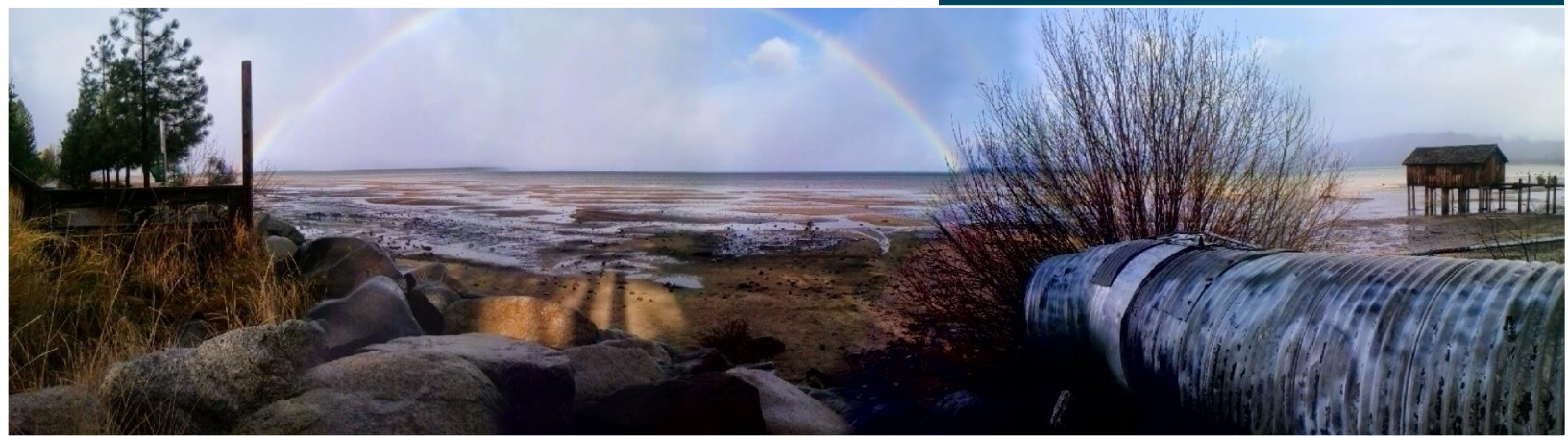# Regional Stormwater Monitoring Program

2017
Update

Framework and Implementation Guidance Document (FIG)

Tahoe Resource Conservation District
Submitted to the California Water Quality Control Board
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CONTENTS

ACRONYMS

ac	acre
BMP	Best Management Practice
CA	California
CEC	Characteristic Effluent Concentration
CEDEN	California Environmental Data Exchange Network
CFD	Community Facility District
CTC	California Tahoe Conservancy
CWA	Clean Water Act
DIN	Dissolved Inorganic Nitrogen
DRI	Desert Research Institute
EIP	Environmental Improvement Program
FSP	Fine Sediment Particles
ft	feet
IMP	Implementers' Monitoring Program
IRWMP	Integrated Regional Watershed Management Plan
L	liter
lb	pound
LSPC	Loading Simulation Program in C++
mg	milligrams
MT	metric tons
NDEP	Nevada Division of Environmental Protection
NHC	Northwest Hydraulic Consultants
NPDES	National Pollutant Discharge Elimination System
NV	Nevada
OP	Ortho-phosphate
PLRM	Pollutant Load Reduction Model
QA/QC	Quality Assurance/Quality Control
RAM	Rapid Assessment Method
RSWMP	Regional Stormwater Monitoring Program
SAG	Scientific Advisory Group
SNPLMA	Southern Nevada Public Land Management Act
ssn	season
SWQIC	Stormwater Quality Improvement Committee
TAC	Technical Advisory Committee
Tahoe RCD, TRCD	Tahoe Resource Conservation District
TIE SC	Tahoe Interagency Executive Steering Committee
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TRPA	Tahoe Regional Planning Agency
TSC	Tahoe Science Consortium
$USD	United States Dollars
WRCC	Western Regional Climate Center
WY	water year

EXECUTIVE SUMMARY

The Regional Stormwater Monitoring Program (RSWMP) has been developed to support a range of purposes including the Lake Tahoe Total Daily Maximum Load (TMDL) management system, the jurisdictional National Pollutant Discharge Elimination System (NPDES) permit and Inter-local Agreement requirements, potential scientific research questions, capital improvement effectiveness evaluations, and potential Pollutant Load Reduction Model (PLRM) improvements. As a regional monitoring program, it is designed to collect reliable information on urban stormwater runoff through a coordinated network of monitoring sites using consistent data collection, management, analysis, and reporting formats.

This document outlines the program directives, three RSWMP objectives, administrative and organizational structure, real time management process, and future funding opportunities for RSWMP. It defines the priority pollutants, output metrics, data management and analysis methods, and reporting formats for implementation of each objective. It also proposes three possible monitoring methods for data collection and gives detailed technical guidance for each monitoring method in the Appendices. Lastly, it documents progress through October 2017.

The priority objective for RSWMP through water year 2016 was to establish and monitor four long-term catchment outfall index sites for status and trends. As of October 2017, six long-term catchment outfall sites and three BMP sites are being monitored. The intent of this objective is to determine whether urban pollutant load reductions are being achieved in the Tahoe Basin in response to stormwater management actions over time. This is the only objective that is currently funded and funding requirements to continue monitoring for status and trends past 2018 are presented. Two monitoring methods are recommended to address this objective. Evaluations of monitoring methods to best address the other two objectives: assessing project effectiveness and informing Characteristic Effluent Concentrations (CECs) used in PLRM, may be conducted in the future if funding allows.

1   INTRODUCTION

Lake Tahoe is an oligotrophic alpine lake located on the California-Nevada border at an elevation of approximately 6,223 feet. The lake surface area is 194 square miles with a contributing drainage area of 314 square miles. Lake Tahoe is fed by 63 tributary streams and 52 intervening zones that drain directly to the lake (LRWQCB and NDEP 2010). Lake Tahoe was designated an Outstanding National Resource Water in 1980. This status affords it with the highest level of protection under the Clean Water Act (CWA) of 1972 and allows for no degradation. Regular monitoring of the lake's deep water transparency began in the 1960's and has shown a significant decline since then, from over 100 feet of clarity to about 70 feet at present. Since Lake Tahoe is allowed no degradation, it qualifies as an impaired water body, and Section 303(d) of the CWA mandates that a Total Maximum Daily Load (TMDL) be developed.

The Lake Tahoe TMDL identifies the primary types and sources of pollutants, establishes a deep water transparency standard, and lays out a timeline to meet the standard. A pollutant source analysis conducted by the Lahontan Regional Water Quality Control Board (Water Board) and Nevada Division of Environmental Protection identified urban runoff, atmospheric deposition, forested upland runoff, and stream channel erosion as the primary sources of fine sediment particle, phosphorus, and nitrogen loads to Lake Tahoe. The largest source of fine sediment particles to Lake Tahoe is urban stormwater runoff, comprising 72 percent of the total fine sediment particle load. Therefore, the urbanized area provides the greatest opportunity to reduce fine sediment particle and phosphorus contributions to the lake. The transparency standard has been set to 29.7 meters (97.4 feet), the annual average Secchi depth measured between 1967 and 1971. To achieve this standard, it is estimated that fine sediment particles, phosphorus, and nitrogen loads must be reduced by 65 percent, 35 percent, and 10 percent, respectively. It is estimated that it will take sixty-five years of implementing pollutant load reduction strategies in the Lake Tahoe Basin to reach this goal.

1.1   BACKGROUND

While there are existing monitoring programs in the Lake Tahoe Basin with established status and trend index sites for lake clarity, nearshore condition, stream loading and atmospheric deposition, there has not been a comparable program funded for urban stormwater. Because of this data gap, the Lake Tahoe Regional Storm Water Monitoring Program (RSWMP) was designed to collect reliable information on urban stormwater runoff from a coordinated network of monitoring sites. These sites will provide critical information related to changes in stormwater quality status and trends in response to implementing water quality improvement projects and improved management actions in urban catchments. With additional funding, RSWMP can also provide data to assess the effectiveness of a specific water quality improvement project in reducing pollutant loads and inform the Characteristic Effluent Concentrations (CECs) used in the Pollutant Load Reduction Model (PLRM; NHC et al 2009) to

ensure that stormwater treatment performance estimates (as modelled by the PLRM using CECs) are representative of Tahoe specific treatment Best Management Practices (BMPs).

RSWMP is an agency and stakeholder directed effort, and a major component of the overall plan to track pollutant load reduction progress under the Lake Tahoe TMDL. The TMDL requires local stormwater jurisdictions to maintain stormwater treatment infrastructure, assess infrastructure condition using rapid assessment methods (RAMs), conduct water quality monitoring, and estimate pollutant reductions from implemented management actions. The Lake Tahoe TMDL Crediting Program (Crediting Program) was developed to track progress made toward achieving the TMDL clarity standard. The Crediting Program (Water Board and NDEP 2011) recommends the use of the PLRM (NHC et al. 2009), an urban hydrology and water quality model, to estimate average annual pollutant loads from urban drainage catchments in the Tahoe Basin. Pollutant loading estimates derived from PLRM are used by the Crediting Program to identify progress that local jurisdictions are making towards Lake Tahoe TMDL load reduction milestones.

The primary tools used to determine pollutant load reduction credits for the Lake Tahoe TMDL are the PLRM and the RAMs (developed by Northwest Hydraulic Consultants and 2NDNATURE respectively). They are described in the Crediting Program Handbook (Water Board and NDEP 2011) and ultimately determine municipal stormwater pollutant load reduction credit awards. The urban stormwater runoff data collected by RSWMP will initially be used as a real time management tool to help inform PLRM estimates and refine CECs used in the model. As the RSWMP data set expands, it will become an additional evaluation tool for determining TMDL success.

RSWMP was originally envisioned in three different phases, an approach that is still accepted by stakeholders today. Phase I (2005-2011) was focused on the conceptual development of a comprehensive stormwater monitoring program for the Lake Tahoe Basin. Led by Dr. Alan Heyvaert at the Desert Research Institute (DRI) and the Tahoe Science Consortium (TSC), a Core Working Group was assembled to develop a conceptual framework for phased implementation. The Core Working Group consisted of eighteen individuals representing various interests, including regulatory agencies, funding groups, science community, and local and state implementing agencies at Lake Tahoe. Phase 2 (2013-2016) was focused on design specifications for the RSWMP framework with specific guidance on stormwater monitoring, analysis, data reporting, program organization, and the development of a Lake Tahoe stormwater specific RSWMP Data Management System. This document comprises a significant portion of Phase II completion. Phase III (2017-), once fully funded, will represent the coordinated implementation of six or more long-term index sites, followed by a detailed analysis and reporting effort.

Users of this program will likely include Basin managers, consultants, and any stormwater stakeholders that wish to conduct urban stormwater monitoring in the Lake Tahoe Basin or that require stormwater runoff information to satisfy reporting requirements or track progress toward TMDL goals. Users may

also include scientists that wish to answer questions related to urban stormwater quality and the impact on the nearshore and deep water transparency. Additional users of this program might include potential funders, Basin scientists, and executives wanting to understand the costs and benefits associated with investing in RSWMP.

1.2   PURPOSE

The purpose of the RSWMP Framework and Implementation Guidance Document is to:

1. Refine and clearly document the objectives of the RSWMP program.

2. Define and document protocols to guide site selection, data collection, data management, data analysis techniques and reporting formats to address each specific RSWMP objective.

3. Formalize programmatic structure and identify potential funding mechanisms of RSWMP.

4. Provide a real time management process to guide decisions regarding resource allocations and data collection techniques.

5. Document the range of expected annual funding needs and prioritize uses of available funds to ensure sustainable partnerships and program support for implementation.

1.3   PROGRAM DIRECTIVES

Specific Program Directives were outlined in the original RSWMP Phase I Document (TSC 2008) and designed to be guiding principles for RSWMP structure and implementation. They are also an important gauge by which to measure current program development success and provide continuity between the original vision of RSWMP and the current expansion and implementation of the program.

Original RSWMP Directives:

1. Develop a stormwater monitoring program that is directly responsive to the needs of all agencies and affiliated partners and requires a feasible amount of annual resources to sustain.

2. Provide program-wide consistency in sampling design, data reporting and quality assurance.

3. Develop data management and communication tools for efficient and effective reporting of current stormwater quality conditions and trends.

4. Assure a significant cost-effective benefit from stormwater monitoring through a coordinated regional program that informs relevant management strategies and decisions.

5. Implement a sustainable RSWMP organizational structure (with dedicated personnel) that has a high likelihood of maintaining the necessary resources agreed to be adequate to sustain the intended program.

1.4   PROGRAM TIMELINE

The general RSWMP guidance provided in this document is intended to remain consistent through the long term. This timeline was selected as it is consistent with other policy and program planning horizons such as the 65 year TMDL. Long term consistent monitoring will establish a dataset that can be compared across temporal and spatial scales to identify changes in pollutant loading in response to improved water quality management practices.

2   RSWMP OBJECTIVES

The RSWMP Data Quality Objectives (DQO) v1.4 (Heyvaert et al. 2011) documented preliminary goals and objectives for the Tahoe stormwater monitoring program. In 2014, the RSWMP team reviewed, refined and prioritized these goals and objectives based on research studies and lessons learned between 2011 and 2014. The review process resulted in identification of two priority objectives and one secondary objective that are documented and discussed below. It should be noted that only the first primary RSWMP objective is fully funded at this time.

The intent of RSWMP development is to work collaboratively with university scientists, environmental agencies, and private contractors to achieve a scientifically sound, cost-effective RSWMP monitoring approach, including a responsive administrative and programmatic structure. Data analysis and discussions with the RSWMP TAC were completed between 2015 and 2017 and this document includes minor changes and updates to the original 2015 document.

2.1   PRIMARY OBJECTIVE #1: STORMWATER STATUS AND TREND MONITORING

The highest priority objective for RSWMP implementation is to determine whether urban pollutant load reductions are being achieved in the Tahoe Basin in response to stormwater management actions. This focused objective is consistent with original RSWMP objectives, including the need to: determine the status of existing stormwater runoff with regard to concentrations and pollutant loads; evaluate catchment scale restoration effects; and provide annual stormwater datasets required to fulfill TMDL reporting for affiliated jurisdictions.

This priority RSWMP objective will be accomplished by establishing and maintaining a long-term targeted urban catchment outfall monitoring network. The majority of catchments included in this network will have water quality improvement projects planned as part of the Tahoe Environmental Improvement Program or as part of other jurisdictional or private property efforts. Monitoring for status and trends at urban catchment outfalls is important because it provides information needed for evaluating progress toward TMDL and other regulatory goals. Estimates of seasonal and annual volumes, runoff concentrations, and stormwater loads derived from the monitoring data will be direct outputs of annual outfall monitoring and will: (1) document the status of stormwater quality (2) evaluate urban stormwater quality trends at urban catchment outfalls after 5 full years of monitoring, and (3) inform the Tahoe Regional Planning Agency (TRPA) Threshold Evaluations on water quality.

Extensive water quality modeling conducted in the Tahoe Basin using both the Loading Simulation Program in C++ (LSPC) Watershed Model and the PLRM have indicated that outfalls draining urban catchments with high densities of impervious land uses have relatively higher pollutant concentrations, stormwater volumes, and associated pollutant loads than less developed catchments. RSWMP implemented a targeted site selection approach to identify and monitor sites that (1) are known to have relatively high distributions of impervious land uses; (2) discharge directly to surface waters or the lake; and (3) are expected to be subject to extensive, committed and well maintained water quality improvement actions. It is expected and desired that the stormwater pollutant concentrations and loads will measurably decrease over time as a result of changes in management actions and water quality improvement projects implemented in urban catchments.

2.2   PRIMARY OBJECTIVE #2: ASSESS PROJECT EFFECTIVENESS

Assessing project effectiveness is currently a secondary RSWMP objective and will be developed in the future on a project by project basis. Over the past two decades, a significant number of capital improvements projects have been implemented on urban and riparian lands to, in part, improve downslope water quality and ultimately reduce pollutant loading to Lake Tahoe. While the quantification of these load reductions has been desired, previous efforts to measure project scale water quality improvements have not been definitively successful. The limitations of past efforts stem from the lack of adequate funding and project duration to develop and implement the necessary monitoring design to complete comparable pre and post project water quality monitoring that confidently attributes a pollutant load reduction signal to a specific capital investment. Given these challenges, urban stormwater modeling tools that have been developed for the Tahoe Basin (i.e. PLRM and the Stream Load Reduction Tool (SLRT)) have provided quantitative estimates of the average annual pollutant load reductions achieved by a specific project and/or collection of spatially contiguous projects. The use of available models allows the development of a relatively consistent method for estimating pollutant load reductions that can be reasonably compared at both local and regional scales.

The project specific data obtained would be used to support the modelling estimates, quantify project benefits, and provide the rationale and evidence that the estimated average annual pollutant load reductions are reasonably valid. Use of available pre-project datasets is encouraged to reduce resource requirements of effectiveness evaluations and data collection duration necessary to evaluate water quality benefits. Adequate funding for effectiveness studies that include development of a comprehensive monitoring plan that outlines what data will be used to evaluate pre and post project conditions, how it will be managed, analyzed and reported to specifically address capital investment versus water quality benefit is important. The future direction of project scale water quality effectiveness in the Tahoe Basin aims to explore consistent, reliable, scientifically defensible, and cost-effective ways to identify and prioritize projects based on benefits that can be confidently linked to reduced pollutant loading to the Lake as a result of project implementation.

This objective conceptually differs from the priority RSWMP objective of stormwater quality status and trend monitoring on both spatial and temporal scales. Status and trend monitoring is conducted at the outfall of an urban catchment over a long time period, while project specific effectiveness data is collected over a shorter time period. The urban catchment time series datasets include a number of water quality improvement projects and/or land management changes that have been implemented over time. Project effectiveness evaluations may also include a number of improvements, but projects are expected to cover a smaller area than an entire urban catchment. The objective of the trend monitoring is to definitively 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, while project effectiveness is specifically designed to determine water quality improvements attributable to a capital investment.

2.3   SECONDARY OBJECTIVE: INFORM PLRM CEC VALUES

The second priority objective of RSWMP is to obtain the data needed to directly inform the development and evaluation of CECs used in the PLRM. CECs are used to estimate average annual load reductions provided by specific stormwater treatment BMP types represented within the PLRM. Though currently unfunded, this RSWMP objective would be achieved through a three year effluent sampling effort at three specific treatment BMPs of the same type. Priority will be given to BMP types that are most common in the Tahoe Basin and modelled in PLRM. When maintained in functional condition, stormwater treatment BMPs are expected to provide significant pollutant load reductions to urban stormwater runoff by reducing pollutant concentrations in treated volumes. By refining the average annual CECs of specific treatment BMP types, the long term average effectiveness of treatment BMPs maintained to modeled condition can be better quantified, thereby improving the predictive power of PLRM. This data would also be used to improve knowledge related to TMDL implementation and real time management needs.

3   RSWMP DEVELOPMENT AND IMPLEMENTATION PROCESS

The RSWMP objectives outlined in Section 2 have been developed to focus regional stormwater monitoring and address the priority management needs for a multi-year coordinated program. The objectives have been agreed upon to ensure that a feasible and focused long term program will be a success. The greatest limitation to a sustainable program will be available funding. Thus, the RSWMP development process followed a top down approach where the specific RSWMP objectives can be met by scaling program priorities relative to available funding.

The RSWMP top down development approach is summarized in Figure 1. This approach required the development team, (includes the SAG and the Steering Team), to comprehensively map the linkage between the monitoring data and achieving a specific RSWMP objective. This approach ultimately informs the data
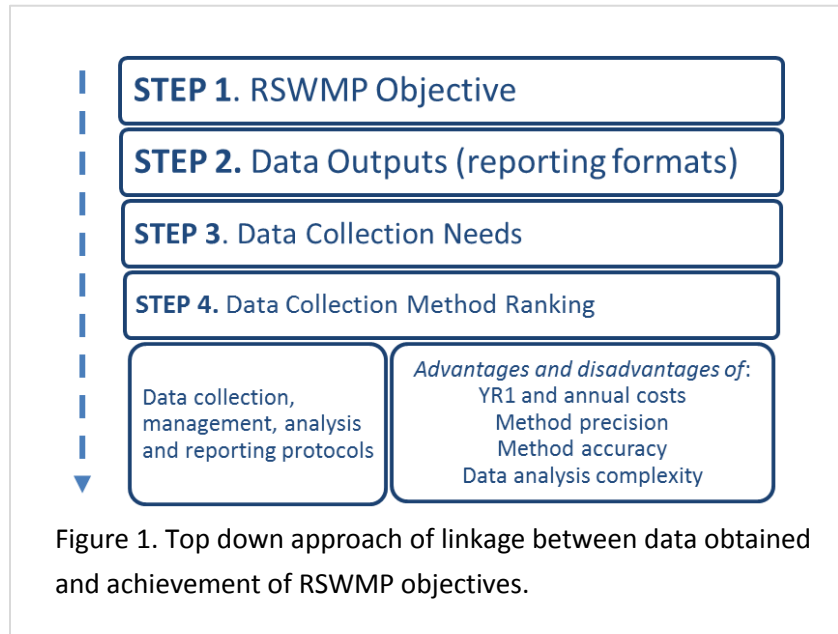
Figure 1. Top down approach of linkage between data obtained and achievement of RSWMP objectives.

collection methods to ensure the data obtained can be efficiently managed and reported in standardized formats that will address the specific RSWMP objective. The fully burdened cost per site to achieve each objective is used to scale the monitoring design, network size, data collection, management, analysis, and reporting methods, as well as the priority pollutants for inclusion into each objective.

The RSWMP objectives described in Section 2 have been defined over years of discussions, iterations and evaluation of the priority needs of stormwater monitoring in the Tahoe Basin (*Step 1*). The linkage between the RSWMP objective and the associated data output format is critical. This document defines the measured units, temporal resolution and the final annual reporting formats of the RSWMP datasets to pair collected data with specific program objectives (*Step 2*). Once the final formats, metrics and units were defined, the data needed to create these outputs were identified (*Step 3*). Any monitoring parameters that were not explicitly needed to generate the annual reporting formats were eliminated. This allowed the development team to focus on obtaining necessary data with the available resources. Data collection for any parameter of interest can be generated using an array of methods and techniques that vary in cost, complexity, accuracy, sampling precision, etc. as described in Section 6.1

With funding availability as a critical driver, site-specific establishment and ongoing annual cost estimates to obtain and manage the raw data were generated and used to inform the preferred data collection methods for the currently funded primary objective #1. Given a range of funding restrictions, data collection techniques that could cost-effectively achieve the data needs were selected (*Step 4*). The cost estimates were used to define the optimal monitoring methods and site network size that would best achieve the objective given feasible funding expectations. Sections 7 and 9 provide the specific outcomes of each of these steps for status and trend monitoring and CEC refinement monitoring. Section 8 provides the critical metrics to consider for project effectiveness assessments (*Step 3*). Steps 2 and 4 were not completed for this objective as they will be project specific.

4   ORGANIZATIONAL CHART, PARTNERS, AND COLLABORATION

4.1   ROLES AND RESPONSIBILITIES

For RSWMP to achieve the directives and objectives outlined in Sections 1 and 2, the program will require extensive collaboration between Tahoe Basin executives, local scientists, regulatory agencies, state political leaders and potential funders. It will also require effective communication with local California and Nevada stormwater jurisdictions, environmental groups, and other watershed stakeholders. The proposed RSWMP structure integrates existing groups involved in stormwater regulation, management, and scientific research in the Tahoe Basin. Figure 2 illustrates the proposed interactions between these groups.
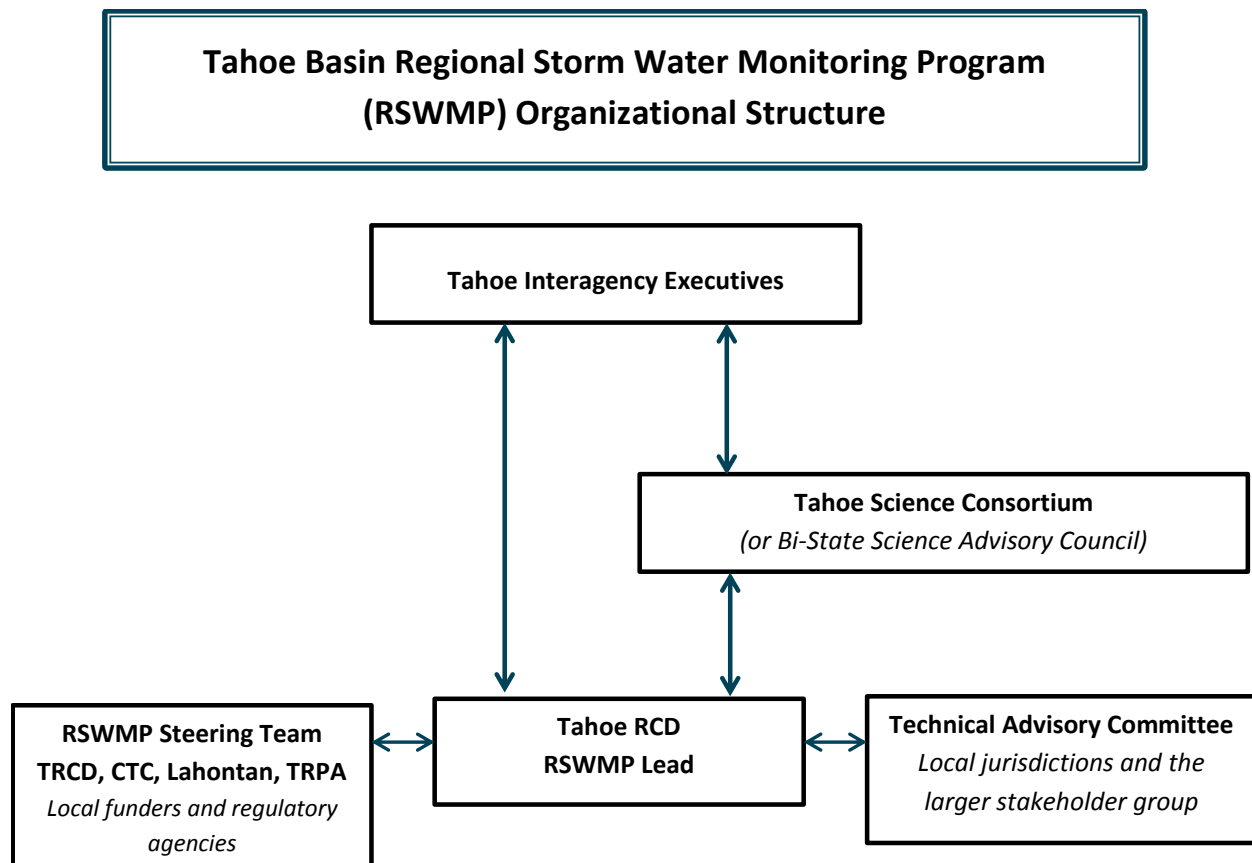
Figure 2: RSWMP Organizational Chart

The Tahoe Interagency Executives (TIE) are a non-decision making body that provides information on Lake Tahoe priorities to political leaders to support funding needs at the local, state and federal levels. It was formed in 2006 and is composed of one executive representing each of the following agencies: TRPA, United States Forest Service, Nevada Division of State Lands, California Tahoe Conservancy (CTC), Lahontan Regional Water Quality Control Board (Water Board) , local jurisdictions (representative from Placer County), Washoe Tribe, the Tahoe Science Consortium (TSC), the private sector (representative from the Lake Tahoe Federal Advisory Committee) and the Nevada Division of Environmental Protection (NDEP). Their primary purpose is to provide overall leadership, interagency integration, coordination, and strategic direction to the Environmental Improvement Program (EIP). Input and support from the TIE or a subset of relevant Tahoe Executives on RSWMP direction and priorities, as well as potential funding opportunities and what is required to sustain RSWMP in the Lake Tahoe Basin, is a critical element in RSWMP implementation. As depicted in Figure 2 above, the RSWMP lead from the Tahoe Resource Conservation District (Tahoe RCD lead), or a representative from the TSC (or a newly formed bi-state Science Advisory Council) will interact with the TIE at its regularly scheduled meetings when appropriate or a subset of relevant Tahoe Executives as needed. The Tahoe RCD lead will present informational items at least once a year to help ensure RSWMP program priorities and needs remain prominent. It is anticipated that the establishment of a bi-state Science Advisory Council (through California Senate Bill 630) will promote and enhance the best use of available scientific information on

matters of interest to both states. The Science Advisory Council is expected to be non-regulatory, with a majority of members comprised of scientists with expertise in disciplines pertinent to achieving and maintaining activities that will advance the attainment of TRPA's environmental thresholds and the EIP. Given this role, the Science Advisory Council may serve as a resource for scientific expertise to support RSWMP. The Science Advisory Council will likely make recommendations to the Tahoe RCD Lead and the RSWMP steering team. They will also likely meet with the TIE through executive level discussions that shape the vision and guide the evolution of urban stormwater monitoring in Lake Tahoe.

The RSWMP Steering Team is comprised of representatives from the Tahoe RCD, TRPA, the Water Board, and the CTC. The primary function of the Steering Team is to provide program guidance, help identify funding opportunities for urban stormwater monitoring needs in the Lake Tahoe Basin, and build lasting partnerships that support program accountability. The Tahoe RCD is the project lead on the Steering team and will provide programmatic coordination and administration, as well as conduct and manage all stormwater monitoring activities, as funding allows.

The RSWMP Technical Advisory Committee (TAC) is comprised of representatives from local California and Nevada stormwater jurisdictions, funders, regulatory agencies, scientists, consultants, environmental groups, and concerned citizens. The TAC provides feedback and support to the RCD lead and the Steering Team on RSWMP direction, current monitoring activities, monitoring locations, data collection needs, management questions, funding strategies, reporting and a variety of other issues that may arise as RSWMP is developed and implemented. The RCD lead will ensure that the TAC remains informed and engaged in the RSWMP process through informal updates at Storm Water Quality Improvement Committee (SWQIC) and Implementers' Monitoring Program (IMP) meetings, as well as at more formal RSWMP TAC meetings.

An RSWMP Scientific Advisory Group (SAG) was formed to provide scientific leadership during the planning and development phase of RSWMP Phase II and to produce RSWMP guidance documents in collaboration with the Steering Team. Representatives from the Desert Research Institute (DRI), 2NDNATURE, Northwest Hydraulic Consultants (NHC), the California State Water Board, and the Center for Watershed Protection are part of the RSWMP SAG. This group was assembled to help develop program structure and guidelines for RSWMP, but is not represented in Figure 2 as there is no funding to support it once the final RSWMP guidance documents are complete. The TSC or the Science Advisory Council is expected to fill the long term scientific support role for RSWMP.

4.2   REAL TIME MANAGEMENT

The real time management approach seeks to improve management outcomes over time through an iterative process of system monitoring and programmatic adjustments that resolve important uncertainties and ultimately lead to improved management outcomes (Walters and Holling, 1990). It is a

learning process that recognizes the uncertainty inherent to complex system management and uses targeted management actions to improve understanding of system function. Central to this process is recognition that management decisions can be used as experimental treatments directed toward specific outcomes, and that monitoring the results of those decisions can help reduce uncertainties associated with future management decisions.

From the beginning RSWMP was intended to function as part of a larger adaptive management process for the Tahoe TMDL (Heyvaert et al 2011b). Its initial design presented a conceptual framework defined in terms of assessment teams and process flow that followed the Plan-Do-Check-Act Model used for other programs in the Tahoe Basin. Some of the structural elements presented in that cycle have changed with the RSWMP implementation realized in these documents. However, the overall process remains intact with direct linkages to management agencies and implementation groups through the TMDL Management System.

The Water Board and NDEP developed the TMDL Management System as a comprehensive adaptive management program that establishes a formal process for (1) reporting program progress, (2) gathering stakeholder feedback, (3) assessing relevant research and monitoring findings, and (4) developing and implementing program and policy adjustments in response to new information.

The TMDL has emphasized pollutant load reductions from urban storm water discharge as a priority for achieving lake clarity targets. RSWMP will provide the information needed to track load reduction progress over time and to help inform real time management program tracking and accounting tools. Each year (as funding allows) the Tahoe RCD will produce an Annual RSWMP Report (Annual Report) summarizing the scientific findings of the funded objectives following the data analysis and reporting protocols outlined in this guidance document. The TMDL program managers will consider RSWMP Annual Report findings as part of their annual Synthesis of Findings and Program Adjustment Recommendation Memo, which is used to guide future TMDL implementation actions and to inform needed changes to established tracking and accounting tools. This will help guide Lake Tahoe TMDL programmatic reviews and policy adjustments on a periodic basis.

4.3   RSWMP REPORTING AND LINKS TO TMDL PROGRAM MANAGEMENT

As funding allows, the Tahoe RCD will produce an Annual Report following the protocols outlined in Appendices A and B of this guidance document. This report will summarize the scientific findings (monitoring outputs) from the current priority objectives. In collaboration with the Steering Team, the Tahoe RCD may conduct an Annual Program Review to review the Annual Report, any new scientific or management needs, potential changes in the funding horizon, and innovative data collection methods to make real time management decisions for RSWMP in the following areas:

1. Priority RSWMP goals and objectives

2. Monitoring methods
3. Funding allocations
4. Guidance document revisions

The current primary RSWMP objective is stormwater status and trends monitoring. This will likely be retained as a priority over the long-term to acquire sufficient data needed for assessing trends in urban catchments. However, other priority RSWMP goals and objectives may change to reflect new scientific findings, management needs, or fluctuations in funding. Changes in priorities may also be recommended by the Science Advisory Council, regulatory agencies associated with the TMDL Management System, funding agencies, or shaped by new provisions in statewide priorities. If any changes in priorities are identified, the information will be reflected in an RSWMP Management Memo (Memo) developed by the Tahoe RCD lead. This Memo will outline the new priorities, management objectives addressed, and monitoring methods to be used. This memo will be distributed to all relevant parties, including, but not limited to members of the RSWMP Steering Team, RSWMP TAC, and RSWMP SAG.

