Water Quality Project Inventory: Lake Tahoe

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Nevada Tahoe Conservation District

Water Quality Project Inventory: Lake Tahoe

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Executive Summary

The Water Quality Project Inventory (Inventory) consists of a computer based tool that includes a database of all public water quality best management practices (BMPs) implemented within the Lake Tahoe Basin and an electronic map (GIS) that shows the locations of all public water quality projects containing the BMPs.

The Inventory is the first comprehensive system that accounts for BMPs implemented in the Tahoe region and it has several uses. The TMDL (Total Maximum Daily Load) program may use information in the Inventory to account for BMPs implemented. Resource managers can use the Inventory map to browse water quality projects and determine which BMPs have been implemented and how they are distributed around the Basin. Implementers can use the database to facilitate BMP maintenance. The Inventory can also be used to report implementation of the Environmental Improvement Program (EIP).

The Inventory database contains quantities of 21 BMPs commonly implemented at Lake Tahoe. This information was collected directly from implementer project files that were stored in many formats and locations by the seven major urban stormwater project implementers at Lake Tahoe.[1] The information was collected by a small, unbiased group of personnel from several agencies known in this report as the Inventory team. This information was extensively quality checked by the Inventory team, project funders, and implementing agencies.

The Inventory team used the GIS to calculate the percentage of the watershed, percentage of urbanized area and percentage of road length treated by water quality projects. These values are calculated by summing the portion of each area or length covered by project area polygons in the GIS. Due to the variability in project area defined on plan sheets, these figures should be considered estimates. Basin-wide results include:

- Road Length Treated- 46%
- Watershed Area Treated- 5%
- Urban Area Treated- 42%

The Inventory can provide many other forms of useful analysis which are more completely explained within this report. Highlights of these features include treatment proportions for each TRPA priority watershed, trend analysis of BMP selection and analysis of BMP regional distributions. This report also describes the potential to enhance the Inventory to assist implementers with BMP maintenance tracking.

The Inventory is available for download at the Nevada Tahoe Conservation District website (www.ntcd.org) in the Documents section. Appendix A contains a brief set of instructions for downloading and using the Inventory.

[1] The seven implementers include the City of South Lake Tahoe, El Dorado County, Douglas County, Washoe County, Placer County, CalTrans, and Nevada Dept. of Transportation.

I. Background

A. Project History

The Water Quality Project Inventory (Inventory) was initially conceptualized by managers of the Lake Tahoe TMDL as a method to account for BMPs within the Lake Tahoe TMDL Watershed Model. BMPs in this inventory are generally structural best management practices for public water quality projects that treat runoff from urban/rural areas. During the scoping stage of the work, the Inventory team recognized several important secondary uses. Water quality project implementers would be able to use the Inventory to track and report their progress toward achieving water quality goals. Also, the Inventory would be useful to resource managers who had not previously been able to determine what BMPs had been implemented in the Lake Tahoe Basin. Last, project implementers could use the Inventory to locate and maintain their BMPs. All of these uses provided the impetus to fund and complete the Inventory.

Initial funding for the project came in the form of a scoping grant from the US Forest Service (USFS). These funds allowed the Nevada Tahoe Conservation District (NTCD) to determine the type of records that were available at each of the seven main water quality project implementers.[2] As the uses of the Inventory and data complexity became clear, the Inventory team determined that a simple spreadsheet inventory could not achieve the objectives of the project. The Inventory team determined that a relational database and GIS map would be crucial to the success of the Inventory and address the needs of all stakeholders.

The second major resource for the Inventory was in-kind labor allocated by the Lahontan Regional Water Quality Control Board (LRWQCB). This allocation allowed significant time for data collection and conceptual development of the Inventory's components. Much of the data collection and entry work was done by interns and staff at the LRWQCB.

The final funding for the Inventory came as a small grant from Nevada Division of Environmental Protection (NDEP). This funding allowed the Inventory team to spend more time collecting data, update GIS software, quality check the final inventory, and produce this report.

B. Goals and Objectives

The scoping process resulted in development of a broader goal and more objectives for the work. The final goal and objectives developed by the Inventory team follow.

[2] The seven implementers include the City of South Lake Tahoe, El Dorado County, Douglas County, Washoe County, Placer County, CalTrans, and Nevada Dept. of Transportation.

Goal: Develop a tool that shows the spatial layout of water quality improvement projects completed in the Lake Tahoe Basin since 1998 and provides an inventory of the BMPs implemented within each project.

Objectives:

1. Make the Inventory easy to operate for non-technical users;
2. Maximize potential audiences by using standard software;
3. Insure the Inventory is easy to distribute ;
4. Make the Inventory easy to update.

Many resource managers, modeling consultants, design engineers agree that a restoration effort like the one currently underway in Lake Tahoe should be carefully tracked and measured. However, this data for the most part, has been stored with the implementers of water quality projects. Unfortunately, the various locations and formats of the data have made it impractical to use. By achieving the stated goals and objectives, the Inventory would convert these disparate pieces of difficult to use data into a unified body of knowledge. Some of the most notable potential uses of this knowledge include implementation progress reporting for the EIP (Environmental Improvement Program), modeling the overall effects of water quality projects, and improving the design of future water quality projects.

II. Description

The Water Quality Project Inventory consists of two major components. The first is a database which contains many elements and provides the user multiple ways to sort and total the BMPs and water quality projects listed in the Inventory. The second component is an electronic map that allows the user to see how projects are distributed around Lake Tahoe and within its sub-watersheds. The map also allows the Inventory to compute spatial results such as the percentage of the watershed covered by water quality projects. The database and map are described in the following section.

A. Database

The Inventory's database was developed using Microsoft Access®. This software was chosen because its wide distribution allowed the Inventory team to achieve Inventory objective #2 most effectively. Users with no knowledge of database programs will be able to display reports on every water quality project in the Basin, see which BMPs were implemented and view BMP totals sorted by various criteria. A user with basic to intermediate knowledge of database use and programming is able to use the data tables for more advanced queries and reports.

