A COMMUNITY WATERSHED PARTNERSHIP

Final Watershed Strategy Report
Tahoma, California

Produced by:
The Tahoe Resource Conservation District

Submitted to:
The Environmental Protection Agency

March 2015

We Do Conservation!

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ACRONYM LIST

TMDL	Total Maximum Daily Load
BMP	Best Management Practice
Tahoe RCD	Tahoe Resource Conservation District
LID	Low Impact Development
CWP	Community Watershed Partnership
SNPLMA	Southern Nevada Public Lands Management Act
NRCS	Natural Resource Conservation Service
EPA	Environmental Protection Agency
CTC	California Tahoe Conservancy
USFS	United States Forest Service
TRPA	Tahoe Regional Planning Agency
Water Board	Lahontan Regional Water Quality Control Board
NPDES	National Pollutant Load Elimination Permit
PLRM	Pollutant Load Reduction Model
IMP	Implementers' Monitoring Program
TAC	Technical Advisory Committee
RSWMP	Regional Stormwater Monitoring Program
CICU	Commercial/Industrial/Communications/Utilities
EIP	Environmental Improvement Plan
ROW	Right of Way
GIS	Geographic Spatial Information
SEZ	Stream Environment Zone
FSP	Fine Sedimanet Particles
SFR	Single Family Residential
TN	Total Nitrogen
TP	Total Phosphorus
QA/QC	Quality Assurance and Quality Control
CFS	Cubic Feet Per Second

INTRODUCTION

Lake Tahoe is among the largest, deepest, and clearest lakes in the world. Its cobalt blue appearance, spectacular alpine setting, and remarkable water clarity is recognized worldwide. Recreational opportunities and scenic vistas have made Lake Tahoe a top national and international tourist destination. While visibility into the lake's depths is currently at 70 feet, it is listed as impaired because over thirty feet of clarity has been lost since the late 1960s. To address the impairment, the Lake Tahoe Total Maximum Daily Load (TMDL) program was adopted in 2011; it brought with it new regulatory requirements for state and local stormwater jurisdictions to reduce urban pollutant loads to Lake Tahoe.

Approved by the Environmental Protection Agency and the states of California and Nevada, the TMDL sets targets for a significant reduction of fine sediments, nitrogen, and phosphorus flowing to Lake Tahoe. Currently, stormwater jurisdictions are required to implement urban best management practices (BMPs) to decrease pollutant loading from urban runoff as part of their TMDL requirements. Through this process area-wide stormwater treatment has become a preferred strategy for effective TMDL implementation. Expected benefits include costs savings related to the economy of scale, and effective maintenance and tracking of pollutant loads.

In 2014, the Tahoe Resource Conservation District (Tahoe RCD) performed a technical analysis of the Tahoma watershed to help support TMDL adaptive management actions. This work was performed under a program called the Community Watershed Partnership. Through this program and the BMP retrofit program the Tahoe RCD has provided homeowners with free technical services related to residential BMP planning and implementation, and is now evaluating the use of LiDAR identified microbasins (small depressions on the landscape) to assist in the effort to implement Low Impact Development (LID) techniques within an area-wide stormwater system versus implementing residential BMPs on parcel by parcel basis.

PROJECT BACKGROUND

The Community Watershed Partnership (CWP) was developed through funding provided by the Southern Nevada Public Lands Management Act (SNPLMA), and sponsored by both the Natural Resources Conservation Service (NRCS) and the Environmental Protection Agency (EPA). The funding for this program is intended to identify and address natural resource concerns or needs at a watershed level, and is designed to engage a variety of stakeholders to help facilitate communication between landowners, the general public, and Basin managers in furthering TMDL implementation and the restoration of Lake Tahoe.

The CWP approach compliments the many environmental improvement projects implemented around the Lake Tahoe Basin by the California Tahoe Conservancy (CTC), U.S.D.A. Forest Service (USFS), the Counties of El Dorado and Placer, and the City of South Lake Tahoe (local stormwater jurisdictions). Improvements gained in water quality have largely resulted from urban capital improvement projects, as well as restoration work in stream environment zones. In addition to implementing large scale projects, there are opportunities for each private property owner to contribute to watershed restoration efforts by either implementing individual water quality BMPs on their parcel, or by partnering with stormwater jurisdictions on area-wide treatment. Ultimately, successful implementation of BMPs on both the public and private scale will move Lake Tahoe closer to attaining its clarity goals. How each neighborhood or urban center executes this process will be a focus for Basin managers for the next several decades.

In 2002, the Tahoe RCD, the Nevada Tahoe Conservation District (NTCD), NRCS, and the Tahoe Regional Planning Agency (TRPA) adopted a Memorandum of Understanding to establish a partnership that would provide technical support to homeowners, contractors and property managers in implementing water quality BMPs. Through grant funded incentive programs, the Tahoe RCD and its partners provided cost free property evaluations and BMP implementation plans for over fifteen years, however deadlines for Basin-wide compliance have come and gone since 2008. After more than a decade, only about three out of every ten private properties on the California side of the Tahoe Basin has achieved BMP compliance; the level of implementation in Tahoma is even lower at approximately 14 percent.

In addition, following the adoption of the TMDL in August 2011, the Lahontan Regional Water Quality Control Board (Water Board) approved a Municipal National Pollutant Discharge Elimination System (NPDES) permit requiring the California jurisdictions in the Lake Tahoe Basin to take measures to decrease pollutant loading from stormwater runoff in urbanized areas. Local California jurisdictions must implement pollutant controls to decrease fine sediment and nutrient inputs, and must monitor and evaluate select urban catchment outfalls and County owned BMPs for flow volumes and sediment and nutrient loads.

In order to assist with implementing TMDL objectives, in 2013 the Tahoe RCD developed a monitoring plan with three primary goals: (1) inform assumptions used to estimate runoff volumes and pollutant loads modeled with the Pollutant Load Reduction Model (PLRM) (2) assess nutrient and sediment loading at chosen catchments, (3) evaluate BMP effectiveness at chosen BMPs. Approved by both California and Nevada TMDL regulators in 2013, the Implementers' Monitoring Plan established a lake-wide partnership between the Tahoe RCD, El Dorado County, Placer County, the City of South Lake Tahoe, Caltrans, Douglas County, Washoe County, NTCD, and the Nevada Department of Transportation known as the Implementers' Monitoring Program (IMP).

PROJECT SCOPE

The Tahoma community was identified as a priority watershed for development of a community-based Watershed Strategy through a CWP ranking process that evaluated proximity to the lake, slope, soils, precipitation, and modeled pollutant load contributions. The development of the CWP Strategy was guided by a Technical Advisory Committee (TAC) led by the Tahoe RCD, and in partnership with EPA, El Dorado County, and the Water Board to ensure the project was well coordinated and relevant to other projects implemented in the watershed.

The goal of EPA's Community Based Watershed Strategy grant is to explore approaches that integrate strategies for public and private solutions using education, information sharing and partnership development in the watershed. Through this effort it is expected there will be an increased knowledge in the usefulness of using LiDAR for planning LID area-wide projects, modeling information related to TMDL adaptive management.

Primary deliverables presented in this report include:

- *Microbasin Field Evaluation* – collaboration with University California, Davis to ground truth LiDAR exercise to locate potential microbasin opportunities for LID area-wide treatment.
- *Pollutant Load Reduction Modeling* – to evaluate level of effort to achieve 100% c*ompliance for residential BMP com*pliance.
- *Water Quality Evaluation* – Evaluation in support of TMDL adaptive management.

Work performed under this project also highlights the monitoring performed by the IMP, as well as provide data comparisons between the currently accepted autosampler method described in the NPDES permit, and an in situ continuous automated turbidimeter method that may prove to be a reliable alternative method for monitoring sediment. The monitoring evaluation will also assess data resolution needs related to number of events collected per year under the NPDES permit.

Tahoma was one of the many sites selected by the IMP as a catchment outfall monitoring site for NPDES permit compliance. Under the current IMP monitoring plan, only four precipitation events per year are monitored. The additional level of data collection will help assess data resolution needs for attaining reasonable annual pollutant loads within the Tahoma catchment. With these funds the Tahoe RCD monitored an additional seven storms beyond what is stated in the IMP Monitoring Plan for the Tahoma Watershed.

Furthermore, data collected under the NPDES permit and the EPA funds are complementary to long-term regional stormwater monitoring efforts proposed under the Tahoe Basin's Regional Storm Water Monitoring Program (RSWMP). All data was collected in a manner consistent with RSWMP monitoring protocols so it can easily be analyzed to align with the goals and objectives presented in the multi-agency driven RSWMP Data Quality Objective Plan (DRI et al 2011a), Quality Assurance Project Plan (DRI et al 2011b), and Sample Analysis Plan (DRI et al 2011c).

WATERSHED CONDITION

Lake Tahoe is currently listed as an impaired water body. The TMDL program was developed to address this impairment through implementing a comprehensive, long-term plan to reverse the decline in deep-water transparency to the 1967-1971 level of 29.7 meters (97.4 feet). TMDL science suggests that approximately 70 percent of fine sediment particles (FSP, <16 µm in diameter), and between 15-35 percent of nutrients are coming from the built environment, and our roadways (Lake Tahoe TMDL Technical Report, 2010).

The Tahoma catchment is considered a rural community on the west shore of Lake Tahoe. The 49.5 acre catchment straddles the Placer County/El Dorado County border and comingles waters from both jurisdictions (Figure 1), 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 commercial/industrial/communications/utilities (CICU) and primary roads. Twenty-eight percent of the catchment area is impervious. The runoff from this catchment has strong hydrologic connectivity to Lake Tahoe and discharges pollutant loads directly to the lake.

No recent water quality improvement projects have been completed in this drainage. However, due to steep roadways, eroding cut slopes and direct discharges of untreated stormwater to Lake Tahoe, El Dorado County plans to implement a water quality improvement project in 2015, listed within the Lake Tahoe Environmental Improvement Program (EIP).