It is intended that data management, analysis, and reporting methods remain consistent over the long-term. However, data collection methods and techniques will inevitably continue to improve as new instrumentation becomes available and technology advances. RSWMP implementers will continue to stay abreast of stormwater data collection techniques and new technology, allowing iterative improvements to ensure the program is implemented in the most cost-effective and scientifically defensible manner possible. The Memo will also outline efficient and coordinated funding allocations to reflect any changes in priorities or fluctuations in available funding.

This document currently identifies the funding necessary to maintain the existing network of established monitoring sites around the Tahoe Basin (as of WY2018) including stormwater monitoring equipment installations, and associated administrative, management, and reporting costs (see Table 1 in Section 5.1). Should funding exceed or fall short of that amount, the Tahoe RCD, in partnership with the Steering Team, will evaluate which priorities should receive funding during a Program Review and discuss these objectives with Tahoe agency executives in the context of the TMDL Management System. Ultimately, some priorities may be dictated by the funding source; however the Tahoe RCD will work collaboratively with the Steering Team, the TAC, and Tahoe agency executives to determine how best to use funds efficiently and effectively to address RSWMP priorities that reflect management objectives.

With adequate funding, updates to this RSWMP guidance document would be made every five years or as needed if priority objectives change or if beneficial innovative monitoring technologies for data collection emerge. Updates to this document will be made by the Tahoe RCD, in collaboration with the Steering Team, and reviewed by interested stakeholders, including the Tahoe agency executives. Figure 3 summarizes the RSWMP reporting, evaluation and programmatic adjustment process.

| RSWMP Guidance Document 2015 *Outlines priority objectives, monitoring methods, funding allocations* | Annual RSWMP Implementation | Annual RSWMP Report *Summarizes scientific findings (monitoring outputs) of current priority objectives* | Program Review *Review scientific findings, changes in management or scientific needs, changes in funding, and new monitoring technologies as needed* | Adaptive Management Memo for RSWMP *Outlines changes, if any, of priority objectives, monitoring methods, funding allocations resulting from Program Review* |

Updated as needed

Updated every 5 years or as necessary

Figure 3: Flow chart of RSWMP reporting and evaluation cycle.

5   FUNDING

5.1   STATUS AND TREND FUNDING REQUIREMENTS

To assist local jurisdictions, Basin Executives, and watershed stakeholders in addressing challenges related to funding RSWMP long term, the next section presents the anticipated costs associated with continuing to fund primary objective #1: monitoring urban stormwater runoff for status and trends at long term catchment outfall sites.

Table 1 shows the average annual cost for sustained monitoring at one site as well as the network of six long term catchment outfall sites (see Table 2) for status and trends for the three primary pollutants, FSP, TP, and TN, and three secondary pollutants, NO_3+NO_2, NH_4, and SRP for ten to twelve runoff events per year. This is the recommended baseline cost to maintain the monitoring network and ensure that all pollutants are represented and a sufficient number of runoff events are sampled. Site establishment costs include equipment purchase and repair, and site installation. The average costs per year include data collection, data management, analysis, and reporting costs; sample analysis, administrative and operational costs.

Initial RSWMP funding provided the start-up costs for site establishment of the monitoring network as shown in Table 1. Each site costs $25,000 to install and equip with remote access equipment. Annual funding required to maintain six catchment outfall sites is $276,000 in 2017 $USD. This includes monitoring continuous hydrology, turbidity, and meteorology; auto-sampling for 10-12 runoff events per year; and reporting seasonal and annual runoff totals, precipitation totals, and loads for six pollutants. (Annual program costs do not increase linearly as the number of sites increases from one to six due to economies of scale.) Currently, RSWMP is funded through December 31, 2018. It is anticipated the program will secure the needed funding to continue monitoring into the future.

Table 1: Initial equipment investment plus average funding required per year to maintain the current network of six status and trend catchment outfall monitoring sites and for one site. Costs shown are in 2017 $USD.

RSWMP Objective: Catchment Status and Trends		
# of sites	Site Establishment Costs	Annual Program Cost
1	$ 25,000	$ 90,000
6	$ 150,000	$ 276,000

It is important to maintain consistent monitoring of the three primary pollutants for at least five years in order to begin establishing pollutant reduction trend in response to improved management actions in the catchment. Funding for RSWMP that falls below $276,000 could jeopardize the long term success of the program; therefore funding opportunities will be pursued from sources outlined in Section 5.4 until this baseline level is reached. Should funding exceed or fall short of these targets, decisions will be made by the RSWMP development team to determine which priorities are most important. Some funding sources have constraints on what funding can be used for and this will influence decisions as well. Annual funding considerations may include the following program priorities:

1. Addressing more/less RSWMP objectives
2. Increasing/decreasing the number of sites monitored
3. Increasing/decreasing the number of pollutants monitored
4. Increasing/decreasing the number of runoff events monitored

5.2   PROJECT EFFECTIVENESS ASSESSMENT FUNDING REQUIREMENTS

Funding requirements for assessing water quality improvement project effectiveness will be determined on a project by project basis. Each implementing agency will have different needs and budgetary constraints to consider. In addition, the specifics of each capital improvement project will vary, and assessing effectiveness will depend on improvement made and how best to evaluate water quality benefit for each specific improvement under site-specific constraints. Funding requirements will also depend on the total number of years of monitored, including pre and post project monitoring. Should RSWMP receive funding for a project effectiveness assessment, detailed monitoring design and budget allocations will be outlined before monitoring begins. No specific data collection method will be recommended for this objective as needs and funding will differ from project to project.

5.3   INFORMING CECS FUNDING REQUIREMENTS

Funding requirements for informing CECs will be identified if or when this objective is pursued.

5.4   RSWMP FUNDING MECHANISMS

RSWMP cannot function without a long term, dedicated funding source. Current program funding provides for operation, maintenance, and reporting of established storm water monitoring sites for status and trends and program development, but existing funding sources will expire by the end of calendar year 2018. To maintain monitoring continuity for status and trends and to add more objectives, the program must identify and secure additional funding. Urban storm water dischargers in California have a regulatory obligation to conduct runoff monitoring, and such requirements are likely to be included as future permit conditions. The Tahoe RCD is working with local government partners to identify a diverse set of stormwater program funding opportunities, and the resulting strategy is expected to support regulatory storm water monitoring needs that ultimately support RSWMP objectives.

The Tahoe RCD and its RSWMP partners will pursue funding from local, state, federal, and private sources. A successful RSWMP funding plan would include a variety of grant funding opportunities, as well as dedicated service fees directed toward stormwater effectiveness monitoring as part of the larger stormwater management program in the Tahoe Basin.

The intention of RSWMP is to maintain a successful program long into the future. This entails maintaining good working relationships with our agency partners to ensure that funding RSWMP remains a priority for all stormwater stakeholders in the Tahoe Basin. A successful long term program will provide the data needed to track the ultimate success of the TMDL program in reducing pollutant loading from urban areas in the Tahoe Basin and restoring Lake clarity to levels seen in the late 1960's.

5.4.1   GRANT FUNDING

Grant funds can supply a portion of the funding needs for RSWMP activities; however, gaps in funding and fluctuations in funding can be challenging to manage or predict. Typically, multi-year or annually renewed agreements can provide security to a program. The current list of grant opportunities the Tahoe RCD will be pursuing include:

- **California Water Bond**: Proposition 1, approved in November 2014 by California voters, will exceed $7.5 billion over 30 years and will fund a wide range of water-related actions and infrastructure improvements. There are $200 million dollars available for stormwater management through IRWMP described below. A wide range of projects are eligible under Proposition 1: recycled water, water conservation, local and regional groundwater and surface

water storage, and stormwater capture. These funds will not likely pay for operation and maintenance costs, however they are typically used for capital improvement projects, and could support RSWMP monitoring collaboration.

- **Integrated Regional Watershed Management Plan (IRWMP)**: The Tahoe Sierra IRWMP describes a set of coordinated strategies for the management of water resources and for the implementation of projects that protect communities from drought while improving water quantity and quality. In support of these IRWMP goals, RSWMP will incorporate approved Integrated Watershed Management activities throughout the region. RSWMP is included in the current Tahoe Sierra IRWMP project list and is eligible for funding if the region is successful in competing for these funds in future rounds.

  As part of an overall funding strategy, the two above described grants are multi-year funds that could be used for monitoring activities, capital improvements, and infrastructure improvements.

- **California Senate Bill 630**: Provides annual funding for lake shore restoration and monitoring. These funds are generated through pier and buoy fees in Lake Tahoe. The legislation sets aside a portion of the collected fees to support nearshore monitoring activities. These locally generated funds could be used to help fund monitoring and equipment for a portion of the network of stormwater outfalls around Lake Tahoe to evaluate how stormwater inputs affect near shore periphyton, phytoplankton, and aquatic invasive species growth.

- **Clean Water Act, 319 Funds**: The Clean Water Act established the Section 319 Non-point Source Management Program to support a variety of actions that target pollution reduction including technical assistance, education, technology transfer, demonstration projects, and monitoring to assess the success of nonpoint source pollution mitigation. Although these are federal funds, annual funding decisions are made by the State Water Board with input from the Regional Water Board. If the Tahoe RCD and its partners successfully compete, these funds could be used to answer questions related to lake-wide stormwater status and trends.

- **Southern Nevada Public Lands Management Act (SNPLMA)**: SNPLMA was established as a means to fund the public share of the EIP as required by the Lake Tahoe Restoration Act. SNPLMA has helped to fund projects related to restoration, water quality, wildlife, forestry, and recreation. There is currently a reserve SNPLMA fund that will likely be re-allocated in the next few years, but the process by which project prioritization and approval occurs is still under discussion with federal partners. SNPLMA funds have been used to support RSWMP previously, and the Tahoe RCD will pursue Tahoe Interagency Executive support for supplemental funds to help close the gap between current funding and future funding opportunities.

5.4.2   FEE-BASED MECHANISMS

Between 2008 and 2010, guidance provided in the EIP Finance Options Report as well as the El Dorado County Funding Analysis Strategy Report evaluated a variety of funding options that could provide viable funding for stormwater management and associated implementation of effectiveness monitoring. Although fee based mechanisms have a significant legal process to follow before approval and may be politically challenging to implement, if supported, they offer a stable funding source that allows for both short-and long-term stormwater program activities, including runoff monitoring. Below are a few of the relevant fee-based mechanisms identified in the funding analysis report (Attachment A).

- **Benefit Assessments**: An assessment is a specific fee designed to pay for improvements that confer a particular or special benefit upon a property within a defined area. An Assessment District is created by a local government agency, such as a city, a county or a special district. The proposed district includes all properties that will directly benefit from the improvements to be constructed. A public hearing is held, at which time property owners have the opportunity to vote on the assessment district. These parcels will pay their total assessment through annual installments on a property tax bill. The Tahoe RCD, in collaboration with local jurisdictions, has the authority to establish such an assessment to fund stormwater management and monitoring activities.

- **Community Facility Districts (CFDs)**: CDFs are typically used to pay for the annual operations and maintenance of something that benefits the paying property, like a local BMP installation. These fees are determined by lot size and amount of impervious surface on the parcel. The annual cost of operations and maintenance is usually based on a 20 year estimate. CFDs ("Mello-Roos Districts"), and Benefit Assessments are primarily Landscaping and Lighting Districts but can include funding for stormwater maintenance and monitoring. Both mechanisms are very effective and manageable, and are commonly used throughout California.

- **Re-development or Impact Fees:** Impact fees are one time payments from property developers to local governments or special districts for off-site improvements or evaluations necessitated by new development. Impact fees typically fund capital improvement projects and could require a certain level of monitoring as part of a regional network. In order for this approach to work there must be a rational linkage between the mitigation fees and reducing impacts to local resources. If local government established a linkage between increased urban runoff due to new development and an increased burden on its street-sweeping fleet and facilities and their storm water filtration systems and/or treatment plants, they could consider charging an impact fee on new development to compensate for this cost.

- **Property Tax/ General Tax:** Many communities are funding stormwater management needs from tax revenue. This approach could sustain aspects of stormwater management beyond stormwater monitoring and could include funding for maintenance and infrastructure needs. Beyond the challenges posed by voter approval in generally anti-tax communities, municipalities have many competing priorities, and as stormwater management costs increase, general budgets don't necessarily increase to meet those needs. This mechanism would likely fund more traditional aspects of stormwater management such as flood control and needed infrastructure improvements, but it is an additional option for generating stormwater fees. A survey of property owners on the California side of the Tahoe Basin conducted for the Placer County, El Dorado County, and the City of South Lake Tahoe in May 2017 concluded that there is some public support for a property related fee for stormwater management (see Attachment B for more information).

- **Regulatory Fees:** Although politically challenging, public agencies can impose certain "regulatory fees" without a balloting requirement. The fees are not taxes, assessments, nor property related fees, but are regulatory fees derived from County authority. These fees are commonly called Sinclair Fees and are largely imposed by public agencies upon commercial and industrial polluters to defray costs of cleanup. Since there is no ballot requirement, local government could charge a fee rate that would generate enough revenue to cover all stormwater program costs including support for RSWMP.

5.4.3   GENERAL BUDGET APPROPRIATIONS

Forming strong partnerships with local government agencies is an important first step in implementing a successful stormwater quality program. Efficiencies can be seen when agencies contribute to a common goal that serves multiple purposes, for example, the cost savings realized when local stormwater jurisdictions collaborate in the collection of stormwater monitoring data. El Dorado and Placer Counties and the City of South Lake Tahoe are currently regulated under a Municipal National Pollutant Discharge Elimination System (NPDES) permit *(NPDES NO. CAG616001 Updated Waste Discharge Requirements and National Pollutant Discharge Elimination System (NPDES) Permit for Stormwater/Urban Runoff Discharges from El Dorado County, Placer County and the City of South Lake Tahoe within the Lake Tahoe Hydrologic Unit, Order No. R6T-2017-0010)*, and are required to monitor BMP effectiveness and catchment outfalls to meet permit requirements. Data collected for permit compliance will be the primary contributor to the RSWMP dataset and will be summarized in annual RSWMP reports. If the Tahoe RCD is successful in building these partnerships, local jurisdictions could help support the RSWMP network either financially or by providing complementary datasets. In addition, other government agencies that want to achieve specific goals and reporting related to stormwater monitoring could also support the RSWMP network in addressing lake-wide status and trend monitoring needs.

5.4.4   PRIVATE/ CORPORATE FUNDING AND SPONSORSHIP

Successful sponsorship rarely captures public support unless problems impact the daily lives of residents and visitors within communities. It is for this reason that a robust outreach and education campaign must also be part of the overall funding strategy; those communities who have successfully convinced their constituents that stormwater management is a worthy investment have benefited from a stable funding source allowing for long term planning flexibility.

Perhaps the biggest advantage given to businesses that sponsor charitable organizations and events is increased visibility in the community. In exchange for a financial donation, a corporation's name and logo can be included on advertisement and other promotional material placed on the website or at the monitoring location.

As the lead administrative agency for RSWMP, the Tahoe RCD will be working with its regional partners to pursue all funding opportunities presented above. Current stormwater funding is projected through 2016. Therefore, it is critical for Basin managers to make decisions now, in 2015, about prioritizing stormwater monitoring needs.

The Tahoe RCD is actively working with local stormwater jurisdictions to identify if stormwater fees in the Lake Tahoe Basin would be supported by the local property owners and residents in California. If the community is in support, and a ballot measure or public voting opportunity was successful, base funds for stormwater management could be sustained for up to a 20 year period or longer. In addition, funding realized during the 3-5, 5-10, or 10-20 year timeframes would benefit from additional private and/or corporate sponsorship, an area that could be developed more fully by local nonprofits through fundraising efforts including the development of a strategy for attracting private partnerships.

6   RSWMP PROGRESS THROUGH OCTOBER 2017

RSWMP development, implementation and monitoring under primary objective #1 are currently funded by the California State Water Quality Control Board through Proposition 84 (through December 2017) and Placer, El Dorado, Washoe, and Douglas Counties, the City of South Lake Tahoe, the Nevada Department of Transportation, and a SNPLMA grant through the United States Forest Service (through December 2018). The specifics within the scope of work under this funding include:

1. The development of a Scientific Assessment Report (SAR) to review past stormwater monitoring in the Tahoe Basin to compile and assess viable stormwater data collection methods and identify data gaps to inform RSWMP objectives. (Submitted to the California State Water Board August 2014)

2. The development of this Framework and Implementation Guidance (FIG) document to outline RSWMP project directives, administrative structure, potential funding opportunities, primary and secondary objectives, and data collection, management, analysis, and reporting needs to address those objectives (Submitted to the California State Water Board March 2015, and this update submitted October 2017).

3. The recommendation of   autosamplers and continuous turbidimeters as the principal data collection methods for primary objective #1, status and trends monitoring at long-term index sites.

4. The establishment of six long-term status and trends index sites and four years of data collection using the recommended method (Appendix A).

5. The completion of a Tahoe specific RSWMP Data Management System (DMS) that allows for remote access to all monitoring sites, management of raw data, and data analysis and reporting in the formats outlined in this document (see Section 6.4).

6.1   MONITORING METHODS

The SAR identified three monitoring methods (data collection methods) that have been used in the Tahoe Basin that have the potential to address RSWMP objectives. They include the use of (1) autosamplers, (2) continuous turbidimeters, and (3) passive samplers. In order for these methods to be considered for RSWMP, they must have (1) a State approved Quality Assurance Project Plan (QAPP), and (2) a fully developed cost template that discloses costs associated with monitoring equipment, staffing needs, administration, and data collection, management, analysis, and reporting,. Autosamplers, turbidimeters and passive samplers are not mutually exclusive and each may be more or less appropriate under different circumstances.

Autosamplers have been used extensively around the United States and the world, and is the generally adopted data collection method among stormwater stakeholders in the Tahoe Basin. Primarily because data collected using autosamplers populated the models that were used to develop the Lake Tahoe TMDL. Autosamplers have the ability to connect to sensors that collect continuous hydrology and continuous turbidity, and they can collect discrete or composited water quality samples at any point along the hydrograph of a stormwater runoff event. With the highly variable hydrographs characteristic of urban runoff, collecting samples at many points along the hydrograph increases the accuracy of calculating event mean concentrations. The autosampler method for the collection of continuous hydrology and water quality samples currently has a State approved QAPP and a fully developed cost template. This method is recommended for addressing primary objective #1 because it results in high quality, high resolution data sets for a reasonable cost and RSWMP management staff can be assured that data collected using this method will be comparable to the original data used to determine baseline

catchment loads in PLRM and by which load reductions in response to management actions will be determined.

Continuous turbidimeters have been used for monitoring several sites around Lake Tahoe and this method has been generally accepted as a cost-effective proxy for monitoring FSP. Turbidimeters take turbidity readings at regular intervals throughout the year (10 minute interval preferred) and can therefore result in high resolution data sets. Equations relating turbidity to FSP have been established for the Tahoe Basin (2NDNATURE and DRI 2014) and thus the need for costly particle size distribution analysis on single or composite water quality samples can be eliminated. This method has been recommended for collecting data at the long-term status and trend sites because of its high resolution output and for the opportunity to do a side by side comparison of the annual and seasonal FSP load resulting from the autosampler and turbidimeter methods. An appendix to the State approved RSWMP QAPP that documents the continuous turbidimeter method was approved by the State in June 2015.

Passive samplers have been used to collect discrete water quality samples at one to three points along the rising limb of the hydrograph at a few sites in the Tahoe Basin, but they can be combined with sensor measurements like turbidimeters to enhance the monitoring data collection. Passive samplers have not been used at catchment outfalls and have not shown to be more cost effective than autosamplers for addressing primary objective #1. Additionally, this was not the method used to collect the data that populated the models that the Crediting Program were based and therefore this method was not recommended for status and trend monitoring. A QAPP for passive sampling has not been developed as of October 2017.   At the beginning of RSWMP Phase II it was anticipated that passive sampling might be used for addressing the secondary objective: Informing CECs. However, due to a lack of funding the secondary objective has not yet been pursued.

6.2   UPDATES TO THIS DOCUMENT

RSWMP Phase II development was completed in June 2017. This document marks the end of the project and includes the following updates:

1. A fully developed and updated cost table for data collection using remote access equipment (see Section 5.1).
2. A description of the Data Management System (DMS) (see Section 6.4) including data collection, data management, analysis, and reporting formats inherent in the DMS.

Future updates to this document may include:

1. Any adjustments to data management, analysis or reporting formats after several years of data collection.

2. Additional updates that may include how to track existing conditions in catchments to help account for possible variability in year to year status and trends data.

6.3   CURRENT MONITORING SITE NETWORK

RSWMP site installation and event monitoring was funded by both the California State Water Quality Control Board through Proposition 84 and the Southern Nevada Public Lands Management Act (SNPLMA) sponsored by the US Forest Service. The RSWMP Steering Team determined that six long-term status and trend sites should be maintained, therefore, all catchment outfall sites are being monitored as RSWMP long-term status and trend index sites as highlighted in this report for primary objective #1 as well as for catchment scale load reduction estimates required for compliance with the Lake Tahoe TMDL. Additionally, three BMP effectiveness sites have been monitored for pollutant removal efficiency and began to address the secondary RSWMP objective of informing CECs in PLRM. However, only two of the three current effectiveness sites are expected to continue in the network beginning October 2017. A new site will be substituted to assess the effectiveness of repaving a road surface in reducing FSP contributions to stormwater runoff beginning October 2017. Table 2 defines the characteristics of each monitoring site and Figure 4 shows the regional distribution of the sites.

Table 2: List of monitoring sites (2014-2017) including designation as a catchment outfall monitoring site for long-term status and trends or a BMP monitoring site, , catchment size, jurisdictional location, and funding source and funding horizon.

| Site Name	Acronym	Catchment Outfall	BMP	Total Acres	Jurisdiction	Funding Source and Horizon
Lakeshore	LS	✓		97.8	Washoe County	SNPLMA and Jurisdictions through December 31, 2018. Jurisdictions only beginning 2019.
Pasadena	PA	✓	✓	78.9	City of South Lake Tahoe	SNPLMA and Jurisdictions through December 31, 2018. Jurisdictions only beginning 2019.
SR431	S5		✓✓	0.61	Nevada Department of Transportation	SNPLMA, Jurisdictions, and extra from NDOT through December 31, 2018. Jurisdictions/NDOT only beginning 2019.
Speedboat	SB	✓		28.9	Placer County, Caltrans	SNPLMA and Jurisdictions through December 31, 2018. Jurisdictions only beginning 2019.
Tahoe Valley	TV	✓		320.9	City of South Lake Tahoe	SNPLMA and Jurisdictions through December 31, 2018. Jurisdictions only beginning 2019.
Tahoma	TA	✓		49.5	Placer County, El Dorado County, Caltrans	SNPLMA and Jurisdictions through December 31, 2018. Jurisdictions only beginning 2019.
Upper Truckee	UT	✓		84.5	City of South Lake Tahoe, Caltrans	SNPLMA and Jurisdictions through December 31, 2018. Jurisdictions only beginning 2019.
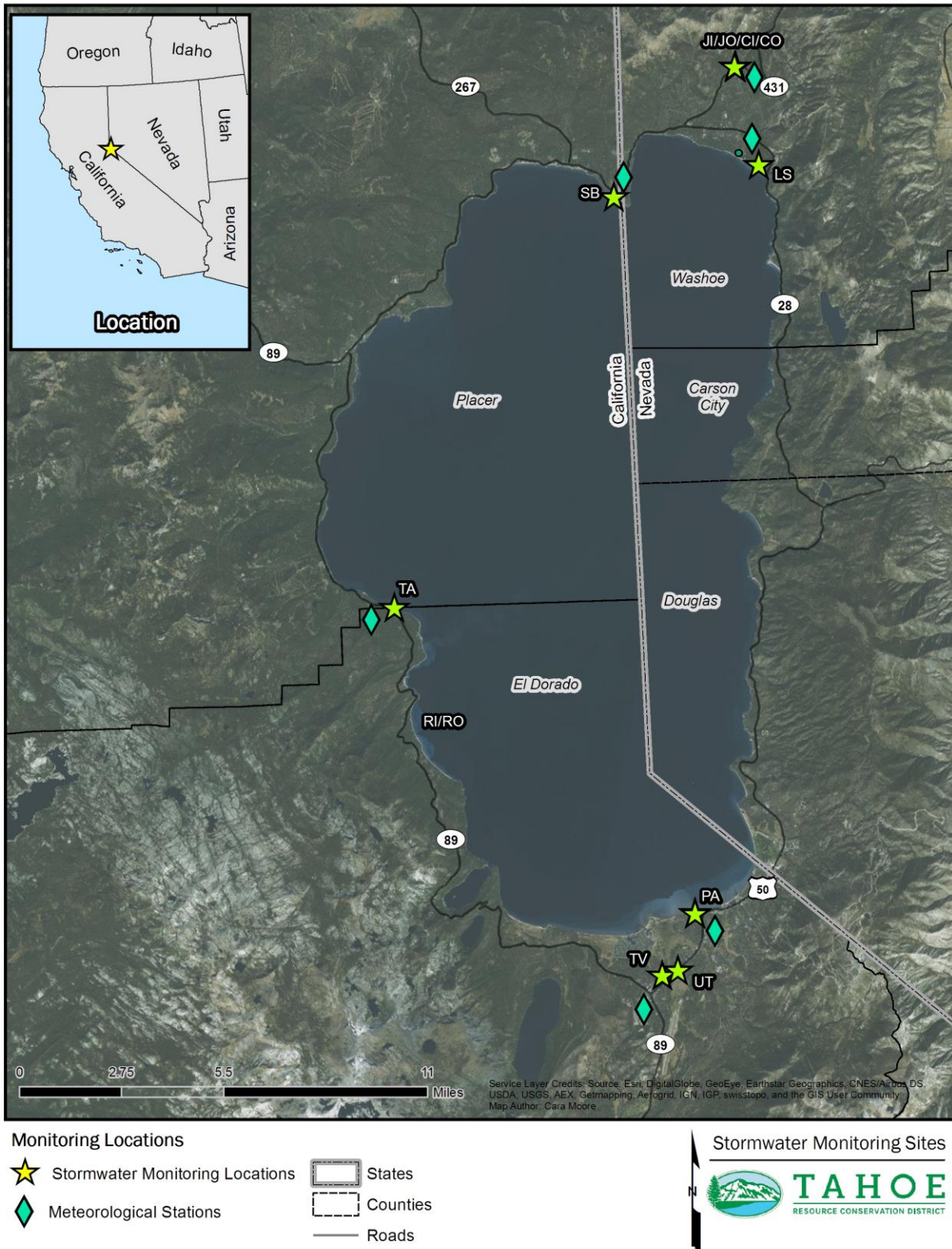
Figure 4: Map showing locations of monitoring sites water years 2014-2017. Please refer to Table 2 for site details and acronym meanings.

The site selection criteria, instrumentation, data collection and management approach, and QAQC protocols for all sites are detailed in the Implementers' Monitoring Plan (TRCD 2013) and follow RSWMP recommended monitoring methods and protocols for status and trends (Appendix A). Site instrumentation and data collection and management for all sites after completion of the Data Management System in December 2016 is described in Section 6.4 below. The first annual report for these sites was produced by the Tahoe RCD and submitted to the Water Board, NDEP, and all partnering jurisdictions on March 15, 2015, the second on March 15, 2016, and the third on March 31, 2017. The first five years of monitoring will only produce status reports; trend evaluations will begin after five complete water years of data. Resources to continue compliance monitoring currently exist through December 31, 2018.

6.4   RSWMP DATA MANAGEMENT SYSTEM

Following the submission of this guidance document in March of 2015, work on a non-proprietary, Lake Tahoe stormwater RSWMP Data Management System commenced. The RSWMP Data Management System became fully functional January 2017, with the capability of producing the performance metric outputs in the reporting formats described in Sections 7.8 and 9.8.

The amount of field and laboratory data collected for evaluating stormwater hydrology and water quality characteristics can quickly exceed the capacity of simple database systems and the ability of project personnel to provide consistent, timely and reliable assessment. For example, tracking hydrologic data at a ten-minute interval for only one monitoring site, generates over 50,000 individual records in the course of a single year. It soon becomes evident that a more robust approach is necessary when this expands to numerous sites monitored over many years, recording multiple variables, often collected at dissimilar or irregular time intervals. Furthermore, this must be implemented in a programmatic manner that preserves the integrity of the data, provides efficient management, supports quality assurance, facilitates access to the data, and ultimately extends its application to insightful tools that address both research and management needs.

Modern data management recognizes that data quantity is expanding rapidly. Advances in hardware and software have made it practical to assemble and retain these base data streams for on-going analysis, relational queries, planned comparisons and post-hoc tests. A well-planned data management system facilitates these functions as well as data protection, quality assurance, efficient management and reporting.

The RSWMP Data Management System is not simply a new relational database for maintaining stormwater records. Rather it is the integrated assemblage of tools and processes leading from data acquisition to structured reporting that addresses specific management and research needs. Several

components for this system were assembled in anticipation of RSWMP development and as supporting tools for the Tahoe TMDL. An overview of the system and linkages is provided below.

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┌─────────────────────────────────┐
│         Tahoe RSWMP             │
│  Data Management System (DMS)   │
└─────────────────────────────────┘

┌──────────────────────────────┐        ┌──────────────────────────────┐
│  ISCO 6712 Automated Sampler │ ─────► │ Campbell CR1000 Datalogger   │
│  ISCO 730 Bubbler Module or  │        └──────────────────────────────┘
│  750 Area Velocity Flow Module│                     │
│  FTS DTS-12 Continuous        │                     ▼
│  Turbidimeter                │        ┌──────────────────┐   ┌──────────────────┐   ┌──────────────┐
└──────────────────────────────┘        │     Acuity       │   │ RSWMP Analysis   │   │   LT Info    │
                                        │ (raw and post    │   │ and Reporting    │   │ (public      │
                                        │ processed        │   │ Tool             │   │ interface)   │
                                        │ discharge/       │   │ (computations    │   └──────────────┘
                                        │ turbidity/       │   │ and reporting    │
                                        │ meteorological   │   │ output)          │
                                        │ data)            │   └──────────────────┘
                                        └──────────────────┘            ▲
┌──────────────────────────────┐                 │                      │
│  Results of sample analysis  │ ──────┐         ▼                      │
│  (Excel format)              │       │  ┌──────────────────────┐      │
└──────────────────────────────┘       ├─►│  Tahoe BMP Database   │──────┘
┌──────────────────────────────┐       │  │ (site characteristics,│
│  Old discharge/turbidity/    │ ──────┘  │ continuous            │
│  meteorological data         │          │ discharge/turbidity/  │
│  (Excel format)              │          │ meteorological data,   │
└──────────────────────────────┘          │ analytic data,        │
                                          │ historic data)        │
                                          └──────────────────────┘
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The Tahoe Stormwater and BMP Performance Database (Tahoe BMP Database - Heyvaert et al. 2010) was built as an internet-accessible SQL Server database designed to assemble and manage the many different types of data derived directly from stormwater monitoring projects. This includes data from meteorological instrumentation, continuous hydrologic measurements and data from in-situ sensors collected from monitoring locations not instrumented with remote access equipment, as well as results from laboratory analyses and metadata associated with site characteristics, maintenance activities, and watershed condition. It provides the capability for creating structured queries, automated statistical analyses and formatted reporting, as well QA/QC tracking and secure access options. Output from this database will be linked to the TMDL Management System through analysis routines and reporting formats that correspond directly to recommendations developed for RSWMP (this guidance document; 2NDNATURE 2014).

The Monitoring Site Management Tool (Acuity) is a web portal that provides RSWMP personnel with remote access to associated monitoring sites instrumented with a Campbell CR1000 datalogger and a cell modem. This tool allows users to set or change sampling parameters, visualize real-time data streams, and implement quality assurance procedures. It is designed to function behind-the-scenes as part of the RSWMP DMS to streamline data management from collection to reporting by feeding data directly into the Tahoe BMP Database. The advantages provided by Acuity include:

- Reduced personnel time in the field.
- Rapid identification of potential monitoring or equipment problems.
- Adjustment of monitoring and sampling parameters in real-time, remotely.

- Real-time graphing display and download of data that allows users to make decisions before entering the field.
- Improved quality and integrity of monitoring and sampling data, with backup files available for both raw and quality-assured data.
- Linked data transfer on command directly into the Tahoe RSWMP Database.

The RSWMP Analysis and Reporting Tool is a web application and Application Program Interface (API) that allows the TRCD and LTInfo users to access and visualize summarized data from the Tahoe BMP Database. The Tool can generate annual reports, BMP reports, and trends reports as described below.

- **An annual report** can be generated by selecting a stormwater site, a monitoring location within that site, and a water year as input. The Tool then generates a map showing the site, a summary table of site characteristics including area and land use, and tables and interactive charts showing daily and seasonal hydrologic and water quality summaries.

- **A BMP performance report** can be generated by selecting a BMP type and one or more BMP sites of that type (as available). The Tool provides a map and summary of the drainage area characteristics of each BMP site selected, effluent concentration statistics, and box plots of influent and effluent concentrations.

- **A trends report** summarizes long-term trends for a selected stormwater site including the number of monitored storm events for the site, precipitation and runoff volume trends and water year and seasonal load trends for all pollutants monitored.

The availability of each of the reports described above is dependent on the data available in the Tahoe Stormwater BMP Database.

LT Info is a public-facing web-based platform that displays the results of the stormwater runoff monitoring conducted under RSWMP. It links directly to the RSWMP Analysis and Reporting Tool via a web services API and displays complicated stormwater monitoring data in easy to interpret formats for everyone from stormwater program managers, to regulators, project funders, and the general public, to use for their unique and individual purposes.

Development of the RSWMP Data Management System (DMS), and in particular the RSWMP Analysis and Reporting Tool, included updates to the existing Tahoe BMP Performance Database so it matches recommendations for the analytic routines and reporting formats described in this guidance document and for the TMDL program (2NDNATURE 2014). Reporting routines were added to provide data output in formats compatible for uploading to the California Environmental Data Exchange Network (CEDEN) to meet State requirements for data dissemination. Ultimately, the techniques and capabilities of the RSWMP DMS help automate day to day tasks, ensure data integrity, provide quality assurance, and streamline the complexities of long-term stormwater data management and reporting for RSWMP.