The heart of the database is contained within two data tables named the *Project Table* and the *BMP Table*. The *Project Table* contains information about more than 130 of the water quality projects that have been completed in the Basin. This information includes:

- Unique Project ID#
- Source of data
- EIP #
- EIP Name
- Implementation Agency
- Implementer Proj. #
- Implementer Proj. Name
- State Funder Proj. #
- State Funder Proj. Name
- Design Consultant
- Construction Contractor
- Federal Funder
- Federal Amount
- State Funder
- State Amount
- Local Funder
- Local Amount
- Monitoring Plan
- Maintenance Schedule
- Project Comments
- Completion Date

Many of these fields are self explanatory, but several do warrant explanation. Like water quality BMPs, databases also have established best management practices. One of these practices is to assign a unique number to every record (in this case, each water quality project) entered into database. The EIP number was considered for this purpose, but quickly discarded because there are cases where several water quality projects are associated with one EIP number. To further complicate the situation, there are cases where several EIP numbers are associated with one water quality project. This many-to-many relationship would cause significant difficulties with the Inventory's searching and sorting functions. Thus, a completely unique number was assigned to each water quality project entered.

There are three project naming fields in the *Project Table*. These fields are an important feature because many agencies have their own names for the same project. This difficulty becomes exacerbated when EIP projects are split into phases by the implementer and complicated further when funders divide the money from a single grant into several projects. The naming issue has become difficult enough that previous efforts to catalog the cost of water quality projects have been unable to accurately resolve costs by project name.

Cost information is broken down into three categories- federal, state, and local. These sector breakdowns are typically used in EIP documents. The *Maintenance Schedule* field was included in the Project Table, but as the Inventory progressed the team realized that this field should be associated with individual BMPs. A field for monitoring was included, but the Inventory team found little information about this aspect of projects in the available documentation. The comments space allowed the team to state assumptions/interpretations about the data as it was collected. These comments are invaluable to future inventory efforts or anyone planning to critically assess the data quality of the Inventory.

Over 1000 BMPs were entered into the second part of the database that was named the *BMP Table*. Data captured about each BMP included:

- Unique BMP ID#
- BMP Type
- BMP Note
- BMP Quantity
- Quantity Units

The BMPs were categorized into 21 types of commonly used water quality structures. The Inventory team determined when to lump or separate BMPs by asking two questions that determined the ways that they could affect pollutant loads. The team generally asked: "How does this BMP affect pollutant concentrations?" and "How does this BMP affect water volume?" For example, curb and gutter was combined into the same category as asphalt swale because both are open to the atmosphere for evaporation, don't allow sediment scouring and do not allow significant infiltration. Conveyance piping was split into another category because it would not allow evaporation to reduce flow and strictly conveys runoff while curb and gutter also protects road shoulders from erosion. The BMP types include:

- Bare Soil Cover
- Catch Basin
- Conveyance Piping
- Swale/Berm/AC Dike
- Detention (Dry) Basin
- Drainage Inlet
- Hard Coverage Removal
- Infiltration Gallery
- Percolation Trench
- Perforated Piping
- Porous Pavement
- Retaining Walls
- RipRap Slope Stabilization
- Rock Lined Channel
- Sediment Trap
- SEZ Restoration
- Soft Coverage to Pavement
- Treatment Vault
- Vegetated Swale
- Water Bar
- Wetland/Retention Basin

The *BMP Note* allowed greater specification of the kind of BMP. This would allow the data to capture the brand and model of each stormwater vault or separate differing kinds of revegetation.

The Inventory team also made decisions about "what is a BMP" when reviewing the contractor invoices. A manhole, for example, was not considered a BMP, as it does not in itself treat or convey stormwater. However, a storm drain manhole is considered a BMP because it collects and routes stormwater. The Inventory team hopes that the implementers can take the time to review the BMP types and quantities for their projects and provide comments or recommendations.

The power of the relational database is to allow these two tables to be referenced, sorted, combined, and displayed in many ways. The tables were combined into one form that shows all of the project data and BMPs associated with the project in one convenient page (See Figure 1). More advanced users of the Inventory can design their own forms that display only the information they need.

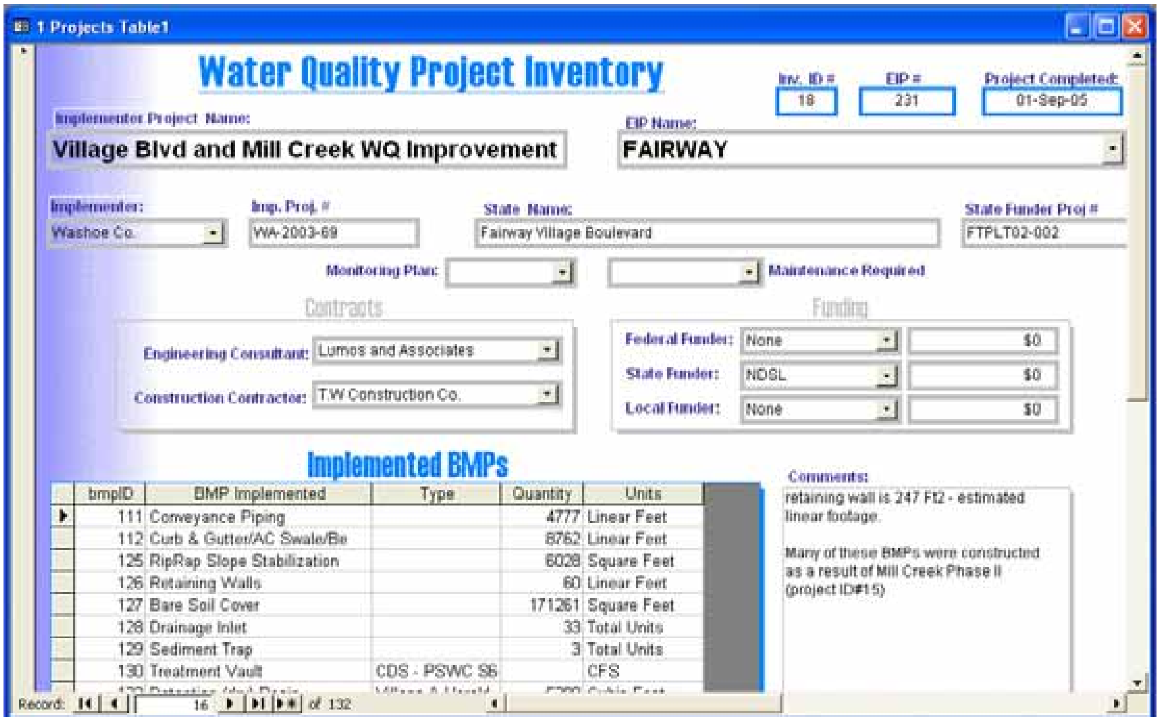

Figure 1. Inventory project viewing form.

In addition, the database portion of the Inventory includes a set of queries that allow summing and averaging of the two data tables. This set of queries makes it particularly easy to update BMP totals, implementer BMP averages, and project expenditures as new projects are added to the Inventory. Once these queries are calculated they can be formatted or exported to spreadsheet programs like Excel®. A user with basic database knowledge can create new queries as needed if they are not already built within the Inventory.

