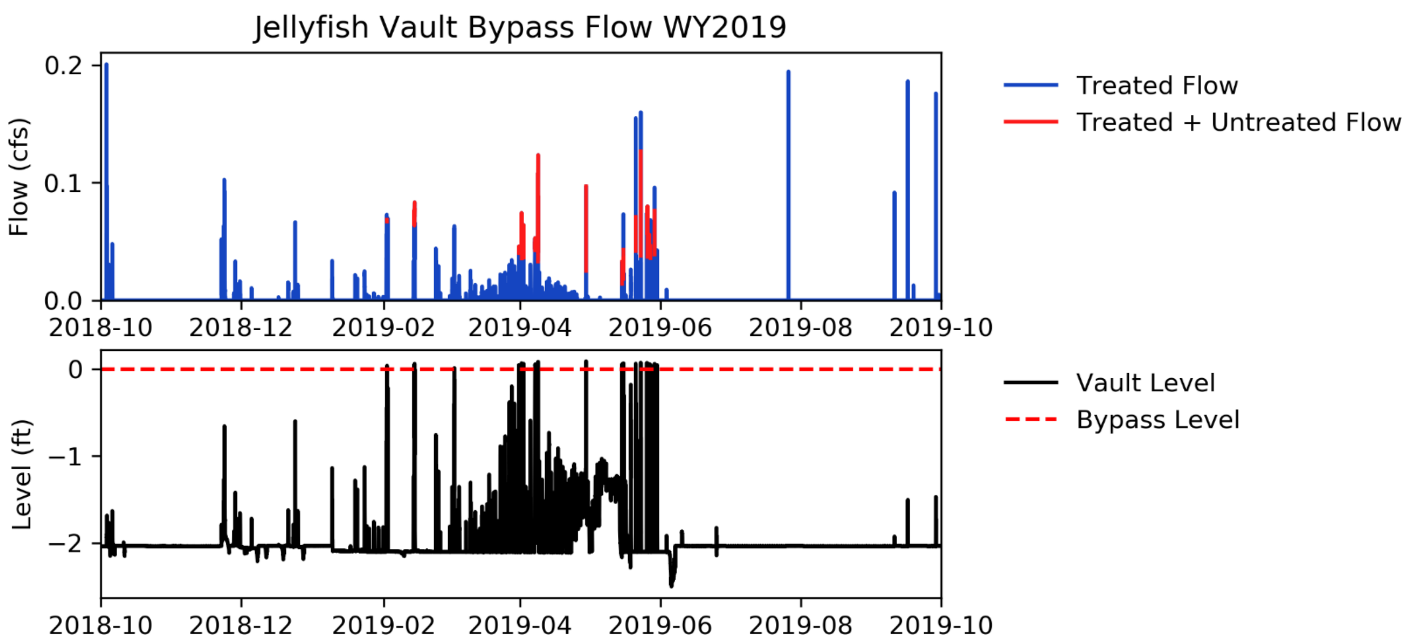

Figure 66 Jellyfish vault level at SR431, WY19 (bottom). Jellyfish outflow shown at the top for reference. Vault level greater than 0 indicates bypass flow.

- During periods of flow, the Jellyfish filter was in bypass mode 2% of the time in WY19 which represents up to 12% of the flow volume (3,017 cf). During bypass mode treated flow is co-mingled with untreated (bypass) flow, so the exact amount of untreated flow is difficult to determine.
- Bypass occurred during 14 runoff events:
  - February 2, 2019 during rain event that produced 0.73 inches of precipitation.
  - February 14, 2019 during an atmospheric river rain on snow event that produced over 4 inches of precipitation.
  - March 3, 2019 during a mixed precipitation event that produced half an inch of water equivalent.
  - March 31, 2019 during a snowmelt event.
  - April 1 - April 2, 2019 during a mixed precipitation event that produced nearly three quarters of an inch of water equivalent.
  - April 7, 2019 during a snowmelt event.
  - April 8, 2019 during a mixed precipitation event that produced less than a quarter inch of water equivalent.
  - April 29, 2019 during a mixed precipitation event that produced less than a quarter inch of water equivalent.
  - May 15-16, 2019 during a mixed precipitation event that produced less than a quarter inch of water equivalent.
  - May 21, 2019 during a rain on snow event that produced less than a half an inch of water equivalent.
  - May 23, 2019 during a rain on snow event that produced less than a half an inch of water equivalent.
  - May 26-27, 2019 during a mixed precipitation event that produced 0.64 inches of water equivalent.
  - May 29 2019 during a thunderstorm event that produced less than a quarter inch of rain.
  - May 30, 2019 during a thunderstorm event that produced less than a quarter inch of rain.
- Seven of the eight sampled events had untreated (bypass) flow (every event except for the September 16, 2019 rain and snow event).

7.2 Elks Club

Elks Club Drive was repaved in August 2018, right before the start of WY19. Data collected at Elks Club in WY18 and WY19 represent pre- and post-paving conditions respectively. Prior to repaving, Elk's Club Drive was in poor condition, covered in cracks and potholes (Figure 67 - PCI*: 29). In August 2018 it was repaved and is now in excellent condition (Figure 68 - PCI*: 99).

Figure 67 Elks Club Drive prior to repaving. (R Wigart)

Figure 68 Elks Club Drive after repaving. (A Buxton)

In addition to analyzing samples for sediment and nutrient content, Elks Club runoff samples also underwent a source apportionment analysis. Samples of asphalt aggregate, asphalt binder, roadside soil (i.e. soil that erodes off the adjacent road shoulder of adjoining land), traction abrasives (i.e. road sand), and vegetation debris were collected near the monitoring site were submitted at the beginning of the project and molecular markers were identified for each of these sediment types. Subsequent runoff samples were then analyzed using the molecular markers and a chemical mass balance model to determine what portion of the sediment in each sample originated from each source.

* PCI is a numerical index between 0 and 100 used to indicate the general condition of pavement. It requires a manual survey and is widely used by transportation departments to evaluate road condition. PCI was developed by the United States Army Corps of Engineers and surveying and calculation methods were standardized by the American Society for Testing Materials (ASTM). The method is based on a visual survey of the number and types of distresses in the pavement including alligator cracking, block cracking, bumps and sags, corrugations, longitudinal and transverse cracking, patching and utility cut patching, potholes, swelling, weathering, raveling, etc. Assessing PCI on roads is the most widely used and accepted method for determining road surface condition so that condition can be tracked and roads can be prioritized for funding for repaving or resurfacing.

Table 18 Results of Elks Club study. P-values* less than 0.001 indicate highly significant results (highlighted in green). P-values less than 0.05 indicate significant results (highlighted in yellow).

Water Year	Statistic	Asphalt aggregate + binder (%)	Traction abrasives (%)	Road side soil (%)	Vegetation debris (%)	Atmos-pheric deposition (%)	TSS concen-tration (mg/L)	Normalized TSS load (lbs/acre/in)	FSP concen-tration (mg/L)	Normalized FSP load (lbs/acre/in)
Pre Paving 2018	Mean	45.00	16.60	34.00	3.00	2.70	83.90	6.30	32.50	1.50
	Standard Deviation	6.51	5.26	6.66	0.95	1.25	50.66	7.58	22.12	1.32
	Min	36.00	10.00	24.00	1.50	1.00	17.50	0.25	3.82	0.14
	Median	45.00	17.00	34.00	3.00	3.00	101.30	3.60	37.26	1.83
	Max	56.00	25.00	45.00	4.50	5.00	137.50	22.11	67.58	3.28
Post Paving 2019	Mean	24.90	8.20	42.20	16.50	5.00	22.70	0.60	6.90	0.10
	Standard Deviation	6.10	2.76	6.83	4.33	1.63	15.47	0.82	5.77	0.08
	Min	14.80	3.00	33.00	10.00	2.00	10.00	0.03	0.57	0.01
	Median	26.20	9.00	41.00	16.00	5.00	15.25	0.29	5.10	0.07
	Max	33.70	11.00	55.00	23.00	8.00	57.00	2.47	19.10	0.27
	T-test p-value	**0.000**	**0.004**	**0.023**	**0.000**	**0.003**	**0.018**	**0.050**	**0.013**	**0.026**

*A t-test is a statistical test, resulting in a p-value, that is used to determine if there is a significant difference between the means of two sets of data. If the p-value is less than 0.001, then results are highly significant, meaning that there is only a 0.1% chance that the differences between the two sets of data were by chance. If the p-value is less than 0.05, results are significant, meaning that there is only a 5% chance the differences between the two sets of data were by chance.

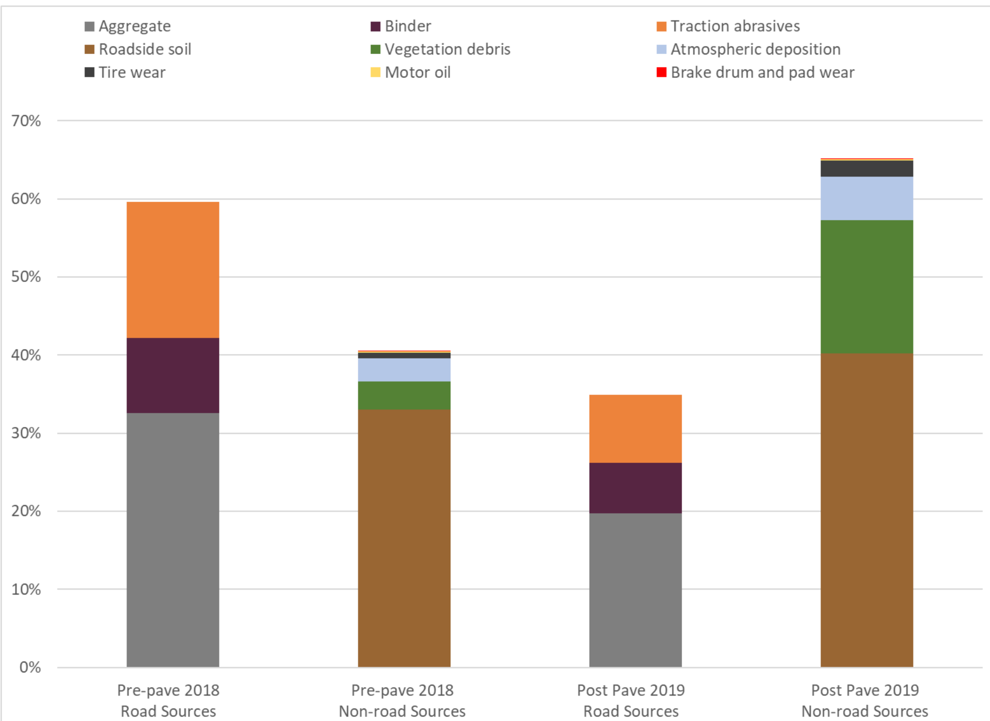

Figure 69 Average annual FSP load attributable to road and non-road sources at Elks Club, WY18 and WY19. 60% and 35% of the FSP in stormwater runoff from Elks Club Drive originated from road sources (asphalt aggregate, asphalt binder, and traction abrasives) in the pre- and post-pave conditions respectively.

Table 18 shows that there was a statistically significant decrease in the relative contribution of particles from road sources (asphalt aggregate plus binder and traction abrasives), and a significant increase in relative contribution of particles from non-road sources (roadside soil, vegetation debris, and atmospheric deposition) before and after pavement condition improvement. Figure 69 shows the percent composition of FSP in stormwater before and after paving. When relative contributions of asphalt aggregate plus binder and traction abrasives decrease, the relative contributions of naturally occurring roadside soil, vegetation debris, and atmospheric deposition increase as these contributions are not changed by improving pavement condition. Assuming that traction abrasive application practices remain fairly consistent from year to year, the decrease in the relative contribution of traction abrasives with improved pavement condition can be reasonably attributed to more efficient sweeping. Street sweeping on a smooth road surface is more effective than on a road surface marred by cracks and potholes allowing more sediment to be recovered. Percent contribution to FSP from each source category in the pre and post pave condition describes only how the composition of FSP in stormwater changed, it does not indicate if total sediment loads decreased. However, Table 18 also shows statistically significant decreases in total suspended sediment (TSS) concentration, FSP concentration, normalized TSS load, and normalized FSP load (pounds of sediment per acre per inch of rain).

Table 19 shows the substantial impact that improving pavement condition on Elk's Club Drive had on water quality in terms of reduced sediment concentrations and loads. Mean annual TSS and FSP concentrations were reduced by 73% and 79% respectively, which resulted in mean annual normalized TSS and FSP load reductions of 90% and 93% respectively. (Normalized load values account for catchment size and remove year to year variability in precipitation frequency, size, intensity, and duration.)

Table 19 Mean annual sediment concentration and load reductions.

Water Year	TSS concen-tration (mg/L)	Normalized TSS load (lbs/acre/in)	FSP concen-tration (mg/L)	Normalized FSP load (lbs/acre/in)
Pre Paving 2018	83.90	6.30	32.50	1.50
Post Paving 2019	22.70	0.60	6.90	0.10
% Reduction	**73%**	**90%**	**79%**	**93%**

8. Trends Analysis

In accordance with the RSWMP FIG section 2.1, monitoring for trends at urban catchment outfalls is important because it provides information needed for evaluating progress toward TMDL and other regulatory goals. Trend analyses are only performed on monitoring sites with at least five years of continuous data. The objective of the trends monitoring is to detect and report the cumulative load reduction benefits of all actions implemented within the catchment over long time frames and ultimately demonstrate a local and regional improvement in pollutant loading to the lake.

Water year 2019 marked the sixth year of monitoring at SR431, Pasadena, and Tahoma and the fifth year of monitoring at Speedboat, Tahoe Valley, and Upper Truckee. Trend analyses will only be reported for the inflow locations at SR431 (CI and JI) as these results will indicate trends in pollutant loading from the catchment. Trend analyses on the outflow locations (CO and JO) are an indication of how well the vaults are maintained over the years and will be included in the seasonal progress reports submitted to NDOT and available on Tahoe RCD's website. Elks Club and Lakeshore have two and three years of monitoring data respectively, therefore trends analyses were not performed on the data from these sites. They are included in this section for annual sediment and nutrient load comparisons to annual precipitation only.

Average annual loads for FSP, TN, and TP are normalized by catchment size (acres) and by inches of precipitation. Normalizing by catchment size allows for comparison between sites, but this analysis is not highlighted here as the objective of trends analysis is to detect load reductions resulting from improved management activities within each catchment, not between catchments. Normalizing by precipitation allows for comparison between water years in a particular catchment, which addresses the objective. Percent runoff (runoff coefficient) is a function of catchment size, the amount of rainfall received, and the volume measured at the catchment outfall. It represents the fraction of runoff that was measured at the outfall compared to what would theoretically be expected if all the rainfall that fell in the catchment were measured at the outfall.

Rainfall normalized average annual load charts for each site with five or more years of data show whether there is an upward, downward, or neutral trend in average annual loading of FSP, TN, and TP at each site. Also presented for each site with five or more years of data is a table that shows average annual percent runoff and rainfall normalized seasonal and average annual loads and trend statistics. The trend statistics indicate if there has been an upward, downward, or neutral trend in pollutant loading over the last five or six years in the selected catchments. Tau is a non-parametric measure of the relationship between data when data does not have a normal distribution, similar to the r^2 value in a regression on normalized data. Tau is a measure of the correspondence between two rankings, in this case between the water year and the normalized pollutant load. Tau is a correlation coefficient that returns a value between -1 and 1 where 0 is no relationship, 1 is a perfect identical relationship and -1 is a perfect opposite relationship with regards to ranked pairs. The pairs in this case are water year and pollutant load. The water years will always be ranked in order from 2014 through 2019. The pollutant loads are then ranked from least to most as well. The rankings of the pairs are then compared. If pollutant load steadily increases from year to year there will be a perfect identical ranking between the pairs, resulting in a Tau of 1. If pollutant load steadily decreases from year to year there will a perfect opposite ranking of the pairs, resulting in a Tau of -1. The p-value indicates the confidence level in Tau; a p-value less than 0.05 ($p<0.05$) denotes a significant relationship. The Theil slope is similar to the slope for a regression on normalized data, but used for data that is not normally distributed. Lastly, charts showing annual sediment and nutrient loads and annual precipitation totals for each site are included to help visualize how precipitation and loads have varied over the period of record for each site.