7   PRIMARY OBJECTIVE IMPLEMENTATION: URBAN STORMWATER STATUS AND TRENDS

Tracking and reporting urban stormwater status and trends will be achieved by consistently monitoring urban stormwater at the established six catchment outfall index sites. These data will be used to:

- Represent the status of stormwater quality from the established long-term index sites
- Provide standardized, comparable and representative data to document the status of urban stormwater quality in the Tahoe Basin over the long term;
- Evaluate trends in urban stormwater beyond climatic variability as a result of consistent long-term monitoring of runoff volumes and pollutant loads.
- Provide reports to inform the TRPA four year Threshold Evaluation.

In order to meet the status and trend objective, it is anticipated that sites need to be consistently maintained and monitored for more than a decade. Short or inconsistent monitoring durations limit the application of the urban catchment outfall monitoring to evaluate trends for volumes and/or each pollutant of interest.

7.1   STATUS AND TRENDS: PRIORITY POLLUTANTS

The ongoing decline in Lake Tahoe's deep water transparency is a result of light scatter from fine sediment particles, primarily those less than 16 micrometers in diameter (FSP<16 μm) and light absorption by phytoplankton. The addition of phosphorus and nitrogen to Lake Tahoe contributes to phytoplankton growth in the pelagic zone and periphyton growth in the nearshore. Fine sediment particles are the most dominant pollutant contributing to the impairment of the lake's deep water transparency, accounting for roughly two thirds of the lake's impairment. Because FSP, phosphorus, and nitrogen are responsible for Lake Tahoe's deep water transparency loss, Lake Tahoe is listed under Section 303(d) of the CWA as impaired by input of these pollutants. The goal of the Lake Tahoe TMDL is to set forth a plan to restore Lake Tahoe's historic deep water transparency by reducing the input of these three primary pollutants.

RSWMP status and trend monitoring will focus on the priority pollutants known to impair lake clarity (LRWQCB and NDEP, 2010):

1. Fine Sediment Particles (FSP < 16 um)
2. Total Phosphorous (TP)
3. Total Nitrogen (TN)

At a minimum, RSWMP will conduct FSP, TP, and TN sampling at all active status and trend sites. The inclusion of dissolved species (orthophosphate (OP) and dissolved inorganic nitrogen (DIN)) will depend

upon available resources and program priorities. Decisions to include OP and/or DIN will be made on a site-by-site basis. To evaluate FSP and nutrient loading trends at selected sites, sampling must be continuously and consistently conducted over at least a five year period.

Depending on site installation characteristics, autosamplers may not always represent the full range of particle sizes in water, especially for particles larger than fine sands (>250 μm). This is due to the fact that the suction capacity of the peristaltic pump in the autosampler in conjunction with the length of the suction tube may not always be adequate to draw the larger particles. However, fine sediment particles (FSP: <16 μm) are a primary pollutant of concern known to negatively impact Lake clarity. Thus, the autosampling technique is expected to adequately meet requirements of the TMDL.

7.2   STATUS AND TRENDS: DATA OUTPUT METRICS

Specific metrics will be used to document status and evaluate trends in urban stormwater runoff over time. Status will be reported on annual water year intervals and include the following metrics for each site in the Status and Trend RSWMP network:

1. **Unit Surface Runoff**: The unit surface runoff (inches time^{-1}) is the total discharge volume (ac-ft time^{-1}) divided by the catchment size (acres) with appropriate unit conversions from feet to inches. Unit surface runoff is a metric that can be compared between different sites across the Basin and over time. It is the discharge metric used in the trend analysis.

2. **Percent Surface Runoff**: The percent runoff is expressed as the fraction of rainfall discharged from the catchment as stormwater runoff (unit surface runoff divided by precipitation). It is anticipated that effective actions to disconnect impervious surfaces and infiltrate stormwater will directly decrease the percent runoff in urban catchments. This metric can be compared over time at a single catchment and between catchments of different sizes and land use distributions.

3. **Total Runoff Volume**: The total seasonal (ssn) and annual discharge volumes are reported for each site. The units for total discharge volumes are either ac-ft ssn^{-1} or ac-ft yr^{-1}.

4. **Pollutant Unit Loading Rate**: The unit pollutant mass load (lb ac^{-1} time^{-1}) is the total pollutant mass load (MT) divided by the catchment size (acres) with appropriate unit conversions from metric tons to pounds. Unit surface runoff is a metric that can be compared between different sites across the Basin and over time. It is the pollutant load metric used in the trend analysis.

5. **Total Pollutant Load**: The total seasonal and annual pollutant mass loads are reported for each site. The units for total pollutant mass loads are either MT ssn^{-1} or MT yr^{-1}.

7.3   STATUS AND TRENDS: SITE SELECTION CRITERIA

RSWMP will have limited funding to implement the status and trend monitoring for the foreseeable future. The site network of urban catchment outfalls will inherently possess less than the recommended number of sites necessary to implement a probabilistic sampling design, or even a sampling design that adequately represents the range of stormwater quality conditions throughout the Tahoe Basin. Because of the reality of fiscal challenges facing RSWMP, and because the development team is aware of the watersheds where water quality improvement projects are being implemented, very specific and targeted site selection criteria were defined in order to optimize the available resources to best achieve this RSWMP objective.

The site selection criteria are:

1. **Direct Connectivity to surface water.** Urban catchment outfalls that directly discharge to the Lake or other perennial surface water are a priority to increase confidence that the measured status and trend results are indicative of the stormwater quality delivered to Lake Tahoe.

2. **High Pollutant Loading**. Given the limitation in the number of sites that can feasibly be included the RSWMP status and trend network, the development team agreed there is a relatively greater ability to detect trends in pollutant load reductions in catchments with relatively high pollutant loading rates and where actions to reduce those loads are most likely to occur.

3. **Water Quality Improvement Plans.** As RSWMP seeks to track the integrated effectiveness of water quality improvement actions, it is important to select sites where improvements are planned in the catchment. All jurisdictions have completed initial stormwater load reduction planning and, through this process, have identified urban catchments where they plan to implement improvements to demonstrate progress. Based on the completion of Stormwater Pollutant Load Reduction Plans, there is reasonable assurance that local jurisdictions will be prioritizing water quality improvement actions in catchments where pollutant loading rates are relatively high.

4. **Absence of Non-Urban Runoff.** The influence of non-urban runoff to the selected point of monitoring can dilute the urban signal, similarly reducing the power of the datasets obtained to detect a decreasing trend in pollutant loading rates, should one exist.

5. **Equitable Jurisdictional Representation.** Each urban jurisdiction has a unique set of management priorities, available funding, political leaders, socio-economic resident base, etc. that will result in differences in how each jurisdiction implements actions to protect and reduce pollutant loading to the Lake. With adequate funding, the optimal network would include, at a minimum, sites that collectively drain lands managed by all 7 of the urban jurisdictions: Douglas

County, NV; Washoe County, NV; Nevada Department of Transportation; City of South Lake
Tahoe, CA; Placer County, CA; El Dorado County, CA; and California Department of
Transportation (Caltrans).

7.4   STATUS AND TREND: DATA COLLECTION NEEDS

To report annual and long term status and trends of stormwater quality from select locations in the
formats desired (Figures 5 and 6), management of the following datasets is required. The RSWMP
temporal resolution for data collection at an urban catchment outfall and supporting rationale for each
parameter is provided in Table 3.

Table 3. Summary of RSWMP status and trend urban catchment outfall monitoring parameters, calculated values
and rationale for selection.

Parameter (ID)	Sampling Resolution	Reporting Resolution (units)	Rationale
Discharge	10 min	Cubic feet per day (cfd)	Stormwater runoff is highly intermittent. The sampling resolution of 10 min is frequent enough to obtain data from the majority of runoff conditions while minimizing the amount of data points obtained to extent possible. The discharge is integrated and managed in the RSWMP Data Management System as a total daily discharge volume (Q_d).
Pollutant Concentration	10 min	mg L^{-1} (daily)	FSP concentration sampling on the same temporal resolution as discharge is desired. Stormwater research in the Tahoe Basin has well vetted the use of automated turbidity probes as a defensible and reliable proxy for fine sediment particle concentrations ([FSP]). The 10 min concentrations are converted to loading rates (mg sec^{-1}) using the associated instantaneous discharge volume and then integrated and managed in the RSWMP Data Management System as a total daily load P_d (see below).
	Event based		To date, automated probes have not been well tested for their application in Tahoe for nutrient species. Targeted flow-weighted sampling of an annual distribution of runoff event types will be conducted for nutrient species and detailed data management protocols are used to standardize how event sample results are used to define the $[P]_d$ for each day of record.
Pollutant load	Calculated	g d^{-1}	Calculated using discharge and pollutant concentration with proper unit conversions P_d.

Parameter (ID)	Sampling Resolution	Reporting Resolution (units)	Rationale
Precipitation	10 min	in d^{-1}	Local stations will be used to calculate annual/seasonal percent surface runoff as local variations in total precipitation can be significant around the lake. Correlations between local stations and regional long term station for daily precipitation will be made and used to fill data gaps in local precipitation data. The Tahoe City station will be used as the regional long term station to define season and water year type as is assumed that a wet or dry year determination will apply to the entire basin even in total precipitation varies.

The RSWMP Data Management System status and trend module will manage site-specific data from urban catchment outfalls in the format summarized in Table 4. The standardization of the annual data management formats allows future flexibility to revise and refine data collection methods as appropriate. It also provides the ability to optimize the day to day data collection techniques based on available resources.

Table 4. Data fields and units for site metadata and annual stormwater monitoring dataset obtained from RSWMP status and trend urban catchment outfalls.

Urban Catchment Outfall Site Metadata Fields					
UCO Site ID	Jurisdiction ID	Drainage area (ac)	% IMP	% DCIA	WY Initiated

Urban Catchment Outfall Time Series Data Fields				
UCO Site ID	Date (mm/dd/yyyy)	Q_d (cf d^{-1})	$[P]_d$ (mg L^{-1})	P_d (g d^{-1})

Regional and local daily precipitation data is required to perform the runoff and pollutant loading trend analyses at each of the urban outfall sites. Each catchment outfall site will be paired with a nearby meteorological station to capture local precipitation data. Local precipitation data will be used to calculate % surface runoff as described in Section 7.2 and for site-specific trend analyses for precipitation. However, while local precipitation and weather patterns undoubtedly exist, regional seasonal patterns are consistent throughout the Tahoe Basin. In other words, a wet winter would be consistently defined for both Tahoe City and South Lake Tahoe, even if the relative precipitation totals

for each location vary. Therefore one precipitation dataset will be used to define seasonal types (wet or dry): the long term Western Regional Climate Center (WRCC) station located in Tahoe City (gauge #48758; www.wrcc.dri.edu). This station has been consistently maintained since 1911 and can serve as a reference to track precipitation changes in the future. The extensive record permits application of a frequency analysis and categorization of season and water year types (Figures 7 and 8) which is used in the status reporting. The precipitation data used for the regional and local meteorological stations will be managed in the RSWMP Data Management System in the format summarized in Tables 5 and 6 respectively.

Table 5. Data fields and units for regional meteorology station data used to analyze regional trends for RSWMP status and trend urban catchment outfalls.

Regional Meteorology Station Site Metadata Fields				
MET Station ID	owner (weblink)	Jurisdiction ID	Elevation (AMSL; ft)	WY Initiated

Regional Meteorology Station Times Series Data Fields						
MET Station ID	Date (mm/dd/yyyy)	PPT_d (in d^{-1})	Mean Daily Air Temp (^{o}F)	Min Daily Air Temp (^{o}F)	Max Daily Air Temp (^{o}F)

Table 6. Data fields and units for local meteorology station data used to analyze local trends for RSWMP status and trend urban catchment outfalls.

Local Meteorology Station Site Metadata Fields				
MET Station ID	Jurisdiction ID	Paired Monitoring Station ID	Elevation (AMSL; ft)	WY Initiated

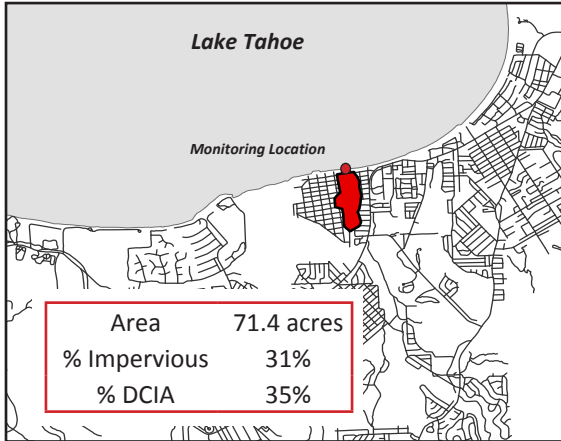| Local Meteorology Station Event Summary Data Fields*				
MET Station ID	Event Date Time Start (mm/dd/yyyy hh:mm)	Event Date Time End (mm/dd/yyyy hh:mm)	Event Duration (hh:mm)	Interevent Duration ([hh]:mm)
Total Event Precipitation (inches)	Peak Precipitation (inches/10 min)	Min Event Air Temp (^{o}F)	Max Event Air Temp (^{o}F)	Event Type

**All column headers (data fields) should be in same row – shown here in two rows due to space constraints on page.

Annual Urban Catchment Outfall Monitoring Status
Water Year 2020 (October 2019-2020)
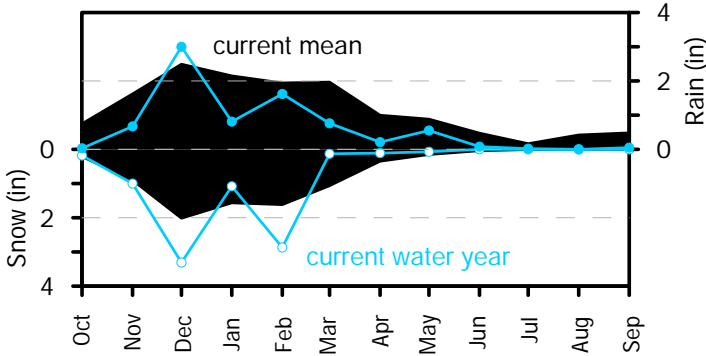## Pasadena Catchment, City of South Lake Tahoe

A. Site Location Map

Lake Tahoe

Monitoring Location

Area	71.4 acres
% Impervious	31%
% DCIA	35%

B. Monitoring and Measurement Data Collection

Parameters	Technique	Instrument/Method
Q	Stage and H Flume	ISCO 730 Bubbler
FSP	Turbidity sensor Regression equation	FTS-DTS-12 Eq. 3.5 (DRI and 2N, 2014)
TN	Autosampler	ISCO 6712
TP		

C. Monthly Rain and Snow Summary
Source: Tahoe City Gauge #48758; www.wrcc.dri.edu

D. Monthly Q and FSP Load Summary
Pasadena Catchment Outfall

E. Surface Runoff and Pollutant Load Metrics

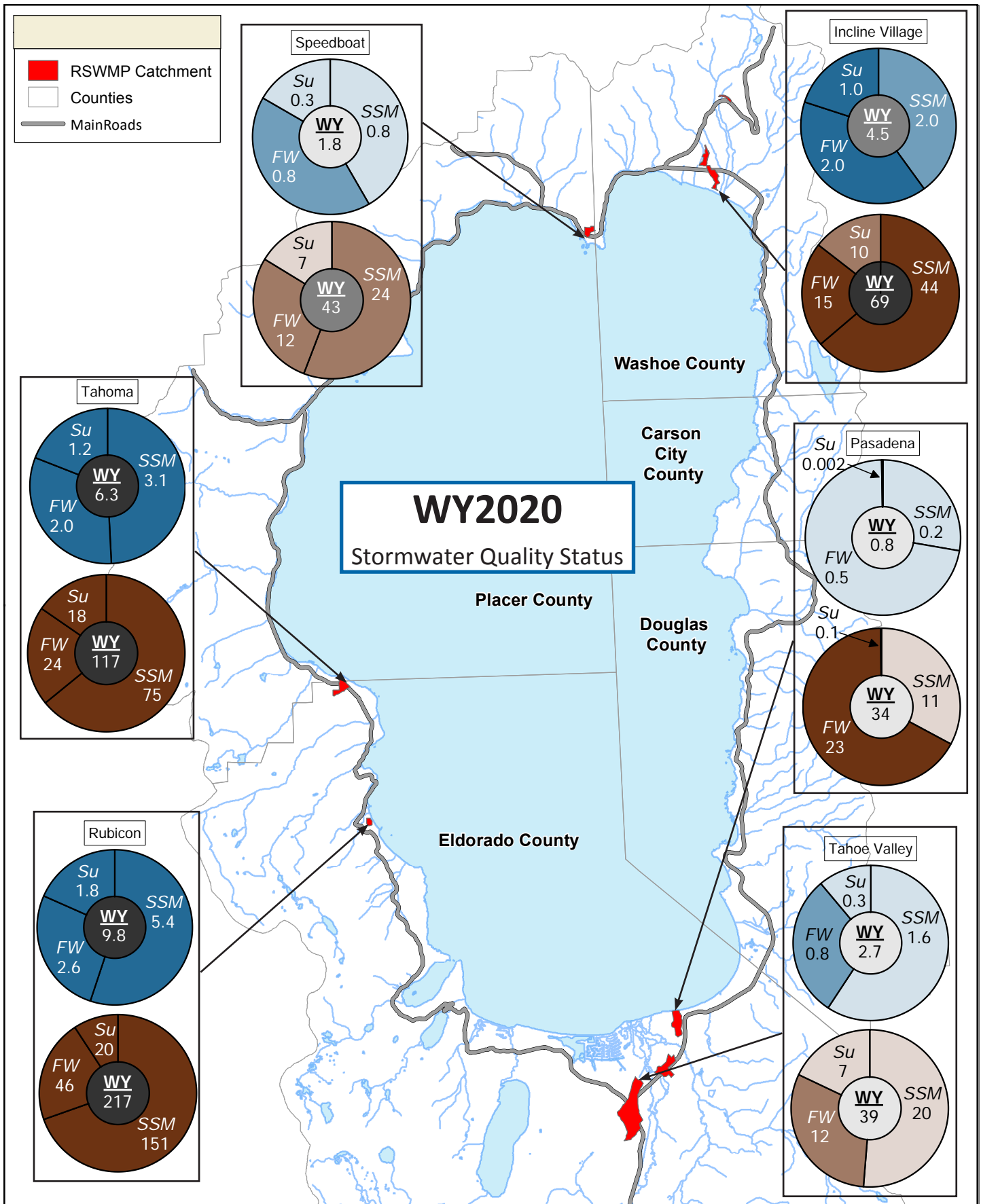| Pasadena Catchment	Units	WY 2020	Units	F/W	SSM	Su
Data Completeness	%	100		100	100	100
Duration no flow	%	62.6	%	40.4	52.2	97.5
WY/season type		V.Dry		Dry	V. Dry	V. Dry
Precipitation (PPT)	in yr^{-1}	16.6	in yr^{-1}	14.6	1.8	0.2
% runoff	%	4.5	%	3.7	11.4	0.83
Surface runoff (U-Q)	in yr^{-1}	0.75	in ssn^{-1}	0.54	0.21	0.002
Total Q (Q)	ac-ft yr^{-1}	4.46	ac-ft ssn^{-1}	3.22	1.22	0.01
FSP unit loading rate (U-FSP)	lbs ac^{-1} yr^{-1}	34.5	lbs ac^{-1} ssn^{-1}	23.1	11.4	0.07
Total FSP load (FSP)	MT yr^{-1}	1.12	MT ssn^{-1}	0.75	0.37	0.002
TN unit loading rate (U-TN)	lbs ac^{-1} yr^{-1}		lbs ac^{-1} ssn^{-1}			
Total TN Load (TN)	MT yr^{-1}		MT ssn^{-1}			
TP unit loading rate (U-TN)	lbs ac^{-1} yr^{-1}		lbs ac^{-1} ssn^{-1}			
Total TP load (TP)	MT yr^{-1}		MT ssn^{-1}			

SITE STATUS SUMMARY FIGURE 5

FIGURE 6. **WY2020**
Regional stormwater status summary. Urban catchment runoff volumes and FSP loads. Runoff reported as in yr^{-1} or ssn^{-1}. FSP loads reported as lbs ac^{-1} yr^{-1} or ssn^{-1}.

Legend:
- RSWMP Catchment
- Counties
- MainRoads

WY2020
Stormwater Quality Status

Speedboat
Su 0.3 | SSM 0.8 | WY 1.8 | FW 0.8
Su 7 | SSM 24 | WY 43 | FW 12

Incline Village
Su 1.0 | SSM 2.0 | WY 4.5 | FW 2.0
Su 10 | SSM 44 | WY 69 | FW 15

Tahoma
Su 1.2 | SSM 3.1 | WY 6.3 | FW 2.0
Su 18 | SSM 75 | WY 117 | FW 24

Pasadena
Su 0.002 | SSM 0.2 | WY 0.8 | FW 0.5
Su 0.1 | SSM 11 | WY 34 | FW 23

Rubicon
Su 1.8 | SSM 5.4 | WY 9.8 | FW 2.6
Su 20 | SSM 151 | WY 217 | FW 46

Tahoe Valley
Su 0.3 | SSM 1.6 | WY 2.7 | FW 0.8
Su 7 | SSM 20 | WY 39 | FW 12

Washoe County
Carson City County
Placer County
Douglas County
Eldorado County

2NDNATURE LLC
www.2ndnaturellc.com

Miles
0 0.75 1.5 3
1 in = 3 miles
N

Key for urban catchment outfall pollutant annual status maps

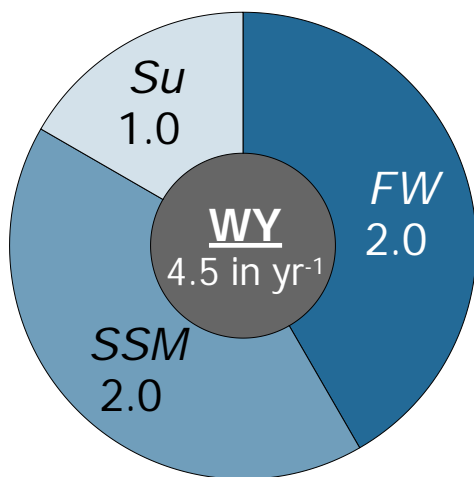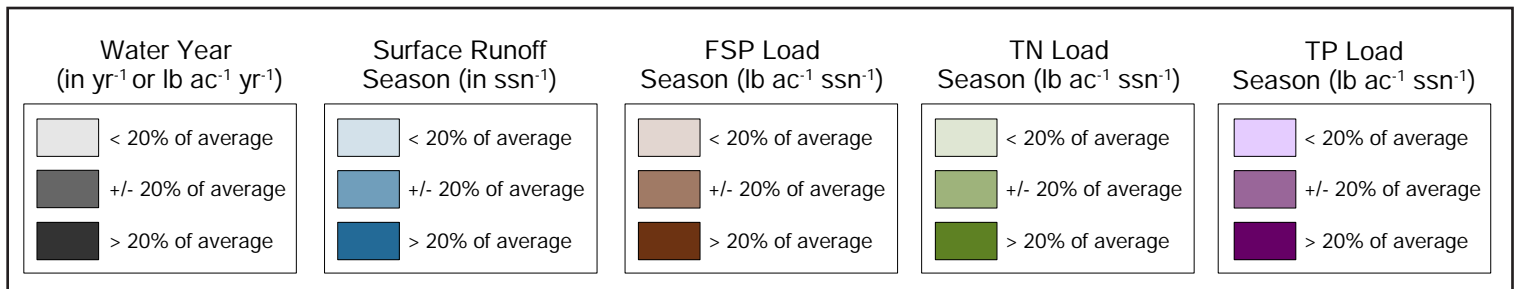*GRAPHIC GUIDE: Unit runoff and pollutant loading rates are directly comparable across sites and over time. The values for unit surface runoff are given below in inches per year for the WY and in inches per season for each season. Unit pollutant loads values are given in pounds per acre per year or per season. The seasonal contributions sum to the water year totals displayed in the center, and the size of each seasonal pie wedge is proportional to its contribution to the water year total. Available data was used to reasonably estimate the basin wide average annual values for each parameter and are shown in the table below.*

Parameter Averages by Water Year and Season

	Water Year	FW	SSM	Su
	(in yr^{-1})	(in ssn^{-1})	(in ssn^{-1})	(in ssn^{-1})
Surface Runoff	4.0	0.8	2.4	0.8
	(lbs ac^{-1} yr^{-1})	(lbs ac^{-1} ssn^{-1})	(lbs ac^{-1} ssn^{-1})	(lbs ac^{-1} ssn^{-1})
FSP Load	50	10	30	10
TN Load	TBD			
TP Load				

Water Year
(in yr^{-1} or lb ac^{-1} yr^{-1})
- < 20% of average
- +/- 20% of average
- > 20% of average

Surface Runoff
Season (in ssn^{-1})
- < 20% of average
- +/- 20% of average
- > 20% of average

FSP Load
Season (lb ac^{-1} ssn^{-1})
- < 20% of average
- +/- 20% of average
- > 20% of average

TN Load
Season (lb ac^{-1} ssn^{-1})
- < 20% of average
- +/- 20% of average
- > 20% of average

TP Load
Season (lb ac^{-1} ssn^{-1})
- < 20% of average
- +/- 20% of average
- > 20% of average

EXAMPLE: WY surface runoff was within 20% of the defined average. Fall/Winter runoff was over 20% of the seasonal average, Spring Snowmelt runoff was within 20% of the average and Summer runoff was below 20% of the average.

DESIGNED BY

Tahoe Basin Fall/Winter Precipitation Classification

Year Type	Season Type Recurrence Interval (years)	Fall/Winter (Oct-Feb) (in/yr)		Annual PPT Exceedance Probability (%)	n
		Lower (in/yr)	Upper (in/yr)		
Very Dry	11		11.41	> 91	9
Dry	4	11.42	16.25	> 67	26
Average	3	16.26	25.53	> 33	35
Wet	4	25.54	36.61	> 10	24
Very Wet	10	36.62		<10	10
Long-Term Average Seasonal Precipitation = 22.01 in/yr					
Water Year Record = 1911 - 2014					

Tahoe Basin Spring Snowmelt (SSM) Classification

Year Type	Season Type Recurrence Interval (years)	SSM (March-May) (in/yr)		Annual PPT Exceedance Probability (%)	n
		Lower (in/yr)	Upper (in/yr)		
Very Dry	12		2.91	> 91	9
Dry	4	2.92	5.18	> 67	26
Average	3	5.19	8.39	> 33	35
Wet	4	8.40	13.49	> 10	25
Very Wet	10	13.50		<10	10
Long-Term Average Seasonal Precipitation = 7.42 in/yr					
Water Year Record = 1910 - 2014					

Tahoe Basin Summer (Su) Classification

Year Type	Season Type Recurrence Interval (years)	SU (June -Sept) (in/yr)		Annual PPT Exceedance Probability (%)	n
		Lower (in/yr)	Upper (in/yr)		
Very Dry	12		0.34	> 91	9
Dry	4	0.35	0.91	> 67	26
Average	3	0.92	2.32	> 33	35
Wet	4	2.33	3.93	> 10	25
Very Wet	10	3.94		<10	10
Long-Term Average Seasonal Precipitation = 1.81 in/yr					
Water Year Record = 1910 - 2014					

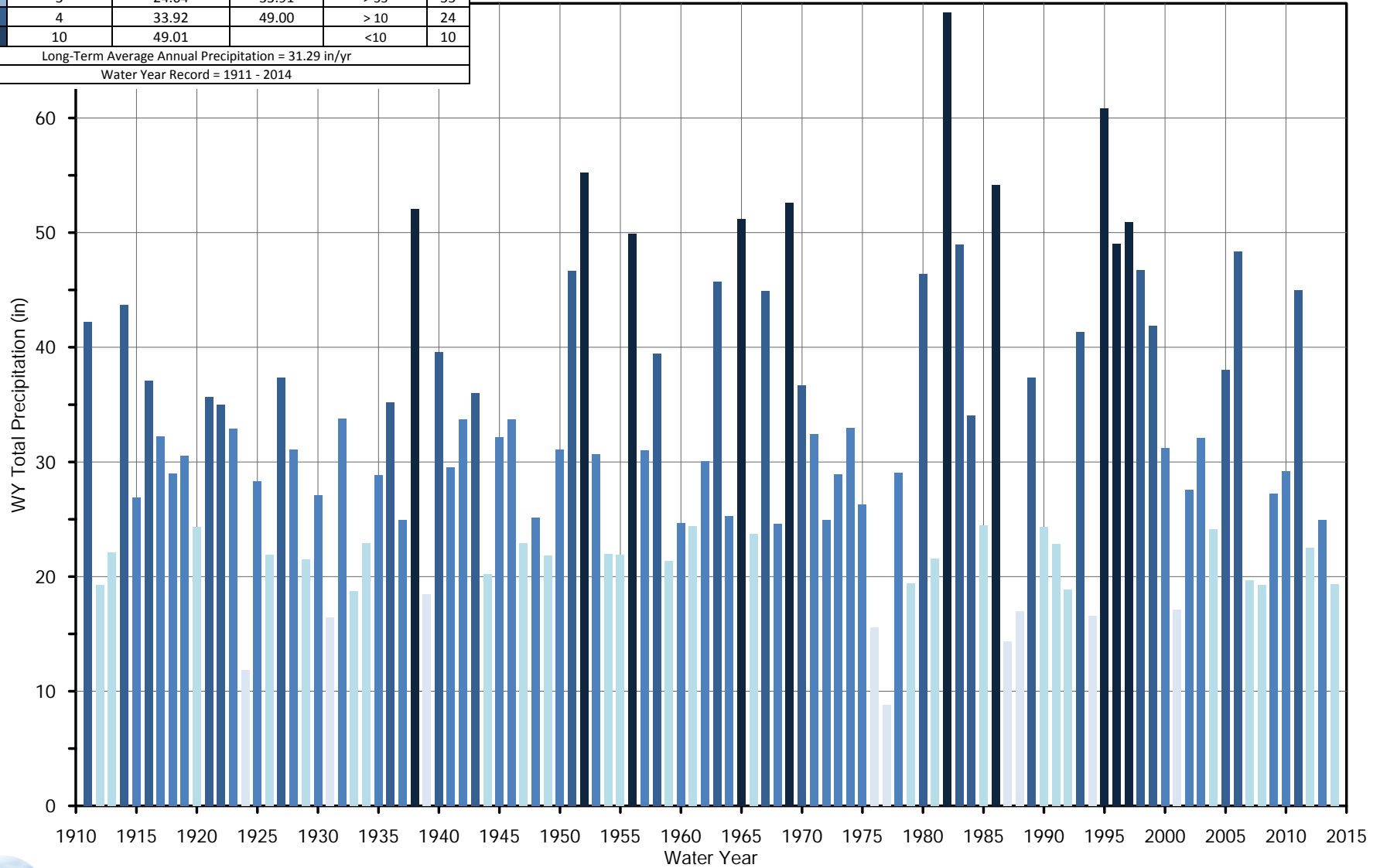Tahoe City gage (#48758) operated by the Western Regional Climate Center; Elevation: 6230 feet; http://www.wrcc.dri.edu

SEASONAL PRECIPITATION CLASSIFICATION - TAHOE CITY

FIGURE 7

Year Type	WY Type Recurrence Interval (years)	Annual Precipitation (in/yr)		Annual PPT Exceedance Probability (%)	n
		Lower (in/yr)	Upper (in/yr)		
Very Dry	11		18.60	> 91	9
Dry	4	18.61	24.63	> 67	26
Average	3	24.64	33.91	> 33	35
Wet	4	33.92	49.00	> 10	24
Very Wet	10	49.01		<10	10
Long-Term Average Annual Precipitation = 31.29 in/yr					
Water Year Record = 1911 - 2014					

Tahoe Basin Water Year Classification

Tahoe City gage (#48758) operated by the Western Regional Climate Center; Elevation: 6230 feet; http://www.wrcc.dri.edu

WATER YEAR CLASSIFICATION - TAHOE BASIN

FIGURE 8

7.5   STATUS AND TREND: DATA COLLECTION METHOD OBJECTIVES

A variety of existing data collection methods and data transformation techniques are currently available (as outlined in Section 6.1) to obtain the desired datasets and produce the associated data outputs on an annual basis (Table 4). Over the course of the multi-year RSWMP status and trend monitoring, sampling instrumentation and techniques are anticipated to evolve. By formalizing the RSWMP data collection needs and the data collection objectives, flexibility remains for RSWMP to revise and improve data collection methods should methodologies be identified that better meet the priority objectives of RSWMP. Section 4.2 outlines the real time management process RSWMP will be following in order to consider and potentially revise the urban catchment outfall data collection techniques in the future.

The following data collection method objectives have been collectively defined to guide the RSWMP method selected and documented in Appendix A for primary objective #1.

1. **Sampling Precision**: Catchment outfall status and trend data will help evaluate changes in urban runoff volumes and pollutant loads in response to management actions. Techniques and data management protocols defined by RSWMP have been designed to minimize variability in the reported seasonal and annual volumes and loads as a result of sampling techniques. Any changes to the data collection protocols defined herein (Appendix A) during the course of the RSWMP program will introduce sampling differences, reduce the sampling precision and potentially introduce additional noise into the seasonal and annual values obtained. However, as mentioned above, RSWMP will maintain the flexibility to use improved methods.

2. **Data Accuracy:** Decades of available stormwater volume and pollutant monitoring were considered by the RSWMP development team to define the most cost-effective monitoring methods that combine reasonable accuracy with the highest possible sampling precision. Site-specific cost estimates included extensive field and dataset QAQC procedures to minimize data gaps, to maximize instrument calibration and sampling representation, and to implement repeatable, scientifically defensible data management procedures.

3. **Capturing a Range of Pollutant Concentrations:** Tahoe stormwater quality monitoring is unique from stormwater monitoring in other urban regions. Due to the documented impact on the clarity of Lake Tahoe, the priority pollutant of concern has been FSP. Recent stormwater research has been leveraged to define reliable instrumentation and data management techniques to monitor turbidity on 10 minute intervals and convert to FSP concentrations. However, recent observations have heightened the concern about the potential impact of elevated nutrient loading to Lake Tahoe's nearshore environment as locals and visitors recognize declining nearshore conditions. As such, RSWMP sample and analysis protocols include relevant nutrient species to further understand the potential impact associated with urban storm water discharges.