The database creates a great ability to review, analyze and manipulate water quality projects and BMPs but it cannot provide spatial information. This requirement of the Inventory is addressed by a GIS map and special linkage script.

B. GIS Map

An adequate inventory of water quality projects requires spatial information to be useful for modeling applications and implementer tracking needs. The Inventory's maps are built in ESRI's ArcMap 9®, a recent version of the most full featured and pervasive geographic information system (GIS) available.

The Inventory's GIS consists of seven layers that represent various features of the Lake Tahoe Basin. These layers can be combined to perform many kinds of spatial analysis. The layers include:

- Major Roads – includes roads like Hwy 50, 89, 267. (source: TRPA)
- Minor Roads – includes all remaining paved roads. (source: TRPA)

- Lake – displays Lake Tahoe. (source: TRPA)
- EIP Projects – a set of polygons representing the TRPA's EIP project areas. (source: TRPA)
- Urban Areas – a set of polygons showing urbanized areas of the Basin. (source: TRPA)
- Watersheds – a set of areas which delineate the 64 priority watershed boundaries defined by TRPA. (source: Inventory team/TRPA)
- Inventory water quality Projects – the set of polygons drawn from project plan sets by the Inventory team. (source: Inventory team)

All of these layers are drawn using NAD 27, Zone 11 projections with map units of meters.

Figure 2. Example of GIS Map with water quality projects in orange, urban areas in grey, and 64 priority watersheds with yellow borders.

To allow users to search for projects and BMPs spatially, each water quality project polygon has been linked to its database form (See Figure 1) . The linkage required integration of two entirely different software programs via a small custom written program called a VBA script. This script is named Access Hyperlink and it is located in the Visual Basic Editor of ArcMap 9®. Access Hyperlink allows a user to simply look at an area of interest on a map and then click on a project to find out its name, date of completion, engineering consultant, BMPs and more. This is one of the more powerful features of the Inventory that has greatly enhanced the ease of access for BMP data.

The GIS also calculates additional spatial information to answer potential large-scale management questions. Presently, the GIS can calculate three interesting percentages. It can determine what percentage of a watershed is covered by a water quality project polygon, what portion of urbanized areas are covered by water quality project polygons, and what percentage of roads are covered by project polygons. The system computes these three calculations for each of TRPA's 64 priority watersheds. (See Appendix A for instructions regarding this feature.) As additional spatial questions arise, advanced GIS users will be able to enhance the Inventory to answer them.

The team discovered that the key to creating a highly useful Inventory was the design of the script that linked the two commercial software programs. The custom script allowed ArcMap 9® to handle browsing and spatial calculation requirements, while Access® worked on the sorting, totaling and display of BMP data. This design philosophy allows each commercial program to complete only the tasks for which it was created.

In addition to creating the database and GIS, the Inventory team also packaged these components into an easily distributable product. The package uses an installation "wizard" to help the user install the database and GIS files in the correct folders of their computer. This assistance helps to avoid the common software errors that occur when GIS data layers are accidentally separated from their main project. It also maintains the linkage between the database and the GIS. The installer wizard and all of the Inventory's files are compressed into a single folder that is less than two megabytes. This relatively small size allows interested parties to receive the Inventory via e-mail. This feature greatly enhances the ease of distribution and satisfies Inventory objective #3.

III. Data Collection & QA/QC

The Inventory team collected thousands of individual pieces of data in many formats from many sources. After the data was entered into the database, extensive QA/QC processes were completed. The sources, collection methods and extensive inter-agency QA/QC give the Inventory team confidence that this is the best information of its kind available in the Lake Tahoe Basin.

A. Data Collection Methods

This section describes the data sources and collection methods in narrative and tabular formats. Information was generally extracted directly from its native format within project implementer records by the Inventory team personnel. This insured that data was collected impartially and consistently. Once the data was entered into the database, paper copies of implementer records were stored in an archive for QA/QC and future reference. The Inventory team used three main documents for data.

As-Built/Record Plansheets- These plans have been certified accurate by the project engineer. This source was typically used for project area polygons, sizing of water quality basins, and as a secondary reference for the number of stormwater vaults.

Final Payment Contractor Invoices- This source was particularly well suited to determining the number and types of BMPs installed at a project because both the contractor and funder carefully check this document. The contractor will ensure that every BMP installed is listed, and the funder will carefully ensure that payment is not made for BMPs that were not installed. This cross-check was very valuable.

Final Design Reports- This document described the existing conditions of the project area and provides a multitude of calculations about the project. In particular, the design report provided drainage size information, design storm sizes and flow rates for BMPs. Design reports are typically revised three times during the design process and final reports are signed by the design team. Many early project design reports were not available at implementer offices and were not collected by the Inventory team.

For California and Nevada road agencies, data was submitted by the implementer. The data came in the form of simple road section maps and spreadsheets containing the BMP data from each project. This self-reported information was not personally verified on project plans by Inventory team members.

Project completion dates were collected from several sources and were intended to represent the month and year that water began to flow through the project. Some dates were captured from final payments to construction contractors and may not define the exact month that the project became operational. Other dates were taken from the date that the funder officially closed the project grant. These dates can be up to a year behind the completion of the water quality project's construction.

The three main data sources for the Inventory often did not contain information about monitoring. This field has been retained in the database for future use and will be completed through continuing coordination with implementers and research institutions. The field contains 4 options for descriptions of associated monitoring, including:

- No Plan
- Photo
- Quantitative
- Effectiveness.

The first two options are self-explanatory while the second two are worthy of some description of their use. The quantitative selection is intended to represent monitoring projects with numeric objectives that quantify maintenance, habitat, or characteristics other than pollutant removal effectiveness. The effectiveness selection should be reserved for monitoring projects that have collected data in order to characterize the operational pollutant removal of particular BMPs or the entire water quality project.

B. QA/QC

Once all data was collected and entered into the database, the Inventory team initiated extensive quality assurance and quality control processes. These processes included normalization of units reported, spot checks with paper records, reporting agency review, and inter-agency cross checks. This section contains descriptions of these processes and comments on data quality for many elements of the database and GIS map. The section finishes with an extensive description of the area measurements that relate to all water quality projects.

The unit normalization process involved combing through the entire BMP table to convert all quantities reported into consistent units. After review of the data, the Inventory team determined that the most efficient unit system would be feet, square feet, cubic feet, cubic feet per second, and total number. This decision was based on the fact that the majority of the BMPs were reported in these units and the familiarity of implementers/public with these units. The normalization process was a significant effort but allowed the Inventory team to calculate Basin wide totals for all BMPs.

