Urban & Groundwater Appendix A:
PSC Performance Review

This appendix provides details on the approach used by the UGSCG to review Pollutant Control Options (PCOs) for surface water Pollutant Source Control (PSC) and to assign achievable land use EMCs for each pollutant of concern based upon PCO implementation at two levels of performance as summarized in Section 3.1. The groundwater PSC evaluation is summarized in Section 3.2 and detailed in Appendix B.

A.1. Potential PCO Review by Land Use - PSCs

PSC-1, PSC-2, and PSC-3 span one or more urban land use categories and apply directly to urban storm water load generation. Separate PCOs were created for private and public property based on differences in opportunities for implementation and funding. Additionally, separate PCOs were developed for pervious surfaces and impervious surfaces due to different runoff processes and differing key pollutants of concern. The following describes existing conditions and defines the BMPs, management actions, and other components that compose a PCO for each treatment tier, as summarized in Table 3.2.

Public Impervious Surfaces
Applicable Land Uses: Roads_Primary, Roads_Secondary, CICU_Impervious

Note on assumptions: All CICU impervious land uses are categorized into public impervious for the purpose of representing load reductions attributable to similar types of PCO implementation. Meaning, PCOs for roadways and CICU impervious surfaces are assumed to be similar in function, and include BMPs focused on reducing particulate pollutant mobilization from impervious surfaces.

Primary Pollutants of Concern: Particulates, including TSS and fine sediment

Pollutant Sources:

- Winter application of road abrasives.
- Erosion of native material due to hydrologic routing from impervious to pervious, over-steepening of slopes, loss of vegetation and/or other impacts that increase the risk of native sediment mobilization.

Current BMP Practices:

- Reductions in annual road abrasive applications (Caltrans reports a reduction from 15,200 MT in 1995-96 to 4,440 MT in 2004-05).
- Periodic recovery of particulates from road shoulders using vactors and road sweepers.
- Road shoulder stabilization and sediment trap construction.
- Periodic use of deicers as partial substitute for road abrasive.
- Reductions in the practice of "slushing", or the distribution of plowed snow during sunny days to allow it to melt on the roadways. Collection and transport of snow to snow storage yards.

- Each municipality throughout the Basin provides variable levels of road deicing, plowing, sweeping, and other winter road maintenance activities, making exact estimations of current practices difficult.

Primary Opportunities for Pollutant Load Reductions:

- Increased scale, where the below activities are conducted on a greater spatial scale and with a greater temporal frequency than existing practices.
    - Roadway sweeping, road shoulder sweeping and sediment trap vactor cleaning.
    - Road shoulder stabilization and sediment trap installation.
    - Slope stabilization and revegetation.
    - Road shoulder, roadway and sediment trap maintenance.

- Advancement in technology or practices:
    - Implementation of innovative deicing techniques that reduce annual road abrasive applications.
    - Implementation of particle recovery technology that focuses on particulates <63 um.
    - Increase maintenance frequency.

Primary Constraints on Pollutant Load Reductions:

- Motorist safety is a priority.
- Slope of roadway.
- Road density.
- Achievable EMCs are linked to rigorous particulate recovery and maintenance activities.

PSC-1 Tier 1: Public Impervious Surfaces

The Tier 1 treatment tier assumes the PCOs are implemented consistently at the typical spatial scale of current practice, but with moderately increased frequency of operations and maintenance than currently conducted. These practices include:

- Continued implementation of high priority stabilization for road shoulders, road slopes, and road-side drainage.
- Developing a road sweeping strategy focused on particulate removal during times between storms to reduce particulates mobilized during subsequent events.
- Increasing temporal sediment trap particulate removal during times between storms to reduce particulates mobilized during subsequent events.
- Prioritizing locations for recovery efforts where particulate accumulations are most likely.
- Moderately increasing maintenance of road shoulders, deteriorating roadways, road side drainage systems, and sediment traps.

PSC-1 Tier 2: Public Impervious Surfaces

Tier 2 assumes aggressive maintenance and a 100% spatial scale of implementation of roadway and public impervious surface BMPs. Significant additional resources are allocated to facilitate the recovery of particulate pollutants that accumulate on public impervious surface, with efforts focused on increasing the winter recovery of fine particles. Tier 2 also assumes that more resources are expended to improve upon the current deicing technology to minimize abrasive applications while maximizing motorist safety. These practices include:

- Stabilizing all road shoulders, road slopes, and road-side drainage systems.
- Increasing sediment trap spatial intervals on all major roads and parking lot peripheries.
- Implementing advanced roadway vacuum technology to maximize recovery of particles <63 um.
- Strategically and aggressively sweeping 100% of roads, road shoulders, sidewalks and parking lots during opportune inter-storm conditions.
- Aggressively recovering particles from sediment traps during opportune inter-storm conditions.
- Aggressively maintaining road shoulders, road-side drainage systems, and sediment traps.

Public Pervious Surfaces
Applicable Land Uses: Veg_Turf

Primary Pollutants of Concern: TN, TP, DN, DP

Pollutant Sources:

- Fertilizer applications

Current BMP Practices:

- Suggested fertilizer use guidelines outlined by the Tahoe Regional Planning Agency's (TRPA) Code of Ordinances.
    - The use of phosphorus fertilizers is discouraged.
    - The timing, frequency and rate of application should be structured.
    - The use of fertilizer in critical areas such as the nearshore zones and in close proximity to streams is to be avoided.
    - Large fertilizer users (parks, golf courses, recreational fields, cemeteries, landscaping companies or private residents maintaining turf surfaces exceeding 1 acre) must submit a Fertilizer Management Plan to the TRPA for review and approval. These plans must include a justification for the use of phosphorus fertilizers based on a soil nutrient availability testing.
- Compliance with TRPA guidelines is low and enforcement has not occurred. Large fertilizer users have not submitted Fertilizer Management Plans.
- Educational resources for turf managers to implement alternative strategies rather than high nutrient fertilizers to maintain turf vigor and health are minimal to non-existent.

Primary Opportunities for Pollutant Load Reductions:

- Reductions in annual P application may have no negative impact on vegetation growth and/or vigor, particularly native vegetation.
- Likely excessive N applications beyond plant needs are currently being applied throughout the Basin.
- Soil augmentation, soil amendments, and slow-release fertilizers can increase the ability of the turf to uptake N and P, while significantly reducing the potential mobilization of nutrients to downstream resources.
- Advancement in technology or practices can guide appropriate strategic fertilizer management for turf surfaces. For example, targeted soil and turf testing could provide specific direction to turf managers on fertilizer application strategies.
- Widespread education of turf managers may encourage responsible fertilizer use and strategic applications.
- Conversion of natural fertilized surfaces to synthetic turf would reduce the need for fertilizer applications.

Primary Constraints for Pollutant Load Reductions:

- Tourist economy is highly influenced by recreational activities on fertilized surfaces.
- Potential water quality and pollutant impacts of synthetic turf implementation are unknown.

PSC-2 Tier 1: Public Pervious Surfaces

Tier 1 assumes the PCOs are implemented consistently at the typical spatial scale of current practice, but with moderately increased frequency of operations and maintenance than currently conducted. These practices include:

- Focusing fertilizer application reductions on the control of P as the primary pollutant of concern. Phosphorus fertilizer applications on public surfaces are discouraged, though not regulated beyond current practices.
- Providing minimal resources, education and/or direction to turf managers on advanced and alterative turf management strategies.
- Providing some incentives for compliance.

PSC-2 Tier 2: Public Pervious Surfaces

Tier 2 assumes advancement in current practices of turf management. Significant resources are dedicated to education and regulatory efforts, resulting in 100% application and compliance of the following advanced management strategies:

- Broadly disseminating information on advanced turf management strategies and providing the resources necessary to implement them.
- Identifying tests and information collection that can be conducted by local turf managers to determine immediate needs of specific turf type to maximize and maintain vigor, growth rates and coverage. Test may include soil and/or turf matter sampling for nutrient content, nutrient ratios, and other key indicators of turf needs.
- Identifying and strategically using soil amendments, mulch, and soil management techniques that enhance the turf's ability to uptake low levels of nutrients.
- Identifying preferred brands of slow-release, low nutrient-content fertilizer brands.
- Making elimination of P applications on all public turf surfaces mandatory. Future applications of P on specific turf may be granted based on demonstrated turf need for phosphorous.
- Developing a mandatory maximum threshold of annual N applications on public turf surfaces. Additional applications of N on specific turf may be granted based on demonstrated turf need for nitrogen.
- Developing incentives for compliance, either regulatory or credit based, to maximize compliance with advances in turf management.

Synthetic v. natural turf

In the development of Tier 2, with respect to the Veg_Turf land use and associated fertilization needs, the UGSCG considered the following pros and cons with the conversion of natural turf surface to synthetic surfaces.

Pros

- Elimination of anthropogenic fertilizer application.
- Reduction of consumptive water use.

Cons

- Potential reduction in tourist satisfaction, potential economic impacts.
- Introduction and leaching of organics and other anthropogenic pollutants.
- TRPA consideration of coverage conversion to impervious
- Maintenance still required.
- Elimination of vegetation.
- Elevated surface temperatures during summer conditions.

Based on existing information, literature, coverage issues, and existing fertilization practices, the UGSCG believes that significant advances in natural turf management can be implemented to meet both the recreational and water quality needs during pervious turf surface maintenance. The UGSCG does not consider the conversion of natural turf to synthetic surfaces in the PSC-2. However, the UGSCG does recommend continued investigations, applications and implementation of synthetic turf in pilot test areas, such as commercial and/or small park turf areas, to improve our understanding of the pros and cons listed above. Some conversions to synthetic surfaces have occurred in the Basin, but no monitoring has been done at these sites to evaluate their potential water quality impacts.

PSC-3: Private Surfaces: Pervious and Impervious
Applicable Land Uses: Residential_SFP, Residential_MFP, CICU_Pervious, Residential_SFI, Residential_MFI

Note on assumptions: Private property PCOs assume that BMP implementation and pollutant load reduction efforts for pervious and impervious surfaces are integrated and thus are represented by the same load reduction. This assumption was necessary do to a lack of monitoring data distinguishing between achievable water quality on impervious vs. pervious surfaces from the implementation of private property BMPs. Additionally, all CICU pervious land uses are categorized into private pervious for the purpose of representing load reductions attributable to similar types of PCO implementation.

Primary Pollutants of Concern: TN, TP, DN, DP, TSS, fine sediment

Pollutant Sources:

- Erosion of native material due to hydrologic routing from impervious to pervious, over-steepening of slopes, loss of vegetation and/or other impacts that increase the risk of native sediment mobilization.
- Fertilizer applications.

Current BMP Practices:

- No requirements or limits on fertilizer use, though the use of phosphorus fertilizers is discouraged.
- Residents are required to implement private property BMPs to reduce runoff and control erosion as outlined by the Tahoe Regional Planning Agency (TRPA). Typical BMPs include:
  - Driveway paving
  - Slope stabilization
  - Mulching and planting of native vegetation
  - Runoff collection and storage from impervious surfaces
- A tiered system of fines for non-compliance has been in place since 2002 but has not been enforced. Compliance is estimated to be slightly over 10% for private properties at the Basin-scale.

Primary Opportunities for Pollutant Load Reductions:

- Private land uses represent the largest quantity of impervious surfaces at the Basin-scale. Runoff reductions from private impervious surfaces have significant potential on pollutant load reductions.
- Slope stabilization and driveway paving may reduce erosion of native materials.
- Reductions in annual P application may have no negative impact on vegetation growth and/or vigor, particularly native vegetation.
- Fertilizer sale control will significantly limit use by local residents.

Primary Constraints for Pollutant Load Reductions:

- Community cooperation and commitment is essential.
- Implementation of PCOs on private property requires individual education, stewardship, and commitment of private resources.

Though existing condition pollutant EMCs from private surfaces are not as high as those from other land uses, such as roads and vegetated turf (Table 3.1), they constitute the highest percentage of developed land use within every setting as defined by the UGSCG. Private BMPs implemented to reduce the volume of runoff generated can have a large impact on Basin-wide pollutant loading. Additionally, fertilizer application on these private lands constitutes the largest surface application of anthropogenic nutrients in the Tahoe Basin (ACOE 2003). As a result, there is a large opportunity to reduce the anthropogenic nutrient loading to storm water and groundwater through advancement in education and management strategies.

PSC-3 Tier 1: Private Surfaces
Tier 1 assumes that the current practices are applied at a greater scale and frequency than current compliance. Compliance for BMP implementation is assumed to increase to 50% of all private properties. Fertilizer applications are discouraged, but not regulated.

PSC-3 Tier 2: Private Surfaces
Tier 2 assumes that the current practices are applied at a greater scale and frequency than current compliance, and greater than the Tier 1. Compliance for BMP implementation is assumed to increase to 100% of all private properties.

Tier 2 also assumes increased community education and active management participation to significantly reduce the annual application of N and P from residential and commercial surfaces each year. Significant resources are dedicated to providing education and support for increased individual stewardship. The following additional assumptions are made:

- Eliminating high nutrient fertilizer sales in the Basin. Accepted brands should be slow-release, low nutrient content fertilizers, preferably devoid of P. Local retailers will be provided with agency accepted signage and literature about home landscape care.
- Eliminating non-native plant sales in the Basin.
- Holding annual individual stewardship community fairs and including numerous educational opportunities on renewable resources, transportation, animal waste management, residential landscaping techniques, and other efforts for each resident and tourist to minimize their impact on Lake Tahoe.

Note to reader - The groundwater PSC evaluation (i.e. PSC-4) is summarized in Section 3.2 and detailed in Appendix B.

A.2. PSC Performance Evaluation

The objective of PSC performance evaluation was to adjust existing conditions land use EMC values for each pollutant and land use, to assumed achievable EMC values as a result of PCO implementation for the Tier 1 and Tier treatment tiers using best available data and professional judgment.

Approach to EMC Adjustments

The implementation of PCOs is considered on a land use basis to minimize complexity and to provide simple incorporation into the Watershed Model. The Watershed Model consists of 20 distinct land uses within the Lake Tahoe Basin. Each land use includes specific EMC for each of the 6 pollutants of concern (i.e. total and dissolved inorganic N and P species, total suspended sediment (TSS), and fine sediment defined as the % of TSS less than 63 um). The Watershed Model generates pollutant loads by an area-weighted integration of pollutant generation from specific land uses as various hydrologic conditions are simulated over the Basin surface. A Geographic Information Systems (GIS) evaluation of the TMDL land use layer for the Lake Tahoe basin resulted in the assignment of 9 of the 20 distinct land use categories in the TMDL land use layer to the UGSCG analysis (Table A-1). The remaining 11 land use categories are designated forest upland and assigned to the Forest Upland Source Category Group (FUSCG).

Table A-1. Land Use Categories Assigned to Each SCG

Land Use Description	Subcategory Name	SCG Responsible
Water Body	Water_Body	n/a
Single Family Residential	Residential_SFP	UGSCG
	Residential_SFI	UGSCG
Multi Family Residential	Residential_MFP	UGSCG
	Residential_MFI	UGSCG
Commercial/Institutional/ Communications/Utilities	CICU-Pervious	UGSCG
	CICU-Impervious	UGSCG
Transportation	Roads_Primary	UGSCG
	Roads_Secondary	UGSCG
	Roads_Unpaved	FUSCG
Vegetated	Ski_Areas-Pervious	FUSCG
	Veg_Unimpacted EP1	FUSCG
	Veg_Unimpacted EP2	FUSCG
	Veg_Unimpacted EP3	FUSCG
	Veg_Unimpacted EP4	FUSCG
	Veg_Unimpacted EP5	FUSCG
	Veg_Recreational	FUSCG
	Veg_Burned	FUSCG
	Veg_Harvest	FUSCG
	Veg_Turf	UGSCG

The UGSCG estimated achievable EMC values for each of the 9 urban upland land uses based upon a limited set of applicable storm water quality data. A decision process was developed to preserve consistency in assigning achievable EMCs based on 1) existing conditions land use values (Table 3-1), 2) available Tahoe-specific storm water data for similar land use types, 3) existing literature data, and 4) professional knowledge of pollutant fate and transport of pollutants generated from each land use.

The existing conditions EMCs in Table 3-1 were compared with available and relevant storm water quality data collected from similar land use surfaces. The primary data sets for this comparison include:

- 2NDNATURE. 2006. Lake Tahoe BMP Monitoring Evaluation Process, Synthesis of existing research. Prepared for: USFS Lake Tahoe Basin Management Unit. October 2006. ftp://2ndnatureinc.com/2ndnature/Tahoe%20References/

  2NDNATURE 2006 is a synthesis of monitoring and performance data from 25 Lake Tahoe BMP performance evaluation studies conducted on several different land uses. The specific studies included were:

  - 2NDNATURE. 2006B. Detention Basin Treatment of Hydrocarbon Compounds in Urban Stormwater. Prepared for: South Tahoe Public Utility District. March 2006.
  - DRI. 2004. Evaluation of Effectiveness of Three Types of Highway Alignment Best Management Practices for Sediment and Nutrient Control. Prepared for USFS-LTBMU, Nevada Division of State Lands and Nevada Department of Transportation. December 2004.
  - DRI & TERC. 2005. Efficiency Assessment of Stormwater Treatment Vaults in the Round Hill General Improvement District. Prepared for: NTCD and Nevada Division of State Lands. April 2005.
  - SH+G. 2003. Assessment of Seasonal Pollutant Loading and Removal Efficiency of Detention Basins. Prepared for: TRPA and US Environmental Protection Agency. February 2003.
  - TERC. 2005. Performance Assessment of the Coon Street Basin, Kings Beach, CA. Prepared for: Placer County Department of Public Works. March 2005.
  - USGS. 2006. Changes in Ground-Water Flow and Chemistry after Completion of Cattlemans Detention Basin, South Lake Tahoe, California – November 2001 to November 2003. Prepared for: EDCDOT, Tahoe Engineering Unit. January 2006.

- 2NDNATURE. 2007. Water quality evaluation of a fertilized turf surface in the Lake Tahoe Basin (2002-2006). Prepared for: Nevada Tahoe Conservation District, Draft Final Report April 20, 2007. ftp://2ndnatureinc.com/2ndnature/Tahoe%20References/
  Relevant areas: Public Pervious.

- CalTrans. 2001. Final Report, CalTrans Tahoe Basin stormwater monitoring program, Monitoring Season 2000-2001 CTSW-RT-01-038. August 2001. http://www.dot.ca.gov/hq/env/stormwater/special/newsetup/index.htm#tahoe
  Relevant areas: Public Impervious.

- CalTrans. J2003. Tahoe Highway Runoff Characterization and Sand Trap Effectiveness Studies, 2000-03 Monitoring Report: CTSW-RT-03-054.36.02. June 2003. http://www.dot.ca.gov/hq/env/stormwater/special/newsetup/index.htm#tahoe
  Relevant areas: Public Impervious.

- CalTrans. A2003. Stormwater Monitoring and Data Management, 2002-2003 Annual Data Summary Report. CTSW-RT-03-069.51.42. August 2003. http://www.dot.ca.gov/hq/env/stormwater/special/newsetup/index.htm#tahoe
  Relevant areas: Public Impervious.

- CalTrans. 2005. Deicer Report for Fiscal Year 2004-2005, CalTrans District 3. October 2005.
  Relevant areas: Public Impervious.

- CalTrans. 2006. Stormwater Monitoring and Research Program, 2004-2005 Annual Data Summary Report. CTSW-RT-06-167.02.02. February 2006. http://www.dot.ca.gov/hq/env/stormwater/special/newsetup/index.htm#tahoe
  Relevant areas: Public Impervious.

- Gunter, MK, 2005. Characterization of nutrient and suspended sediment concentrations in stormwater runoff in the Lake Tahoe basin. MS Thesis, Univ. Nevada Reno.
  Relevant areas: Private Pervious and Impervious.

Using the data presented in Table A-2 (see Section A.3) and the existing conditions EMC values assigned to each land use, the UGSCG determined Tier 2 achievable EMC for each of the 54 values. The achievable Tier 2 values assume that the appropriate PCOs applicable to each land use type are implemented on 100% of the land use and completed to 100% achievable performance effectiveness, including rigorous maintenance (Table 3-2). Table A-3 presents the anticipated achievable Tier 2 EMCs based on the respective implementation of the PCOs for each land use. Table A-3 also provides a note of the data source or rationale used to approximate achievable Tier 2 EMCs. The determination of achievable values was based on existing data, geochemical fate and transport assumptions and professional judgment. To remain consistent, the UGSCG adjusted EMCs using a decision tree based on information and data available for each of the 54 EMC values:

- ❖ Are there relevant storm water monitoring data points that represent achievable and desired conditions for Tier 2? If there is a single data point, that value was assigned. If there are multiple relevant data points, the lowest value was chosen. If no,
  - ➢ Is there another TMDL land use category that reasonably approximates desired conditions and does the data suggest that the other land use EMC value is representative and achievable? If yes, that value was assigned. If no,
    - Did validation of land use EMCs using existing data and/or professional judgment of other existing conditions land use EMC values (Table A-2) suggest that the existing conditions EMC is near the achievable level expected from applying PCOs? If yes, value reduced by 10%.

Tier 1 EMCs were determined for each land use and pollutant of concern through a comparison of existing condition EMCs and achievable EMCs based on the assumption that Tier 1 treatment will improve water quality, but will not reach Tier 2 levels (i.e. Tier 2 ≤ Tier 1 < existing conditions). Table A-4 provides the values and associated summary of information/data sources relied upon to estimate Tier 1 EMC values. As discussed in Section 3.1, the specifications of the two performance levels for each PCO define whether pollutant load reductions are achieved by increasing the scale of existing PCO practices and/or the implementation of more advanced PCOs than those currently used in the Basin. The differences in PCO implementation between existing conditions, Tier 1, and Tier 2 determined the adjustments made to each EMC for each land use in Tier 1. The determination of EMC values was conducted along a decision tree based on information and data available for each of the 54 EMC values:

- Is there a relevant storm water monitoring data set point that represents Tier 1 conditions? If yes, that value was assigned. If no,
  - Are the current PCOs similar to those to be implemented under Tier 2? In other words, can minimum achievable concentrations (Tier 2 EMCs) be reached using a more widespread application of current practices? If yes, the Tier 1 value was assigned to be the same as the Tier 2 value. If no,
    - Do current PCOs rely primarily on education and compliance? If so, the Tier 1 value was assigned a 10% reduction from the existing condition EMC due to an assumed minimal increase in compliance. If no,
      - Does professional judgment suggest that a substantial reduction in EMC can be achieved under Tier 1 standard assumptions using current PCOs, but that more advanced PCOs are necessary to reach minimum achievable concentrations (Tier 2 EMCs)? If yes, the Tier 1 value was assigned to the midpoint value between the existing conditions EMC and the Tier 2 EMC. If no,
        - Did validation of land use EMCs using existing data and/or professional judgment of other existing conditions land use EMC values (Table A-2) suggest that the existing conditions EMC are near the achievable level expected from applying PCOs? If yes, value was assigned a 10% reduction from the existing condition EMC.

Major Assumptions and Limitations

- The majority of Lake Tahoe storm water monitoring data is relatively inaccessible in a statistically robust manner. The majority of EMC values have been extracted from summary tables within independent storm water monitoring studies conducted by a wide array of researchers. If existing storm water data were contained in an accessible database, EMC evaluations and adjustments could be based on Tahoe-specific data queries on the land use of monitoring station, event type, and catchment characteristics. Minimum and/or 25th percentile EMC observations could be used to better predict achievable Tier 1 and Tier 2 EMC values for each land use and each pollutant of concern.

- Pollutant loading estimation by land use is representative of existing Lake Tahoe storm water pollutant generation.

- The aggregate of BMPs in a PCO applied for each land use category results in a net reduction of the land use EMC.

- The existing conditions EMCs assume the same values for pervious and impervious surfaces from predominantly private land uses, likely due to the lack of water quality monitoring data that can definitively separate the pollutant generation from these pervious and impervious surfaces (Residential and CICU land uses).

- Atmospheric source controls will likely have the greatest land use EMC reduction for TN and DN on impervious surfaces, and future modeling may want to incorporate these anticipated reductions in urban storm water prior to HSC and SWT to more accurately estimate potential N pollutant load reductions. Therefore, the UGSCG provided minimal adjustment of TN and DN EMCs on impervious urban surfaces as a result of PSC-1 Tier 1 and PSC-1 Tier 2 (Table 3-2).

- There is an extremely limited amount of accessible and applicable fine sediment distribution data from the Tahoe Basin and elsewhere. The TMDL EMC existing conditions characterize fine sediment as a fraction of TSS, resulting in an inherent reduction in fine sediment load as the EMC of TSS is adjusted due to PCO application. Due to the lack of available data the relative distributions of fine sediment were unchanged for PCO application. Since fine sediment has recently been considered the most critical pollutant of concern for lake clarity, future focused investigations addressing the fine sediment generation and PSC impacts to fine sediment loading is advisable to improve load reduction estimates.

- The EMCs potentially necessary to achieve water quality objectives for Lake Tahoe are fairly low relative to what typical municipalities are trying to achieve. Therefore, the majority of data sources outside of the Tahoe Basin are not extremely useful for this effort. The Tahoe Basin community will need to be an innovator of advanced storm water practices and monitoring of advanced practices to reduce the impacts of humans on urban water quality.

A.3. PSC Performance Tables

Table A-2. Comparison of existing conditions EMC values to available and assumed relevant EMC values reported by other researchers. Relative differences between the available sources and the existing conditions EMCs were evaluated. This comparison provided insight towards estimations of achievable EMC values given recommended PCOs by the UGSCG (Section 3-1). Available rine sediment (% TSS < 63 um) data is sparse and thus not evaluated by the UGSCG. All EMC values expressed in mg/L.

Pollutant of Concern	Existing Conditions EMC	EMC from other sources	Relative difference	Source of value
Residential_SF Pervious and Impervious				
TSS	56.4	289	-80%	Mean of mean of all residential BMP influent values (2NDNATURE 2006)
TSS	56.4	90	-37%	Median of mean of low density residential EMC TMDL database Appendix F (Gunter 2005)
TSS	56.4	36	56%	Min of mean of low density residential EMC TMDL database Appendix F (Gunter 2005)
TSS	56.4	182	-69%	Mean of mean of low density residential EMC TMDL database Appendix F (Gunter 2005)
TN	1.75	2.484	-30%	Mean of mean of all residential BMP influent values (2NDNATURE 2006)
TN	1.75	1.467	19%	Median of mean of low density residential EMC TMDL database Appendix F (Gunter 2005)
TN	1.75	0.467	275%	Min of mean of low density residential EMC TMDL database Appendix F (Gunter 2005)
TN	1.75	1.660	5%	Mean of mean of low density residential EMC TMDL database Appendix F (Gunter 2005)
DN	0.144	0.450	-68%	Mean of mean of all residential BMP influent values (2NDNATURE 2006)
DN	0.144	0.142	1%	Median of mean of low density residential EMC TMDL database Appendix F (Gunter 2005)
DN	0.144	0.055	162%	Min of mean of low density residential EMC TMDL database Appendix F (Gunter 2005)
DN	0.144	0.126	14%	Mean of mean of low density residential EMC TMDL database Appendix F (Gunter 2005)
TP	0.468	0.747	-37%	Mean of mean of all residential BMP influent values (2NDNATURE 2006)
TP	0.468	0.388	21%	Median of mean of low density residential EMC TMDL database Appendix F (Gunter 2005)
TP	0.468	0.119	293%	Min of mean of low density residential EMC TMDL database Appendix F (Gunter 2005)
TP	0.468	0.463	1%	Mean of mean of low density residential EMC TMDL database Appendix F (Gunter 2005)
DP	0.144	0.082	76%	Mean of mean of all residential BMP influent values (2NDNATURE 2006)
DP	0.144	0.075	92%	Median of mean of low density residential EMC TMDL database Appendix F (Gunter 2005)
DP	0.144	0.028	414%	Min of mean of low density residential EMC TMDL database Appendix F (Gunter 2005)
DP	0.144	0.074	95%	Mean of mean of low density residential EMC TMDL database Appendix F (Gunter 2005)
Residential_MF Pervious and Impervious				
TSS	150	289	-48%	Mean of mean of all residential BMP influent values (2NDNATURE 2006)
TSS	150	125	20%	Median of mean of high density residential EMC TMDL database Appendix F (Gunter 2005)
TSS	150	116	29%	Min of mean of high density residential EMC TMDL database Appendix F (Gunter 2005)
TSS	150	159	-6%	Mean of mean of high density residential EMC TMDL database Appendix F (Gunter 2005)
TN	2.84	2.484	14%	Mean of mean of all residential BMP influent values (2NDNATURE 2006)
TN	2.84	2.616	9%	Median of mean of high density residential EMC TMDL database Appendix F (Gunter 2005)
TN	2.84	1.598	78%	Min of mean of high density residential EMC TMDL database Appendix F (Gunter 2005)
TN	2.84	2.278	25%	Mean of mean of low density residential EMC TMDL database Appendix F (Gunter 2005)
DN	0.42	0.450	-7%	Mean of mean of all residential BMP influent values (2NDNATURE 2006)
DN	0.42	0.348	21%	Median of mean of high density residential EMC TMDL database Appendix F (Gunter 2005)
DN	0.42	0.289	45%	Min of mean of high density residential EMC TMDL database Appendix F (Gunter 2005)
DN	0.42	0.361	16%	Mean of mean of high density residential EMC TMDL database Appendix F (Gunter 2005)
TP	0.588	0.747	-21%	Mean of mean of all residential BMP influent values (2NDNATURE 2006)
TP	0.588	0.494	19%	Median of mean of high density residential EMC TMDL database Appendix F (Gunter 2005)