8.1 SR431 Contech MFS Inflow

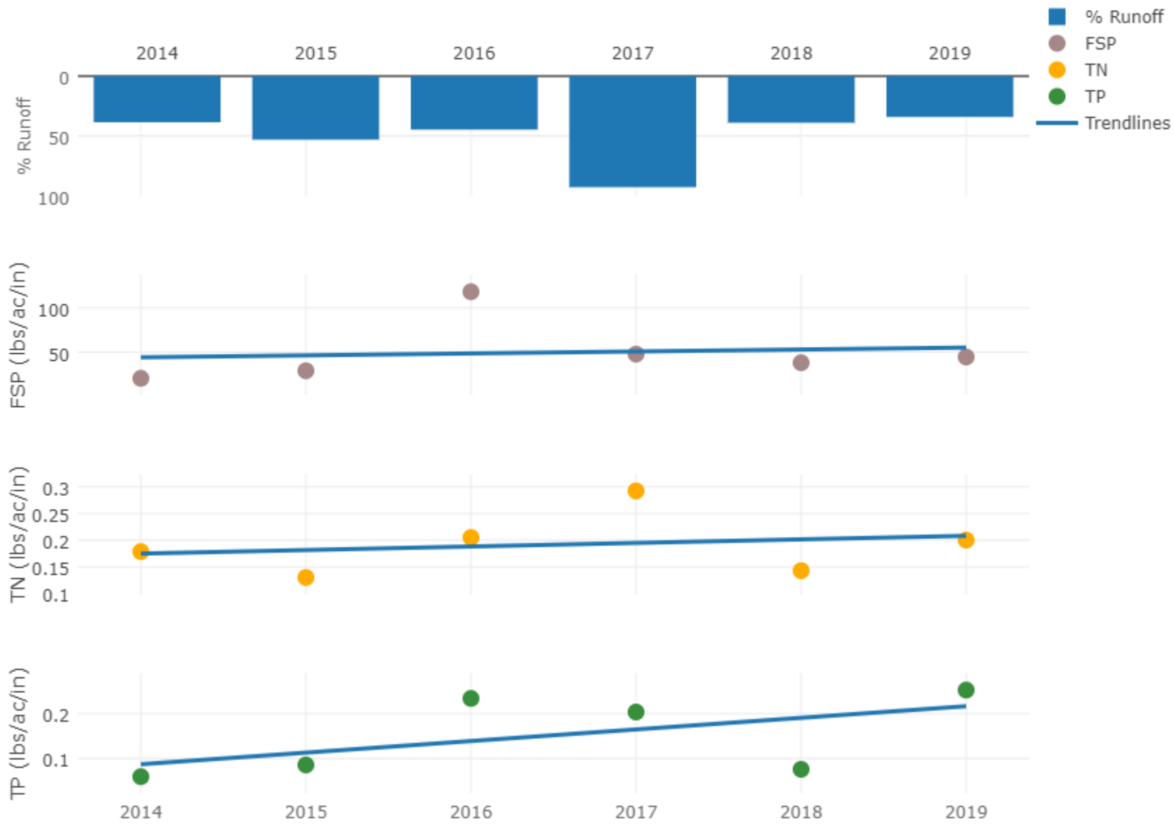

Figure 70 6-year rainfall normalized annual pollutant load trends in FSP, TN, and TP loads at the Contech MFS Inflow, WY14-19.

- Percent runoff varied between 34.2% in WY19 to 78.9% in WY17. Differences in % runoff between CI and JI are attributed to sediment accumulation in the splitter chamber that caused an unequal division of runoff to each vault.
- There is no significant trend in average annual FSP loads as indicated by a Tau value close to 0 and p-value greater than 0.05.
- There is no significant trend in average annual TN loads as indicated by a Tau value close to 0 and p-value greater than 0.05.
- There is no significant trend in average annual TP loads as indicated by a Tau value close to 0 and p-value greater than 0.05.

Table 20 6-year seasonal and annual rainfall normalized pollutant loads at the Contech MFS Inflow, WY14-19.

		FSP (lbs/acre/inch)				TN (lbs/acre/inch)				TP (lbs/acre/inch)			
Year	% Runoff	Fall/ Winter	Spring	Summer	Annual	Fall/ Winter	Spring	Summer	Annual	Fall/ Winter	Spring	Summer	Annual
2014	38.6%	8.358	43.467	23.094	20.612	0.065	0.230	0.386	0.179	0.021	0.122	0.079	0.060
2015	53.2%	29.875	41.461	7.517	29.122	0.127	0.164	0.086	0.130	0.097	0.110	0.015	0.086
2016	44.7%	84.812	183.564	0.000	118.153	0.179	0.260	0.000	0.205	0.149	0.399	0.000	0.234
2017	78.9%	19.239	139.993	20.235	40.646	0.178	0.611	0.048	0.248	0.064	0.688	0.035	0.173
2018	39.0%	23.391	51.881	20.808	38.173	0.136	0.116	0.554	0.143	0.083	0.068	0.113	0.076
2019	34.2%	11.579	153.825	8.569	44.627	0.083	0.565	0.228	0.200	0.066	0.866	0.070	0.253
Tau	na	-0.067	0.200	-0.200	0.333	0.200	0.200	0.000	0.200	-0.067	0.333	0.200	0.467
P-Value	na	0.851	0.573	0.624	0.348	0.573	0.573	1.000	0.573	0.851	0.348	0.624	0.188
Theil Slope (per year)	na	-2.161	3.473	-1.738	4.390	0.004	0.067	0.011	0.004	-0.004	0.149	0.011	0.026

Figure 71 through Figure 78 show sediment and nutrient loads for the Contech MFS compared to total annual precipitation for WY14 through WY19. This illustrates how loading and precipitation have varied over the monitored period.

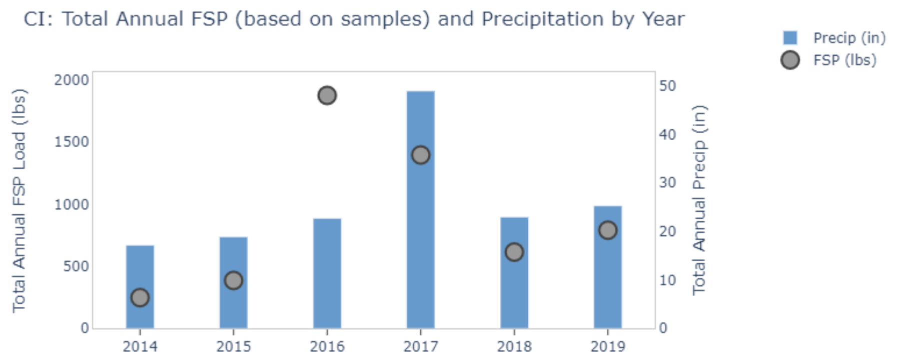

Figure 71 Total annual FSP load (based on samples) and precipitation by year for Contech MFS Inflow WY14-WY19.

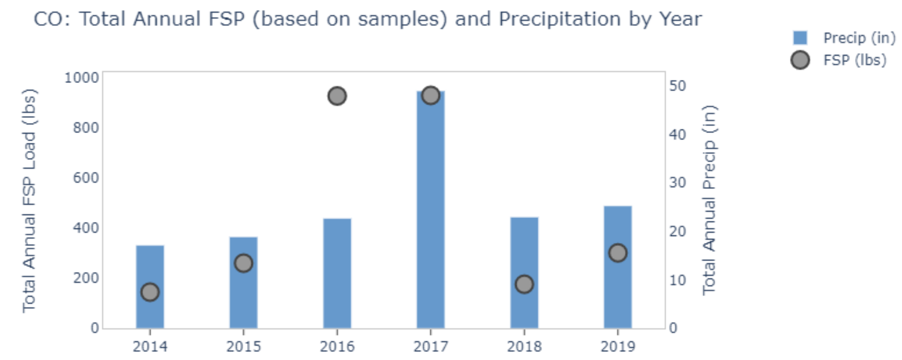

Figure 72 Total annual FSP load (based on samples) and precipitation by year for Contech MFS Outflow WY14-WY19.

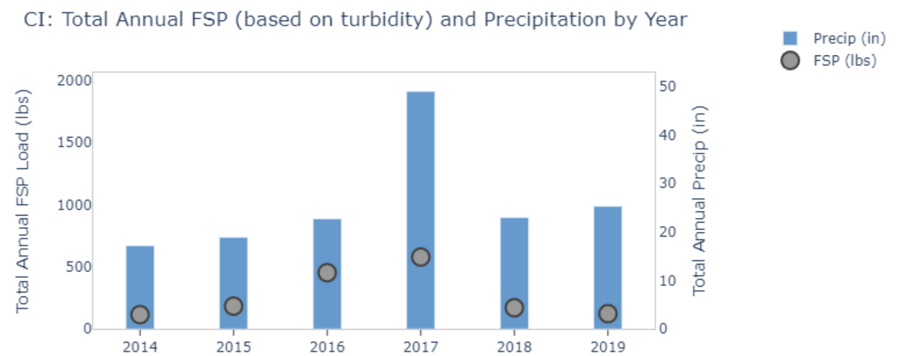

Figure 73 Total annual FSP load (based on continuous turbidity) and precipitation by year for Contech MFS Inflow WY14-WY19.

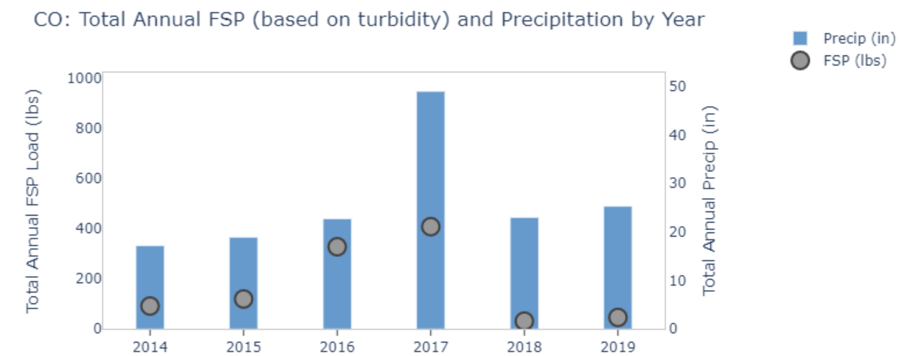

Figure 74 Total annual FSP load (based on continuous turbidity) and precipitation by year for Contech MFS Outflow WY14-WY19.

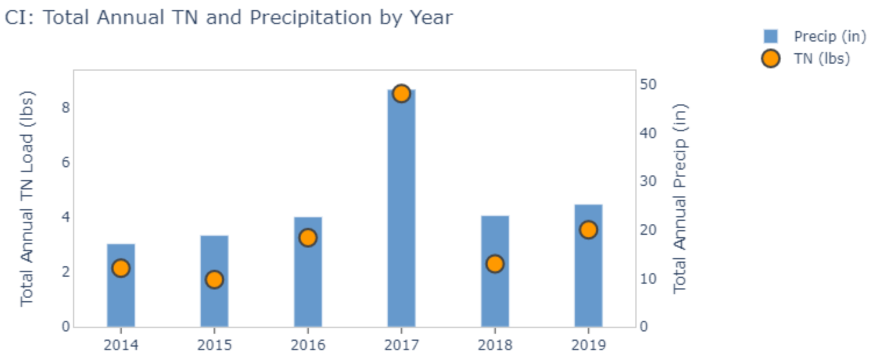

Figure 75 Total annual TN load and precipitation by year for Contech MFS Inflow WY14-WY19.

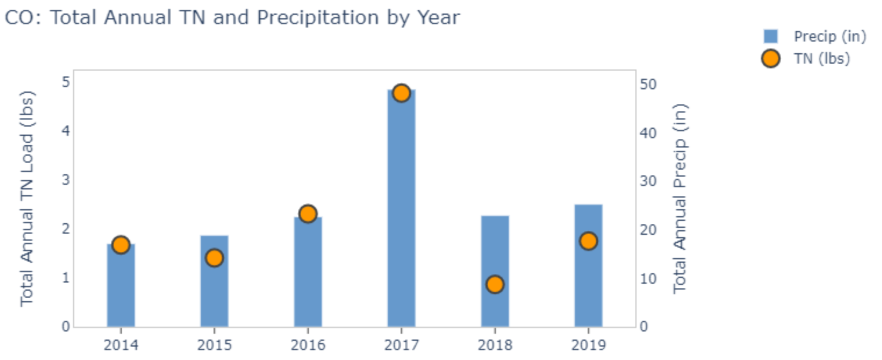

Figure 76 Total annual TN load and precipitation by year for Contech MFS Outflow WY14-WY19.

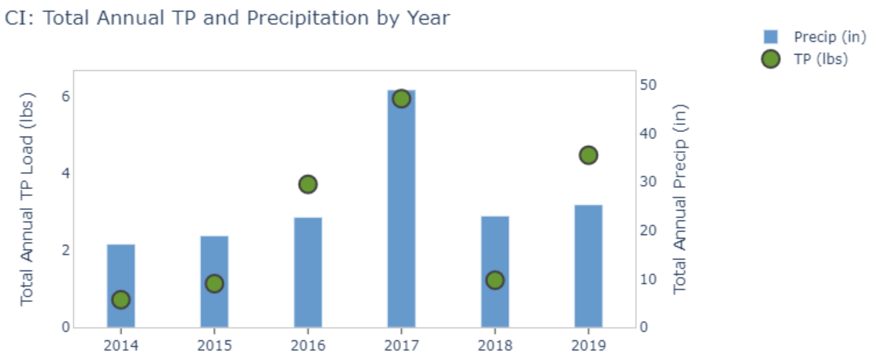

Figure 77 Total annual TP load and precipitation by year for Contech MFS Inflow WY14-WY19.

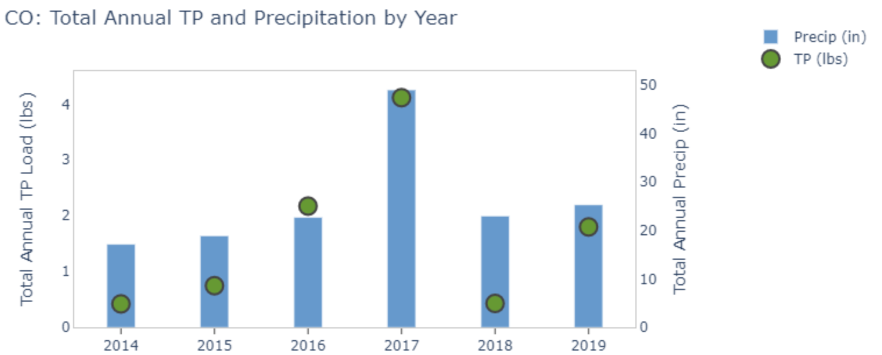

Figure 78 Total annual TP load and precipitation by year for Contech MFS Outflow WY14-WY19.

8.2 SR431 Jellyfish Inflow

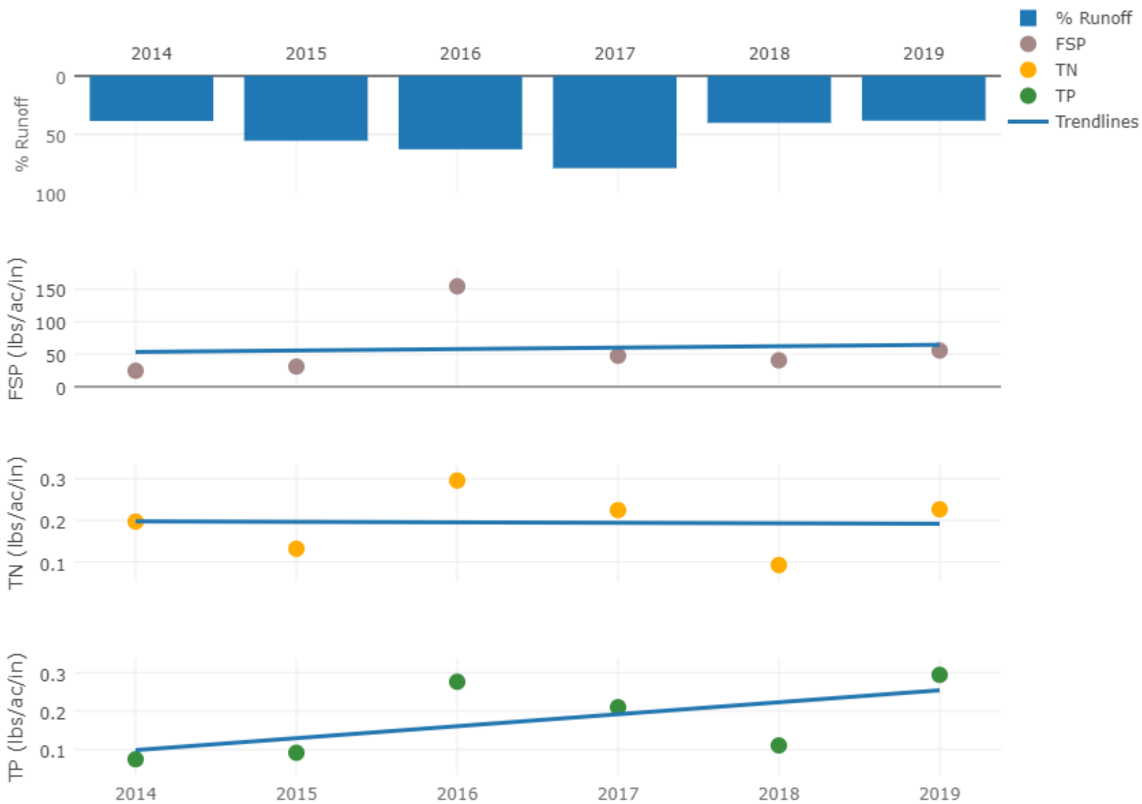

Figure 79 6-year rainfall normalized annual pollutant load trends in FSP, TN, and TP loads at the Jellyfish Inflow, WY14-19.