The Inventory team also invested time to spot-check the database records with the paper records copied from implementers. Over 70 individual values were pseudo-randomly selected for checking. Even though the data entry process was completed over a three month period by several team members, all spot-checked entries were correct. This process gave the team confidence that few if any errors were introduced during the process of entering implementer information into the database.

The Inventory team also sent copies of all water quality projects to implementers for comment. This process allowed each implementer to check for missing projects, inaccurate BMP counts, erroneous project information or other issues that might affect the database. At the date of this writing several implementers had not responded to this opportunity. All implementers have indicated their interest and the Inventory team does expect to make small changes to the Inventory based on future responses.

Another QA/QC process involved cross-checking the project records of several agencies involved with a particular water quality project. The Inventory team was often able to gather records from implementation agencies, state funders, federal funders, and regulatory agencies. In most cases, these records were compared to determine if all projects were included, project completion date, project costs, project names and major BMPs installed within the project.

The water quality project polygons drawn on the GIS map deserve significant discussion. These polygons were originally intended to represent general locations of the BMPs listed within the database. However, the Inventory effort required specific definitions of several project-related areas to provide good analysis of "treated area." The Inventory team used the Storm Water Quality Improvement Committee's (SWQIC) definition of these project-related areas but also defined two additional areas. All areas are shown in Figure 3 below. In general, the Inventory team feels that the area most resource managers would consider "treated area" is composed of the blue and green portions of Figure 3 and is known as the project catchment by the SWQIC. For the purposes of the current Inventory, "treated area" could be more accurately stated as, "an area which drains to a water quality BMP, received source control BMPs, has been assessed by a water quality design team to be free from significant water quality issues or has been assessed by a water quality design team to have no cost-effective water quality improvements within the scope of current EIP standards."

Project plans usually contain a summary page showing the project area defined in Figure 3. This area was used most frequently to delineate the project polygons used in the Inventory. The quality of the project plans used to determine these areas has changed over the 15 year history of the projects included in the Inventory and some show the project areas differently than others. In a few cases, only the construction areas as shown in Figure 3 were given in the plan set. This would lead to a significant under-accounting of the project catchment. Another difficult situation noted by the Inventory team occurred when the project area was located downstream from a developed catchment area. In a few cases projects were treating runoff from the upstream (green) portion of the catchment. This situation could again cause the Inventory to significantly under-account for total project catchment. Conversations with implementers indicated that this situation is somewhat uncommon because many upstream areas are undeveloped forest. Runoff from these forested areas is typically diverted around urban water quality projects. These issues contribute to unavoidable error when aggregating project areas Basin-wide, but give the Inventory team confidence that the "treated area" defined in our results is a conservative estimate of the total area treated by water quality BMPs at Lake Tahoe.

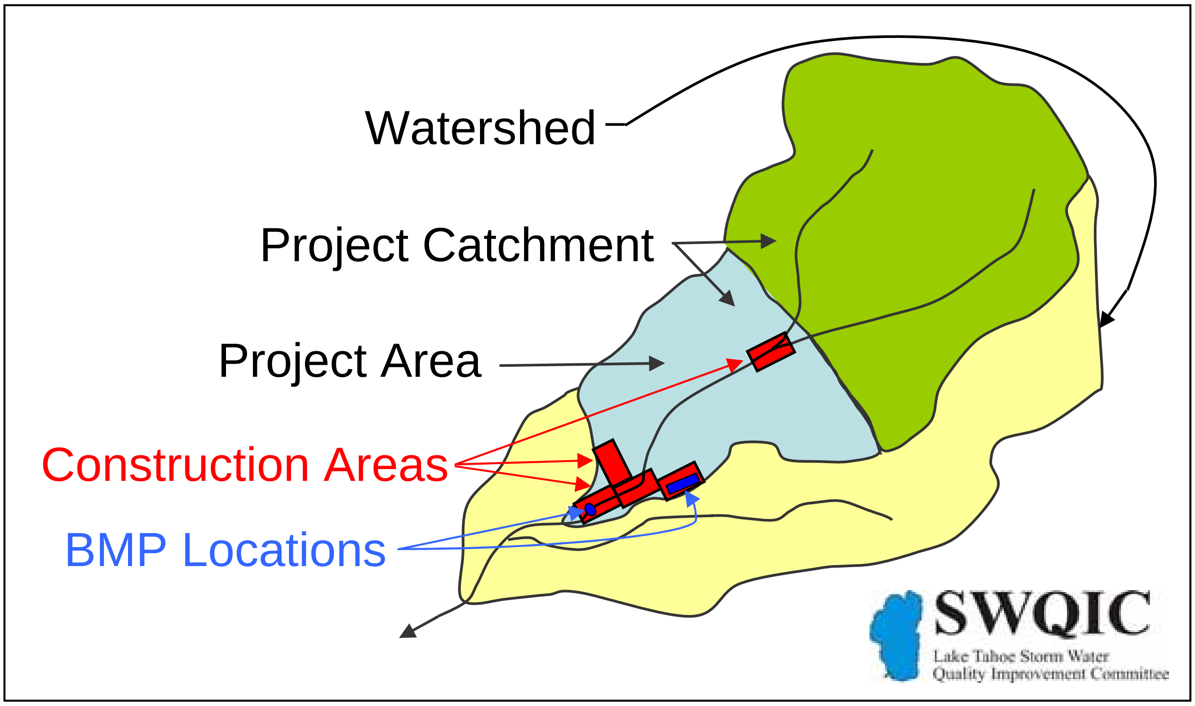

Figure 3. Area definitions based on SWQIC FEA documentation. Features labeled in red and blue have been added by the Inventory team to describe terms used in this document.

This section has reviewed important meta-data about the information stored in the Inventory. The extensive QA/QC process completed by the Inventory team lends confidence that the Inventory contains the best information available. Given the highly fragmented and occasionally conflicting nature of the data collected for the Inventory database, the team expects that slight adjustments to BMP totals and project areas will be made as additional resources become available.

IV. Results

The database and GIS map portions of the Inventory have provided interesting results that will be useful for tracking progress towards water quality goals and making management decisions. The Inventory contains over 130 water quality projects and over 1000 BMPs compiled from a wide variety of sources and formats. The results are presented in two sections: one for numerical analysis of the database and one for spatial analysis of the GIS map. A discussion of error follows the results.