Pollutant of Concern	Existing Conditions EMC	EMC from other sources	Relative difference	Source of value
TP	0.588	0.437	35%	Min of mean of high density residential EMC TMDL database Appendix F (Gunter 2005)
TP	0.588	0.621	-5%	Mean of mean of high density residential EMC TMDL database Appendix F (Gunter 2005)
DP	0.144	0.082	76%	Mean of mean of all residential BMP influent values (2NDNATURE 2006)
DP	0.144	0.085	69%	Median of mean of high density residential EMC TMDL database Appendix F (Gunter 2005)
DP	0.144	0.070	106%	Min of mean of high density residential EMC TMDL database Appendix F (Gunter 2005)
DP	0.144	0.085	69%	Mean of mean of high density residential EMC TMDL database Appendix F (Gunter 2005)
CICU_Pervious and Impervious				
TSS	296.4	199	49%	Mean of mean of all commercial and industrial BMP influent values (2NDNATURE 2006)
TSS	296.4	247	20%	Median of mean of commercial EMC TMDL database Appendix F (Gunter 2005)
TSS	296.4	199	49%	Min of mean of commercial EMC TMDL database Appendix F (Gunter 2005)
TSS	296.4	267	11%	Mean of mean of commercial EMC TMDL database Appendix F (Gunter 2005)
TN	2.472	3.619	-32%	Mean of mean of all commercial and industrial BMP influent values (2NDNATURE 2006)
TN	2.472	2.099	18%	Median of mean of commercial EMC TMDL database Appendix F (Gunter 2005)
TN	2.472	1.827	35%	Min of mean of commercial EMC TMDL database Appendix F (Gunter 2005)
TN	2.472	2.366	4%	Mean of mean of commercial EMC TMDL database Appendix F (Gunter 2005)
DN	0.294	0.417	-29%	Mean of mean of all commercial and industrial BMP influent values (2NDNATURE 2006)
DN	0.294	0.244	20%	Median of mean of commercial EMC TMDL database Appendix F (Gunter 2005)
DN	0.294	0.096	206%	Min of mean of commercial EMC TMDL database Appendix F (Gunter 2005)
DN	0.294	0.256	15%	Mean of mean of commercial EMC TMDL database Appendix F (Gunter 2005)
DN	0.294	0.687	-57%	Average of summer thunderstorm roadway values for Lake Tahoe: Table 6.2 (CalTrans A2001)
DN	0.294	0.400	-27%	Average from Tahoe roads: Table 6.2 (CalTrans A2001)
DN	0.294	0.488	-40%	Statewide non-urban roadway runoff mean: Table 7 (CalTrans 2001)
TP	0.702	0.614	14%	Mean of mean of all commercial and industrial BMP influent values (2NDNATURE 2006)
TP	0.702	0.587	20%	Median of mean of commercial EMC TMDL database Appendix F (Gunter 2005)
TP	0.702	0.379	85%	Min of mean of commercial EMC TMDL database Appendix F (Gunter 2005)
TP	0.702	0.755	-7%	Mean of mean of commercial EMC TMDL database Appendix F (Gunter 2005)
TP	0.702	0.225	212%	Statewide non-urban roadway runoff mean: Table 7 (CalTrans 2001)
TP	0.702	0.280	151%	Statewide urban roadway runoff: Table 7 (CalTrans 2001)
TP	0.702	0.367	91%	Average of summer thunderstorm roadway values for Lake Tahoe: Table 6.2 (CalTrans A2001)
DP	0.078	0.067	17%	Mean of mean of all commercial and industrial BMP influent values (2NDNATURE 2006)
DP	0.078	0.032	144%	Median of mean of commercial EMC TMDL database Appendix F (Gunter 2005)
DP	0.078	0.022	255%	Min of mean of commercial EMC TMDL database Appendix F (Gunter 2005)
DP	0.078	0.041	90%	Mean of mean of commercial EMC TMDL database Appendix F (Gunter 2005)
DP	0.078	0.144	-46%	TMDL Roads_Secondary
DP	0.078	0.144	-46%	TMDL Res SF and MF
DP	0.078	0.110	-29%	Annual Tahoe average from Table 6.2 (CalTrans A2001)
DP	0.078	0.096	-19%	Statewide non-urban roadway runoff mean: Table 7 (CalTrans 2001)
Veg_Turf				
TSS	12	N/A		no data available
TN	4.876	3.355	45%	Village Green runoff median (2002-2006) (2NDNATURE 2007)
DN	0.487	0.55	-11%	Village Green runoff median (2002-2006) (2NDNATURE 2007)
TP	1.500	1.25	20%	Village Green 2002 median SRP: P applied regularly (2NDNATURE 2007)
DP	0.263	0.63	-58%	Village Green 2002 median SRP: P applied regularly (2NDNATURE 2007)
DP	0.263	0.31	-15%	Village Green 2003-2006 median SRP when no P applied as fertilizer

Pollutant of Concern	Existing Conditions EMC	EMC from other sources	Relative difference	Source of value
Roads_Primary				
TSS	951.6	124	667%	Statewide urban roadway mean Table 7 (CalTrans 2003B)
TSS	951.6	989	-4%	Annual Tahoe average from Table 6.2 (CalTrans A2001)
TSS	951.6	794.67	20%	Average inflow of Stormceptor, Sediment Trap and Sediment Basin (DRI 2004)
TSS	951.6	1361	-30%	Average summer thunderstorm inflow of Stormceptor and Sediment Trap (DRI 2004)
TN	3.924	2.00	96%	Annual Tahoe average from Table 6.2 (CalTrans A2001)
TN	3.924	2.98	32%	Statewide urban roadway runoff: Table 7 (CalTrans 2001)
TN	3.924	1.80	118%	Statewide non-urban roadway runoff mean: Table 7 (CalTrans 2001)
TN	3.924	3.35	17%	Average inflow of Stormceptor, Sediment Trap and Sediment Basin (DRI 2004)
TN	3.924	6.33	-38%	Average summer thunderstorm inflow of Stormceptor and Sediment Trap (DRI 2004)
DN	0.720	0.98	-27%	Statewide urban roadway runoff: Table 7 (CalTrans 2001)
DN	0.720	0.49	48%	Statewide non-urban roadway runoff mean: Table 7 (CalTrans 2001)
DN	0.720	0.687	5%	Average of summer thunderstorm values for Lake Tahoe: Table 6.2 (CalTrans 2001)
DN	0.720	0.22	227%	Average inflow of Stormceptor, Sediment Trap and Sediment Basin (DRI 2004)
DN	0.720	0.45	62%	Average summer thunderstorm inflow of Stormceptor and Sediment Trap (DRI 2004) (NOx only)
TP	1.980	0.37	440%	Average of summer thunderstorm values for Lake Tahoe: Table 6.2 (CalTrans 2001)
TP	1.980	1.30	52%	Annual Tahoe average from Table 6.2 (CalTrans A2001)
TP	1.980	0.28	607%	Statewide urban roadway runoff: Table 7 (CalTrans 2001)
TP	1.980	0.91	118%	Average inflow of Stormceptor, Sediment Trap and Sediment Basin (DRI 2004)
TP	1.980	1.95	2%	Average summer thunderstorm inflow of Stormceptor and Sediment Trap (DRI 2004)
DP	0.096	0.144	-33%	TMDL Roads_Secondary
DP	0.096	0.22	-56%	Average of summer thunderstorm values for Lake Tahoe: Table 6.2 (CalTrans 2001)
DP	0.096	0.11	-13%	Annual Tahoe average from Table 6.2 (CalTrans A2001)
DP	0.096	0.108	-11%	Statewide urban roadway runoff: Table 7 (CalTrans 2001)
DP	0.096	0.096	0%	Statewide non-urban roadway runoff mean: Table 7 (CalTrans 2001)
DP	0.096	0.04	140%	Average inflow of Stormceptor, Sediment Trap and Sediment Basin (DRI 2004)
DP	0.096	0.048	100%	Average summer thunderstorm inflow of Stormceptor and Sediment Trap (DRI 2004)
Roads_Secondary				
TSS	150	94	60%	Statewide Stormwater Runoff Averages from Table 6.2 (CalTrans A2001); Also Table 7 (CalTrans 2001)
TN	2.844	2.00	42%	Annual Tahoe average from Table 6.2 (CalTrans A2001)
TN	2.844	1.8	58%	Statewide non-urban roadway runoff mean: Table 7 (CalTrans 2001)
DN	0.420	0.488	-14%	Statewide non-urban roadway runoff mean: Table 7 (CalTrans 2001)
TP	0.588	1.3	-55%	Annual Tahoe average from Table 6.2 (CalTrans A2001)
TP	0.588	0.37	59%	Average of summer thunderstorm values for Lake Tahoe: Table 6.2 (CalTrans 2001)
TP	0.588	0.225	161%	Statewide non-urban roadway runoff mean: Table 7 (CalTrans 2001)
DP	0.144	0.11	31%	Annual Tahoe average from Table 6.2 (CalTrans A2001)
DP	0.144	0.096	50%	Statewide non-urban roadway runoff mean: Table 7 (CalTrans 2001)

Table A-3. Estimated achievable Tier 2 EMC values, assuming 100% application and 100% performance effectiveness of relevant PCOs (Table 3-2). Adjustments to the existing conditions EMCs under Tier 2 were made based on several data sources, which are described in the "Value/data source" column. The Tier 2 values are color coded to indicate the UGSCG rationale for the Tier 2 EMC estimates. All EMC values are expressed in mg/L.

PSC Category	Landuse Category	Pollutant of Concern	Existing Conditions EMC	Tier 2 EMC	Value/data source
Public Impervious	Roads_Primary	TN	3.924	**2.00**	CalTrans sand trap effluent mean: Table 6.11 (CalTrans J2003); NDOT Stormcepter effluent mean: Appendix C (DRI 2004); NDOT Sediment trap effluent mean: Table 4.2 (DRI 2004); Annual Tahoe average from Table 6.2 (CalTrans 2001); atmospheric reductions may reduce further
		DN	0.720	**0.600**	CalTrans sand trap effluent mean: Table 6.11 (CalTrans J2003); Average of summer thunderstorm values for Lake Tahoe: CalTrans Table 6.2 (Caltrans 2001)
		TP	1.980	**0.367**	Average of summer thunderstorm values for Lake Tahoe: CalTrans Table 6.2 (Caltrans 2001)
		DP	0.096	**0.021**	NDOT Stormcepter effluent mean: Appendix C (DRI 2004); NDOT Sediment trap effluent mean: Table 4.2 (DRI 2004)
		TSS	951.6	**124**	Statewide urban roadway mean: Table 7 (CalTrans A2003); CalTran sand trap effluent mean: Tables 3.3.2 and 3.3.4 (CalTrans 2006)
		Fine Sed (%TSS)	85%	85%	No change, insufficient data
	Roads_Secondary	TN	2.844	**1.80**	Statewide non-urban roadway runoff mean: Table 7 (CalTrans A2003); atmospheric reductions may reduce further
		DN	0.420	**0.378**	Minimal change expected from pollutant source controls; value at or near achievable levels; atmospheric reduction may reduce further
		TP	0.588	**0.225**	Statewide Non-urban roadway runoff mean: Table 7 (CalTrans A2003)
		DP	0.144	**0.096**	Statewide Non-urban roadway runoff mean: Table 7 (CalTrans A2003)
		TSS	150	**50**	Average of summer thunderstorm values for Lake Tahoe: Table 6.2 (CalTrans 2001); CalTrans sand trap effluent: Tables 3.2.2 and 3.2.4 (CalTrans 2006)
		Fine Sed (%TSS)	85%	85%	No change, insufficient data
	CICU_Impervious	TN	2.472	**1.80**	Statewide non-urban roadway runoff mean: Table 7 (CalTrans A2003); Min of mean of commercial EMC TMDL database Appendix F (Gunter 2005); atmospheric reductions may reduce further
		DN	0.294	**0.096**	Min of mean of commercial EMC TMDL database Appendix F (Gunter 2005)
		TP	0.702	**0.37**	Average of summer thunderstorm values for Lake Tahoe: Table 6.2 (CalTrans 2001); Min of mean of commercial EMC TMDL database Appendix F (Gunter 2005)
		DP	0.078	**0.022**	Min of mean of commercial EMC TMDL database Appendix F (Gunter 2005)
		TSS	296.4	**112**	Average of summer thunderstorm values for Lake Tahoe: Table 6.2 (CalTrans 2001)
		Fine Sed (%TSS)	85%	85%	No change, insufficient data
Public Pervious	Veg_Turf	TN	4.876	**2.38**	Village Green: 25th percentile of all TN turf runoff 2002-2006 (2NDNATURE 2007)
		DN	0.487	**0.350**	Village Green: 25th percentile of all DIN turf runoff 2002-2006 (2NDNATURE 2007)
		TP	1.500	**0.363**	Village Green: 25th percentile of all TP turf runoff 2003-2006; No P applied as fertilizer
		DP	0.263	**0.237**	Minimal change expected from pollutant source controls; value at or near achievable levels.
		TSS	12	**10.8**	Minimal change expected from pollutant source controls; value at or near achievable levels.
		Fine Sed (%TSS)	63%	63%	No change, insufficient data
Private	Residential_SFP	TN	1.752	**0.467**	Min of mean of low density residential EMC TMDL database Appendix F (Gunter 2005)
		DN	0.144	**0.055**	Min of mean of low density residential EMC TMDL database Appendix F (Gunter 2005)

PSC Category	Landuse Category	Pollutant of Concern	Existing Conditions EMC	Tier 2 EMC	Value/data source
		TP	0.468	**0.199**	Min of mean of low density residential EMC TMDL database Appendix F (Gunter 2005)
		DP	0.144	**0.028**	Min of mean of low density residential EMC TMDL database Appendix F (Gunter 2005)
		TSS	56.4	**38**	Min of mean of low density residential EMC TMDL database Appendix F (Gunter 2005); agrees with Veg_ep2 existing condition EMC
		Fine Sed (%TSS)	76%	76%	No change, insufficient data
	Residential_MFP	TN	2.844	**1.598**	Min of mean of high density residential EMC TMDL database Appendix F (Gunter 2005); agrees with Residential_SFP existing conditions EMC
		DN	0.420	**0.289**	Min of mean of high density residential EMC TMDL database Appendix F (Gunter 2005)
		TP	0.588	**0.437**	Min of mean of high density residential EMC TMDL database Appendix F (Gunter 2005); agrees with Residential_SFP existing conditions EMC
		DP	0.144	**0.07**	Min of mean of high density residential EMC TMDL database Appendix F (Gunter 2005)
		TSS	150	**56.4**	From Residential_SFP existing conditions EMCs
		Fine Sed (%TSS)	88%	88%	No change, insufficient data
	CICU_Pervious	TN	2.472	**1.800**	Statewide non-urban roadway runoff mean: Table 7 (CalTrans A2003); Min of mean of commercial EMC TMDL database Appendix F (Gunter 2005); atmospheric reductions may reduce further
		DN	0.293	**0.096**	Min of mean of commercial EMC TMDL database Appendix F (Gunter 2005)
		TP	0.702	**0.37**	Average of summer thunderstorm values for Lake Tahoe: Table 6.2 (CalTrans 2001); Min of mean of commercial EMC TMDL database Appendix F (Gunter 2005)
		DP	0.078	**0.022**	Min of mean of commercial EMC TMDL database Appendix F (Gunter 2005)
		TSS	296.4	**112**	Average of summer thunderstorm values for Lake Tahoe: Table 6.2 (CalTrans 2001); Min of mean of commercial EMC TMDL database Appendix F (Gunter 2005); agrees with Residential_MFP existing conditions EMCs
		Fine Sed (%TSS)	85%	85%	No change, insufficient data
	Residential_SFI	TN	1.752	**0.467**	Same as Residential_SFP to be consistent with existing conditions: residential pervious and impervious EMCs are identical
		DN	0.144	**0.055**	Same as Residential_SFP to be consistent with existing conditions: residential pervious and impervious EMCs are identical
		TP	0.468	**0.199**	Same as Residential_SFP to be consistent with existing conditions: residential pervious and impervious EMCs are identical
		DP	0.144	**0.028**	Same as Residential_SFP to be consistent with existing conditions: residential pervious and impervious EMCs are identical
		TSS	56.4	**38**	Same as Residential_SFP to be consistent with existing conditions: residential pervious and impervious EMCs are identical
		Fine Sed (%TSS)	76%	76%	No change, insufficient data
	Residential_MFI	TN	2.844	**1.598**	Same as Residential_MFP to be consistent with existing conditions: residential pervious and impervious EMCs are identical
		DN	0.420	**0.289**	Same as Residential_MFP to be consistent with existing conditions: residential pervious and impervious EMCs are identical
		TP	0.588	**0.437**	Same as Residential_MFP to be consistent with existing conditions: residential pervious and impervious EMCs are identical
		DP	0.144	**0.07**	Same as Residential_MFP to be consistent with existing conditions: residential pervious and impervious EMCs are identical
		TSS	150	**56.4**	Same as Residential_MFP to be consistent with existing conditions: residential pervious and impervious EMCs are identical
		Fine Sed (%TSS)	88%	88%	No change, insufficient data

Green values indicate revised EMCs are based on existing Lake Tahoe storm water or statewide monitoring data assumed to represent desired conditions for Tier 2.

Grey values indicate revised EMCs are existing TMDL land use EMC values from other existing land use conditions.

Blue values indicate minimal change expected due to PCO implementation of pollutant source controls.

Table A-4. Using the existing conditions and Tier 2achievable values as book ends, Tier 1 EMC values were estimated based on the assumed effectiveness of Tier 1 PCO's. The UGSCG rationale for each Tier 1 EMC is presented. All EMC values are expressed as mg/L.

PSC Category	Landuse Category	Pollutant of Concern	Existing Conditions EMC (TMDL)	Tier 1 EMC	Assumptions in Tier 1 performance relative to Tier 2
Public Impervious	Roads_Primary	TN	3.924	2.962	50% of reduction in EMC under Tier 2 from less maintenance
		DN	0.720	0.705	50% of reduction in EMC under Tier 2 from less maintenance
		TP	1.980	1.173	50% of reduction in EMC under Tier 2 from less maintenance
		DP	0.096	0.061	50% of reduction in EMC under Tier 2 from less maintenance
		TSS	951.6	538	50% of reduction in EMC under Tier 2 from less maintenance; Runoff values from moderately-sanded road (HW 267 in Placer County) (CalTrans F2006) (39% reduction)
		Fine Sed (%TSS)	85%	85%	No change, insufficient data
	Roads_Secondary	TN	2.844	2.322	50% of reduction in EMC under Tier 2 from less maintenance
		DN	0.420	0.420	No measurable change expected from pollutant source controls; value at or near achievable levels; atmospheric reduction may reduce further
		TP	0.588	0.407	50% of reduction in EMC under Tier 2 from less maintenance
		DP	0.144	0.120	50% of reduction in EMC under Tier 2 from less maintenance
		TSS	150	100	50% of reduction in EMC under Tier 2 from less maintenance
		Fine Sed (%TSS)	85%	85%	No change, insufficient data
	CICU_Impervious	TN	2.472	2.136	50% of reduction in EMC under Tier 2 from less maintenance
		DN	0.294	0.195	50% of reduction in EMC under Tier 2 from less maintenance
		TP	0.702	0.536	50% of reduction in EMC under Tier 2 from less maintenance
		DP	0.078	0.050	50% of reduction in EMC under Tier 2 from less maintenance
		TSS	296.4	204	50% of reduction in EMC under Tier 2 from less maintenance
		Fine Sed (%TSS)	85%	85%	No change, insufficient data
Public Pervious	Veg_Turf	TN	4.876	4.388	10% reduction from slightly increased education and compliance
		DN	0.487	0.438	10% reduction from slightly increased education and compliance
		TP	1.500	1.350	10% reduction from slightly increased education and compliance
		DP	0.263	0.263	No measurable change expected from pollutant source controls; value at or near achievable levels
		TSS	12	12	No measurable change expected from pollutant source controls; value at or near achievable levels
		Fine Sed (%TSS)	63%	63%	No change, insufficient data
Private	Residential_SFP	TN	1.752	1.577	10% reduction from slightly increased education and compliance
		DN	0.144	0.130	10% reduction from slightly increased education and compliance
		TP	0.468	0.421	10% reduction from slightly increased education and compliance
		DP	0.144	0.130	10% reduction from slightly increased education and compliance
		TSS	56.4	38	Same as Tier 2 because BMP technology already available
		Fine Sed (%TSS)	76%	76%	No change, insufficient data
	Residential_MFP	TN	2.844	2.560	10% reduction from slightly increased education and compliance
		DN	0.420	0.378	10% reduction from slightly increased education and compliance
		TP	0.588	0.529	10% reduction from slightly increased education and compliance
		DP	0.144	0.130	10% reduction from slightly increased education and compliance
		TSS	150	56.4	Same as Tier 2 because BMP technology already available

PSC Category	Landuse Category	Pollutant of Concern	Existing Conditions EMC (TMDL)	Tier 1 EMC	Assumptions in Tier 1 performance relative to Tier 2
		Fine Sed (%TSS)	88%	88%	No change, insufficient data
	CICU_Pervious	TN	2.472	2.136	Same as CICU_Impervious to be consistent with existing conditions: commercial pervious and impervious EMCs are identical
		DN	0.293	0.195	Same as CICU_Impervious to be consistent with existing conditions: commercial pervious and impervious EMCs are identical
		TP	0.702	0.536	Same as CICU_Impervious to be consistent with existing conditions: commercial pervious and impervious EMCs are identical
		DP	0.078	0.050	Same as CICU_Impervious to be consistent with existing conditions: commercial pervious and impervious EMCs are identical
		TSS	296.4	204	Same as CICU_Impervious to be consistent with existing conditions: commercial pervious and impervious EMCs are identical
		Fine Sed (%TSS)	85%	85%	No change, insufficient data
	Residential_SFI	TN	1.752	1.577	Same as Residential_SFP to be consistent with existing conditions: residential pervious and impervious EMCs are identical
		DN	0.144	0.130	Same as Residential_SFP to be consistent with existing conditions: residential pervious and impervious EMCs are identical
		TP	0.468	0.421	Same as Residential_SFP to be consistent with existing conditions: residential pervious and impervious EMCs are identical
		DP	0.144	0.130	Same as Residential_SFP to be consistent with existing conditions: residential pervious and impervious EMCs are identical
		TSS	56.4	38	Same as Residential_SFP to be consistent with existing conditions: residential pervious and impervious EMCs are identical
		Fine Sed (%TSS)	76%	76%	No change, insufficient data
	Residential_MFI	TN	2.844	2.560	Same as Residential_MFP to be consistent with existing conditions: residential pervious and impervious EMCs are identical
		DN	0.420	0.378	Same as Residential_MFP to be consistent with existing conditions: residential pervious and impervious EMCs are identical
		TP	0.588	0.529	Same as Residential_MFP to be consistent with existing conditions: residential pervious and impervious EMCs are identical
		DP	0.144	0.130	Same as Residential_MFP to be consistent with existing conditions: residential pervious and impervious EMCs are identical
		TSS	150	56.4	Same as Residential_MFP to be consistent with existing conditions: residential pervious and impervious EMCs are identical
		Fine Sed (%TSS)	88%	88%	No change, insufficient data

Urban & Groundwater Appendix B: Groundwater Loading Assessment

A primary process relied upon for storm water management in Lake Tahoe is infiltration, which reduces volumes and associated pollutant loads in surface water through routing of runoff to groundwater. The UGSCG was tasked with evaluating the potential impacts of urban storm water PCO implementation on groundwater nutrient loads relative to existing conditions. The UGSCG created a simple, yet relatively robust method for estimating and tracking the changes in groundwater nutrient loads resulting from application of urban upland treatment tiers.

B1. Summary of Approach

Two main data sources/tools were used by the UGSCG for the evaluation of the impacts of urban storm water PCOs on groundwater nutrient loads relative to existing conditions.

1. The groundwater evaluation conducted by the Army Corps of Engineers (ACOE 2003) is regarded as the most thorough synthesis of existing knowledge on the groundwater discharge and nutrient water quality in Lake Tahoe Basin. Data from this study are considered by the UGSCG to be the best source of information on the existing conditions of groundwater nutrient concentrations and nutrient fluxes to the Lake.

2. The EPA's Storm Water Management Model (SWMM – Huber, 1998) was used to track volumes for both surface runoff and infiltrated water using a continuous hydrology simulation. SWMM allowed the UGSCG to quantify the infiltrated volumes and track associated EMCs for urbanized areas for existing conditions, and the Tier 1 and Tier 2 treatment tiers.

The UGSCG used the ACOE (2003) groundwater data to inform and evaluate the infiltration results from SWMM existing conditions simulations. A number of data comparison efforts were used to relate the infiltrated volumes and associated dissolved nitrogen (DN) and dissolved phosphorus (DP) EMCs from SWMM to the conditions reported by ACOE (2003). Once the SWMM results were assessed and an unsaturated zone scaling factor was obtained, the UGSCG created a simple accounting method to estimate the relative impacts of PCOs implemented for each major load reduction element (i.e. PSC, HSC and SWT) on groundwater nutrient quality and infiltration volumes. The groundwater accounting method also informed the assessment regarding the relative impact of each individual load reduction element. Based on the time constraints of Phase II of the TMDL project, the UGSCG decided that this approach provided the most efficient and reliable method to estimate the relative changes in groundwater nutrient loading as a result of PCO implementation.

Assumptions of Approach

The following major assumptions were made for the selected approach:

1. The groundwater reservoir volume is at steady state. Therefore, over longer time intervals the total volume of water infiltrated to the subsurface will equal the flux out of the groundwater

reservoir to the Basin streams and the Lake. This assumption allowed a direct concentration comparison between SWMM infiltration water quality and ACOE (2003) observations.

2. Infiltrated concentrations in urbanized areas correspond to the estimated anthropogenic concentration reported by the Army Corps of Engineers (ACOE 2003).

3. The unsaturated zone between the surface and groundwater reservoirs results in some level of natural biological and/or geochemical removal of DN and DP. Geochemical changes to DN and DP naturally occur in the unsaturated zone as urban storm water is infiltrated.

B2. SWMM Modeling Assumptions and Approach

To estimate the relative impacts on groundwater quality from the implementation of urban upland treatment tiers, the UGSCG developed a simple mass balance modeling approach using components of SWMM and the pollutant load reduction methodologies developed during Phase 1 of the TMDL (nhc and Geosyntec, 2006). The following section briefly describes: 1) the components of SWMM employed for the analysis; 2) the general modeling approach; 3) key input data and a discussion of sensitivity; and, 4) output provided to the groundwater assessment.

Components of SWMM Modeling Approach

The EPA’s SWMM version 4 was used to simulate rainfall-runoff processes and hydrologic performance of PCOs to provide a relative estimate of infiltrated volumes to groundwater. SWMM was used in the analysis because it provided a means to track volume losses associated with infiltration through continuous simulation. Four of the six available SWMM modules were used in the analysis: the Rainfall Block, the Temperature Block, the Runoff Block, and the Storage Treatment Block. These four modules are used to simulate rainfall/runoff hydrology, infiltration, and detention storage dynamics. The Runoff Block allows for simple routing of flows within a drainage catchment and the Storage Treatment Block allows for the hydraulic simulation of both flow- and volume-based BMPs.

To assess a full range of hydrologic conditions that incorporate large and small storm events, and to simulate snowmelt, the modeling approach employed long-term hydrology (e.g., multiple years of precipitation record in 1 hour time steps) rather than event-based hydrology (e.g., 20-year, 1-hour event). The Marlette Lake SnoTel monitoring data set from 1996 to 2004 (Station ID: 19k04s) was used for the precipitation and daily temperature records. Annual average precipitation at this station is approximately 32 inches per year. The Marlette Lake rainfall record was selected because it provides a reasonable estimate of average annual precipitation over the entire Tahoe Basin. Localized precipitation in the Tahoe Basin is recognized to vary substantially from the Marlette Lake average. However, the intent of informing the groundwater assessment was to provide a reasonable Tahoe Basin estimate of infiltrated volumes. SWMM snowfall and snow melt coefficients were adjusted to account for the difference in elevation between the location of the Marlette Lake gage and the majority of urban upland areas. SWMM determines if precipitation is snowfall, or if the accumulated snow melts, based on the daily min/max temperature records and specified coefficients.

Modeling Approach

The following approach was used to estimate hydrology and infiltrated runoff quality for urban upland settings (see Section 4) under scenarios for existing conditions, and the Tier 1 and Tier 2 treatment tiers (see Section 5).

Step 1 - Compile Existing Conditions Input Data
GIS layers of TMDL subwatersheds and TRPA Plan Area Statements were intersected to create a GIS layer of "urban" area within a subwatershed. This step was necessary to filter out forest uplands in each TMDL subwatershed, which are not included in the UGSCG analysis. Next, the filtered "urban" area was related to urban upland setting classifications. The total urban area in each setting was then used as the basis for querying GIS layers to compile necessary existing conditions data (e.g., land use distributions, hydrologic soil groups, average slopes, etc.)

Step 2 – Develop Existing Conditions Input Data for Simulation
To standardize modeling assumptions and to allow for a simple scalar extrapolation of loads in the groundwater analysis, a normalized 100-acre drainage catchment was selected for use in all SWMM simulations. Data compiled in Step 1 was developed into input formats appropriate for SWMM, and within the context of a normalized 100-acre drainage catchment. The following bullets provide examples of how input data were developed:

- The area of each land use category present within a setting was divided by the total urban area within the setting to derive relative land use percentages by setting. For simplification purposes, land use categories were consolidated into private pervious, private impervious, public pervious, and public impervious. The summation of impervious land use percentages within a setting was multiplied by 100-acres to develop input data for impervious and pervious areas for model simulation. For the existing condition, the impervious areas were considered to be directly connected to the storm drain system such that infiltration only occurs as a result of rainfall and subsequent infiltration in the pervious areas. This is consistent with the Watershed Model representation of pervious and impervious surfaces.

- Digital soil survey data obtained from the Natural Resources Conservation Service (NRCS) were used to determine the hydrologic soil groups (i.e. A through D) for each urban upland setting (http://soildatamart.nrcs.usda.gov/). The distribution of hydrologic soil groups within a setting, as the percent of the total pervious area, was then used to estimate area-weighted input parameters for infiltration. The SWMM modeling used the Green-Ampt infiltration equation; where input parameters for infiltration simulations are saturated hydraulic conductivity, soil suction head, and effective porosity (initial soil moisture deficit). Literature sources such as James and James (2000) and Chow (1964) were consulted to relate the distribution of hydrologic soils groups into the required input parameters for the Green-Ampt infiltration equation.

- Average slopes for each urban setting were estimated using a 30-meter digital elevation model (DEM) of the Tahoe Basin obtained from the USGS National Elevation Data Set (http://ned.usgs.gov/).

Step 3 – Develop Tier 1 and Tier 2 Input Data for Simulation
The effects of implementing PCOs on the volume and loads of infiltrated storm water for Tier 1 and Tier 2 were evaluated using SWMM and simple land use-based pollutant load equations (i.e., Load = EMC x Volume). PSCs were evaluated through an adjustment to land use-based EMCs

as described in Section 3. HSCs were evaluated through an adjustment to the impervious area connectivity and resulting additional infiltration of impervious area runoff. SWTs were evaluated by applying constant infiltration rates in volume- and flow-based scenarios dependent upon the setting. The specific level of PCO implementation depends on the treatment tier and the particular land use category. Refer to Section 6 - Analysis Methodology in the main report and Appendix D for a description of the treatment tier PCO implementation assumptions.

Step 4 – Compute Average Annual Output Using Hydrologic Simulations

For each urban upland setting, and using the input data developed in Steps 1-3, continuous hydrologic simulations were run in SWMM to estimate average annual volumes of runoff and infiltration. Three model simulations were run for each setting to estimate changes in average annual runoff and infiltration among the existing conditions scenario, Tier 1, and Tier 2.

Step 5 – Develop Estimates of DN and DP Runoff Concentrations

Estimates of characteristic runoff concentrations for DN and DP were developed outside of SWMM simulations by area weighting event mean concentrations (EMCs) for individual land use categories based upon the percentage of each land use category present within a setting. This approach was used for the existing conditions, Tier 1, and Tier 2. Land use specific EMCs for the existing conditions were taken from Phase 1 (TMDL Phase 1 Technical Report, LRWQCB). Land use specific achievable EMCs for Tier 1 and Tier 2s were taken from this UGSCG report (Section 3).