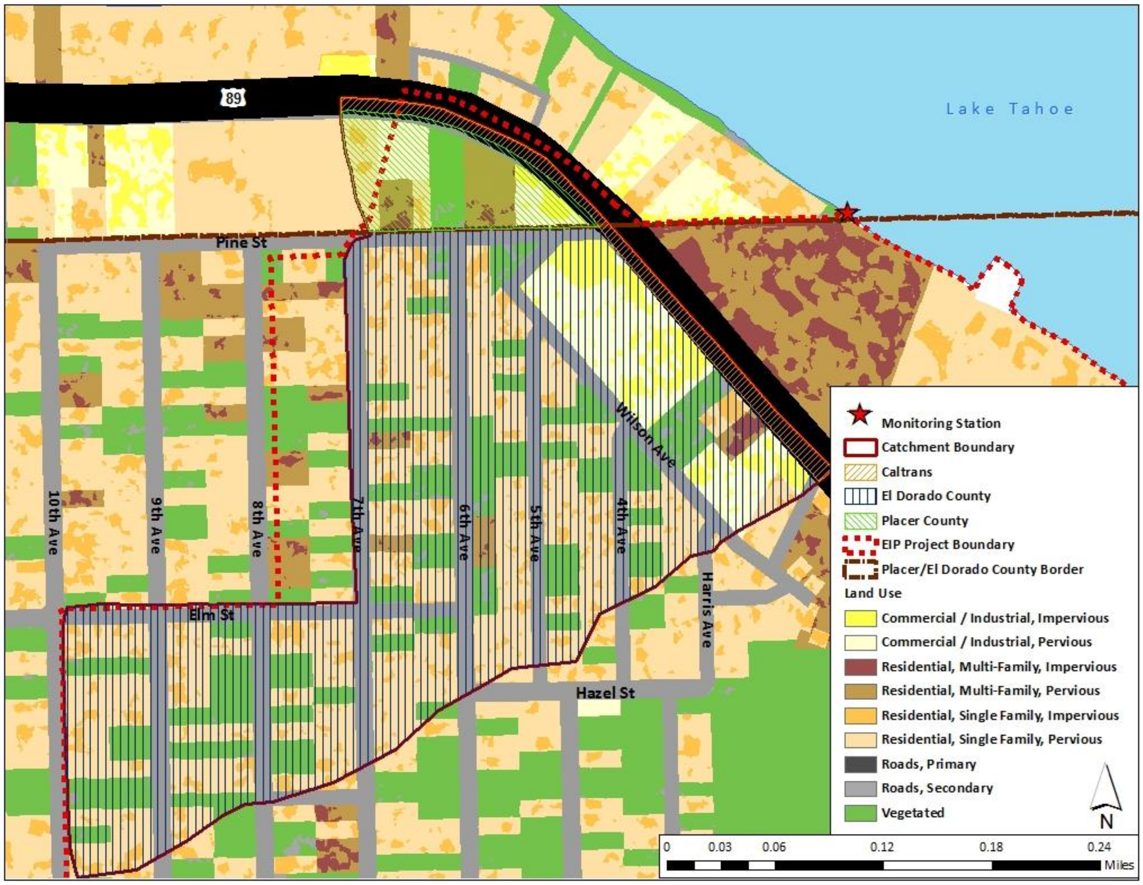

Figure 1: Tahoma monitoring station, including catchment boundary, EIP project boundary, and land use.

The EIP project will focus on reducing sediment delivery to the lake through source control, hydrologic design, and stormwater treatment. Source control will be achieved by stabilizing eroding cut slopes with vegetation and/or rock armoring, stabilizing existing drainages with rock, and where feasible, with bio-engineering techniques, and eliminating eroding roadside ditches by installing curb and gutter or rock-lined channels and vegetated swales. It is anticipated that improved hydrologic design will store and spread out stormwater more effectively in the upper watershed and/or treat runoff from the El Dorado County right-of-way (ROW) before it discharges to Lake Tahoe. El Dorado also proposes to work with Caltrans, the CTC, Placer County, the Tahoe RCD and private land owners to develop a comprehensive watershed management plan within the project boundary.

The monitoring station (station T1) is located near the mouth of the drainage, and data from this site will characterize runoff from the catchment outfall. This site also provides the unique opportunity to collect data related to pre- and post- water quality improvements. The lessons learned in this catchment will be valuable to other moderate density residential neighborhoods with direct hydrologic connectivity to Lake Tahoe.

SOILS & VEGETATION

Tahoma soils have slopes that range from 2 - 50 percent. The Tahoma soil series consists of deep well drained soils that formed in material weathered from basic volcanic rock. Tahoma soils tend toward gravel and sandy and clay loam - forested on a southeast facing convex slope of 10 percent under a cover of red fir. Rock fragments in the upper 20 inches ranges from 5 to 35 percent gravel and 0 to 15 percent cobbles; the lower part ranges from 5 to 50 percent gravel and 0 to 20 percent cobbles and stones. The soil structure ranges from weak to strongly granular, but organic matter tends to be low at five to seven percent. The physical structure of the soils characteristics in this watershed result in predominantly well drained soils that are moderately permeability. The mean annual precipitation is approximately 40 inches.

Native vegetation is representative of a typical Mediterranean environment with mixed conifers and shrubs where the principal species are red fir, white fir, Jeffrey pine, lodgepole pine, mountain whitethorn, manzanita, and mahala mat (Watershed Assessment, 2000).

PROJECT APPROACH

Knowledge gained from this project will be used to assist El Dorado County with planning for future project implementation in the Tahoma, California watershed, as well as assist with TMDL adaptive management strategies related to EIP project effectiveness monitoring. Watershed evaluations presented in this section discuss opportunities for improving stormwater quality affecting Lake Tahoe, the specific tools, details on approach, and findings are summarized below.

DISPERSED MICROBASINS

Tahoe Resource Conservation District (Tahoe RCD) staff conducted a field assessment of potential microbasins identified by the University of California, Davis and the Universidad de Granada though the use of Light Detection and Ranging (LiDAR) data. The microbasins assessed were located on public lands in the Tahoma area. The main finding during field assessment was that all areas identified as potential microbasins were difficult to visually identify, and high groundwater was a common constraint.

Geoff Schladow (University of California, Davis) in collaboration with the Universidad de Granada, analyzed LiDAR data for the Tahoe basin to determine potential micro basins for storm water infiltration. The LiDAR data have a horizontal resolution of 0.5m and an estimated vertical accuracy of 3.5cm. The micro basins are identified as natural depressions in the landscape, and analyses is conducted to determine the potential volume of water that could be detained with retaining wall heights of 0.75m, 1m, 1.25m, 1.5m, 1.75m, and 2m. The idea is that these micro basins could be utilized to provide distributed storm water treatment capabilities similar to much larger detention basins at a fraction of the cost. The Tahoe RCD conducted an initial field assessment of the potential storm basins identified with LiDAR to determine if the basins would be feasible to install. The field assessment was focused in the Tahoma area (see Figure 2. below).

In collaboration with NRCS, Tahoe RCD staff identified the following selection considerations for initial assessment to narrow down the number of basins:

- Public land ownership, determined with a geographic information system (GIS)
- Hydrologic connectivity to urban areas, determined visually with GIS/Google Earth

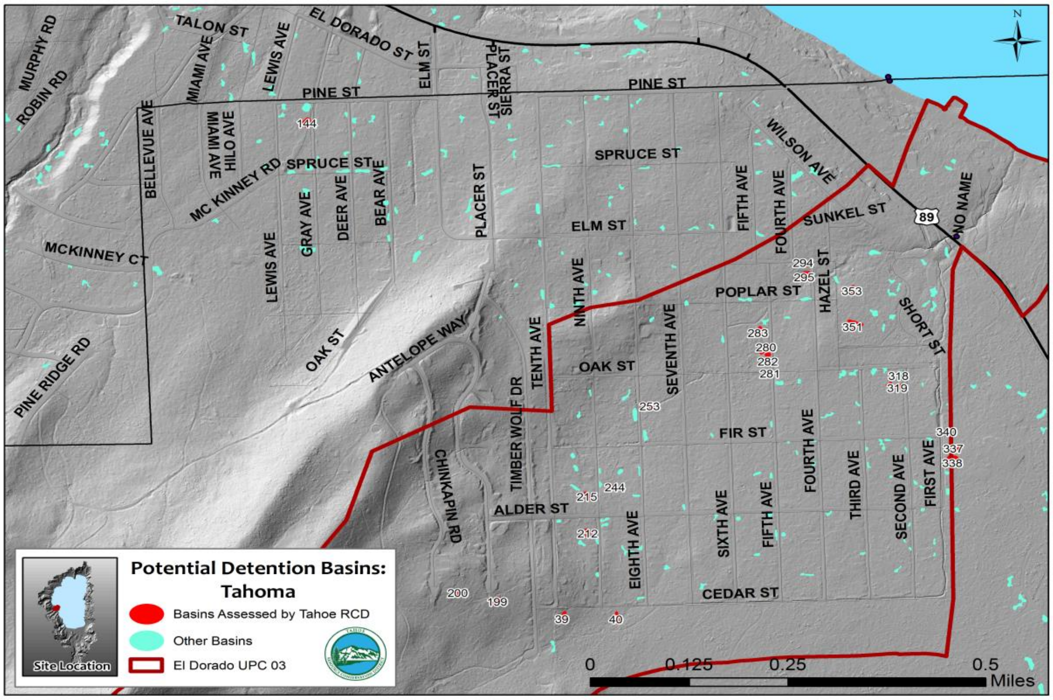

Figure 2. Tahoma Project Area and Microbasin locations.

During field visits it was found that using parcel addresses and measurements based off of parcel boundaries with a tape measure and compass was much more efficient for determining basin locations than GPS alone. During field assessments some or all of the following was conducted for each basin:

- Took photos of site
- Assessment of general vegetative type (wet/dry)
- Determining depth to seasonal groundwater table (< or > 12 inches), (using vegetative indicators and/or soil cores conducted by NRCS)
- Assessment of hydrologic connectivity to urban areas

In Tahoma, the LiDAR microbasin analysis identified a total of 372 potential detention basins. Using ArcGIS to determine the basins that lay *entirely* within public land boundaries lowered the number of potential basins down to 98. Of these, approximately 55 had the potential to catch urban runoff (based on visual assessment with ArcGIS/Google Earth), with the rest situated in non-urban areas. The Tahoe RCD focused efforts on potential detention basins within El Dorado County's Urban Planning Catchment 03 (EDC UPC03) because it identified 21 "potential" basins on public lands in the Tahoma area.

Tahoe RCD field investigations identified that for all potential microbasin locations identified by the LiDAR technique, they either lacked evidence of any surface flow to the location, or were identified as having shallow groundwater. After discussions with the California Tahoe Conservancy, it was determined that similar field assessment were conducted in the Meyers area of South Lake Tahoe and the CTC found similar results. Because of this, the Tahoe RCD took a revised approach in utilizing the LiDAR information to evaluate locations within the El Dorado County right of way (ROW). Additional information on steam environment zone (SEZ) location and PLRM modelling were also considered as part of the revised analysis; results are presented in the next section.