A. BMP Totals

The relational database allows a multitude of analysis techniques for answering a variety of questions. This section provides answers to several general questions via tables and narrative.

On the following page, the "Basin-wide" column of Table 1 lists the BMP totals installed in the Lake Tahoe Basin via all projects that are in the database. This table also shows BMP totals broken down by State, pre/post-EIP timing, and implementation agency.

BMP Implemented	Units	Basin-wide	State NV	State CA	Pre-EIP	Post-EIP	Washoe	Douglas	Other NV	El Dorado	City SLT	Placer	NDOT	CalTrans
Bare Soil Cover (aka Reveg.)	SQ. FT.	7159278	3310410	3848868	3763188	3396090	602891	210035	109778	913046	1105353	855353	2387706	975116
Catch Basin	#	229	105	124	120	109	95	10			4	120		
Conveyance Piping	LIN. FT.	149781	54034	95747	73257	76524	16990	2355	5577	21979	37924	22274	29112	13570
Curb & Gutter/AC Swale/Berm/AC	LIN. FT.	555118	228886	326232	283795	271323	29889	25070	37189	120459	113588	44113	136738	48072
Detention (dry) Basin	CU. FT.	1121833	87681	1034152	812729	309104	16831	10200	18600	282965	690674	60513	42050	
Drainage Inlet	#	1347	580	767	595	752	35	103	120	200	327	199	322	41
Hard Coverage Removal	SQ. FT.	52133		52133	26933	25200				18000	34133			
Infiltration Gallery	#	2	2			2		2						
Percolation Trench	LIN. FT.	6352	2450	3902	3840	2512	1070		1380	665	1450	1787		
Perforated Piping	LIN. FT.	10523	1380	9143	4615	5908			1380	1191	3809	3615		528
Porous Pavement	SQ. FT.	5637		5637		5637				5637				
Retaining Walls	LIN. FT.	53451	30457	22994	23105	30346	11177	6918	4822	3921	10753	8320	7540	
RipRap Slope Stabilization	SQ. FT.	1361096	1009982	351114	472155	888941	9052	66746	11530	50676	16831	132307	922654	151300
Rock Lined Channel	LIN. FT.	64976	2612	62364	52402	12574	1122	538	952	19468	8776	34120		
Sediment Trap	#	482	101	381	235	247	32	32	29	175	41	106	8	59
SEZ Restoration	SQ. FT.	435406	58930	376476	161226	274180	31900		27030		205065	171411		
Soft Coverage to Pavement	SQ. FT.	20243		20243	8243	12000				7083	12000	1160		
Treatment Vault	#	74	54	20	14	60	4	4	30	2	13	5	16	
Vegetated Swale	LIN. FT.	61148	3150	57998	13353	47795	150		3000	9969	42485	5544		
Water Bar	#	101		101	101							101		
Wetland/Retention Basin	CU. FT.	58193	37660	20533	10200	47993	28450		9210		10200	10333		

Table 1. Totals of all BMPs in the Inventory database including divisions by State, EIP initiation, and implementation agency.

State Implementation Comparisons

Since roughly 1/3 of the Tahoe watershed is in Nevada and 2/3 is in California,[3] a similar ratio of BMPs would be a reasonable expectation for use of BMPs. The results show that many of the BMPs have been implemented near this ratio. In fact the total number of all BMP entries in the Inventory (70% in CA) is very close to this ratio.

Individual BMP installation ratios can differ significantly from the overall ratio, indicating differences in landforms or possibly differing treatment strategies. For instance, California projects contain over 11 times more volume of *Dry Detention Basins* than Nevada projects. Nevada projects use almost three times as many *Stormwater Treatment Vaults*. Nevada implementers and the Inventory team agree that this is the result of steeper watersheds with very little flat area for large detention basins. A corroborating fact for this belief is that Nevada has nearly three times more area of *Rip Rap Slope Stabilization*. Nevada also utilizes 33% more retaining walls than California.

An example of differing strategies between the two states is their respective uses of *Vegetated Swale*. Nevada has installed 3150 linear feet of *Vegetated Swale* while California has over 57,900 liner feet. This 18-fold differential may indicate differences in treatment strategies between design teams in the two states.

The Inventory team also noted significant differences between the states when comparing *SEZ Restoration* area and *Wetland/Retention Basin* volume. Nevada has nearly twice the volume of *Wetland/Retention Basins* as CA, while California has over six times the area of *SEZ Restoration* as NV. These seemingly incongruous differences may be the result of semantic issues. The Inventory team suspects that these quantities may be mixed and/or recorded differently by the various project implementers in their final contractor payment documentation.

Timeline Observations

While the database can be queried by completion year, Table 1 shows a breakdown of BMPs installed before and after the official start of the EIP. January 1, 1998 was selected as the cutoff for pre/post-EIP projects. The first project recorded in the Inventory was completed in October of 1984.[4] The most recent projects included are due to complete construction in the summer of 2005. Changes in completion rates may be due to increased focus on particular management strategies (BMPs) or reduced opportunity for use of a particular strategy (BMP).

About half of the BMPs recorded show significant changes in implementation rate based on the start of the EIP. Implementers are decreasing the rate of implementation of two BMPs and increasing this rate in six others. Surprisingly, less than half as much *Detention (Dry) Basin* volume has been installed since the start of the EIP than before the EIP. Less surprisingly, one quarter as much *Rock Lined Channel* has been installed.

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[3] USGS, Stream and Groundwater Monitoring Program report. http://tahoe.usgs.gov/files/fs-100-97.pdf

[4] The oldest project in implementer files was completed by the City of South Lake Tahoe in 1964.

Since the beginning of the EIP, implementers have significantly increased the rate of installation of six BMP types. Highlights of these changes include:

- *Rip Rap Slope Stabilization* has nearly doubled
- *SEZ Restoration* has almost doubled
- *Stormwater Treatment Vaults* have roughly quadrupled,
- *Wetand/Retention Basin* volume over 4.5 times more
- *Vegetated Swale* over 3.5 times more
- *Porous Pavement* increased from 0 sq. ft. to 5637 sq. ft.

Many of the BMPs showed similar implementation quantities before the EIP and since the EIP. *Sediment Traps, Hard Coverage Removal, Curb & Gutter, Conveyance Piping, and Bare Soil Cover* (commonly called "Re-vegetation") all show roughly equal rates of implementation. Funders may be comforted to know that their funding has not increased the rate of *Curb & Gutter* implementation. Others may be disappointed to see that *Hard Coverage Removal* rate has also not increased.