Key Input Data and Sensitivity of Input Data

The following tables list key hydrologic input data for each setting and simulation of existing conditions, and the Tier 1 and Tier 2 treatment tiers. A brief discussion of output sensitivity to the key input parameters is provided after the tables.

Table B-1. Key SWMM Input Parameters for Existing Conditions

	UGSCG Settings			
Parameter	**CS**	**CM**	**DS**	**DM**
Simulated Area (ac)	100	100	100	100
% Imperviousness	25%	29%	19%	20%
Impervious Area Depression Storage (in)	0	0	0	0
Pervious Area Depression Storage (in)	0.06	0.06	0.06	0.06
Impervious Area Manning's Roughness Coefficient for Overland Flow	0.01	0.01	0.01	0.01
Pervious Area Manning's Roughness Coefficient for Overland Flow	0.4	0.4	0.4	0.4
Ave. Catchment Slope (%)	15%	6%	20%	7%
Sat. Hydraulic Conductivity (in/hr)	0.16	0.2	0.15	0.17
Soil Suction Head (in)	6.8	6.5	7.3	6.9
Initial Moisture Deficit (in)	0.3	0.3	0.3	0.3
Snowmelt Coefficient (in/hr-^{o}F)	0.005	0.005	0.005	0.005

Table B-2. Key SWMM Input Parameters for Tier 1

	UGSCG Settings			
Parameter	**CS**	**CM**	**DS**	**DM**
Hydrologic Source Control				
% Impervious Area Disconnected	30%	34%	33%	39%
Infiltration Rate (in/hr)	0.1	0.1	0.1	0.1

	UGSCG Settings			
Parameter	**CS**	**CM**	**DS**	**DM**
Storm Water Treatment				
Design Volume (ft^3/imperv. acre)	N/A	3,630	N/A	3,630
Length-to-Width Ratio	2	2	2	2
Design Depth (ft)	N/A	3	N/A	3
Drain Time (hrs)	N/A	48	N/A	48
Design Flow Rate (cfs/imperv. acre)	0.03	N/A	0.03	N/A
Infiltration Rate (in/hr)	0.05	0.2	0.05	0.2

Table B-3. Key SWMM Input Parameters for Tier 2

	UGSCG Settings			
PCO Parameter	**CS**	**CM**	**DS**	**DM**
Hydrologic Source Control				
% Impervious Area Disconnected	59%	69%	65%	74%
Infiltration Rate (in/hr)	0.1	0.1	0.1	0.1
Storm Water Treatment				
Design Volume (ft^3/imperv. acre)	N/A	3,630	N/A	3,630
Length-to-Width Ratio	2	2	2	2
Design Depth	N/A	3	N/A	3
Drain Time	N/A	48	N/A	48
Design Flow Rate (cfs/imperv. acre)	0.06	N/A	0.06	N/A
Infiltration Rate (in/hr)	0.1	0.3	0.1	0.3

For the input parameters shown in Table B-1, the percent imperviousness and saturated hydraulic conductivity are the most sensitive input parameters affecting estimated runoff and infiltration volumes from a simulated drainage catchment. Depression storage has a moderate affect on the volume infiltrated during small storms and during snowmelt events. While the Manning's roughness coefficient for overland flow, catchment slope, and the snowmelt coefficient will affect the rate of the runoff, the volume infiltrated is not very sensitive to these parameters. Other soil parameters, such as soil suction head and initial moisture deficit have a small affect on infiltrated volumes.

For the implementation of HSCs (Tables B-2 and B-3), the percent of imperviousness area disconnected and infiltration rate are both highly sensitive input parameters. However, the input parameters chosen for these fields are conservative in nature. For example, the infiltration rate for HSCs is less than the average saturated hydraulic conductivity for each UGSCG setting.

For the implementation of volume-based SWT (Tables B-2 and B-3), the design volume, depth, and infiltration rate have a significant affect on the total infiltration volumes. Flow-based SWT does not typically have large volume losses due to short residence times, but infiltration volumes are largely a function of the design flow rate, footprint area, and infiltration rate. The other parameters listed for SWT are important for the SWMM simulation, but are considered relatively insensitive to the determination of infiltration volumes.

Output Provided to Groundwater Assessment

Output from SWMM model simulations was provided to the groundwater loading assessment as a summary of average annual runoff volumes and infiltration. Also provided to the groundwater loading assessment were characteristic EMCs for DN and DP. Output was provided for each setting and the three scenarios: 1) existing conditions; 2) Tier 1; and, 3) Tier 2.

Figure B-1 summarizes the hydrologic output used to inform the groundwater assessment as percentages of the average annual precipitation volume. Output is partitioned in Figure B-1 as the percentage of precipitation that is either transformed to surface runoff, or infiltrated in 1) the drainage catchment, 2) HSCs, or 3) SWTs.

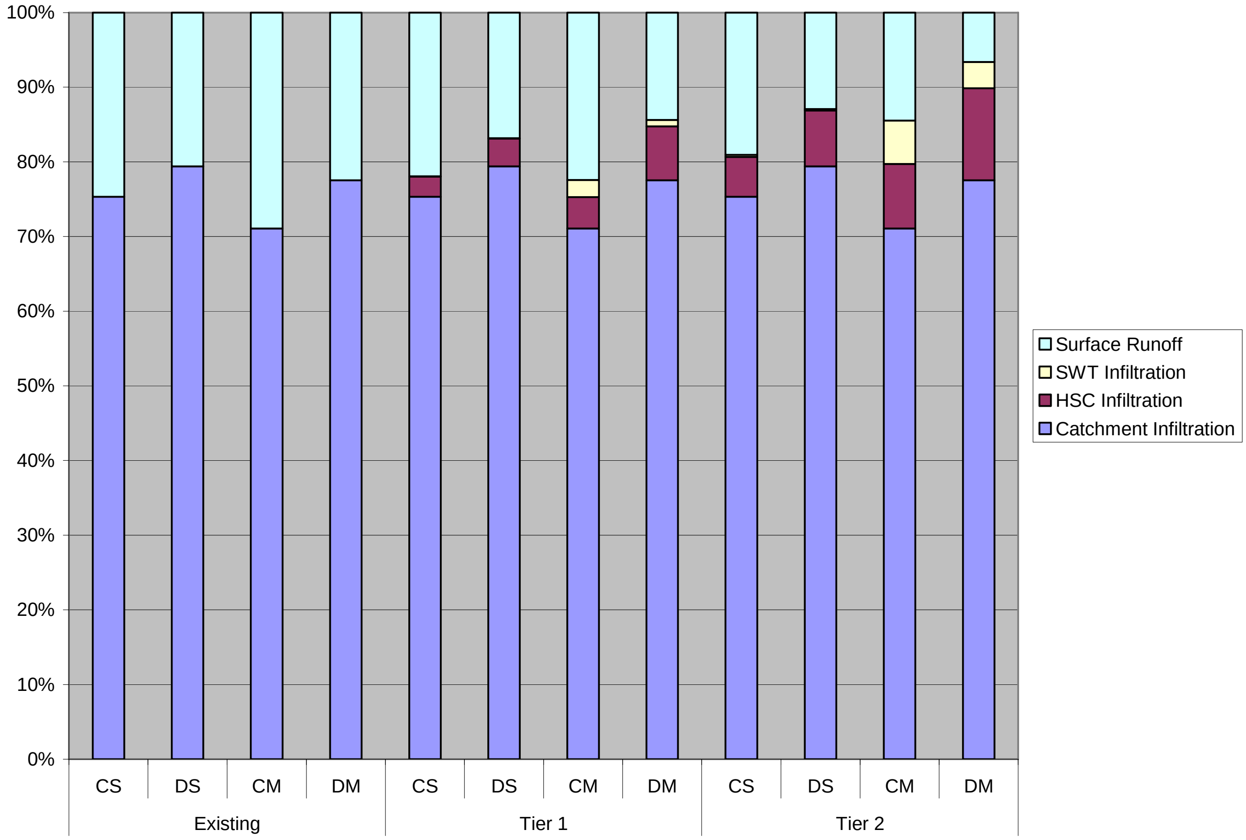


Figure B-1. Hydrologic Output Informing the Groundwater Assessment

The following points are noted from examination of the hydrologic output shown in Figure B-1:

- Under existing conditions, infiltration in the drainage catchment is estimated to range between 70 and 80 percent of the annual precipitation volume across all settings. Dispersed settings have less surface runoff because less of the area within the dispersed settings is impervious.
- With PCO implementation, infiltration volumes are expected to increase relative to existing conditions from 3% to 16%, dependent upon the treatment tier employed and the setting.
- In general, HSCs have a larger impact on total infiltration volumes relative to SWTs. This is primarily because residential and commercial land uses compose the largest fraction of

impervious area within each setting. Tier 1 and Tier 2 assume that HSCs are implemented on 50% and 100% of this impervious area, respectively.

- Tier 1 implementation is estimated to result in approximately 50 percent less infiltration than Tier 2 implementation. Again, this output is influenced by the HSC assumption regarding the level of private BMP implementation for impervious surfaces.
- Infiltration volumes from SWT are estimated to be less in the steep sloped settings (CS and DS) relative to moderately sloped settings (CM and DM). This output is influenced by the assumption that flow-based SWTs infiltrate less than volume-based SWTs, where implementation of flow-based SWTs are more prevalent in steep settings and implementation of volume-based SWTs are more prevalent in moderately sloped settings.

Table B-4 lists the characteristic EMCs for DN and DP in each setting for the three scenarios: 1) existing conditions; 2) Tier 1; and, 3) Tier 2. Estimates of characteristic EMCs for DN and DP were developed outside of SWMM simulations by area weighting event mean concentrations (EMCs) by individual land use percentages within a setting. Land use specific EMCs for the existing conditions were taken from Phase 1 (TMDL Phase 1 Technical Report, LRWQCB). Land use specific achievable EMCs for Tier 1 and Tier 2 were taken from this UGSCG report (Section 3). Values in Table B-4 provide an average estimate of the quality of runoff infiltrated by setting and treatment tier for the groundwater assessment.

Table B-4. Characteristic EMCs by Setting and Treatment Tier

		Characteristic EMCs	
Scenario	**Setting**	**DN (mg/L)**	**DP (mg/L)**
Existing	CS	0.31	0.13
	DS	0.30	0.12
	CM	0.27	0.12
	DM	0.27	0.11
Tier 1	CS	0.29	0.11
	DS	0.26	0.10
	CM	0.27	0.10
	DM	0.25	0.10
Tier 2	CS	0.24	0.06
	DS	0.22	0.05
	CM	0.22	0.06
	DM	0.21	0.06

B3. Groundwater Assessment

In the process of integrating the ACOE (2003) data with results from the SWMM output, several differences between the ACOE groundwater quality data and the SWMM output were reconciled:

1. **Spatial extent:** The ACOE (2003) groundwater evaluation divided the Lake Tahoe Basin into 5 regions ranging from 14,000 – 100,000 acres in area. The SWMM model, however, simulated much smaller areas. In order to reconcile these spatial differences, a method was designed to scale up SWMM spatial results to the extent of the ACOE regions. All SWMM runs were made on nominal 100-acre drainage catchments with average land-use distributions for each setting as defined by the UGSCG. Infiltrated volumes and nutrient loads were normalized by area to produce values per acre of each setting. Using GIS, the area of each UGSCG setting within the ACOE regions was calculated. Area-weighted infiltrated volume, EMC, and nutrient loads were integrated for each of the ACOE regions using the setting data.

2. **Infiltrated volumes:** The ACOE groundwater evaluation provides the average annual flux of groundwater to the lake at the land-lake interface for each of the 5 regions. SWMM, however, does not model groundwater discharge to the Lake. Rather, SWMM was used to estimate the total volume of water infiltrated on an average annual basis. When the setting infiltration volumes were integrated for each of the five ACOE regions, the total infiltrated volumes estimated by SWMM were one to two orders of magnitude greater than the regional groundwater flux estimates to the Lake provided by the ACOE (2003). The UGSCG assumes that this annual volume discrepancy is due to the fact that not all of the infiltrated water discharges to the Lake as groundwater and some significant fraction of infiltrated waters are delivered to the stream channels. As a simple check on this assumption, the total streamflow to the Lake (4.68×10^8 m^3/yr) was added to the total ACOE groundwater flux (6.41×10^7 m^3/yr) resulting in a total volume flux of 5.32×10^8 m^3/yr. The basin-wide infiltrated volume estimated from SWMM is 5.9×10^8 m^3/yr.

3. **Pollutants of concern:** In order to compare the infiltrated nutrient EMCs to groundwater nutrient EMCs, ACOE and SWMM reported nutrient species had to be converted to same species. The ACOE groundwater evaluation reported the following dissolved nutrient species:
   - Dissolved Kjeldahl Nitrogen (DKN): dissolved organic nitrogen + NH_4^+
   - Dissolved Nitrate (NOx)
   - Total Dissolved Nitrogen (DN): DKN + NOx
   - Dissolved Orthophosphate (SRP)
   - Total Dissolved Phosphorus (DP)

   SWMM uses the TMDL land-use EMC and thus provides estimates of the dissolved inorganic fractions:
   - DN = Dissolved Inorganic Nitrogen (DN): NOx + NH_4^+
   - DP = Dissolved Orthophosphate (SRP)

   To remain consistent with the Watershed Model and the surface water UGSCG dissolved species of concern, the groundwater evaluation focuses on DN and DP. The ACOE nutrient concentrations and fluxes were converted to these dissolved inorganic species using available Tahoe specific data. Thodal (1997) found that approximately 90% of DIN in Lake Tahoe groundwater was NOx. Therefore, the UGSCG scaled the ACOE NOx data by a factor of 1.111 to convert these EMCs to DN parameter used by the UGSCG.

4. **EMCs vs. Loads:** The ACOE (2003) provides estimates of total groundwater nutrient EMCs, volumes and loads as well as the ambient/anthropogenic breakdown of those loads for each respective region. Due to the differences between modeled infiltrated volumes and ACOE estimates of groundwater fluxes and the assumption that over the long-term the groundwater reservoir is as steady-state, the UGSCG calibration focused on EMC comparisons. For each ACOE (2003) region, the anthropogenic EMC was calculated using the ambient and total groundwater EMC values provided by ACOE (2003):

   Anthropogenic gw EMC = Total gw EMC – Ambient gw EMC

   By isolating the DN and DP assumed to be contributed to groundwater by urban activities by ACOE (2003), the UGSCG could evaluate the infiltrated water quality in urban areas as estimated by the land use aggregation. As mentioned above, geochemical changes to DN and DP naturally occur in the unsaturated zone as infiltrated urban storm water migrates to the groundwater. ACOE anthropogenic EMCs and SWMM infiltrated EMCs for each region were compared to estimate the changes in nutrient concentrations as urban storm water is infiltrated. Unsaturated zone treatment for DN and DP were reported in the form of unsaturated zone scaling factors.

   Unsaturated zone scaling factor =
   ACOE anthropogenic gw EMCs /SWMM infiltrated EMCs

   For DP, the estimated infiltrated EMCs were consistently higher than the ACOE anthropogenic EMCs. This finding agrees with the common knowledge that DP has low groundwater mobility and a high electrostatic attraction to adhere to soil particle surfaces (Sharpley 1995). The presence of clay soils, which compose approximately 12.25% of Lake Tahoe soils (USDA 1995), increases the phosphate adsorption capacity of the soil.

   The appropriate unsaturated zone scaling factors for DP ranged from 0 – 34% for the 5 regions, with an average regional scaling factor of 24% for DP chosen for the Basin. Using this simple and cost-effective method, the UGSCG estimates that 76% of SRP is retained and/or retarded in the unsaturated zone. A series of experiments conducted in Ontario, Canada—a setting with similar soils and topography to Lake Tahoe—showed that 85% of phosphorus in septic tank effluent remained in the unsaturated zone (Robertson 1998a, 1998b, 1996 and 1991).

   The scaling factors for DN showed much greater variability, ranging from 37-212% for the five regions, with an average of 117%. Due to this wide range values, as well as DN mobility in groundwater (ACOE 2003), the UGSCG decided to not apply an unsaturated zone scaling factor for DN infiltration.

   As a comparison for the estimated infiltration EMCs, prior to unsaturated zone scaling, the infiltrated EMCs were compared to average urban storm water BMP influent concentrations from 15 sites in Tahoe (2NDNATURE, 2006). Average infiltrated EMCs estimated from the UGSCG analysis (Table B-4) agreed reasonably well with the BMP influent concentrations of 0.44 mg/L for DN and 0.12 mg/L for DP.

The outcomes from the comparison include:

1. SWMM provides reasonable estimates of infiltrated volumes under existing conditions.
2. Comparisons with ACOE (2003) data allowed for the development of a scaling factor to approximate a DP load reduction of infiltrated waters as a result of infiltration. No scaling factor was applied to DN loads.

3. SWMM output on the setting scale was used to track the relative changes in infiltrated volumes and groundwater nutrient EMCs and loads under Tier 1 and Tier 2.

Considering time and funding constraints, the UGSCG believes that the above method is a reasonable approach to track relative groundwater nutrient changes as the urban upland treatment tiers are evaluated. Steps taken to verify the results using existing literature data confirm that estimates and assumptions of existing conditions are reasonable. Given the above assessment, the UGSCG believes that SWMM can be used to estimate *relative* changes in infiltrated volumes, nutrient EMCs and nutrient loads introduced to groundwater under the Tier 1 and Tier 2 treatment tiers. Below we present the UGSCG approach to track groundwater infiltration loads and water quality using SWMM.

Effects of Stormwater PCOs on Nutrient Loading to Groundwater

Using the information gleaned from the above exercise, the UGSCG developed a methodology for evaluating the relative impacts of storm water PCOs on infiltrated volumes and groundwater nutrient EMCs and loads under Tier 1 and Tier 2. The reader should note that confidence in absolute load changes across treatment tiers is low. However, the UGSCG has a reasonable level of confidence that the direction of change in loading of each of the dissolved nutrient species and the relative magnitude of change across treatment tiers will be informative. Figure B-2 schematically presents the approach outlined below to evaluate urban storm water PCOs with respect to groundwater quality.

1. **Adjust EMCs and infiltrated volumes:** SWMM runs were made using adjusted EMCs and infiltrated volumes on the same 100-acre representative settings used above. As designated by each treatment tier, PCOs for each major load reduction element (i.e. PSC, HSC and SWT) were applied to the representative settings.

2. **Normalize infiltrated volumes and nutrient loads:** SWMM infiltration volumes and associated EMCs were extracted for each setting and across each treatment tier. Infiltrated volumes and nutrient loads from the existing conditions, Tier 1, and Tier 2 SWMM runs were normalized by the setting area to get values per acre of each setting. The volumes, EMCs and loads of each area and each PCO were then tracked separately. The unsaturated zone scaling factor was applied to the DP loads, and the loads were then integrated to determine the total setting infiltrated load of DN and DP.

3. **Basin scale loading estimates:** Using the area distribution of each urban upland setting in the Basin, a rough approximation of Basin-wide infiltrated volumes and infiltrated nutrient loads were calculated using area-weighted setting results from SWMM. The scaling factors for DP were applied to the infiltrated EMCs to estimate adjusted infiltrated loads after the natural unsaturated zone treatment. Results from Tier 1 and Tier 2 were compared to existing conditions estimates to provide a relative approximation of the impacts of urban storm water PCOs on groundwater nutrient loads in the Lake Tahoe Basin.

The following assumptions were made in the SWMM infiltrated load estimates and apply to all treatment tiers:

- Only infiltration from the urbanized portions of the settings was considered.
- A constant infiltration rate and capacity were assumed.
- EMC adjustments based on the aggregate impact of PSCs were applied to all infiltrated runoff no matter where it was infiltrated in the Basin.

The certain key conditions and assumptions that vary between the tiers are outlined below.

Existing Conditions:

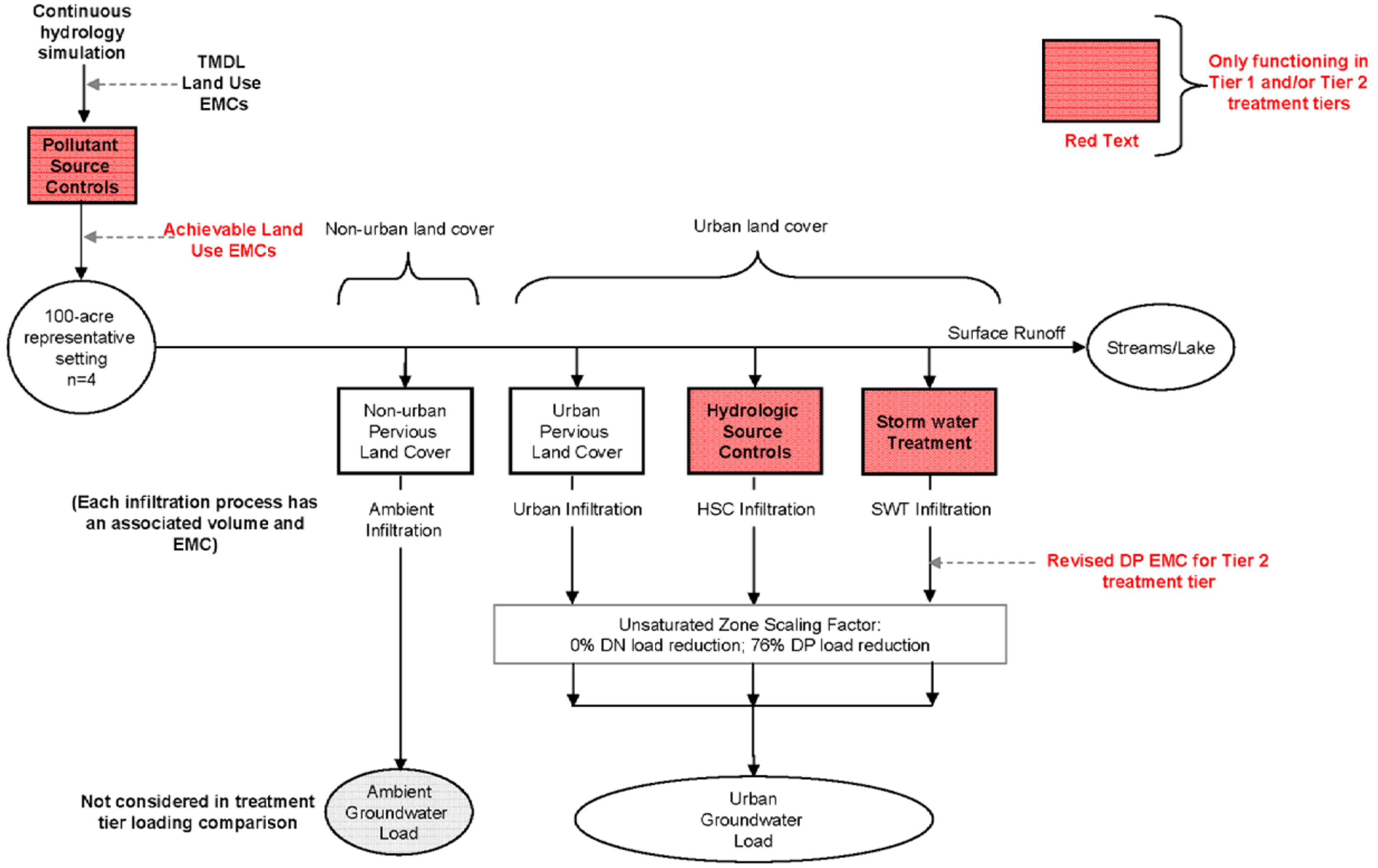
- No infiltration through HSC or SWT.
- The infiltrated EMCs were area weighted averages of the existing conditions TMDL EMCs based on the typical land use breakdown for each of the 4 settings.
- A 76% reduction in the infiltrated DP load occurred in all infiltrated volumes based on the unsaturated zone scaling factor developed above.

Tier 1:

- Infiltration occurred through HSC and SWT.
- The infiltrated EMCs were adjusted due to the application of PSC.
- A 76% reduction in the infiltrated DP load occurred in all infiltrated volumes based on the unsaturated zone scaling factor developed above.

Tier 2:

- Infiltration occurred through HSC and SWT (more volume infiltrated than Tier 1).
- The infiltrated EMCs were adjusted due to the application of PSC (more EMC reduction than Tier 1).
- The infiltrated EMCs for DP were reduced to 0.03 mg/L for volumes infiltrated through SWT PCOs due to the application of activated alumna adsorptive media in SWT-1B (Table 3-7).
- A 76% reduction in the infiltrated DP load occurred in all infiltrated volumes based on the unsaturated zone scaling factor developed above.



This box model represents how SWMM estimated loading to groundwater under existing conditions (processes shown in red do not apply) as well as the Tier 1 and Tier 2 treatment tiers (all processes apply).

Infiltrated loads of DN and DP were normalized to setting size to provide volumes and nutrient loads per acre of setting. This allowed for comparisons to be made both across treatment tiers and across settings. It also allowed for the UGSCG to scale up these results to make basin-wide loading estimates.

Figure B-2. Conceptual model for urban stormwater infiltration estimates

Urban & Groundwater Appendix C: Setting Development

Appendix C provides an expanded description of the approach and methods used to define and categorize urban upland settings summarized in Section 4. The reader will note some redundancy in text relative to Section 4.

C.1. Approach

For the purposes of this UGSCG analysis, a classification of subwatersheds in the Watershed Model is needed to define potential PCO implementation. This classification is accomplished by defining settings based on key physiographic characteristics of a subwatershed that directly influence the planning, design, and construction of urban storm water quality improvement projects in the Basin. Numerous characteristics (and permutations or combinations of these) could be applied to define urban upland settings in the Lake Tahoe Basin. Many different characteristics were considered for use in setting classification (soils, slopes, impervious area, land use, etc.). However, many of these characteristics are captured directly in Watershed Model computations of loads. The UGSCG approach therefore focused on a few key physiographic characteristics that relate to PCO selection and implementation rather than runoff characteristics. This approach allows PCO implementation to be conceptually represented by subwatershed in the Watershed Model, and facilitates load computations in the model at the Tahoe Basin scale that represent PCO implementation in the treatment tiers. Variations in loads by subwatershed based on soils, land use, and land use characteristics are computed directly in the Watershed Model.

After consideration of an extensive list of potential characteristics, selected key physiographic characteristics for definition of urban upland settings are:

1. Impervious area configuration
2. Average slope of urban upland area

In a simple way, this approach intends to consider both the spatial application of PCOs needed for pollutant load reductions and the feasibility of implementing different types of PCOs given typical opportunities and constraints for storm water quality project implementation in the Tahoe Basin.

Additional watershed characteristics (e.g., soils, land use types, meteorology, depth to groundwater, upland forest drainage, etc.) are recognized as influencing the selection, application, and sizing of PCOs at the project scale. The approach for developing treatment tiers captures, to the extent practical, the effects of these variables on performance of PCOs rather than using them to define settings (see Section 5). Pollutant load reductions will not be constant for each setting, but will vary according to these secondary characteristics. As discussed above, part of this variability is computed directly in the Watershed Model, which already incorporates subwatershed characteristics such as land use types, meteorology, and erosion potential.

Threshold for Urban Upland Setting

The UGSCG set a minimum threshold of impervious area for TMDL subwatersheds to be treated as urban upland settings. Many of the subwatersheds in the Watershed Model have little or no urban development and PCOs defined here are thus not applicable to these subwatersheds. The impervious area threshold reduces the number of subwatersheds assessed by the UGSCG while capturing the majority of "urban" area in the analysis. From review of TMDL subwatershed GIS layer and the impervious area GIS layer (Minor and Cablk, 2004), it appears that a reasonable threshold for classifying a subwatershed as an urban upland setting is 1% impervious area. Figure C-1 illustrates the results using the 1% impervious area threshold assumption. The TMDL subwatershed delineation contains 184 subwatersheds. The 1% impervious area threshold yields 70 subwatersheds for assessment by the UGSCG. In aggregate, they represent roughly 96% of the total impervious area in the Basin. Figure C-2 displays the specific subwatersheds analyzed as urban upland.

The urban upland setting classifications developed by the UGSCG are generalized descriptions of key physiographic characteristics of a subwatershed, used as a tool in the determination of the spatial application of PCOs, and the feasibility of implementing different types of PCOs on urban upland land uses. The classification of a subwatershed as an urban upland setting means that urban upland PCOs are applied to urban upland land uses within the subwatershed. However, other PCOs (especially those for forest uplands) may also be applied to undeveloped land uses in the same subwatershed. To avoid duplication in Watershed Model computations, urban upland PCOs are considered applicable to particular developed land uses and forest upland PCOs are considered applicable to other undeveloped land uses. Table A-1 in Appendix A lists the land uses assigned to either urban upland or forest upland.

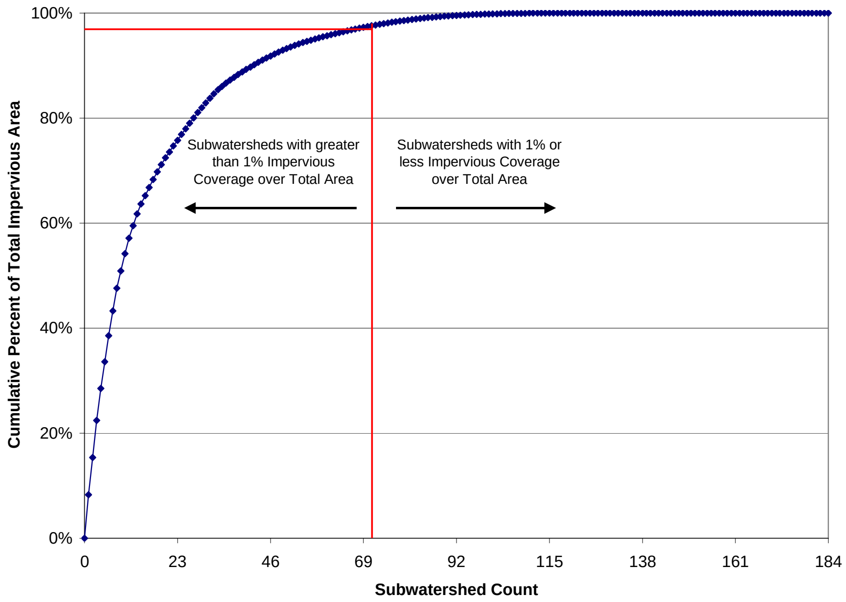


Figure C-1. One percent impervious area threshold assumption.

Spatial Scale Assessment and Ungrouped Intervening Zones

The UGSCG reviewed two drainage catchment delineations for the Tahoe Basin to determine if the finer resolution delineation would improve the analyses of PCOs for the UGSCG assessment. The two drainage catchment delineations are defined and referenced as follows for this brief summary:

Subwatersheds – 184 drainage catchments delineated in the Watershed Model; developed from an aggregation of the subbasin delineation

<u>Subbasins</u> – 596 drainage catchments that appear to be predominantly developed based on 1) the Tahoe Basin 40 foot contour layer, and 2) the Tahoe Basin stream layer. Note that a subbasin was created for every stream segment present in the stream layer regardless of the size of the stream segment or drainage area for that segment.