4. **Cost Comparison:** The RSWMP development team created a standardized cost estimate template to systematically generate and compare the fully burdened cost of monitoring one urban outfall monitoring site. A variety of different methods to obtain hydrology and a defined number of pollutant concentrations were considered in this evaluation, as were program administration, data management, analysis and reporting. The cost ($USD) for a series of status and trend data collection methods were compared and used to inform the selection of the data collection methods documented in Appendix C. Future refinements to the data collection and management RSWMP protocols will include comparable estimates of the five year site cost. It is assumed the majority of site monitoring instrumentation will have a five year life span.

7.6   STATUS AND TREND: DATA COLLECTION METHOD RATIONALE

The Scientific Assessment and Recommendations Report (TRCD et al 2014) included a detailed review of the previous stormwater hydrology and pollutant concentration monitoring techniques conducted in the Tahoe Basin over the past two decades. Over this time, the Tahoe Basin has seen a significant amount of available resources to conduct research and implement monitoring on urban stormwater runoff. This has resulted in a large amount of existing knowledge, expertise and lessons learned. The ability of the method and associated instrumentation to meet the data collection needs has also been considered.

The detailed cost comparisons of the annual site instrumentation, data collection, data management and QAQC, and data analysis to obtain, manage and translate site-specific data into the annual reporting formats was a critical part of the selection process. The RSWMP development team utilized this knowledge base and carefully selected the most cost-effective and reliable data collection methods to ultimately report the status and evaluate the trends of urban stormwater runoff in the Tahoe Basin.

A summary of the RSWMP urban catchment outfall monitoring methods, rationale and estimated five-year cost estimates are provided in Table 7. Autosamplers act as both a data logger for continuous stage and turbidity readings as well as a programmable machine for taking water quality samples and logging the date and time of when the samples were taken. The stage sensor (a bubbler or area-velocity sensor) and the continuous turbidimeter are connected directly to the autosampler computer. Stage is converted to flow (discharge) using an equation specific to the flume, culvert or controlled cross-section. The detailed protocols for measuring each parameter and translating these values into the site-specific and regional dataset managed in the RSWMP Data Management System are summarized in Table 8 and provided in Appendix A.

Field Parameter	Sampling resolution	Data collection method	Rationale for selection	Estimated 5yr cost per site (2015 $USD)
Table 7. Urban catchment outfall monitoring techniques by RSWMP to evaluate urban stormwater quality status and trends in the Tahoe Basin.				
Discharge Q_i	10 min	Bubbler or area-velocity sensor to measure flow in flume, culvert or other stable, controlled cross section.	High resolution flow monitoring desired to obtain data from majority of stormwater runoff events. Stage monitoring more cost effective and instrumentation more reliable than area- velocity instrumentation, particularly in intermittent discharge, low discharge, and freeze/thaw conditions. Stable cross section required to ensure consistent and precise conversion from stage to flow using established formulas.	$80,000
Turbidity TB_i	10 min	Automated continuous turbidimeter	High resolution FSP concentration monitoring desired to obtain data from all stormwater runoff events. Turbidity as a surrogate for FSP concentrations well established. Recommended conversion equations established using nearly 1,000 data points from Tahoe stormwater (2NDNATURE and DRI 2014). Specific automated turbidity instrumentation in intermittent and freeze/thaw conditions has been well tested by Tahoe stormwater researchers.	$70,000 (FSP)
Water sample collection	Discharge weighted event sampling	Water sample collection with an automated sampler	Specific automated turbidity instrumentation in intermittent and freeze/thaw conditions has been well tested by Tahoe stormwater researchers. Protocols have been refined to consistently extrapolate sampled runoff events to unsampled runoff throughout the year (see Appendix A).	$83,000 (3 nutrient species)

| Precipitation | 1 hour | Raw data downloaded from the WRCC website | Long-term regional precipitation record is used to determine water year type (wet or dry).The WRCC has operated and maintained a meteorological station in Tahoe City since 1911. | $5,000 |
| | 10 min | Meteorological station with heated tipping bucket and data logger within a 1 mile radius of monitoring site. | Local precipitation data necessary for rainfall runoff response calculations due to high variability in precipitation rates and totals in different areas around the Tahoe Basin. Necessary for more accurate PLRM modelling on the catchment scale. | |

Table 8. Summary of data collection and data management protocols for urban catchment outfall data monitoring.

Field Parameter	Sampling resolution	Data collection method	Field QAQC procedures	Raw data transformation process	Reporting parameter
Discharge Q_i	10 min	Bubbler or area-velocity sensor to measure flow in flume, culvert or other stable, controlled cross section.	Monthly maintenance and calibration to outside stage reading. A minimum of 12 manual discharge measurements per year that reasonably represent the range of discharge conditions at site.	All data gaps are filled using neighboring operating site correlations. The instantaneous discharge values are integrated on daily time steps to quantify the measured daily discharge volume at the site.	Daily discharge: Q_d (cfd)
Turbidity TB_i	10 min	Automated continuous turbidimeter	Monthly maintenance and calibration to manual turbidity reading. A minimum of 12 manual turbidity measurements per year that reasonably represent the range of turbidity conditions at site.	All data gaps are filled by a) determining days of no discharge; b) creating seasonal discharge to turbidity rating curves for site and using best fit equation to estimate missing data. Measured instantaneous turbidity time series are converted to FSP concentration using basin wide established rating curves (2NDNATURE and DRI 2014).	Daily pollutant concentration: $[P]_d$ (mg L^{-1}) and Daily pollutant load:

				The product of instantaneous discharge and FSP concentration are averaged on daily intervals and extrapolated to daily FSP loads. The daily load divided by the daily discharge provides the mean daily FSP concentration for each day of record. Standard unit conversions are incorporated in all calculations.	P_d (g d^{-1})
Event mean pollutant concentration [P$_{EMC}$]	Discharge weighted event sampling	Water sample collection with an automated sampler	Monthly sample line clearing. Unit programming prior to event based on rainfall runoff relationship. Estimate total runoff volume at site from forecasted precipitation totals, divide volume to collect 10-12 flow weighted samples per event.	Standardized discharge weighted sample composite procedures. Sample submitted to analytical lab for sample analyses per pollutant. Sample concentrations averaged to define an event mean concentration (EMC) for each event type sampled throughout the water year. The event type EMCs are used to define the daily pollutant concentration for each day of record. The product of daily discharge and daily pollutant concentrations is the daily pollutant load.	Daily pollutant concentration: $[P]_d$ (mg L^{-1}) and Daily pollutant load: P_d (g d^{-1})
Precipitation	1 hour	Raw data downloaded from the WRCC website	Monthly data download	Use summary tool on website to get daily precipitations totals for every day of the water year.	Daily precipitation total: PPT_d (in d^{-1})
	10 min	Meteorological station with heated tipping bucket and data logger	Bi-monthly data offload and maintenance to ensure tipping bucket is clear of debris.	Extract periods of precipitation from raw data. Define start and end of event, event duration, total precipitation in inches, event peak precipitation in 10 min interval	Daily precipitation total: PPT_d (in d^{-1})

				(intensity), max and min temp, and event type (rain, rain on snow, snow, snowmelt, thunderstorm). Use to calculate seasonal and annual precipitation totals as well as site-specific rain-fall runoff responses for predicting flow-paced sampling intervals.	And Event precipitation total: PPT_e (in)

7.7   STATUS AND TREND: DATA ANALYSIS METHODS

All site metadata and water year datasets obtained from urban catchment outfall monitoring and respective meteorological stations will be managed into the daily time series formats (Tables 4-6) and uploaded to the RSWMP Data Management System by December 31 for the previous water year. The customized Data Management System includes automated data analysis queries to generate each of the values required to compile and create the annual status summary for each site (Figure 5). Following the completion of consistent stormwater and pollutant load monitoring at a specific site for five continuous years, an RSWMP technical team will begin annual implementation of standardized trend analyses and generate the results exemplified in Figure 9 for each site. The specific data analysis process selected to complete the trend analysis was developed to:

a)   provide a standardized and repeatable process for the RSWMP technical team to follow year after year;

b)   provide a method to consistently adjust the measured datasets for precipitation variations over time, better isolating the signal due to management actions;

c)   generate output values that can be easily compared over time and across sites within the monitoring network; and

d)   be completed by a user without expertise in statistical methods or associated software platforms.

Data analysis, display and QAQC technical guidance to generate and report the values presented in the site status and trend summaries, annual status and trend map comparisons are presented in Appendix A.
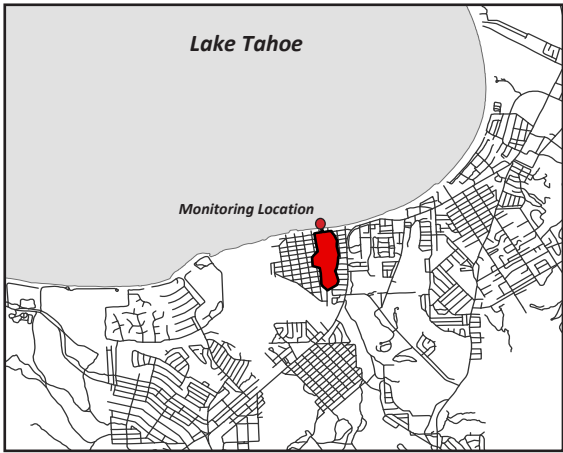
7.8   STATUS AND TREND: DATA REPORTING FORMATS

The RSWMP annual status report format is presented in Figure 5. Annual compilation of the RSWMP stormwater status monitoring network for the respective water year will be summarized using a regional map display with a defined format and nomenclature (Figure 6). Similarly, Figure 9 presents the annual trend status summary by site, which is summarized in a regional map shown in Figure 10.

A. Site Location Map

Lake Tahoe

Monitoring Location

Urban Catchment Outfall Monitoring Trends
Monitoring interval: 1984-2020
Pasadena Catchment, City of South Lake Tahoe
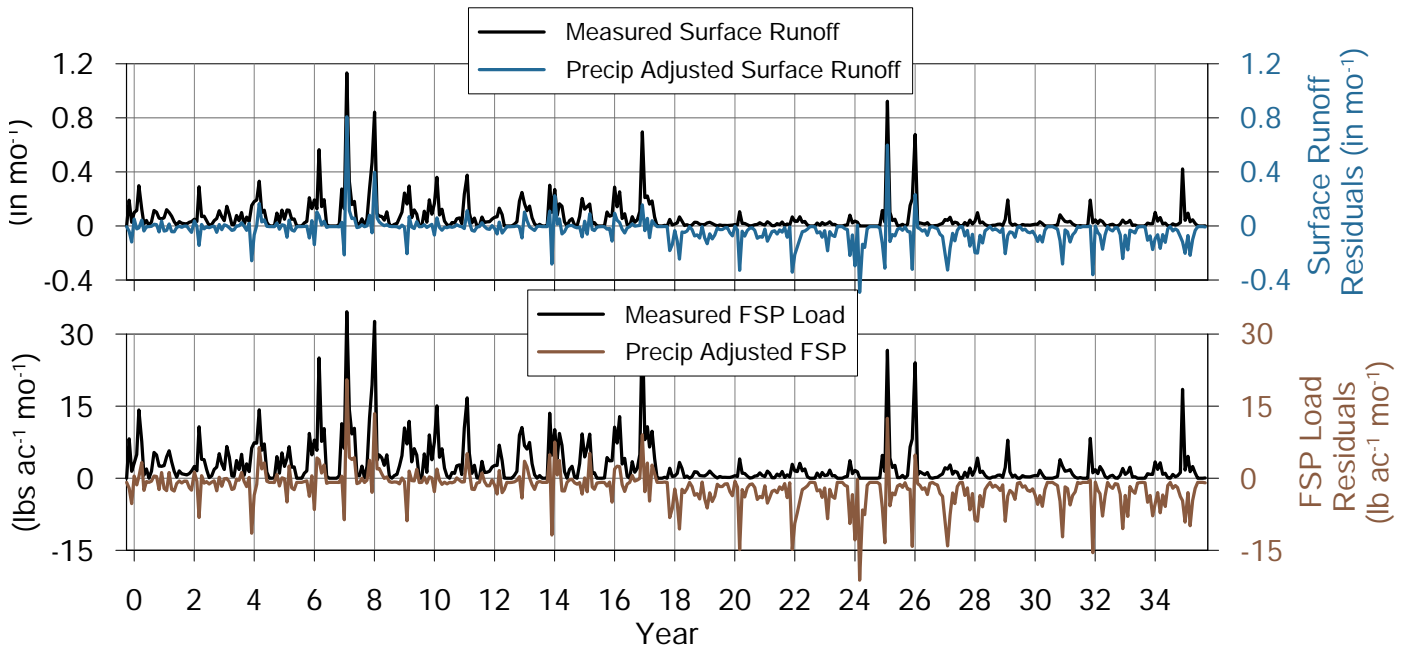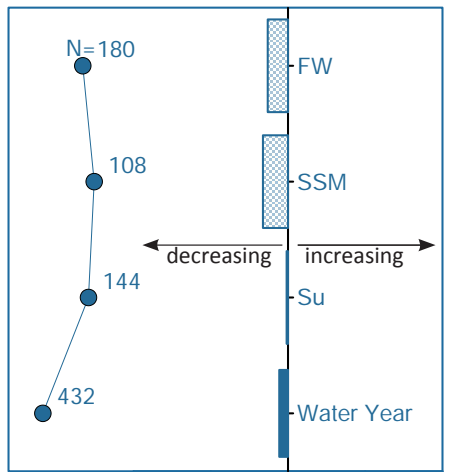
B. Precipitation and flow adjusted variables and equations for Q and FSP loads

Adjusted Variable (units)	Independent Variable (units)	Regression Equation
Q (in mo^{-1}): FW and Su		Q = 0.0444*Precip + 0.0049
Q (in mo^{-1}): SSM		Q = 0.0499*Precip + 0.028
FSP (lbs ac^{-1} mo^{-1}): FW and Su	Precip (in mo^{-1})	FSP = 1.85*Precip + 0.86
FSP (lbs ac^{-1} mo^{-1}): SSM		FSP = 2.05*Precip + 2.19

C. Timeseries of Surface Runoff and Pollutant Loads

— Measured Surface Runoff
— Precip Adjusted Surface Runoff

(in mo^{-1})

Surface Runoff Residuals (in mo^{-1})

— Measured FSP Load
— Precip Adjusted FSP

(lbs ac^{-1} mo^{-1})

FSP Load Residuals (lb ac^{-1} mo^{-1})

Year

D. Surface Runoff Trends

N=180

FW

108

SSM

← decreasing   increasing →

144

Su

432

Water Year

Trend in Precip adjusted Surface Runoff (in yr^{-1})

E. FSP Load Trends

N=180

FW

108

SSM

← decreasing   increasing →

144

Su

432

Water Year

Trend in Precip adjusted FSP Load (lbs ac^{-1} yr^{-1})

All water year and seasonal surface runoff and FSP loads show statistically significant decreasing trends over the 36 years of record. An average decreasing trend in FSP loading of 0.05 lbs ac^{-1} yr^{-1} has been measured at the Pasadena Catchment as a result of cumulative effective water quality improvement actions.
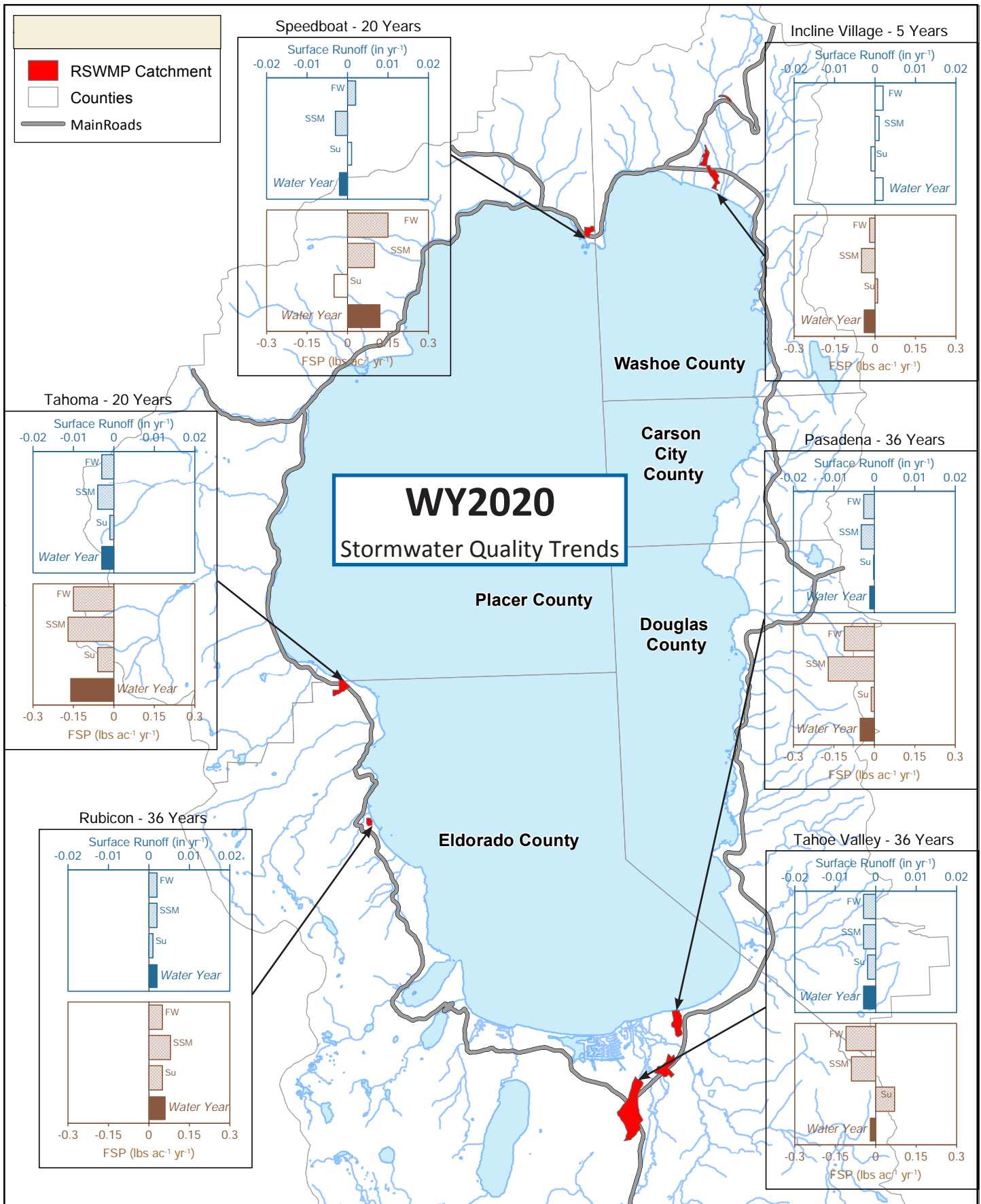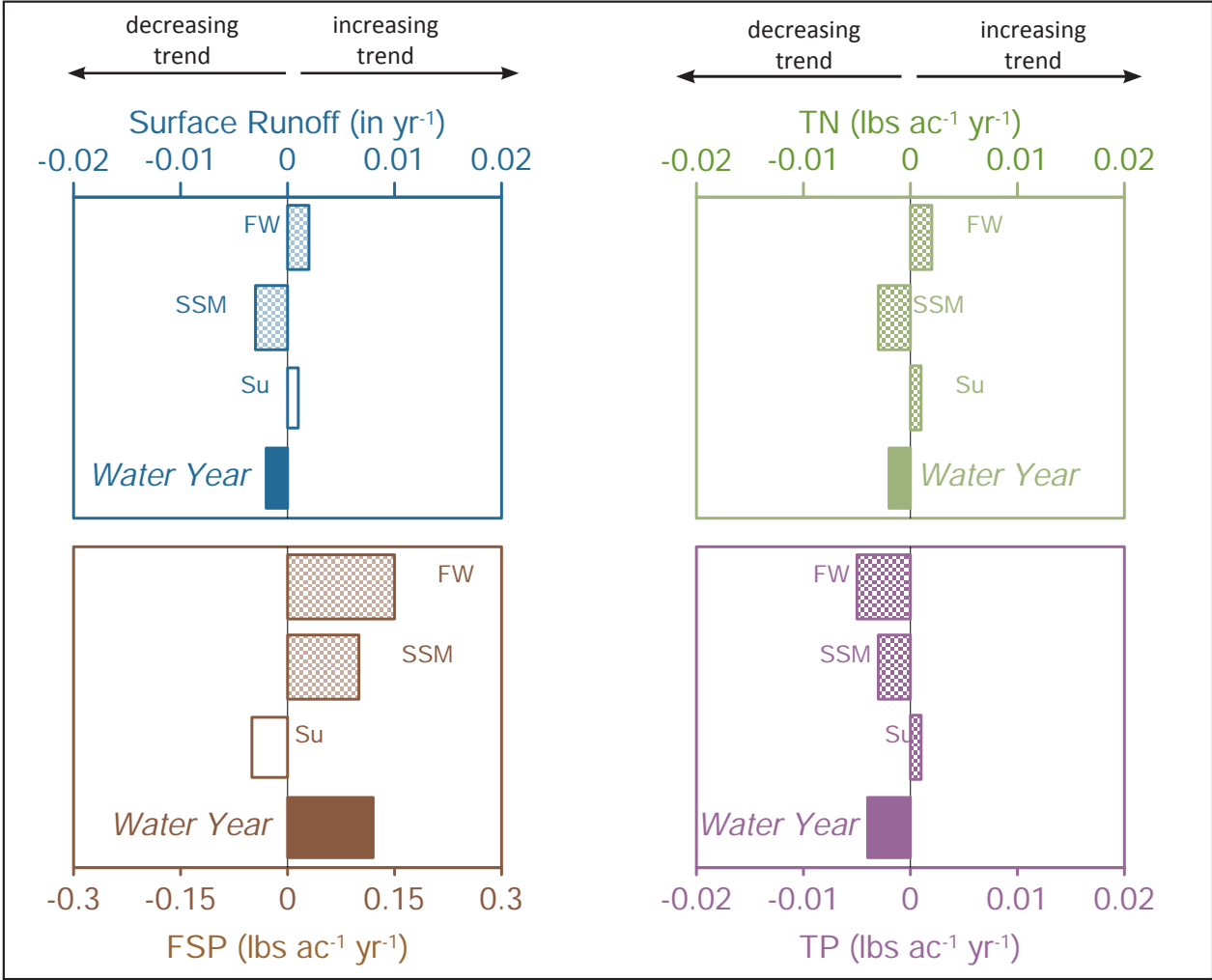
TREND STATUS SUMMARY: DISCHARGE AND FINE SEDIMENT

FIGURE 9

FIGURE 10. **WY2020**
Urban surface runoff and FSP load trends for status and trend monitoring stations. Runoff (blue) reported as inches ssn^{-1} or yr^{-1} and FSP (brown) reported as lbs ac^{-1} ssn^{-1} or yr^{-1}.

WY2020
Stormwater Quality Trends

Speedboat - 20 Years
Incline Village - 5 Years
Tahoma - 20 Years
Pasadena - 36 Years
Rubicon - 36 Years
Tahoe Valley - 36 Years

Washoe County
Carson City County
Placer County
Douglas County
Eldorado County

Legend:
- RSWMP Catchment
- Counties
- MainRoads

Miles
0   0.75 1.5   3
1 in = 3 miles

2NDNATURE LLC
www.2ndnaturellc.com

Key for urban catchment outfall pollutant trend maps

GRAPHIC GUIDE: Seasonal and interannual trends in unit runoff and pollutant loads are directly comparable across sites and over time. The values for surface runoff are given in inches year[-1] (in yr^{-1}) for surface runoff and pounds per acre per year for pollutant loads (lbs ac[-1] yr^{-1}). The magnitude, direction, and statistical significance of the trend is presented for the water year and three seasons by parameter. Available data was used to reasonably estimate the values for each parameter.

EXAMPLE (upper left): Surface water runoff displays a statiscally significant decreasing trend of 0.002 inches of runoff per year over the duration of the dataset. The summer surface runoff data suggests a negligible and insignificant increasing trend.

8 PRIMARY OBJECTIVE IMPLEMENTATION: ASSESS PROJECT EFFECTIVENESS

The objective of selected metrics is to best quantify the improvements to downslope water quality due to the implementation of the project itself. Because this objective is project specific, the monitoring methods and metrics for this objective are not as well defined as for the two primary objectives, but metrics that should be considered are outlined below.

8.1   METRIC DEVELOPMENT CONSIDERATIONS

The specific locations and types of data collected will be determined by the specific site and improvement details, and these will vary greatly across projects. In addition, the data collection strategy must, to the extent possible, employ a sampling methodology that maximizes the ability to detect a signal given the natural variability and sample imprecision. This requires a monitoring design where site conditions pre and post improvement are compared at times and locations that accentuate the differences due to the project and minimize the differences in the measured values that are due to natural variability. While the theory of this monitoring design is easy to outline, the execution and associated analysis of the datasets obtained or evaluated inherently contain noise that could be complicated and costly to reduce.

The following are key objectives when selecting metrics and the associated techniques by which site functional changes will be measured at each site.

1. **Maximize the signal of the metric due to the management actions**: The timing and locations of pre and post project data comparisons should be designed in a manner that maximizes the signal in the data due to management actions. This is achieved by selecting consistent data collection sites that are within the measureable influence of the project effects. Similarly, the timing of data collection should be selected based on when the deviation in the site conditions would be the greatest as a result of the actions.

2. **Accuracy v precision:** Metrics applicable to multiple project scale evaluations will require very specific, precise and consistent definitions that can be reliably used to assess a number of different regional projects and provide meaningful results. It is important to consider the ability to obtain the sampled data with reasonable accuracy. The most cost-effective and scientifically defensible techniques will combine reasonable accuracy with the highest possible sampling precision.

3. **Ensure a range of values:** The selected metric values must be expected to measurably change as a result of successful project implementation. Metric values that possess little to no difference

between impaired and desired conditions relative to natural variability or sampling error cannot properly evaluate the benefits associated with the project.

4. **Collection of metrics:** While all metrics may not be relevant or applicable to all projects, the effectiveness of any project should be consistently evaluated by a selection of the metrics listed below:

- Physical Metrics: Most immediately measurable post project. They measure the physical change but do not necessarily indicate associated water quality benefits without the other listed metrics.
- Hydrologic Metrics: The critical parameter for estimating functional improvement. They measure changes in surface water runoff volume. Cost effective monitoring methods to evaluate the hydrologic changes to the system as a result of project implementation are highly desired.
- Water Quality: The second critical parameter for estimating functional improvement. They measure changes in surface water pollutant loading. Cost effective monitoring methods to definitively indicate pollutant load reductions to downstream surface waters and the lake are highly encouraged.
- Vegetation: A measurable indicator of functional hydrologic improvements for meadow, SEZ or other vegetated surfaces. Changes in vegetation cover can be constrained for natural climatic variability to isolate effects of successful project implementation.

9   SECONDARY OBJECTIVE IMPLEMENTATION: INFORM PLRM CECS

Several large scale stormwater treatment BMP types are modeled in PLRM (dry basins, wet basins, media filters, etc.). The stormwater volumes 'treated' by the BMP in the model are assigned a CEC, which is a static value. The default PLRM CECs may not be representative of the actual BMP performance if (1) the physical configuration of the BMP in PLRM is not accurate, (2) the BMP has not received adequate or regular maintenance, or (3) inflow pollutant concentrations are misrepresented in the model. Treatment BMP CEC representation in PLRM can be improved or calibrated using effluent sample collection representing the range of event types and flow conditions that occurred at the site during the duration of monitoring.

Refining the CECs for specific BMP types modeled in PLRM will be achieved by consistently sampling the treated effluent of a collection of existing stormwater BMPs of the same type. This RSWMP objective aims to fill a critical data gap in PLRM by providing Tahoe-specific CECs by sampling the treated effluent of BMPs that have been recently maintained and are verified to be functional throughout the monitoring period. The RSWMP monitoring design to achieve this objective is a focused and discrete three year data collection effort to sample a range of effluent conditions from three specific BMPs of the

same type. Coordination and collaboration with the respective jurisdictions responsible for each BMP selected for monitoring is essential to ensure adequate maintenance is performed within the year prior to monitoring initiation.

9.1   INFORM PLRM CECS: PRIORITY POLLUTANTS

The PLRM CEC monitoring will focus on the pollutants modeled in PLRM (nhc et al 2009).

1. Fine Sediment Particles (FSP < 16 um)
2. Total Phosphorous (TP)
3. Total Nitrogen (TN)

Inclusion of dissolved nutrient species like OP and DIN will be made on a site by site basis and depend on resource availability.

9.2   INFORM PLRM CECS: DATA OUTPUT METRICS

The monitoring design and data analysis approach will translate three years of measured effluent concentrations into a single measured recommended CEC (mg/L) for a specific BMP type for each pollutant (CEC_{BMP-p}). The recommended reporting format to summarize the data obtained plus the CEC recommendation is presented in Figure 11. Annual progress reports will follow the same format, populating the information and data available until the three year data collection effort is complete.

9.3   INFORM PLRM CECS: SITE SELECTION CRITERIA

There are two main criteria for selecting sites to inform PLRM CECs: BMP type and BMP recent and regular maintenance.

RSWMP will solicit explicit funding to implement the monitoring design for a specific BMP type. The monitoring design has focused on minimizing total costs, while maximizing the precision and accuracy of the approach to generate realistic and representative CECs. Below are the BMP types modeled in PLRM, ranked based on their expected performance to remove FSP from urban stormwater runoff and reduce pollutant loads to Lake Tahoe (2NDNATURE 2009).

1. Filtration Units (often media filled cartridge filters) – cartridge filters contained within a confined space similar to treatment vaults containing granular or media type selected to remove fraction of stormwater pollutants. Results in downgradient reduced effluent pollutant concentrations. No volume reductions due to impervious base.

2. Dry Basin – a constructed basin designed to detain stormwater runoff for some minimum time to allow particle and associated nutrient settling. Results in downgradient volume reduction and reduced effluent pollutant concentrations.

3. Treatment Vault – flow-through confined space structure that separates sediment, debris and other particulate pollutants from the water volumes via various settling techniques. Results in downgradient reduced effluent pollutant concentrations due to particle capture. No volume reductions due to impervious base.

4. Wet Basin – a constructed basin that detains runoff and has a persistent pool of surface water typically through the wet season and intermittently and/or consistently in the dry season. Results in downgradient volume reduction and reduced effluent pollutant concentrations.

2NDNATURE and NHC 2012 obtained a limited amount of relevant data for existing dry basins and wet basins in the Tahoe Basin; however, none of the selected BMP sites had been recently maintained prior to the monitoring.

For each BMP type, three specific BMPs will be monitored in a consistent manner. The population of BMPs of the same type may represent a range of expected pollutant loading rates, drainage areas, contributing land uses, configurations or capacity. The requirement for inclusion is that all BMPs are assessed annually and maintained in acceptable condition during the duration of the monitoring. Jurisdictions are most likely to regularly maintain and annually assess BMPs that are included in their respective registered catchments and stormwater pollutant load reduction plans. RSWMP's collaboration and coordination with responsible jurisdictions will result in a dual benefit: BMPs will be regularly maintained for monitoring and jurisdictions will be more likely to meet annual regulatory inspection requirements.

9.4   INFORM PLRM CECS: DATA COLLECTION NEEDS

A CEC is defined as the average annual effluent concentration in treated outflow volumes for a particular pollutant. The most cost effective sampling approach is to sample BMP treated effluent over a range of event types and event characteristics for three complete water years. The four distinct runoff event types are winter rain, rain on snow, spring snow melt and summer rains. Each event type possesses a unique set of pollutant sources, precipitation patterns (intensity and duration), antecedent moisture conditions, and the like, and representative sampling of each of the four event types must be achieved. In addition, it is assumed that the collection of sample water years will collectively represent a range of water year types (wet and dry). The more events sampled over the monitoring duration, the greater the power of the dataset from which the average annual CEC is derived.

The critical sampling consideration for representative treated effluent BMP monitoring is the instrumentation of 3 recently maintained BMPs of the same type. If or when funding for this objective becomes available, it will require collaboration and coordination between the RSWMP research team and each jurisdiction responsible for maintenance of the selected BMPs. Methods described in the BMP RAM (www.tahoebmpram.com) manual are used to evaluate and track the condition of each of the

BMPs included in the monitoring by completing field evaluations each May for the respective 3 consecutive water years studied.

Inflow concentration sampling and BMP hydrology monitoring for CEC estimation may not be of value due to the increased complexity of the monitoring, higher costs, and the structure of PLRM stormwater treatment BMP modelling. Concurrent sampling of inflow pollutant concentrations (devoid of hydrology) can be used to quantify the percent concentration reductions over a range of event types and characteristics. Similarly, the inclusion of BMP flow through hydrology facilitates pollutant loading and associated load and volume reduction estimates. While this information can expand the understanding of pollutant fate and transport in specific BMP types, PLRM models BMP performance using a single, static effluent concentration for all treated volumes (i.e., a CEC). Therefore, the most focused and applicable data collection need is a representative population of the effluent concentrations from a collection of specific BMPs of the same type, over a range of potential runoff, event, season and water year types.

Table 9 summarizes the recommended event sampling frequency for each of the three BMPs monitored of a specific type, resulting in a target effluent sample dataset of 216 samples over the three year evaluation.

Table 9. Summary of RSWMP effluent monitoring design presented for a single BMP of a specific type. The monitoring design includes an average of two effluent samples per event from three unique BMPs of the same type monitored at the event frequency provided below over a three year period.

Parameter (ID)	Sampling Resolution	Event Types	Target annual sampling frequency (#)	Reporting Resolution (units)
Treated effluent pollutant concentration $[P]_e$	Event based	Fall/Winter Rain (Oct 1–Dec 31)	3	mg/L
		Rain on Snow (Jan 1–Mar 31)	3	
		Spring Snow Melt (April 1–May 31)	4	
		Summer Rain (June 1– Sept 31)	2	

It is recommended that BMP CEC data management include the site-specific data from each unique BMP in the format summarized in Table 10. Regionally relevant daily precipitation data will be obtained and

managed by RSWMP to complete the status and trend evaluations (see Section 7.4). RSWMP will utilize the seasonal precipitation totals and frequency analyses to report the season type for each season monitored as reported on Figures 7 and 8. The standardization of the annual dataset format allows future flexibility by the RSWMP program to revise and refine data collection methods as appropriate. It also provides the ability to optimize the day to day data collection techniques based on available resources.