POLLUTANT LOAD REDUCTION MODELING

The Lake Tahoe TMDL requires that Tahoe jurisdictions reduce pollutant loading of FSP, TN, and TP to help improve water clarity in Lake Tahoe. The PLRM was developed as a tool to estimate pollutant load reduction to the lake based on the implementation of water quality improvement projects and management actions in a watershed. Using methods described in the Lake Tahoe Clarity Crediting Program Handbook (Crediting Handbook), pollutant load reductions are translated into Lake Clarity Credits used to track TMDL progress. All PLRM models were established using the approach described in the PLRM user's manual (NHC 2009**).**

Combining LiDAR, GIS, and PLRM tools, the Tahoe RCD focused on the upper portion of the Tahoma watershed which drains to a large (16,617ft^3) detention basin located on the corner of 6th Avenue and Elm Street (referred to as "6th Avenue detention basin"). For PLRM modeling purposes, the Tahoma catchment is divided into three separate sub-catchments: the area above 6th Avenue detention basin, the area below 6th Avenue detention basin, and the area within Caltrans' jurisdiction (Figure 3). The 6th Avenue detention basin was built in 1989 and is therefore modeled using baseline assumptions. According to PLRM v2, the 6th Avenue detention basin treats 90% of the runoff from the catchment that drains into it under baseline conditions. With maintenance, the basin would treat approximately 93 percent of fine sediment particle (FSP) loading, which equates to 0.56 credits (Table 1).

Table 1. Fine sediment particle (FSP) reduction (percent, pounds per year, and number of credits) by the 6th Avenue basin in Tahoma under baseline conditions and with basin maintenance.

Tahoma Catchment - Above 6th Ave Detention Basin 6th Ave Detention Basin FSP treatment efficiency			
	FSP % reduction	FSP lbs/year reduction	# Credits
Baseline	90	3153	None - Baseline
With Maintenance	93	3266	0.56

Due to the low number of TMDL credits achieved by this approach, the Tahoe RCD investigated what type of work could be performed below the 6th Avenue basin to help El Dorado County in achieving cost effective management strategies for TMDL implementation.

In the Tahoma sub-catchment below the 6th avenue detention basin, the pervious area in El Dorado County's ROW that is not located in SEZ totals 96,600sf. If less than 20 percent of the ROW (1ft depth) were converted to LID technology such as rain gardens, microbasins or bio-swales it would result in 16,430ft^3 of volume captured; similar to the volume capacity seen at the 6th Avenue detention basin. PLRMv2 model results of FSP reduction are shown in Table 3; the results indicate that the volume of FSP would be reduced by approximately 25 percent (2102 lbs/year reduction or 10.5 credits). Additionally, the PLRM estimates a reduction of approximately 7000 lbs/year of FSP (or 35 credits) if 100 percent of the road runoff is captured in the lower watershed.

Figure 3 below also shows BMP compliance rates for single family residential (SFR) in the Tahoma catchment. BMP compliance rates in each sub-catchment are shown in Table 2 (the Caltrans sub-catchment contains no SFR parcels). There are currently 16 BMP compliance certificates identified in the Tahoma catchment with approximately 14 percent compliance, while 115 SFR parcels have not yet implemented BMPs.

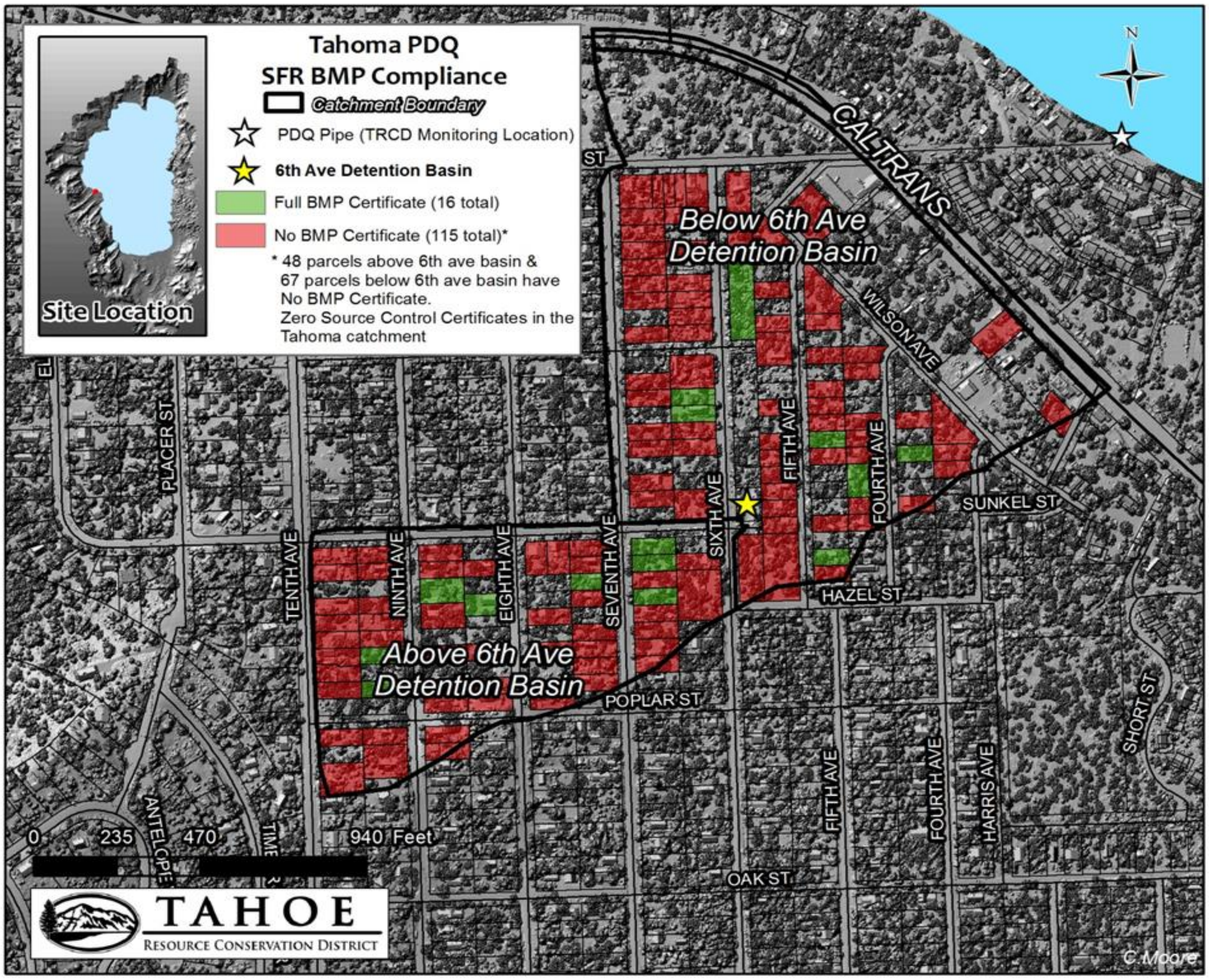

Figure 3. Tahoma Catchment and Single Family Residential BMP Compliance.

Table 2. BMP compliance rate for single family residential parcels in the Tahoma catchment.

Tahoma Catchment	SFR BMP Compliance Rate		
	Complete BMPs	Incomplete BMPs	% Compliance
Total	16	115	14
Above 6th Avenue	8	48	16
Below 6th Avenue	8	67	12

Table 3. Number of potential Lake Clarity Credits that could be obtained through 100% SFR BMP compliance in the Tahoma catchment.

Tahoma Catchment	100% SFR BMP Potential Credits
	# Credits
Above 6th Ave Basin	0.6
Below 6th Ave Basin	0.2

The range of TMDL pollutant load reduction credits achieved through implementing area-wide treatment in the county's ROW would provide the greatest potential for attaining TMDL credits. Alternatively, working with 115 individual homeowners to implement SFR BMPs is likely a more staff intensive and costly approach to attaining TMDL credits. Specifically, if the County were to achieve 100 percent SFR compliance in the Tahoma watershed they would attain only 0.8 credits (Table 3) as compared to between 10 and 30 credits by implementing dispersed LID treatment in the ROW (Table 4).

Figure 4. below identifies areas of impervious ROW where dispersed LID treatment of stormwater could likely be implemented.

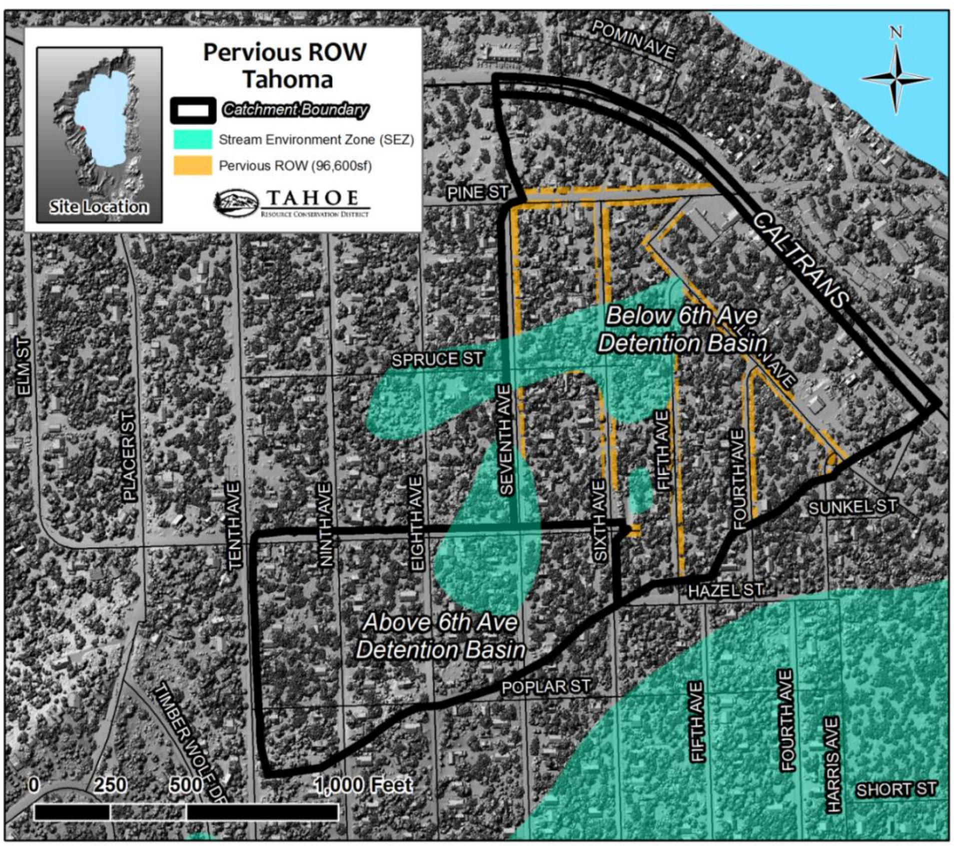

Figure 4. El Dorado county pervious right of way outside of the stream environment zone (SEZ) in the catchment below 6th Avenue detention basin in Tahoma.