B. GIS Results

The GIS map allows for spatial analysis of water quality projects for several important areas. The GIS now calculates the percentage of the watershed, percentage of urbanized area and percentage of road length treated by water quality projects. These values are calculated by summing the portion of each area or length covered by project polygons. (See the definition of "treated area" in QA/QC section (III.B)) Due to the variability in project area defined on plan sheets, these figures should be considered estimates. See Part C. of this section for a discussion of error sources.

Basin-wide results include:

- Road Length Treated- 46%
- Watersheds Area Treated- 5%
- Urban Area Treated- 42%

	Basin Total	Within Projects	Portion Treated
Watershed Land Area (sq.ft.)	8,757,980,712	444,527,385	5%
Urbanized Area (sq.ft.)	1,047,316,993	444,527,385	42%
Sum of Project Areas (sq.ft.)	515,911,022	515,911,022	-
Non-overlapped Project Area (sq.ft.)	444,527,385	444,527,385	-
Roadway Length (ft.)	3,226,122	1,503,604	46%

Table 2. Values estimated by the Inventory GIS for treatment areas and proportions.

Table 2 shows two total values for project area. The first (Sum of Project Areas) calculates the area of each project and then sums them all for a total. This method will overestimate the actual “treated area” of projects because many projects treat the same area as other projects. The second calculation of project area (Non-overlapped Project Area) removes these overlapping portions and calculates a total project area 71,383,637 sq. ft. less than the sum of all project areas.

The Inventory team also calculated these results for each of the 64 priority watersheds (See Appendix B for these results). The “Identify” feature of the GIS may also be used to view the analysis for each watershed individually. The values range widely as shown by the large standard deviations in Table 3. (See Table 3 below for statistics of the individual priority watershed analysis.) Generally, the minimum proportion of treatment is zero for each category, however this result is often due to the fact that some watersheds do not have any urban area or planned projects. The maximum values for each category are:

- Watershed Area Treated- **50%** (Bijou Park sub-watershed)
- Urban Area Treated- **90%** (First Creek sub-watershed)
- Road Length Treated- **100%** (4 sub-watersheds)

The 100% road length treated values generally result from watersheds on the east shore which have a single road passing through them (Hwy 28) which has been treated by NDOT.

	% Watershed Treated	% Roads Treated	% Urban Area Treated
Mean	6	33	21
Std. Dev.	9	31	25
Max	50	100	90
Min	0	0	0

Table 3. Statistical analysis of percent treatment values estimated by the Inventory GIS for each priority watershed.

C. Sources of Error

There are two main places within the Inventory where error could be introduced into the data. The first, and probably most significant, is the water quality project area shown in the GIS map. The second is in the numbers and types of BMPs associated with each water quality project.

The Inventory team relied on project plans to characterize water quality project areas. The Lake Tahoe TMDL is particularly interested in the catchment area of the water quality projects. (See Figure 3 for area references.) Unfortunately, this area is not typically denoted on project plans. Often, the plans show only the project area, which will result in an under-accounting of the catchment area. A good example of this situation is provided by a project named Ski Run Water Quality Improvement Facilities (project #025). In this case, the project area only includes a city block, which contains a treatment wetland that accepts runoff from a much larger urbanized catchment area.

An example follows to quantify an extreme case of the potential error introduced byselecting different areas for each Inventory project polygon. Upper Kingsbury North (#022) is a project that treats a steep series of very low density roads in a residential area near the top of the Burke Creek watershed. In order to gain a quantitative understanding for the potential size of the error in this particularly difficult project, the Inventory team drew the project polygon in three ways. (See Figure 4, below) The first delineation in blue loosely fit the polygon to the summary project overview drawing on the front of the record plan set. This area corresponded closely with the area shown in the TRPA's EIP map. The area calculated was 54% larger than the TRPA urban area shown in grey for this neighborhood. The second method, shown in orange, delineated project area using roads and terrain. This method is the one actually recorded in the Inventory and was roughly 10% larger than the TRPA's urban area shown for this neighborhood. The third delineation used the individual plan sheets to draw the smallest polygon that encompassed all of the construction areas. The area calculated by this method was 33% smaller than the TRPA urban area shown for the neighborhood. Thus the Inventory team concludes that the possible error due to delineation in this extreme scenario was between -33% and 54%. This particular project is more prone to these delineation errors due to the widely distributed construction areas and steep slopes of this upper watershed. In the Inventory team's opinion, the bulk of the project areas have less error due to the delineation issue than this example.

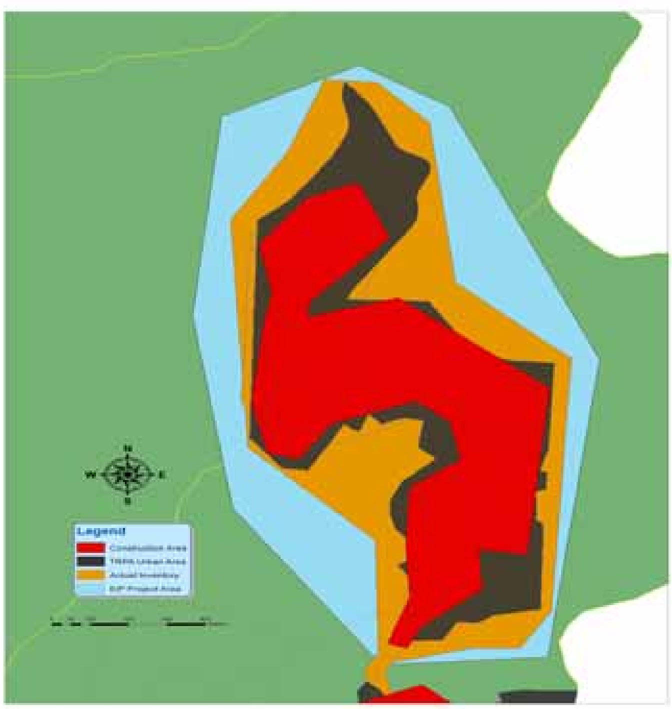

Figure 4. A representation of possible choices for project polygon areas.

It is outside the scope of the current Inventory to determine the actual designed catchment areas for each water quality improvement project. The Inventory team is requesting that the individual implementers, during their review of the inventory, pay particular attention to this issue. We further recommend that future water quality projects clearly delineate the various areas associated with water quality projects according to SWQIC definitions.