Table 10. Data fields and units for site metadata and annual stormwater monitoring dataset obtained from RSWMP unique BMPs effluent monitoring.

BMP Effluent Monitoring Site Metadata Fields											
BMP Site ID	Jurisdiction ID	BMP Type	Drainage area (ac)	% impervious area	Dominant land use type	Capacity stage (ft)	Treated outflow stage (ft)	Sample stage (ft)	Met Station ID	WY Initiated	

BMP Effluent Monitoring Event Data Fields				
BMP Site ID	Date (mm/dd/yyyy)	Event type	Stage (ft)	$[P]_i$ (mg L^{-1})

9.5   INFORM PLRM CECS: DATA COLLECTION METHOD OBJECTIVES

A variety of existing data collection methods and data transformation techniques are currently available to obtain the desired datasets and produce the data outputs necessary to generate a recommended CEC. As informing CECs is not currently funded, a specific data collection approach to meet the objectives below has not yet been selected and defined. By formalizing the RSWMP data collection needs and the data collection objectives, flexibility remains for RSWMP to select the most cost-effective data collection methods to meet this objective. Section 4.2 outlines the real time management process RSWMP will follow in order to consider and potentially select the CEC data collection method in the future.

- **Sampling Precision**: The ultimate use of BMP effluent sampling is to generate a representative dataset to appropriately recommend a CEC value by specific treatment BMP type in the Tahoe Basin, assuming it is maintained in acceptable condition. Techniques and data management protocols defined by RSWMP have been designed to minimize the amount of variability as a result of sampling techniques to the extent possible. Given that CEC development will be achieved by discrete three

year evaluations of sites representing a specific BMP type, the sampling techniques will remain constant across sites and over the duration of each unique BMP type evaluation.

- **Data Accuracy:** It is important to consider the ability to obtain treated effluent pollutant concentrations with reasonable accuracy. Decades of available stormwater volume and pollutant monitoring were considered by the RSWMP development team to define the most cost-effective potential monitoring methods (as described in Section 6.1) that combine reasonable accuracy with the highest possible sampling precision.

- **Capturing Range of Effluent Concentrations:** Current PLRM CEC values were based on the National BMP Database and several assumptions to estimate Tahoe Basin effluent concentrations, for FSP in particular. The monitoring design should focus on obtaining a representative range of effluent concentrations expected at the sites using robust yet cost effective sample collection methods.

- **Cost Comparisons:** The RSWMP development team will create a standardized cost estimate template to systematically generate and compare the fully burdened cost of implementing the recommended three year evaluation of three unique BMPs per type as part of the planned updates to this document at the end of the project period (see Section 6.2). A variety of different methods to obtain BMP hydrology and sample inflow and effluent pollutant concentrations were considered in this evaluation. The team compared the research costs given a range of different datasets and data collection methods to select the most cost-effective and defensible approach that makes attainment of necessary funding more feasible.

9.6   INFORM PLRM CECS: DATA COLLECTION METHOD RATIONALE

The RSWMP development team leveraged the existing CEC development research to select several reliable data collection methods (TRCD et al. 2014; 2NDNATURE and NHC 2012) as described in Section 6.1. A detailed cost comparison of the annual site instrumentation, data collection, data management and QAQC, and data analysis to obtain, manage and translate the site-specific data into the annual reporting formats, will be a critical part of the method selection process. Currently, this objective is not funded and it is understood that future work and funding will need to be identified to implement this objective. A summary of the RSWMP treated effluent sampling technique rationale is provided in Table 11.

Table 11. BMP effluent monitoring techniques by RSWMP to inform PLRM CEC values.

Parameter (ID)	Sampling Resolution	Data collection method	Rationale	Min # of sites per BMP Type	Min # of total effluent samples	Cost for CEC recommendation for 1 BMP type ($USD 2015)
Treated effluent pollutant concentration [P_i]	Event based (see table 9)	TBD	Cost effective, repeatable technique to obtain many effluent samples at same effluent discharge over a range of outflow conditions and event types	3	216	TBD

9.7   INFORM PLRM CECS: DATA ANALYSIS METHODS

All site metadata and effluent pollutant concentration datasets obtained from treated outfalls will be managed in formats outlined in Table 10 and uploaded to the RSWMP Data Management System by December 31 for the previous water year. The customized Data Management System includes automated data analysis queries to generate a collection of the values required to compile and create the CEC results summaries by BMP Type (Figure 11).

9.8   INFORM PLRM CECS: DATA REPORTING FORMATS

The recommended reporting format to summarize the data obtained plus the percent effectiveness of the BMP type is presented in Figure 11. Annual progress reports will follow the same format, populating the information and data available once a three year data collection effort is complete.
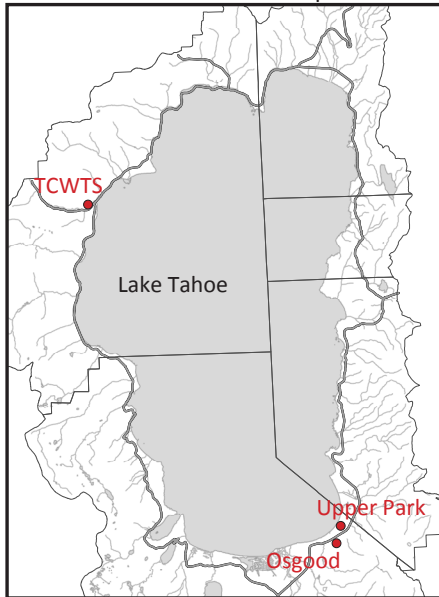
Wet Basins: Characteristic Effluent Concentrations

Monitoring Years: 3 (2018-2020)

A. Characteristic Effluent Concentrations

Pollutant	FSP (mg/L)	TP (mg/L)	TN (mg/L)
Recommended CEC (boostrapped median)	**15.0**	**0.082**	**TBD**
90% Confidence Interval	10.5 to 16.0	0.076 to 0.091	TBD

B. Site Location Map*

C. Site Characteristics*

Catchment	Jurisdiction	Area (ac)	% Imperv	Dominant Urban Land Use (% of total)
TCWTS	Placer	281	42%	SFR; 16%
Osgood	CSLT	341	23%	CICU; 27%
Upper Park	CSLT	225	30%	SFR; 13%

Sites are shown for illustrative purposes only and are not intended to reflect actual decisions on monitoring locations.
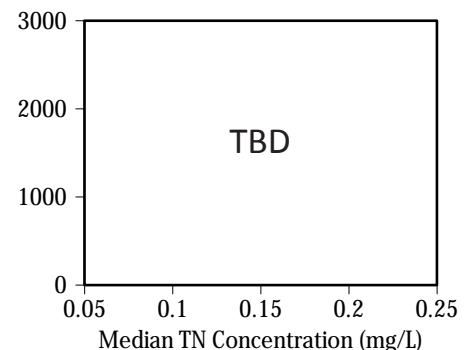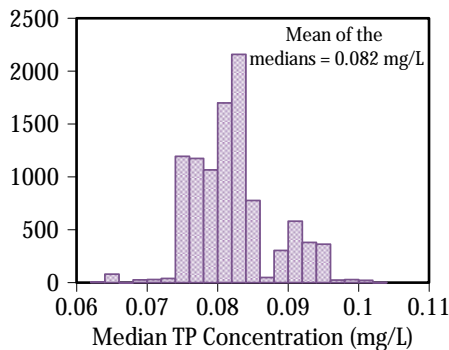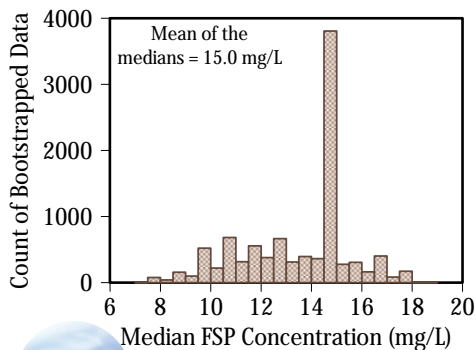
D. Water Year type, number of samples, and BMP RAM Scores

Year	WY Type	Number of samples	# relative to target	Annual BMP RAM Scores		
				TCWTS	Osgood	Upper Park
2016	Ave	66	on target	5.0	5.0	5.0
2017	Wet	70	+4	4.3	4.2	4.5
2018	Dry	62	-4	3.5	4.0	3.9

E. Effluent Data (WY16- WY18)
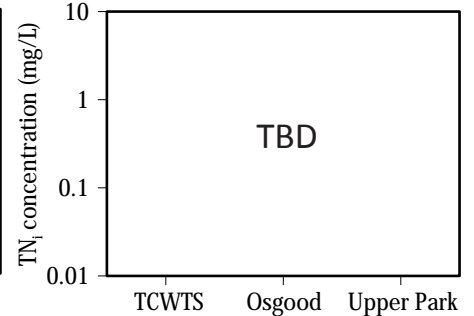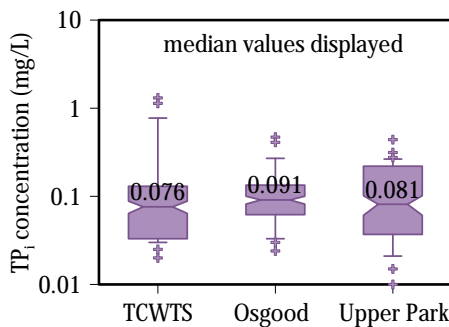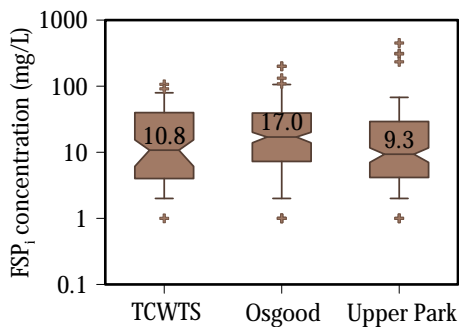
F. Bootstrapped Data

Box-Whisker plots show the 25th, 50th, and 75th percentile (boxes) and the 10/90 (whiskers) percentile distributions of the measured data. The 50th percentile (the median) is labeled for each site. Bootstrapping was conducted for 10,000 iterations using the monitoring data. In each iteration, the median of the combined dataset (198 measurements sampled with replacement) was determined.

10 APPENDIX A: STATUS AND TREND PROTOCOLS

Appendix A details the data collection, management, analysis and reporting protocols necessary to create annual site and regional summaries of the Tahoe Basin stormwater status and trends. The term *status* is used to report the total seasonal and annual discharge volumes and pollutant mass loads for a single year. The term *trends* is used to report the inter-annual changes in seasonal and water year unit discharge volumes and unit pollutant mass loads.

10.1 URBAN CATCHMENT OUTFALL SITE META DATA

The necessary site metadata fields (Tables 4, 5, 6 and A8, A10, and A11) to describe the catchment contributing to the urban catchment outfall are listed below. The catchment should be delineated in GIS based on topography and known drainage infrastructure, and then verified in the field and adjusted as necessary. The following briefly describes how to determine each field:

- **UCO Site ID**: unique identifier for each urban catchment outfall. ID should be easily interpretable for people knowledgeable of Tahoe stormwater.
- **Jurisdiction ID**: one of the 7 urban jurisdictions responsible for stormwater management in the Tahoe Basin. Commonly the boundaries of an urban catchment will cross multiple jurisdictions. The jurisdiction responsible for the majority of the urban area within the catchment should be assigned.
- **Drainage area (acres)**: the total area in acres contributing to the catchment outfall. Calculate the total area of the delineated catchment in GIS using the 'Calculate Geometry' tool.
- **% IMP**: the percentage of the total catchment area that is designated as impervious. Clip the most recent TMDL Land Use GIS Layer (currently the draft 2011 land use layer is available as part of PLRM v2 and can be downloaded from https://share.nhcweb.com/public.php?service=files&t=a8dc70db94dd13ad3b18fd2e2c1e79df but may be moved to the TMDL Management Systems site) to the catchment boundary and determine the acreage of impervious area within the catchment. Divide by the total drainage area to determine percent impervious.
- **% DCIA**: the percentage of the impervious area that is directly connected to the catchment outfall. Directly connected impervious area should be estimated in the field. The most recent guidance for estimating DCIA is found in the Interim Guidance Paper for Formulating and Evaluating Alternatives for Tahoe Basin Water Quality Improvement Projects (2008), available at http://www.trpa.org/wp-content/uploads/FEA_Interim_Guidance_Paper.pdf. Additionally, the March 2011 PLRM Road Shoulder Conditions Layer (currently not publically available but will likely be available on the TMDL Management Systems site at a later date) includes an estimate of road shoulder connectivity.

- **WY Initiated**: the water year in which the site was established and the spatial attributes were calculated.
- **MET station ID**: the unique identifier associated with the meteorology station closest to the urban catchment outfall and most representative of the weather occurring throughout the catchment.
- **Owner**: weblink to agency that houses, maintains, or distributes Regional meteorological data. Western Regional Climate Center: www.wrcc.dri.edu.
- **Elevation**: the elevation of the meteorological station in feet above mean sea level (AMSL).
- **Paired Monitoring Station ID**: the monitoring station paired with the local meteorological station. Each monitoring station has a meteorological station within a 1-2 mile radius of the monitoring site.

It is anticipated that these metadata fields will only change over time with the completion of significant water quality improvement projects within the catchment. At the completion of such a project, the drainage area, % IMP and % DCIA should be recalculated, and if the values have changed by more than 10%, a new record with the current water year should be added to the table. Additionally, land use changes may change incrementally over time with new development or changes in coverage. Every 5 years, the % IMP and % DCIA should be recalculated and if the values have changed by more than 10%, a new record with the current water year should be added to the table.

10.2 STATUS AND TREND FIELD DATA COLLECTION PROTOCOLS

The goal of RSWMP status and trend data collection is to estimate seasonal and annual surface runoff volumes and pollutant loads at urban catchment outfall sites. These data will be used to evaluate spatial and temporal patterns of pollutant loading from urban runoff in the Lake Tahoe basin. The basis of this evaluation depends on accurate event runoff characterization. The monitoring protocols described below use water level (stage) sensors to estimate continuous discharge and autosamplers to collect event runoff samples. This approach yields event mean pollutant concentrations that can inform automated routines in the RSWMP Data Management System to approximate pollutant concentrations and loads during non-sampled discharge events. Ultimately, these data contribute to basin-wide estimates of urban stormwater loading to Lake Tahoe.

10.2.1 CONTINUOUS DISCHARGE MONITORING AND EVENT SAMPLING

Continuous discharge monitoring and event water sampling requires the installation of an automated sampler. The autosampling approach provides reliable estimates of event mean concentration and is especially useful when site hydrographs show considerable within-event variability. Installation of

autosampling equipment provides flexibility in sampling programs that can be tailored to site or event conditions.

10.2.1.1 OVERVIEW

The general approach to continuous discharge and event sampling is outlined below.

1. Install autosamplers (recommended ISCO 6712 or better) in protective housings adjacent to the flow path to sample the expected range of discharge conditions and event types over the water year (October 1 – September 30).
2. Mount stage (bubbler module) or area-velocity sensor (AV sensor) directly in flow path in flume, culvert or other controlled cross section.
3. Measure continuous hydrology at 10-min intervals in units of cfs. (Note: the 5-min interval is also acceptable – as an even divisor of ten – if catchment conditions or runoff factors indicate a shorter logging period would be useful.)
4. Mount autosampler intake tubes at fixed locations directly in the flow path, and usually just beyond the point of stage or AV sensor installation.
5. Collect water samples in tandem with discharge data for 10 - 12 runoff events during the water year that represent all four event types specified in the current Tahoe NPDES permit (R6T-2017-0010).
    o Annual event sampling distribution should target 3 fall rain events, 3 rain-on-snow events, 4 snowmelt events, and 2 summer thunderstorm events.
    o For each sampled runoff event, collect water samples from predetermined fixed volume intervals. The specific fixed volume interval will be unique to each event and based on predicted magnitude of runoff based on forecasted precipitation totals and specific to the catchment area and its flow characteristics.
    o A sufficient sampling density is required to adequately represent the event hydrograph, with a target of 12 or more samples collected from each site during an event of 24 hours or less. Longer duration events require continued sampling on the same schedule.
    o A single flow weighted composite is submitted to the analytical laboratory for pollutant concentration analyses. Analytic results then represent event mean concentration (EMC) of each pollutant for the corresponding event type.
6. Group event mean concentrations by event type (i.e. fall rain, rain-on-snow, snowmelt, or summer thunderstorm) and calculate the event type mean pollutant concentration.
7. Apply the appropriate event type mean pollutant concentration to each hydrology measurement based on information shown in Table A1 (e.g. the fall rain event type mean concentration is associated with all hydrology measurements between Oct 1 and Dec 31).

Table A1. Seasonal periods applied in calculations of event type mean pollutant concentrations at each monitoring site. These are used to estimate daily loads throughout the water year for each specified pollutant of concern. $[P]_d$ is the daily pollutant concentration for every day of that season (see Section 10.2.1.10 step 12).

Event Type	$[P]_d$ (mg/L)	Start Date	End Date
Fall Rain	Fall rain event type mean	October 1	December 31
Rain on Snow	Rain-on-snow event type mean	January 1	February 28
Snowmelt	Non-event snowmelt type mean	March 1	May 31
Thunderstorm	Summer thunderstorm event type mean	June 1	September 30

10.2.1.2 SITE SET UP AND EQUIPMENT INSTALLATION

Site preparation and equipment installation begins after initial RSWMP site selection based on criteria discussed in Section 7.3. The following steps summarize installation procedures once a field reconnaissance survey confirms that the site is suitable for monitoring in terms of existing conveyance and drainage system configuration, access and safety. Ideally, the monitoring site is located in an area with simple hydraulics, no steep slopes or sudden grade changes, and can easily accommodate the installation of both a flume and adjacent equipment housing.

1. Identify flow indicators and cues to determine range of flow (e.g. rusted culverts, channel morphology) and select appropriate placement for flume or other flow measurement control device and sample intake tubing. Avoid sites with potential backwater conditions or other influences that would compromise the quality of flow measurements.
2. Use the rational method to estimate average annual peak discharge potential and for selecting appropriate flume or flow measurement system. The rational method is applicable to drainage areas less than or equal to 200 acres.

$$Q = RC * i * A$$

where,

   Q = Peak discharge (cubic feet per second)

   RC = Runoff coefficient (dimensionless)

   i = Rainfall intensity (inch per hour)

   A = drainage area (square feet)

Based on previous stormwater runoff monitoring for the Tahoe TMDL it was found that average annual runoff coefficients for low to moderate sloped mixed-used urban drainages in the Tahoe Basin generally fall in the range of residential suburban type of development shown in Table A2.

Table A2. Rational method runoff coefficients (American Society of Civil Engineers and the Water Pollution Control Federation, 1969).

Type of Development		Runoff Coefficients
Business		
Downtown		0.70 to 0.95
Neighborhood		0.50 to 0.70
Residential		
Single family		0.30 to 0.50
Multi-units (detached)		0.40 to 0.60
Multi-units (attached)		0.60 to 0.75
Residential (suburban)		0.25 to 0.40
Apartment		0.50 to 0.70
Industrial		
Light		0.50 to 0.80
Heavy		0.60 to 0.90
Park, Cemeteries		0.10 to 0.25
Playgrounds		0.20 to 0.35
Railroad Yard		0.20 to 0.35
Unimproved		0.10 to 0.30
Character of Surface		
Pavement		
Asphalt and Concrete		0.70 to 0.95
Brick		0.70 to 0.85
Roofs		0.75 to 0.95
Lawns, Sandy Soil		
Flat	2%	0.05 to 0.10
Average	2% to 7%	0.10 to 0.15
Steep	7%	0.15 to 0.20
Lawns, Heavy Soil		
Flat	2%	0.13 to 0.17
Average	2% to 7%	0.18 to 0.22
Steep	7%	0.25 to 0.35

The rainfall intensity (i) term used in the rational method equation can be derived from a specified design storm or from an intensity-duration-frequency (IDF) curve or precipitation frequency (PF) table using the appropriate storm return frequency and a duration equivalent to the time of concentration (t_c) for the catchment or drainage. In the Tahoe Basin the 20-year, 1-hour design storm has been adopted as a standard, corresponding to about one inch of precipitation (LRWQCB 2003). Thus, for an initial approximation the 1-inch per hour rainfall intensity can be used to estimate peak discharge with the rational method. Alternatively, a catchment or drainage specific time of concentration can be calculated by the FAA method (1970):

$$t_c = [1.8 * (1.1 - C) * (L)^{0.5}] / [S^{0.33}]$$

where,

t_c = time of concentration (minutes)

C = Rational method runoff coefficient

L = Longest watercourse length in drainage (feet)

S = average slope of the watercourse

The calculated time of concentration is then used to represent duration on an IDF curve or in a PF table with a selected recurrence interval to estimate precipitation intensity (or depth) over the period of duration. Site-specific PF tables can be derived for a particular catchment or drainage using the NOAA interactive website shown in Table A3.

Table A3. Precipitation frequency (PF) table for Tahoe City, CA (NOAA Hydrometeorological Design Studies Center; http://www.nws.noaa.gov/oh/hdsc/index.html).

Duration	PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]
	Average recurrence interval (years)
	1	2	5	10	25	50	100	200	500	1000
5-min	0.149 (0.128-0.175)	0.191 (0.164-0.225)	0.252 (0.215-0.297)	0.305 (0.258-0.364)	0.384 (0.312-0.478)	0.451 (0.357-0.576)	0.525 (0.403-0.691)	0.608 (0.451-0.828)	0.733 (0.517-1.05)	0.841 (0.569-1.25)
10-min	0.213 (0.183-0.250)	0.274 (0.235-0.322)	0.361 (0.309-0.426)	0.437 (0.370-0.522)	0.551 (0.447-0.685)	0.647 (0.512-0.826)	0.753 (0.578-0.990)	0.871 (0.646-1.19)	1.05 (0.741-1.50)	1.21 (0.815-1.80)
15-min	0.257 (0.221-0.303)	0.331 (0.284-0.390)	0.437 (0.373-0.516)	0.529 (0.448-0.631)	0.666 (0.541-0.829)	0.782 (0.619-0.998)	0.910 (0.699-1.20)	1.05 (0.782-1.44)	1.27 (0.896-1.82)	1.46 (0.986-2.18)
30-min	0.324 (0.279-0.381)	0.417 (0.358-0.491)	0.550 (0.470-0.649)	0.666 (0.564-0.794)	0.839 (0.681-1.04)	0.985 (0.779-1.26)	1.15 (0.880-1.51)	1.33 (0.984-1.81)	1.60 (1.13-2.29)	1.83 (1.24-2.74)
60-min	0.438 (0.376-0.514)	0.563 (0.483-0.662)	0.742 (0.635-0.876)	0.899 (0.761-1.07)	1.13 (0.919-1.41)	1.33 (1.05-1.70)	1.55 (1.19-2.04)	1.79 (1.33-2.44)	2.16 (1.52-3.09)	2.48 (1.68-3.70)
2-hr	0.603 (0.519-0.709)	0.769 (0.660-0.905)	1.01 (0.860-1.19)	1.22 (1.03-1.45)	1.53 (1.24-1.90)	1.79 (1.42-2.28)	2.08 (1.59-2.73)	2.39 (1.78-3.26)	2.86 (2.02-4.10)	3.26 (2.21-4.87)
3-hr	0.750 (0.645-0.881)	0.950 (0.815-1.12)	1.24 (1.06-1.46)	1.49 (1.26-1.77)	1.86 (1.51-2.31)	2.17 (1.72-2.78)	2.52 (1.93-3.31)	2.90 (2.15-3.94)	3.46 (2.44-4.95)	3.92 (2.65-5.86)
6-hr	1.13 (0.968-1.32)	1.41 (1.21-1.66)	1.81 (1.55-2.14)	2.17 (1.83-2.58)	2.68 (2.18-3.34)	3.11 (2.46-3.97)	3.58 (2.75-4.71)	4.09 (3.03-5.56)	4.83 (3.41-6.92)	5.46 (3.69-8.14)
12-hr	1.70 (1.46-1.99)	2.11 (1.81-2.49)	2.69 (2.30-3.18)	3.18 (2.70-3.80)	3.89 (3.16-4.84)	4.47 (3.54-5.70)	5.08 (3.90-6.68)	5.74 (4.26-7.82)	6.69 (4.72-9.57)	7.46 (5.05-11.1)
24-hr	2.53 (2.21-2.97)	3.17 (2.75-3.71)	4.02 (3.49-4.73)	4.74 (4.08-5.61)	5.74 (4.79-7.00)	6.53 (5.36-8.13)	7.37 (5.91-9.37)	8.25 (6.45-10.8)	9.49 (7.15-12.9)	10.5 (7.66-14.7)
2-day	3.55 (3.09-4.16)	4.49 (3.91-5.27)	5.76 (4.99-6.77)	6.80 (5.86-8.06)	8.26 (6.90-10.1)	9.40 (7.71-11.7)	10.6 (8.50-13.5)	11.8 (9.26-15.4)	13.6 (10.2-18.4)	15.0 (10.9-20.9)
3-day	4.23 (3.68-4.95)	5.40 (4.70-6.33)	6.97 (6.05-8.20)	8.28 (7.13-9.80)	10.1 (8.43-12.3)	11.5 (9.43-14.3)	13.0 (10.4-16.5)	14.5 (11.3-18.9)	16.7 (12.5-22.6)	18.4 (13.4-25.7)
4-day	4.64 (4.04-5.44)	5.97 (5.20-7.01)	7.76 (6.73-9.13)	9.23 (7.95-10.9)	11.3 (9.42-13.8)	12.9 (10.5-16.0)	14.5 (11.6-18.4)	16.2 (12.7-21.2)	18.6 (14.0-25.2)	20.5 (15.0-28.7)
7-day	5.55 (4.84-6.51)	7.25 (6.30-8.51)	9.51 (8.25-11.2)	11.4 (9.78-13.5)	13.9 (11.6-17.0)	15.9 (13.0-19.8)	17.9 (14.4-22.8)	20.0 (15.7-26.1)	22.9 (17.2-31.0)	25.1 (18.4-35.1)
10-day	6.25 (5.44-7.33)	8.22 (7.15-9.65)	10.8 (9.39-12.7)	13.0 (11.2-15.4)	15.9 (13.3-19.4)	18.1 (14.9-22.5)	20.4 (16.4-25.9)	22.7 (17.8-29.7)	26.0 (19.6-35.2)	28.4 (20.8-39.8)
20-day	8.26 (7.19-9.69)	10.9 (9.52-12.8)	14.4 (12.5-17.0)	17.3 (14.9-20.4)	21.0 (17.6-25.7)	23.9 (19.6-29.8)	26.8 (21.5-34.1)	29.8 (23.3-38.8)	33.7 (25.4-45.6)	36.6 (26.8-51.2)
30-day	9.84 (8.56-11.5)	13.0 (11.3-15.3)	17.1 (14.9-20.1)	20.4 (17.6-24.2)	24.8 (20.8-30.3)	28.1 (23.1-35.0)	31.4 (25.2-40.0)	34.7 (27.2-45.3)	39.1 (29.5-52.9)	42.3 (30.9-59.2)
45-day	12.0 (10.5-14.1)	15.8 (13.8-18.6)	20.7 (18.0-24.4)	24.6 (21.2-29.1)	29.7 (24.8-36.3)	33.6 (27.5-41.7)	37.3 (30.0-47.5)	41.1 (32.1-53.6)	46.0 (34.6-62.3)	49.6 (36.2-69.3)
60-day	14.1 (12.3-16.6)	18.5 (16.1-21.7)	24.0 (20.8-28.3)	28.4 (24.5-33.6)	34.1 (28.5-41.7)	38.4 (31.5-47.7)	42.6 (34.2-54.1)	46.7 (36.5-60.9)	52.0 (39.1-70.4)	55.8 (40.8-78.0)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).
Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.
Please refer to NOAA Atlas 14 document for more information.

3. Depending on site characteristics, install either a bubbler module (for measuring stage) or an area-velocity sensor (for measuring stage and velocity). Attach sensor to autosampler computer to log data and program autosampler to take continuous measurements every 10 minutes. A bubbler module is preferred if site characteristics are such that flow monitoring will be most accurate using a flume or weir. The bubbler will measure stage, and flow will be calculated using an equation specific to the flume or weir and logged by the autosampler. If a bubbler module is mounted in a culvert pipe, stage will be converted to flow using the Manning's equation. An area velocity sensor can be used in a culvert pipe assuming laminar flow and less than 5% slope. (Laminar flow can be achieved with a smooth walled pipe insert.) The diameter of the pipe is input into the auto-sampler and flow will be calculated using the cross-sectional area determined by the stage and pipe diameter multiplied by the velocity and logged by the autosampler.

4. Install sample intake tubing where runoff is well mixed and representative of the runoff flow. This is typically near mid-stream in the pipe, culvert or channel. If placed too low, water samples may be dominated by heavier sediment travelling near the bottom of the pipe, culvert or channel, and the strainer may become buried by sediment. If placed too high, then the water sample may contain excess floating material and little solids. Additionally, the strainer may not be adequately submerged if placed too high.

5. A low-flow stainless steel strainer is attached to the end of the suction intake tube facing upstream, parallel to the water flow and downstream of the flow measuring device (bubbler or area-velocity sensor) to avoid creating turbulence that could affect flow measurements. The suction intake must be covered with water during sampling to avoid incomplete sample collection.

6. The autosampler is placed in a secure, vented enclosure as close to the water source as possible to minimize the length of sample tubing from intake to collection bottle. Autosamplers are limited in the height to which they can lift water, typically less than 30 feet. To minimize water freezing in the suction line, intake tubing should maintain a positive gradient between the strainer and the sampler pump so all residual water drains completely out of the suction line to the strainer.

7. After installation the sampler must be calibrated to collect the desired aliquot volume. For individual 1-liter sample bottles this should be around 850 to 950 mL, but always less than 1000 mL to avoid overfilling bottles.

8. Install staff plate or ruler in a location that is easily read and well secured to take manual stage measurements for QAQC. The staff plate or ruler should be of durable, easily cleaned material that will hold up under expected water and weather conditions so that it can remain fixed for the duration of the monitoring period.

10.2.1.3 AUTOSAMPLER SITE AND INSTRUMENT MAINTENANCE

Tracking equipment performance is an important aspect of monitoring success. Therefore, site inspection and maintenance should be scheduled on a monthly basis. This can be done during site visits for event preparation if the time is available for full site inspections and it falls within the scheduled period. Any equipment failures are to be assessed by field personnel on site to determine if the unit can be fixed in the field or should be returned to the office or the manufacturer for repairs. Keep a small

watertight container in the equipment housing with a water-repellent writing pad and indelible maker as well as waterproof labeling tape, hose connectors, fuses and other miscellaneous components.

1. Inspect housing unit, clean out accumulated dirt, open or seal vents, depending on season. Wipe off sampler equipment with clean water. Apply silicon lubricant spray to locks.
2. Examine the flume, intake strainers and flow sensors to verify proper placement and to ensure they are still secure and clean.
3. Verify that sample tubing is free of obstructions and in good condition over its entire length.
4. Inspect the battery voltage, electronics and autosampler desiccant condition.
5. Verify sampling and purging volumes.
6. Confirm that stage readings are correct using installed staff plate or ruler.
7. Confirm that flow measurements are correct using a hand-held flow meter.
8. Fill out a site inspection form. Record date and time of maintenance work, any developing problems or observed changes in site conditions and return this to the office.

10.2.1.4 WEATHER MONITORING AND AUTOSAMPLER EVENT PROGRAMMING

Weather monitoring is critical for determination of whether the upcoming event fits monitoring objectives and to prepare the sampling equipment and field crews. Weather tracking not only includes precipitation events, but also the occurrence of warmer conditions that promote snowmelt-driven events (non-event snowmelt).

*   Monitor weather to assist with anticipation of targeted discharges associated with winter rain, rain on snow and summer thunderstorm events. Possible data sources include:
    o   Check ***WWW.WUNDERGROUND.COM***
    o   Check NOAA National Weather Service (www.nws.noaa.gov).
    o   Check the Weather Channel (***WWW.WEATHER.COM***).
*   In most cases, the National Weather Service will issue a quantitative precipitation forecast (QPF) as each storm approaches, including precipitation and storm duration estimates.
*   Based on the forecasts, field crews should evaluate the type of event expected and its expected magnitude, and then compare these to the events already sampled (see Table A5).

Field crews must adequately prepare in advance of these events by checking and programming equipment at each site, having clean sample bottles on hand and establishing logistical plans to visit each site during the event in order to verify proper function and the collection of sample bottles. Logistical coordination is required to assure that field tasks are carried out when necessary, including nights, on weekends, and during holidays.

If the event is expected to produce adequate runoff volume, as described below, the duration of the forecasted precipitation event is also used to select the sampling interval to be programmed into the

autosampler controller. If precipitation falls short of the prediction, then there may not be enough samples collected to meet sampling frequency criteria. If precipitation significantly exceeds the prediction, then autosampler bottles may need to be replaced during the event.

The autosampler is programmed to collect at a fixed flow volume increment that is specific to each sampling event. Below are the steps used to gain and document site information over time and to optimize the flow trigger setting per event type at a specific site.

1. For estimating storm runoff volumes, develop a rainfall to runoff relationship from prior events. Initially, storm runoff volumes can be estimated using the following equation.

$$V_r = (PF/12) * Area * RC$$

where,

V_r = Runoff volume (cubic feet)

PF = precipitation forecast (inches)

Area = drainage area (square feet)

RC = runoff coefficient

2. Once the sample trigger volume is defined for the upcoming event, program the autosampler to trigger as stage begins to rise with event runoff and then to continue sampling in sequential 1-liter bottles on a constant runoff volume basis, estimated from the rainfall runoff relationship to provide a sampling density of at least 10 or more samples collected during the event or for each 24 hour period, whichever is greater. Longer duration events require continued sampling on the same schedule. The targeted number of samples can increase as runoff prediction accuracy increases.

3. Site specific records are kept to optimize and define the sampling interval based on site, storm predictions, temperatures, snow pack and other factors shown in the template Table A4 below. However, the table below is only a starting point, and sites must be checked during a runoff event to evaluate if the predicted sampling interval is adequate or if adjustments need to be made.