Table 4. Tahoma catchment; volume capacity and associated FSP reduction.

Tahoma Catchment - Below 6th Ave Detention Basin Pervious channel with 16,430cf volume capacity			
% Roadway draining to LID	FSP % reduction	FSP lbs/year reduction	# Credits
25	24.9	2,102	10.5
50	49.6	4,186	20.9
75	73.9	6,234	31.1
100	83.1	7,008	35.0

In the upper portion of the watershed the PLRM results also indicate that maintaining the 6th Avenue basin would provide approximately the same amount of credits as those gained by regulating SFR BMP implementation. At this time, it is not likely that the County would pursue regulatory action to achieve this level of TMDL credit; a more palatable approach however, might involve the development of a Benefit Assessment that would guarantee long term maintenance of infrastructure, while homeowners could receive a complete BMP certificate from TRPA once source control measures alone are implemented. On average with a typical lot, installing SFR BMPs can cost between $1,500-$3,500. A common constraint for implementing BPMs is that many residents don't have the available funding to either install or pay someone to install their BMPs. A benefit Assessment could allow for a spreading out of the SFR cost over a 25 to 40 year period and the County would then have funding for maintenance and TMDL load reduction accounting; this approach offers regulatory compliance for homeowners and the County. Through similar CWP efforts in the Tahoe Basin, the Tahoe RCD and TRPA have seen that this type of private-public partnership encourages homeowners to do their part, especially when they see leadership from local government that brings cost effective solutions.

In summary, the LiDAR, GIS and PLRM analysis provided useful for evaluating implementation scenarios and identifying effective approaches to capturing stormwater and attaining TMDL credits. Although these results are modeled and therefore theoretical, it should be understood that PLRM results are driving management decisions in the Lake Tahoe Basin, and in times of funding shortfalls, the stormwater jurisdictions will be looking to the most cost effective approaches in achieving TMDL compliance.

WATER QUALITY EVALUATION

The Tahoma monitoring station – T1 provides a good opportunity to monitor pre- and post- EIP project implementation, with the hope that there will be detectable decreases in pollutant loading after the project is completed.

The T1 site is located at the outfall of the drainage and instrumentation in the pipe includes:

1. An automated ISCO sampler for logging stage and turbidity readings, calculating flows, and collecting samples
2. A bubbler module for measuring stage

3. A turbidimeter for measuring continuous turbidity
4. A solar panel for charging Marine Cycle 12V batteries to power equipment
5. A nearby meteorological station to record localized precipitation and ambient temperature. The meteorological station has a heated tipping bucket to record precipitation so that an accurate measurement can be taken when precipitation falls as snow.

Tahoe RCD staff members watched the weather carefully and prepared the automated sampler for event sampling prior to each predicted precipitation event. This includes ensuring that the automated sampler was full of clean sample bottles and programming the flow based pacing of the samples based on forecasted precipitation totals. During events, Tahoe RCD staff checked on the samplers often to ensure that sample pacing was accurate for actual precipitation totals, stage readings were correct in the pipe, and samplers were functioning properly.

At the end of each event, data was offloaded from the ISCO automated sampler and water quality samples were collected. Data was transferred to a central Tahoe RCD computer and added to an excel spreadsheet designed to manage continuous flow, continuous turbidity, sample dates and times, and event type. Samples were properly labeled in the field, transported to a laboratory immediately after collection in a cooler, composited on a flow-weighted basis, and shipped to an analytical laboratory using proper chain-of-custody procedures. Samples were analyzed for the Lake Tahoe TMDL pollutants of concern: fine sediment particles (FSP) concentration, total nitrogen (TN) concentration, and total phosphorus (TP) concentration.

Ten percent of all samples analyzed were quality assurance - quality control (QA/QC) samples. These samples were used to ensure proper instrument function, field sampling methods, sample handling procedures, and laboratory methods.

According to the Association of California Water Agencies, water year 2014 was one of the driest in the State's recorded history, with less than 60% of average precipitation. Figure 5 shows the continuous hydrology and cumulative precipitation for water year 2014. 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). The seasons are defined as such to better fit with precipitation patterns and storm event types that occur in the Tahoe Basin. The total precipitation for water year 2014 at the Tahoma meteorological station was 20.56 inches. The majority of the precipitation fell in the fall/winter season (14.95 inches). The spring season received 1.60 inches and the summer season received 4.01 inches (Precipitation occurring as snow is converted to inches of water). A total of 36 discrete precipitation events were measured at the Tahoma meteorological station, 15 in the fall/winter, 13 in the spring, and 8 in the summer. Fall/winter and spring precipitation events were either snow, rain, or mixed rain and snow. Summer events were either thunderstorms or frontal rain storms. Half of the events during water year 2014 produced less than a tenth of an inch of precipitation, and three quarters of the events produced less than half an inch. The largest storm occurred between February 7, 2014 and February 10, 2014, falling as mixed rain and snow and producing 9.32 inches of precipitation in Tahoma. However, the highest peak flows (about 3.2 cubic feet per second (cfs)) were experienced during a high intensity thunderstorm on August 10, 2014.

Flow weighted water quality samples were taken across the hydrograph for all eleven runoff events. Continuous hydrology, continuous turbidity and events sampled during water year 2014 are presented in Figure 6. The highest turbidities were seen during the largest storm of the year (February 7-10, 2014). The greatest flows were seen during the thunderstorm that occurred on August 10, 2014 as the peak precipitation reached 0.28 inches in ten minutes. Continuous hydrology, continuous turbidity, and water quality samples for the eleven individual events are presented in Appendix A.

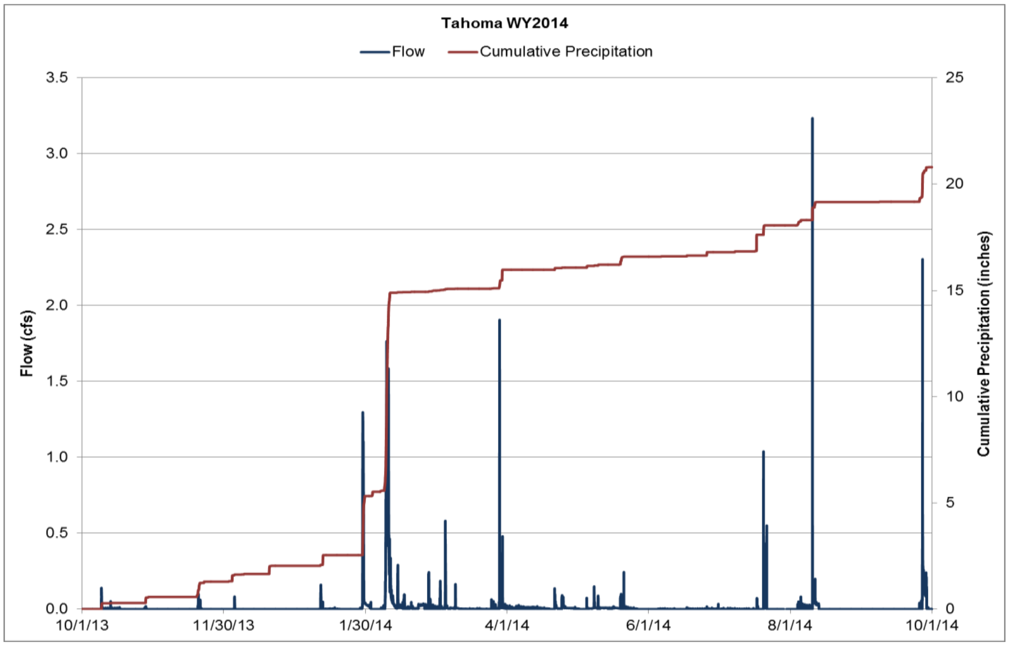

Figure 5: Continuous hydrology and cumulative precipitation at the Tahoma catchment outfall during water year 2014.

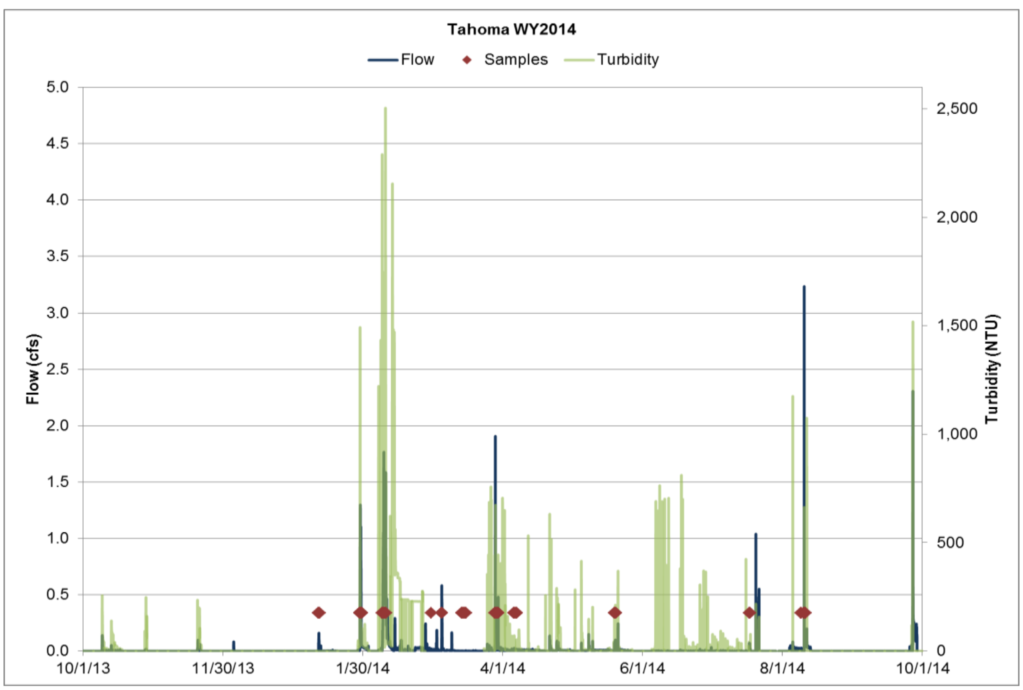

Figure 6: Continuous hydrology, continuous turbidity, and sampled events at the Tahoma catchment outfall during water year 2014.