The UGSCG classified 70 subwatersheds out of the 184 subwatersheds in the Watershed Model as urban upland, including 10 intervening zone "aggregated" subwatersheds. The UGSCG and Watershed Model team agreed to ungroup the intervening zone subwatersheds into individual intervening zones, and then apply the approach for assigning urban upland settings to each individual intervening zone. This increased the number of subwatersheds from 70 to 108 for the UGSCG assessment. The finer spatial scale for intervening zones appears necessary for the following reasons.

- The majority of the intervening zones have a significant amount of urban development.
- Applying the urban upland setting criteria to the disaggregated intervening zones resulted in different settings for certain intervening zones relative to the setting assigned to the aggregated intervening zone subwatershed.

Beyond disaggregating the intervening zones, further breakdown of the subwatersheds using the finer scale 596 subbasins was not warranted because it would not change the UGSCG analyses of PCOs. This conclusion is supported by the following points.

- The overwhelming majority of subbasins that could be used to create a finer spatial resolution are within subwatersheds defined as predominantly forest upland by the UGSCG (i.e. subwatersheds with less than 1% impervious area).
- For the majority of cases where subbasins are within a subwatershed that meets the definition of urban upland, the subbasins bisect the subwatershed. In this configuration the finer scale subbasins did not change the classification of the setting and only resulted in more of the same setting. This situation will not change the analyses of PCOs for the UGSCG.
- In certain instances, the rationale for subbasin delineation is not readily apparent in the urban areas. In these instances the subwatershed delineation provides a more logical delineation for the urban drainage catchments in the Basin.

Configuration of Impervious Area

The configuration of impervious area is a key physiographic characteristic that discriminates the relative influence impervious area has on the planning, design, and construction of urban storm water quality improvement projects in the Basin. As the concentration of urban development increases, the opportunities for implementation of many types of storm water management improvements will decrease. To represent this characteristic, two categories of impervious area configuration were defined for urban upland settings as either 1) dispersed, or 2) concentrated. The quantitative breakpoints for impervious area configuration are defined in Section C.2.

<u>Dispersed</u>
Impervious area is situated throughout a setting with significant area available for construction of storm water management improvements. The available area is either commingled within the extents of the existing impervious area, downstream of the impervious area, or a combination of both.

<u>Concentrated</u>
Impervious area is situated in a relatively dense configuration within the setting. Minimal area is available for storm water management improvements both within the extent of the existing impervious area and downstream of the impervious area.

Average Slope of Urban Area

Average slope in a urban area was selected as a key physiographic characteristic because 1) slopes in a project area strongly influence the application and sizing of PCOs for storm water management, and, 2) average slopes with the urban area of a subwatershed can be readily calculated in GIS using layers developed for the TMDL with a Digital Elevation Model (DEM) of the Tahoe Basin. Two categories of average slopes define an urban upland setting, as either 1) moderate, or 2) steep. The quantitative breakpoints for the slope are defined in Section C.2.

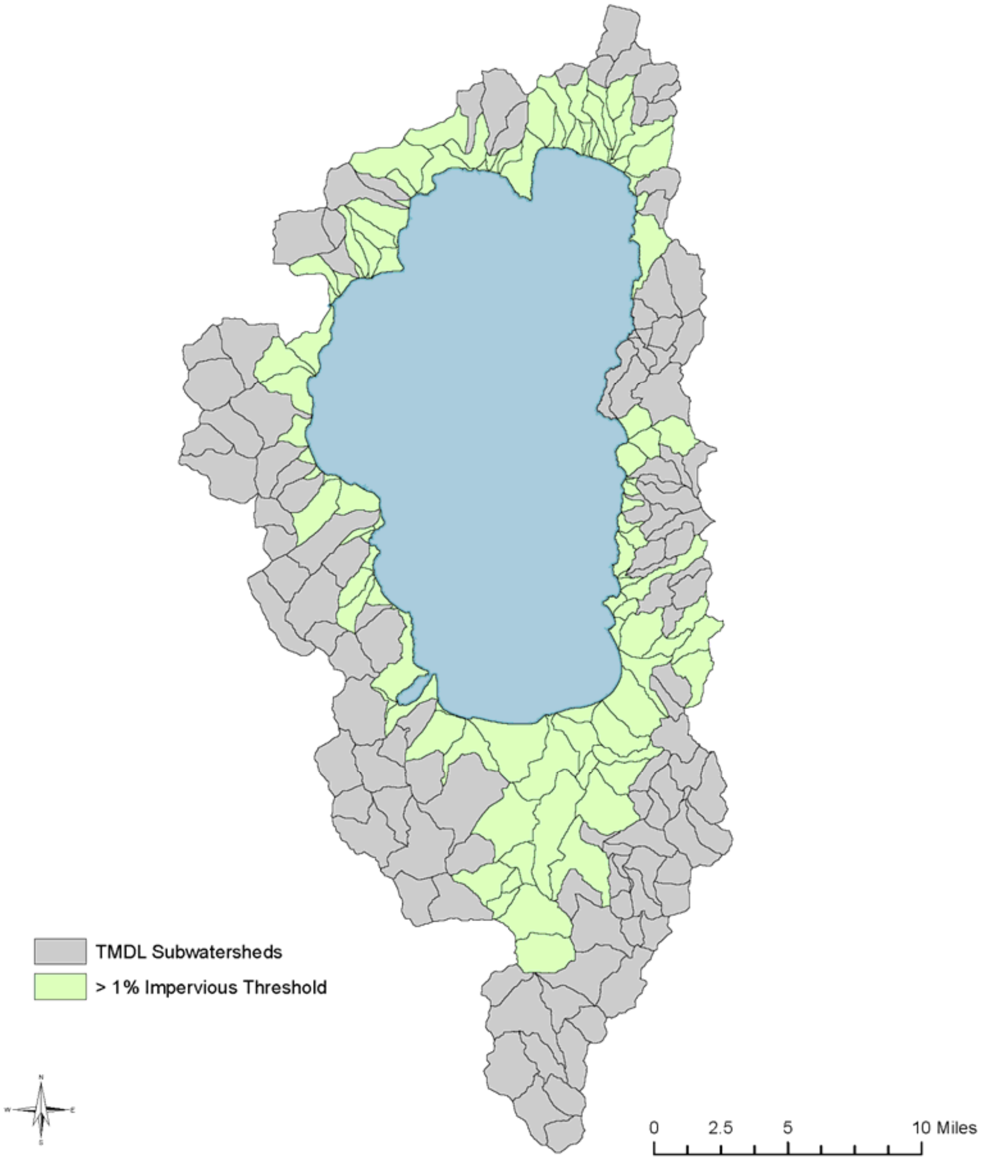


Figure C-2. Subwatersheds meeting urban upland threshold.

C.2. Methods

The criteria used to define settings are described below. Figure C-3 provides a conceptual illustration of the methods and results for reference with the following discussion.

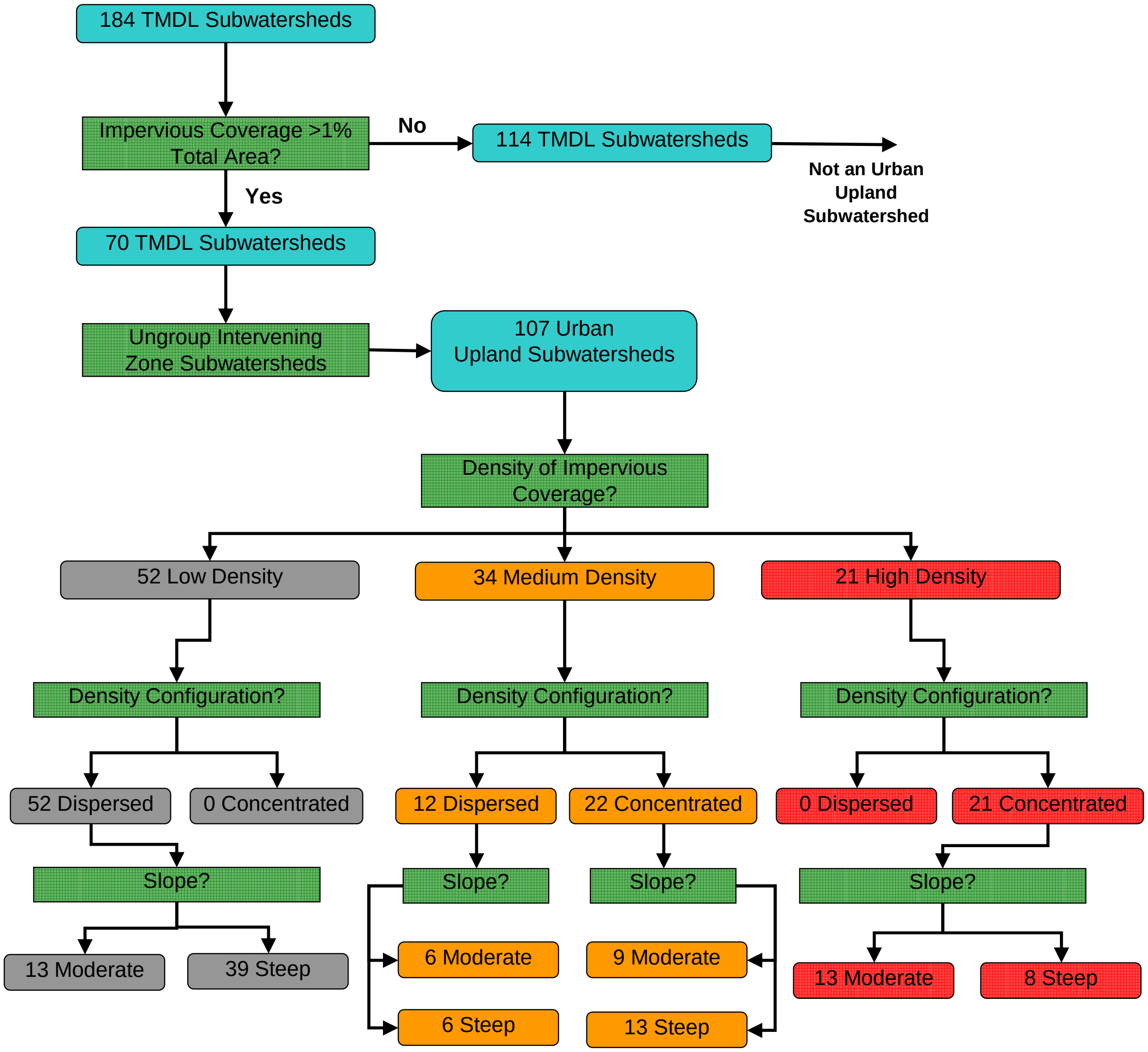


Figure C-3. Illustration of methods and results for setting classifications.

Density of Impervious Area

The density of impervious area within a subwatershed was used as a surrogate to determine the configuration of impervious area because: 1) impervious density is a simple indicator of overall watershed function relative to potential impacts on downstream water bodies (e.g., Impervious Cover Model, Center for Watershed Protection, 2003); 2) the density of existing impervious area within a project area strongly influences the selection and sizing of PCOs for storm water management; and, 3) impervious density is readily calculated by subwatershed using available GIS layers developed for the TMDL.

The density of impervious area in each subwatershed was categorized as low, medium, or high. The breakpoint between the categories was defined through a GIS assessment using the TMDL subwatershed layer, the land use layer, and the impervious area layer. The categories consider both the density of impervious area within the entire subwatershed (impervious area divided by total subwatershed area) and the density of impervious area within the urban area of a subwatershed (impervious area divided by urbanized area within the subwatershed). The following quantitative break points were applied:

> Low Density:
> 1) The impervious area for the total subwatershed area is between 1% - 5%, or 2) the impervious area for the urban area of the subwatershed is less than 30%.
>
> Medium Density:
> 1) The impervious area for the total subwatershed area is between 5%-20%, and 2) the impervious area within the urban area of a subwatershed is between 30% - 50%.
>
> High Density:
> 1) The impervious area within the total subwatershed area is greater than 20%, or 2) the impervious area within the urban area of a subwatershed is greater than 50%.

The GIS analysis was used with the assumption that low density settings are best represented by the definition of dispersed impervious area for all subwatersheds. Conversely, the high density setting is best represented by the definition of concentrated impervious area for all subwatersheds. This assumption was validated through visual inspection of subwatersheds. Table C-1 illustrates this distillation of potential unique cases using this assumption.

Table C-1. Intermediate Urban Upland Setting Categories

Key Physiographic Characteristics			
Unique Case	**Impervious Density**	**Configuration**	**Slope**
1	Low	Dispersed	Moderate
2	Low	Dispersed	Steep
~~3~~	~~Low~~	~~Concentrated~~	~~Moderate~~
~~4~~	~~Low~~	~~Concentrated~~	~~Steep~~
5	Medium	Dispersed	Moderate
6	Medium	Dispersed	Steep
7	Medium	Concentrated	Moderate
8	Medium	Concentrated	Steep
~~9~~	~~High~~	~~Dispersed~~	~~Moderate~~
~~10~~	~~High~~	~~Dispersed~~	~~Steep~~
11	High	Concentrated	Moderate
12	High	Concentrated	Steep

Using the ungrouped intervening zone subwatersheds, a total to 107 subwatersheds were classified based on impervious density as follows:

- 52 subwatersheds were classified as low density, having a dispersed impervious area configuration. This represents roughly 18% of the total impervious area in the Basin.
- 21 subwatersheds were classified as high density, having concentrated impervious area configuration. This represents roughly 29% of the total impervious area in the Basin.

- 34 subwatersheds were classified as medium density and required visual inspection to determine the appropriate classification of impervious area density. This represents roughly 49% of the total impervious area in the Basin.
- The remaining impervious area, roughly 4% of the total impervious area in the Basin, was not captured in urban uplands.

The configuration of impervious area was visually inspected in GIS for each subwatershed with a medium density classification to determine the relative level of opportunities and constraints for storm water management, based on: 1) the available open space within the extents of the impervious area; and 2) the available open space downstream of impervious area prior to runoff entering a receiving water body. Table C-2 illustrates the set of unique cases for urban upland settings after assigning impervious area configuration to the medium density settings. Figure C-4 illustrates the subwatersheds classified by impervious area configuration.

Table C-2. Tabulation of Urban Upland Settings for Urban Subwatersheds

	Key Physiographic Characteristics	
Unique Case	**Impervious Area Configuration**	**Average Slope**
1	Concentrated	Steep
2	Concentrated	Moderate
3	Dispersed	Steep
4	Dispersed	Moderate

Average Slope of Urban Area

The average slope of the urban area within each subwatershed is identified as either moderate or steep. The calculation of slope was processed in GIS using the Tahoe Basin DEM and the bounds of the urban area from the GIS land use layer within each subwatershed. The evaluation of slope is based on the following definitions, recognizing that the determination of average slope at the subwatershed scale is a broad approximation and does not adequately represent the storm water project implementation scale for PCO selection and application.

Moderate Slope:
Average slope within the urban area of a subwatershed is less than 10%.

Steep Slope:
Average slope within the urban area of a subwatershed is greater than 10%.

The 10% slope criterion was selected as the quantitative breakpoint between moderate and steep slopes based upon best professional judgment. In general, storm water projects in the Tahoe Basin tend to implement more intensive spatial applications of PCOs on slopes of roughly 10% or greater. Additionally, more armored PCO application is typical on slopes of roughly 10% or greater. This criterion recognizes that the determination of average slope in the urban area at a subwatershed scale is a broad approximation of actual storm water management project PCO implementation.

Out of the 107 subwatersheds denoted as urban upland settings, 41 subwatersheds are classified as having a moderate slope and 66 subwatersheds area are classified as having a steep slope. Figure C-5 illustrates the subwatersheds classified by slope.

Assigned Urban Upland Settings

Based on the designation of impervious area configuration and average urban slope, urban uplands settings were assigned to each subwatershed meeting the threshold criteria (Figure C-2). Table C-3 below tabulates the number of subwatersheds assigned to one of the four urban upland settings. With inclusion of the ungrouped intervening zones, there are a total of 107 subwatersheds defined as an urban upland setting. Figure C-6 illustrates the results of the setting assessment for urban uplands and spatial classification of subwatersheds into urban upland settings.

Table C-3. Tabulation of Urban Upland Settings for Urban Subwatersheds

		Key Physiographic Characteristics	
Count	Setting Identification	Impervious Area Configuration	Average Slope
21	Concentrated-Steep	Concentrated	Steep
22	Concentrated-Moderate	Concentrated	Moderate
45	Dispersed-Steep	Dispersed	Steep
19	Dispersed-Moderate	Dispersed	Moderate

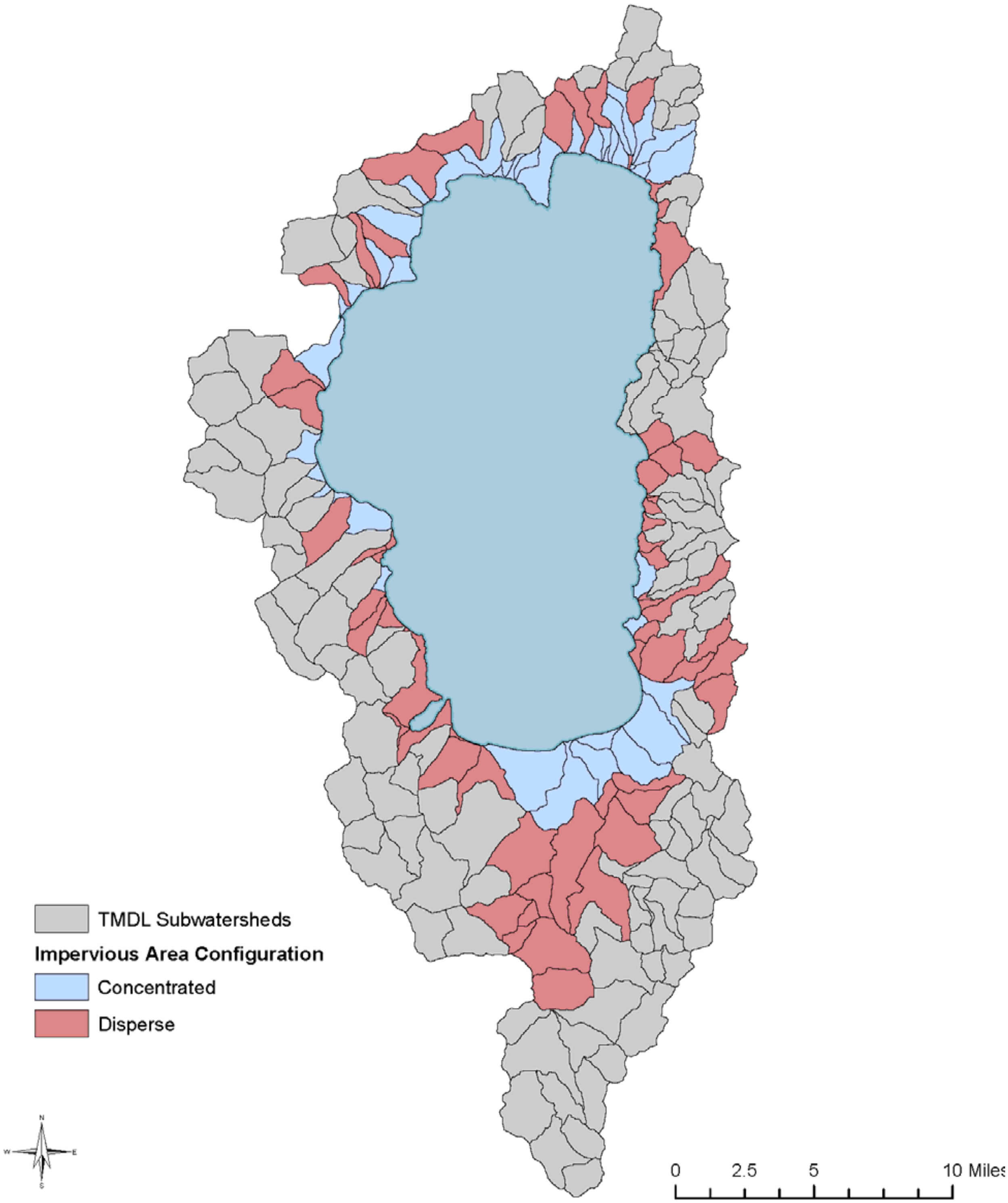


Figure C-4. Impervious area configuration.

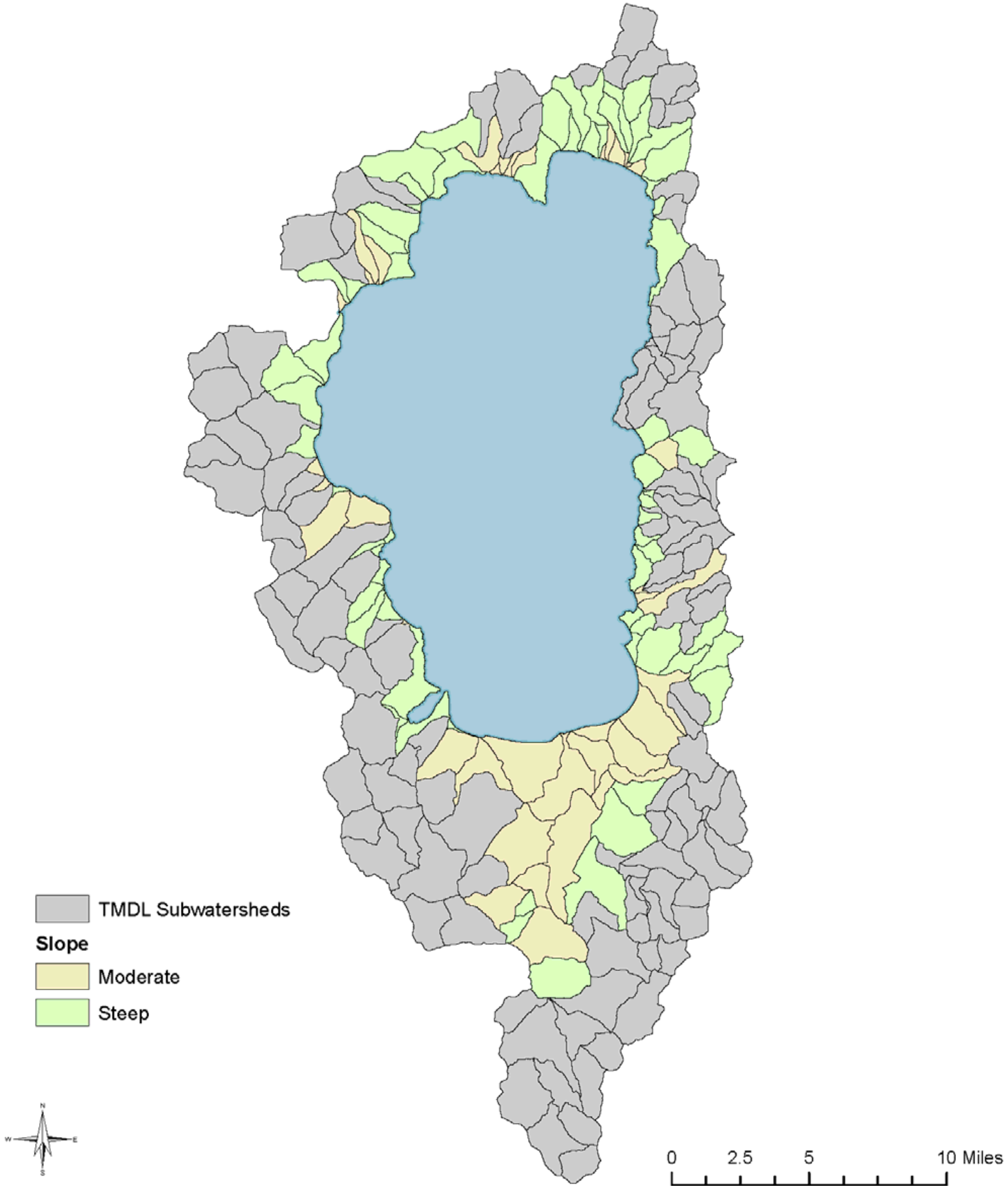


Figure C-5. Average slopes within urban upland.

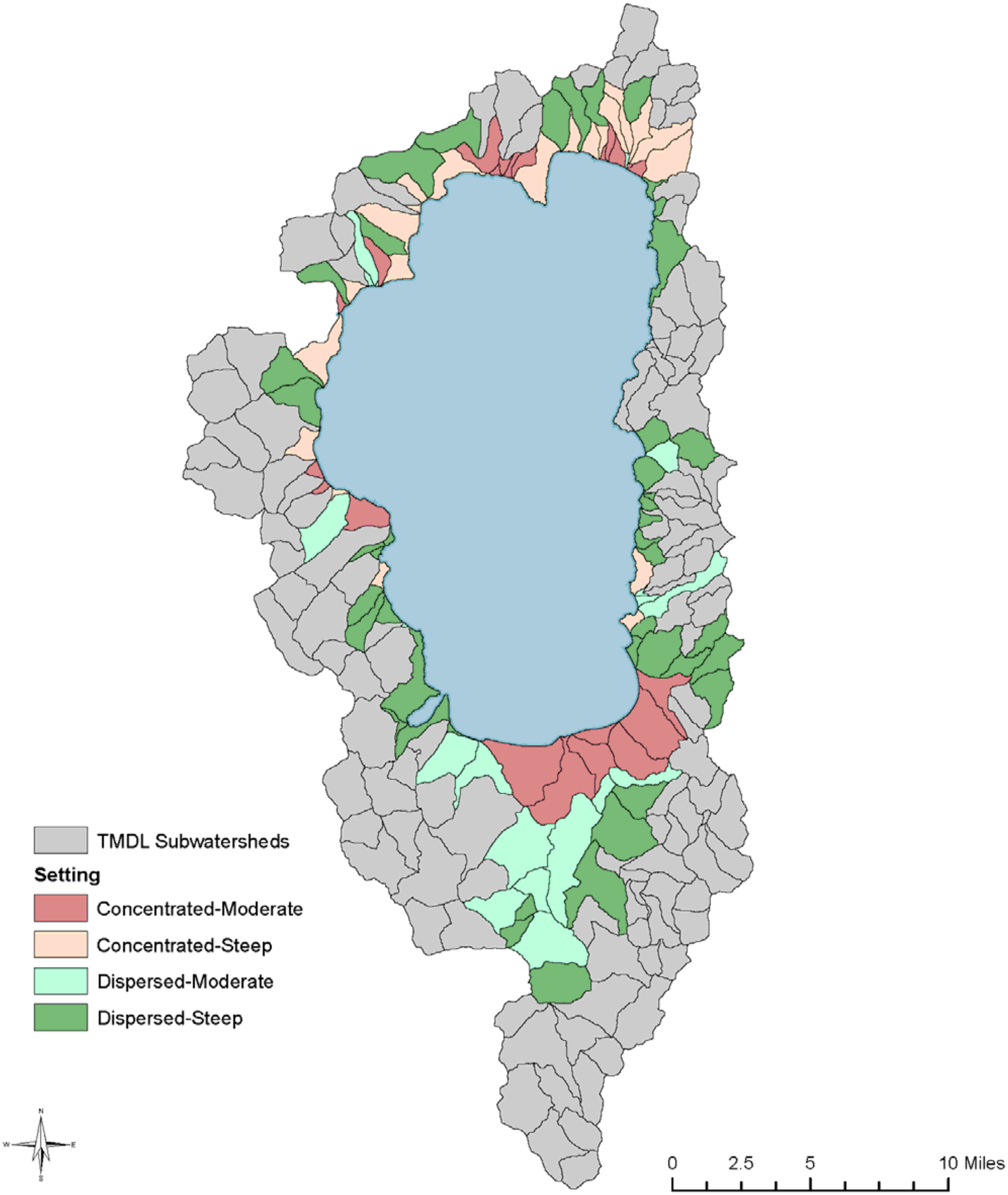


Figure C-6. Urban upland setting classification.

Urban and Groundwater Appendix D: Input Tables and Reference Tables

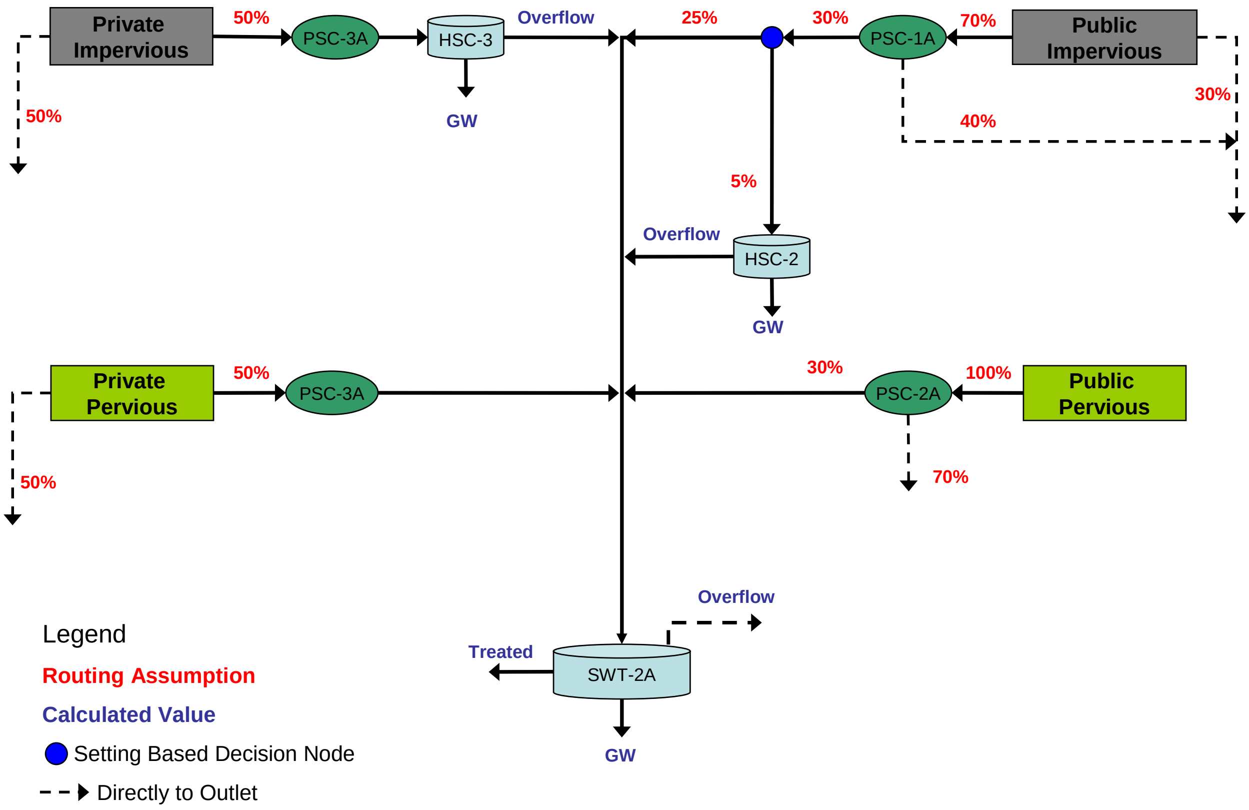
Appendix D provides a summary by setting of each Input Table to the Watershed Model (Input Table) and Reference Tables. Routing diagrams are provided and can be used to interpret each Input Table. Similar information is also provided for the Pump and Treat Tier.