Another source of error came in the form of estimating quantities of certain BMPs. For example, detention basin volumes were frequently not listed on the final contractor payment sheet and had to be estimated by direct measurement from the project plans. The basins' irregular shapes required the team to measure a characteristic length, width, and depth to give an estimate of total retention volume. Other BMPs, such as rock-lined channels, were billed by the contractor in linear feet on some projects and square feet on other projects. The Inventory team used consistent units for each type of BMP. Therefore, when necessary, the Inventory team made assumptions about the width of, for example a rock lined channel, to determine a linear value and then recorded the assumption in the project notes.

D. Limitations

The water quality Project Inventory contains the best basin-wide source of information available on completed water quality projects in the Tahoe Basin. However, as discussed above, some results should be considered estimates. In particular, the treated areas represented in the GIS maps may over or underestimate the actual treated area. However, in the opinion of the Inventory team, these results are suitable for most tactical-level management decisions made in Lake Tahoe, and provide a reasonably accurate snapshot of treated areas.

The Inventory was originally conceived to provide information about installed BMPs for use in the TMDL Watershed Model. In most cases this use has been satisfied. The regional distribution of BMPs is available and the Inventory GIS can be integrated with TMDL GIS systems. However, the scope of the Inventory did not allow for individual BMPs to be located within each project area. This can create difficulties for modelers because the Inventory cannot resolve the specific sub-watershed/drainage area of each BMP. This is exacerbated when a project is located in multiple sub-watersheds. This limitation will become more notable because modern EIP projects are becoming more comprehensive and covering greater areas. For these reasons, NTCD has submitted proposals to funding agencies for further development of the Inventory. If funded, the future version would be able to resolve the location of each major BMP and determine its drainage area.

Currently, the database does not contain financial information for each project. Implementer records have typically been very detailed, often showing several rounds of proposed costs for the project, interim reports on expenditures and occasionally final costs. Many of these costs (including final costs) are not consistent with records maintained by funders or regulatory agencies. The Inventory team recognized the potential disservice of providing inaccurate cost information and has determined that cost information is outside of the scope of the current Inventory. For future efforts, the

Inventory team recommends that cost data come from individual state and federal funders.

The final limitation of this version of the Inventory was noted by implementers as the data was collected. The Inventory has the potential to perform as an excellent tool to simplify the maintenance of BMPs. Maintenance is not only required by funding agreements, but also significantly enhances performance of BMPs over time. As designed, the Inventory gives implementers easy access to general information about which BMPs exist, but does not locate the BMPs exactingly enough to be useful for maintenance. The ideal BMP maintenance tracking system would display locations of each BMP on a parcel map and would flag a BMP that needs maintenance. The Inventory team suggests including these features in a future system.

V. Conclusion & Recommendations

The process of designing and using the Water Quality Project Inventory has led the Inventory team to several conclusions regarding this effort. This section captures important conclusions about the creation process, benefits/liabilities of the current design and future potential of the Inventory. This section also contains several recommendations for potential enhancements of the Inventory.

- Implementation of very large and widely distributed projects requires a centralized tracking system to account for program progress in a consistent and systematic way. This tracking system should include a GIS. Data entry would require only a few hours of effort per project at the completion of each project.
- The design of the Water Quality Project Inventory capitalized on the strengths of two individual software applications (Access® and ArcView 9®) by linking them with a custom written script. This design makes the Inventory easy for the end user, accessible to a very wide range of users and customizable for advanced users.
- The Inventory's objectives to keep the system simple and create a distribution package significantly enhanced the usefulness of this tool.
- Proprietary, commercial versions of infrastructure management software exist and should be considered for future versions of the water quality Project Inventory. These software packages can contain many more advanced features than the current Inventory, but require expensive consultation for training, support or customization. Use of a proprietary system would require a central, web-based location accessible to all users or require agreement of all users to purchase the same non-web enabled system.
- Current project naming conventions have created unnecessary difficulties in referencing and inventorying past projects. The small effort required to coordinate project names between the EIP, funders, and implementers would reduce significant confusion in daily reference and monetary accounting.
- Roughly 2/3 of all BMPs installed are in California, and 1/3 are in Nevada. This corresponds well with the Basin's proportion of land area in each state.

- The start of the EIP program marked a change in the <u>rate</u> of installation for many BMPs.
- Project area is defined differently by different implementers and design consultants. These differences make the "project area" difficult to consistently delineate and lead to error when calculating Basin-wide totals. Specific information about the catchments of individual BMPs is easier to define consistently. The Inventory team recommends coordinating the Inventory through SWQIC to make it consistent with FEA guidelines and as useful as possible to implementing agencies. This coordination should attempt to resolve differences in terminology.
- "Treated area" is a phrase that requires a very specific, context-sensitive definition. For the purposes of the Inventory all areas are defined in Figure 3. The Inventory team suspects that Catchment Area is the best match for most peoples' opinion of "Treated Area." The Inventory team would like to encourage further discussion about the names used to define these areas among implementers, funders and resource managers. A consistent naming scheme for project associated areas would be useful to further inventorying efforts and water quality project design teams.
- During current efforts to update the EIP project list, it could be fruitful to assign unique EIP numbers to all past water quality projects. This would assist all agencies involved with the delivery of water quality projects with an easy reference system. It would also eliminate the need for the entirely separate numbering system that is required for the current Inventory.
- The Water Quality Project Inventory requires updating as new projects are finished or missing projects are discovered. The Inventory was designed to be easily updateable, but this should be done in a consistent manor. The team recommends designation/funding of an Inventory Administrator at one of the Basin agencies. Implementers should be required as part of grant agreements to provide copies of the project as-built plans, final contractor payment and final design report to this administrator. The role of the administrator would be to insure consistency in reporting, documentation, and data entry into the on-going Inventory.
- Ideally, a single, official copy of the Inventory would be located on-line where it could be accessed by all interested parties. A centralized location would allow a single web-enabled, proprietary solution to be accessed by all users. One possible location for the Inventory would be the TIIMS.ORG website, which already contains GIS information. However, this would not obviate the need for an Inventory Administrator as described in the previous recommendation.
- To satisfy the maintenance needs of implementers and the advanced modeling needs of resource managers, the Inventory should be enhanced to provide spatial information about each major BMP and its drainage area. When this information is collected, paper copies of the as-built project plans, the final contractor payment document, and final design report should be archived for QA/QC purposes.

- Funding agencies should continue efforts to populate database fields including funding sources and dollar amounts.
- The structure of the inventory should be slightly adjusted to allow maintenance schedule or practices to be stored in the BMP Table with each individual BMP. The current Inventory locates this field within the Project Table such that it can only apply to an entire project. This structure will not allow maintenance information to be individually associated with each BMP.
- The creation of a consistent set of units to measure water quality projects would allow consistent aggregation of the effects of the projects and would eliminate issues that required a variety of assumptions within the current Inventory. A system of units like this would also increase comparability of the projects to each other and increase the defensibility of the Inventory's GIS results.