Summary data for all eleven events are presented in Table 1. Three precipitation events were sampled during the fall/winter, six during the spring, and two during the summer. In general, only precipitation events greater than 0.3 inches produced sufficient runoff for water quality sampling, though one spring rain on snow event of only 0.05 inches produced sufficient runoff to sample as melting snow increased the total runoff volume. Two snowmelt events were sampled when temperatures rose to the mid-50˚F and snowmelt at the Tahoma catchment outfall was sufficient to sample. It is interesting to note that while FSP concentrations were extremely low for both snowmelt events, TN and TP concentrations were not. However, loads for all three pollutants were low for these two events as total runoff volumes were relatively low. The high intensity thunderstorm that began on August 10, 2014 had very high concentrations of all three pollutants, as did the first significant storm of the season beginning on January 11, 2014. Though FSP concentrations were about average, the highest FSP loads were produced during the two fall/winter mixed rain and snow events that occurred beginning January 29, 2014 and February 8, 2014 because of the large runoff volumes. These two events also produced the highest loads for TN and TP. The March 29, 2014 and August 10, 2014 also produced relatively large FSP loads. As one Lake Clarity Credit is equal to about 200 lbs, the volume from these four storms alone would be equal more than four TMDL credits if captured and infiltrated prior to discharging to the lake.

The NPDES permit requires that seasonal and annual precipitation and runoff volumes, as well as average seasonal and annual loads for FSP, TN, and TP are reported. These statistics are presented in Table 5. Seasonal and annual precipitation values represent the total precipitation that fell in the Tahoma catchment for that period, not just the sum of the storm totals of the events sampled. Seasonal and annual runoff volumes represent the cumulative runoff volume measured at the Tahoma outfall during the respective period, not just the sum of the volumes of the events sampled. As not every runoff event was sampled during the year, the average seasonal and annual loads represent an average (volume weighted) load estimation for the respective period based on the events that were sampled in that period.

It is not surprising that fall/winter accounts for the highest loading as the total runoff volume is approximately three times higher than the other two seasons. It is also interesting to note that though summer received significantly more precipitation than the spring did, the runoff volumes were similar. This is likely due to the additional runoff produced by snowmelt in the spring.

The PLRM estimates 5,263 pounds of FSP from the Tahoma catchment as an 18-year average. Considering that precipitation during water year 2014 was about 60 percent of average, FSP loads this year would be predicted to be about 3,158 pounds, which is not unreasonable compared to 2,503 lbs.

Table 5: Summary data for eleven sampled events at the Tahoma catchment outfall including runoff volumes, storm totals, and event mean concentrations (EMCs) and event loads for FSP, TN, and TP.

Season	Runoff Start (Date Time)	Runoff End (Date Time)	Runoff Duration (hh:mm)	Runoff Volume (cf)	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)
Fall/Winter	1/11/14 11:30	1/11/14 22:10	10:40	2,048	0.52	rain/snow	75%	383	49	3,762	0.5	1,015	0.1
Fall/Winter	1/29/14 9:10	1/30/14 2:20	17:10	34,160	2.79	rain/snow	100%	120	255	1,408	3.0	318	0.7
Fall/Winter	2/8/14 1:20	2/10/14 4:30	51:10	120,236	9.32	rain/snow	100%	51	381	235	1.8	341	2.6
Spring	3/5/14 22:20	3/6/14 8:40	10:20	5,672	0.05	rain on snow	100%	179	63	793	0.3	984	0.3
Spring	3/14/14 16:00	3/16/14 16:00	48:00	175	na	snowmelt	100%	<1	<0.1	346	<0.1	55	<0.1
Spring	3/29/14 3:00	3/29/14 17:00	14:00	10,630	0.37	rain	100%	170	113	1,510	1.0	942	0.6
Spring	3/30/14 2:40	3/30/14 23:50	21:10	3,735	0.50	snow	70%	188	44	1,554	0.4	1,116	0.3
Spring	4/6/14 7:00	4/8/14 7:00	48:00	2,039	na	snowmelt	100%	<1	<0.1	388	<0.1	87	<0.1
Spring	5/20/14 0:00	5/20/14 21:40	21:40	1,943	0.38	rain	100%	57	7	851	0.1	402	<0.1
Summer	7/17/14 18:40	7/18/14 6:10	11:30	645	0.77	thunderstorm	100%	28	1	2,887	0.1	265	<0.1
Summer	8/10/14 14:50	8/11/14 6:00	15:10	7,086	0.59	thunderstorm	100%	270	120	2,337	1.0	1,769	0.8

Equations to convert turbidity to FSP have been developed specifically for the Lake Tahoe Basin (2NDNATURE 2014). Using these equations, continuous turbidity measurements at the Tahoma catchment outfall were converted to FSP load estimates. Table 7 summarizes the seasonal and annual FSP loads calculated using continuous turbidity data and compares them to the estimates made from event sampling (Table 6). Continuous turbidity appears to underestimate loads during spring and summer runoff and over estimate during the fall and winter season as compared to the autosampler; annual load estimates however, are reasonably close.

Table 6: Seasonal and annual precipitation and runoff volumes, plus average seasonal and annual load estimations for FSP, TN, and TP for Water Year 2014 at the Tahoma catchment outfall.

TAHOMA CATCHMENT	Precipitation (in)	Runoff Volume (cf)	FSP load (lbs)	TN load (lbs)	TP load (lbs)
Fall/Winter (Oct1-Feb28)	14.95	207,798	910	7	4
Spring (Mar1-May31)	1.60	65,114	673	5	3
Summer (Jun1-Sep30)	4.01	59,000	921	9	6
Annual Totals	20.56	331,911	2,503	21	14

Table 7: Comparison of FSP load estimates in the Tahoma catchment calculated using continuous turbidity and autosampler methods.

TAHOMA CATCHMENT	Runoff Volume (cf)	FSP load (lbs) from continuous turbidity	FSP load (lbs) from event sampling
Fall/Winter (Oct1-Feb28)	207,798	1,446	910
Spring (Mar1-May31)	65,114	204	673
Summer (Jun1-Sep30)	59,000	258	921
Annual Totals	331,911	1,908	2,503

Beyond understanding how these two methods compare in measuring specific pollutant values, a greater challenge with using the continuous turbidimeter is working with scientists and stakeholders to agree on acceptable QA/QC methods for smoothing out data that shows anomalies due to influx of large debris, pine needles, and other factors that affect reliable in situ readings throughout the year. This question is currently being addressed through the IMP and the RSWMP monitoring programs. Answering this question will greatly help with transparency and stakeholder trust toward switching to additional monitoring methods in the future. It should be noted that the Lake Tahoe Watershed Model, the PLRM, and NPDES pollutant load allocations were all based on data collected with the autosampler method. It is for this reason that scientific transparency and stakeholder dialogue is an important aspect of any adaptive management strategy.

Additional comparisons of stormwater data are shown in Table 8. Average seasonal and annual load estimations are calculated using all eleven storms (as in Table 6 and 7) collected in water year 2014. Results indicate that average seasonal and annual load estimations that would result from sampled the four largest as compared to the four smallest events of the season. In general, the load estimations calculated using the largest events were very similar to the load estimations calculated using all eleven events for water year 2014. This is likely due to the relatively large proportion of runoff volume contributed by the larger storms. It should be noted however, that this relationship may not hold if dissolved nutrients were also being monitored, as baseline TMDL data (personal communication with Alan Heyvaert) identified larger concentrations of dissolved nutrients present in smaller events; more specifically snowmelt events.

Table 8: Comparison of average seasonal and annual load estimations calculated using all eleven events sampled to estimations calculated using the largest or smallest event of the season.

TAHOMA CATCHMENT	FSP load (lbs)			TN load (lbs)			TP load (lbs)		
	all events	largest event	smallest event	all events	largest event	smallest event	all events	largest event	smallest event
Fall/Winter (Oct1-Feb28)	910	658	4,970	7	3	49	4	4	13
Spring (Mar1-May31)	673	692	232	5	6	3	3	4	2
Summer (Jun1-Sep30)	921	995	103	9	9	<0.1	6	7	1
Annual Totals	2,503	2,345	5,305	21	18	52	14	15	16

Information presented in Table 8 also illustrates that FSP would likely be significantly over estimated if monitoring efforts continuously captured the smallest events within the water year. In this case the average annual FSP loads would be approximately doubled. In addition, TN loads in the fall/winter of water year 2014 would be seven times higher, the summer TN loads would be at least 90 times lower, and average annual loads would be about two and a half times higher if only the smallest events were captured. Average annual TP load estimated using the smallest storms is similar to the load estimated using all eleven storms, however, fall/winter loads are increased by about three times, and summer loads by six times. Thus, average seasonal and annual load estimations are likely to be more accurate when a range of storm sizes are sampled in each season; however a concentrated effort to capture larger events less often throughout the water year appears to produce a reasonable annual load calculation - while achieving significant cost savings.

ADAPTIVE MANAGEMENT RECOMMENDATIONS

The Lake Tahoe TMDL has demonstrated the importance of reducing pollutant loads to Lake Tahoe in order to restore mid-lake clarity and near-shore condition. To encourage public support, adaptive management efforts have to make clear the potential benefits and values that private property owners will gain from becoming a financial partner in an area-wide storm water projects. Educating business and property owners about how implementing BMP's demonstrates good stewardship is not enough; if it were, BMP compliance rates would be much higher than currently realized. Demonstrated leadership from local government and community incentives such as improved bike trails, street lighting, and transportation coupled with stormwater infrastructure has proven to be an effective approach in both the Harrison Avenue and Kings Beach corridors within the Lake Tahoe Basin. In addition, for broader support beyond SFR parcels it is important to demonstrate the value a comprehensive storm water system can bring to a commercial district and the value it can add to individual property owners. For example, a large piece of commercial property may cost a half million dollars to adequately BMP, but as a partner in an area-wide system the property owner's contribution assessment could be less than half that cost. In addition, where usable space is a premium, a commercial property owner may find value in not using their parking space to install individual detention basins on site. In particular, when addressing commercial properties, systems that consider the integration of aesthetic enhancements, recreation benefits, parking and circulation improvements have a better chance of gaining investment (financially and politically) by commercial property owners as well (Tahoe RCD, 2015).