D.1. Concentrated-Steep Setting

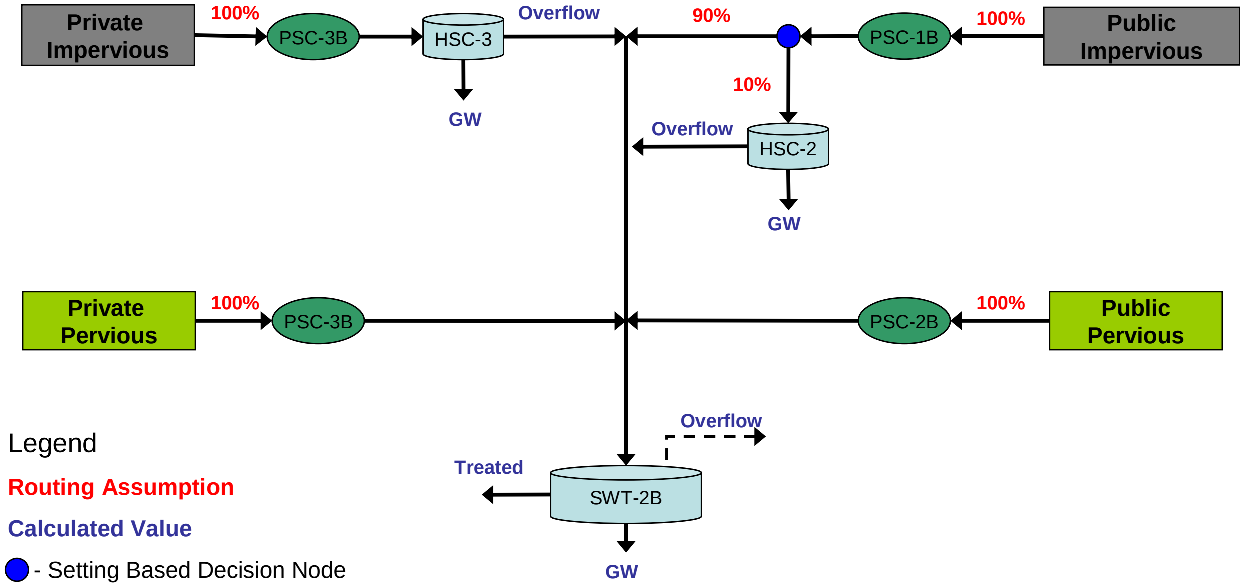
Table D-1. Concentrated-Steep Setting Input Table

Treatment Tier	Land Use Group	Routing	% Spatial Application	Lookup Table(s)		
				PSC	HSC	SWT
EPLR	Private Impervious	Directly to outlet	50%			
		PSC to HSC to SWT	50%	EPLR EMC	HSC-3	SWT-2A
	Private Pervious	Directly to outlet	50%			
		PSC to SWT	50%	EPLR EMC		SWT-2A
	Public Impervious	Directly to outlet	30%			
		PSC only	40%	EPLR EMC		SWT-2A
		PSC to SWT	25%	EPLR EMC		SWT-2A
		PSC to HSC to SWT	5%	EPLR EMC	HSC-2	SWT-2A
	Public Pervious	PSC	70%			
		PSC to SWT	30%	EPLR EMC		SWT-2A
MFLR	Private Impervious	PSC to HSC to SWT	100%	MFLR EMC	HSC-3	SWT-2B
	Private Pervious	PSC to SWT	100%	MFLR EMC		SWT-2B
	Public Impervious	PSC to SWT	90%	MFLR EMC		SWT-2B
		PSC to HSC to SWT	10%	MFLR EMC	HSC-2	SWT-2B
	Public Pervious	PSC to SWT	100%	MFLR EMC		SWT-2B

Concentrated-Steep Tier 1



Concentrated-Steep Tier 2

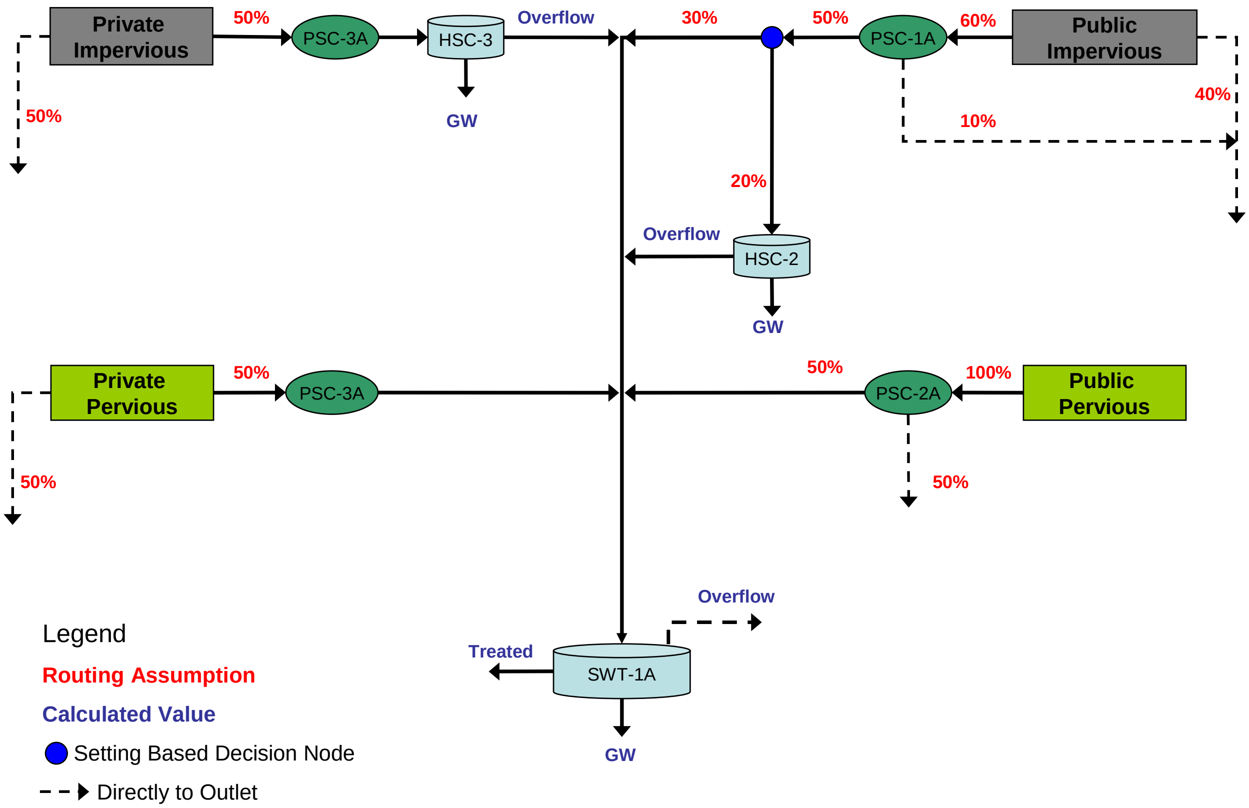


D.2. Concentrated-Moderate Setting

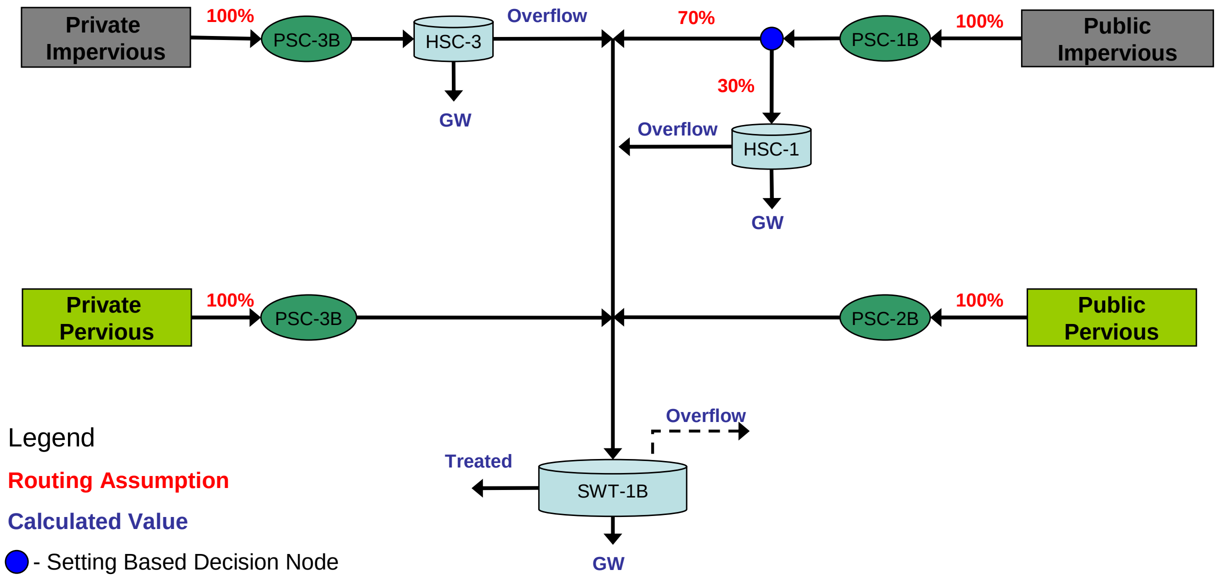
Table D-2. Concentrated-Moderate Setting Input Table

Treatment Tier	Land Use Group	Routing	% Spatial Application	Lookup Table(s)		
				PSC	HSC	SWT
EPLR	Private Impervious	Directly to outlet	50%			
		PSC to HSC to SWT	50%	EPLR EMC	HSC-3	SWT-1A
	Private Pervious	Directly to outlet	50%			
		PSC to SWT	50%	EPLR EMC		SWT-1A
	Public Impervious	Directly to outlet	40%			
		PSC only	10%	EPLR EMC		SWT-1A
		PSC to SWT	30%	EPLR EMC		SWT-1A
		PSC to HSC to SWT	20%	EPLR EMC	HSC-1	SWT-1A
	Public Pervious	PSC	50%			
		PSC to SWT	50%	EPLR EMC		SWT-1A
MFLR	Private Impervious	PSC to HSC to SWT	100%	MFLR EMC	HSC-3	SWT-1B
	Private Pervious	PSC to SWT	100%	MFLR EMC		SWT-1B
	Public Impervious	PSC to SWT	70%	MFLR EMC		SWT-1B
		PSC to HSC to SWT	30%	MFLR EMC	HSC-1	SWT-1B
	Public Pervious	PSC to SWT	100%	MFLR EMC		SWT-1B

Concentrated-Moderate Tier 1



Concentrated-Moderate Tier 2

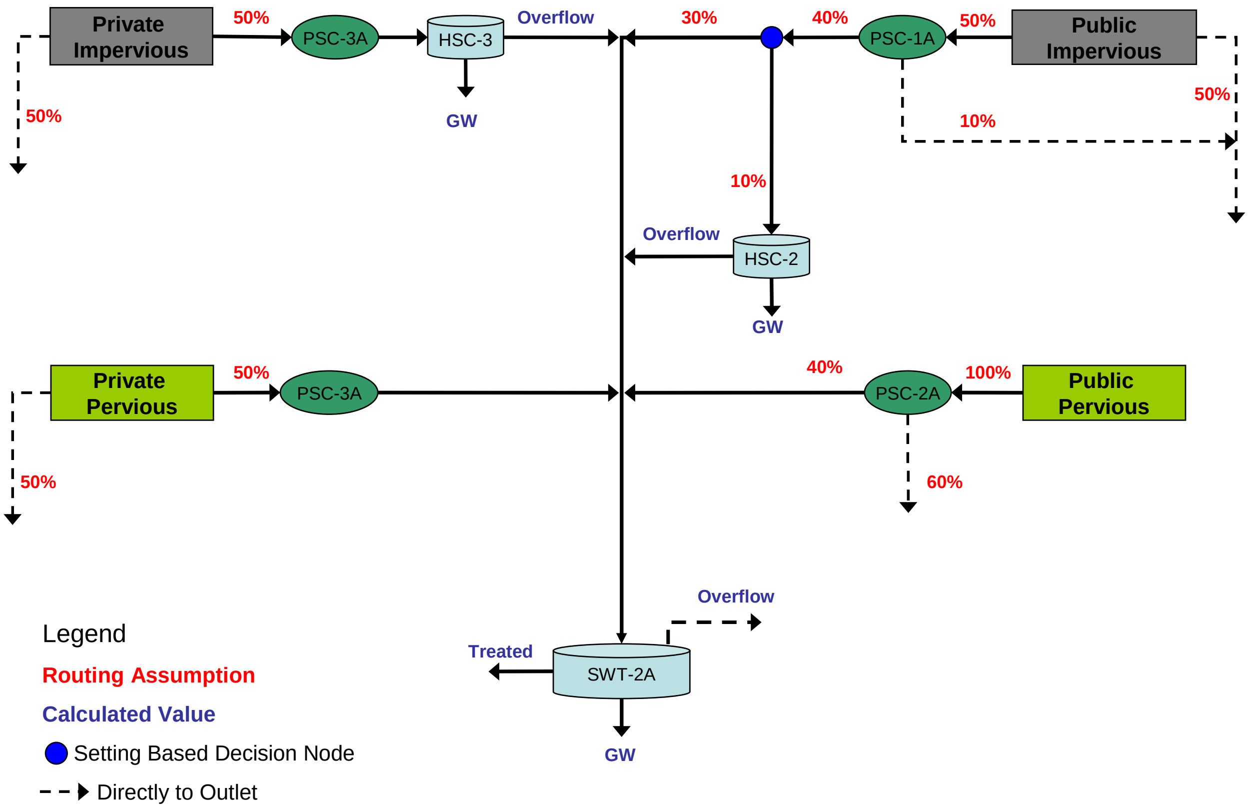


D.3. Dispersed-Steep Setting

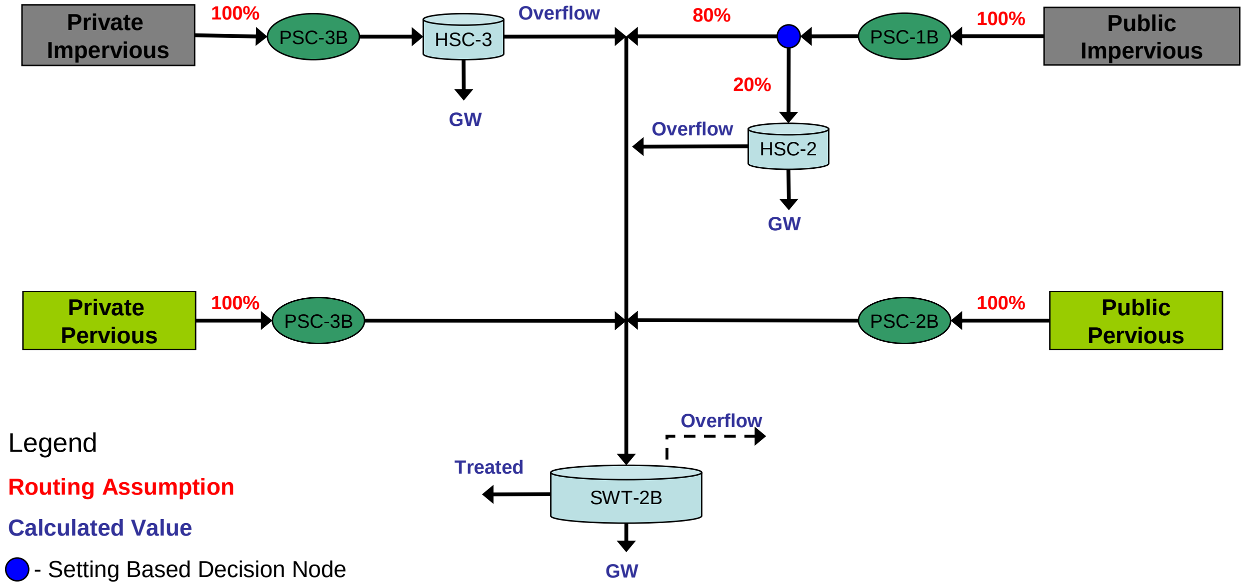
Table D-3. Dispersed-Steep Setting Input Table

Treatment Tier	Land Use Group	Routing	% Spatial Application	Lookup Table(s)		
				PSC	HSC	SWT
EPLR	Private Impervious	Directly to outlet	50%			
		PSC to HSC to SWT	50%	EPLR EMC	HSC-3	SWT-2A
	Private Pervious	Directly to outlet	50%			
		PSC to SWT	50%	EPLR EMC		SWT-2A
	Public Impervious	Directly to outlet	50%			
		PSC only	10%	EPLR EMC		SWT-2A
		PSC to SWT	30%	EPLR EMC		SWT-2A
		PSC to HSC to SWT	10%	EPLR EMC	HSC-2	SWT-2A
	Public Pervious	PSC	60%			
		PSC to SWT	40%	EPLR EMC		SWT-2A
MFLR	Private Impervious	PSC to HSC to SWT	100%	MFLR EMC	HSC-3	SWT-2B
	Private Pervious	PSC to SWT	100%	MFLR EMC		SWT-2B
	Public Impervious	PSC to SWT	80%	MFLR EMC		SWT-2B
		PSC to HSC to SWT	20%	MFLR EMC	HSC-2	SWT-2B
	Public Pervious	PSC to SWT	100%	MFLR EMC		SWT-2B

Dispersed-Steep Tier 1



Dispersed-Steep Tier 2

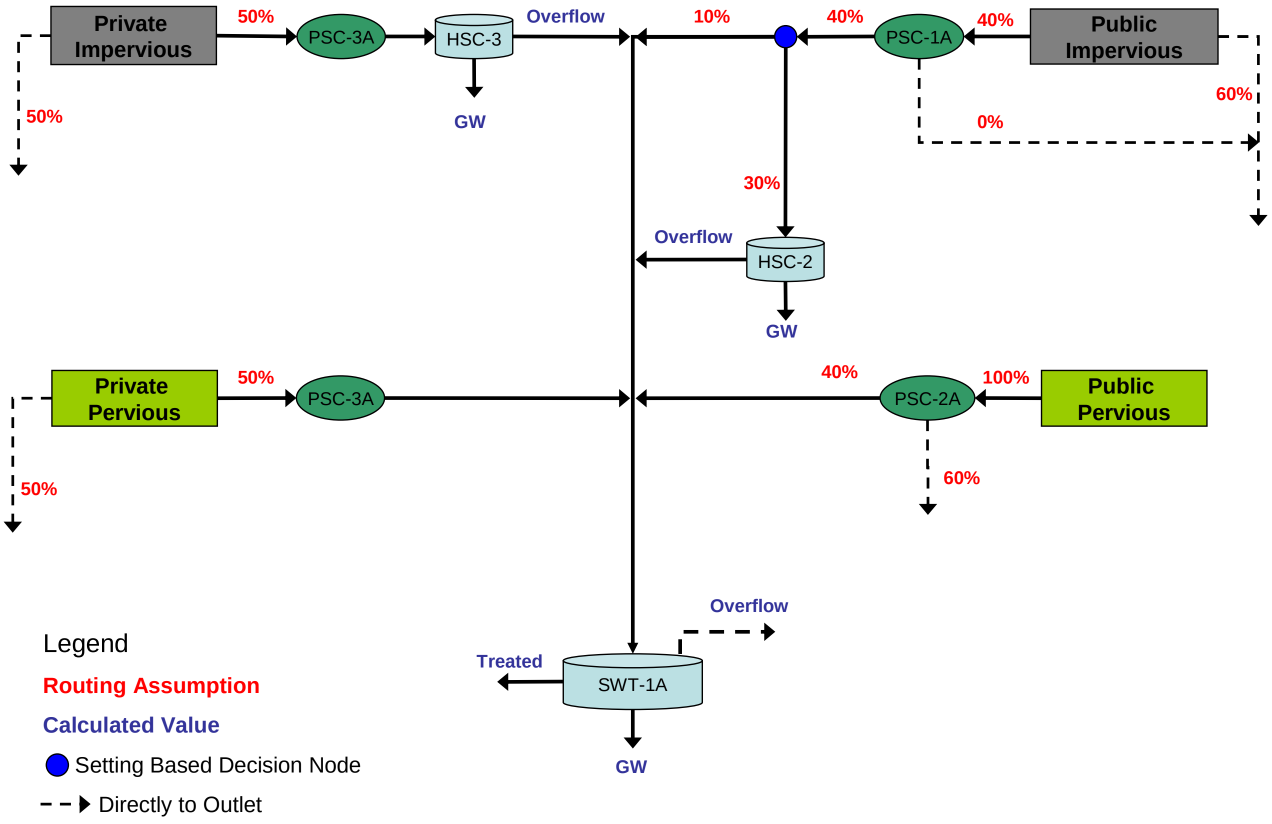


D.4. Dispersed-Moderate Setting

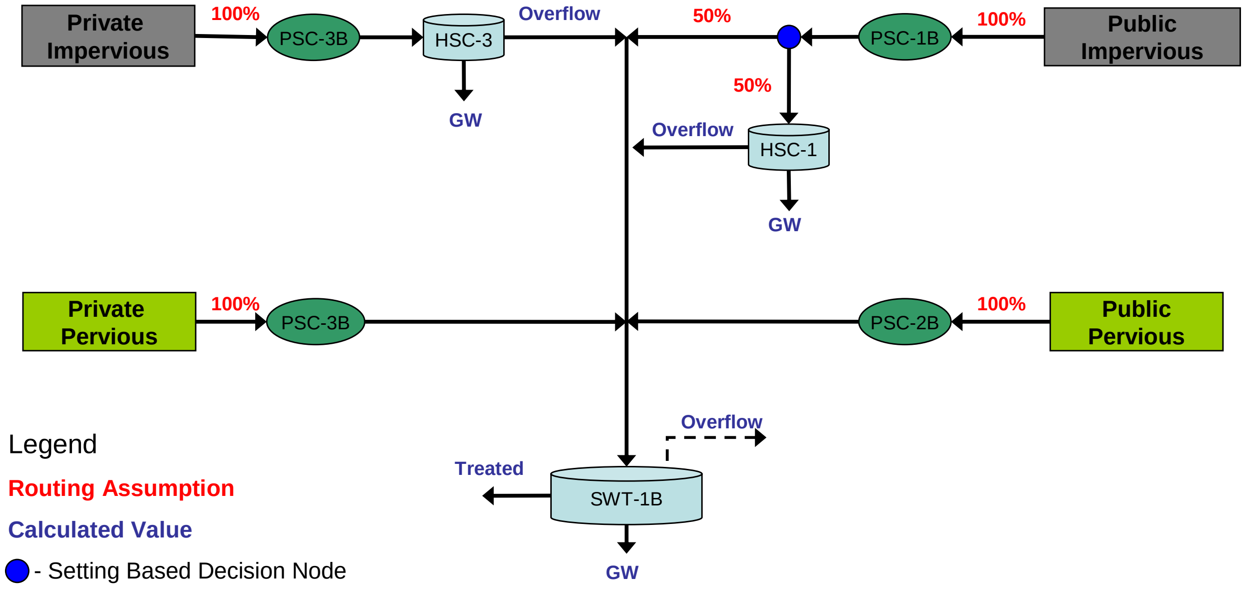
Table D-4. Dispersed-Moderate Setting Input Table

Treatment Tier	Land Use Group	Routing	% Spatial Application	Lookup Table(s)		
				PSC	HSC	SWT
EPLR	Private Impervious	Directly to outlet	50%			
		PSC to HSC to SWT	50%	EPLR EMC	HSC-3	SWT-1A
	Private Pervious	Directly to outlet	50%			
		PSC to SWT	50%	EPLR EMC		SWT-1A
	Public Impervious	Directly to outlet	60%			
		PSC only	0%	EPLR EMC		SWT-1A
		PSC to SWT	10%	EPLR EMC		SWT-1A
		PSC to HSC to SWT	30%	EPLR EMC	HSC-1	SWT-1A
	Public Pervious	PSC	60%			
		PSC to SWT	40%	EPLR EMC		SWT-1A
MFLR	Private Impervious	PSC to HSC to SWT	100%	MFLR EMC	HSC-3	SWT-1B
	Private Pervious	PSC to SWT	100%	MFLR EMC		SWT-1B
	Public Impervious	PSC to SWT	50%	MFLR EMC		SWT-1B
		PSC to HSC to SWT	50%	MFLR EMC	HSC-1	SWT-1B
	Public Pervious	PSC to SWT	100%	MFLR EMC		SWT-1B

Dispersed-Moderate Tier 1



Dispersed-Moderate Tier 2

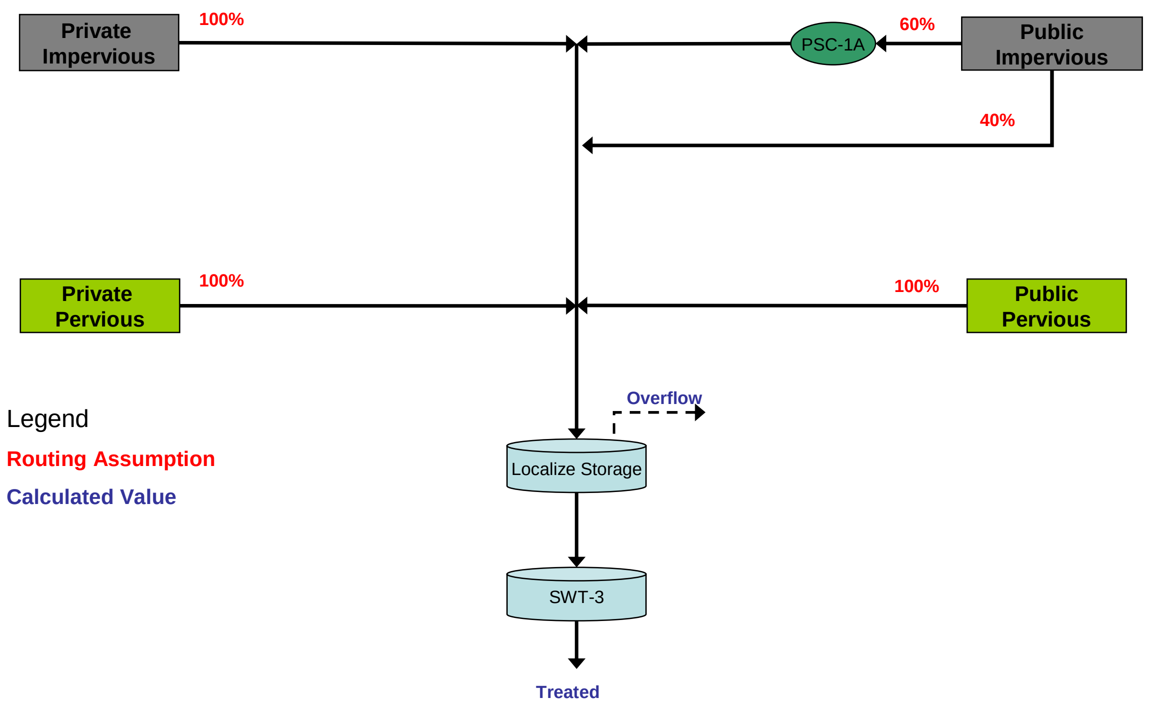


D.5. Pump and Treat Tier

Table D-5. Pump and Treat Input Table

Treatment Tier	Land Use Group	Routing	% Spatial Application	Reference Table(s)		
				PSC	HSC	SWT
P&T	Private Impervious	SWT	100%			Pump and Treat
	Private Pervious	SWT	100%			Pump and Treat
	Public Impervious	PSC to SWT	60%	Tier 1 EMC		Pump and Treat
		SWT	40%			Pump and Treat
	Public Pervious	PSC to SWT	100%			Pump and Treat

Pump and Treat Tier



D.6. PSC Reference Table

Table D-6. Tier 1 and Tier 2 EMCs (mg/L)

PSC Category	Landuse Category	Pollutant of Concern	Existing Conditions EMC (TMDL Phase 1)	Tier 1 EMC	Tier 2 EMC
Public Impervious	Roads_Primary	TN	3.92	2.96	2.00
		DN	0.72	0.70	0.60
		TP	1.98	1.17	0.37
		DP	0.10	0.06	0.02
		TSS	952	538	124
		Fine Sed (%TSS)	85%	85%	85%
	Roads_Secondary	TN	2.84	2.32	1.80
		DN	0.42	0.42	0.38
		TP	0.59	0.41	0.23
		DP	0.14	0.12	0.10
		TSS	150	100	50
		Fine Sed (%TSS)	85%	85%	85%
	CICU_Impervious	TN	2.47	2.14	1.80
		DN	0.29	0.20	0.10
		TP	0.70	0.54	0.37
		DP	0.08	0.05	0.02
		TSS	296	204	112
		Fine Sed (%TSS)	85%	85%	85%
Public Pervious	Veg_Turf	TN	4.88	4.39	2.38
		DN	0.49	0.44	0.35
		TP	1.50	1.35	0.36
		DP	0.26	0.26	0.24
		TSS	12	12	11
		Fine Sed (%TSS)	63%	63%	63%
Public Impervious and Pervious	Residential_SFP	TN	1.75	1.58	0.47
		DN	0.14	0.13	0.06
		TP	0.47	0.42	0.20
		DP	0.14	0.13	0.03
		TSS	56	38	38
		Fine Sed (%TSS)	76%	76%	76%
	Residential_MFP	TN	2.84	2.56	1.60
		DN	0.42	0.38	0.29
		TP	0.59	0.53	0.44
		DP	0.14	0.13	0.07
		TSS	150	56	56
		Fine Sed (%TSS)	88%	88%	88%
	CICU_Pervious	TN	2.47	2.14	1.80
		DN	0.29	0.20	0.10
		TP	0.70	0.54	0.37
		DP	0.08	0.05	0.02
		TSS	296	204	112

PSC Category	**Landuse Category**	**Pollutant of Concern**	**Existing Conditions EMC (TMDL Phase 1)**	**Tier 1 EMC**	**Tier 2 EMC**
		Fine Sed (%TSS)	0.85	0.85	0.85
	Residential_SFI	TN	1.75	1.58	0.47
		DN	0.14	0.13	0.06
		TP	0.47	0.42	0.20
		DP	0.14	0.13	0.03
		TSS	56	38	38
		Fine Sed (%TSS)	76%	76%	76%
	Residential_MFI	TN	2.84	2.56	1.60
		DN	0.42	0.38	0.29
		TP	0.59	0.53	0.44
		DP	0.14	0.13	0.07
		TSS	150	56	56
		Fine Sed (%TSS)	88%	88%	88%