- Percent runoff varied between 38.6% in WY14 to 79.1% in WY17. Differences in % runoff between CI and JI are attributed to sediment accumulation in the splitter chamber that caused an unequal division of runoff to each vault.
- There is no significant trend in average annual FSP loads as indicated by a Tau value close to 0 and p-value greater than 0.05.
- There is no significant trend in average annual TN loads as indicated by a Tau value close to 0 and p-value greater than 0.05.
- There is currently no significant trend in average annual TP loads, but a Tau value nearing 1 and p-value nearing 0.05 indicate it may be significant in the future.

Table 21 6-year seasonal and annual rainfall normalized pollutant loads at the Jellyfish Inflow, WY14-19.

		FSP (lbs/acre/inch)				TN (lbs/acre/inch)				TP (lbs/acre/inch)			
Year	% Runoff	Fall/ Winter	Spring	Summer	Annual	Fall/ Winter	Spring	Summer	Annual	Fall/ Winter	Spring	Summer	Annual
2014	38.6%	13.733	51.563	18.989	24.558	0.060	0.313	0.384	0.197	0.033	0.160	0.075	0.075
2015	55.5%	30.438	46.614	8.065	31.038	0.116	0.174	0.109	0.132	0.095	0.133	0.017	0.092
2016	62.9%	117.285	228.200	0.000	154.437	0.214	0.457	0.000	0.296	0.223	0.385	0.000	0.276
2017	79.1%	23.050	168.400	19.423	47.637	0.111	0.787	0.076	0.225	0.076	0.874	0.041	0.210
2018	40.2%	20.067	59.455	18.262	40.577	0.072	0.076	0.526	0.093	0.070	0.146	0.105	0.111
2019	38.3%	12.119	199.426	9.226	55.674	0.090	0.649	0.263	0.227	0.059	1.068	0.071	0.294
Tau	na	-0.333	0.333	-0.200	0.467	-0.067	0.200	0.000	0.067	-0.200	0.467	0.200	0.600
P-Value	na	0.348	0.348	0.624	0.188	0.851	0.573	1.000	0.851	0.573	0.188	0.624	0.091
Theil Slope (per year)	na	-3.457	15.513	-0.671	6.158	-0.002	0.067	0.009	0.001	-0.009	0.182	0.010	0.042

Figure 80 through Figure 87 show sediment and nutrient loads for the Jellyfish compared to total annual precipitation for WY14 through WY19. This illustrates how loading and precipitation have varied over the monitored period.

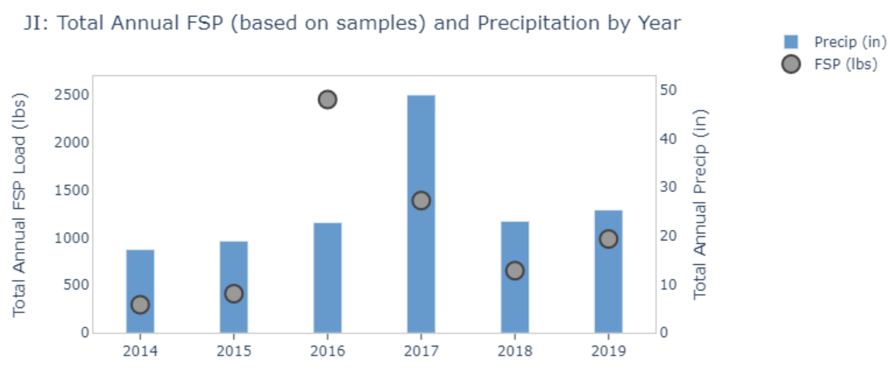

Figure 80 Total annual FSP load (based on samples) and precipitation by year for Jellyfish Inflow WY14-WY19.

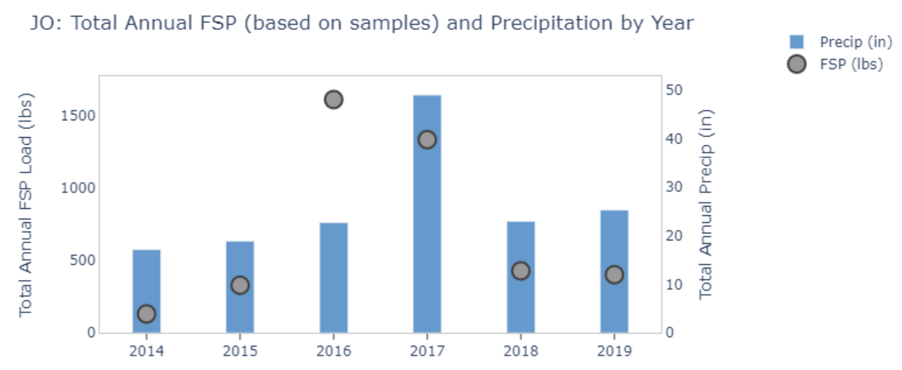

Figure 81 Total annual FSP load (based on samples) and precipitation by year for Jellyfish Outflow WY14-WY19.

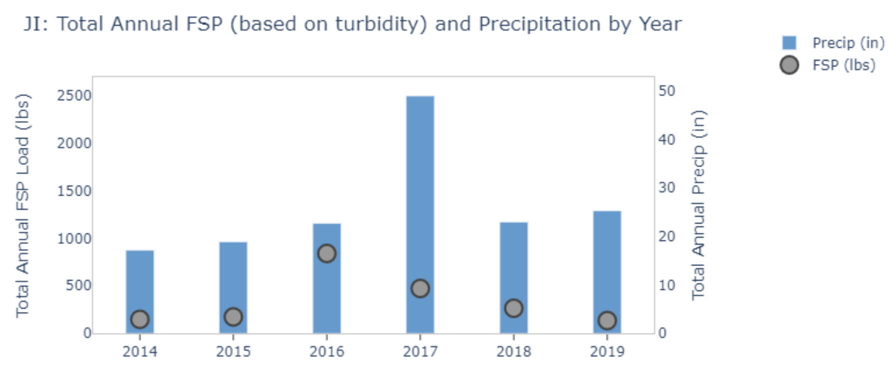

Figure 82 Total annual FSP load (based on continuous turbidity) and precipitation by year for Jellyfish Inflow WY14-WY19.

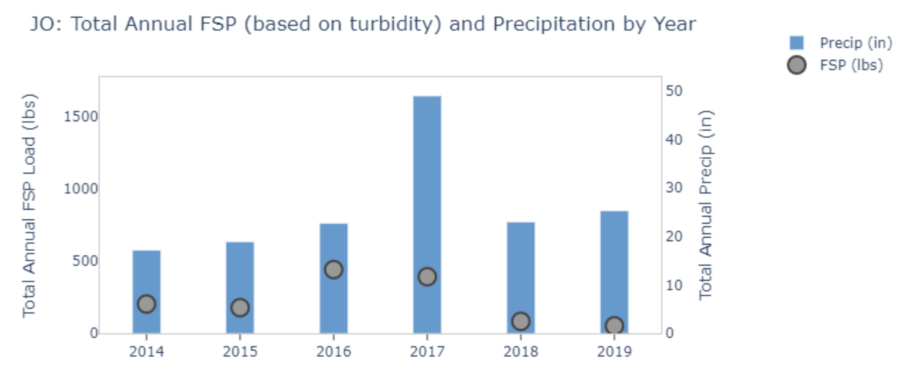

Figure 83 Total annual FSP load (based on continuous turbidity) and precipitation by year for Jellyfish Outflow WY14-WY19.

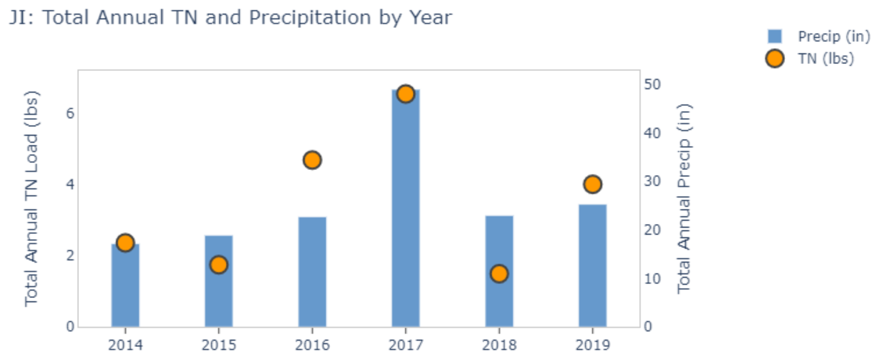

Figure 84 Total annual TN load and precipitation by year for Jellyfish Inflow WY14-WY19.

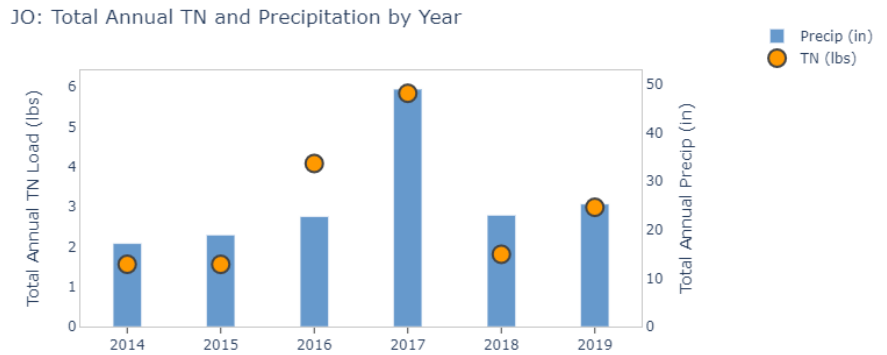

Figure 85 Total annual TN load and precipitation by year for Jellyfish Outflow WY14-WY19.

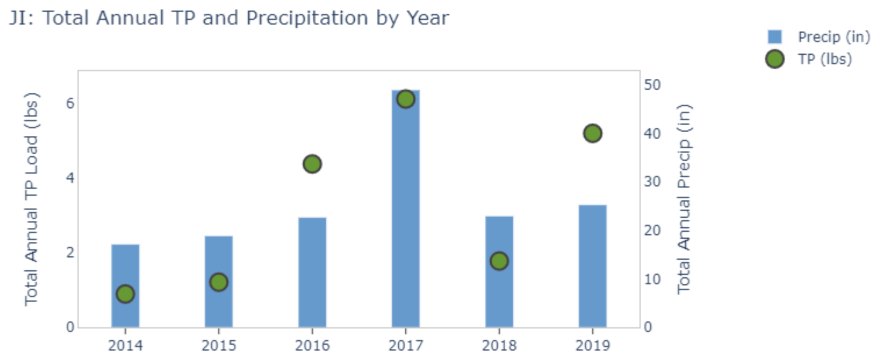

Figure 86 Total annual TP load and precipitation by year for Jellyfish Inflow WY14-WY19.

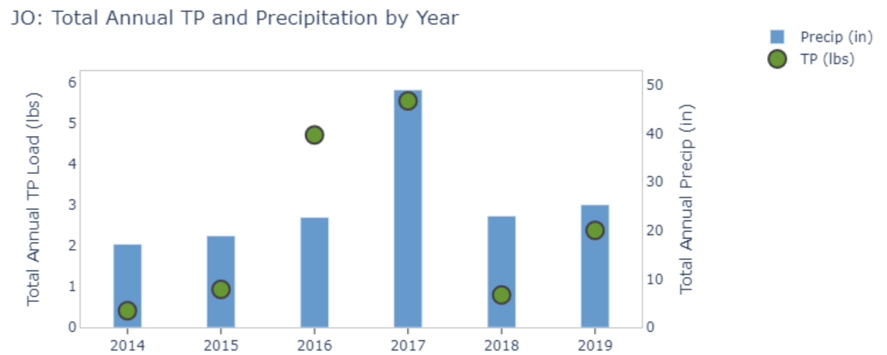

Figure 87 Total annual TP load and precipitation by year for Jellyfish Outflow WY14-WY19.

8.3 Elks Club

Figure 88 through Figure 91 show sediment and nutrient loads for Elks Club compared to total annual precipitation for WY18 through WY19. This illustrates how loading and precipitation have varied over the monitored period.

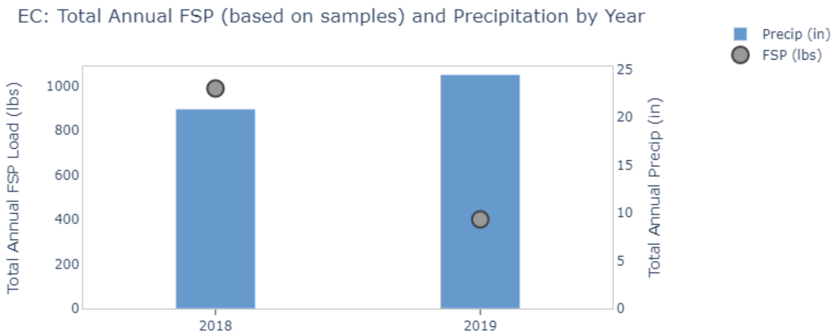

Figure 88 Total annual FSP load (based on samples) and precipitation by year for Elks Club WY18-WY19.

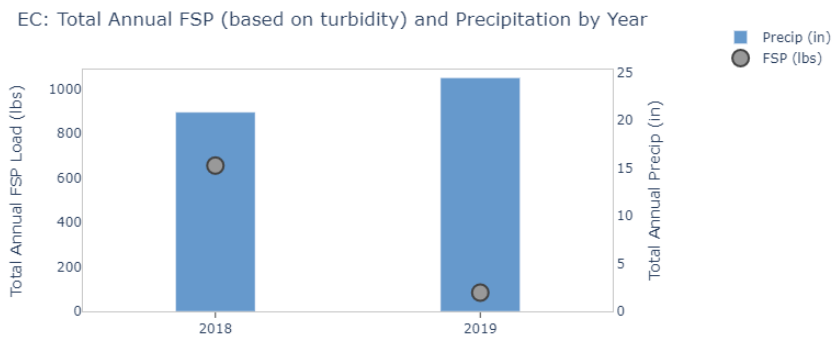

Figure 89 Total annual FSP load (based on continuous turbidity) and precipitation by year for Elks Club WY18-WY19.

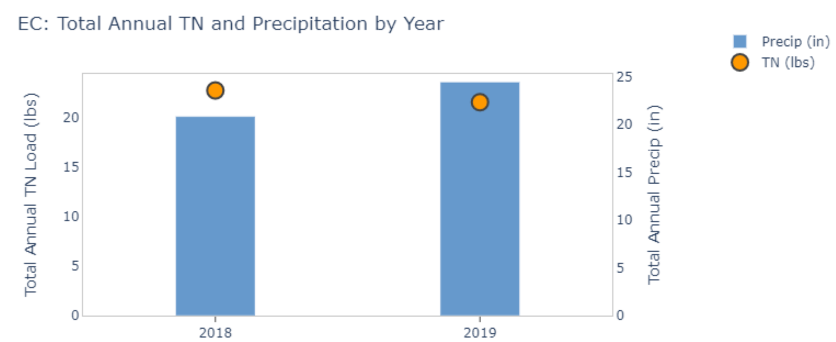

Figure 90 Total annual TN load and precipitation by year for Elks Club WY18-WY19.

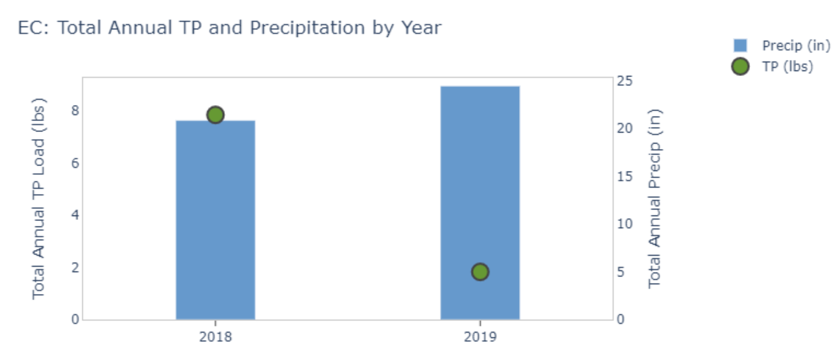

Figure 91 Total annual TP load and precipitation by year for Elks Club WY18-WY19.

8.4 Lakeshore

Figure 92 through Figure 95 show sediment and nutrient loads for Lakeshore compared to total annual precipitation for WY17 through WY19. This illustrates how loading and precipitation have varied over the monitored period.

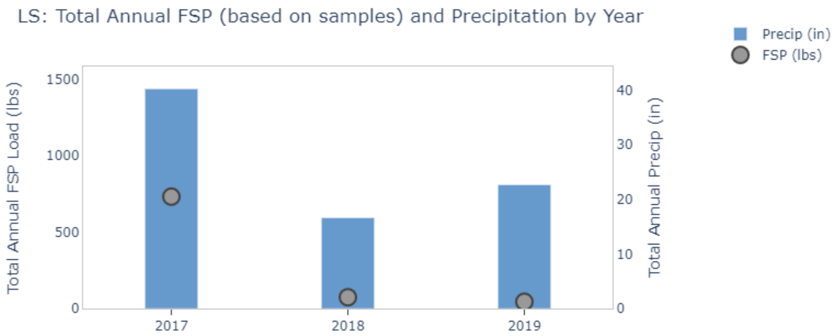

Figure 92 Total annual FSP load (based on samples) and precipitation by year for Lakeshore WY17-WY19.