Appendix A.

The Water Quality Project Inventory is available for download and use by interested parties. It is a 1.3 megabyte executable installation file that requires Microsoft Access 2000® and ESRI ArcView 9.0® to operate properly. The Inventory team has tested this installation on several computers, but can provide no support beyond these instructions for installation and operation.

A. Installation

1. Download the "Water Quality Project Inventory" file from the NTCD website. http://ntcd.org/documents.htm
2. Run the "WQ Inventory Setup.exe" file. This program will place the required GIS and database files into the "Program Files" directory on the c: drive. This insures that all necessary files are properly referenced in the directory structure. (Do not remove files from the "Data" folder.)

B. Operation

To View Project and BMP Information

1. Run the WQ Inventory from the "All Programs" button in the Start menu.
2. The WQ Inventory will open as an ArcMap project.
3. Zoom to the scale and area of interest.
4. Select the hyperlink ( ) tool to enable the GIS to call the database information for a particular project.
5. Click on a project area with the hyperlink tool to jump to the database display form for that project.
6. Click on the GIS button on the task bar to return to the GIS.
7. Click on another project area if desired.

To View % Treatments by Watershed

8. Select the Info ( ) tool to enable the GIS to give information about treatment percentages for a particular watershed.
9. Click on the green portion of a watershed to see the % treated information.
   These percentages are displayed by:

PCT_WS_TR	(% watershed treated)
PCT_RD_TRT	(% roads treated)
PCT_URB_TR	(% urban area treated)

Appendix B.

This table shows the proportion of treatment for each of the 64 priority watersheds in the Lake Tahoe Basin. The % treated area values were calculated by dividing the water quality project area by total watershed or total urban area within each sub-watershed. The road length value was calculated by determining the length of roads within water quality project areas and then dividing by the total length of roads within each watershed. These values were calculated on 6/1/05. Subsequent updates to the inventory may affect these values.

6/1/05

NAME	AREA(sq. m.)	% Watershed Treated	% Road Length Treated	% Urban Area Treated
LAKE TAHOE	498,108,095.4	N/A	N/A	N/A
BARTON CREEK	2,899,177.4	2	7	2
BIJOU CREEK	7,311,817.2	19	25	26
BIJOU PARK	7,988,846.5	50	83	80
BLACKWOOD CREEK	28,901,091.8	0	0	0
BLISS CREEK	1,610,438.9	2	100	0
BLISS STATE PARK	5,446,238.0	2	14	0
BONPLAND	2,284,764.5	0	100	0
BURKE CREEK	12,863,083.7	13	56	39
BURNT CEDAR CREEK	2,340,590.6	25	32	29
BURTON CREEK	14,832,922.8	0	0	0
CAMP RICHARDSON	10,729,767.4	3	12	7
CARNELIAN BAY CREEK	2,592,080.1	0	0	0
CARNELIAN CANYON	9,247,430.7	0	7	4
CASCADE CREEK	12,220,634.5	0	35	26
CAVE ROCK	4,084,310.2	3	48	19
CEDAR FLATS	4,724,225.2	12	17	33
DEADMAN POINT	3,518,675.0	0	0	0
DOLLAR CREEK	4,718,414.9	0	0	0
EAGLE CREEK	21,143,575.5	0	7	0
EAGLE ROCK	2,108,990.7	11	60	19
EAST STATELINE POINT	4,836,432.9	4	19	8
EDGEWOOD CREEK	17,295,730.6	17	55	64
FIRST CREEK	4,518,743.4	8	89	90
GENERAL CREEK	23,381,479.8	7	76	82
GLENBROOK CREEK	13,072,678.3	1	3	0
GRIFF CREEK	11,773,512.9	1	39	22
HOMEWOOD CREEK	2,609,951.5	1	31	60
INCLINE CREEK	17,379,499.6	9	44	38
KINGS BEACH	1,643,367.4	2	7	5
LAKE FOREST CREEK	1,811,851.6	0	0	0
LINCOLN CREEK	6,667,570.5	0	0	2
LOGAN HOUSE CREEK	5,581,765.9	0	0	0
LONELY GULCH CREEK	2,802,059.0	16	81	77
MADDEN CREEK	5,917,624.4	1	27	16
MARLETTE CREEK	12,809,162.4	0	0	0

MCFAUL CREEK	10,204,451.2	2	39	20
MEEKS	22,698,955.9	1	22	29
MILL CREEK	5,699,200.0	4	28	14
MKINNEY CREEK	12,683,137.4	23	61	47
NORTH LOGAN HOUSE CREEK	5,287,757.1	0	0	0
NORTH ZEPHYR CREEK	6,779,051.4	0	0	0
PARADISE FLAT	2,869,242.9	16	40	36
QUAIL LAKE CREEK	4,245,494.9	5	59	58
RUBICON CREEK	7,394,652.6	5	27	0
SAND HARBOR	5,568,144.3	1	44	0
SECOND CREEK	4,787,589.7	32	67	75
SECRET HARBOR CREEK	11,087,090.4	3	100	0
SIERRA CREEK	3,087,693.1	24	78	65
SKYLAND	2,034,557.8	23	59	48
SLAUGHTER HOUSE	12,659,547.5	4	100	0
TAHOE STATE PARK	3,166,357.1	2	28	8
TAHOE VISTA	15,599,237.6	9	25	21
TALLAC CREEK	11,866,036.9	0	8	20
TAYLOR CREEK	47,706,986.3	0	0	0
THIRD CREEK	15,626,876.0	6	41	26
TROUT CREEK	106,932,780.2	3	35	29
TRUCKEE RIVER	11,678.1	0	0	0
TUNNEL CREEK	4,432,092.0	2	94	12
UPPER TRUCKEE RIVER	146,562,930.8	5	37	35
WARD CREEK	34,254,204.5	6	4	14
WATSON	6,036,852.1	0	0	19
WOOD CREEK	6,126,078.3	18	58	50
ZEPHYR CREEK	4,861,546.1	1	6	0
Max*	146,562,930.8	**50.0**	**100.0**	**90.0**
Min*	11,678.1	0.0	0.0	0.0
Mean*	**12,919,662.3**	**6.4**	**33.9**	**21.8**
SD*	22,715,126.4	9.5	31.7	25.4

*These totals do not include the values for the surface area of the lake itself.