D.7. HSC Reference Tables

Table D-7. HSC-1 F-Table

Stage (ft)	Surface Area (acres)	Volume (acre-ft)	Outlet 1	Outlet 2
			Infiltration (cfs)	Overflow (cfs)[1]
0	0	0.000	0	0
0.01	0.1	0.001	0.030	0
0.1	0.1	0.010	0.030	0
0.11	0.1	0.011	0.030	10
0.5	0.1	0.050	0.030	10

Table D-8. HSC-2 F-Table

Stage (ft)	Surface Area (acres)	Volume (acre-ft)	Outlet 1	Outlet 2
			Infiltration (cfs)	Overflow (cfs)[1]
0	0	0.000	0.000	0
0.01	0.1	0.001	0.020	0
0.05	0.1	0.005	0.020	0
0.051	0.1	0.005	0.020	10
0.5	0.1	0.050	0.020	10

Table D-9. HSC-3 F-Table

Stage (ft)	Surface Area (acres)	Volume (acre-ft)	Outlet 1	Outlet 2
			Infiltration (cfs)	Overflow (cfs)[1]
0	0	0	0	0
0.01	0.050	0.0004	0.015	0
0.1	0.050	0.0040	0.015	0
0.4	0.050	0.0160	0.015	0
0.6	0.050	0.0240	0.015	0
0.8	0.050	0.0320	0.015	0
1	0.050	0.0400	0.015	0
1.2	0.050	0.0480	0.015	0
1.4	0.050	0.0560	0.015	0
1.6	0.050	0.0640	0.015	0
1.8	0.050	0.0720	0.015	0
2	0.050	0.0800	0.015	0
2.01	0.050	0.0804	0.015	10

1 - Actual overflow calculated in continuous simulation

D.8. SWT Reference Tables

Table D-10. SWT Effluent Quality Table

PCO	BMP Assumptions	TN (mg/L)	DN (mg/L)	TP (mg/L)	DP (mg/L)	TSS (mg/L)
SWT-1A	Median Effluent from Dry Detention Ponds from Tahoe Data Only	1.1	0.12	0.16	0.05	25
SWT-1B	25th Percentile from Dry Detention Ponds from Tahoe Data Only	1	0.07	0.14	0.04	19
SWT-2A	Median Effluent from Underground Mechanical Devices from Tahoe Data Only	1.42	0.28	0.18	0.09	47.5
SWT-2B	Lowest Median Effluent Between Media Filters and Hydrodynamic Devices in ASCE BMP Database and Mechanical Devices and Media Filters from Tahoe Data	0.64	0.28	0.13	0.03	15
SWT-3	Pump and Treat Alternative - treatment system (microfiltration)	0.23	Influent	0.034	0.012	5

Table D-11. SWT-1A F-Table

Stage (ft)	Area (ac)	Volume (ac-ft)	Treated Discharge (cfs)	Infiltration Rate (cfs)	Bypass Rate (cfs)
0.000	0.028	0.000	0.000	0.000	0
0.462	0.028	0.013	0.008	0.006	0
0.923	0.028	0.026	0.016	0.006	0
1.385	0.028	0.038	0.024	0.006	0
1.510	0.028	0.042	0.029	0.006	0
2.077	0.028	0.058	0.031	0.006	0
2.538	0.028	0.071	0.032	0.006	0
3.000	0.028	0.083	0.034	0.006	0
3.000	0.028	0.083	0.000	0.000	10

Table D-12. SWT-1B F-Table

Stage (ft)	Area (ac)	Volume (ac-ft)	Treated Discharge (cfs)	Infiltration Rate (cfs)	Bypass Rate (cfs)
0.000	0.028	0.000	0.000	0.000	0
0.231	0.028	0.006	0.004	0.004	0
0.692	0.028	0.019	0.012	0.004	0
1.154	0.028	0.032	0.020	0.004	0
1.500	0.028	0.042	0.028	0.004	0
1.846	0.028	0.051	0.030	0.004	0
2.308	0.028	0.064	0.032	0.004	0
2.769	0.028	0.077	0.033	0.004	0
3.000	0.028	0.083	0.000	0.004	10

Table D-13. SWT-2A F-Table

Stage (ft)	Area (ac)	Volume (ac-ft)	Treated Discharge (cfs)	Infiltration Rate (cfs)	Bypass Rate (cfs)
0.000	0.005	0.000	0.000	0.000	0
0.133	0.005	0.001	0.013	0.000	0
0.267	0.005	0.001	0.027	0.000	0
0.400	0.005	0.002	0.040	0.000	0
0.533	0.005	0.002	0.053	0.000	0
0.667	0.005	0.003	0.067	0.000	0
0.800	0.005	0.004	0.080	0.000	0
0.933	0.005	0.004	0.093	0.000	0
1.000	0.005	0.005	0.000	0.000	10

Table D-14. SWT-2B F-Table

Stage (ft)	Area (ac)	Volume (ac-ft)	Treated Discharge (cfs)	Infiltration Rate (cfs)	Bypass Rate (cfs)
0.000	0.005	0.000	0.000	0.000	0
0.133	0.005	0.001	0.013	0.000	0
0.267	0.005	0.001	0.027	0.000	0
0.400	0.005	0.002	0.040	0.000	0
0.533	0.005	0.002	0.053	0.000	0
0.667	0.005	0.003	0.067	0.000	0
0.800	0.005	0.004	0.080	0.000	0
0.933	0.005	0.004	0.093	0.000	0
1.000	0.005	0.005	0.000	0.000	10

Table D-15. Pump and Treat F-Table

Stage (ft)	Area (ac)	Volume (ac-ft)	Treated Discharge (cfs)	Infiltration Rate (cfs)	Bypass Rate (cfs)
0.0000	0.0018	0.00E+00	0.00E+00	0.00E+00	0
0.9231	0.0018	1.65E-03	1.62E-02	0.00E+00	0
1.8462	0.0018	3.30E-03	3.25E-02	0.00E+00	0
2.7692	0.0018	4.95E-03	4.87E-02	0.00E+00	0
3.0100	0.0018	5.38E-03	5.88E-02	0.00E+00	0
4.1538	0.0018	7.43E-03	6.29E-02	0.00E+00	0
5.0769	0.0018	9.08E-03	6.69E-02	0.00E+00	0
6.0000	0.0018	1.07E-02	7.10E-02	0.00E+00	0
6.0001	0.0018	1.07E-02	0.00E+00	0.00E+00	10

Urban & Groundwater Appendix E: Capital Cost Estimates

Appendix E provides capital cost estimates by setting. Supporting tables used to develop unit cost estimates are also provided. O&M cost estimates are provided in the main report and not repeated here. Cost estimates for the Pump and Treat Alternative are provided in the main report and are not repeated here.

E.1. Unit Cost Assumptions

Table E-1 displays unit costs used to estimate total capital costs by urban upland setting. Unit costs were estimated using methods dependent upon the construction item. The most recent cost data available from 2007 engineer’s estimates and bid summaries for projects in the Basin were used. Certain unit costs were also adjusted by setting depending on the opportunities and constraints discussed in Section 4 of the main report.

Tables of units costs are provided below Table 3-1 for certain items/descriptions where the rationale for develop of costs may be difficult to follow.

Table E-1. Unit Costs by Setting

No.	Item/Description	Units	Concentrated-Steep	Concentrated-Moderate	Disperse-Steep	Disperse-Moderate
1	Mobilization	LS	$200,000	$200,000	$200,000	$200,000
2	Traffic Control and Construction Staking	LS	$200,000	$200,000	$100,000	$100,000
3	Temporary Erosion Control & SWPPP & NPDES Permit & Compliance	LS	$100,000	$100,000	$100,000	$100,000
4	Remove and Replace AC Driveways	SF	$10	$10	$10	$10
5	Adjust Utilities; Potholing	EA	$2,000	$2,000	$2,000	$2,000
6	Relocate or Abandon Utility	LF	$150	$150	$150	$150
7	Road Shoulder Stabilization	LF	$70	$70	$50	$40
8	Storm Drain System	LF	$210	$210	$210	$210
9	Separation of Forest Runoff from Urban Runoff	LF	$180	$180	$120	$100
10	Revegetation and Soil Restoration	SF	$2	$2	$2	$2
11	Tree Removal (Average 12"+)	EA	$600	$600	$600	$600
12	Detention Basin or functional equivalent (SWT-1A)	SF	n/a	$15	n/a	$15
13	Advanced Detention Basin or functional equivalent (SWT-1B)	SF	n/a	$66	n/a	$53
14	Mechanical Separation or functional equivalent (SWT-2B)	SF	$200	n/a	$200	n/a
15	Advanced Mechanical Separation or functional equivalent (SWT-2B)	SF	$438	n/a	$427	n/a
16	Pervious Conveyance Stabilization	LF	$120	$120	$120	$120
17	Miscellaneous Acquisitions	SF	$38	$41	$27	$28

No.	Item/Description	Units	Concentrated-Steep	Concentrated-Moderate	Disperse-Steep	Disperse-Moderate
18	Misc. Drainage Components	EA	$1,000	$1,000	$1,000	$1,000
19	Miscellaneous Activities not in Directly Included in Estimate	Percent of Subtotal	20%	20%	20%	20%
20	Planning, Design, and Oversight	Percent of Total	40%	40%	40%	40%
Private Sector Improvements						
21	Single Family Private Property BMP Certified	Parcel	$4,700	$4,300	$4,300	$3,600
22	Multi Family Private Property BMP Certified	Parcel	$13,100	$11,500	$11,500	$10,000
23	CICU BMP Certified - Private	Parcel	$57,000	$51,300	$51,300	$45,000
24	CICU BMP Certified - Public	Parcel	$57,000	$51,300	$51,300	$45,000

Table E-2. Item 7 – Road Shoulder Stabilization

Estimated Complexity/Cost by LF		Estimated Percentage of Implementation by Setting			
		Concentrated-Steep	Concentrated-Moderate	Disperse-Steep	Disperse-Moderate
Low	$25	10%	10%	30%	50%
Medium	$50	10%	10%	40%	30%
High	$75	80%	80%	30%	20%
Average Cost:		$70	$70	$50	$40

Table E-3. Item 8 –Storm Drain System

Item in Storm Drain System	Units	Unit Cost	Quantity	Cost
Drop Inlet/Sediment Trap	EA	$7,500	2	$15,000
Storm Drain Manhole	EA	$7,500	1	$7,500
Storm Drain	LF	$100	200	$20,000
Total:				$42,500
Storm Drain System Per LF:				$210

Table E-4. Item 9 – Separation of Forest Runoff

Estimated Complexity/Cost by LF		Estimated Percentage of Implementation by Setting			
		Concentrated-Steep	Concentrated-Moderate	Disperse-Steep	Disperse-Moderate
Low	$50	10%	10%	30%	50%
Medium	$100	10%	10%	40%	30%
High	$200	80%	80%	30%	20%
Average Cost:		$180	$180	$120	$100

Table E-5. Item 14 – SWT 2A

Dispersed-Moderate

SWT-1B	Units	Unit Cost	Quantity	Cost
Detention Basin	SF	$15	1	$15
Advanced Treatment	SF	$10	1	$10
Acquisition or functional equivalent	SF	$28	1	$28
			SWT per SF:	$53

Concentrated-Moderate

SWT-1B	Units	Unit Cost	Quantity	Cost
Detention Basin	SF	$15	1	$15
Advanced Treatment	SF	$10	1	$10
Acquisition or functional equivalent	SF	$41	1	$41
			SWT per SF:	$66

Table E-6. Item 15 – SWT 2B

Dispersed-Steep

SWT-2B	Units	Unit Cost	Quantity	Cost
Advanced Treatment	SF	$400	1	$400
Acquisition or functional equivalent	SF	$27	1	$27
			SWT per SF:	$427

Concentrated Steep

SWT-2B	Units	Unit Cost	Quantity	Cost
Advanced Treatment	SF	$400	1	$400
Acquisition or functional equivalent	SF	$38	1	$38
			SWT per SF:	$438

Table E-7. Item 17 – Miscellaneous Acquisitions

Estimated Cost by SF		Estimated Percentage of Implementation by Setting			
		Concentrated-Steep	Concentrated-Moderate	Disperse-Steep	Disperse-Moderate
Low	$20	10%	10%	50%	50%
Medium	$30	30%	10%	40%	30%
High	$45	60%	80%	10%	20%
Average Cost:		$38	$41	$27	$28

Table E-8. Item 21-24 – Parcel BMP Implementation

Land Use	Estimated Complexity/Cost by Parcel		Estimated Percentage of Parcels by Setting			
			Concentrated-Steep	Concentrated-Moderate	Disperse-Steep	Disperse-Moderate
SFR	Certified	0	10%	10%	10%	10%
	Low	$1,500	18%	25%	25%	40%
	Medium	$5,000	39%	40%	40%	30%
	High	$7,500	33%	25%	25%	20%
	Average Cost:		$4,700	$4,300	$4,300	$3,600
MFR	Certified	0	10%	10%	10%	10%
	Low	$5,000	18%	25%	25%	40%
	Medium	$10,000	39%	40%	40%	30%
	High	$25,000	33%	25%	25%	20%
	Average Cost:		$13,100	$11,500	$11,500	$10,000
CICU	Certified	0	10%	10%	10%	10%
	Low	$25,000	18%	25%	25%	40%
	Medium	$50,000	39%	40%	40%	30%
	High	$100,000	33%	25%	25%	20%
	Average Cost:		$57,000	$51,300	$51,300	$45,000

E.2. Capital Cost Estimates for Settings

Table E-9. Concentrated-Steep Setting Capital Cost Estimate

No.	Description	Units	Concentrated-Steep	Total Quantity	Tier 1 % of Total	Tier 1 Cost	Tier 2 % of Total	Tier 2 Cost
1	Mobilization	LS	$200,000	1	50%	$100,000	100%	$200,000
2	Traffic Control and Construction Staking	LS	$200,000	1	50%	$100,000	100%	$200,000
3	Temporary Erosion Control & SWPPP & NPDES Permit & Compliance	LS	$100,000	1	70%	$70,000	100%	$100,000
4	Remove and Replace AC Driveways	SF	$10	8,300	70%	$58,100	100%	$83,000
5	Adjust Utilities; Potholing	EA	$2,000	80	70%	$112,000	100%	$160,000
6	Relocate or Abandon Utility	LF	$150	250	70%	$26,250	100%	$37,500
7	Road Shoulder Stabilization	LF	$70	31,680	70%	$1,552,320	100%	$2,217,600
8	Storm Drain System	LF	$210	7,920	70%	$1,164,240	100%	$1,663,200
9	Separation of Forest Runoff from Urban Runoff	LF	$180	2,000	100%	$360,000	100%	$360,000
10	Revegetation and Soil Restoration	SF	$2	75,000	70%	$105,000	100%	$150,000
11	Tree Removal (Average 12"+)	EA	$600	40	70%	$16,800	100%	$24,000
12	Mechanical Separation or functional equivalent (SWT-2A)	SF	$200	3,000	30%	$180,000	0%	$0
13	Advanced Mechanical Separation or functional equivalent (SWT-2B)	SF	$438	3,000	0%	$0	100%	$1,314,000
14	Pervious Conveyance Stabilization	LF	$120	2,000	70%	$168,000	100%	$240,000
15	Miscellaneous Acquisitions	SF	$38	15,000	50%	$285,000	100%	$570,000
16	Misc. Drainage Components	EA	$1,000	40	70%	$28,000	100%	$40,000
17	Miscellaneous Activities not in Directly Included in Estimate	% of Subtotal	20%	1	100%	$865,142	100%	$1,471,860
18	Planning, Design, and Oversight	% of Total	40%	1	100%	$2,076,341	100%	$2,943,720
					Estimate of Cost for Public Project:	$7,267,193		$11,774,880
			Private Sector Improvements					
1	Single Family Private Property BMP Certified	Parcel	$4,700	145	50%	$340,750	100%	$681,500
2	Multi Family Private Property BMP Certified	Parcel	$13,100	14	50%	$91,700	100%	$183,400
3	CICU BMP Certified - Private	Parcel	$57,000	5	50%	$142,500	100%	$285,000
4	CICU BMP Certified - Public	Parcel	$57,000	2	50%	$57,000	100%	$114,000
					Estimate of Cost for Private Sector:	$631,950		$1,263,900
					Estimate of Total Cost for 80-acre project area:	$7,900,000		$13,040,000
					Estimate of Total Cost in $/acre:	$99,000		$163,000

Table E-10. Concentrated-Moderate Setting Capital Cost Estimate

No.	Description	Units	Concentrated-Moderate	Total Quantity	Tier 1 % of Total	Tier 1 Cost	Tier 2 % of Total	Tier 2 Cost
1	Mobilization	LS	$200,000	1	50%	$100,000	100%	$200,000
2	Traffic Control and Construction Staking	LS	$200,000	1	50%	$100,000	100%	$200,000
3	Temporary Erosion Control & SWPPP & NPDES Permit & Compliance	LS	$100,000	1	60%	$60,000	100%	$100,000
4	Remove and Replace AC Driveways	SF	$10	6,850	60%	$41,100	100%	$68,500
5	Adjust Utilities; Potholing	EA	$2,000	80	60%	$96,000	100%	$160,000
6	Relocate or Abandon Utility	LF	$150	250	60%	$22,500	100%	$37,500
7	Road Shoulder Stabilization	LF	$70	34,320	60%	$1,441,440	100%	$2,402,400
8	Storm Drain System	LF	$210	8,580	60%	$1,081,080	100%	$1,801,800
9	Separation of Forest Runoff from Urban Runoff	LF	$180	3,000	100%	$540,000	100%	$540,000
10	Revegetation and Soil Restoration	SF	$2	75,000	50%	$75,000	100%	$150,000
11	Tree Removal (Average 12"+)	EA	$600	40	60%	$14,400	100%	$24,000
12	Detention Basin or functional equivalent (SWT-1A)	SF	$15	30,000	50%	$225,000	0%	$0
13	Advanced Detention Basin or functional equivalent (SWT-1B)	SF	$66	30,000	0%	$0	100%	$1,980,000
14	Pervious Conveyance Stabilization	LF	$120	1,000	60%	$72,000	100%	$120,000
15	Miscellaneous Acquisitions	SF	$41	15,000	50%	$307,500	100%	$615,000
16	Misc. Drainage Components	EA	$1,000	40	60%	$24,000	100%	$40,000
17	Miscellaneous Activities not in Directly Included in Estimate	% of Subtotal	20%	1	100%	$840,004	100%	$1,687,840
18	Planning, Design, and Oversight	% of Total	40%	1	100%	$2,016,010	100%	$3,375,680
					Estimate of Cost for Public Project:	$7,056,034		$13,502,720
	Private Sector Improvements							
1	Single Family Private Property BMP Certified	Parcel	$4,300	111	50%	$238,650	100%	$477,300
2	Multi Family Private Property BMP Certified	Parcel	$11,500	13	50%	$74,750	100%	$149,500
3	CICU BMP Certified - Private	Parcel	$51,300	10	50%	$256,500	100%	$513,000
4	CICU BMP Certified - Public	Parcel	$51,300	3	50%	$76,950	100%	$153,900
					Estimate of Cost for Private Sector:	$646,850		$1,293,700
					Estimate of Total Cost for 80-acre project area:	$7,703,000		$14,796,000
					Estimate of Total Cost in $/acre:	$96,000		$185,000

Table E-11. Dispersed-Steep Setting Capital Cost Estimate

No.	Description	Units	Dispersed-Steep	Total Quantity	Tier 1 % of Total	Tier 1 Cost	Tier 2 % of Total	Tier 2 Cost
1	Mobilization	LS	$200,000	1	50%	$100,000	100%	$200,000
2	Traffic Control and Construction Staking	LS	$100,000	1	50%	$50,000	100%	$100,000
3	Temporary Erosion Control & SWPPP & NPDES Permit & Compliance	LS	$100,000	1	50%	$50,000	100%	$100,000
4	Remove and Replace AC Driveways	SF	$10	7,900	50%	$39,500	100%	$79,000
5	Adjust Utilities; Potholing	EA	$2,000	50	50%	$50,000	100%	$100,000
6	Relocate or Abandon Utility	LF	$150	250	50%	$18,750	100%	$37,500
7	Road Shoulder Stabilization	LF	$50	26,400	50%	$660,000	100%	$1,320,000
8	Storm Drain System	LF	$210	5,280	50%	$554,400	100%	$1,108,800
9	Separation of Forest Runoff from Urban Runoff	LF	$120	2,000	100%	$240,000	100%	$240,000
10	Revegetation and Soil Restoration	SF	$2	100,000	50%	$100,000	100%	$200,000
11	Tree Removal (Average 12"+)	EA	$600	80	50%	$24,000	100%	$48,000
12	Mechanical Separation or functional equivalent (SWT-2A)	SF	$200	2,500	40%	$200,000	0%	$0
13	Advanced Mechanical Separation or functional equivalent (SWT-2B)	SF	$427	2,500	0%	$0	100%	$1,067,500
14	Pervious Conveyance Stabilization	LF	$120	2,000	50%	$120,000	100%	$240,000
15	Miscellaneous Acquisitions	SF	$27	10,000	50%	$135,000	100%	$270,000
16	Misc. Drainage Components	EA	$1,000	30	50%	$15,000	100%	$30,000
17	Miscellaneous Activities not in Directly Included in Estimate	% of Subtotal	20%	1	100%	$471,330	100%	$1,028,160
18	Planning, Design, and Oversight	% of Total	40%	1	100%	$1,131,192	100%	$2,056,320
Estimate of Cost for Public Project:						$3,959,172		$8,225,280
Private Sector Improvements								
1	Single Family Private Property BMP Certified	Parcel	$4,300	145	50%	$311,750	100%	$623,500
2	Multi Family Private Property BMP Certified	Parcel	$11,500	9	50%	$51,750	100%	$103,500
3	CICU BMP Certified - Private	Parcel	$51,300	3	50%	$76,950	100%	$153,900
4	CICU BMP Certified - Public	Parcel	$51,300	1	50%	$25,650	100%	$51,300
Estimate of Cost for Private Sector:						$466,100		$932,200
Estimate of Total Cost for 80-acre project area:						$4,425,000		$9,157,000
Estimate of Total Cost in $/acre:						$55,000		$114,000

Table E-12. Dispersed-Moderate Setting Capital Cost Estimate

No.	Description	Units	Dispersed-Moderate	Total Quantity	Tier 1 % of Total	Tier 1 Cost	Tier 2 % of Total	Tier 2 Cost
1	Mobilization	LS	$200,000	1	50%	$100,000	100%	$200,000
2	Traffic Control and Construction Staking	LS	$100,000	1	50%	$50,000	100%	$100,000
3	Temporary Erosion Control & SWPPP & NPDES Permit & Compliance	LS	$100,000	1	40%	$40,000	100%	$100,000
4	Remove and Replace AC Driveways	SF	$10	6,700	40%	$26,800	100%	$67,000
5	Adjust Utilities; Potholing	EA	$2,000	50	40%	$40,000	100%	$100,000
6	Relocate or Abandon Utility	LF	$150	250	40%	$15,000	100%	$37,500
7	Road Shoulder Stabilization	LF	$40	29,040	40%	$464,640	100%	$1,161,600
8	Storm Drain System	LF	$210	5,808	40%	$487,872	100%	$1,219,680
9	Separation of Forest Runoff from Urban Runoff	LF	$100	3,000	100%	$300,000	100%	$300,000
10	Revegetation and Soil Restoration	SF	$2	100,000	40%	$80,000	100%	$200,000
11	Tree Removal (Average 12"+)	EA	$600	80	40%	$19,200	100%	$48,000
12	Detention Basin or functional equivalent (SWT-1A)	SF	$15	25,000	0%	$0	0%	$0
13	Advanced Detention Basin or functional equivalent (SWT-1B)	SF	$53	25,000	0%	$0	100%	$1,325,000
14	Pervious Conveyance Stabilization	LF	$120	1,000	40%	$48,000	100%	$120,000
15	Miscellaneous Acquisitions	SF	$28	5,000	50%	$70,000	100%	$140,000
16	Misc. Drainage Components	EA	$1,000	30	40%	$12,000	100%	$30,000
17	Miscellaneous Activities not in Directly Included in Estimate	% of Subtotal	20%	1	100%	$350,702	100%	$1,029,756
18	Planning, Design, and Oversight	% of Total	40%	1	100%	$841,686	100%	$2,059,512
Estimate of Cost for Public Project:						$2,945,900		$8,238,048
Private Sector Improvements								
1	Single Family Private Property BMP Certified	Parcel	$3,600	55	50%	$99,000	100%	$198,000
2	Multi Family Private Property BMP Certified	Parcel	$10,000	2	50%	$10,000	100%	$20,000
3	CICU BMP Certified - Private	Parcel	$45,000	1	50%	$22,500	100%	$45,000
4	CICU BMP Certified - Public	Parcel	$45,000	1	50%	$22,500	100%	$45,000
Estimate of Cost for Private Sector:						$154,000		$308,000
Estimate of Total Cost for 80-acre project area:						$3,100,000		$8,546,000
Estimate of Total Cost in $/acre:						$39,000		$107,000

Forest Uplands Appendix A: Additional Tables

Table A-1. Forest Upland PCOs and descriptions.

Pollutant Control Option	Description
Organic matter amendment	This PCO consists of a number of materials that may be used to increase organic matter in the soil, increase infiltration and water holding capacity as well as nutrient delivery to microbes and plants.
Ripping-subsoiling (& depth)	Ripping consists of using a tractor or bucket mounted ripper shanks with a range of teeth. Some ripping approaches involve full disruption of compacted soil (such as subsoiling) while other approaches used chisel type teeth and create furrows without full disruption. When assessing ripping/subsoiling, the depth of penetration must be taken into account.
Tilling (& depth)	Use of a number of techniques, usually by backhoe or excavator bucket, to loosen up and mix compacted or otherwise disturbed soil. This PCO must be assessed relative to the depth of tilling.
Soil surface roughening	Application of anu number of techniques that leaves the surface of the soil roughened in order to slow surface flows.
Seeding (& type)	Application of seed to a disturbed site in order to re-establish vegetation. Usually used in combination with other PCOs.
Mulching (& type)	Mulch is material that is surface applied to a soil in order to reduce raindrop impact, reduce velocities of surface flows, reduce soil water evaporation and in some cases (pine needles, woody material) can add nutrients to the soil over long periods of time. Mulch is broken up into many types and include: tub grindings, pine needles, straw, wood fiber, rice hulls, wood chips, coarse woody debris and others. Further, mulch effectiveness must be evaluated over time in order to understand comparative effectiveness. For instance, straw mulch will be effective for 1-3 years while tub grindings may persist for 5 or more seasons.
Irrigation	Temporary irrigation is used to help with initial establishment of vegetation following full treatment. A low frequency, long duration irrigation regime encourages deep root penetration, improves drought tolerance of plants and increases shear and tensile strength within the soil.
Functional restoration	Functional restoration is a package of treatments designed to restore full hydrologic and ecological function to a disturbed area. Treatments include full recontouring to match native slope angles, application of soil organic matter, organic fertilzer, mixing of that material into the soil profile, seeding with native species and mulching with long lasting mulch such as pine needles or tub grindings.

Pollutant Control Option	Description
Road obliteration	Road obliteration is the process of removing and functionally restoring road. The restoration treatment is essentially a package of individual PCOs (the same as "functional restoration") and includes application of soil organic matter, organic fertilzer, mixing of that material into the soil profile, seeding with native species and mulching with long lasting mulch such as pine needles or tub grindings. Full hydrological function is restored to these areas if done correctly.
Traffic exclusion	Use of any number of methods to ensure that foot or vehicle traffic is excluded from a treatment area. This PCO is used following application of other PCO traetment packages in order to maintain the integrity of the treatment.
Pine needle filter berms	Pine needles are piled up in a "U" shaped berm to slow down and filter sediment from overland flow. Pine needle berms are typically anchored in place with rocks or stakes. Pine needle filter berms are intented to serve as temporary sediment (not permanent) controls.
Flow path check dams	Check dams constructed of pine needles and/or rocks are placed in flow paths to slow down and pool water, allowing time for water to infiltrate and sediment to be filtered out (by pine needles). The placement interval of check dams depends on the slope of the flow path.
Hydroseeding	A method of applying seed, fertilizer and mulch to a disturbed slope. This PCO is typically used as a surface treatment only.
Infiltration ditches	A ditch or water conveyance structure is created by tilling soil and adding organic material that encourages infiltration such as wood chips or tub grindings. The purpose is to achieve maximum infiltration while water is conveyed through the ditch in non-saturated conditions.
Infiltration swales	A broad low-lying area that has been treated by other PCOs (soil organic amendment, tiling, seeding, etc) as well as possibly pine needle filter berms. This PCO group is designed to infiltrate maximum amounts of water without containing it, thereby requiring less ground surface that a 'settling pond'.
Rock-lined ditches	A PCO used in water conveyance situations where a ditch is armored by rocks in order to resist erosive shear forces.
Settling ponds	A depression created in order to contain runoff and settle out sediment.
Water bars/rolling dips	Water bars consist of a range of practices aimed at dewatering a road and shunting runoff to another area. Effectiveness is linked to where the water is routed. For instance, a water bar may concentrate water into an erodible area and cause considerable sediment movement or it may be routed into a spreading area that creates minimal impact.

Table A-2. Summary of sub-watershed numbers with corresponding tributary names, soil types, areas, FUSCG fraction and SGFs.