When considering adaptive management for monitoring TMDL progress, the Tahoe RCD is working with TMDL partners and Basin stakeholders to better understand implications of utilizing a suit of monitoring methods, and is currently through funding provided by SNPLMA and State Water Board, in the process of evaluating method costs, QA/QC, and side by side data comparisons. This work will be completed in 2016, as the data presented in this report should be considered preliminary. There is of course additional considerations beyond method cost and QA/QC, specifically individual project goals; as the continuous turbidimeter may not be appropriate for use when nutrient data is a central objective for monitoring as with issues related to near shore degradation.

REFERENCES

Final Watershed Strategy Report, Meyers California, Tahoe RCD, 2015.Lake Tahoe Watershed Assessment, USFS 2000.

Lake Tahoe Technical TMDL, Lahontan and NDEP, 2010.

Lake Tahoe Watershed Assessment, USDS Forest Service, 2000

Pollutant Load Reduction Model (PLRM) User's Manual, NHC, December 2009.

RSWMP Quality Assurance Project Plan, Lake Tahoe TMDL 2011.

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

APPENDIX A – EVENT HYDROGRAPHS

Event hydrographs for each of the eleven sampled events are presented below. Individual samples are represented by red diamonds, and samples lying on the same horizontal line were composited into a flow weighted sample.

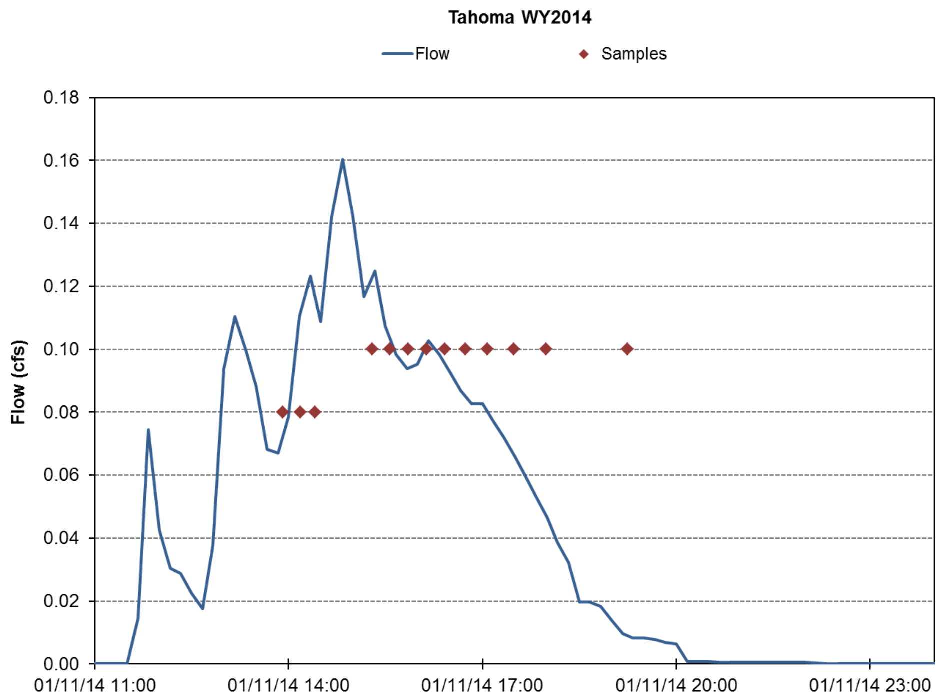

Figure A1: Continuous hydrology and water quality samples for the 1/11/2014 event. Total volume sampled: 2,048 cf. The continuous turbidity sensor failed during this event.

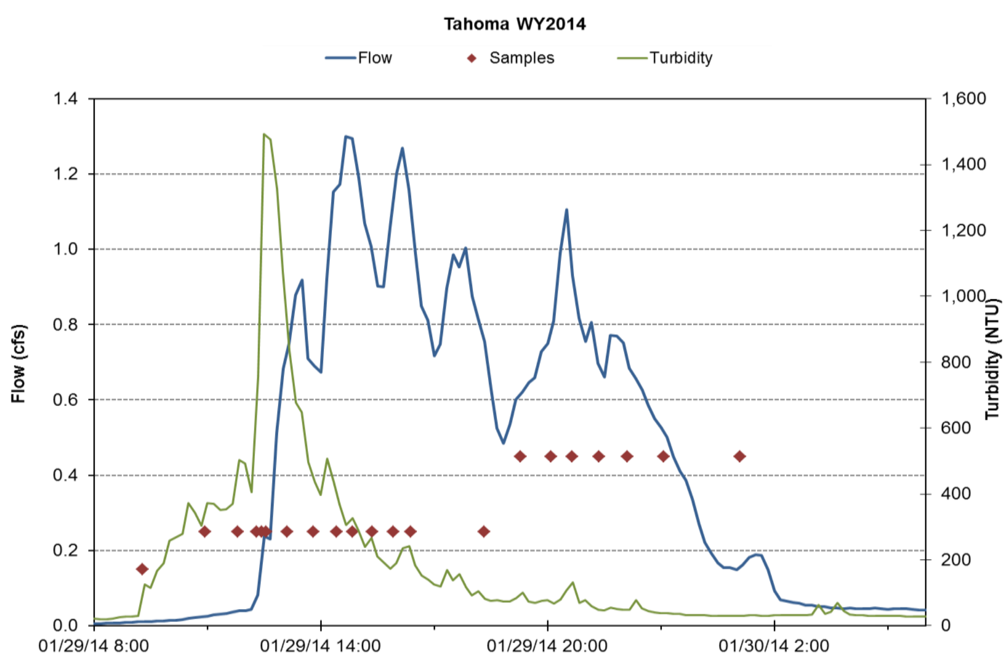

Figure A2: Continuous hydrology, continuous turbidity, and water quality samples for the 1/29/2014 event. Total volume sampled: 34,160 cf.

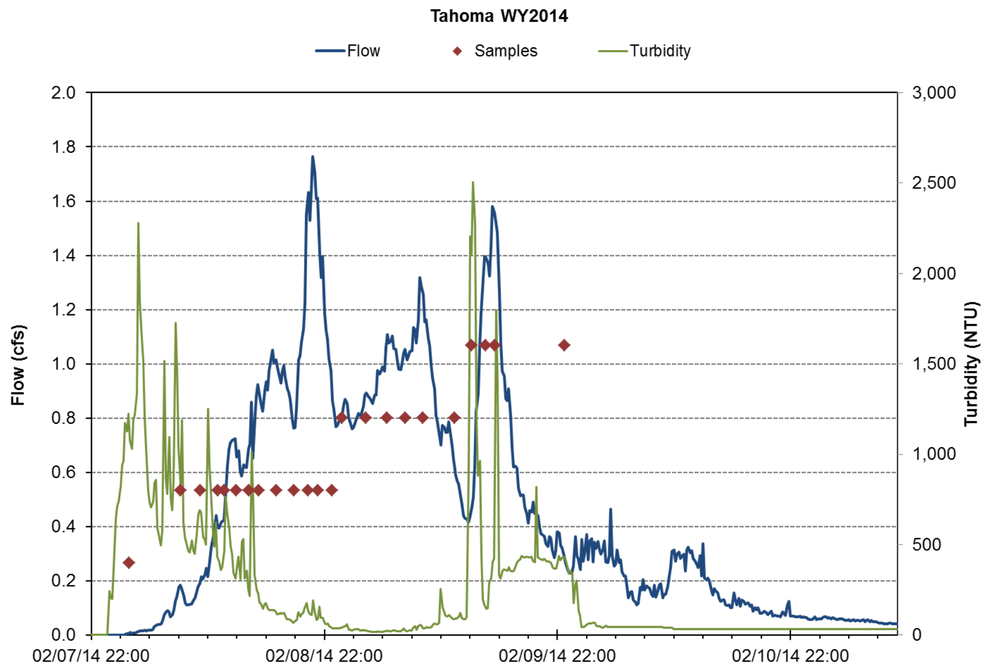

Figure A3: Continuous hydrology, continuous turbidity, and water quality samples for the 2/8/2014 event. Total volume sampled: 120,236 cf.

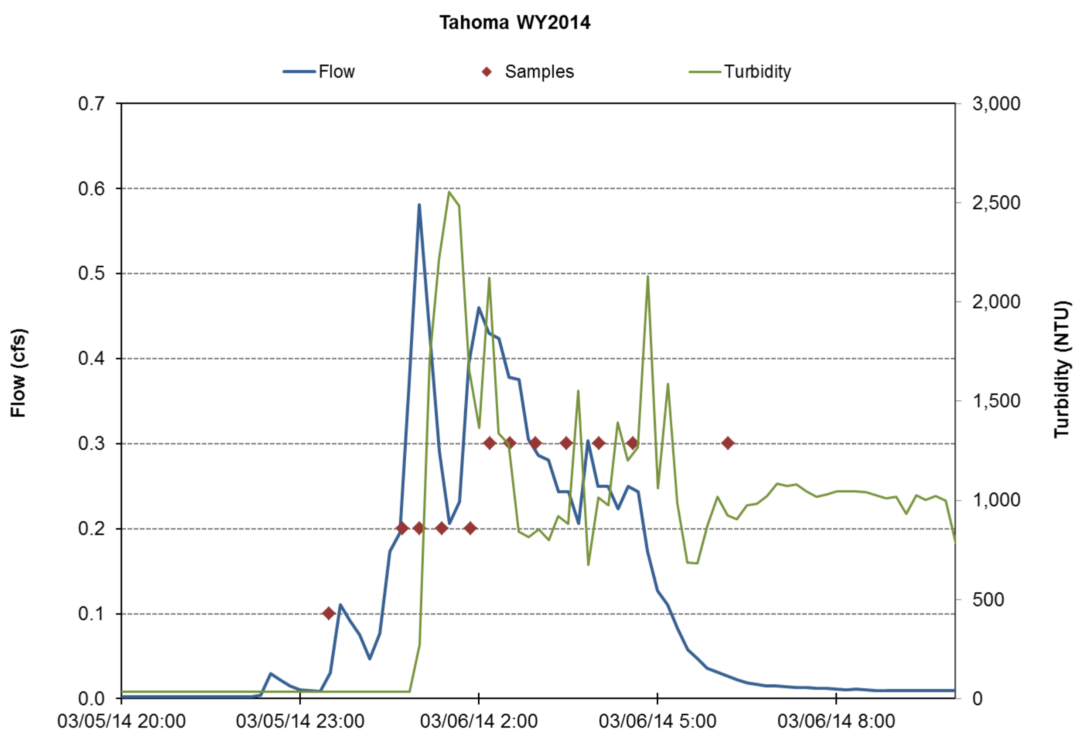

Figure A4: Continuous hydrology, continuous turbidity, and water quality samples for the 3/5/2014 event. Total volume sampled: 5,672 cf.