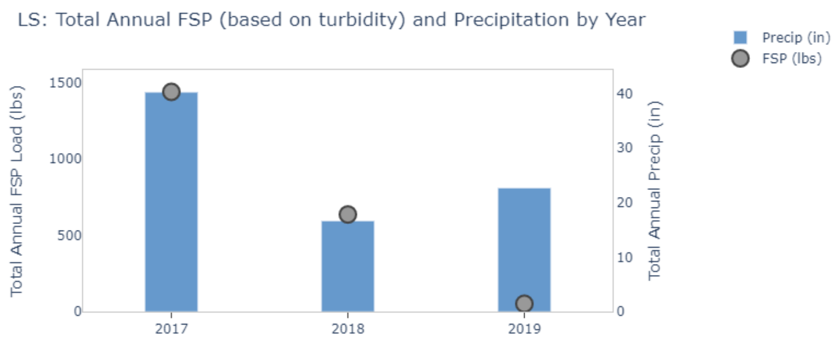

Figure 93 Total annual FSP load (based on continuous turbidity) and precipitation by year for Lakeshore WY17-WY19.

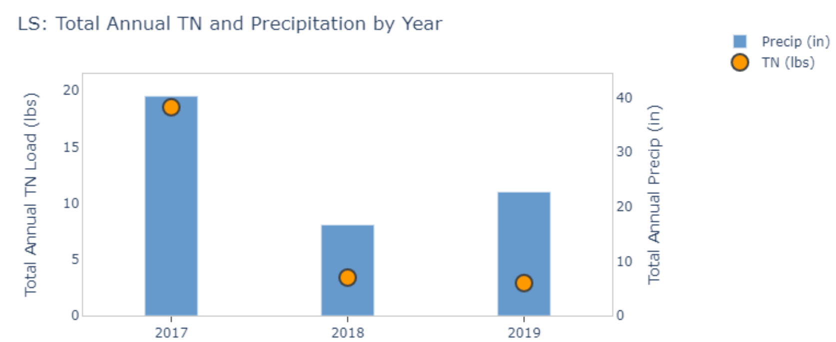

Figure 94 Total annual TN load and precipitation by year for Lakeshore WY17-WY19.

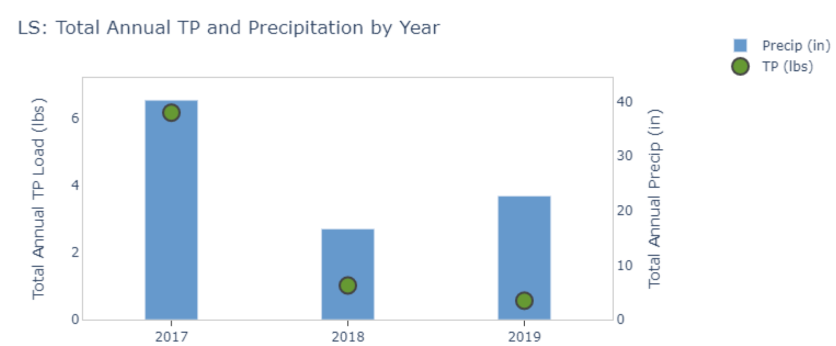

Figure 95 Total annual TP load and precipitation by year for Lakeshore WY17-WY19.

8.5 Pasadena

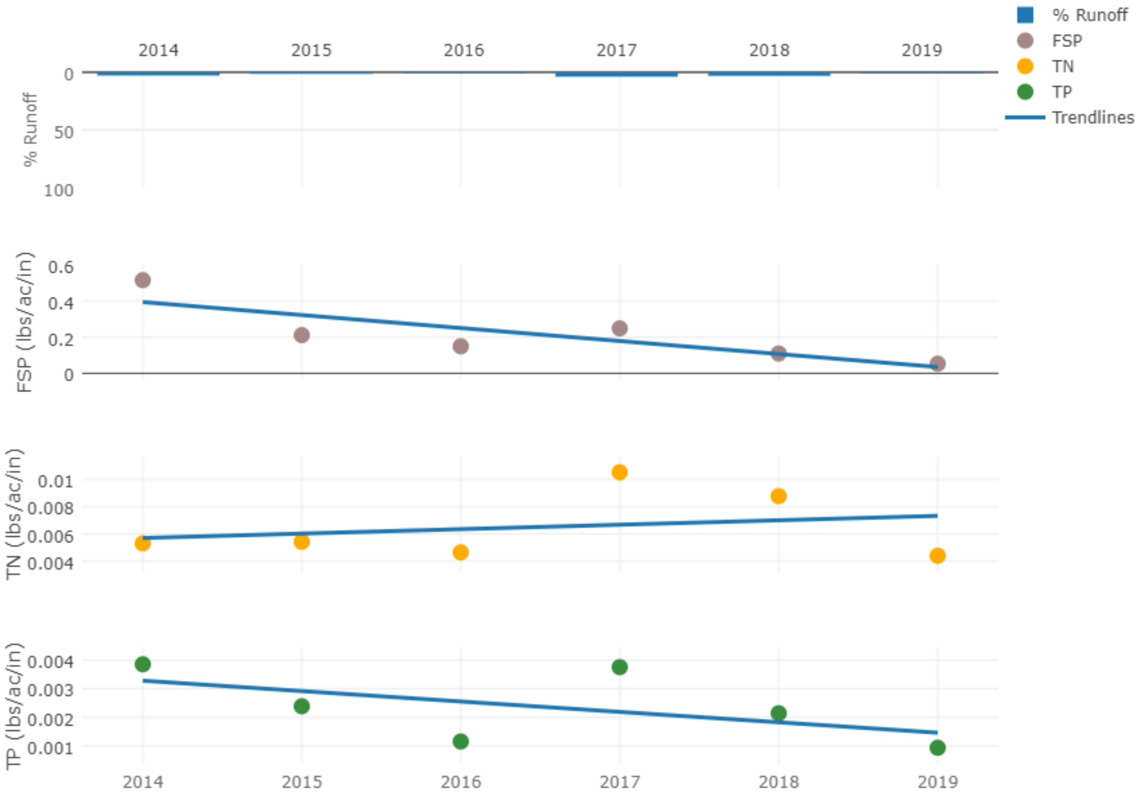

Figure 96 6-year rainfall normalized annual pollutant load trends in FSP, TN, and TP loads at the Pasadena Outflow, WY14-19.

- Percent runoff was less than 4% in all five water years but varied between 0.8% in WY16 to 3.9% in WY17.
- There is a significant decreasing trend in average annual and summer FSP loads as indicated by a Tau value close to -1 and a p-value less than 0.05.
- There is no significant trend in average annual TN loads as indicated by a Tau value close to 0 and p-value greater than 0.05.
- There is currently no significant trend in average annual TP loads, but a Tau value nearing 1 and p-value nearing 0.05 indicate it may be significant in the future.
- There is a significant decreasing trend in summer TP loads as indicated by a Tau value close to -1 and a p-value less than 0.05 (Table 22).

Table 22 6-year seasonal and annual rainfall normalized pollutant loads at the Pasadena Outflow, WY14-19.

		FSP (lbs/acre/inch)				TN (lbs/acre/inch)				TP (lbs/acre/inch)			
Year	% Runoff	Fall/ Winter	Spring	Summer	Annual	Fall/ Winter	Spring	Summer	Annual	Fall/ Winter	Spring	Summer	Annual
2014	2.8%	0.453	0.000	1.042	0.517	0.006	0.000	0.009	0.005	0.004	0.000	0.007	0.004
2015	1.4%	0.166	0.038	0.495	0.212	0.004	0.001	0.013	0.005	0.002	0.000	0.006	0.002
2016	0.8%	0.129	0.178	0.000	0.150	0.006	0.002	0.000	0.005	0.001	0.001	0.000	0.001
2017	3.9%	0.245	0.206	0.397	0.249	0.010	0.005	0.026	0.011	0.004	0.001	0.005	0.004
2018	3.1%	0.140	0.082	0.090	0.110	0.014	0.003	0.012	0.009	0.003	0.001	0.002	0.002
2019	1.0%	0.074	0.003	0.039	0.053	0.006	0.001	0.005	0.004	0.001	0.000	0.000	0.001
Tau	na	-0.600	-0.200	-1.000	-0.733	0.467	0.000	-0.200	-0.067	-0.333	0.000	-1.000	-0.600
P-Value	na	0.091	0.624	0.014	0.039	0.188	1.000	0.624	0.851	0.348	1.000	0.014	0.091
Theil Slope (per year)	na	-0.066	-0.028	-0.190	-0.062	0.002	0.000	-0.001	0.000	0.000	0.000	-0.001	0.000

Figure 97 through Figure 100 show sediment and nutrient loads for Pasadena compared to total annual precipitation for WY14 through WY19. This illustrates how loading and precipitation have varied over the monitored period.

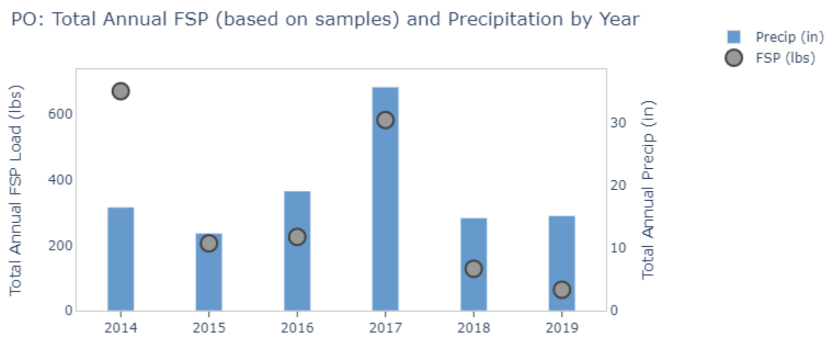

Figure 97 Total annual FSP load (based on samples) and precipitation by year for Pasadena WY14-WY19.

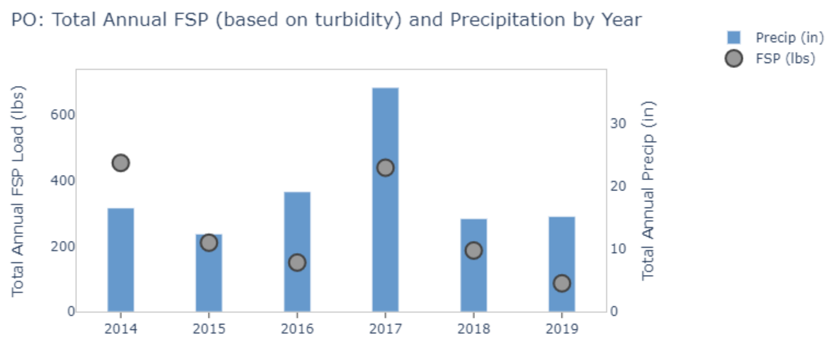

Figure 98 Total annual FSP load (based on continuous turbidity) and precipitation by year for Pasadena WY14-WY19.

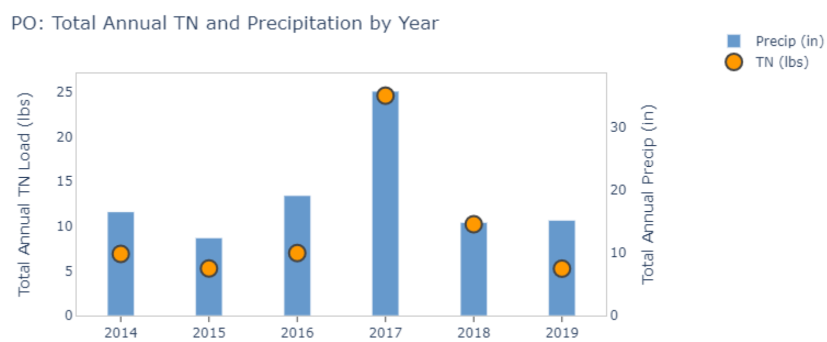

Figure 99 Total annual TN load and precipitation by year for Pasadena WY14-WY19.

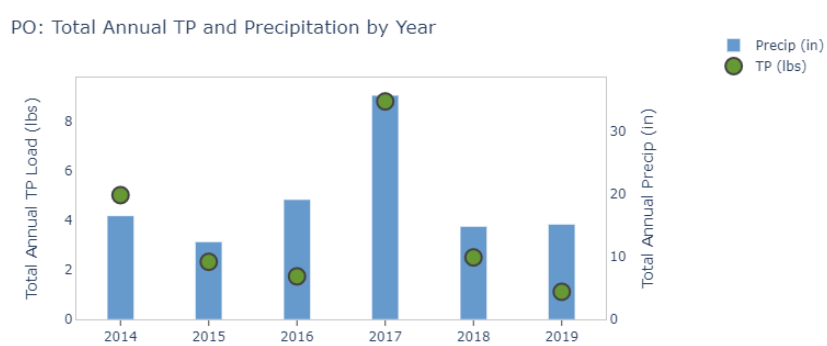

Figure 100 Total annual TP load and precipitation by year for Pasadena WY14-WY19.

8.6 Speedboat

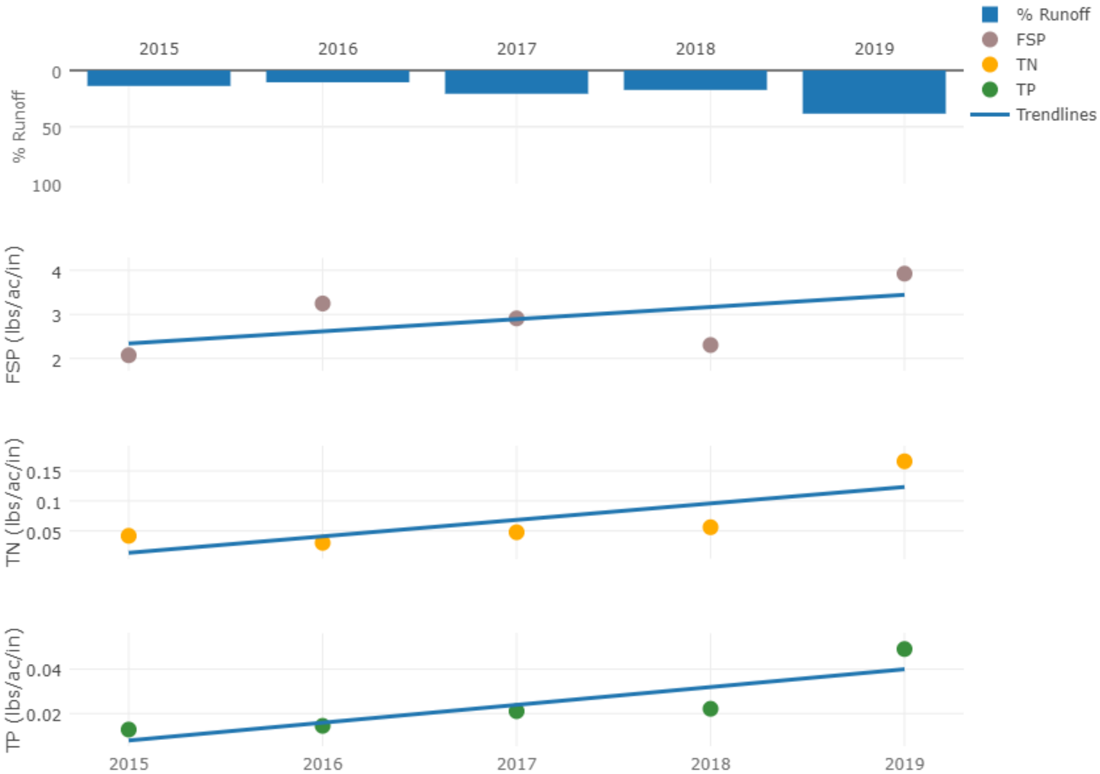

Figure 101 5-year rainfall normalized annual pollutant load trends in FSP, TN, and TP loads at Speedboat, WY15-19.

- Percent runoff varied between 17.3% in WY18 to 45.4% in WY19.
- There is no significant trend in average annual FSP loads as indicated by a Tau value close to 0 and p-value greater than 0.05.
- There is a significant increasing trend in average annual TN loads as indicated by a Tau value close to 1 and a p-value equal to 0.05.
- There is a significant increasing trend in average annual, fall/winter, and spring TP loads as indicated by Tau values close to 1 and a p-value of 0.05 or less.

Table 23 0.5-year seasonal and annual rainfall normalized pollutant loads at Speedboat, WY15-19.