#	Sub-Watershed Number	Tributary Name	% Volcanic	% Granitic-mixed	Area (ac)	FUSCG fraction	FUSCG Area (ac)	SGF
	LAKE TAHOE BASIN		**17.45%**	**82.55%**	**199386**	**82.67%**	**164828**	
1	1000	IVZ1000	88.07%	11.93%	1250.11	28.30%	353.84	3.6736
2	1010	MILL CREEK	12.10%	87.90%	1251.40	74.64%	934.01	0.5909
3	1020	INCLINE CREEK	99.72%	0.28%	17.83	4.00%	0.71	7.5000
4	1021	INCLINE CREEK	97.32%	2.68%	559.63	59.47%	332.79	2.4540
5	1022	INCLINE CREEK	60.75%	39.25%	717.81	73.88%	530.34	1.8507
6	1023	INCLINE CREEK	37.13%	62.87%	847.16	63.77%	540.20	2.0514
7	1024	INCLINE CREEK	21.40%	78.60%	327.88	98.03%	321.41	0.9163
8	1025	INCLINE CREEK	0.00%	100.00%	500.78	100.00%	500.77	0.1921
9	1026	INCLINE CREEK	0.00%	100.00%	278.62	100.00%	278.62	0.1944
10	1027	INCLINE CREEK	7.56%	92.44%	1045.88	100.00%	1045.89	0.4738
11	1030	THIRD CREEK	98.46%	1.54%	39.42	3.75%	1.48	7.3800
12	1031	THIRD CREEK	78.54%	21.46%	546.42	45.65%	249.46	2.5427
13	1032	THIRD CREEK	63.85%	36.15%	517.92	40.68%	210.68	1.5072
14	1033	THIRD CREEK	32.38%	67.62%	505.52	99.82%	504.62	0.1049
15	1034	THIRD CREEK	16.11%	83.89%	880.17	96.12%	846.03	0.6463
16	1035	THIRD CREEK	25.05%	74.95%	1372.08	99.92%	1370.92	0.5085
17	1040	WOOD CREEK	97.65%	2.35%	183.51	21.69%	39.80	6.1385
18	1041	WOOD CREEK	41.27%	58.73%	642.05	91.43%	587.06	0.7883
19	1042	WOOD CREEK	39.22%	60.78%	435.31	100.00%	435.31	0.1190
20	1050	BURNT CEDAR CREEK	94.44%	5.56%	183.13	28.09%	51.43	2.4585
21	1060	SECOND CREEK	62.99%	37.01%	875.86	90.45%	792.22	0.6789
22	1070	FIRST CREEK	59.97%	40.03%	1115.40	96.16%	1072.56	0.9889
23	2000	IVZ2000	4.45%	95.55%	2865.04	94.00%	2693.23	0.1058
24	2010	SLAUGHTER HOUSE	0.00%	100.00%	1122.82	95.62%	1073.61	0.0138
25	2011	SLAUGHTER HOUSE	23.07%	76.93%	1994.39	94.91%	1892.81	0.0884
26	2020	BLISS CREEK	0.00%	100.00%	349.65	98.70%	345.10	0.2448
27	2030	SECRET HARBOR CREEK	0.00%	100.00%	173.61	98.22%	170.51	0.1803
28	2031	SECRET HARBOR CREEK	0.00%	100.00%	720.64	100.00%	720.65	0.1331
29	2032	SECRET HARBOR CREEK	0.00%	100.00%	387.03	99.90%	386.65	0.2585
30	2033	SECRET HARBOR CREEK	10.86%	89.14%	967.32	100.00%	967.31	0.1209
31	2040	MARLETTE CREEK	0.05%	99.95%	1297.17	98.83%	1281.99	0.1121
32	2041	MARLETTE CREEK	25.21%	74.79%	1846.50	80.88%	1493.50	0.1607
33	2050	BONPLAND	0.33%	99.67%	564.40	99.97%	564.25	0.1162
34	2060	TUNNEL CREEK	0.00%	100.00%	812.02	99.96%	811.73	0.1639
35	3000	IVZ3000	21.76%	78.24%	2789.71	64.97%	1812.46	0.0507
36	3010	MCFAUL CREEK	0.00%	100.00%	294.81	15.48%	45.64	0.0110
37	3011	MCFAUL CREEK	0.00%	100.00%	767.10	96.98%	743.97	0.0098
38	3012	MCFAUL CREEK	0.00%	100.00%	862.26	100.00%	862.26	0.0110
39	3013	MCFAUL CREEK	0.00%	100.00%	382.87	129.87%	497.22	0.0100
40	3020	ZEPHYR CREEK	0.00%	100.00%	1070.69	98.01%	1049.42	0.0169
41	3030	NORTH ZEPHYR CREEK	0.00%	100.00%	49.30	66.85%	32.96	0.0150
42	3031	NORTH ZEPHYR CREEK	0.00%	100.00%	662.38	100.00%	662.38	0.0102

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43	3032	NORTH ZEPHYR CREEK	0.00%	100.00%	306.22	99.45%	304.55	0.0106
44	3033	NORTH ZEPHYR CREEK	0.00%	100.00%	657.73	100.00%	657.74	0.0104
45	3040	LINCOLN CREEK	0.00%	100.00%	308.89	96.75%	298.86	0.0098
46	3041	LINCOLN CREEK	37.71%	62.29%	758.00	100.00%	758.01	0.0753
47	3042	LINCOLN CREEK	0.81%	99.19%	581.21	100.00%	581.21	0.0098
48	3050	CAVE ROCK	0.00%	100.00%	449.32	94.70%	425.50	0.0068
49	3060	LOGAN HOUSE CREEK	0.00%	100.00%	47.82	70.56%	33.74	0.0070
50	3061	LOGAN HOUSE CREEK	48.80%	51.20%	979.36	100.00%	979.35	0.0847
51	3062	LOGAN HOUSE CREEK	73.38%	26.62%	352.32	100.00%	352.33	0.0541
52	3070	NORTH LOGAN HOUSE CREEK	24.13%	75.87%	698.60	99.88%	697.76	0.0787
53	3080	GLENBROOK CREEK	65.70%	34.30%	572.05	82.13%	469.82	0.1149
54	3081	GLENBROOK CREEK	71.83%	28.17%	421.57	99.83%	420.84	0.1427
55	3082	GLENBROOK CREEK	76.22%	23.78%	979.88	98.78%	967.93	0.1347
56	3083	GLENBROOK CREEK	53.08%	46.92%	654.23	100.00%	654.23	0.1502
57	4000	IVZ4000	0.00%	100.00%	2353.05	54.15%	1274.26	0.0379
58	4010	BIJOU CREEK	0.00%	100.00%	1420.92	62.90%	893.70	0.0352
59	4020	EDGEWOOD CREEK	0.00%	100.00%	971.08	47.66%	462.85	0.0602
60	4021	EDGEWOOD CREEK	0.00%	100.00%	479.32	99.99%	479.27	0.0507
61	4022	EDGEWOOD CREEK	0.00%	100.00%	824.61	93.82%	773.61	0.0336
62	4023	EDGEWOOD CREEK	0.00%	100.00%	1111.11	86.29%	958.72	0.0732
63	4024	EDGEWOOD CREEK	0.00%	100.00%	888.15	69.04%	613.20	0.0638
64	4030	BURKE CREEK	0.00%	100.00%	1405.74	70.03%	984.51	0.0183
65	4031	BURKE CREEK	0.00%	100.00%	546.24	76.42%	417.42	0.0218
66	4032	BURKE CREEK	0.00%	100.00%	625.49	93.64%	585.70	0.0216
67	4033	BURKE CREEK	0.00%	100.00%	395.93	99.19%	392.71	0.0195
68	5000	IVZ5000	2.10%	97.90%	2641.90	67.27%	1777.11	0.0689
69	5010	UPPER TRUCKEE RIVER	1.29%	98.71%	2113.34	54.76%	1157.19	0.0545
70	5011	UPPER TRUCKEE RIVER	0.00%	100.00%	3014.03	66.23%	1996.32	0.0424
71	5012	UPPER TRUCKEE RIVER	0.91%	99.09%	2447.86	85.49%	2092.76	0.0456
72	5013	UPPER TRUCKEE RIVER	0.00%	100.00%	1212.87	96.16%	1166.35	0.0268
73	5014	UPPER TRUCKEE RIVER	0.00%	100.00%	790.25	58.38%	461.37	0.0449
74	5015	UPPER TRUCKEE RIVER	0.00%	100.00%	1242.50	89.74%	1114.97	0.0260
75	5016	UPPER TRUCKEE RIVER	0.00%	100.00%	272.08	81.03%	220.47	0.0488
76	5017	UPPER TRUCKEE RIVER	0.00%	100.00%	412.90	90.13%	372.16	0.0263
77	5018	UPPER TRUCKEE RIVER	0.00%	100.00%	1739.98	76.90%	1337.98	0.0280
78	5019	UPPER TRUCKEE RIVER	0.00%	100.00%	1366.03	96.91%	1323.87	0.0359
79	5020	UPPER TRUCKEE RIVER	4.37%	95.63%	2252.15	88.45%	1992.01	0.0275
80	5021	UPPER TRUCKEE RIVER	4.57%	95.43%	1767.52	87.11%	1539.66	0.0208
81	5022	UPPER TRUCKEE RIVER	6.74%	93.26%	959.18	99.09%	950.44	0.0708
82	5023	UPPER TRUCKEE RIVER	5.74%	94.26%	2677.41	99.40%	2661.46	0.0763
83	5024	UPPER TRUCKEE RIVER	11.12%	88.88%	2173.21	99.99%	2173.00	0.0967
84	5025	UPPER TRUCKEE RIVER	61.70%	38.30%	1550.62	100.00%	1550.61	0.5105
85	5026	UPPER TRUCKEE RIVER	91.23%	8.77%	891.98	100.00%	891.98	0.5033
86	5027	UPPER TRUCKEE RIVER	18.00%	82.00%	991.10	100.00%	991.11	0.0788
87	5028	UPPER TRUCKEE RIVER	79.51%	20.49%	941.01	100.00%	941.00	0.3512

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88	5029	UPPER TRUCKEE RIVER	0.00%	100.00%	1196.40	98.90%	1183.23	0.0331
89	5030	UPPER TRUCKEE RIVER	68.34%	31.66%	1281.79	100.00%	1281.79	0.4987
90	5031	UPPER TRUCKEE RIVER	0.00%	100.00%	845.25	99.85%	844.00	0.0287
91	5032	UPPER TRUCKEE RIVER	0.00%	100.00%	2156.40	99.44%	2144.36	0.0344
92	5033	UPPER TRUCKEE RIVER	2.01%	97.99%	1905.70	98.90%	1884.82	0.0461
93	5050	TROUT CREEK	0.00%	100.00%	1013.29	44.14%	447.30	0.0696
94	5051	TROUT CREEK	0.00%	100.00%	681.50	86.04%	586.40	0.0262
95	5052	TROUT CREEK	0.00%	100.00%	1240.10	99.88%	1238.65	0.0414
96	5053	TROUT CREEK	0.00%	100.00%	365.33	42.15%	154.00	0.0401
97	5054	TROUT CREEK	0.00%	100.00%	2147.79	90.85%	1951.30	0.0291
98	5055	TROUT CREEK	0.00%	100.00%	2326.35	92.02%	2140.81	0.0286
99	5056	TROUT CREEK	0.00%	100.00%	1003.97	99.72%	1001.18	0.0225
100	5057	TROUT CREEK	0.00%	100.00%	1996.01	100.00%	1996.01	0.0299
101	5058	TROUT CREEK	0.00%	100.00%	385.87	100.00%	385.87	0.0341
102	5059	TROUT CREEK	0.00%	100.00%	1146.06	100.00%	1146.06	0.0190
103	5060	TROUT CREEK	0.00%	100.00%	280.39	100.00%	280.38	0.0211
104	5061	TROUT CREEK	0.00%	100.00%	440.72	100.00%	440.72	0.0249
105	5062	TROUT CREEK	0.00%	100.00%	463.71	99.90%	463.25	0.0223
106	5063	TROUT CREEK	0.00%	100.00%	229.29	100.00%	229.29	0.0238
107	5064	TROUT CREEK	0.00%	100.00%	780.41	99.67%	777.80	0.0274
108	5065	TROUT CREEK	0.00%	100.00%	474.43	99.82%	473.57	0.0259
109	5066	TROUT CREEK	1.39%	98.61%	682.92	99.88%	682.12	0.0297
110	5067	TROUT CREEK	0.00%	100.00%	958.98	100.00%	958.98	0.0204
111	5068	TROUT CREEK	0.00%	100.00%	774.67	100.00%	774.67	0.0149
112	5069	TROUT CREEK	0.00%	100.00%	845.04	100.00%	845.03	0.0197
113	5070	TROUT CREEK	0.00%	100.00%	965.44	78.48%	757.69	0.0286
114	5071	TROUT CREEK	0.00%	100.00%	402.35	100.00%	402.36	0.0212
115	5072	TROUT CREEK	0.00%	100.00%	609.59	100.00%	609.58	0.0227
116	5073	TROUT CREEK	0.00%	100.00%	552.91	100.00%	552.92	0.0177
117	5074	TROUT CREEK	0.00%	100.00%	828.04	100.00%	828.03	0.0727
118	5075	TROUT CREEK	0.00%	100.00%	938.35	100.00%	938.34	0.0276
119	5076	TROUT CREEK	0.00%	100.00%	1475.27	100.00%	1475.26	0.0220
120	5077	TROUT CREEK	0.00%	100.00%	64.80	100.00%	64.80	0.28961438
121	5078	TROUT CREEK	0.00%	100.00%	951.26	97.82%	930.55	0.0210
122	5079	TROUT CREEK	0.67%	99.33%	1388.35	99.81%	1385.70	0.0197
123	6000	IVZ6000	0.11%	99.89%	1687.50	95.88%	1617.97	0.0426
124	6001	IVZ6001	0.00%	100.00%	651.83	57.37%	373.94	0.0536
125	6010	GENERAL CREEK	0.00%	100.00%	2013.49	99.35%	2000.41	0.0558
126	6011	GENERAL CREEK	0.00%	100.00%	1130.77	100.00%	1130.77	0.0461
127	6012	GENERAL CREEK	0.00%	100.00%	1740.13	100.00%	1740.14	0.0536
128	6020	MEEKS	0.00%	100.00%	1189.60	95.73%	1138.79	0.0534
129	6021	MEEKS	0.00%	100.00%	2116.86	100.00%	2116.86	0.0425
130	6022	MEEKS	0.00%	100.00%	739.04	99.24%	733.40	0.0354
131	6023	MEEKS	0.00%	100.00%	1238.35	94.71%	1172.89	0.0371
132	6030	SIERRA CREEK	0.00%	100.00%	568.21	93.36%	530.46	0.0433

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133	6040	LONELY GULCH CREEK	0.00%	100.00%	688.19	92.68%	637.78	0.0439
134	6050	PARADISE FLAT	0.00%	100.00%	398.17	94.33%	375.61	0.0376
135	6060	RUBICON CREEK	0.00%	100.00%	1826.78	94.59%	1727.94	0.0357
136	6080	EAGLE CREEK	0.96%	99.04%	137.75	98.73%	136.00	0.0216
137	6081	EAGLE CREEK	1.83%	98.17%	2449.09	97.55%	2389.12	0.0366
138	6082	EAGLE CREEK	21.61%	78.39%	1757.07	95.86%	1684.28	0.0461
139	6090	CASCADE CREEK	0.00%	100.00%	616.34	62.91%	387.71	0.0255
140	6091	CASCADE CREEK	0.00%	100.00%	685.45	99.86%	684.47	0.0154
141	6092	CASCADE CREEK	25.00%	75.00%	1547.23	96.74%	1496.86	0.0177
142	6100	TALLAC CREEK	0.00%	100.00%	891.07	98.96%	881.80	0.0621
143	6101	TALLAC CREEK	45.54%	54.46%	1286.30	99.42%	1278.85	0.0802
144	6110	TAYLOR CREEK	0.00%	100.00%	1135.13	97.50%	1106.72	0.2072
145	6111	TAYLOR CREEK	31.26%	68.74%	3718.71	56.20%	2089.79	0.0605
146	6112	TAYLOR CREEK	32.81%	67.19%	2817.65	97.27%	2740.81	0.0745
147	6113	TAYLOR CREEK	90.07%	9.93%	1189.14	93.40%	1110.70	0.1092
148	6114	TAYLOR CREEK	47.79%	52.21%	1961.59	94.51%	1853.94	0.0213
149	6115	TAYLOR CREEK	99.37%	0.63%	963.40	96.42%	928.91	0.0134
150	6120	UNNAMED CK	0.00%	100.00%	173.52	88.95%	154.35	0.0622
151	7000	IVZ7000	39.58%	60.42%	1737.07	61.45%	1067.50	0.2282
152	7010	BLACKWOOD CREEK	94.22%	5.78%	2262.10	98.53%	2228.83	0.2767
153	7011	BLACKWOOD CREEK	97.75%	2.25%	1551.35	99.38%	1541.80	0.3403
154	7012	BLACKWOOD CREEK	100.00%	0.00%	977.28	100.00%	977.28	0.2090
155	7013	BLACKWOOD CREEK	98.28%	1.72%	2347.48	99.41%	2333.61	0.2600
156	7020	MADDEN CREEK	92.72%	7.28%	1308.51	99.00%	1295.37	0.3435
157	7030	HOMEWOOD CREEK	88.98%	11.02%	644.70	97.72%	630.01	0.5353
158	7040	QUAIL LAKE CREEK	64.38%	35.62%	947.37	96.20%	911.34	0.3444
159	7050	MKINNEY CREEK	0.01%	99.99%	1428.32	87.27%	1246.43	0.0584
160	7051	MKINNEY CREEK	23.74%	76.26%	879.54	99.31%	873.45	0.1269
161	7052	MKINNEY CREEK	0.00%	100.00%	750.88	94.09%	706.48	0.0487
162	8000	IVZ8000	95.24%	4.76%	3047.10	55.88%	1702.74	0.5689
163	8010	DOLLAR CREEK	100.00%	0.00%	698.36	34.10%	238.15	1.0481
164	8020	UNNAMED CK LAKE FOREST 1	92.70%	7.30%	447.56	50.50%	226.00	1.4038
165	8030	UNNAMED CK LAKE FOREST 2	92.99%	7.01%	647.87	81.51%	528.05	1.1082
166	8040	BURTON CREEK	95.00%	5.00%	621.76	97.39%	605.56	1.2913
167	8041	BURTON CREEK	100.00%	0.00%	598.12	100.00%	598.13	0.6298
168	8042	BURTON CREEK	96.41%	3.59%	2223.93	99.96%	2223.10	0.9655
169	8050	TAHOE STATE PARK	99.92%	0.08%	684.40	100.07%	684.85	1.1113
170	8060	WARD CREEK	94.77%	5.23%	1144.44	91.43%	1046.32	0.3132
171	8061	WARD CREEK	92.53%	7.47%	2109.47	98.49%	2077.55	0.3111
172	8062	WARD CREEK	99.46%	0.54%	944.20	97.84%	923.84	0.1012
173	8063	WARD CREEK	99.52%	0.48%	2039.06	100.00%	2039.05	0.2702
174	9000	IVZ9000	86.83%	13.17%	3743.58	62.33%	2333.28	0.7074
175	9010	KINGS BEACH	99.96%	0.04%	287.34	76.75%	220.53	0.8548
176	9020	GRIFF CREEK	89.97%	10.03%	117.59	39.42%	46.36	1.4046
177	9021	GRIFF CREEK	99.99%	0.01%	900.22	99.36%	894.47	0.6888

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178	9022	GRIFF CREEK	98.51%	1.49%	1832.98	97.08%	1779.45	0.6851
179	9030	TAHOE VISTA	92.94%	7.06%	854.92	56.10%	479.59	1.1833
180	9031	TAHOE VISTA	99.84%	0.16%	856.90	96.56%	827.39	0.9849
181	9032	TAHOE VISTA	99.47%	0.53%	1270.31	92.70%	1177.61	0.9781
182	9040	CARNELIAN CANYON	98.90%	1.10%	1973.56	93.80%	1851.13	0.9838
183	9050	CARNELIAN BAY CREEK	100.00%	0.00%	578.61	99.32%	574.65	1.1019
184	9060	WATSON	96.94%	3.06%	1491.25	98.76%	1472.68	0.7874

Forest Uplands Appendix B: Fire Literature Review

Forests of the Lake Tahoe region have adapted to regular occurrence of fire, a natural process that has been suppressed in the past century or more. During the Comstock Era beginning in the late 1800’s, mineral mining in Nevada created great demand for timber to construct and support mine shafts. The Lake Tahoe region was the nearest source of high-quality timber in the area. As logging companies acquired land to harvest timber, widespread suppression of forest fires became standard practice to protect their investment. By the turn of the century, most of the Lake Tahoe Basin was logged (Tahoe Regional Planning Agency, 1971). As the trees grew back in the post-Comstock era, continued fire suppression has led to dense tree re-growth, increased litter layer depths and ever-increasing risk of catastrophic wildfire. In conjunction with thinning, prescribed fire is slowly being reintroduced as a resource management tool to reduce fuel loading in overstocked forests of the Lake Tahoe Basin. Although prescribed fire has proven to be an effective tool for reducing fuel loads and fire hazards while also restoring and maintaining important ecosystem functions, there are many questions and concerns about its potential impacts on water quality. This literature review is a brief summary of research focused on the impacts of fire – both prescribed and wildfire – on water quality.

1.1. Overview

Prescribed burning is the controlled use of fire to achieve specific forest management objectives (Walstad et al. 1990). Prescribed burning has become a common forest management tool for reducing undesirable vegetation and heavy fuel loads in the Sierra Nevada (Schoch and Binkley 1986; Neary et al. 1999; Reuter and Miller 2000). Prescribed fires create a highly variable mosaic of burn severity, litter/duff consumption and unburned areas (Robichaud 2000; Robichaud and Miller 1999). If properly managed, prescribed fires are generally low- to moderate-intensity and are capable of burning at low temperatures and short flame heights for a controlled period of time. Fires of this type replicate the historical naturally occurring fires in the Sierra Nevada (Taylor 1997). In contrast, wildfires are those fires that are ignited unintentionally or by natural processes (e.g. lightning) are generally difficult to control. Wildfires tend to exhibit more erratic burning patterns, higher temperatures and higher flame lengths than prescribed fires.

The effect of fire on water quality largely depends on how fire characteristics such as frequency, intensity, duration and spatial extent of burning (Boerner 1982) interact with watershed characteristics including weather, slope, soil type, geology, land use, proportion of vegetation burned and timing of vegetation regrowth (Ranalli 2004).

Fire has direct and indirect effects on many forest ecosystem processes. Temporarily decreased transpiration occurring as a result of vegetation removal can effectively increase stream flows, which has the potential to dilute nutrient concentrations in streams and conceal impacts of burning on water quality. Vegetation loss also reduces nutrient uptake and can result in increased nutrient leaching or runoff to streams. Further, alteration of balanced nutrient cycling disrupts ion exchanges within soil, causing increased nutrient leaching into soil and eventually streams during the first two seasons following a burn (Payne 1999).

Fire-induced heat transfer in soils is a very complex process that is influenced by numerous soil physical properties (moisture, texture, porosity, pore continuity) and fuel characteristics (mass, size class, moisture, surface area, structural arrangement/configuration). Predicting burn temperature and resulting effects on soil physical and chemical properties is very difficult due to the wide array of interdependent variables.

1.2. Nutrient Effects

Fire plays an important role in recycling mineral nutrients back into the soil in all Sierran conifer forests. Research has shown that fire alters mineral soil-nutrient concentrations by means of five key mechanisms: 1) Direct volatilization of nutrients reduces the total mount of nutrients in the soil; 2) Mineralization induced by heating increases nutrient availability; 3) Ash deposition and subsequent leaching further add nutrients to the mineral soil; 4) Soil erosion following fire decreases total nutrient amount; and 5) Transportation of nutrients due to the differences in the relative availability of nutrients in the ash versus the mineral soil further influence the relative abundance of nutrients in the mineral soil (Behan 1970; DeBano 1991; Rice 1993).

Fire can affect nutrient cycling through the combustion of vegetation, volatilization of organic matter, heating of soils, deposition of ash and solubility of nutrients (Payne 1999). Heating and combustion of vegetation, organic matter and portions of the forest floor can trigger many complex soil reactions. Burning organic matter releases nutrients such as N, P, sulfur (S) and carbon (C) (Sackett, Hasse and Harrington 1996), increases the mobility of large amounts of calcium, magnesium, sodium and potassium (Marion 1982; DeBano and Dunn 1982; Agee 1996) and deposits ash on the soil surface. Although C, N and S remain susceptible to volatilization at lower burn temperatures, other elements, such as P, require greater burn temperatures to volatilize and significant losses in P are typically the result of off-site particulate transport from ash convection, runoff and erosion (Riason et al. 1985; Caldwell et al. 2002; Loupe 2005; Murphy et al. 2006a). Combustion also causes the conversion of organic nutrients into inorganic forms (DeBano and Dunn 1982; Johnson et al. 1982).

Nutrient availability (particularly nitrogen) in the soil can also be increased by translocation of nutrients downward into the soil during a fire (Wells 1971). For instance, total nitrogen (N) has been shown to decrease immediately following burning while available ammonium N in the underlying soil is usually higher following fire because of this transfer mechanism (DeBano 1991). In contrast, phosphorous (P) does not appear to be translocated downward in the soil as easily as N compounds. Therefore, post-fire P increases are predominantly in the ash layer at or near the surface (DeBano 1991), where it is more susceptible to mobilization by surface erosion processes.

Nutrient solubility is also altered by fire. Soluble nutrients are created through ash deposition, leaching and ionic exchange reactions in the soil (Johnson et al. 1982). Leaching of ash can generate an initial flush of nutrients that tapers off over time (Payne 1999). The burning and leaching process also increases soil pH (DeBano and Dunn 1982; Agee 1996), which leads to increased cation exchange and improves soil affinity for nutrient retention (Payne 1999). The influence of ash is the basis of the USDA Forest Service hypothesis which suggests that the interaction between calcium and increased pH causes the immobilization of insoluble P that might otherwise runoff to surface water or percolate through soils (McGurk et al. 1997).

Davis (1989) suggests that nutrients mobilized by fire events will enter surface water if there is a lack of vegetation to assimilate nutrients – an effect that is exacerbated during large runoff events. Additional nutrients may be immobilized within the soil or leached by subsurface flow to surface water (Sackett, Hasse and Harrington 1996; DeBano and Neary 1996; Grier 1975; DeBano and Dunn 1982). DeBano and Neary (1996) assert that low nutrient concentrations normally occur in stream water due to the highly interactive system of nutrient exchange between soil and vegetation. Recent research by Miller et al. (2005) supports this assertion, identifying high concentrations of biologically available N and P in overland flow in undisturbed Sierra Nevada coniferous forests. Heavy accumulations of forest floor duff (O horizons) resulting from long-term fire suppression may be a source of increased stream nutrient levels in relatively undisturbed watersheds (Miller et al. 2005). The presence of a robust soil-vegetation community to uptake and immobilize nutrients may help to significantly reduce or eliminate the risk of water quality impacts associated with burning (DeBano and Dunn 1982). Many studies have reported rapid vegetation establishment and growth following low-intensity prescribed burns (McColl and Grigal 1975; Wells et al. 1979; Snyder, Haupt and Belt 1975; Ffoliott, Clary and Larson 1977; Stark 1977; Sackett, Hasse and Harrington 1996; Harris and Covington 1983).

Prescribed Fire

The water quality impacts of prescribed burns are difficult to predict and unique to the conditions of each watershed and burn characteristics of each fire. However, research in the Sierra Nevada has consistently shown that prescribed fire results in negligible or short-lived adverse effects on water quality. Research by Stephens et al. (2005) indicates that a prescribed fire in the Lake Tahoe Basin had no effect on soluble reactive phosphorous (SRP) and only minimal effects on nitrate in stream water. Similarly, Chorover et al. (1994) measured small increases in soil solution and stream water ammonium and nitrate following prescribed fire at a granitic soil site in the western Sierras. Kilgore (1971) reported no changes in stream water chemistry following a prescribed burn in an upper montane fir forest. Murphy et al. (2006a) found no significant increases in the leaching of ammonium, nitrate, phosphate or sulfate following a prescribed burn in a Sierra Nevada forest with volcanic soils. Loupe (2005) reported that prescribed burning resulted in a net decrease of inorganic N and P concentrations in surface runoff at a site near North Lake Tahoe. Beche, Stephens and Resh (2005) measured increases in sulfate, total P, calcium and magnesium that persisted less than one year following a prescribed burn in a Sierra Nevada riparian zone. Similarly, many other studies have shown small, short-term increases in nitrate and phosphate concentration in stream water following the first post-burn rain event with relatively rapid recovery to pre-burn levels, ranging from 10 days to several months after a burn treatment (Lewis 1974; Binkley et al. 1992; Gottfriend and DeBano 1990). Both Lewis (1974) and Binkley et al. (1992) reported that subsequent rains failed to produce elevated nutrient concentrations. Caldwell et al. (2002) found that N volatilization was the dominant mechanism of N loss during prescribed fire in the eastern Sierra Nevada.

Several studies outside the Sierra Nevada indicated longer durations of increased nutrient concentrations before stream water returned to pre-burn levels. In-stream nutrient concentrations returned to pre-burn levels in one year in a prescribed burn study by DeBano and Klopatek (1988). Another prescribed burn study found that water quality returned to pre-burn levels within two years when revegetation treatments were incorporated. Without revegetation, water quality was impaired for four years before returning to pre-burn levels (Wright, Churchill and Stevens 1982). Covington and Sackett (1986) reported that N returned to control plot levels in 4-5 years after periodic burning of a ponderosa pine forest.

Wildfire

Wildfire typically causes large losses of system N due to volatilization while increasing soil mineral N due to mineralization of soil organic N (Neary et al. 1999; Murphy et al. 2006b). In contrast, the effects of wildfires on inorganic P are largely dependent on fire intensity and, therefore, far less predictable with some studies reporting increases (Saa et al. 1993) Hauer and Spencer 1998) and others noting decreases (Carreira et al. 1996; Ketterings and Bingham 2000).

Most studies that have measured water quality during and immediately following wildfire have reported that an increase in various forms of N above pre-fire levels occurs immediately. During the first few days of a wildfire, Spencer and Hauer (1991) reported ammonium concentrations in streams in the burned watersheds that were more than 40 times greater than the control stream. Ammonium concentrations fluctuated greatly during the 6-week fire before declining to background levels within two months. Chessman (1986) measured stream nutrient concentrations in 10 streams following a wildfire in Southeastern Australia and found that the highest concentrations of nitrate in 4 of the 10 burned watersheds during the first storm following fire, while in other streams, nitrate concentrations remained very low until the second or third storm. The highest ammonium concentrations in most streams were measured during the third storm. Longer-term studies of in-stream nitrate concentration following wildfires have reported a fairly consistent temporal trend: nitrate increases during storms for several months following a wildfire with mean or maximum monthly nitrate concentrations and loading continuing to increase until a peak is reached in the first or second year after the wildfire during spring snowmelt followed by a slow decline thereafter (Tiedemann et al. 1978; Feller and Kimmins 1984; Gluns and Toews 1989; Williams and Melack 1997; Gerla and Galloway 1998).

Similar to N, most studies that have measured water quality during and immediately following a wildfire have found that an increase in several forms of P above pre-fire levels also occurs immediately. Spencer and Hauer (1991) measured concentrations of SPR in stream water from a burned watershed more than 40 times greater than SRP concentrations in streams from the unburned watersheds. Additionally, maximum concentration of SRP in the stream from the burned watershed was measured within 24 hours of the start of the wildfire. SRP accounted for as much as 84 percent of the total P measured in the burned watersheds following the fire. Both total P and SRP declined steadily and returned to background levels within two weeks after the passage of the fire.