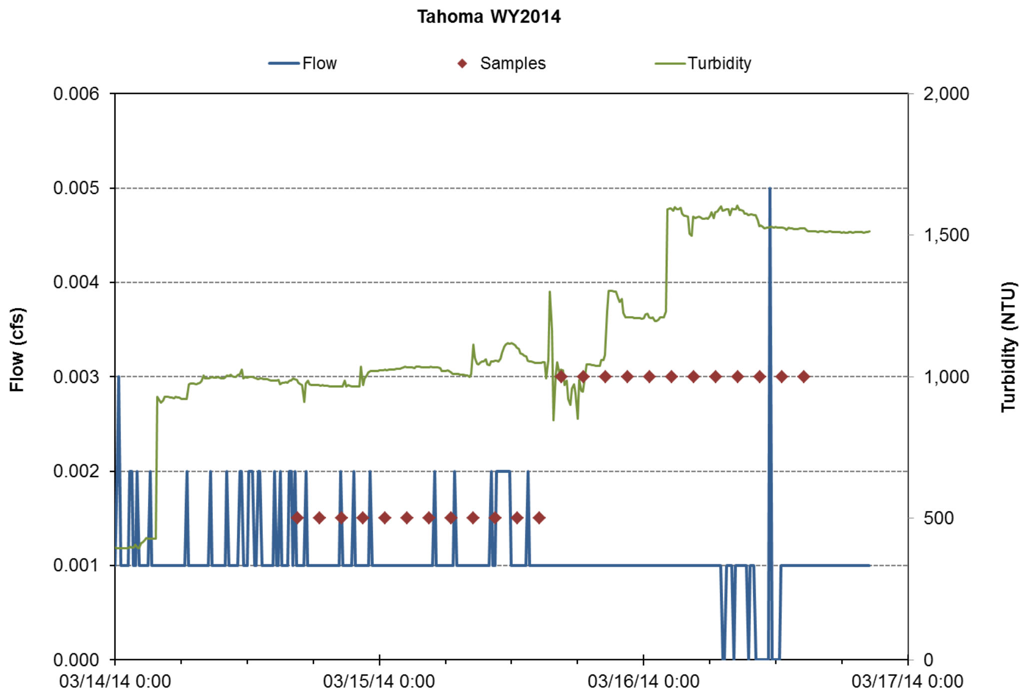

Figure A5: Continuous hydrology, continuous turbidity, and water quality samples for the 3/14/2014 event. Flows were extremely low during this event and result in the sporadic looking hydrograph.
Total volume sampled: 175 cf.

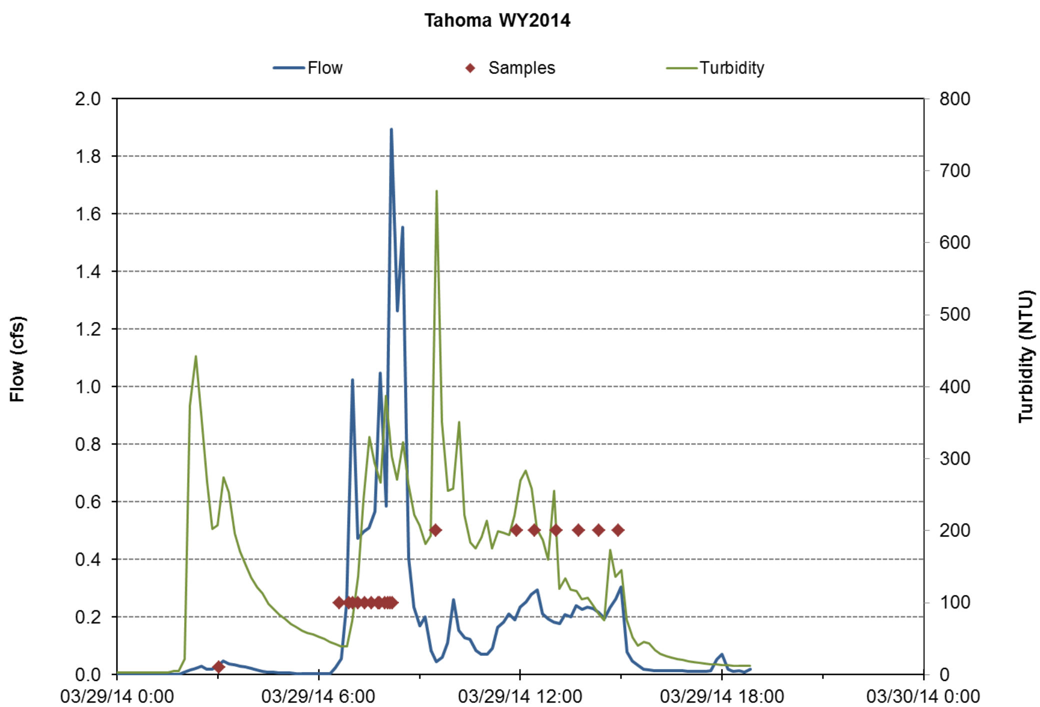

Figure A6: Continuous hydrology, continuous turbidity, and water quality samples for the 3/29/2014 event.
Total volume sampled: 10,630 cf.

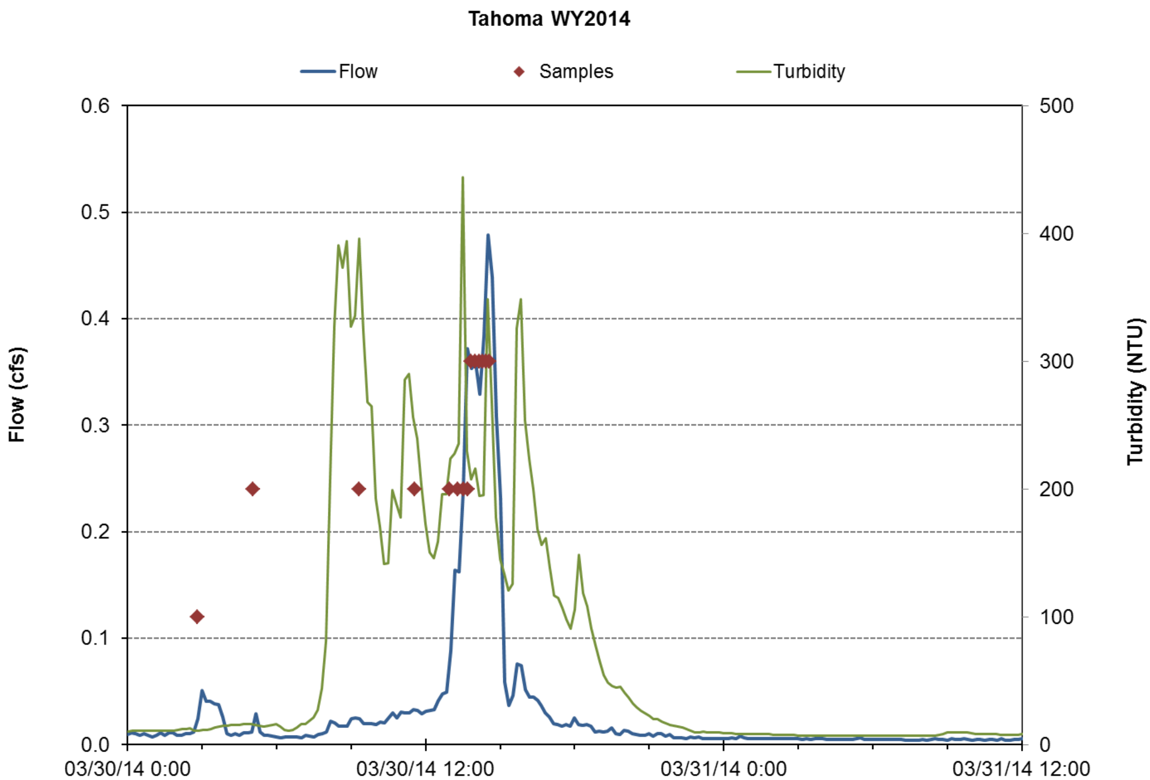

Figure A7: Continuous hydrology, continuous turbidity, and water quality samples for the 3/30/2014 event. Total volume sampled: 3,735 cf.