Table A4: Template used to define sampling interval at each site.

Site Name:
Location: (general description)
GPS coordinates: (decimal WGS84)
Drainage Area: (square feet)
Impervious Cover: (%)
Hydrologic Connectivity: (%)
Runoff Coefficient: (dimensionless)
Elevation: (feet amsl)
Average Slope: (feet/feet)
Watercourse Length: (feet)

	Storm ID (Site ID-WY-##)	Start (date time)	Duration (hh:mm)	Total precip (in)	Peak precip (in/hr)	Max temp (°F)	Min temp (°F)	Existing snowpack (in)	Antecedent period (hh:mm)	Runoff volume (cf)	Peak runoff (cfs)	Sampling interval (cf)	Samples (#)
Predicted													
Measured													
Predicted													
Measured													
Predicted													
Measured													

4. Set autosamplers to start at the beginning of runoff event by selecting a stage at which the autosampler is enabled (i.e. triggered to begin sampling). This trigger can be determined and revised based on improved runoff records as described above, but is often determined by the minimum at which the equipment is accurately able to measure stage (usually 0.04-0.08 feet).

5. Start autosampler and verify distributor arm location. Once the above settings have been verified, the autosampler program can be initiated, typically by selecting the program and then pressing "start".

10.2.1.5 EVENT SAMPLE COLLECTION

RSWMP urban outfall monitoring will sample a distribution of discrete runoff event types over the water year, as shown in Table A5. Field crew will visit each site prior to monitored events to inspect site conditions and to verify that equipment is ready for sampling. Additional site visits during an event may be necessary to ensure that equipment continues to work properly and that the sampling interval is set properly to collect representative samples.

Table A5. Targeted minimum number of event types to be sampled per water year at each autosampler site.

Event Types	Target annual sampling frequency (#)
Fall/Winter Rain (Oct 1–Dec 31)	3
Rain on Snow (Jan 1–Mar 31)	3
Spring Snow Melt (April 1–May 31)	4
Summer Rain (June 1– Sept 31)	2

1. When removing bottles or sampler bases, immediately cap the bottle, check the labels for site ID, sample date, bottle position number, and make sure that the correct bottles were indeed filled as reported by the equipment.
2. Verify bottle identification and sequence before removing from the sampler site. Use indelible pens to mark labels, bottles, and caps.
3. Note any unusual conditions or circumstances in the field logs.
4. If the sample volume was not correct, it should be noted in the field log and recalibrated prior to the next monitoring event.
5. Samples are transported back to the lab in coolers at constant temperature (near 4°C). Make sure bottle caps are tight, and keep bottle upright to minimize leaks. Use clear, wide packing tape to secure labels if there is any danger they may fall off in transport. Keep samples in the dark as much as practical.
6. After collection of all samples, the sampling event is terminated and data are downloaded from the station's autosampler data logger. These data are needed for creating composites and for calculating event mean concentrations. Verify the location and filename of the data file, and that is has downloaded successfully.
7. It is extremely important that the hydrograph and sampling profile are examined to determine whether equipment adjustments are needed for continued monitoring.
8. Ultimately it may be advantageous to fit the autosampler with a large composite jar(s) to collect smaller volumes over a greater number of sampling draws during the event. This would occur after a monitoring site has been established for some time and the runoff characteristics and equipment reliability are known. The advantage is that it will eliminate the laboratory event compositing step. The disadvantage is that single samples from specific periods on the hydrograph cannot be isolated for individual analysis.
9. Time interval sampling or adjusting the flow volume sampling during and event is used in cases where there is much uncertainty about the size of the event or timing of runoff. Field personnel must complete site visits to change out bottle carousels before reaching full capacity, which can happen when the runoff substantially exceeds predictions.

10.2.1.6 RAW DATA MANAGEMENT

Raw data is offloaded from the auto-samplers with data transfer devices at the time samples are collected or maintenance is required. Any other field measurements and observations are recorded in the site inspection form (Section 10.2.1.3). Samples, data transfer devices and forms are transported to a processing lab immediately after collection. Data transfer devices are offloaded onto a computer, and all data are input into an Excel workbook for storing continuous parameters (date, time, stage, velocity (if applicable), flow, and turbidity (if applicable)), as well as dates and times of samples taken during the event. Each monitoring site has its own Excel workbook. A separate Excel workbook is used for calculating flow-weighted compositing schedules for desired composites at each monitoring station for each runoff event.

Single and/or composite samples are sent to a proper analytical laboratory in a cooler within appropriate holding times for analysis of desired priority pollutants with an approved chain of custody form. Single samples may be selected for analysis for QAQC purposes or to gain more information about a particular part of the hydrograph such as the first flush (the first sample in the hydrograph) or the sample nearest peak flow. Values are recorded on standard data sheets in the laboratory. Results from analytical laboratories are sent to Tahoe RCD staff that enters them into the Excel workbook for storing nutrient and sediment data. All Excel workbooks are housed on one central computer (with backup device) and managed by Tahoe RCD staff. All raw data is uploaded to the RSWMP Data Management System on a regular schedule.

A minimum of 10% of all samples analyzed will be quality control (QC) samples to identify problems related to field sampling and sample processing. The samples will include the following QC types: field blanks (de-ionized water poured into an autosampler bottle in the field) and field replicates (two samples taken by the autosampler , triggered one after another in quick succession, or one sample taken by the autosampler and one grab sample taken directly in the flow path of the runoff by hand). The analytical laboratory will have their own set of protocols for doing method blanks. These samples will be used to ensure proper instrument function, sample handling procedures, and laboratory methods. This equates to approximately three field QC samples per storm event, rotating sites and QC sample type throughout the year. These samples will be sent to an analytical laboratory and the data will be managed in the excel workbooks as outlined above for other samples.

10.2.1.7 DATA QAQC

Raw instrument stage and flow data must be corrected based on field measurements, and any data gaps should be filled using relationships to other sites. Developing appropriate relationships to field data and to other sites will require at least three water years of data collection to ensure the relationships capture a range of flow conditions. During subsequent years, the corrections can occur less frequently after the relationships have been established and refined.

- Develop inside (instrument) vs outside (field; spot) relationship for stage.
    - Set up Excel spreadsheet with: Date/Time; Field Depth (ft); Instrument Depth (ft).
    - Enter the date and time and field depth reading (D_{OUT}).
    - Create lookup query to identify the closest instrument reading (D_{IN}) to the corresponding date/time of the field reading: VLOOKUP(lookup_value, table_array, col_index_num, range_lookup), where
        - Lookup value is the Date/Time field
        - Table array is the instrument time series data, where the first column in the time series data array is the instrument Date/Time field.

- ▪ Column index number is the number of the column corresponding to the instrument depth values (D_{IN}), where Date/Time is column #1 and depth column number is counted sequentially to the right.
- ▪ Range Lookup is "TRUE" so that the query looks for the closest value, not an exact match.
  - o Create XY Scatter Plot, where outside readings (D_{OUT}) are the X-axis and instrument readings (D_{IN}) are the Y-axis.
  - o Examine data to ensure that relationship between individual readings is reasonable. Remove any values where the validity of the measurement (field or instrument) cannot be confirmed. Outliers could be due to:
    - ▪ Instrument is not working correctly.
    - ▪ Date/Time is not matched correctly. This could be due to instrument data gaps, misalignment due to daylight savings time, inaccurate time recording of field measurements, or format of the Date/Time data cells. As necessary, adjust the Date/Time field to correct for these inconsistencies.
    - ▪ Outside reading is incorrect. Verify with field photos that data has been correctly entered.
  - o Create Linear Trendline through data and set y-intercept to 0. Display equation and R-squared value on chart. Acceptable R-square values are 0.8 and higher. If the R-square value is lower than 0.8, review Section 10.2.1.3 for proper maintenance and QAQC tasks. Equation will yield $D_{IN} = m * D_{OUT}$.
  - o Create a new column in Excel for the correct depth measurements, D_{CORR}
  - o Calculate the corrected instrument depth (D_{CORR}) by rearranging the above equation where $D_{CORR} = D_{IN} / m$.
- • Develop inside vs outside relationship for flow
  - o As necessary, correct the instrument discharge data (Q_i) based on the corrected depth data (D_{CORR}).
  - o Follow instructions above, using Date/Time; Field Flow (cfs); Instrument Discharge (cfs) to correct the instrument discharge data (Q_i), where Q_{IN} is the instrument discharge readings, Q_{OUT} is the manual discharge field measurements, and Q_{CORR} is the corrected instrument discharge.
- • Adjusting relationships
  - o Invariably the relationships described above will change over time as more data is collected and a broader range of runoff events are sampled. As these relationships are refined over time, there could be a need to revise calculations from previous water years. This has the potential to create data management confusion and is a substantial effort that will likely not significantly change results. The following protocol is described to maintain data accuracy while limiting the data management burden.

- o Initial QAQC relationships should be developed during the first 3 years, at which time the all data and metric calculations are provisional. Provided that the 3 years represent a range of water year types, the relationship developed at the end of this time will be the final relationship and the 3 years of data will be finalized. If the 3 years do not represent a range of flow conditions, this provisional time may be extended to 5 years to ensure a proper range has been identified.
  - o Field QAQC measurements will continue to be conducted and added to the spreadsheet.
  - o At the end of every water year, the relationship will be reviewed.
  - o A new relationship will be applied to the current water year and to data moving forward if:
    - ▪ Significant drift in the relationship has occurred. This will be noted if the R-squared value drops below 0.8, and if the new water year data forms a better relationship when separated from previous data.
    - ▪ Modifications to the outfall monitoring location and instrument setup occurred. This includes modification to the flume, installation of new equipment, etc.
  - o The new relationship is applied to data moving forward, using the same 3-year provisional time frame. Previously finalized data should not be adjusted.
- Identify and resolve instrument data gaps
  - o There are two reasonable methods for resolving gaps in the continuous time series: (1) Apply seasonal ratio using a proximate site to adjust the seasonal total volumes, and (2) Apply seasonal averages based on the site data to fill in time series data gaps. The methodologies and the appropriate application of each are presented below.
  - o Proximal Site Seasonal Ratios
    - ▪ Identify a nearby monitoring site with similar catchment characteristics (area, land use distribution, etc.).
    - ▪ Calculate seasonal volume for proximal as described in Section 10.2.1.9, as Q_{SSN}.
    - ▪ For the time period when data is missing at the site, calculate the total volume measured at the proximal site as Q_{MISS}.
    - ▪ Calculate the seasonal ratio of the total volume at the proximal that is represented by the missing data, as $R_{SSN-Q} = Q_{MISS} / Q_{SSN}$.
    - ▪ Calculate the total available seasonal volume at the site using the methodology described in Section 10.2.1.8, as Q_{AVAIL}.
    - ▪ Apply the seasonal ratio to the available volume total to adjust the seasonal volume total at the site, as $Q_{SSN} = Q_{AVAIL} + (R_{SSN-Q} * Q_{AVAIL}) / (1- R_{SSN-Q})$.
    - ▪ This method is preferred, as it preserves the relative magnitude and timing of flow events. However, there must be a nearby catchment that is being monitored for continuous discharge and with similar hydrology characteristics, such that a similar runoff response is expected given a rainfall event.
  - o Site Seasonal Averages

- By season (Fall/Winter, Spring Snow Melt, Summer), calculate the average flow using all available data (including periods of no flow) as $\overline{Q_{SSN}}$.
- Apply the seasonal average to all time periods in that season when instrument data is missing.
- This adjusted time series is used to calculate seasonal metrics described in Section 10.2.1.9.
- This method should be employed when no monitoring data is available for an appropriate nearby catchment. This method assumes there is some proportion of flow during every time step and will underestimate flows during peak events; however, we assume that over the duration of the data gap, the flows are averaged out.

10.2.1.8 DAILY DISCHARGE CALCULATION

Use the corrected instantaneous time series to calculate the daily discharge volumes and import this data to the RSWMP Data Management System. The volume of discharge per day is determined by taking the average, including times of no flow (Q_i = 0), of the instantaneous discharge measurements, Q_i, over each day and multiplying by the number of seconds in a day.

- Calculate daily discharge
  - Create a pivot table in Excel with the date and corrected instantaneous discharge (Q_{CORR}).
  - Set the date field as the 'ROWS' and the average of the instantaneous discharge field as the 'VALUES'. This will provide $\overline{Q_{CORR}}$.
  - Multiply the average daily discharge by the number of seconds in a day to calculate the daily discharge in cfd:

$$Q_d = \overline{Q_{CORR}} \times 86400$$

- Import daily data into RSWMP Data Management System by December 31st for the prior water year.
  - In a new spreadsheet, set up the datasheet with 3 columns: UCO Site ID, Date, Q, where:
    - UCO Site ID: unique identifier for each urban catchment outfall. This ID should be identically formatted to the name used in the Site Metadata table.
    - Date: formatted as mm/dd/yyyy
    - Q: Q_d in units of cubic feet per day
  - Note: if data gaps exist and the proximal site seasonal ratios method is being used, there will be days with missing Q$_d$. If the site seasonal averages method is used, there will be no data gaps in the Data Management System.
  - Save spreadsheet and import into the Time Series table.

o   Note, if this site also has continuous turbidity data (described below), combine the
   discharge and FSP data into one spreadsheet and then import into the RSWMP Data
   Management System.

10.2.1.9 SEASONAL AND ANNUAL VOLUME CALCULATIONS

1.   Calculate seasonal and annual volumes
   •   Aggregate the daily discharge volumes described in 10.2.1.8 according to:
      o Season
         ▪   Sum all Q_d in units of cubic feet per day for the Fall/Winter season (October
            1 – February 28), result is in cubic feet (Q_{SSN-fw}).
         ▪   Sum all Q_d in units of cubic feet per day for the Spring season (March 1 –
            May 31), result is in cubic feet (Q_{SSN-sp}).
         ▪   Sum all Q_d in units of cubic feet per day for the Summer season (June 1 –
            September 30) result is in cubic feet (Q_{SSN-su}).
      o Annual
         ▪   Sum all Q_d in units of cubic feet per day for the entire water year (October 1
            – September 30), result is in cubic feet (Q_{AN}).

10.2.1.10   EVENT MEAN CONCENTRATION (EMC) AND EVENT LOAD CALCULATION

1.   Calculate event mean concentrations ([P]_{EMC}) and event loads (P_E).
   a.   For a series of autosamples the flow-weighted event mean composites are created by
      aggregating measured aliquots from each in proportion to the sample's runoff volume as a
      percentage of the total runoff volume.

$$A_i = V_i \Big/ \sum V_i \times 100$$

   where,

   A_i = individual sample aliquot (percentage of total composite volume)

   V_i = incremental volume of flow for each individual sample

2.   Individual sample aliquots reduce to equal volumes when constant flow volume samples are
   collected in the field. For this reason the equal flow volume increment method is preferred,
   although not always feasible.
3.   Submit to analytical laboratory for measurement of pollutant concentrations and water quality
   characteristics in individual samples selected and/or composite samples created from each
   autosampler for each event.
4.   Submit representative event samples to laboratory (Section 10.2.1.6).
5.   Calculate event loads (P_E) as the product of event mean concentration ([P]_{EMC}) and the event total
   volume (Q_E).

10.2.1.11   DEVELOPMENT OF SEASONAL AND ANNUAL LOAD ESTIMATES

The following event specific data is managed for each urban catchment outfall monitoring site in digital templates. The RSWMP management staff manually extracts this information from the autosampler and flow unit records.

1. Graphical plots of the discharge (Q_i) and time of sample collection over time (x-axis) should be used to define the event start and end visually to quantify the event duration (t_i) and total event discharge (Q_E) as accurately as possible.

$$Q_E = \sum Q_i * t$$

where,

Q_E = total event discharge (cf)

Q_i = instantaneous discharge (cfs)

t = time (seconds)

2. Create a data table that contains the following information for each event sampled (Table A6):

   i.   Site and sampler location
   ii.   Event ID (#) for the season
   iii. Runoff event type ID (rain, snow, snowmelt, thunderstorm)
   iv.   Event duration (hh:mm)
   v.   EMC concentrations from for each analyte of interest
   vi.   Use n/a if any of the event data are missing

Table A6: Event Summary data table.

Site ID	Event ID #	Event Type (FWR, RoS, SSM, Su)	Event Duration (t_i; hrs)	Event Discharge (Q_E; cf)	$[P]_{EMC}$ (mg/L)

9. The recommended approach for estimating of event type mean pollutant concentration is to calculate the total sampled pollutant load divided by the total sample event volume for each event type per water year.

$$[P]_{ET} = \sum ([P]_{EMCj} \times Q_{Ej}) / \sum Q_{Ej} \qquad (i = 1 \text{ to } n)$$

where,

$[P]_{ET}$ = flow-weighted event type mean runoff pollutant concentration (mg/L). For example, $[FSP]_{RoS}$ is the FSP concentration for all rain on snow events for the respective water year.

[P]$_{EMCi}$ = pollutant event mean concentration for storm event i, and n is the number of sampled storm events in that event type for the water year (mg/L).

Q$_E$ = total discharge for each event sampled of the respective type during the water year, and

10. The [P]$_{ET}$ (event type mean concentrations for each pollutant) is applied to each instantaneous flow measurement by season based on the Table A5 of start and end dates of each Event Type.

11. Calculate daily discharge for every day in the water year.

$$Q_d = \sum Q_i * t$$

where,

Q$_d$ = total daily discharge (cfd)

Q$_i$ = instantaneous discharge (cfs)

t = time (seconds)

12. Calculate a daily pollutant loading rate for each day of record.

$$P_d = Q_d * [P]_{ET} * 0.028$$

where,

P_d = total daily pollutant load (g/d)

Q$_d$ = total daily discharge (cf/d) (from Section 10.2.1.8)

[P]$_{ET}$ (mg/L) = flow-weighted event type mean runoff pollutant concentration.

0.028 (mg to g and cf to L conversion)

Final reporting formats for annual urban outfall monitoring sites are outlined in Table A7. These annual data will be imported into the RSWMP Data Management System by December 31 annually:

Table A7: Daily Summary data table

Urban Catchment Outfall				
Time Series Data Fields				
UCO Site ID	Date (mm/dd/yyyy)	Q_d (cf/d)	$[P]_d$ (mg/L)	P_d (g/d)

10.2.2 CONTINUOUS TURBIDITY MEASUREMENTS

Continuous turbidity monitoring requires installation of a turbidity sensor connected to the automated sampler. Collected parameters include date time (on a 10 minute interval) and turbidity reading in NTU. The turbidity data (TB_i) is converted to FSP concentrations ($[FSP]_i$) using established Tahoe Basin relationships (2NDNATURE and DRI 2014). The product of FSP concentrations ($[FSP]_i$) and discharge data (Q_i) is averaged to calculate mean daily FSP concentrations $[FSP]_d$, and summed to calculate daily FSP loads (FSP_d). (Calculations are shown in Section 10.2.2.6 and 10.2.2.7.)

10.2.2.1 SITE SET-UP AND EQUIPMENT CONSIDERATIONS

The recommend continuous turbidimeter is the Forest Technology Systems (FTS) DTS-12 instream turbidity sensor with an ISCO 6712 or better automated sampler for data logging. The optical mechanism on the sensor requires an unobstructed view of a 3 inch diameter spherical pool of water. Mount sensor in a pool of well mixed, representative runoff with positive drainage to prevent freezing around sensor. Freezing around sensor will cause the wiper arm that wipes the optical lens every 10 minutes to fail. Turbidimeter should be mounted where it is easily removed and replaced to facilitate maintenance checks.

10.2.2.2 INSTRUMENT MAINTENANCE AND FIELD QAQC

Turbidimeters should be checked approximately once a month to verify wiper function and condition. If wiper is functioning properly, a window of clean glass will be visible on the optical lens, much like a wiper on a windshield. If streaks are evident, clean the wiper first by removing it and using a small brush to clean the wiper. If streaking still occurs, install a new wiper. If the wiper does not function at all return it to the manufacturer for repairs or replacement.

Field QAQC with a portable turbidimeter is not recommended as different turbidity sensors will give different turbidity readings and therefore they are not directly comparable. This is due to the fact that different sensors interpret particles differently. FTS claims that their sensors will not drift for at least a year. An annual check of zero turbidity should be performed by removing the turbidimeter, cleaning it,

and submerging it in deionized water to verify a reading of 0 NTU. This is the only calibration possible by RSWMP personnel. If sensor is not reading 0 when placed in deionized water, return it to the manufacturer for repairs or replacement.

Though turbidity measurements taken by a different instrument are not directly comparable to the FTS DTS-12, it is recommended that turbidity is measured in the lab on single samples taken by the autosampler and compared to readings by the DTS-12. This is to identify any possible problems with the DTS-12 as different instruments will have readings that are at least reasonably close to one another.

10.2.2.3 LABORATORY SAMPLE SUBMISSION SELECTION

Single samples taken with the autosampler will be sent to an analytical laboratory for TSS and particle size distribution analysis if the continuous turbidimeter indicates that the sample may have a turbidity of greater than 800 NTU. Universal turbidity to FSP rating curves are lacking data on the higher end of the curve, and this data will help to refine the equations that transform turbidity to FSP in the Tahoe Basin.

Samples will be submitted to the laboratory following the protocols outlined in Section 10.2.1.6.

10.2.2.4 RAW DATA MANAGEMENT

Raw continuous turbidity data is offloaded from the automated sampler with the other continuous parameters and is managed in the same excel workbook as the continuous flow data (Section 10.2.1.6). Turbidity readings are stored in a column next to the corresponding continuous flow data from the same date and time.

10.2.2.5 DATA QAQC

Raw instrument turbidity data must be corrected based on field measurements, turbidity to FSP relationships should be refined, and any data gaps should be filled using relationships to other sites. Developing appropriate relationships to field data and to other sites will require at least three water years of data collection to ensure the relationships capture a range of flow conditions. During subsequent years, the corrections can occur more frequently after the relationships have been established and refined.

- Develop inside vs outside relationship for turbidity
  - Set up Excel spreadsheet with: Date/Time; Outside Turbidity (NTU); Instrument Turbidity (NTU).
  - Enter the date and time and outside reading (TB_{OUT}).

- o Create lookup query to identify the closest instrument reading (TB_{IN}) to the corresponding date/time of the field reading: VLOOKUP(lookup_value, table_array, col_index_num, range_lookup), where
  - Lookup value is the Date/Time field
  - Table array is the instrument time series data, where the first column in the time series data array is the instrument Date/Time field.
  - Column index number is the number of the column number of the instrument turbidity reading, where Date/Time is column #1 and turbidity column number is counted sequentially to the right.
  - Range Lookup is "TRUE" so that the query looks for the closest value, not an exact match.
- o Create XY Scatter Plot, where manual readings (TB_{OUT}) are the X-axis and instrument readings (TB_{IN}) are the Y-axis.
- o Examine data to ensure that relationship between individual readings is reasonable. Remove any values where the validity of the measurement (field or instrument) cannot be confirmed. Outliers could be due to:
  - Instrument is not working correctly.
  - Date/Time is not matched correctly. This could be due to instrument data gaps, or misalignment due to daylight savings time or inaccurate time recording of field measurements. As necessary, adjust the Date/Time field to correct for these inconsistencies.
  - Outside reading is incorrect. Review field notes and photographs to confirm data has been correctly entered.
- o Create Linear Trendline through data and set y-intercept to 0. Display equation and R-squared value on chart. Acceptable R-square values are 0.8 and higher. If the R-square value is lower than 0.8, review Section 10.2.2.2 for proper maintenance and QAQC tasks. Equation will yield $TB_{IN} = m * TB_{OUT}$.
- o Calculate the corrected instrument turbidity (TB_{CORR}) by rearranging the above equation where $TB_{CORR} = TB_{IN} / m$.

- Adjusting relationships
  - o Invariably the relationships described above will change over time as more data is collected and a broader range of runoff events are sampled. As these relationships are refined over time, there may be a need to revise calculations from previous water years. This has the potential to create data management confusion and is a substantial effort that will likely not significantly change results. The following protocol is described to maintain data accuracy while limiting the data management burden.
  - o Initial QAQC relationships should be developed during the first 3 years, at which time the all data and metric calculations are provisional. Provided that the 3 years represent a range of water year types, the relationship developed at the end of this time will be

the final relationship and the 3 years of data will be finalized. If the 3 years do not represent a range of flow conditions, this provisional time may be extended to 5 years to ensure a proper range has been identified.

- o Field QAQC measurements will continue to be conducted and added to the spreadsheet.
- o At the end of every water year, the relationship will be reviewed.
- o A new relationship will be developed if:
    - Significant drift in the relationship has occurred. This will be noted if the R-squared value drops below 0.8, and if the new water year data forms a better relationship when separated from previous data.
    - Modifications to the outfall monitoring location and instrument setup occurred. This includes modification to the flume, installation of new equipment, etc.
- o The new relationship is applied to data moving forward, using the same 3-year provisional time frame. Previously finalized data should not be adjusted.

- Identify and resolve instrument data gaps
    - o There are two reasonable methods for resolving gaps in the continuous time series: (1) Apply seasonal ratio using a proximate site to adjust the seasonal total loads, and (2) Apply seasonal averages based on the site data to fill in time series data gaps. The methodologies and the appropriate application of each are presented below.
    - o Proximal Site Seasonal Ratios
        - Identify a nearby monitoring site with similar catchment characteristics (area, land use distribution, etc.).
        - Calculate FSP seasonal loads for proximal as described below in Site Seasonal Averages, as FSP_{SSN}.
        - For the time period when data is missing at the site, calculate the total FSP load measured at the proximal site as FSP_{MISS}.
        - Calculate the seasonal ratio of the total FSP load at the proximal that is represented by the missing data, as $RS_{SSN-FSP} = FSP_{MISS} / FSP_{SSN}$.
        - Calculate the total available seasonal FSP load at the site using the methodology described in Section 10.4, as FSP_{AVAIL}.
        - Apply the seasonal ratio to the available FSP load total to adjust the seasonal FSP load total at the site, as $FSP_{SSN} = FSP_{AVAIL} + (R_{SSN-FSP}*FSP_{AVAIL}) / (1- R_{SSN-FSP})$.
        - This method is preferred, as it preserves the relative magnitude and timing of loading events. However, there must be a nearby catchment that is being monitored for continuous discharge and with similar hydrology characteristics, such that a similar runoff and loading response is expected given a rainfall event.
    - o Site Seasonal Averages
        - By season (Fall/Winter, Spring Snow Melt, Summer), calculate the average FSP concentration using all available data (including periods of no flow) as $\overline{FSP}_{SSN}$.

- Apply the seasonal average to all time periods in that season when instrument data is missing.
- This adjusted time series is used to calculate seasonal metrics described in Section 10.4.
- This method should be employed when no monitoring data is available for an appropriate nearby catchment. This method assumes there is some proportion of flow during every time step and will underestimate flows during peak events; however, we assume that over the duration of the data gap, the flows are averaged out.

10.2.2.6 TURBIDITY TO FSP CONCENTRATION CONVERSION

The conversion of instantaneous turbidity to [FSP] should be conducted using the process described in 2NDNATURE and DRI 2014. The equation provided below summarizes the empirical relation between turbidity and [FSP] (Figure 2.3C, 2NDNATURE and DRI 2014) based on Basin-wide data. It is possible to calculate a more accurate estimate of [FSP] based on region and month of sample collection, but for this Basin wide analysis, the extra effort and complexity required to obtain the next level of accuracy does not outweigh the simplicity of using one equation that can be universally applied to all sites and seasons.

- Convert instrument turbidity series to FSP concentration using the following equation:

$$[FSP]_i = 0.34 * TB_i\text{\textasciicircum}1.07$$

  where

  - $[FSP]_i$ is the instantaneous FSP concentration in mg/L
  - TB_i is the instantaneous turbidity value in NTU
- Adjusting relationships
  - The relationship above was developed using 969 data points collected in the Tahoe Basin from 2003-2011. Researchers identified the need for targeted stormwater sample submission to an analytical laboratory to quantify FSP concentrations (both mass and count) is recommended when field turbidity is greater than 800 NTU to fill data gaps and improve model prediction for highly turbid stormwater.
  - When over 25 additional samples for turbidity greater than 800ntu have been analyzed for FSP concentration and the results have been properly QAQC'd, a similar process to that described in 2NDNATURE and DRI 2014 should be applied to improve the relationship provided above.
  - The new relationship will likely change the results of the previously calculated metrics for all sites and water years. It is recommended that the site with the greatest calculated loads is tested first with the new relationship. If the loads change by more than 10% then all years at all sites should be recalculated. If they do not, then the

previous calculations should stay and only the data collected moving forward should use the new relationship.

Use the corrected instantaneous time series to calculate the daily mass loads and concentrations and import this data to the RSWMP Data Management System. The mass load per day is determined by converting the corrected instantaneous FSP concentration, $[FSP]_{CORR}$, to a pollutant loading rate, FSP, using the corrected instantaneous discharge, Q_{CORR}. The daily rate is calculated by taking the average, including zeros, of the loading rate over each day and multiplying by the number of seconds in a day. The daily FSP concentration, $[FSP]_d$, is determined by dividing the daily pollutant loading rate, FSP_d, by the daily discharge, Q_d, with appropriate unit conversions between grams and milligrams and liters and cubic feet.

- Calculate daily FSP mass load
  - Create a spreadsheet with the date, time, corrected instantaneous discharge (Q_{CORR}), and corrected instantaneous FSP concentration $[FSP]_{CORR}$.
  - Calculate the instantaneous FSP mass load per second as
  $$FSP_i = Q_{CORR} \times [FSP]_{CORR} \times 0.0283$$
  - Create a pivot table in Excel with the date and instantaneous FSP mass load (FSP_i).
  - Set the date field as the 'ROWS' and the average of the instantaneous FSP mass load field as the 'VALUES'. This will provide $\overline{FSP_i}$.
  - Multiply the average FSP mass load by the number of seconds in a day to calculate the daily load in grams per day
  $$FSP_d = \overline{FSP_i} \times 86400$$
- Calculate daily FSP concentration
  - Create a spreadsheet with date, daily discharge (Q_d) and daily FSP mass load (FSP_d).
  - Calculate the daily FSP concentration in mg/L as
  $$[FSP]_d = FSP_d \div Q_d \times 35.31$$
- Import data into RSWMP Data Management System
  - In a new spreadsheet, set up the datasheet with 5 columns: UCO Site ID, Date, Q, [FSP], and FSP where:
    - UCO Site ID: unique identifier for each urban catchment outfall. This ID should be identically formatted to the name used in the Site Metadata table.
    - Date: formatted as mm/dd/yyyy
    - Q: daily discharge (Q_d) in units of cubic feet per day
    - [FSP]: daily FSP concentration ($[FSP]_d$) in milligrams per liter
    - FSP: daily FSP load (FSP_d) in grams per day

- o   Note: if data gaps exist and the proximal site seasonal ratios method is being used, there will be days with missing [FSP] and FSP. If the site seasonal averages method is used, there will be no data gaps in the Data Management System.
- o   Save spreadsheet and import into the Time Series table.

10.2.3 METEOROLOGICAL DATA

Regional meteorological data will be sourced from the long term Western Regional Climate Center (WRCC) station located in Tahoe City called Tahoe City Cross. Raw data from this station is downloaded from the WRCC website (www.wrcc.dri.edu) and managed in an excel workbook. Raw data should include daily precipitation in inches, cumulative precipitation for the water year in inches, and average, minimum, and maximum daily temperatures in degrees Fahrenheit. This station is maintained and data QAQC'd by WRCC.

Local meteorological stations (ideally within a one mile radius of each monitoring site and at the same elevation) are installed and maintained by the Tahoe RCD. Local stations should log readings every 5, 10, or 15 minutes (10 minutes preferred). Raw data should include, at a minimum, date and time, precipitation in inches, and temperature in degrees Fahrenheit. For optimum performance and accuracy, the following guidelines should be adhered to when setting up and operating a weather station.

10.2.3.1 SITE SET-UP AND EQUIPMENT CONSIDERATIONS

It is recommended that a Davis Instruments Vantage Pro weather station with a heated tipping bucket is used for local meteorological stations.

1. Logistical Location: Weather station sensors and data loggers should be easily accessible for service and inspection. Ideally, the weather station should be located in a site that has a clean power supply. (Power surges wreak havoc on the delicate data loggers.) Government buildings such as schools, fire departments and public service buildings usually work well.

2. Geographical Location: Weather stations should be located in the most open and natural environment possible. Temperature, wind, and precipitation values can be affected by tree or building cover. Proximity to heat sources such as heaters, chimneys, exhaust vents and the like will hinder accurate data collection. Proximity to heat absorbing surfaces such as roof tops and asphalt should also be avoided, as should proximity to water sources like sprinklers, roadside spray, and water bodies. Sensors should be located at least 2.1 meters above ground level and 0.6 meters above the expected high snow level. Orientation of specific sensors is usually outlined with directions unique to the manufacturer.

3. Equipment limitations: If using a wireless system, make sure communication requirements can be met. Cabled systems should be well planned and installed to prevent damage to cables and degradation of the site used. Property owners who volunteer their location for a weather station should be confident that the equipment poses no hazard whatsoever.

4. Other Considerations: When trying to collect total precipitation values in snow country, a heater may be necessary to melt snow in the rain gauge. Many of the commonly used tipping bucket rain gauges are compatible with these heaters but caution must be taken in the retrofit as there is a high fire hazard if not installed properly.

5. Since the sensors are located in a relatively high location, birds often utilize them as perches when eating their lunch. It is not uncommon to find pine nuts in the rain gauge even though there are no pine trees nearby. For this reason, make sure tipping bucket screens are in place and inspected periodically. If near pine trees, also inspect for pine needles in the mechanical portion of the tipping bucket. They can and do make it past the screens and eventually stop the buckets from tipping. Areas with large amounts of airborne particles are prone to accumulation in the bucket assembly and additional cleaning of the bucket is required.

6. Follow the manufacturer's guidelines. Each set of equipment will have different requirements for optimum data collection.

10.2.3.2 INSTRUMENT MAINTENANCE AND FIELD QAQC

Rain collectors are checked for debris approximately one time per month. Simple rain gauges are installed near each meteorological station and checked for total precipitation at the end of each storm event. The storm total in the rain gauge is compared to the storm total measured by the weather station to verify weather station function and accuracy.