		FSP (lbs/acre/inch)				TN (lbs/acre/inch)				TP (lbs/acre/inch)			
Year	% Runoff	Fall/ Winter	Spring	Summer	Annual	Fall/ Winter	Spring	Summer	Annual	Fall/ Winter	Spring	Summer	Annual
2015	13.8%	2.342	2.125	1.110	2.071	0.039	0.037	0.060	0.042	0.015	0.010	0.008	0.013
2016	10.6%	2.532	4.798	0.317	3.247	0.031	0.028	0.035	0.030	0.014	0.015	0.007	0.014
2017	20.7%	2.379	6.468	0.270	2.909	0.037	0.113	0.021	0.048	0.017	0.049	0.004	0.021
2018	17.3%	1.171	3.236	0.000	2.303	0.081	0.037	0.000	0.056	0.017	0.027	0.000	0.022
2019	38.4%	1.262	7.684	14.410	3.925	0.191	0.107	0.157	0.166	0.045	0.054	0.069	0.049
Tau	na	-0.400	0.600	0.000	0.400	0.600	0.400	0.000	0.800	0.800	0.800	0.000	1.000
P-Value	na	0.327	0.142	1.000	0.327	0.142	0.327	1.000	0.050	0.050	0.050	1.000	0.014
Theil Slope (per year)	na	-0.330	1.175	1.649	0.322	0.031	0.011	0.005	0.015	0.002	0.008	0.007	0.005

Figure 102 through Figure 105 show sediment and nutrient loads for Speedboat compared to total annual precipitation for WY15 through WY19. This illustrates how loading and precipitation have varied over the monitored period.

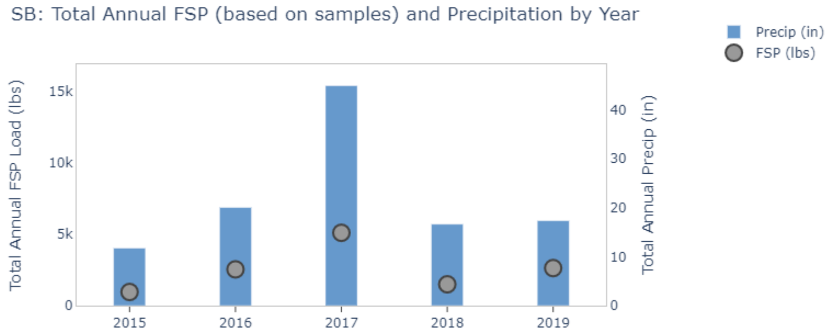

Figure 102 Total annual FSP load (based on samples) and precipitation by year for Speedboat WY15-WY19.

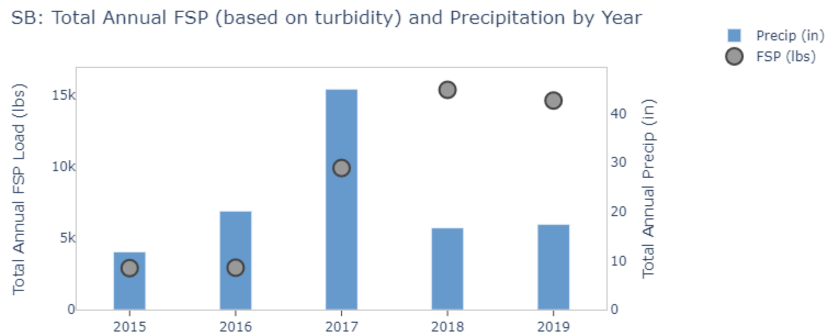

Figure 103 Total annual FSP load (based on continuous turbidity) and precipitation by year for Speedboat WY15-WY19.

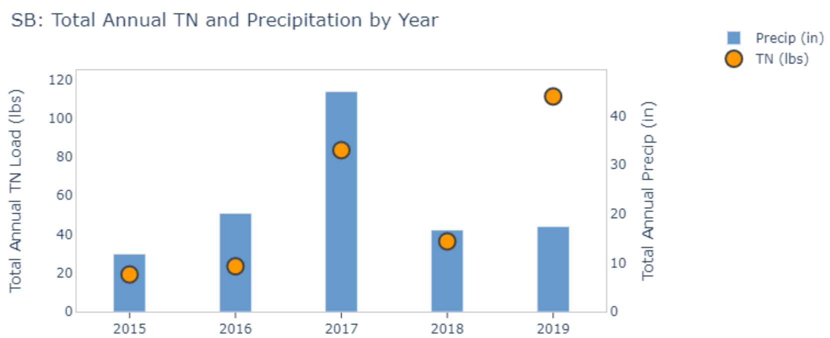

Figure 104 Total annual TN load and precipitation by year for Speedboat WY15-WY19.

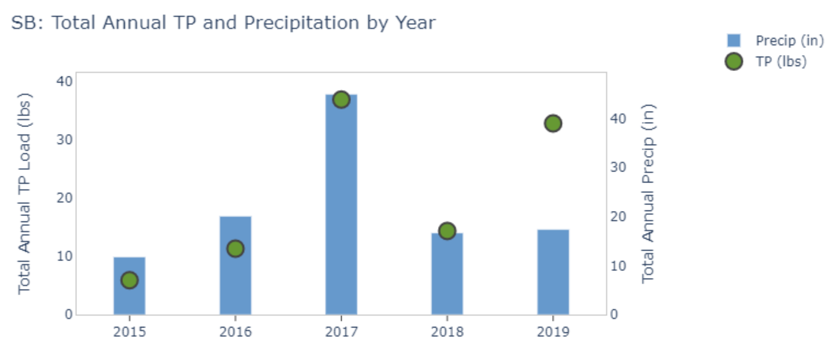

Figure 105 Total annual TP load and precipitation by year for Speedboat WY15-WY19.

8.7 Tahoe Valley

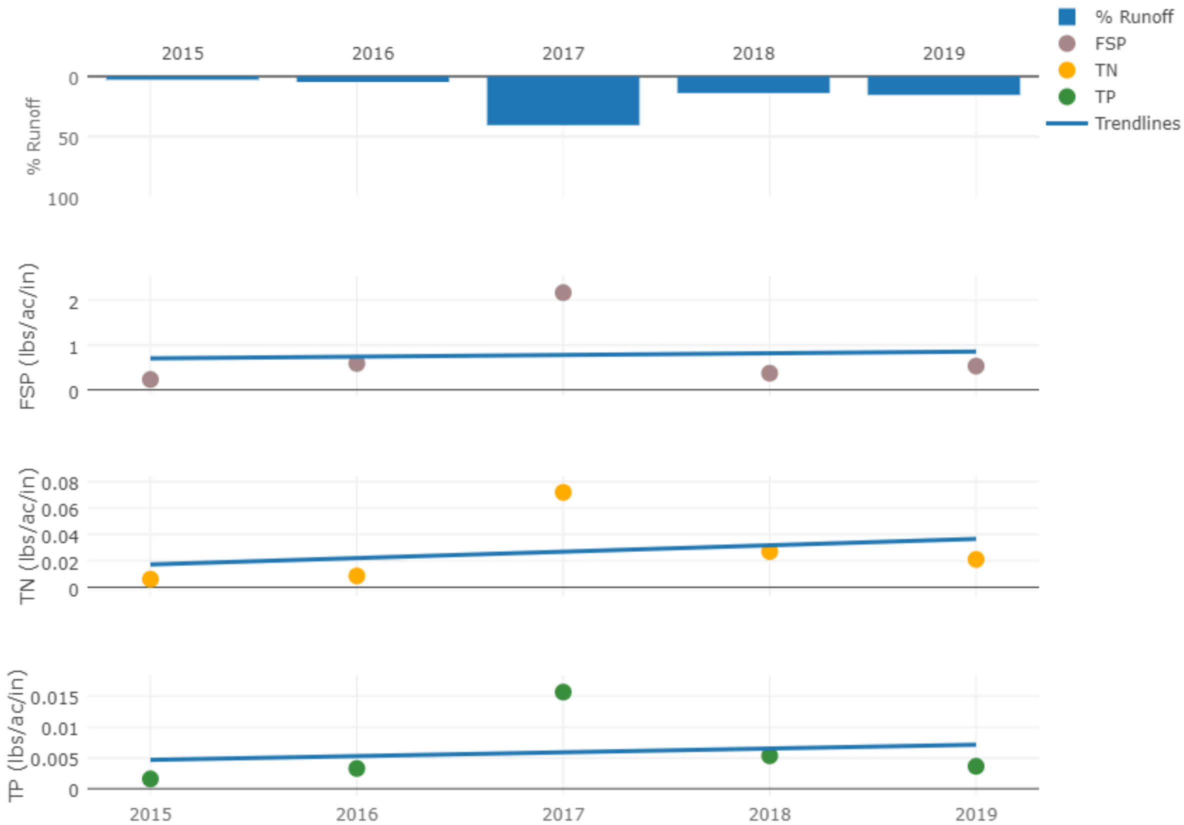

Figure 106 5-year rainfall normalized annual pollutant load trends in FSP, TN, and TP loads at Tahoe Valley, WY15-19.

- Percent runoff varied between 3.9% in WY15 to 40.7% in WY17.
- There is no significant trend in average annual FSP loads as indicated by a Tau value close to 0 and p-value greater than 0.05.
- There is no significant trend in average annual TN loads as indicated by a Tau value close to 0 and p-value greater than 0.05.
- There is no significant trend in average annual TP loads as indicated by a Tau value close to 0 and p-value greater than 0.05.

Table 24 5-year seasonal and annual rainfall normalized pollutant loads at Tahoe Valley, WY15-19.

Year	% Runoff	FSP (lbs/acre/inch)				TN (lbs/acre/inch)				TP (lbs/acre/inch)			
		Fall/ Winter	Spring	Summer	Annual	Fall/ Winter	Spring	Summer	Annual	Fall/ Winter	Spring	Summer	Annual
2015	2.7%	0.320	0.001	0.194	0.230	0.008	0.003	0.004	0.006	0.002	0.001	0.001	0.002
2016	4.7%	0.439	0.919	0.000	0.588	0.006	0.014	0.000	0.009	0.002	0.005	0.000	0.003
2017	40.7%	1.401	120.326	0.000	2.168	0.038	5.272	0.000	0.072	0.010	0.920	0.000	0.016
2018	13.9%	0.089	0.623	0.238	0.370	0.028	0.027	0.018	0.027	0.004	0.007	0.003	0.005
2019	15.5%	0.113	1.787	0.945	0.529	0.009	0.058	0.047	0.021	0.001	0.012	0.001	0.004
Tau	na	-0.200	0.400	0.333	0.200	0.200	0.600	0.333	0.400	0.000	0.600	-0.333	0.400
P-Value	na	0.624	0.327	0.497	0.624	0.624	0.142	0.497	0.327	1.000	0.142	0.497	0.327
Theil Slope (per year)	na	-0.064	0.368	0.101	0.061	0.000	0.012	0.008	0.004	0.000	0.002	-0.001	0.001

Figure 107 through Figure 110 show sediment and nutrient loads for Tahoe Valley compared to total annual precipitation for WY15 through WY19. This illustrates how loading and precipitation have varied over the monitored period.

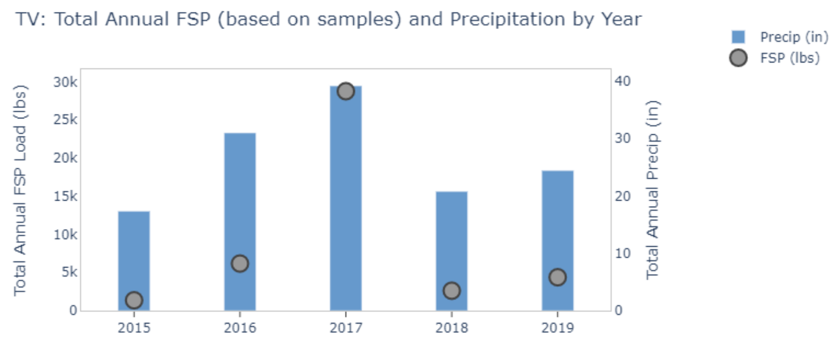

Figure 107 Total annual FSP load (based on samples) and precipitation by year for Tahoe Valley WY15-WY19.

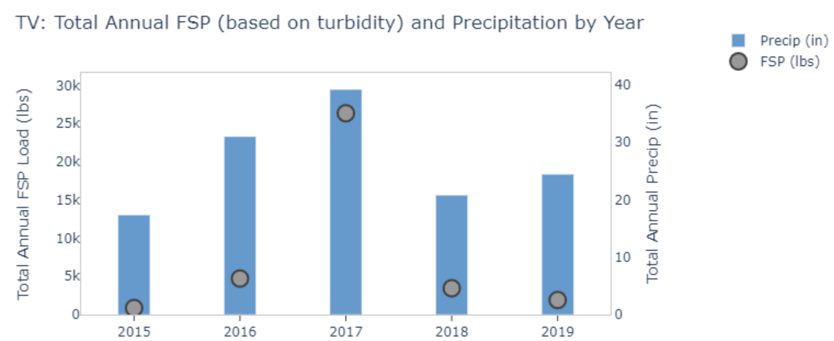

Figure 108 Total annual FSP load (based on continuous turbidity) and precipitation by year for Tahoe Valley WY15-WY19.

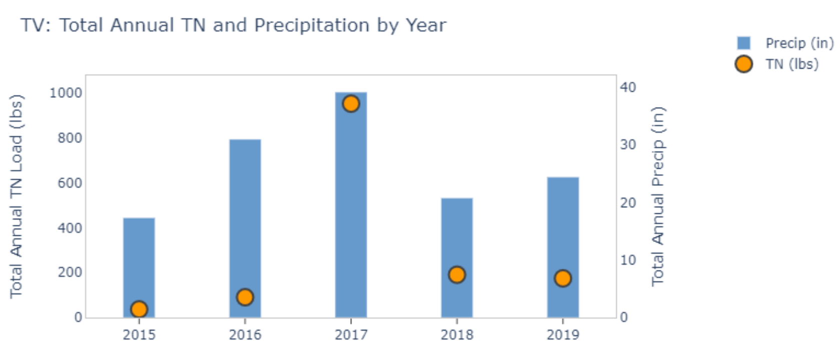

Figure 109 Total annual TN load and precipitation by year for Tahoe Valley WY15-WY19.

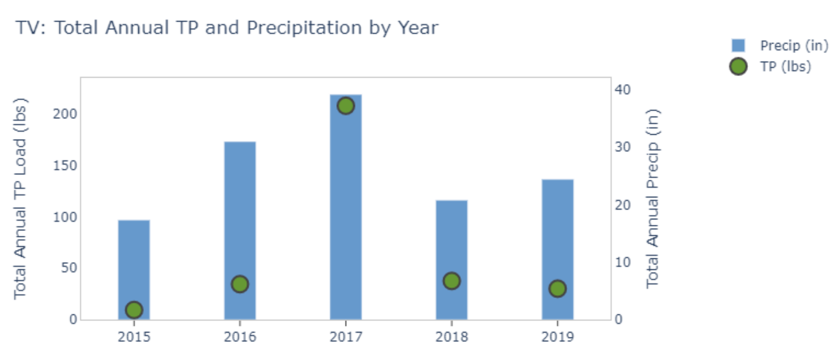

Figure 110 Total annual TP load and precipitation by year for Tahoe Valley WY15-WY19.

8.8 Tahoma

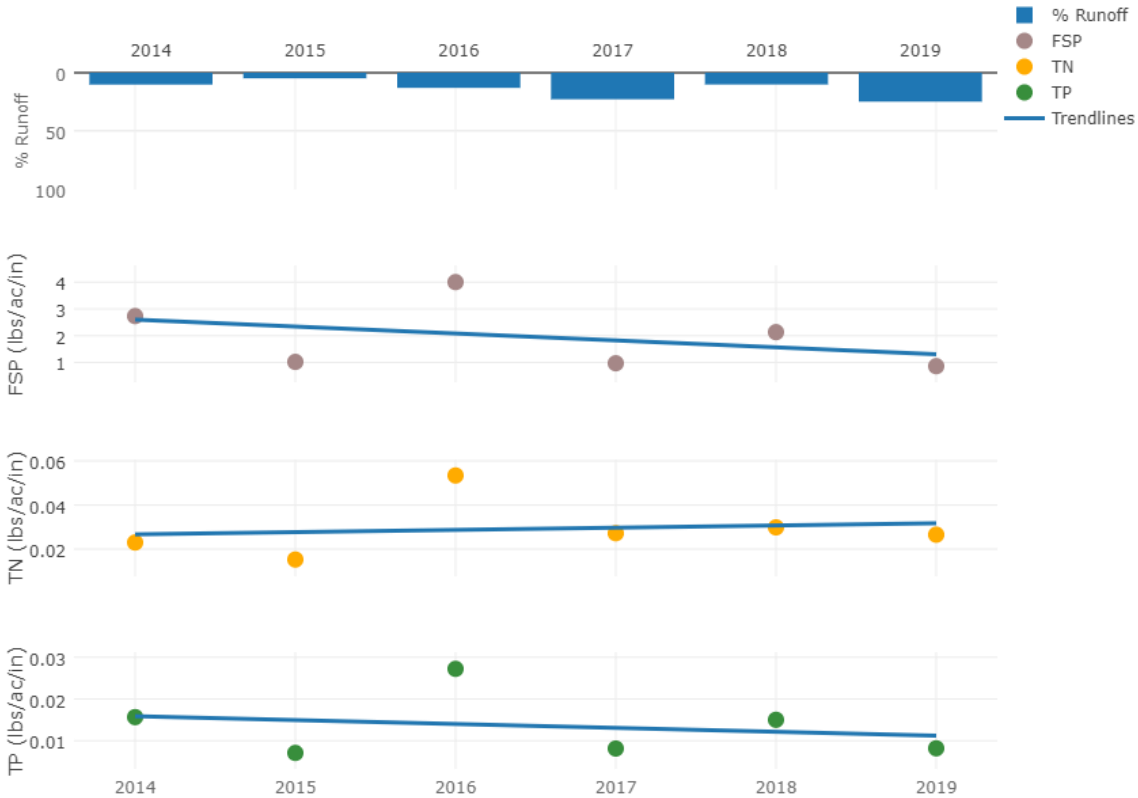

Figure 111 6-year rainfall normalized annual pollutant load trends in FSP, TN, and TP loads at Tahoma, WY14-19.