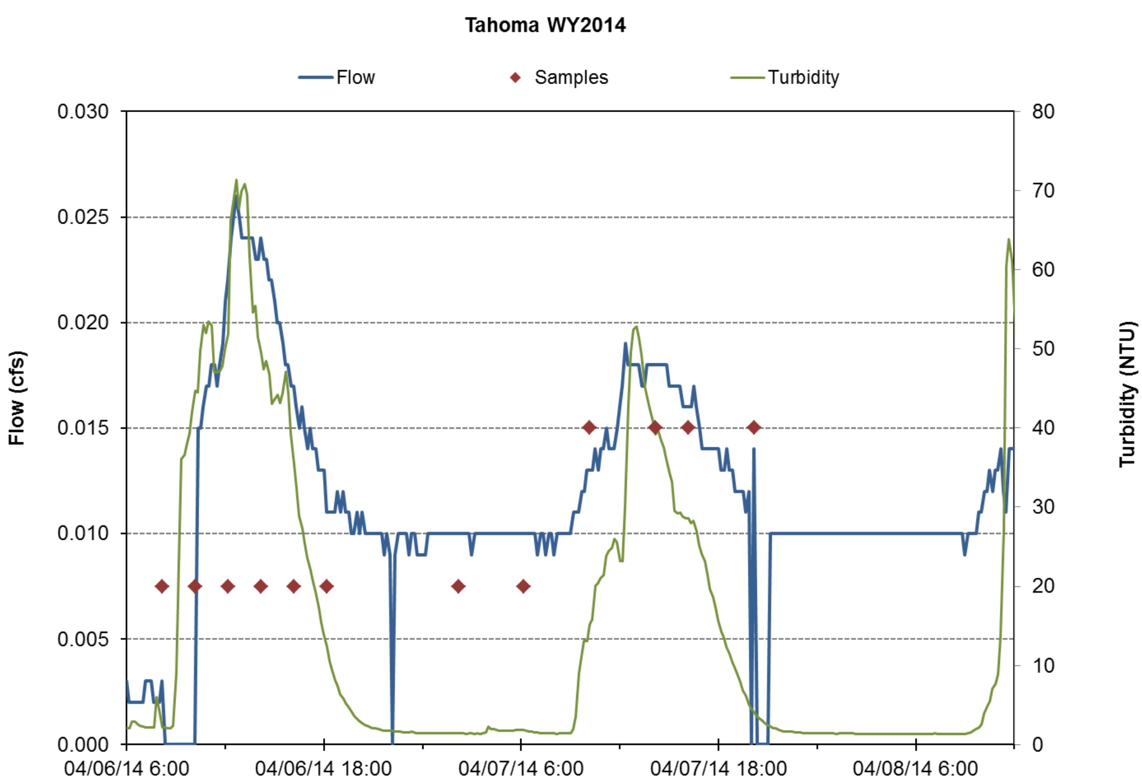

Figure A8: Continuous hydrology, continuous turbidity, and water quality samples for the 4/6/2014 event. Total volume sampled: 2,039 cf.

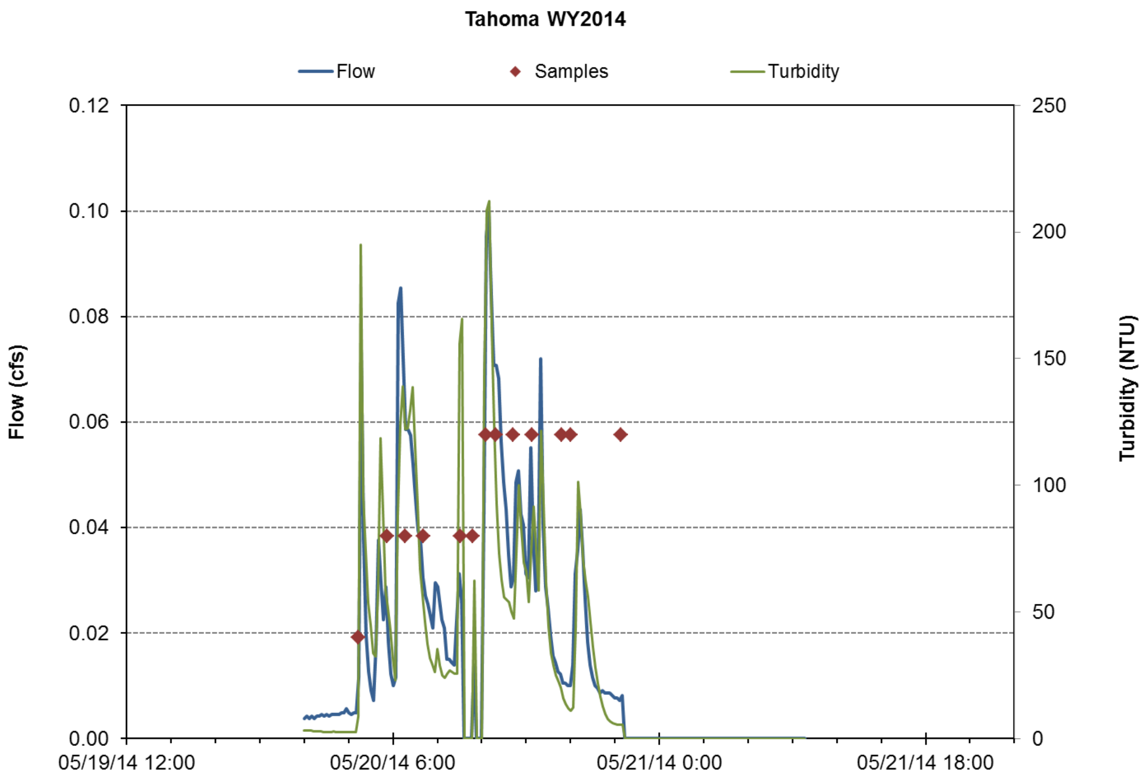

Figure A9: Continuous hydrology, continuous turbidity, and water quality samples for the 5/20/2014 event. Total volume sampled: 1,943 cf.

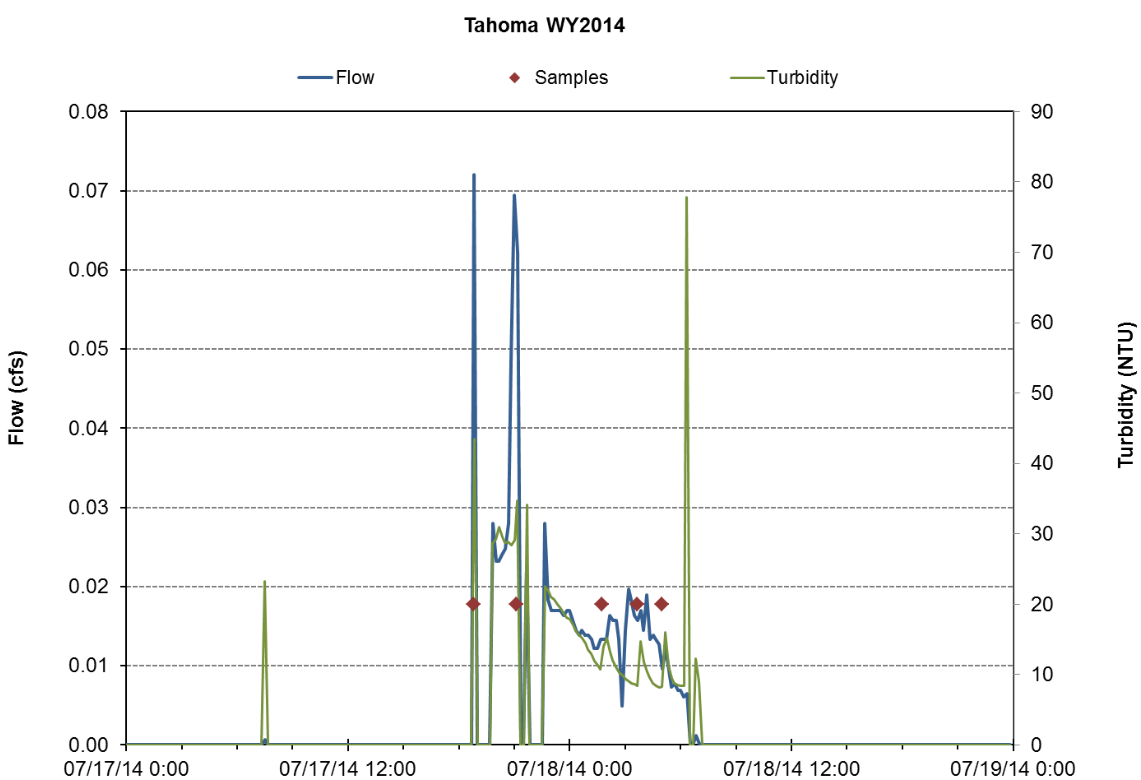

Figure A10: Continuous hydrology, continuous turbidity, and water quality samples for the 7/17/2014 event. Total volume sampled: 645 cf.

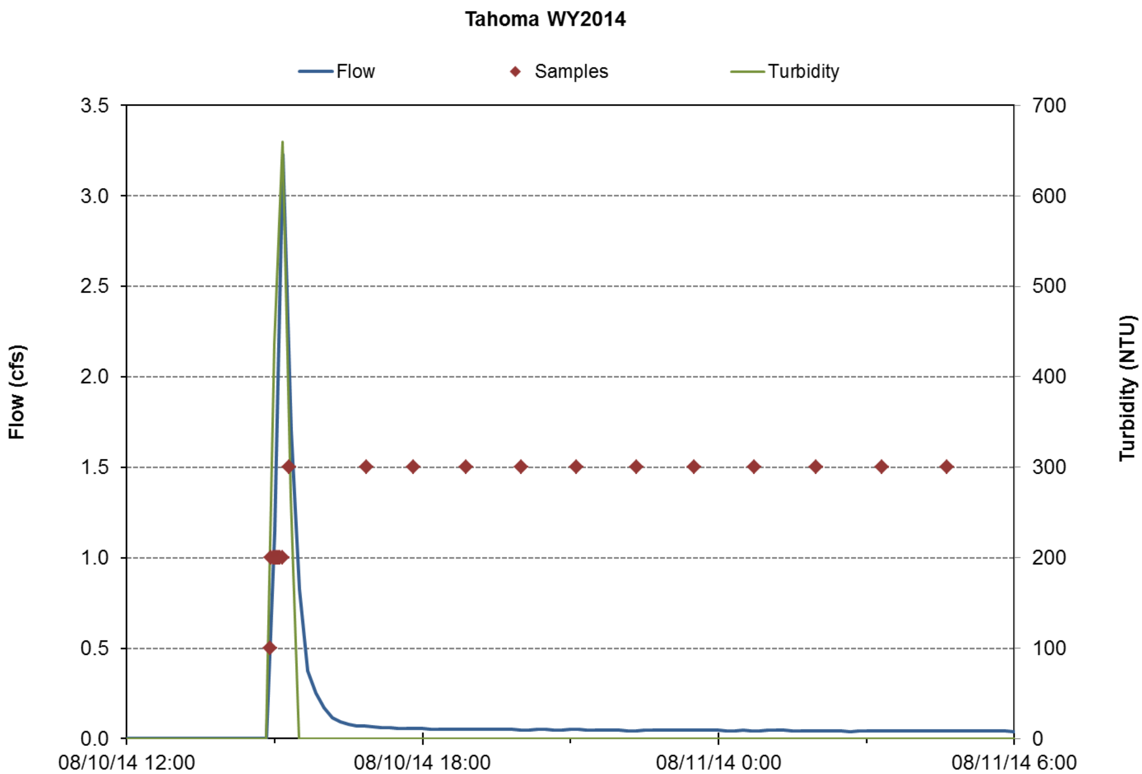

Figure A11: Continuous hydrology, continuous turbidity, and water quality samples for the 8/10/2014 event. Total volume sampled: 7,086 cf.