10.2.3.3 RAW DATA MANAGEMENT

Data is downloaded every two weeks using laptop computers and Weatherlink software. Raw data is transferred to an excel workbook that stores parameters that include, but are not limited to, date/time (10 minute intervals), temperature, and inches of rain. Summaries of individual precipitation events (start and end date/time, event duration, inter-event duration, total precipitation (inches), peak precipitation (inches/10 minutes), maximum and minimum temperature, and event type (rain, snow, mixed rain and snow, rain on snow, and thunderstorm) are extracted from raw data (see Table A13). Visual observations are made during precipitation events and event type is recorded, but maximum and

minimum temperatures are used to better define the local event type as snow, rain, or mixed rain and snow. Event runoff volumes at each monitoring site are plotted against event precipitation totals to predict rainfall/runoff response and aid in programing volume based sample pacing into the autosamplers during future precipitation events. At the end of the water year seasonal and annual precipitation totals are summed from event totals occurring within the desired time period.

10.2.3.4 DATA QAQC

Data is QAQC'd by comparing event and annual totals to the closest neighboring station. If any significant discrepancies are found a decision is made as to what the most reliable data is and annual precipitation totals are calculated using selected event values. Any data gaps are filled in with data from the closest neighboring meteorological station.

10.2.3.5 CALCULATE PRECIPITATION TOTALS

The monthly, seasonal, and water year precipitation totals are determined for the regional and local weather stations and used in the metric and trend analyses.

- Calculate monthly, seasonal and water year precipitation totals
    - Create a spreadsheet with the date and daily precipitation totals (PPT_d).
    - Sum the totals for each month, season, and water year
- Calculate monthly snow and rain totals
    - At the highest resolution of the data, designate the precipitation type as snow or rain based on the temperature data, where
        - Rain occurs when air temperature is greater than or equal to 32 degrees F.
        - Snow occurs when daily average air temperature is less than 32 degrees F.
    - Calculate monthly rain totals (PPT_{mo-r}) for all days in month where PPT_d is rain.
    - Calculate monthly snow totals (PPT_{mo-s}) for all days in month where PPT_d is snow.
- Using all available data from all years, calculate monthly rain and snow mean values as $\overline{PPT_{mo-r}}$ and $\overline{PPT_{mo-s}}$.

10.3 STATUS AND TREND DATA MANAGEMENT

At the end of each water year, the collected data is QAQC'd and corrected using the protocols described above. By December 31st, all corrected data should be imported to the RSWMP Data Management System for the following tables: UCO Site Metadata, UCO Time Series, MET Station Metadata, MET Time Series. Data is imported using spreadsheet templates. Ensure the field names and data types correspond to the tables below.

1.   UCO Site Metadata

Table A8. Urban catchment outfall site metadata fields

Urban Catchment Outfall Site Metadata Fields					
UCO Site ID	Jurisdiction ID	Drainage area (ac)	% IMP	% DCIA	WY Initiated
Text	Text	Double	Double	Double	Integer

   a.   This data is imported during the first water year of monitoring at the site.
   b.   This data only needs to be re-imported if changes to the drainage age or land use were significant.

2.   UCO Time Series

Table A9: Urban catchment outfall time series fields

Urban Catchment Outfall Time Series Data Fields									
UCO Site ID	Date	Q_d (cf d^{-1})	$[FSP]_d$ (mg L^{-1})	FSP_d (g d^{-1})	$[TN]_d$ (mg L^{-1})	TN_d (g d^{-1})	$[TP]_d$ (mg L^{-1})	TP_d (g d^{-1})	Code
Text	Date (mm/dd/yyyy)	Double	Double	Double	Double	Double	Double	Double	Text

   a.   [FSP], [TN], and [TP] are Fine Sediment Particle, Total Nitrogen, and Total Phosphorus concentration respectively, in mg/L, for each day.
   b.   FSP, TN, and TP are loads, in g, for each pollutant each day
   c.   This data is imported annually following proper QAQC and correction of the data and calculations of the metrics.
   d.   Data should be qualified with a preliminary code if the QAQC relationships have not been finalized.
   e.   When data relationships have been finalized, the preliminary data should be deleted and the final data should be imported into the RSWMP Data Management System.

3.   MET Station Metadata

Table A10. Regional meteorology station site metadata fields

Regional Meteorology Station Site Metadata Fields				
MET Station ID	owner (weblink)	Jurisdiction ID	Elevation (AMSL; ft)	WY Initiated
Text	Text	Text	Double	Integer

a. This data is imported during the first water year of monitoring at the site.

b. This data only needs to be re-imported if changes to the ownership occur.

Table A11. Local meteorology station site metadata fields

Local Meteorology Station Site Metadata Fields				
MET Station ID	Jurisdiction ID	Paired Monitoring Station ID	Elevation (AMSL; ft)	WY Initiated
Text	*Text*	*Text*	*Double*	*Integer*

a. This data is imported during the first water year of monitoring at the site.

b. This data only needs to be re-imported if changes to the jurisdiction or paired monitoring station occur.

4. MET Time Series

Table A12. Regional meteorology station time series data fields

Regional Meteorology Station Time Series Data Fields					
MET Station ID	Date (mm/dd/yyyy)	PPT_d (in d^{-1})	Mean Daily Air Temp (^{o}F)	Min Daily Air Temp (^{o}F)	Max Daily Air Temp (^{o}F)
Text	*Date (mm/dd/yyyy)*	*Double*	*Double*	*Double*	*Double*

a. This data is imported annually following proper QAQC and correction of the data and calculations of the metrics.

Table A13. Local meteorology station time series data fields

Local Meteorology Station Time Series Data Fields*				
MET Station ID	Event Date Time Start (mm/dd/yyyy hh:mm)	Event Date Time End (mm/dd/yyyy hh:mm)	Event Duration ([hh]:mm)	Interevent Duration (hh:mm)
Text	*Date (mm/dd/yyyy)*	*Date (mm/dd/yyyy)*	*Time ([hh]:mm)*	*Time ([hh]:mm)*
Total Event Precipitation (inches)	Peak Precipitation (inches/10 min)	Min Event Air Temp (^{o}F)	Max Event Air Temp (^{o}F)	Event Type
Double	*Double*	*Double*	*Double*	*Text*

***All column headers (data fields) should be in same row – shown here in two rows due to space constraints on page. This data is imported annually following proper QAQC and correction of the data and calculations of the metrics.

10.4 STATUS AND TREND DATA ANALYSIS & DATA REPORTING PROTOCOLS

This section describes steps to analyze and create annual site and regional summaries of the Tahoe Basin stormwater status and trends. Specific metric calculations were developed in previous research for the Basin and are documented in 2NDNATURE 2014. To perform these analyses, understanding the climatic context within which the data was collected is critical. Precipitation variations over monthly, seasonal, and water year timescales are used to place the water quality data into this hydrologic framework. The selected seasons each represent a 3-5 month time interval (Table A14) and are the designations defined in the CA MS4 permits and NV MOU.

Table A14. Seasonal designations as defined in the NPDES permit

Season	Start	End	# of days
Fall/Winter (FW)	October 1	February 28	151
Spring Snowmelt (SSM)	March 1	May 31	92
Summer (Su)	June 1	September 30	122

10.4.1 CLIMATIC CONTEXT

The seasonal and water year categorizations are reported in the status sections and monthly precipitation totals are directly used to adjust priority status metrics for the trend analysis.

10.4.1.1 DETERMINE SEASONAL AND WATER YEAR TYPES.

Seasonal and water year type definitions are created using reasonable recurrence intervals to bracket average precipitations totals and to categorize extreme (very wet and very dry) with a less than 10% probability of occurring.

- Order the data in Excel with separate tabs for the WY and each season (4 tabs total)
  - In each tab, create spreadsheet with the year, PPT total, Rank, Recurrence Interval, Probability of Exceedance, and Characterization.
  - Calculate the recurrence interval (T) for each record
  - Calculate the probability of exceedance
- Define type breaks, where types are defined based on the exceedance probability (see Table A15).
- Define upper and lower ends for each type by identifying the two records closest in value to exceedance breaks and performing a trend analysis to get the value associated with the exceedance.
- Assign each record with a water year classification based on the ranges determined above.
- Count the number of records classified as each type.

With each new year of data, it is likely that the upper and lower ends for each type could change, especially with smaller datasets. For datasets where the total number of records is less than 100, the types should be redefined each year and previously designated years should be reclassified as appropriate. When the dataset numbers greater than 100, the reclassification should occur every 10 years.

10.4.1.2 REPORTING FORMATS

- Populate table using analysis described above.

Table A15. Climatic classification

Type	Recurrence Interval (years)	Lower End (in/yr)	Upper End (in/year)	Annual PPT Exceedance Probability (%)	Number of Records
Very Dry	T	Lower range of type designation	Upper range of type designation	>91,	n
Dry				>67,	
Average				>33	
Wet				>10	
Very Wet				≤ 10	

- Create Water Year time series as a vertical bar chart, where
  - Year is the x-axis,
  - Total precipitation (in) is the y-axis, and
  - Each data point colored by type (very dry, dry, average, wet, very wet).

- Create monthly rain and snow time series as a line and fill chart, where
  - Month is the x-axis,
  - Line chart plots current year monthly snow total on primary y-axis and monthly rain total on secondary y-axis
  - Fill chart plots mean of monthly snow on primary y-axis and mean of monthly rain on secondary y-axis

10.4.2 STORMWATER STATUS METRICS AND REPORTING FORMATS

Status reporting was developed to compare water quality metrics in a standardized way between sites around the Basin for any given year. The metrics are expected to: a) collectively summarize each site and water year results, b) provide values that are expected to be sensitive to effective management actions, c) allow result comparisons across catchments and over time, and d) be relatively simple to consistently generate year after year.

10.4.2.1 METRIC CALCULATIONS

Five metrics are determined for each site and used in the status and trend analyses: total discharge volume, percent runoff, unit surface runoff, total pollutant load, and unit pollutant load. To compare metrics across sites and over time, parameter averages are calculated by water year and season for unit surface runoff and unit pollutant loads. Metric calculations are computed automatically using data uploaded to the RSWMP Data Management System and are described conceptually below.

- Calculate total discharge volume (ac-ft per year) by month, season, and water year using proper unit conversions between cubic feet and ac-ft.
- Calculate Unit Surface Runoff (inches per year) for each month, season, and water year. Divide the total discharge volume by the area of the catchment and incorporate proper unit conversions between and feet and inches.
- Calculate % surface runoff by season and water year. Divide the total discharge volume by the volume of precipitation over the catchment and incorporate proper unit conversions.
- Total Pollutant Mass Load (metric tons) by month, season, and water year using proper unit conversions between grams and metric tons.
- Calculate Unit Pollutant Load (pounds per acre over time) for each month, season, and water year. Divide the total pollutant mass load by the area of the catchment and incorporate proper unit conversions between pounds and metric tons.
- Using all available data from all years, calculate monthly discharge and pollutant load mean values.

- Determine Parameter Averages by season and water year for unit surface runoff and unit pollutant load using data from all monitored sites. Calculate upper and lower ranges that are within 20% of the parameter average.

10.4.2.2 REPORTING FORMATS

The annual status report (Figure A1) for each site includes site location and key catchment characteristics (A), monitoring techniques (B), the total snow and precipitation context of the year relative to the historic record (C), the monthly Q and pollutant loads for the year relative to the historic record (D), and a collection of seasonal and annual volume and pollutant metrics that summarize the monitoring results for the specific year (E). Annual compilation of the RSWMP regional status summary for the existing sites across the Tahoe Basin are summarized using a regional map display (Figure A2), with one map per pollutant.

Site Status Summary

- Site location map
  - In GIS create a simple black and white map showing catchment polygon on roads layer, at a scale sufficient to give regional context to location.
  a. Include details of area, % impervious, and % DCIA based on values in UCO Site Metadata table (Table A8).
- Monitoring table
  - For each parameter measured (discharge and all pollutants), include
    - Techniques to calculate the parameter
    - Instrumentation and methods to collect data
- Monthly rain and snow summary graph
  - Use monthly rain and snow time series described above in Section 10.4.1
- Monthly Q & FSP load summary graph
  - Create monthly Q and FSP load time series as a line and fill chart, where
    - Month is the x-axis,
    - Line chart plots current year monthly Q total (acre-ft) on primary y-axis and monthly FSP total (lbs) on secondary y-axis.
    - Fill chart plots mean of monthly discharge on primary y-axis and mean of monthly pollutant load on secondary y-axis
- Surface runoff and pollutant load metrics table
  - Populate table shown in Figure A1 using the metrics calculated above.

Annual Urban Catchment Outfall Monitoring Status
Water Year 2020 (October 2019-2020)
Pasadena Catchment, City of South Lake Tahoe
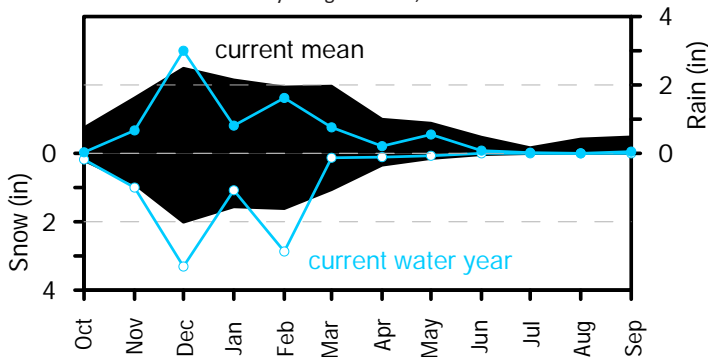
A. Site Location Map

Area	71.4 acres
% Impervious	31%
% DCIA	35%

B. Monitoring and Measurement Data Collection

Parameters	Technique	Instrument/Method
Q	Stage and H Flume	ISCO 730 Bubbler
FSP	Turbidity sensor Regression equation	FTS-DTS-12 Eq. 3.5 (DRI and 2N, 2014)
TN	Autosampler	ISCO 6712
TP		

C. Monthly Rain and Snow Summary
Source: Tahoe City Gauge #48758; www.wrcc.dri.edu

D. Monthly Q and FSP Load Summary
Pasadena Catchment Outfall

E. Surface Runoff and Pollutant Load Metrics

Pasadena Catchment	Units	WY 2020	Units	F/W	SSM	Su
Data Completeness	%	100		100	100	100
Duration no flow	%	62.6	%	40.4	52.2	97.5
WY/season type		V.Dry		Dry	V. Dry	V. Dry
Precipitation *(PPT)*	in yr^{-1}	16.6	in yr^{-1}	14.6	1.8	0.2
% runoff	%	4.5	%	3.7	11.4	0.83
Surface runoff *(U-Q)*	in yr^{-1}	0.75	in ssn^{-1}	0.54	0.21	0.002
Total Q *(Q)*	ac-ft yr^{-1}	4.46	ac-ft ssn^{-1}	3.22	1.22	0.01
FSP unit loading rate *(U-FSP)*	lbs ac^{-1} yr^{-1}	34.5	lbs ac^{-1} ssn^{-1}	23.1	11.4	0.07
Total FSP load *(FSP)*	MT yr^{-1}	1.12	MT ssn^{-1}	0.75	0.37	0.002
TN unit loading rate *(U-TN)*	lbs ac^{-1} yr^{-1}		lbs ac^{-1} ssn^{-1}			
Total TN Load *(TN)*	MT yr^{-1}		MT ssn^{-1}			
TP unit loading rate *(U-TN)*	lbs ac^{-1} yr^{-1}		lbs ac^{-1} ssn^{-1}			
Total TP load *(TP)*	MT yr^{-1}		MT ssn^{-1}			

SITE STATUS SUMMARY   FIGURE A1
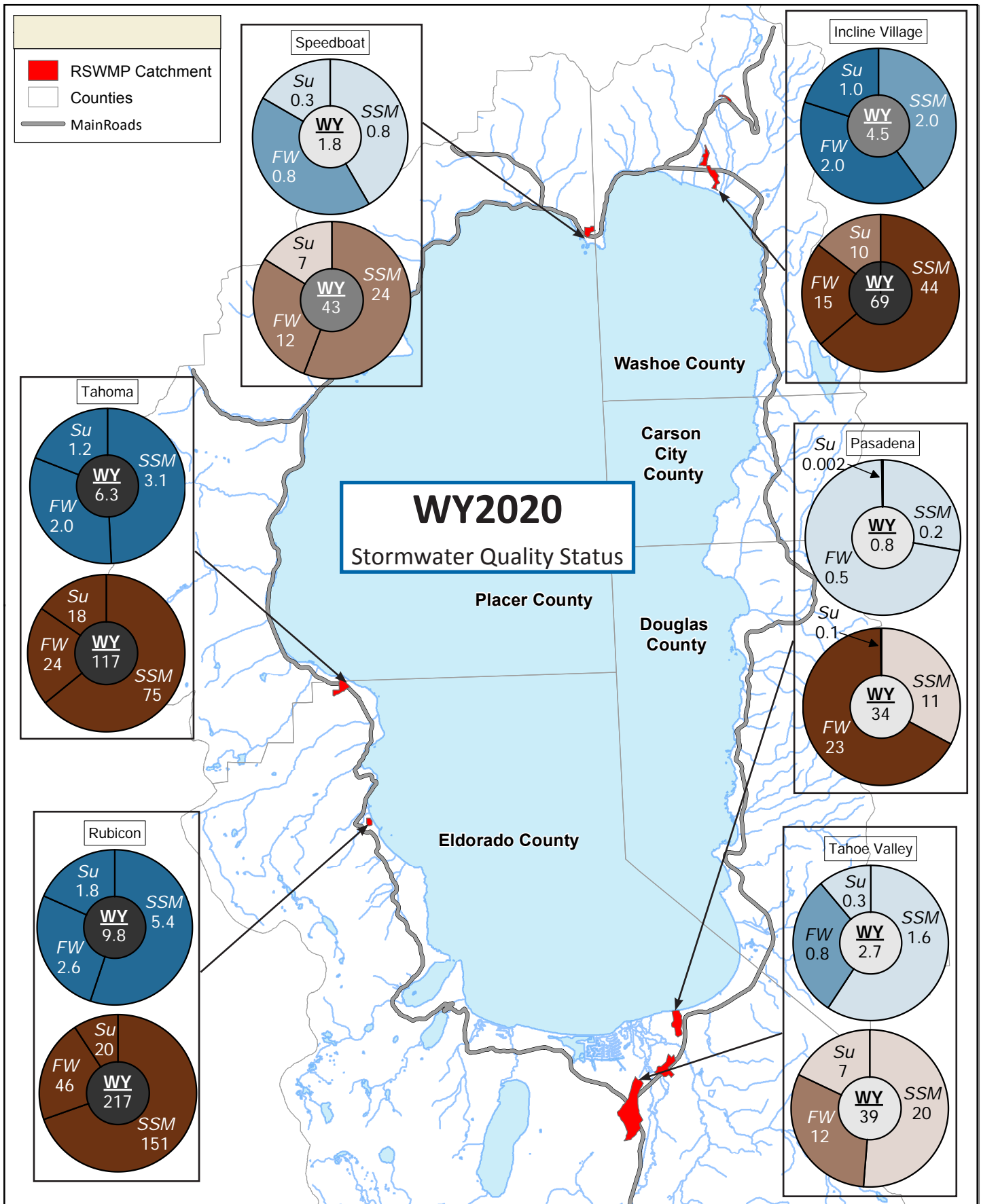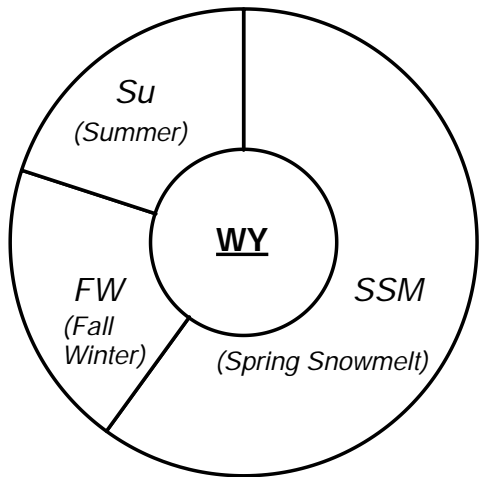
FIGURE A2. **WY2020**
Regional stormwater status summary. Urban catchment runoff volumes and FSP loads. Runoff reported as in yr^{-1} or ssn^{-1}. FSP loads reported as lbs ac^{-1} yr^{-1} or ssn^{-1}.

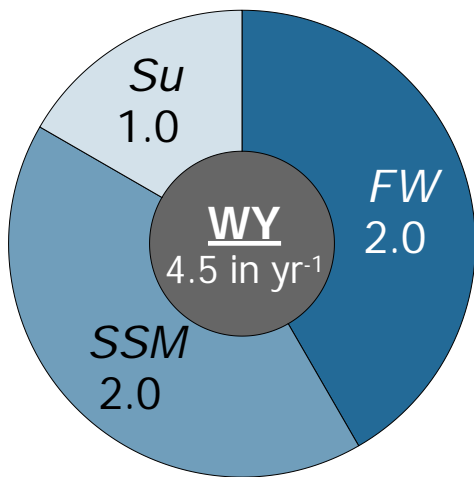# Key for urban catchment outfall pollutant annual status maps

GRAPHIC GUIDE: Unit runoff and pollutant loading rates are directly comparable across sites and over time. The values for unit surface runoff are given below in inches per year for the WY and in inches per season for each season. Unit pollutant loads values are given in pounds per acre per year or per season. The seasonal contributions sum to the water year totals displayed in the center, and the size of each seasonal pie wedge is proportional to its contribution to the water year total. Available data was used to reasonably estimate the basin wide average annual values for each parameter and are shown in the table below.

Parameter Averages by Water Year and Season

	Water Year	FW	SSM	Su
	(in yr^{-1})	(in ssn^{-1})	(in ssn^{-1})	(in ssn^{-1})
Surface Runoff	4.0	0.8	2.4	0.8
	(lbs ac^{-1} yr^{-1})	(lbs ac^{-1} ssn^{-1})	(lbs ac^{-1} ssn^{-1})	(lbs ac^{-1} ssn^{-1})
FSP Load	50	10	30	10
TN Load				
TP Load		TBD		

Water Year
(in yr^{-1} or lb ac^{-1} yr^{-1})

- < 20% of average
- +/- 20% of average
- > 20% of average

Surface Runoff
Season (in ssn^{-1})

- < 20% of average
- +/- 20% of average
- > 20% of average

FSP Load
Season (lb ac^{-1} ssn^{-1})

- < 20% of average
- +/- 20% of average
- > 20% of average

TN Load
Season (lb ac^{-1} ssn^{-1})

- < 20% of average
- +/- 20% of average
- > 20% of average

TP Load
Season (lb ac^{-1} ssn^{-1})

- < 20% of average
- +/- 20% of average
- > 20% of average

EXAMPLE: WY surface runoff was within 20% of the defined average. Fall/Winter runoff was over 20% of the seasonal average, Spring Snowmelt runoff was within 20% of the average and Summer runoff was below 20% of the average.

Regional Status Summary

- Create regional map
    - In GIS create a simple map showing all catchment polygons on roads layer, at a scale sufficient to view the majority of the Tahoe Basin.
- Create site pie/doughnut charts
    - Create one spreadsheet per parameter (Q, FSP, N, P) with the parameter average $\overline{U-X}$, low parameter value (U-X$_{LOW}$), high parameter value (U-X$_{HIGH}$), and a column for each site.
    - Enter values by row for the water year and each season.
    - Create doughnut plots for each site in Grapher.
    - Color each wedge and the center based on the site's value relative to the parameter average, low and high values.

10.4.3 STORMWATER TREND ANALYSES AND REPORTING FORMATS

The stormwater trend approach is designed to achieve the following: (a) provide a feasible and repeatable process that maximizes the temporal resolution of datasets obtained; (b) minimize user time and complexity associated with data management and data analysis for a user that is likely not a statistician; (c) allow reliable comparisons of trends across urban catchments of different sizes and attributes; and (d) be compiled into repeatable data outputs and reporting formats that can be easily interpreted by natural resource managers.

The trend analysis should not be performed before 3 years of quality data is available for a site. Additionally, if the 3 years do not represent a range of water year types (dry to wet), then wait until 5 years of data is available. The trend analysis can be completed in three steps: (1) plot monthly time series; (2) adjust measurement data to natural precipitation variability; and (3) conduct trend analyses.

10.4.3.1 MONTHLY TIME SERIES

- Create a time series chart for each parameter (unit surface runoff, unit pollutant loads for FSP, N and P):
    - Month is the x-axis
    - Monthly unit parameter (U-Q$_{mo}$, U-P$_{mo}$) is the y-axis

10.4.3.2 ADJUST MEASUREMENT DATA TO NATURAL PRECIPITATION VARIABILITY

The monthly data can be adjusted using one of two options: best fit equations or LOWESS regression. Use scatterplots in Excel to determine best-fit equations between monthly precipitation totals and unit surface runoff and monthly precipitation totals and unit pollutant loads. Best-fit linear equations are the

simplest form for explaining a relationship between two variables and should be used whenever possible. If the relationship between precipitation and the parameter of interest has a greater r^2 value when an exponential or logarithmic equation is used rather than a linear equation, then the equation with the greatest r^2 value should be used. Based on the best-fit equation, calculate the predicted value for unit surface runoff or unit pollutant load for each month of data. Then, determine the residual value, the difference between the measured and predicted, for each month.

LOWESS regression should be applied when a linear, exponential, or logarithmic function does not describe the data well, such as when r^2 values are less than 0.5. LOWESS regression cannot be completed in Excel and the recommended software package is Minitab 16. Information to obtain Minitab can be found here, Purchase and download a Minitab software license here: http://www.minitab.com/en-us/products/minitab/features/?WT.srch=1&WT.mc_id=SE003691. LOWESS regression is unique in that it does not provide an equation. Instead, when conducted in recommended Minitab software, the method automatically provides a predicted and residual value for each month. Copy and paste monthly precipitation and monthly unit surface runoff and monthly pollutant loads into a Minitab Worksheet. At a command prompt in Minitab execute the LOWRES function to determine the LOWESS fits and residuals for every month.

10.4.3.3 TREND ANALYSIS

The technique used to conduct the trend analysis on the monthly precipitation adjusted data is a seasonal Mann-Kendall analysis. The results of seasonal Mann-Kendall analysis include an estimate of the interannual trend (e.g., inches of surface runoff per year) for each season or year and a confidence level of the slope. The recommended software used to complete the seasonal Mann-Kendall analysis is Minitab. Store the monthly residual data (for unit surface runoff and unit pollutant loads) and the season type (FW, SSM, or Su) in a Minitab Worksheet. Execute the seasonal Mann-Kendall analysis in Minitab using the SEAKEN function. Copy the "Data Display" p-values and slopes for each season and year and paste in an Excel spreadsheet. Calculate the seasonal and annual rate and multiply the slope by the number of days in the season or water year to obtain the trends.
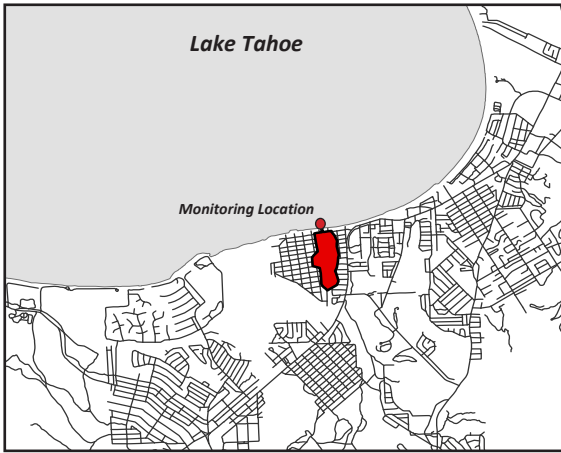
10.4.3.4 REPORTING FORMATS

The annual trend summary (Figure A3) for each site includes general information about the site (A and B), the time series of monthly stormwater runoff and pollutant loading data obtained (C), the results of trend analyses (D and E), and a simple summary statement. Annual compilations of the RSWMP regional trend summary for the existing sites across the Tahoe Basin are summarized using a regional map display (Figure A4), with one map per pollutant.

Urban Catchment Outfall Monitoring Trends
Monitoring interval: 1984-2020
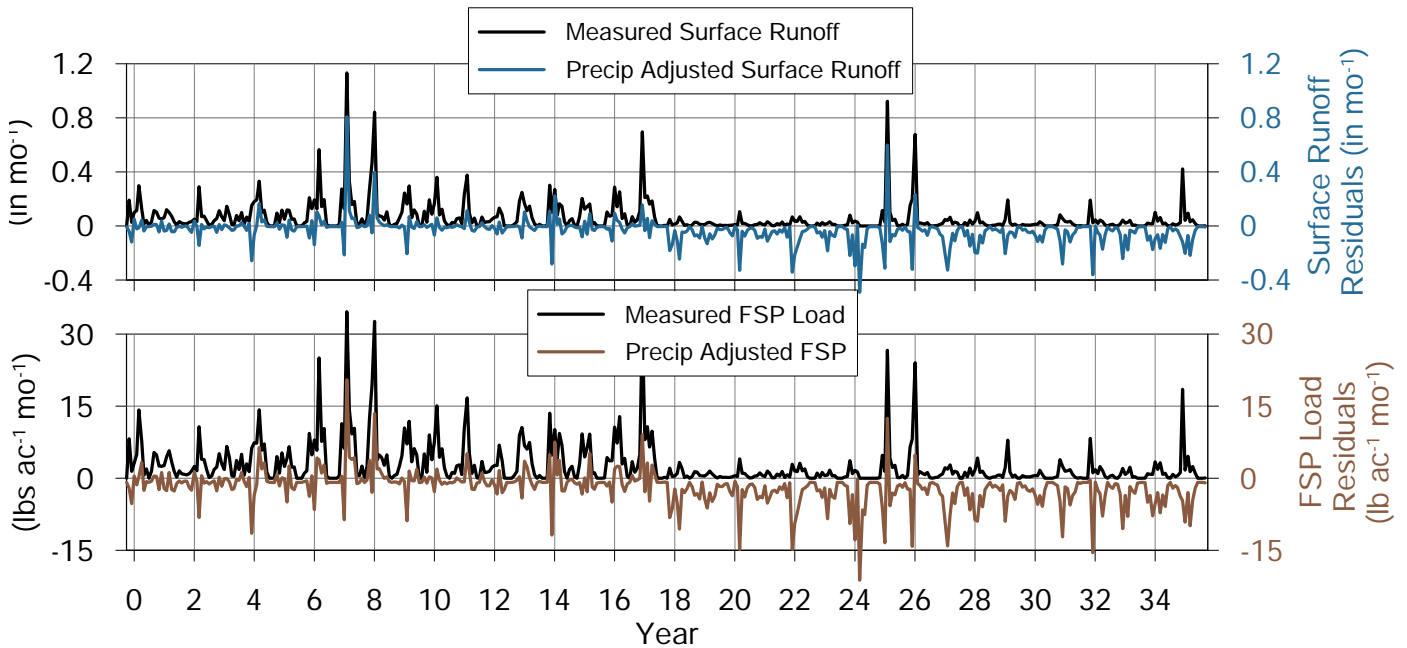## Pasadena Catchment, City of South Lake Tahoe

A. Site Location Map
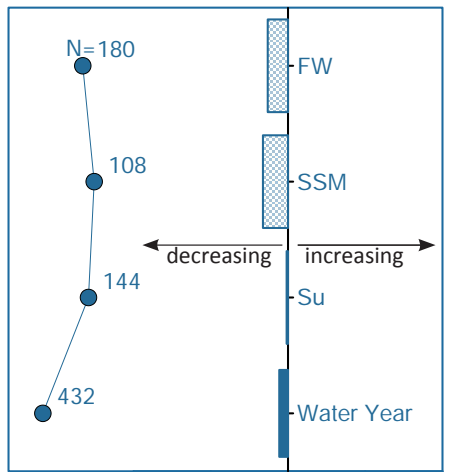
Lake Tahoe

Monitoring Location

B. Precipitation and flow adjusted variables and equations for Q and FSP loads

Adjusted Variable (units)	Independent Variable (units)	Regression Equation
Q (in mo^{-1}): FW and Su		Q = 0.0444*Precip + 0.0049
Q (in mo^{-1}): SSM	Precip (in mo^{-1})	Q = 0.0499*Precip + 0.028
FSP (lbs ac^{-1} mo^{-1}): FW and Su		FSP = 1.85*Precip + 0.86
FSP (lbs ac^{-1} mo^{-1}): SSM		FSP = 2.05*Precip + 2.19

C. Timeseries of Surface Runoff and Pollutant Loads

Legend: Measured Surface Runoff; Precip Adjusted Surface Runoff

Left axis: (in mo^{-1}); Right axis: Surface Runoff Residuals (in mo^{-1})

Legend: Measured FSP Load; Precip Adjusted FSP

Left axis: (lbs ac^{-1} mo^{-1}); Right axis: FSP Load Residuals (lb ac^{-1} mo^{-1})

X-axis: Year

D. Surface Runoff Trends

N=180 (FW)
108 (SSM)
144 (Su)
432 (Water Year)

decreasing ← → increasing

Trend in Precip adjusted Surface Runoff (in yr^{-1})

E. FSP Load Trends

N=180 (FW)
108 (SSM)
144 (Su)
432 (Water Year)

decreasing ← → increasing

Trend in Precip adjusted FSP Load (lbs ac^{-1} yr^{-1})

All water year and seasonal surface runoff and FSP loads show statistically significant decreasing trends over the 36 years of record. An average decreasing trend in FSP loading of 0.05 lbs ac^{-1} yr^{-1} has been measured at the Pasadena Catchment as a result of cumulative effective water quality improvement actions.