- Percent runoff varied between 4.8% in WY15 to 22.9% in WY17. Backwatered conditions in WY19 may have resulted in a falsely elevated percent runoff.
- There is no significant trend in average annual FSP loads as indicated by a Tau value close to 0 and p-value greater than 0.05.
- There is no significant trend in average annual TN loads as indicated by a Tau value close to 0 and p-value greater than 0.05.
- There is no significant trend in average annual TP loads as indicated by a Tau value close to 0 and p-value greater than 0.05.

Table 25 6-year seasonal and annual rainfall normalized pollutant loads at Tahoma, WY14-19. Percent runoff in 2019 highlighted in pink may be artificially high due to runoff volume errors associated with backwatering.

		FSP (lbs/acre/inch)				TN (lbs/acre/inch)				TP (lbs/acre/inch)			
Year	% Runoff	Fall/ Winter	Spring	Summer	Annual	Fall/ Winter	Spring	Summer	Annual	Fall/ Winter	Spring	Summer	Annual
2014	10.2%	1.482	7.679	4.643	2.733	0.011	0.061	0.044	0.023	0.007	0.044	0.031	0.016
2015	4.8%	0.971	0.567	1.858	1.020	0.006	0.009	0.067	0.015	0.006	0.003	0.015	0.007
2016	13.1%	4.410	2.797	9.639	4.002	0.036	0.016	0.634	0.053	0.028	0.010	0.181	0.027
2017	22.9%	0.987	1.105	0.000	0.969	0.026	0.040	0.000	0.027	0.008	0.010	0.000	0.008
2018	10.1%	0.220	4.032	0.000	2.132	0.020	0.041	0.000	0.030	0.004	0.027	0.000	0.015
2019	24.9%	0.296	2.687	0.250	0.861	0.016	0.062	0.015	0.027	0.005	0.019	0.000	0.008
Tau	na	-0.467	-0.067	-0.333	-0.467	0.067	0.467	0.000	0.200	-0.333	0.200	-0.333	-0.067
P-Value	na	0.188	0.851	0.497	0.188	0.851	0.188	1.000	0.573	0.348	0.573	0.497	0.851
Theil Slope (per year)	na	-0.250	-0.036	-0.640	-0.150	0.001	0.011	0.009	0.001	-0.001	0.003	-0.005	0.000

Figure 112 through Figure 115 show sediment and nutrient loads for Tahoma compared to total annual precipitation for WY14 through WY19. This illustrates how loading and precipitation have varied over the monitored period.

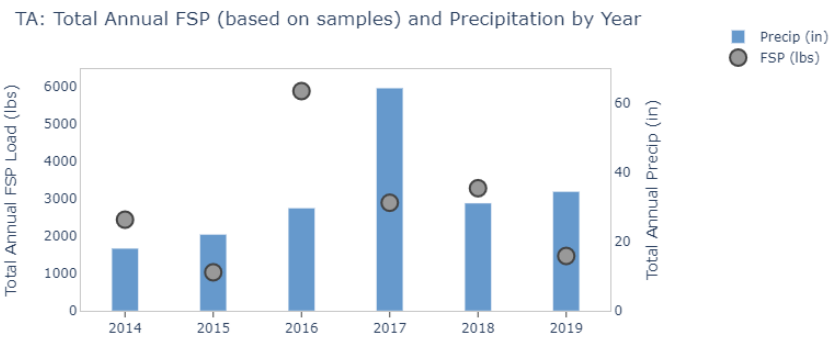

Figure 112 Total annual FSP load (based on samples) and precipitation by year for Tahoma WY14-WY19.

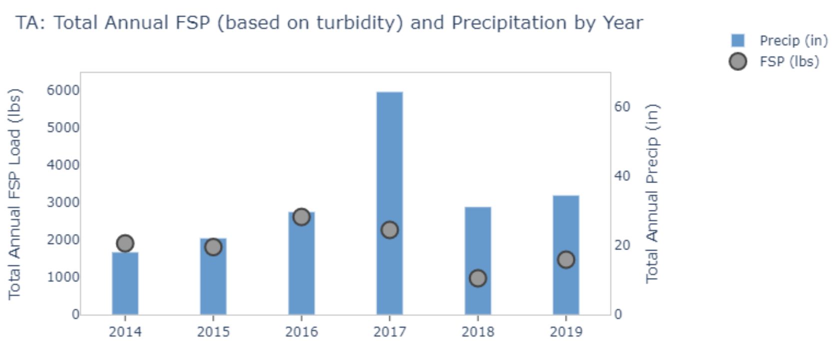

Figure 113 Total annual FSP load (based on continuous turbidity) and precipitation by year for Tahoma WY14-WY19.

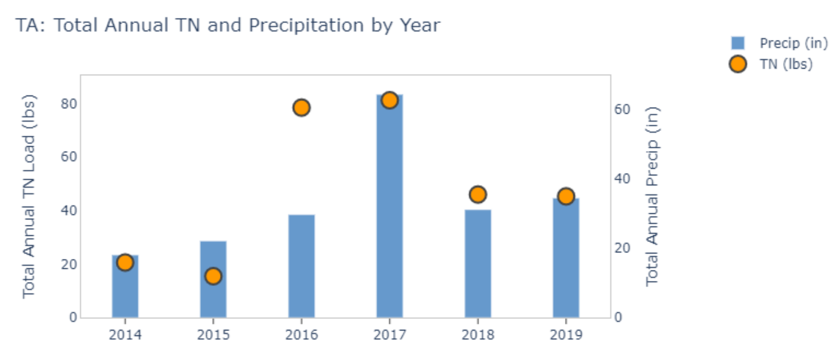

Figure 114 Total annual TN load and precipitation by year for Tahoma WY14-WY19.

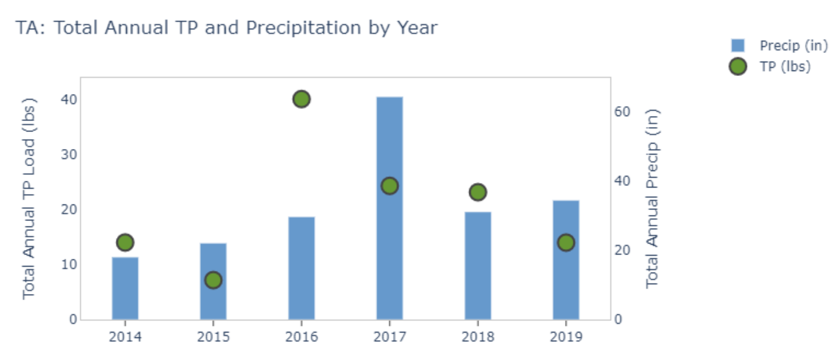

Figure 115 Total annual TP load and precipitation by year for Tahoma WY14-WY19.

8.9 Upper Truckee

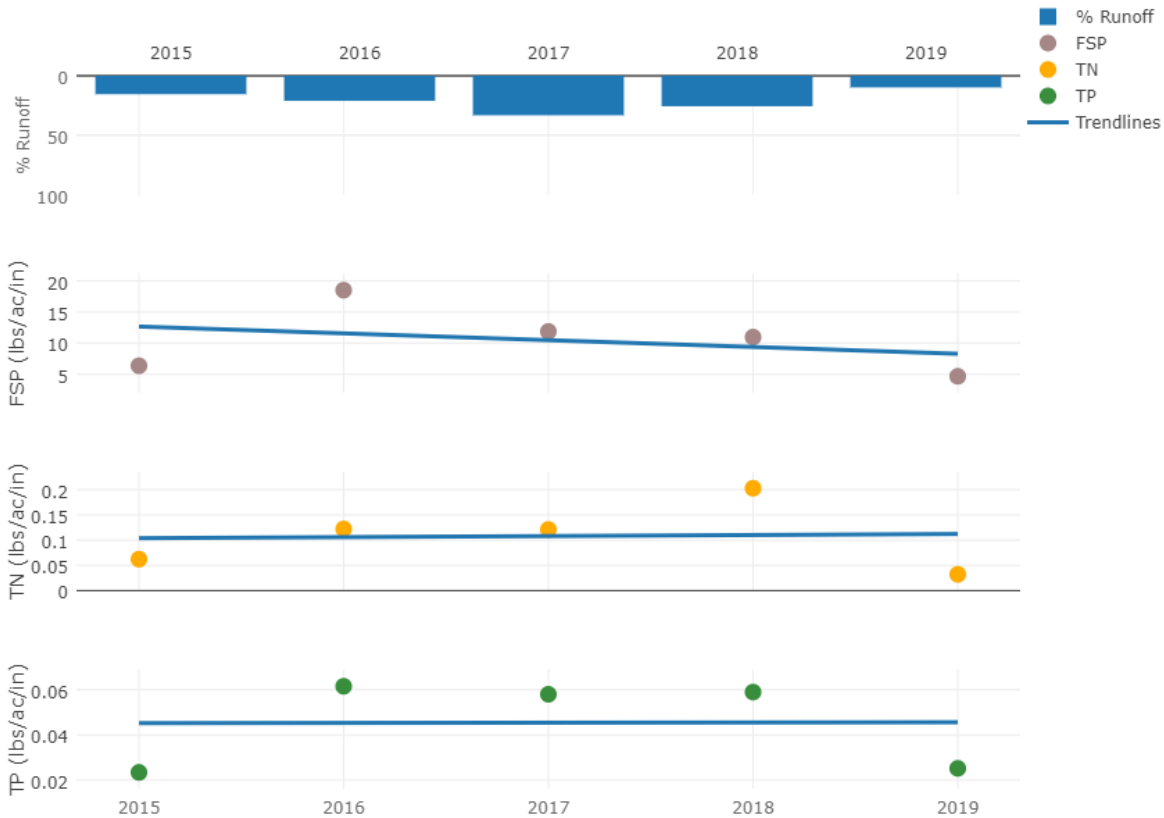

Figure 116 5-year rainfall normalized annual pollutant load trends in FSP, TN, and TP loads at Upper Truckee, WY15-19.

- Percent runoff varied between 9.8% in WY19 to 33.3% in WY17.
- There is no significant trend in average annual FSP loads as indicated by a Tau value close to 0 and p-value greater than 0.05.
- There is no significant trend in average annual TN loads as indicated by a Tau value close to 0 and p-value greater than 0.05.
- There is no significant trend in average annual TP loads as indicated by a Tau value close to 0 and p-value greater than 0.05.

Table 26 5-year seasonal and annual rainfall normalized pollutant loads at Upper Truckee, WY15-19.

		FSP (lbs/acre/inch)				TN (lbs/acre/inch)				TP (lbs/acre/inch)			
Year	% Runoff	Fall/ Winter	Spring	Summer	Annual	Fall/ Winter	Spring	Summer	Annual	Fall/ Winter	Spring	Summer	Annual
2015	15.5%	6.297	11.878	0.000	6.367	0.049	0.151	0.000	0.062	0.022	0.047	0.000	0.023
2016	21.1%	14.220	28.052	0.000	18.498	0.121	0.128	0.000	0.122	0.053	0.081	0.000	0.061
2017	33.3%	8.219	502.504	6.832	11.869	0.069	5.003	0.579	0.121	0.040	2.253	0.143	0.058
2018	25.6%	7.244	15.326	0.000	10.956	0.350	0.100	0.000	0.203	0.048	0.075	0.000	0.059
2019	9.8%	4.188	6.599	0.000	4.673	0.027	0.053	0.000	0.032	0.022	0.037	0.000	0.025
Tau	na	-0.400	-0.200	na	-0.400	0.000	-0.600	na	0.000	0.000	-0.200	na	0.000
P-Value	na	0.327	0.624	na	0.327	1.000	0.142	na	1.000	1.000	0.624	na	1.000
Theil Slope (per year)	na	-1.495	-3.841	na	-2.255	0.002	-0.024	na	0.014	-0.001	-0.003	na	0.000

Figure 117 through Figure 120 show sediment and nutrient loads for Upper Truckee compared to total annual precipitation for WY15 through WY19. This illustrates how loading and precipitation have varied over the monitored period.

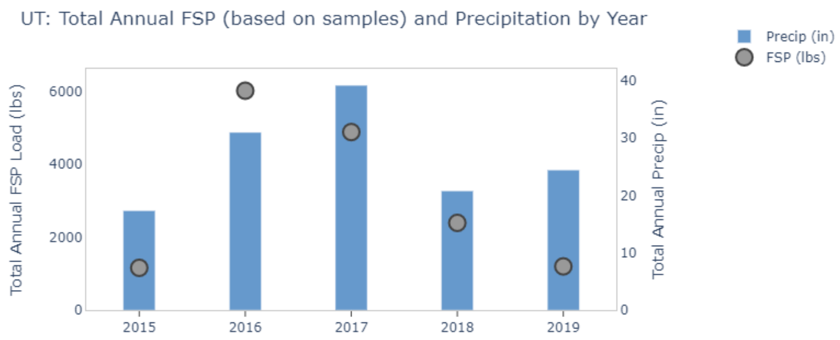

Figure 117 Total annual FSP load (based on samples) and precipitation by year for Upper Truckee WY15-WY19.

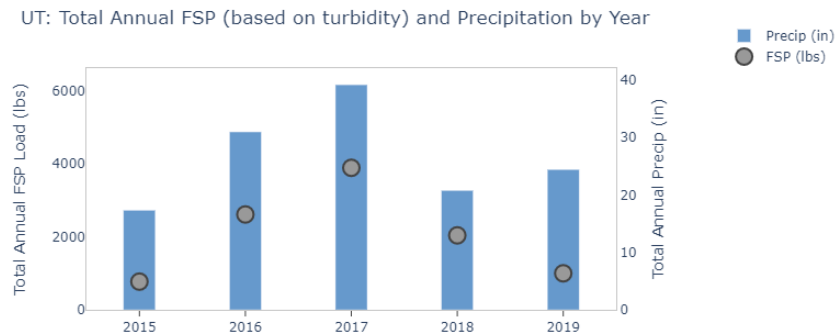

Figure 118 Total annual FSP load (based on continuous turbidity) and precipitation by year for Upper Truckee WY15-WY19.

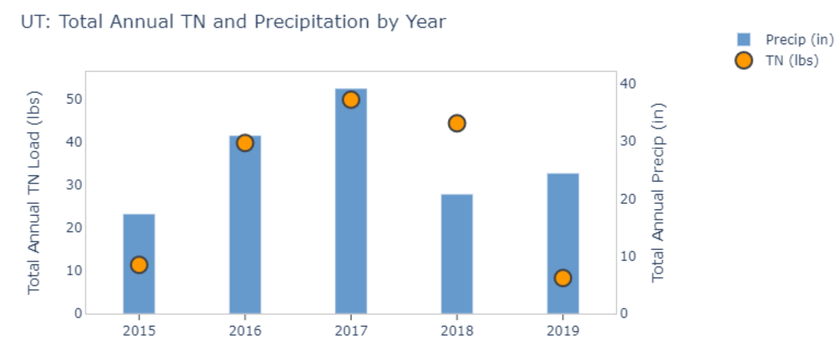

Figure 119 Total annual TN load and precipitation by year for Upper Truckee WY15-WY19.

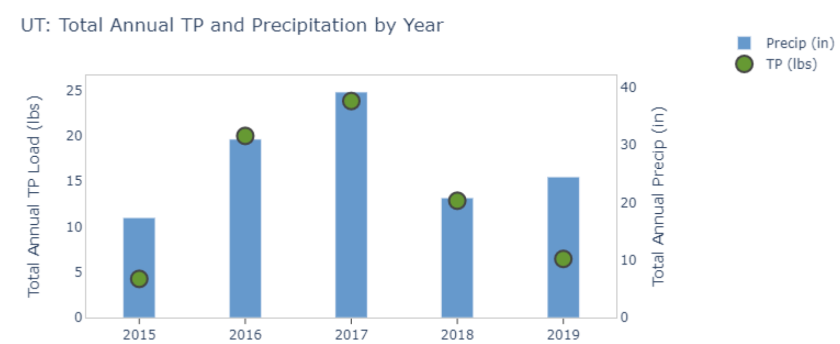

Figure 120 Total annual TP load and precipitation by year for Upper Truckee WY15-WY19.

9. PLRM Modeling Results

Tahoe RCD compared average annual runoff volumes and pollutant loads predicted by PLRMv2.1 to annual volumes and pollutant loads measured in WY19 at all sites; results are presented in Table 27. In reviewing model performance, **it is important to highlight that PLRM represents average annual conditions based on an 18-year meteorological average, and each water year is unique. Therefore, differences between PLRM estimates and measured values are expected.**

WY19 was a very wet precipitation year for the Tahoe basin therefore field measured runoff volumes, and FSP, TN, and TP loads are expected to be greater than modeled values. The PLRM estimated runoff volumes were generally within a similar range as the measured runoff volumes. All of the modeled FSP loads were higher than the measured values, with the exception of Jellyfish Inflow (based on FSP from samples) and Speedboat (based on FSP from turbidity). Almost all modeled TN loads (with the exception of Speedboat) were higher than the measured values. For TP, Contech Inflow, Jellyfish Inflow, and Speedboat modeled loads were lower than measured values, and modeled loads were higher than measured values for all of the other sites. Models in registered catchments (Lakeshore and Pasadena) were sourced from Washoe County (through the Nevada Tahoe Conservation District) and the City of South Lake Tahoe respectively and include all current BMPs and improved road operations. Models in unregistered catchments assume baseline conditions from 2004, with the exception of Elks Club Drive which uses the median Road RAM measurement from WY19.

PLRM is the standard basin-wide model for pollutant load reduction estimates for the Lake Tahoe TMDL. All seven jurisdictions in two states are required to use the same modeling tool for estimating pollutant loads, allowing for comparisons of pollutant load reductions to be made across jurisdictions.

It is unrealistic to expect the model to perform perfectly; however, PLRM estimates relative conditions. For example, Tahoe Valley has the greatest annual runoff volume of all sites, which was predicted by PLRM. PLRM assumes that roads and commercial properties tend to be the highest polluting land uses, while multi-family residential and single family residential are less so, which conforms to our basic understanding of Tahoe stormwater pollutant sources.

Table 27 PLRM predicted and WY19 measured values for all monitored catchments. The first FSP column represents the FSP load calculated using event mean concentrations, while the second FSP column represents the FSP load estimated using continuous turbidity data. Registered catchments use models that include BMPs and improved road operations. Unregistered catchments use models based on baseline (2004) conditions.

Water Year 2019 Oct. 1, 2018 - Sept. 30, 2019		Annual Runoff Volumes (cf)		Annual FSP Loads (Based on Samples) (lbs)		Annual FSP Loads (Based on Turbidity) (lbs)		Annual TN Loads (lbs)		Annual TP Loads (lbs)	
Catchment Name	Registered?	PLRM	Measured	PLRM	Measured	PLRM	Measured	PLRM	Measured	PLRM	Measured
Elk's Club	no	187,308	387,197	2,469	400	2,469	84	35.0	21.6	9.0	1.8
Lakeshore	yes	357,192	79,202	2,885	44	2,885	51	56.0	2.9	14.0	0.6
Pasadena	yes	143,748	41,261	446	64	446	86	13.0	5.2	5.0	1.1
Speedboat	no	317,988	932,570	4,911	2,628	4,911	14,611	58.4	111.2	17.0	32.8
Tahoe Valley	no	5,449,356	4,646,487	53,305	4,371	53,305	1,903	764.0	174.6	196.0	30.0
Tahoma	no	666,468	1,543,946	10,801	1,470	10,801	1,470	127.0	45.3	37.0	14.0
Upper Truckee	no	352,836	91,370	5,039	1,199	5,039	1,000	67.0	8.3	18.0	6.5

10. Lessons Learned

Monitoring stations should be checked regularly, especially during runoff events, to identify any potential equipment malfunctions that may result in data gaps. There are a multitude of technical difficulties that can be encountered with stormwater monitoring, including equipment failure, freezing conditions, power failure, vandalism, and obstruction by sediment, snow, trash or other debris. Identifying and correcting these problems early results in a more accurate data set with fewer and shorter data gaps. Beginning WY17 all monitoring and weather stations are remotely accessible. This enables access to the stations and their status during all weather conditions and any time of day or night and allows for problems to be detected and remedied earlier than was previously possible when site visits were required to know station status. Additionally, alarms are set to send email alerts when certain parameters reach a pre-determined threshold.

The biggest cause of data gaps is power failure. Although all stations are equipped with solar panels to recharge batteries, some stations do not have enough sun exposure to keep batteries continuously charged (especially during winter), and during periods of extended cloud cover or snow blockage and subsequent decrease in solar recharge, all stations are subject to power failure. Checking battery voltage remotely on a regular basis and having alerts sent when charge drops below a voltage threshold has alleviated this problem but batteries must be continuously checked and changed.

When snow accumulation is frequent and excessive, it is very important to stay on top of site maintenance. Keeping the sites dug out and unfrozen is a continuous task, but necessary to maintain data integrity. The remote access system is very beneficial in identifying when the sites are frozen and in need of maintenance.

High lake levels following WY17 and WY19 caused intermittent backwatered conditions at Tahoma (Figure 121). Under backwatered conditions flow monitoring is not possible. On August 1, 2019 a replicate set of monitoring sensors were installed about 50 feet upstream of the original sensors at Tahoma. They are now available for use during backwatered conditions.

Field verifying data as a QAQC procedure is essential to ensure an accurate and reliable dataset. Tahoe RCD staff members regularly check stage and make note of precipitation type and totals during storms to ensure equipment is functioning properly. The greater the level of QAQC during precipitation events, the higher the level of certainty the dataset is representative. The importance of detailed field notes and photographs cannot be understated. With passing time, the human memory lapses, while field notes and photographs can be referred to years and even decades after a monitoring event to explain what happened throughout the monitoring period.

Short duration, high intensity thunderstorms can be particularly difficult to sample, as the sometimes unpredictably large flow volumes can quickly fill all 24 sample bottles in the autosampler if the flow pacing is set too low. The result is that a portion of the end of the runoff hydrograph is not sampled. Due to the short nature of these events, it is incredibly difficult for staff to reach sites before runoff has ended to replace the full bottles with empty ones. Summer thunderstorms also tend to be very episodic in nature, and not all sites receive runoff over the summer period. As a result, several requisite summer events can easily be missed or do not produce enough runoff to sample.

Storm events not captured in a particular season due to insufficient runoff can be substituted by a different storm in the next season to meet permit and agreement requirements of one storm event per season as approved by the Lahontan Regional Water Quality Control Board (Lahontan). **All efforts are made to successfully sample several events during each season so that average seasonal pollutant concentrations and loads can be calculated. However, annual precipitation patterns are highly variable, and in some years, there is insufficient runoff for sampling in any given season. Approval of the**

annual permit/ILA monitoring requirement should not be withheld for this reason. Fortunately, estimated FSP concentrations and loads can be calculated from the continuous turbidity data, so these values should never be missing from any season unless there is no runoff at all.

Figure 121 Backwatered conditions at the Tahoma catchment outfall due to high lake levels, July 17, 2019. Lake water extends into the flume.

Monitoring equipment at SR431 is located under the pavement in a wide pull-out and accessed through two hatches, one for the inflow locations and one for the outflow locations. Often, the hatches are located under many feet of hard icy snow that has been plowed off SR431 and stored in the pull-out making access impossible (Figure 122). NDOT maintenance crews must be called before sample collection to remove the snow with heavy equipment ahead of time.

Figure 122 Snow berms covering access to monitoring equipment at SR431, April 1, 2019.

11. Changes: Accepted and Proposed

Changes Accepted

A new NPDES permit was issued to California jurisdictions in 2017. The new permit aligned all monitoring activities with the Regional Stormwater Monitoring Program (RSWMP) Framework and Implementation Guidance Document (Tahoe RCD et al 2015), most notably that six (rather than four) catchment outfalls and two (rather than three) BMPs must be monitored. Additionally, the first flush sampling requirement was dropped as sample analysis costs are high and continuous turbidimeter readings can replace this information. The Nevada Inter-local Agreements (ILAs) were issued in 2016 and require participation in IMP.

In the spring of WY17 Tahoe RCD proposed a new BMP monitoring site. The new location was approved by IMP, Lahontan, NDEP and monitoring equipment was removed from the Pasadena Inflow and installed at Elks Club Drive as described in section 2.2. Monitoring at Elks Club began in WY18. Elks Club Drive will be considered a BMP site as resurfacing the road with a polymer enhanced asphalt mixture should be considered a best management practice for reducing FSP in stormwater runoff since it will be easier to sweep and less prone to degradation from chains, heavy equipment, plow blades, and the freeze/thaw cycle.

In the winter of WY19 the California Department of Transportation (Caltrans) joined IMP. A new site capturing only stormwater runoff from state route 89 in Tahoe City was installed in August of 2019. Monitoring of this site began October 1, 2019 at the commencement of water year 2020.

Changes Proposed

Because annual precipitation during all seasons is highly variable, and summer thunderstorms in particular tend to be very episodic in nature, not all sites receive sufficient runoff to sample the requisite number of events in every season, especially in the summer. **It may be advisable to amend permit and agreement language to acknowledge that all efforts are made to successfully sample several events during each season so that average seasonal pollutant concentrations and loads can be calculated. However, this is not always possible, and approval of the annual permit/ILA monitoring requirement should not be withheld for this reason.**

References

2NDNATURE, Desert Research Institute. 2014. Surrogate Indicators to Monitor Fine Sediment Particles in the Lake Tahoe Basin. March 2014.

California Regional Water Quality Control Board, Lahontan Region and Nevada Division of Environmental Protection. 2010. Final Total Maximum Daily Load Report. November 2010.

Desert Research Institute Division of Hydrologic Sciences and Tahoe Resource Conservation District. 2015. Performance Evaluation of Two Stormwater Filtration Treatment Devices Installed by the Nevada Department of Transportation. Prepared for the Nevada Department of Transportation and the Nevada Division of Environmental Protection. December 2015.

Desert Research Institute Division of Hydrologic Sciences and University of California, Davis, Tahoe Environmental Research Center. 2011a. Tahoe Regional Storm Water Monitoring Program Quality Assurance Project Plan, (RSWMP QAPP). May 10, 2011.

Desert Research Institute Division of Hydrologic Sciences and University of California, Davis, Tahoe Environmental Research Center. 2011b. Tahoe Regional Storm Water Monitoring Program Sampling and Analysis Plan, (RSWMP SAP). May 10, 2011.

Northwest Hydraulic Consultants, Inc. 2017. PLRM Stormwater Treatment BMP Data Evaluation Project. Prepared for the Nevada Division of Environmental Protection. September 2017.

Tahoe Resource Conservation District (Tahoe RCD). 2013. Implementers' Monitoring Plan, Implementers' Monitoring Program (IMP), Component of the Regional Storm Water Monitoring Program (RSWMP), Tahoe Resource Conservation District, Submitted to the Lahontan Regional Water Quality Control Board and the Nevada Division of Environmental Protection, April 30, 2013.

Tahoe RCD, 2NDNATURE, Desert Research Institute, Northwest Hydraulic Consultants. 2017. RSWMP Framework and Implementation Guidance Document 2017 Update. Submitted the California State Water Board. October 31, 2017.

Appendix A: Raw Analytical Data

Table A.1-Table A.9 present all available raw analytical data for autosampler composite (AC) samples. Other than QAQC samples, only AC samples were analyzed in WY19 except for one single sample at Lakeshore (LS-AS) on September 16,2019 due to low flow. Raw analytic data shows turbidity; TSS, FSP, TN, and TP concentrations; and particle size distribution.

Table A.1 Raw analytical data for samples taken at the inflow and outflow of the SR431 Contech MFS in WY19.

Sample	Sample Start (Date/Time)	Total TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5	%< 1	%< 2	%< 4	%< 8	%< 16	%< 20	%< 63	%< 125	%< 250	%< 500	%< 1000	%< 2000
CI-AC	10/3/2018 10:14	179	84	70	5,150	562	0.37	3.26	8.25	15.6	26.1	38.8	44.7	65.2	77.2	87.4	92.9	100	100
CI-AC	11/23/2018 10:17	262	270	190	1,850	438	0.53	5.79	17.3	32.7	52.3	72.4	77.8	92.9	98.3	100	100	100	100
CI-AC	2/2/2019 0:43	1,120	2,854	1,001	3,970	6,020	0.74	8.09	24.3	45.2	69.6	89.4	94.3	99.8	100	100	100	100	100
CI-AC	2/14/2019 0:15	381	301	196	1,000	1,170	0.32	3.22	8.61	16.3	30.4	51.3	59.0	91.5	97.8	100	100	100	100
CI-AC	5/15/2019 9:47	1,498	761	791	3,820	4,807	0.28	2.85	7.69	15.1	29.9	52.8	61.0	91.7	96.9	99.9	100	100	100
CI-AC	5/21/2019 8:18	992	872	646	2,010	3,670	0.34	3.60	10.5	21.6	40.6	65.1	73.3	98.1	99.5	100	100	100	100
CI-AC	5/26/2019 1:50	1,056	651	671	1,970	3,368	0.35	3.77	11.1	22.3	40.7	63.5	71.0	95.0	99.3	100	100	100	100
CI-AC	9/16/2019 11:18	222	92	100	2,660	818	0.19	2.07	6.24	13.0	25.5	45.2	51.6	76.7	89.7	94.7	97.2	100	100
CO-AC	10/3/2018 12:05	78	66	54	5,940	446	0.48	4.97	14.0	27.7	46.7	69.0	76.4	92.6	97.2	100	100	100	100
CO-AC	11/23/2018 10:37	138	175	95	1,380	601	0.80	8.04	20.9	34.6	50.7	68.9	74.9	93.5	99.1	100	100	100	100
CO-AC	2/2/2019 1:10	805	1,599	782	3,300	3,844	1.01	10.9	31.7	56.0	79.5	97.1	99.6	100	100	100	100	100	100
CO-AC	2/14/2019 0:02	306	274	170	1,050	1,145	0.34	3.51	9.59	18.4	33.9	55.6	63.3	93.4	98.2	100	100	100	100
CO-AC	5/15/2019 23:22	382	246	225	2,070	1,479	0.32	3.27	9.00	17.8	34.4	58.8	67.7	97.1	99.1	100	100	100	100
CO-AC	5/21/2019 8:18	668	666	411	1,540	2,753	0.33	3.55	10.4	21.0	38.6	61.5	69.2	95.0	99.4	100	100	100	100
CO-AC	5/26/2019 2:51	524	396	392	1,400	2,012	0.41	4.43	13.4	27.1	48.9	74.8	82.3	99.6	100	100	100	100	100
CO-AC	9/16/2019 11:28	340	170	197	3,430	1,265	0.28	3.04	9.05	18.4	34.8	57.9	65.1	86.3	93.9	97.2	99.0	100	100

Table A.2 Raw analytical data for samples taken at the inflow and outflow of the SR431 Jellyfish in WY19.

Sample	Sample Start (Date/Time)	Total TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5	%< 1	%< 2	%< 4	%< 8	%< 16	%< 20	%< 63	%< 125	%< 250	%< 500	%< 1000	%< 2000
JI-AC	10/3/2018 10:14	262	97	95	4,850	578	0.23	2.41	6.79	13.1	22.7	36.3	41.2	64.8	77.9	89.0	96.1	100	100
JI-AC	11/23/2018 10:17	270	249	194	2,720	607	0.46	5.02	15.2	30.1	50.8	72.0	77.7	94.1	99.2	100	100	100	100
JI-AC	2/2/2019 0:37	945	1,824	900	3,230	4,273	0.93	9.99	29.0	51.9	76.1	95.2	99.0	100	100	100	100	100	100
JI-AC	2/13/2019 20:23	381	301	196	1,000	1,170	0.32	3.22	8.61	16.3	30.4	51.3	59.0	91.5	97.8	100	100	100	100
JI-AC	5/15/2019 9:46	1,498	3,616	791	3,820	4,807	0.28	2.85	7.69	15.1	29.9	52.8	61.0	91.7	96.9	99.9	100	100	100
JI-AC	5/21/2019 8:18	1,210	1,249	807	2,360	4,831	0.35	3.75	11.2	23.2	43.2	66.7	74.0	95.6	99.4	100	100	100	100
JI-AC	5/26/2019 1:50	1,160	686	820	2,090	3,695	0.39	4.13	11.9	24.1	45.0	70.7	78.9	100	100	100	100	100	100
JI-AC	9/16/2019 11:18	216	90	104	2,970	806	0.21	2.30	6.89	14.4	28.0	48.2	54.6	79.0	92.7	98.5	100	100	100
JO-AC	10/3/2018 15:42	71	67	55	4,880	421	0.63	6.38	17.4	33.2	54.5	77.8	84.5	95.6	98.6	100	100	100	100
JO-AC	11/23/2018 10:21	187	203	131	2,620	413	0.49	5.33	15.7	30.1	49.3	69.9	75.9	95.1	99.4	100	100	100	100
JO-AC	2/2/2019 0:47	1,025	1,999	972	3,390	4,858	0.77	8.54	26.0	48.7	74.1	94.8	98.8	100	100	100	100	100	100
JO-AC	2/13/2019 20:32	327	255	189	1,020	1,139	0.36	3.66	9.92	18.8	34.9	57.7	65.6	94.9	98.6	100	100	100	100
JO-AC	5/15/2019 9:51	272	213	156	2,300	1,233	0.30	3.11	8.60	17.2	33.5	57.5	66.3	96.5	98.8	100	100	100	100
JO-AC	5/21/2019 8:20	660	687	442	1,730	3,067	0.36	3.82	11.2	22.9	42.6	66.9	74.3	95.0	99.4	100	100	100	100
JO-AC	5/26/2019 1:57	428	375	319	1,290	1,736	0.42	4.49	13.3	27.0	49.1	74.5	82.0	99.3	99.9	100	100	100	100
JO-AC	9/16/2019 11:20	110	64	67	3,790	541	0.31	3.19	9.00	18.4	36.1	61.1	68.3	85.9	94.6	97.9	99.4	100	100

Table A.3 Raw analytical data for samples taken at Elks Club in WY19.