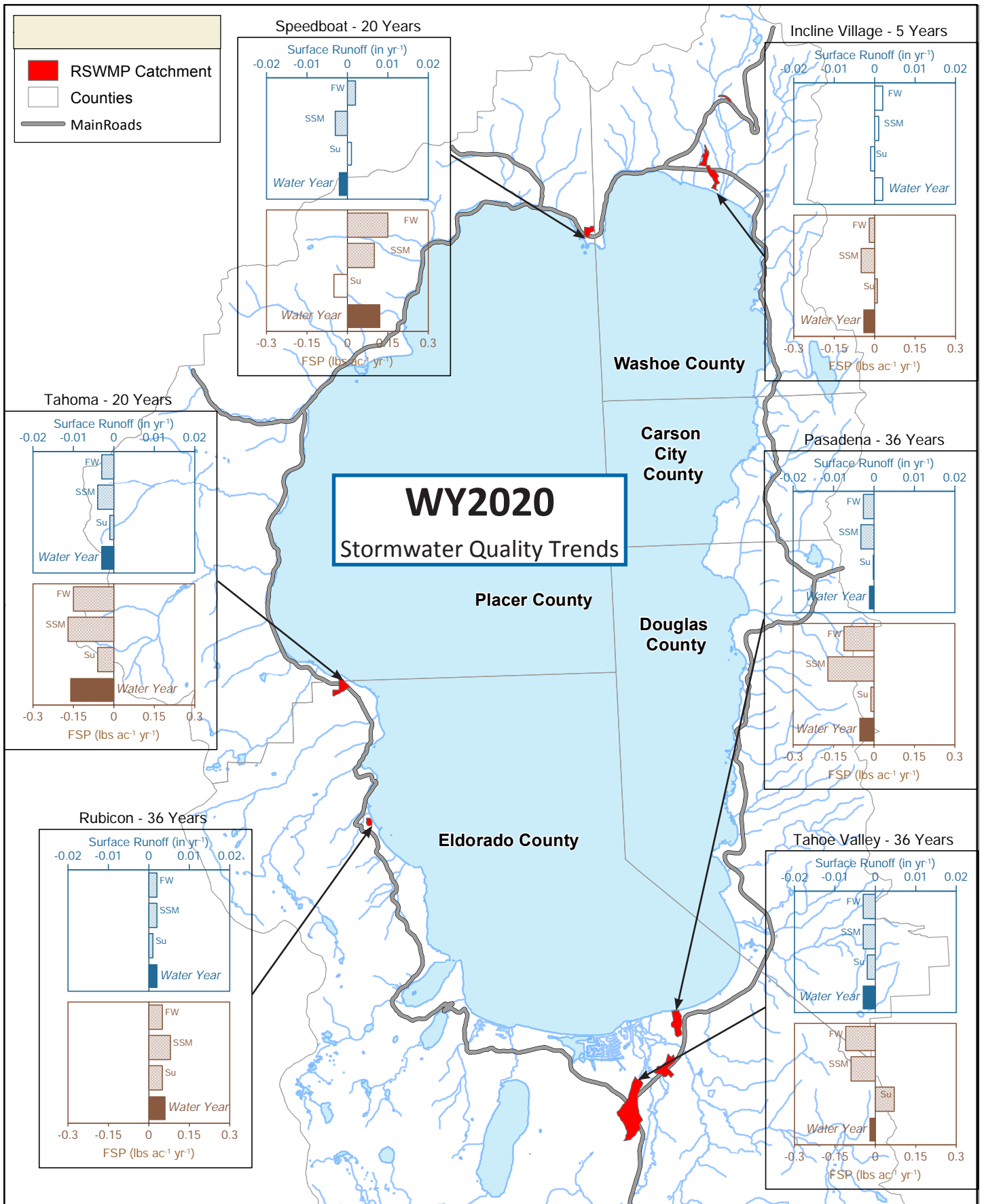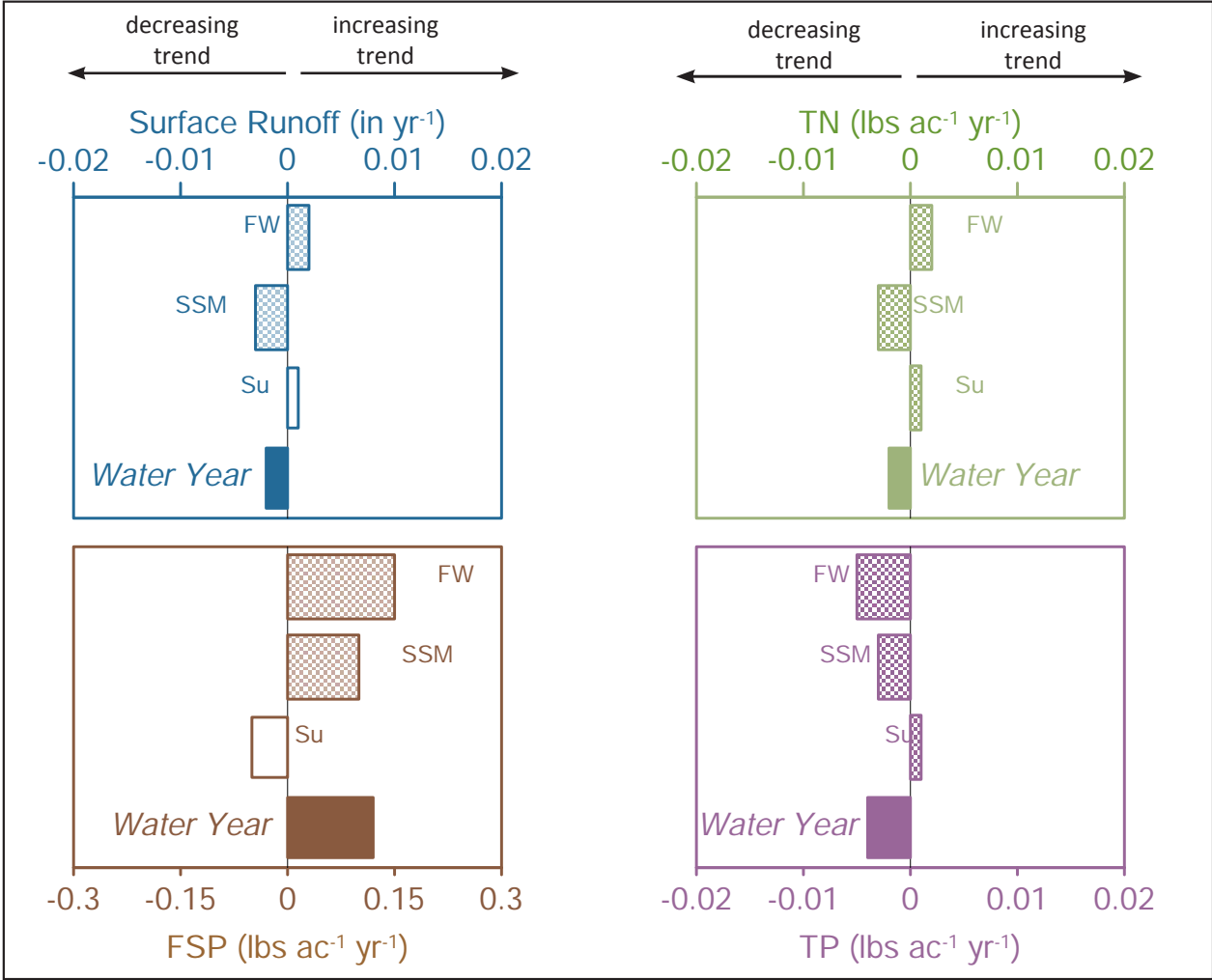TREND STATUS SUMMARY: DISCHARGE AND FINE SEDIMENT

FIGURE A3
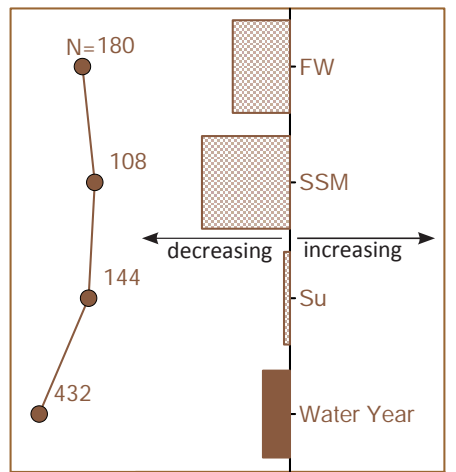
FIGURE A4. **WY2020**
Urban surface runoff and FSP load trends for status and trend monitoring stations. Runoff (blue) reported as inches ssn⁻¹ or yr⁻¹ and FSP (brown) reported as lbs ac⁻¹ ssn⁻¹ or yr⁻¹.

Key for urban catchment outfall pollutant trend maps

GRAPHIC GUIDE: Seasonal and interannual trends in unit runoff and pollutant loads are directly comparable across sites and over time. The values for surface runoff are given in inches year^{-1} (in yr^{-1}) for surface runoff and pounds per acre per year for pollutant loads (lbs ac^{-1} yr^{-1}). The magnitude, direction, and statistical significance of the trend is presented for the water year and three seasons by parameter. Available data was used to reasonably estimate the values for each parameter.

EXAMPLE (upper left): Surface water runoff displays a statiscally significant decreasing trend of 0.002 inches of runoff per year over the duration of the dataset. The summer surface runoff data suggests a negligible and insignificant increasing trend.

<u>Site Trend Summary</u>

- Site Location Map
    - o In GIS create a simple black and white map showing catchment polygon on roads layer, at a scale sufficient to give regional context to location.
- Variables and equations
    - o For each adjusted variable (discharge and all pollutants) for fall/winter & summer and spring snowmelt, include:
        - Independent variable (monthly precipitation)
        - Regression methodology (best fit or LOWESS). If best fit, include regression equation.
- Monthly surface runoff and pollutant load time series
    - o For each variable, create line chart using all available data for all water years where
        - Month is x-axis
        - Measured monthly value is the primary y-axis
        - Parameter residual is the secondary y-axis
- Trends
    - o Create a horizontal bar chart to display the seasonal and interannual Mann-Kendall trends, where
        - The rate is the x-axis
        - The fill is based on the significance of the trend (P_VALUE).
- Description
    - o Write a summary of the seasonal and annual trends for all parameters, including the direction of the trend and its significance.

<u>Regional Trend Summary</u>

- Create regional map
    - o In GIS create a simple map showing all catchment polygons on roads layer, at a scale sufficient to view the majority of the Tahoe Basin.
- Trend Bar Charts
    - o For each site, add the horizontal bar charts developed for the site trend summary.

11 APPENDIX B: INFORM PLRM CEC PROTOCOLS

Appendix B details the data collection protocols that could be used to update the CECs, and the data management, analysis, and reporting protocols that will be used to update the CECs in PLRM for common and well-maintained stormwater treatment facilities in the Tahoe Basin. The protocols follow a focused approach that samples the treated effluent of BMPs of the same type that are verified to be performing in an acceptable condition throughout the monitoring period.

11.1 BMP CEC SITE META DATA

The following briefly describes the necessary site metadata fields to characterize both the catchment contributing to the treatment BMP and the treatment BMP itself (see Table B2 in Section 11.3). The catchment should be delineated in GIS based on topography and known drainage infrastructure, and then verified in the field and adjusted as necessary. The treatment BMP should be surveyed in the field.

- BMP Site ID: unique identifier for each treatment BMP. ID should be easily interpretable for people knowledgeable of Tahoe stormwater.
- Jurisdiction ID: one of the 7 urban jurisdictions responsible for stormwater management in the Tahoe Basin. The jurisdiction responsible for maintaining the treatment BMP.
- BMP type: one of the four priority BMP types modeled in PLRM where Tahoe-specific monitoring of well-maintained BMPs is needed. Includes media filter, dry basin, wet basin, and treatment vault. Consult the BMP RAM Technical Document (available at www.tahoebmpram.com) for how to determine the BMP type.
- Drainage area (acres): the total area in acres contributing to the catchment outfall. Calculate the total area of the delineated catchment in GIS using the 'Calculate Geometry' tool.
- % IMP: the percentage of the total catchment area that is designated as impervious. Clip the most recent TMDL Land Use GIS Layer (currently the draft 2011 land use layer is available as part of PLRM v2 and can be downloaded from https://share.nhcweb.com/public.php?service=files&t=a8dc70db94dd13ad3b18fd2e2c1e79df though it is likely to be moved to the TMDL Management Systems site) to the catchment boundary and determine the acreage of impervious area within the catchment. Divide by the total drainage area to determine percent impervious.
- Dominant urban land use type: the land use with the greatest percent area within the catchment. Clip the most recent TMDL Land Use GIS Layer (currently the draft 2011 land use layer is available as part of PLRM v2 and can be downloaded from https://share.nhcweb.com/public.php?service=files&t=a8dc70db94dd13ad3b18fd2e2c1e79df though it is likely to be moved to the TMDL Management Systems site) to the catchment boundary and determine the acreage for each land use type: single family residential, multi-

family residential, commercial-industrial-communications-utilities, and erosion potential. Divide by the total drainage area to determine percent land use. The land use with the greatest percentage is the dominant land use. If two land uses are within 5% of each other, include both.

- Capacity stage: the water depth at which the treatment BMP reaches capacity. Above the capacity stage, water will flow through the BMP bypass outlet. Survey the treatment BMP to determine the relative elevations of the base of the BMP surface and the stage at which flow enters the bypass outlet. The difference between the two elevations is the capacity stage.
- Treated outflow stage: The water depth at which water flows through the treatment outlet. Below the treated outflow stage, water can only exit the treatment BMP via infiltration through the ground surface. Survey the treatment BMP to determine the relative elevations of the base of the BMP surface and the stage at which flow enters the treatment outlet. The difference between the two elevations is the treated outflow stage.
- MET station ID: the unique identifier associated with the meteorology station closest to the treatment BMP location and most representative of the weather occurring at the BMP.
- WY Initiated: the water year in which the site was established and the spatial attributes were calculated.

It is anticipated that these metadata fields will only change over time with the completion of significant water quality improvement projects within the catchment or significant maintenance or reconstruction of the treatment BMP.

- For catchment characteristics:
  - At the completion of a project, the drainage area, % impervious area and dominant land use should be recalculated and if the values have changed by more than 10% or the dominant land use changes, a new record with the current water year should be added to the table.
  - Additionally, land use changes may change incrementally over time with new development or changes in coverage. Every 5 years, the % IMP and dominant land use should be recalculated and if the % impervious value has changed by more than 10% or there is a different dominant land use, a new record with the current water year should be added to the table.
- For BMP characteristics
  - At the completion of significant maintenance actions, the capacity stage and treated outflow stage should be re-measured. If the percent change in the values is greater than 5% and the absolute change more than 0.15ft, a new record with the current water year should be added to the table.

11.2 BMP CEC FIELD DATA COLLECTION PROTOCOLS

The goal of RSWMP CEC data collection is to inform the characteristic effluent concentrations modeled in PLRM. Measured effluent concentrations from three specific BMPs of the same type generate a single measured recommended CEC (mg/L) for a specific BMP type for each pollutant (CEC_{BMP-P}). This approach is expected to provide a reasonable spatial and temporal distribution of treated effluent conditions of priority BMP types over a feasible, cost effective time interval.

11.2.1 SITE SET-UP AND EQUIPMENT CONSIDERATIONS

11.2.1.1 BMP TYPE AND SITE SELECTION

The type of BMP selected should consider the following criteria:

1. There are at least three BMPs of the same type in the Tahoe Basin that are adequate for monitoring and where equipment can be reliably installed and maintained.
2. The BMP type has been recommended for the treatment of stormwater runoff and shown to reduce the pollutants of concern; FSP, TN, and/or TP.
3. There is a general interest in the BMP type's efficacy in treating the pollutants of concern in the Tahoe Basin among implementing agencies.
4. There is the possibility of wide applicability of the BMP type for stormwater treatment in the Tahoe basin.
5. The current CEC in the PLRM has been shown to be in need of refinement.

11.2.1.2 PASSIVE SAMPLER INSTALLATION

A minimum of three passive samplers should be installed at the outlet of the treatment BMP to sample treated outflow across the range of flows anticipated within the outfall structure. Passive samplers should be installed to sample: (1) the onset of treated outflow, (2) the maximum treated outflow depth, and (3) a range of flows in between. Care must be taken to ensure passive samplers <u>do not</u> sample bypass flow.

<u>Determine sampling elevations</u>

1. Visually inspect the treatment BMP outfall to determine the most appropriate location to sample outflow. Options include sampling within the outfall structure itself, or within the treatment BMP near the outlet at a stage just above the outlet structure. Factors influencing this decision will include equipment security, access, and the stage to discharge relationship. It is logistically difficult to install passive samplers less than 0.2' apart but options exist to use tube

drains or other means to collect and route samples to passive sample bottles at known stage intervals. However, for large BMP structures, where a small change in stage equates to a significant amount of water volume, effort should be made to place the passive samplers as close together as possible to ensure that collection is probable.

2. Determine the minimum water depth at the select sampling location associated with treated outflow (D_{TO-min}). Within the outfall structure, this will be at the base of the structure. Within the treatment BMP, this will be at the elevation of the treated outlet.

3. Determine the maximum water depth at the selected sampling location associated with treated outflow (D_{TO-max}). Within the outfall structure, this will depend upon the site design. Within the treatment BMP, this be just below the elevation of the bypass outlet.

4. Using visual indicators (e.g., rust lines, staining, flow debris), estimate the depth associated with the most frequent flows (D_{TO-fq}).

5. Select sampling elevations:
    1. D_{TO-min}
    2. D_{TO-max}
    3. D_{TO-fq}
    4. If installing a fourth passive sampler, place halfway between D_{TO-min} and D_{TO-fq}

6. Once the samplers are installed at the selected locations, they remain at those intervals for the duration of an event. It is desirable that they remain at those intervals for the entire three year evaluation period, but adjustments may need to be made to better capture representative effluent samples.

7. For best results, samplers should be installed during low flow conditions when access to the channel is the greatest.

Determine appropriate installation approach

Depending on the sampling location, passive samplers can be installed via one of two methods: using intake tubes or attached to posts.

1. Intake tubes are placed at the specified elevations within outfall structures like culverts, where there is insufficient space to place the passive samplers or access is difficult. The tubes are then routed to the outside of the structure where the passive samplers are housed.   The passive samplers must be housed at an elevation lower than the outfall structure to facilitate passive filling by gravity.

2. Posts are placed within the treatment BMP and the passive sampler housing is attached to the posts at the specified elevations.

Install passive samplers and staff plates

Nalgene Storm Water Samplers are the preferred passive sampler product, as they are cost-effective, EPA compliant, convenient and versatile. Setbacks include that they collect only one liter of sample volume and only collect samples on the rising limb of the hydrograph. Larger-volume passive samplers can be fabricated for installation to increase the flexibility to submit water samples for multiple pollutant analyses, if desired. To avoid contamination Storm Water Samplers should not be left at site between sampling events.

1. Intake Tubes:
   - Personnel Needed: 1-2 experienced field personnel 6-8 hours per station to install passive samplers and instrumentation.
   - Equipment Needed:
     - three (3) Nalgene Stormwater Samplers [Cat. No. 1100-1000]
     - three (3) Nalgene Stormwater Mounting Kits (includes mounting tube, clamp, wire hanger, cable tie, and mounting stake)
     - Nalgene Installation Guide
     - drill
     - clear plastic tubing
     - mesh screen
     - job locker, or something similar to protect passive samplers
   - Install passive samplers. Installation and housing must be secure and sturdy enough to remain in place during high flow events and potential collisions with debris.
   - Based on selected sampling stages, drill holes within outfall structure to ensure proper sampling of the targeted discharges.
   - Secure tubing within outfall structure. Cover tubing with mesh to prevent clogging with debris. Ensure tubing is flush with the outfall structure surface to minimize disturbance of sample.
   - In job locker, place Nalgene Stormwater Samplers.
   - Connect tubing from sampling structure to samplers.
   - Install remaining intake tubes.
2. Posts:
   - Personnel Needed: 1-2 experienced field personnel 6-8 hours per station to install passive samplers and instrumentation.
   - Equipment Needed:
     - three (3) Nalgene Stormwater Samplers [Cat. No. 1100-1000]
     - three (3) Nalgene Stormwater Mounting Kits (includes mounting tube, clamp, wire hanger, cable tie, and mounting stake)
     - slot-headed screwdriver
     - flagging

- o shovel
- o digging bar
- o Nalgene Installation Guide
- o vertical steel mounting stake (post) or rebar
- o side braces
- o level
- o radiator clamps
- Install passive samplers. Installation and housing must be secure and sturdy enough to remain in place during high flow events and potential collisions with debris.
  - o Secure vertical steel post/rebar so (1) it is buried 1-2 feet in substrate for stabilization and (2) it rises at least 1 foot higher above the BMP capacity stage.
  - o If possible, place side braces to further secure vertical post.
  - o Depending on the differences in stage between targeted discharges, it may be possible to secure more than one sampler to a single vertical post/rebar.
- Based on selected sampling stages, location of post/rebar within the BMP and location of vertical post/rebar holes determine the position of each sampler housing to ensure proper sampling of the targeted discharges at stages associated with D_{TO-min}, D_{TO-max}, and D_{TO-fq} etc. Top of Storm Water Sampler should be at the selected sampling stage.
- Install Nalgene Mounting Kit according to installation guide. Install kit on upstream side of post/rebar to reduce obstruction of sample.
- Test placement of Storm Water Sampler at station. Use level to ensure that sampler will rest evenly on housing. Make any adjustments necessary.
- Install remaining passive samplers.

3. Staff plates
   - Install staff plates or rulers (depending on the site installation type) in a location that can be easily viewed.
   - Ensure the bottom of the staff plate is equivalent to the bottom of the outlet, such that 0' reading on the staff plate is equivalent to when there is no flow from the treated outlet.

11.2.2 INSTRUMENT MAINTENANCE AND FIELD QAQC

11.2.2.1 MAINTAIN PASSIVE SAMPLERS

- During any site visits and at a minimum four times a year (once per season), assess the passive sampler installation.
- Verify passive sampler mounting installation is in good condition. If mounting appears unstable or unable to withstand the anticipated flow and field personnel are unable to secure mounting,

do not sample site. Contact field personnel who installed the mounting and request service to stabilize the mounting.

- Verify staff plate installation is in good condition and has not moved. If staff plate appears insecure, field personnel should make every effort to secure the installation and note of the field datasheet that its location may have been altered.

11.2.2.2 TRACK EVENT TYPES

Every water year, a log of the samples collected should be maintained to ensure the sampling is meeting the targeted values. Update Table B1 as data is collected to inform future event sampling. The target number assumes that two samples are collected during twelve events per year at three sites.

Table B1. Targeted minimum number of event types to be sampled per water year at each BMP.

Event Types	Target annual sampling frequency (#)	# Events	# Samples Collected
Fall/Winter Rain (Oct 1–Dec 31)	3		
Rain on Snow (Jan 1–Mar 31)	3		
Spring Snow Melt (April 1–May 31)	4		
Summer Rain (June 1– Sept 31)	2		
		TOTAL	
		TARGET	72

11.2.3 EVENT SAMPLING

11.2.3.1 ANTICIPATE A RUNOFF EVENT

Weather monitoring is critical for determination of whether the upcoming event fits monitoring objectives. Weather tracking not only includes precipitation events, but also the occurrence of warmer conditions that promote snowmelt-driven events.

- Monitor weather to assist with anticipation of targeted discharges associated with winter rain, rain on snow and summer thunderstorm events. Possible data sources include:
  - Check **WWW.WUNDERGROUND.COM**
  - Check NOAA National Weather Service (www.nws.noaa.gov).
  - Check the Weather Channel (**WWW.WEATHER.COM**).
- In most cases, the National Weather Service will issue a quantitative precipitation forecast (QPF) as each storm approaches, including precipitation and storm duration estimates.
- Based on the forecasts, field crews should evaluate the type of event expected and its expected magnitude, and then compare these to the events already sampled (see Table B1).

11.2.3.2 INSTALL SAMPLE BOTTLE (PRE-EVENT)

Prior to the onset of the event, field personnel must visit the site to prepare for sample collection. DO NOT leave empty sample bottles at site for more than 7 days to avoid contamination from wind. Ideally clean bottles are installed within 3 days of a targeted event.

- Equipment required:
    - Clean 1-Liter HDPE sampling bottle
    - Tools to open passive sampler housing. May include small pry bar, shovel to remove snow, etc.
    - Field datasheet
- Verify passive sampler mounting installation is in good condition. If mounting appears unstable or unable to withstand the anticipated flow and field personnel are unable to secure mounting, do not sample site. Contact field personnel who installed the mounting and request service to stabilize the mounting. If applicable, ensuring intakes tubes are clean and the inlets are free of debris.
- Deploy empty, clean, 1-liter HDPE sampling bottle for each passive sampler. Be careful not to touch the inside of the bottle and contaminate sample. If temperatures are expected to be elevated (greater than 70 degrees), sample bottle can be 'blacked' out with tape or marker or paint, to reduce the sun's impact to the collected sample's temperature.

- Verify staff plate installation is in good condition and has not moved. If staff plate appears insecure, field personnel should make every effort to secure the installation and note of the field datasheet that its location may have been altered.

11.2.3.3 COLLECT SAMPLE (POST-EVENT)

Following the event, field personnel must visit to collect the sample.

- Equipment required:
    - Clean 1-Liter HDPE sampling bottle
    - Tools to open passive sampler housing. May include small pry bar, shovel to remove snow, etc.
    - Field datasheet
- Following a discharge event, arrive at the site within 12 hours of the end of the event.
- Remove Storm Water Sampler from housing and immediately seal top with lid. Sample must have been properly collected in order to be submitted to lab.
    - If sample has exceeded the proper holding time in the passive sampler, then samples cannot be submitted to lab. Sediment holding times are lengthy. Samples to be submitted for nutrients can remain at site up to 12 hours if water/air

temperatures are below 38°C. Evaluations of sample condition must be made in field based on conditions prior to submission to laboratory.

- o If the runoff volume was not great enough to fill the bottle and properly seal the lid, sample in unusable - the exception being that field personnel arrived within an hour of sample collection. In this case, sample can be submitted to lab, but must be flagged as 'unsealed'.

- Close housing to avoid contamination.

11.2.4 TURBIDITY MEASUREMENTS

Please refer to Section 10.2.2.

11.2.5 BMP RAM CONDITION ASSESSMENTS

It is recommended that BMP RAM (www.tahoebmpram.com) is used to evaluate and track the condition of each of the BMPs included in the monitoring by completing field evaluations each May-June for the respective three consecutive water years studied. This will ensure the treatment BMPs are working properly. Detailed BMP RAM protocols and technical documentation is available for download from the website.

11.2.5.1 INVENTORY & SET UP

- Inventory the treatment BMPs and add each to the BMP RAM database. Depending upon the treatment BMP type, different data entry is required.
- Perform maintenance at the BMP to ensure it is in the best achievable condition.
- Complete benchmark observations as necessary for the BMP type, and enter benchmark and threshold observations into BMP RAM website.

11.2.5.2 ANNUAL CONDITION ASSESSMENTS

- Following the spring snowmelt season (likely in May or June), conduct BMP RAM field observations at each site to determine the BMP condition score.
- If the BMP RAM score is <3.5, perform maintenance and reassess the site.

11.3 BMP CEC DATA MANAGEMENT

By December 31st, all corrected data should be imported to the RSWMP database for the following tables: BMP Site Metadata (Table B2), BMP Event Data (Table B3). Regionally relevant weather data will

be uploaded per the protocols in Appendix A to the following tables: MET Site Metadata (Table A10), MET Time Series (Table A12). Data is imported using spreadsheet templates. Ensure the field names and data types correspond to the tables below.

5.   BMP Site Metadata

Table B2. BMP effluent monitoring site metadata fields

BMP Effluent Monitoring Site Metadata Fields									
BMP Site ID	Jurisdiction ID	BMP Type	Drainage area (ac)	% IMP	Dominant urban land use type	Capacity stage (ft)	Treated outflow stage (ft)	MET Station ID	WY Initiated
Text	Text	Text	Double	Double	Text	Double	Double	Text	Integer

a.   This data is imported during the first water year of monitoring at the site.

b.   This data only needs to be imported if changes to the drainage age, land use, or BMP were significant.

6.   BMP Event Data

Table B3. BMP effluent monitoring event data fields

BMP Effluent Monitoring Event Data Fields				
BMP Site ID	Date	Event type	Stage (ft)	$[P]_i$ (mg L^{-1})
Text	Date (mm/dd/yyyy)	Text	Double	Double

a.   This data is imported annually following proper QAQC and correction of the data and calculations of the metrics, where

i.   Stage (ft) is the sampling elevation of the installed passive sampler (see Section 11.2.1.2), and

ii.   [P] is the pollutant concentration of the collected sample.

11.4 BMP CEC DATA ANALYSIS, DATA REPORTING PROTOCOLS

This section describes the steps to analyze and report the collected data to inform the average annual CEC values in PLRM for well-maintained treatment BMPs. Bootstrapping, a statistical technique to extract additional information in a measured dataset, is used to estimate the statistical significance, or the confidence interval, around the median of the pollutant concentrations measured for a specific BMP type.

11.4.1 BOOTSTRAPPING

The specific CECs for each BMP and pollutant (CEC$_{BMP-P}$) are determined using a statistical technique to estimate the median and the 90% confidence interval of the median. The protocol for this technique was developed in the R statistical package. R is available for free download at: http://www.r-project.org/). The code to complete this analysis was developed in previous research (2NDNATURE 2014). Conceptually, the protocol involves the following steps:

1. Organize all data for a single pollutant and a single BMP type in one column (3 years of data).
2. Complete steps a to c 10,000 times (this is a standard for the bootstrapping method):
   a. Sample, with replacement, the data using the number of measurements collected. Sample, with replacement, also a standard for bootstrapping, refers to the process of picking one sample from the distribution and putting it back into the population before picking the second sample.
   b. Calculate the median.
   c. Store the median value.
3. Plot a histogram of 10,000 medians.
4. Calculate the mean of 10,000 medians – this is the recommended CEC for the specific BMP type and priority pollutant, *(P)*.
5. Calculate the 5% and the 95% percentile of the 10,000 medians; this is the 90% confidence interval range for the pollutant concentration.

11.4.2 REPORTING FORMATS

The BMP CEC results (Figure B1) for each BMP type includes the recommended CECs for each pollutant (A), site location map (B), site characteristics (C), summary of water year type, samples, and RAM scores (D), site effluent data (E) and site bootstrapped data (F).

- Recommended CECs table (A)
  - For each pollutant include
    - Bootstrapped median as the recommended CEC value
    - 90% confidence interval range
- Site location map (B)
  - In GIS create a simple map showing all catchment polygons on roads layer, at a scale sufficient to view the majority of the Tahoe Basin.
7. Site characteristics table (C)
   a. Include details of jurisdiction, area, % impervious, and dominant land use based on values in BMP Site Metadata table.
- Monitoring table (D)
  - For each year of monitoring
    - Water year classification type (see Appendix A)
    - Number of samples collected

- # relative to the target
- Annual BMP scores by site, exported from www.tahoebmpram.com
- Effluent data by site and pollutant (E)
  - Create box-whisker plots for each pollutant and site where
    - Site is the x-axis
    - Measured pollutant concentration is the y-axis
    - Display median and 5th, 25th, 75th, and 95th percentiles
- Bootstrapped data by site and pollutant (F)
  - Create box-whisker plots for each pollutant and site
  - Create box-whisker plots for each pollutant and site where
    - Site is the x-axis
    - Bootstrapped pollutant concentration is the y-axis
    - Display median and 5th, 25th, 75th, and 95th percentiles

12 REFERENCES

2NDNATURE, NHC, and Environmental Incentives. 2009. BMP RAM Technical Document, Lake Tahoe Basin. Prepared for the U.S. Army Corps of Engineers, Sacramento District. September 2009.

2NDNATURE and NHC. 2012. Focused Stormwater Quality Monitoring to Inform Assumptions & Evaluate Predictive Capabilities of Existing Tools. Final Technical Report. Prepared for USFS Pacific Southwest Research Station. June 2012.

2NDNATURE and DRI. 2014. Surrogate Indicators to Monitor Fine Sediment Particles in the Lake Tahoe Basin. Technical contributions from Desert Research Institute and Tahoe Environmental Research Center, University of California, Davis. March 2014.

2NDNATURE, LLC. 2014. Aligning Stormwater Quality Datasets with Priority Management Objectives. Final Guidance Prepared for the USFS Pacific Southwest Research Station. December 2014.

Heyvaert, A.C., M. Leisenring, N. Beck and B. Wolfe. 2010. Tahoe Stormwater and BMP Performance Database Monitoring and Reporting Guidance Document. Prepared for the USDA Forest Service Pacific Southwest Research Station. Final. October 5, 2010.

Heyvaert, A.C., Reuter, J. E. 2011a. Tahoe RSWMP Data Quality Objectives. Division of Hydrologic Sciences, Desert Research Institute and Tahoe Environmental Research Center, University of California, Davis. May 10, 2011.

Heyvaert, A.C., Reuter, J. E. 2011b. Quality Assurance Program Plan, Tahoe Regional Stormwater Monitoring Program. Division of Hydrologic Sciences, Desert Research Institute and Tahoe Environmental Research Center, University of California, Davis. May 10, 2011.

Lahontan Regional Water Quality Control Board (LRWQCB) and Nevada Division of Environmental Protection (NDEP). 2010. Lake Tahoe Total Maximum Daily Load Technical Report. June 2010.

Lahontan Regional Water Quality Control Board (LRWQCB) and Nevada Division of Environmental Protection (NDEP). 2011. Lake Clarity Crediting Program Handbook: for Lake Tahoe TMDL Implementation v1.0. Prepared by Environmental Incentives, LLC. South Lake Tahoe, CA.

Northwest Hydraulic Consultants (NHC), Geosyntec Consultants, and 2NDNATURE. 2009. Pollutant Load Reduction Model (PLRM) Model Development Document. Prepared for Tahoe Basin Storm Water Quality Improvement Committee. South Tahoe Basin, CA. October 2009.

Tahoe Resource Conservation District (TRCD). 2013. Implementers' Monitoring Program Monitoring Plan. April 30, 2013.

Tahoe RCD, 2NDNATURE, and Heyvaert, A.C. 2014. RSWMP Scientific Assessment Report. August 2014.

Tahoe RCD. 2014. RSWMP Annual Work Plan. August 2014.

Tahoe Science Consortium (TSC). 2008. Tahoe Basin Regional Stormwater Monitoring Program (RSWMP) Phase I Conceptual Development Plan. March 2008.

Walters, C.J., and C.S. Holling. 1990. Large-scale management experiments and learning by doing. *Ecology* 71:2060- 2068.