Sample	Sample Start (Date/Time)	Total TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5	%< 1	%< 2	%< 4	%< 8	%< 16	%< 20	%< 63	%< 125	%< 250	%< 500	%< 1000	%< 2000
EC-AC	10/3/2018 11:16	140	138	98	4,680	1,032	0.50	5.21	14.6	28.3	48.0	69.8	76.0	93.3	97.6	99.8	100	100	100
EC-AC	11/23/2018 14:06	18	14	5	510	106	0.16	1.55	3.74	6.80	13.9	29.9	36.8	74.2	89.1	97.2	99.1	100	100
EC-AC	11/27/2018 16:55	32	32	4	730	128	0.07	0.73	1.91	3.68	7.03	13.4	16.2	31.8	38.7	47.7	75.4	98.3	100
EC-AC	1/16/2019 18:36	13	17	1	310	117	0.09	0.73	1.49	2.42	3.62	4.54	4.77	4.81	5.95	14.0	45.8	88.6	100
EC-AC	2/2/2019 2:41	35	38	9	1,030	125	0.14	1.38	3.70	6.95	12.9	26.5	33.6	79.2	94.6	100	100	100	100
EC-AC	3/5/2019 10:16	11	17	8	270	73	1.36	12.9	30.9	46.9	65.2	74.7	77.4	84.1	89.5	99.1	100	100	100
EC-AC	3/27/2019 4:38	57	35	19	400	132	0.19	1.90	5.20	10.0	18.1	33.5	40.5	77.4	94.0	100	100	100	100
EC-AC	3/29/2019 7:23	12	3	2	210	34	0.05	0.48	1.33	2.59	7.35	18.6	23.1	62.4	85.3	96.7	100	100	100
EC-AC	4/1/2019 18:10	29	18	18	320	88	0.34	3.61	10.3	20.2	36.9	61.2	68.5	91.0	96.6	99.7	100	100	100
EC-AC	5/16/2019 19:10	10	6	2	190	18	0.03	0.33	1.06	2.86	8.65	23.4	30.8	73.5	90.2	97.5	98.8	100	100
EC-AC	5/26/2019 2:25	10	6	3	200	29	0.12	1.25	3.66	7.82	17.1	31.2	37.3	67.2	85.9	95.2	98.9	100	100
EC-AC	6/19/2019 7:51	130	61	12	na	na	0.01	0.09	0.32	0.81	2.79	9.57	13.3	39.3	60.8	85.1	94.8	98.8	100
EC-AC	9/16/2019 12:26	100	95	63	4,870	59	0.49	4.80	12.8	25.4	43.6	62.7	68.7	89.9	97.6	99.8	100	100	100

Table A.4 Raw analytical data for samples taken at Lakeshore in WY19.

Sample	Sample Start (Date/Time)	Total TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5	%< 1	%< 2	%< 4	%< 8	%< 16	%< 20	%< 63	%< 125	%< 250	%< 500	%< 1000	%< 2000
LS-AC	12/24/2018 16:55	74	48	24	910	378	0.21	2.08	5.49	10.2	18.3	32.5	38.8	76.6	91.6	98.7	99.0	100	100
LS-AC	1/16/2019 18:58	57	57	31	1,030	268	0.29	3.01	8.58	17.4	32.6	54.8	62.4	90.1	95.7	97.7	99.0	100	100
LS-AC	1/20/2019 12:38	93	100	57	680	412	0.35	3.68	10.5	21.2	39.0	61.4	68.7	93.7	98.4	100	100	100	100
LS-AC	2/13/2019 17:03	28	17	8	570	110	0.10	0.98	2.67	5.54	12.3	28.6	36.5	77.9	91.0	98.9	99.4	100	100
LS-AC	4/1/2019 19:41	27	16	10	450	99	0.13	1.33	3.62	7.37	16.0	35.2	43.9	87.2	97.9	100	100	100	100
LS-AC	4/7/2019 15:15	11	11	8	350	87	0.52	5.01	13.0	25.4	46.8	74.6	83.0	100	100	100	100	100	100
LS-AC	4/8/2019 22:21	12	11	8	410	83	0.43	4.39	12.1	23.5	42.6	67.0	75.3	95.2	98.9	99.9	100	100	100
LS-AS	9/16/2019 12:28	188	132	115	5,840	71	0.40	3.82	10.40	21.3	40.0	61.4	67.5	84.4	93.2	97.7	100	100	100

Table A.5 Raw analytical data for samples taken at Pasadena in WY19.

Sample	Sample Start (Date/Time)	Total TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5	%< 1	%< 2	%< 4	%< 8	%< 16	%< 20	%< 63	%< 125	%< 250	%< 500	%< 1000	%< 2000
PO-AC	10/3/2018 12:30	124	107	64	9,390	1,691	0.32	3.22	8.69	17.8	33.0	51.5	57.5	81.4	95.2	99.3	100	100	100
PO-AC	11/23/2018 11:10	51	36	13	1,070	383	0.13	1.29	3.62	7.45	14.1	26.5	32.4	71.5	90.4	99.9	100	100	100
PO-AC	1/16/2019 19:33	51	49	32	1,490	312	0.41	4.18	11.6	22.6	40.1	63.0	70.2	90.8	97.3	99.7	100	100	100
PO-AC	2/13/2019 14:03	42	40	16	760	148	0.17	1.82	5.37	11.3	21.8	38.1	44.0	72.3	88.2	95.7	97.1	100	100
PO-AC	4/2/2019 4:58	7	55	5	980	254	0.41	4.28	12.3	24.6	43.2	65.9	72.6	91.7	97.6	100	100	100	100
PO-AC	9/16/2019 13:03	122	100	89	11,350	108	0.38	4.21	13.1	26.5	46.6	72.6	80.4	98.7	100	100	100	100	100

Table A.6 Raw analytical data for samples taken at Speedboat, WY19.

Sample	Sample Start (Date/Time)	Total TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5	%< 1	%< 2	%< 4	%< 8	%< 16	%< 20	%< 63	%< 125	%< 250	%< 500	%< 1000	%< 2000
SB-AC	10/3/2018 13:23	91	55	35	7,290	1,324	0.33	3.24	8.41	15.1	24.6	38.3	43.7	70.6	87.6	96.3	98.7	100	100
SB-AC	11/21/2018 20:00	56	38	12	1,000	390	0.13	1.33	3.38	6.04	10.9	22.4	28.5	71.5	91.0	100	100	100	100
SB-AC	11/27/2018 13:58	25	19	7	710	179	0.18	1.79	4.69	8.46	14.8	28.3	34.9	75.9	92.1	99.9	100	100	100
SB-AC	1/8/2019 12:40	10	58	4	360	294	0.40	3.76	9.15	15.2	24.4	40.5	46.9	68.6	73.8	76.9	86.9	98.2	100
SB-AC	3/5/2019 13:20	116	115	98	880	566	0.69	7.35	21.2	39.7	62.7	84.4	89.5	96.9	99.0	100	100	100	100
SB-AC	3/29/2019 7:23	26	18	9	410	117	0.14	1.41	3.92	8.07	16.7	35.1	43.3	82.7	96.2	100	100	100	100
SB-AC	5/16/2019 0:26	196	104	99	2,000	880	0.27	2.84	8.01	15.9	29.7	50.5	57.9	87.7	95.6	99.3	100	100	100
SB-AC	6/2/2019 16:45	1,628	694	783	5,060	4,172	0.26	2.55	6.64	12.9	26.2	48.1	56.3	88.5	95.4	100	100	100	100
SB-AC	9/16/2019 11:50	322	158	169	7,570	96	0.34	3.51	9.87	19.3	33.7	52.4	58.7	90.6	100	100	100	100	100

Table A.7 Raw analytical data for samples taken at Tahoe Valley, WY19.

Sample	Sample Start (Date/Time)	Total TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5	%< 1	%< 2	%< 4	%< 8	%< 16	%< 20	%< 63	%< 125	%< 250	%< 500	%< 1000	%< 2000
TV-AC	11/23/2018 12:43	30	25	8	580	165	0.18	1.72	4.37	7.8	13.9	26.4	32.6	71.1	87.4	97.7	99.2	100	100
TV-AC	1/16/2019 16:23	40	43	30	740	205	0.63	6.40	17.2	31.5	51.5	75.0	81.7	94.9	97.9	99.9	100	100	100
TV-AC	2/13/2019 6:23	29	29	7	1,160	98	0.12	1.22	3.15	6.0	11.9	25.2	31.8	75.5	93.9	99.3	99.4	100	100
TV-AC	3/5/2019 15:11	37	44	32	470	161	1.32	12.5	29.3	46.8	67.5	86.4	89.4	95.7	98.2	100	100	100	100
TV-AC	3/29/2019 7:33	16	7	4	460	39	0.08	0.82	2.11	4.2	10.3	27.0	35.7	78.0	91.3	97.6	99.3	100	100
TV-AC	5/15/2019 23:10	27	16	8	560	128	0.09	0.85	2.23	4.6	11.5	27.9	35.2	73.9	90.2	99.5	100	100	100
TV-AC	9/16/2019 11:33	350	240	174	8,730	116	0.31	3.25	9.69	20.2	35.1	49.7	54.1	73.1	88.1	96.2	99.3	100	100

Table A.8 Raw analytical data for samples taken at Tahoma, WY19.

Sample	Sample Start (Date/Time)	Total TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5	%< 1	%< 2	%< 4	%< 8	%< 16	%< 20	%< 63	%< 125	%< 250	%< 500	%< 1000	%< 2000
TA-AC	10/3/2018 11:30	180	75	65	6,840	1,467	0.23	2.27	6.00	11.8	21.7	35.9	41.3	68.0	80.6	91.8	97.5	100	100
TA-AC	11/23/2018 10:28	37	20	6	620	275	0.08	0.83	2.36	4.6	8.5	17.2	21.9	56.6	79.1	96.1	98.5	100	100
TA-AC	11/27/2018 13:18	31	24	8	550	165	0.15	1.51	4.04	7.6	13.9	26.9	33.4	74.2	91.2	100	100	100	100
TA-AC	1/20/2019 11:11	211	161	109	900	735	0.32	3.30	8.98	17.2	31.7	51.7	58.7	87.2	96.3	100	100	100	100
TA-AC	3/6/2019 10:18	34	23	21	300	123	0.44	4.54	12.3	22.8	39.3	62.7	69.7	89.6	96.2	100	100	100	100
TA-AC	3/30/2019 10:20	26	9	4	300	58	0.09	0.91	2.34	4.1	7.5	15.4	19.4	46.4	63.4	77.4	85.7	100	100
TA-AC	9/16/2019 11:03	512	238	170	9,850	134	0.16	1.62	4.53	9.2	18.3	33.1	38.7	71.3	87.1	96.5	98.4	100	100

Table A.9 Raw analytical data for samples taken at Upper Truckee, WY19.

Sample	Sample Start (Date/Time)	Total TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5	%< 1	%< 2	%< 4	%< 8	%< 16	%< 20	%< 63	%< 125	%< 250	%< 500	%< 1000	%< 2000
UT-AC	11/23/2018 11:46	42	11	14	940	226	0.21	2.13	5.88	11.2	18.6	32.8	39.9	80.8	94.7	100	100	100	100
UT-AC	1/16/2019 14:21	123	165	123	1,320	572	1.35	14.1	39.6	68.1	90.7	100	100	100	100	100	100	100	100
UT-AC	2/13/2019 6:56	451	600	289	1,550	1,539	0.44	4.65	13.4	25.7	44.4	64.0	70.0	92.3	98.3	100	100	100	100
UT-AC	3/5/2019 13:45	273	335	264	1,370	1,300	1.00	10.8	31.3	55.6	80.5	96.8	99.3	100	100	100	100	100	100
UT-AC	4/1/2019 21:36	188	216	122	1,750	872	0.43	4.56	13.3	25.9	44.0	64.9	71.3	92.7	97.1	99.0	99.5	100	100
UT-AC	5/16/2019 2:30	63	55	36	940	263	0.31	3.13	8.46	16.5	31.4	56.8	66.2	94.7	99.3	100	100	100	100

Appendix B: Quality Assurance/Quality Control Summary

Field duplicates are samples collected at the same time and treated identically and are used to assess the reproducibility of collected data. This provides a measure of analytical precision and can be used for detecting problems in sample collection, handling, transport processing, and analysis. The actual procedures for collecting field duplicate samples depend on the sampling methods and protocols used. When automated sampling equipment is used, duplicates need to be collected manually either by: (a) triggering the sampler manually twice in quick succession (two MS samples) or (b) manually triggering a sample and then collecting a grab sample at the same time (one MS sample and one GS sample), (RSWMP SAP, 2011). Differences in paired samples greater than 20% indicate a problem. Field blanks (FB) are collected to identify sample contamination occurring during field collection, handling, transport, storage, and during laboratory handling and analysis. Field blanks are collected throughout the sampling season by pouring reagent-grade "blank" water into the autosampler bottles in the field and then exposing them to conditions equivalent to the standard sample bottles.

Table B.1 MS and GS sample data from WY19. No paired samples had a difference between them of greater than 20%.

Sample	Date Time	TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5 um	%< 1 um	%< 2 um	%< 4 um	%< 8 um	%< 16 um	%< 20 um	%< 63 um	%< 125 um	%< 250 um	%< 500 um	%< 1000 um	%< 2000 um
SB-GS	1/9/2019 15:55	114.6	149.00	65.3	820	591	0.45	4.56	11.8	20.6	34.1	57	65.9	96.9	99.952	100	100	100	100
SB-MS	1/9/2019 15:56	115.4	146.00	67.0	850	591	0.5	5.05	13	22.3	35.8	58.1	67	96.3	99.0816	100	100	100	100
TV-MS	1/17/19 11:14	11.5	15.20	4.3	390	108	0.24	2.26	5.45	9.7	18.7	37.8	46.2	84.4	95.5	98.6	99	100	100
TV-GS	1/17/19 11:15	13.0	15.90	4.7	400	108	0.27	2.34	5.25	9.3	17.8	36.1	44.9	83.2	92.8	94.9	98	100	100
UT-MS	2/14/19 9:41	134.0	165.00	73.3	900	553	0.33	3.51	10.10	20.3	36.5	54.7	60.8	87.4	96.0	100.0	100	100	100
UT-GS	2/14/19 9:42	144.0	173.00	84.4	930	541	0.37	3.98	11.70	23.0	40.0	58.6	64.4	87.8	96.5	100.0	100	100	100
PO-MS	2/14/19 10:03	64.0	35.20	28.3	720	145	0.20	2.12	6.33	13.7	26.4	44.2	50.2	77.2	93.2	99.5	100	100	100
PO-GS	2/14/19 10:04	65.0	39.20	28.1	680	142	0.20	2.13	6.19	13.2	25.5	43.3	49.7	77.7	92.7	99.1	100	100	100
LS-GS	4/2/2019 6:46	20.0	11.80	6.6	360	84	0.11	1.11	3.13	6.6	14.7	32.9	40.6	82.2	94.3	99.4	100	100	100
LS-MS	4/2/2019 6:47	21.0	11.10	7.6	370	84	0.12	1.26	3.47	7.1	16.2	36.3	44.7	86.8	96.6	100.0	100	100	100

Table B.2 Field blank sample data from all sites in WY19. No values were greater than the method detection limit indicating no contamination. All samples were too clear for PSD analysis.

Sample	Date Time	TSS (mg/L)	Turbidity (NTU)	FSP (mg/L)	TN (ug/L)	TP (ug/L)	%< 0.5 um	%< 1 um	%< 2 um	%< 4 um	%< 8 um	%< 16 um	%< 20 um	%< 63 um	%< 125 um	%< 250 um	%< 500 um	%< 1000 um	%< 2000 um
CI-FB	5/16/2019 14:15	<0.3	0.13	na	<35	<1	na	na	na	na	na	na	na	na	na	na	na	na	na
JI-FB	5/16/2019 14:00	<0.3	0.47	na	<35	<1	na	na	na	na	na	na	na	na	na	na	na	na	na
PO-FB	1/17/2019 9:35	<0.3	0.47	na	<35	3	na	na	na	na	na	na	na	na	na	na	na	na	na
SB-FB	3/6/2019 9:30	<0.3	0.06	na	<35	1	na	na	na	na	na	na	na	na	na	na	na	na	na
TV-FB	2/14/19 10:45	<0.3	0.09	na	<35	1	na	na	na	na	na	na	na	na	na	na	na	na	na