Following the "Gondola Fire," the largest wildfire in recent history within the Lake Tahoe Basin, Allander (2004) reported elevated in-stream concentrations of both nitrate and SRP for several years after the fire. Concentrations of nitrate have continued to show much greater seasonal variability than pre-fire levels. However, four years following the fire, in-stream SRP concentrations had nearly returned to pre-fire levels. Murphy et al. (2006b) noted increased soil solution concentrations of ammonium, nitrate, phosphate and sulfate in burned areas during the first winter following the Gondola Fire. Increased concentrations of inorganic N and P were also measured in surface runoff from the burned area (Miller et al. 2006). All three studies indicate that a wildfire in the Lake Tahoe Basin can result in short- and long-term increases in labile nutrient concentrations throughout the watershed and its tributary streams.

Pile Burning

Pile burning (slash burning) is an alternative to broadcast burning in which slash is piled and ignited to reduce fuels in overstocked areas. In comparison to broadcast burning, pile burns are hot, concentrated and often exhibit high surface and sub-surface temperatures (Payne 1999).

Research on slash burning has yielded varied and inconclusive results on the effects of this practice on water quality (Snyder, Haupt and Belt 1975; Stednick, Tripp and McDonald 1982; Winzler and Kelly 1982). However, a majority of these results suggested short-term or insignificant increases in nutrient concentrations. Research conducted by Winzler and Kelly (1982) indicated no changes in stream water nutrient concentrations following slash burning at a northern California site. However, because baseline conditions were not measured and post-burn data were omitted, the results are inconclusive at best. Snyder, Haupt and Belt (1975) reported that nutrient impacts associated with slash burning were most significant onsite, with only small nutrient concentrations measured downstream of the treated area. In another study, variable impacts of slash burning on water chemistry were noted, but no significant water quality effects were reported (Stednick, Tripp and McDonald 1982).

1.3. Infiltration, Runoff and Sediment Yield Effects

Soil infiltration capacity, the ability of water to percolate through soil, can also be affected by heat from burning. Extreme heating of soil can volatilize water repellent compounds in accumulated organic matter and form a water repellent (“hydrophobic”) layer (DeBano 1981; Brock and DeBano 1988). Fire studies have shown that extreme heating leads to reduced infiltration capacity (Cory and Morris 1969; Klock and Grier 1979; Robichaud 2000). Changes in post-burn infiltration capacity are affected by factors such as soil type and texture, soil moisture and above-ground fuel loading (DeBano 1981). If changes in wettability and infiltration are severe, water quality of streams may be affected by nutrient loss due to surface runoff and erosion (DeBano et al. 1967).

Prescribed Fire

Research suggests that low-intensity burns have minimal effects on infiltration. Shubert et al. (1975) reported that low-intensity burns led to temporary, short-term reductions in infiltration while Agee (1973) reported high infiltration rates and no measurable change in runoff and erosion following low-intensity prescribed fires in forested areas of the Sierra Nevada. Robichaud et al. (1994) measured high infiltration rates and low sediment yields using rainfall simulation following a spring season, low-intensity prescribed burn in northern Idaho. Where fires have led to a reduction in infiltration, runoff and sediment yield has been found to be greatest immediately following the fire. Additionally, significant relationship has been shown between post-fire runoff and woody soil cover, and a decrease in runoff was observed as woody cover increased (Marcos et al. 2000).

The spatial variability of post-prescribed fire surface conditions results in spatially varying runoff and erosion rates. Assessment following two prescribed burns – one in Idaho and one in Montana – indicated that only 5-15 percent of the burned areas had burned at high-severity (Robichaud 1996, 2000). As expected, initial infiltration rates in the high-severity burned areas were lower than in the unburned and undisturbed areas. More importantly, initial infiltration rates in the areas burned at low-severity (comprising the largest portion of the burned area) fell within the upper end of the range measured in the unburned and undisturbed areas (Robichaud 2000). The total sediment yields from three 30-minute rainfall simulations on the low-severity burned plots were an order of magnitude smaller than the values from the plots burned at high-severity (Robichaud 1996). Benavides-Solorio and MacDonald (2005) reported similar differences in sediment yields.

Runoff and sediment yield were also measured at the catchment-scale (~17-22 ac.) during natural rain events after the same prescribed burns in Idaho and Montana described above (Robichaud

1996, 2000). At both sites, runoff and sediment yields were relatively low from the catchments subjected to both timber harvest and prescribed fire (Covert et al. 2005). This is likely attributed to the generally low burn severity and averaging of fire effects in the treatment area (Covert 2003; Robichaud 1996).

Wildfire

High-severity wildfires have a tendancy to have much greater effects on runoff and erosion than prescribed fires. This is due in great part to the loss of protective cover and fire-induced soil water repellency, which can cause severe flooding and erosion after even moderate rain events (DeBano et al. 1998; Neary et al. 2005). In severely burned areas, high-intensity, short-duration rain events have been shown to increase peak stream flows from 2 to 2000 times (Williams and Melack 1997; DeBano et al. 1998; Neary et al. 1999; Neary et al. 2005). Drawing on both field research and modeling results, Elliot and Robichaud (2001) concluded that 200-year average annual sediment delivery following wildfire is at least an order of magnitude higher than that following forest operations and prescribed fire with forest buffers. In other words, the increased frequency of disturbance from active forest management results in far lower long-term average sediment delivery rates than would occur following less frequent but higher intensity wildfire disturbances. Other estimates suggest that high-severity wildfires could increase runoff and erosion rates by two or more orders of magnitude (Robichaud et al., in press). Published sediment yields after high-severity wildfires range from 0.004 to 49 T/ac/yr in the first year after fire (Benavides-Solorio and MacDonald 2005; Moody and Martin 2001; Robichaud et al. 2000). Most long-term studies have reported a return to pre-fire erosion levels within 3-4 years after burning (Benavides-Solorio and MacDonald 2005; Robichaud and Brown 2000).

Recent research suggests that a single erosion event following a wildfire can be quite severe compared to the expected long-term average annual erosion. Carroll et al. (2007) estimated that erosion from the first rain event following the Gondola Fire in Lake Tahoe was at least an order of magnitude greater than the expected average annual erosion based on the 1000-year projections for the Lake Tahoe Basin reported in other studies. Interestingly, Carroll et al. (2007) found that the bulk of the ash and sediment erosion following the Gondola Fire remained in the riparian zone rather than flushing from the watershed. This is significant because if the fire had occurred in an area with an impaired riparian zone or with direct drainage to Lake Tahoe, a large pulse of sediment and nutrients would have entered the Lake. However, while immediate impacts on lake clarity were minimized, the topsoil lost from upland areas is likely to hinder post-fire revegetation and overall watershed health.

1.4. Conclusions

- In the Sierra Nevada, fire research has tended to focus on lower elevation, west slope areas whereas little research has examined the effects of fire in the higher elevations, eastern slopes and the Lake Tahoe Basin.

- Research in the Sierra Nevada has consistently shown that low-intensity prescribed fire increases pH, stimulates mineralization and facilitates nutrient cycling with negligible or short-lived effects on in-stream nutrient concentrations, runoff and erosion. In general, prescribed fire studies have reported a relatively rapid return to pre-burn nutrient levels, ranging from 10 days to several months after a burn treatment.

- The increased frequency of disturbance from regular prescribed burning results in far lower long-term average sediment delivery rates than would occur as a result of less frequent but higher intensity wildfire disturbances.

- High-intensity wildfires have much greater effects on runoff and erosion than low-intensity prescribed fires, largely due to the reduction in surface cover and fire-induced soil water repellency. Erosion has been estimated to increase by at least 2 orders of magnitude following wildfires. Most long-term studies have reported a return to pre-fire erosion levels within 3-4 years after burning.

- In severely burned areas, high-intensity, short-duration rain events have been shown to increase peak stream flows from 2 to 2000 times. Increased stream flows following wildfire are primarily attributed to increased runoff associated with areas of hydrophobic soil and reduced transpiration due to reduction in vegetation.

- The Gondola Fire in the Lake Tahoe Basin resulted in immediate and long-term increases in labile nutrient concentrations (primarily nitrate and SRP) throughout the burned watershed and its tributary streams, persisting for 3-4 years.

- Wildfire typically results in large losses of N due to volatilization and translocation downward into the soil. Longer-term studies of in-stream nitrate concentration following wildfires have reported a fairly consistent temporal trend: nitrate increases during storms for several months following a wildfire with mean or maximum monthly nitrate concentrations and loading continuing to increase until a peak is reached in the first or second year after the wildfire during spring snowmelt followed by a slow decline thereafter.

- Many of the highest nitrate concentrations in stream water have been measured during storms within weeks or months following fire.

- P increases following wildfire predominantly occur in the ash layer at or near the surface. Since P is not as readily translocated downward in the soil as N compounds, increases in stream water P concentrations are typically the result of off-site particulate transport from ash convection, runoff and erosion and can be quite drastic immediately following wildfire.

- Nitrate accounts for the majority of the total N and SRP accounts for the majority of the total P measured in surface water following a wildfire.

- Research on the effects of pile burning on soil physical and chemical properties and surface water quality is extremely limited and generally inconclusive. Initial results suggest that soil impacts in burned areas have little effect on downstream nutrient concentrations.

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Appendix A

Stream Channel Erosion Nutrient Framework Analysis

by 2nd Nature, Inc.

The Stream SCG is tasked with evaluating pollutant load generation and associated pollutant control options (PCOs) from in-channel processes, primarily through the erosion of channel toe, bed and bank sediments. Empirical modeling efforts are used by the Stream SCG to estimate the sediment load reductions anticipated as a result of implementation of various PCOs within Lake Tahoe stream channels. The Stream SCG is also interested in capturing and evaluating the potential impacts various PCOs may have on the fate and transport of nitrogen and phosphorous in the stream environment. The Stream SCG presents a simplified approach to estimate potential total phosphorous load reductions using existing sediment generation modeling efforts conducted by the Stream SCG. In an effort to better capture and communicate the potential functional relationships between various stream channel conditions and relative N and P fate and transport, the Stream SCG presents and explores a number of functional schematics. While the schematics do not provide quantitative estimates of N and P loads anticipated with stream conditions, they do communicate both the interacting processes and relative sources and sinks of nutrients in three distinct channel conditions reflecting a range from existing degraded status to restored conditions through PCO implementation.

Modeling nutrients from stream erosion

The primary pollutants of concern for the Lake Tahoe TMDL include total suspended sediment (TSS), the fine sediment fraction (< 63 um), total nitrogen (TN), dissolved nitrogen (DN), total phosphorus (TP) and dissolved phosphorous (DP). The current Lake Tahoe pollutant loading budget employed by the TMDL assumes that stream channel erosion contributes over 25% of the total fine particle load to Lake Tahoe, but only 2.5% and 4% of the annual TN and TP loading to the Lake, respectively. The Stream SCG is using empirical modeling efforts to quantify the annual reductions of sediment anticipated from in-stream PCOs. The Stream SCG assumes that stream bank sediments contain very little TN, deeming the efforts associated with attempting to estimate TN loads generated from in-channel bank erosion unnecessary. Phosphorous, in contrast, is present in measurable concentrations within the volcanic and granitic geology that comprises the Tahoe Basin.

TP loads generated from stream channel erosion can be simply estimated by applying a scaling factor based on the average phosphorus content of channel sediments. Tahoe-specific data exists to perform such estimates. Analyses of bank sediments from potentially erodable portions of LTIMP streams indicate that total phosphorus (TP) composes 0.0075-0.0199% (mean = 0.0153%) of the total sediment mass (Ferguson 2005; Ferguson and Qualls 2005;). Using this value, modeled sediment loads can easily be converted to simple estimates for phosphorus loads.

While the Stream SCG is tasked with addressing pollutant sources generated within the stream channel, water quality sampling data from Tahoe streams indicate that in-stream relationships between total suspended sediment (TSS) and TP do not only reflect the channel sediment sources. Using available USGS water quality and discharge data, TSS and TP instantaneous loads were correlated for 4 of the 5 largest stream sediment sources to Lake Tahoe – Upper Truckee River, Ward Creek, Blackwood Creek and General Creek. USGS data are not available for Third Creek, the 4th largest stream sediment source to Lake Tahoe. The USGS TSS and TP data can be considered an aggregate of all of the contributing material from within the watershed that reaches the USGS gage. Figure 1 indicates that on average TP composes 0.311-0.530% of TSS load across these streams. In comparison to the TP:sediment ratio of 0.0153% contained in Tahoe stream bank sediments (Ferguson 2005; Ferguson and Qualls 2005), these TP:TSS ratios are much larger. The large difference between bank sediment and in-stream TP:TSS ratios suggest that there are other high-phosphorus sediment sources dominating the in-stream TP signal, including upland surface runoff and urban stormwater. These data suggest that simply controlling in-stream sediment generation will reduce overall sediment loads from stream erosion, but bank stabilization alone may not maximize all nutrient retention and cycling opportunities within Tahoe stream systems.

Integrating system-wide functional processes

A framework was developed to qualitatively compare the functional relationships between sediment and nutrient sources/sinks and characteristics of the stream channel and adjacent riparian corridor, including:

- stream channel geometry,
- groundwater connectivity,
- vegetation conditions,
- soil characteristics, and
- stream hydrology.

These characteristics were evaluated across three distinct channel conditions.

- *Existing conditions*: Generic characteristics of existing impaired Lake Tahoe streams with high bank erosion potential.
- *Protected bank conditions*: Toe and bank reinforcement performed to reduce erosive potential but minimal changes made to channel geometry.
- *Restored channel conditions*: Channel geometry modified in an effort to restore many natural fluvial processes.

The purpose of this evaluation is to capture and communicate the functional interactions of these processes and identify the relative magnitude of sources and sinks of sediment and nutrients across these three contrasting channel conditions.

Figures 2 through 4 compare the assumptions regarding channel morphology, groundwater connectivity, vegetation, and soil characteristics for each of the three conditions.

Existing Conditions:

The typical channel morphology under existing conditions is generalized as an enlarged and/or entrenched channel with steep, unprotected banks and a moderate to high erosion risk (Figure 2). Due to the enlarged and/or entrenched existing channel, overbank flow is very infrequent, contributing to a high summer depth to groundwater a short distance from the thalweg and minimal bank and meadow moisture and vegetation. This channel morphology results in the B soil horizon having the greatest hydrologic interactions with the active channel. The B horizon soils have a much lower organic content and associated cation exchange capacity (CEC)[1] than A horizon soils, resulting in much lower opportunity to remove dissolved nutrients from solution due to soil/water interactions.

Protected bank conditions:
The protected bank conditions differ from existing conditions only in the construction of a vegetated rock slope and toe protection designed to reduce in-channel sediment sources (Figure 3). Morphologic, hydrologic, soil and vegetative conditions are assumed to be similar to existing conditions, including infrequent overbank flows, high summer depth to groundwater, low meadow moisture and minimal vegetation. Empirical modeling efforts of protected bank conditions as depicted in Figure 3 suggest that toe and bank protection can effectively be applied even on steep banks to significantly reduce toe and bank sediment loss. Any bank and riparian revegetation efforts under this PCO will need to utilize riparian species able to survive the low bank/meadow moisture conditions and a repressed local groundwater table.

Restored channel conditions:
The restored channel conditions assume that the stream geometry is modified to create a shallower channel by reducing channel slope, increasing channel length by widening the meander belt, raising channel bed elevation, and reducing bank angles (Figure 4). These changes to channel geometry will directly increase overbank flow frequency and duration. As a result, annual bank and terrace soil moisture content also increase, allowing for increased survival of bank and meadow vegetation, increased flood plain sediment deposition, and reduced shear stress within the channel during high flows. Channel morphology results in a significant increase in A horizon soil exposure in the active channel. The high CEC of A horizon soils can act as a nutrient sink under these conditions.

Using the typical characteristics defined for each channel condition, relative sources and sinks of sediment and nutrients within the channel were evaluated (Figures 6 and 7). Arrows indicate the relative contribution of each particular process (ranging from very low/none to high) (Figure 5), and can be used for comparisons within a single condition as well as across conditions. While these relative estimates do not provide quantitative information on pollutant load reductions associated with a particular restoration activity, they provide a framework for evaluating the impacts of restoration on the various functional relationships acting between channel morphology, hydrology, nutrient cycling and sediment generation.

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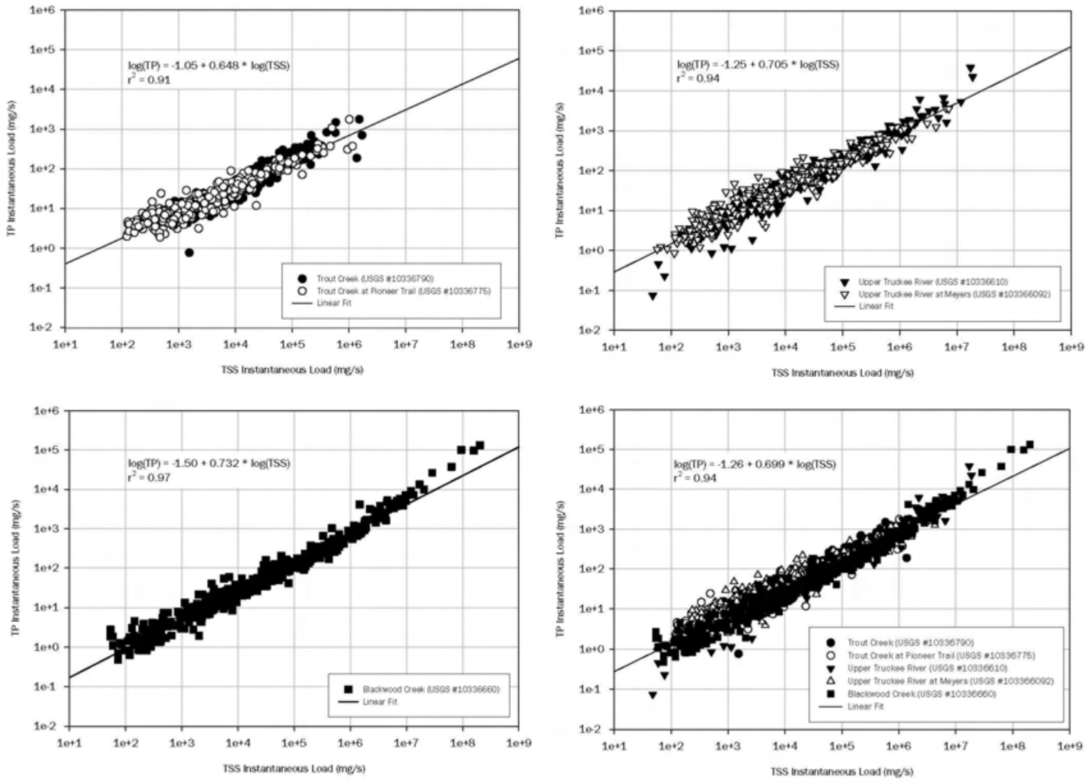
[1] Cation exchange capacity: capacity of a soil for ion exchange with charged ions. It can be used as a measure of potential nutrient retention capacity. Higher values indicate a greater potential for phosphorous and nitrogen removal from stream and groundwater.



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TP content of potentially erodable LTIMP stream bank sediments:
Average: 0.0153%
Range: 0.0075 – 0.0199%

Figure 1: The correlation between TP and TSS instantaneous loads for 4 of the 5 stream sediment sources to Lake Tahoe. Data are presented on a log scale and are for the entire period of USGS record for each gage. For each stream, the mean and median TP as a percentage of TSS are presented. These values exceed the average percentage of TP in Tahoe stream bank sediments (0.0153%) by more than an order of magnitude, suggesting that there are other high-phosphorus sources dominating the in-channel signal. Other watershed sources of phosphorus to the stream water conveyed in-channel potentially include upland surface runoff and urban stormwater.

Source: USGS (waterdata.usgs.gov)

EXISTING CONDITIONS

Channel cross-section
Incised channel: most annual peak flows contained within channel
Low width to depth ratio (w:d)
Over bank flow infrequent
Bank erosion risk at Q > bkfl high
Toe erosion risk at Q > bkfl high
Toe erosion risk at Q<bkfl mod

Channel plan view
Channel slope slightly lower than valley slope
Narrow meander belt

Physical connection to groundwater
Depth to groundwater (z) two stream widths from thalweg deeper than meadow plant root zone.
Low summer moisture content of adjacent marsh deposits
Low summer moisture content of channel banks

Vegetation Conditions
Low riparian vegetation density and survival
Low terrace meadow vegetation density and survival

Soil Conditions
A horizon soils have high organic content and CEC 150-300 meq/100g. A horizon rarely inundated by stream flows.
B horizon soils exposed/unvegetated on banks. B horizon soils have lower organic content and lower CEC (10-20 meq/100g).

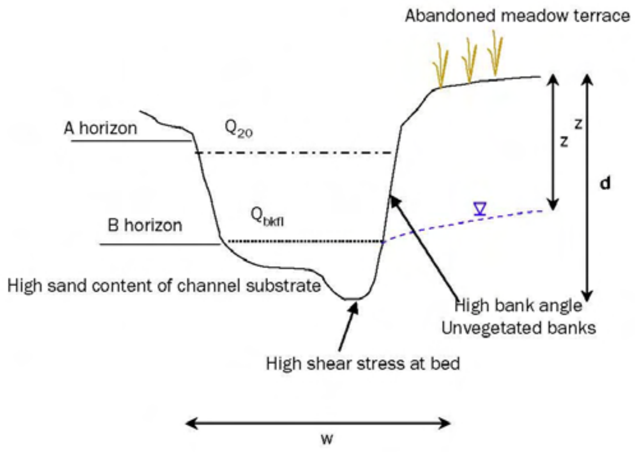
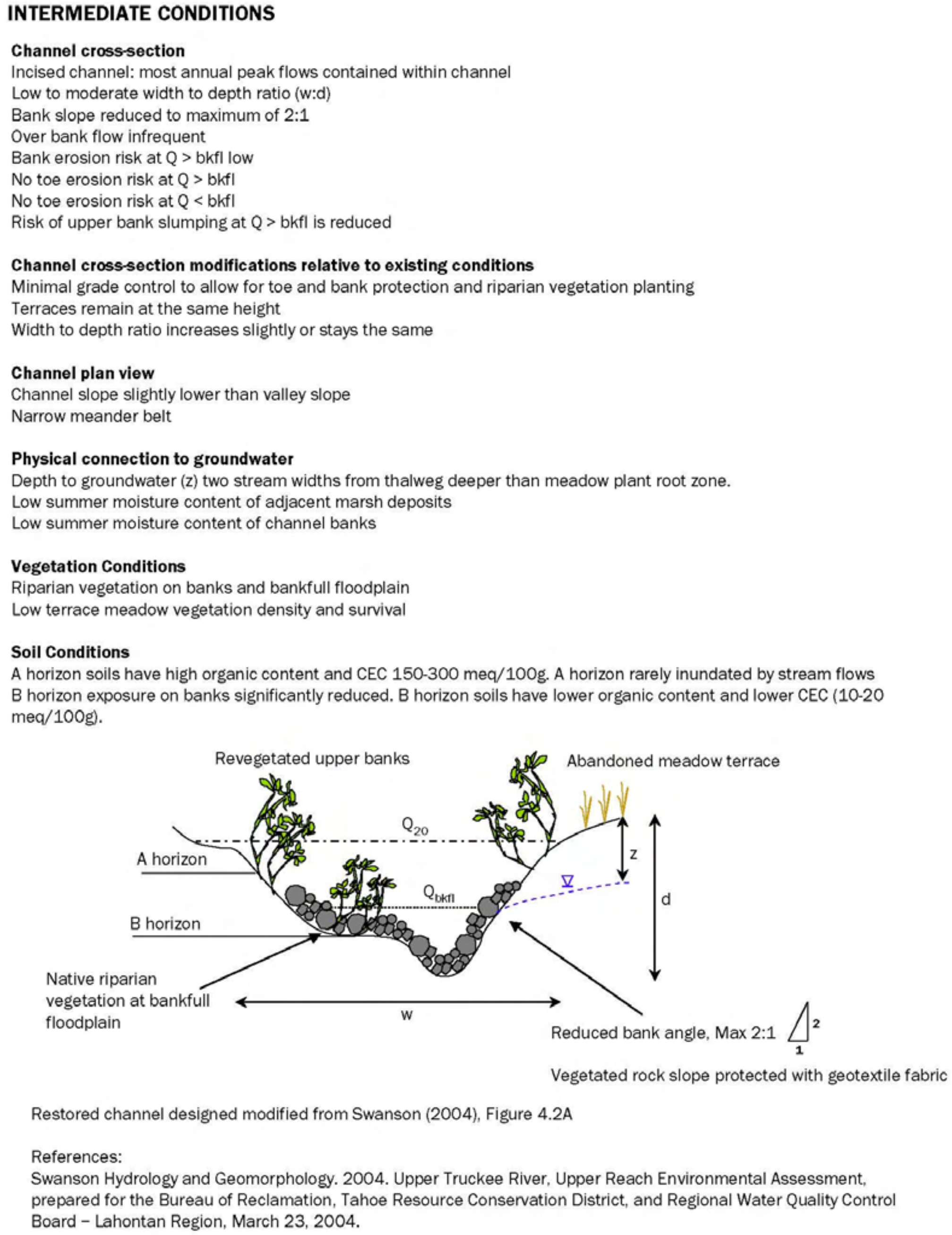


Figure 2. Generalized stream characteristics under existing conditions.



INTERMEDIATE CONDITIONS

Channel cross-section
Incised channel: most annual peak flows contained within channel
Low to moderate width to depth ratio (w:d)
Bank slope reduced to maximum of 2:1
Over bank flow infrequent
Bank erosion risk at Q > bkfl low
No toe erosion risk at Q > bkfl
No toe erosion risk at Q < bkfl
Risk of upper bank slumping at Q > bkfl is reduced

Channel cross-section modifications relative to existing conditions
Minimal grade control to allow for toe and bank protection and riparian vegetation planting
Terraces remain at the same height
Width to depth ratio increases slightly or stays the same

Channel plan view
Channel slope slightly lower than valley slope
Narrow meander belt

Physical connection to groundwater
Depth to groundwater (z) two stream widths from thalweg deeper than meadow plant root zone.
Low summer moisture content of adjacent marsh deposits
Low summer moisture content of channel banks

Vegetation Conditions
Riparian vegetation on banks and bankfull floodplain
Low terrace meadow vegetation density and survival

Soil Conditions
A horizon soils have high organic content and CEC 150-300 meq/100g. A horizon rarely inundated by stream flows
B horizon exposure on banks significantly reduced. B horizon soils have lower organic content and lower CEC (10-20 meq/100g).

Restored channel designed modified from Swanson (2004), Figure 4.2A

References:
Swanson Hydrology and Geomorphology. 2004. Upper Truckee River, Upper Reach Environmental Assessment, prepared for the Bureau of Reclamation, Tahoe Resource Conservation District, and Regional Water Quality Control Board – Lahontan Region, March 23, 2004.

Figure 3. Generalized stream characteristics under protected bank conditions.

DESIRED CONDITIONS

Channel cross-section
Channel at grade with adjacent meadow
Annual peak flows typically access floodplain
High width to depth ratio (w:d)
Overbank flow frequent
Bank erosion risk at Q > bkfl low
Toe erosion risk at Q > bkfl moderate

Channel plan view
Channel slope << valley slope
Widened meander belt

Physical connection to groundwater
Depth to groundwater (z) two stream widths from thalweg is within meadow plant root zone.
Adequate summer moisture content of adjacent marsh deposits
Moderate summer moisture content of channel banks

Vegetation Conditions
High riparian vegetation density and survival
High terrace meadow vegetation density and survival

Soil Conditions
Increased surface area of A horizon soils in active channel
A horizon in frequent contact with stream flows
B horizon exposure on banks significantly reduced
Sand fraction of channel substrate reduced

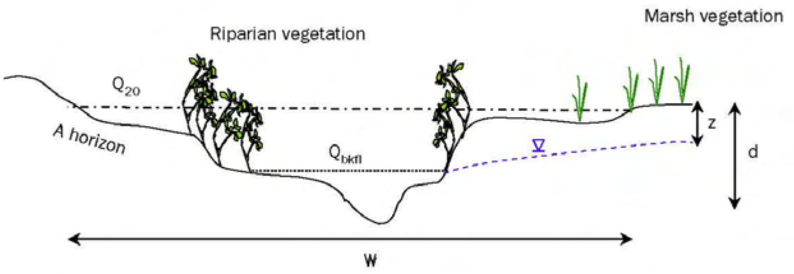


Figure 4. Generalized stream characteristics under restored channel conditions.

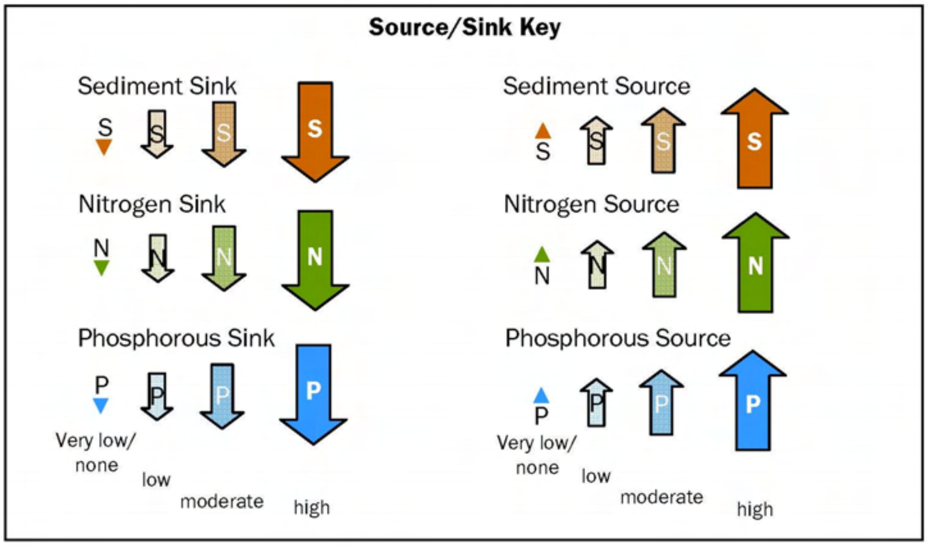


Figure 5. Key used to indicate relative magnitudes of estimated annual sediment and nutrient sources and sinks in comparisons of stream channel conditions (Figures 6 and 7).

The Stream SCG assumes that channel morphology primarily impacts the stream channel sediment/nutrient budgets by affecting:

- hydrologic conditions and erosion potential (Figure 6), and
- seasonal groundwater dynamics and vegetation health (Figure 7).

Figure 6 displays the relative sediment and nutrient sources and sinks for the three channel conditions as they relate to channel morphology, hydrology and erosion potential under two flow conditions (Q < bankfull; bankfull < Q < 20 year recurrence interval (RI)). Extreme flow conditions (Q > 20 year RI) were not considered due to the infrequency of these flows and the minimal data available on which to base relative pollutant sources and sinks.

Figure 7 contrasts spring conditions with typical late summer conditions to compare the seasonal extremes of groundwater levels and vegetation. The Stream SCG recognizes that groundwater and vegetation dynamics vary spatially and are not strictly seasonally dominated, but these are general assumptions that attempt to represent nutrient cycling processes acting in a typical stream reach.

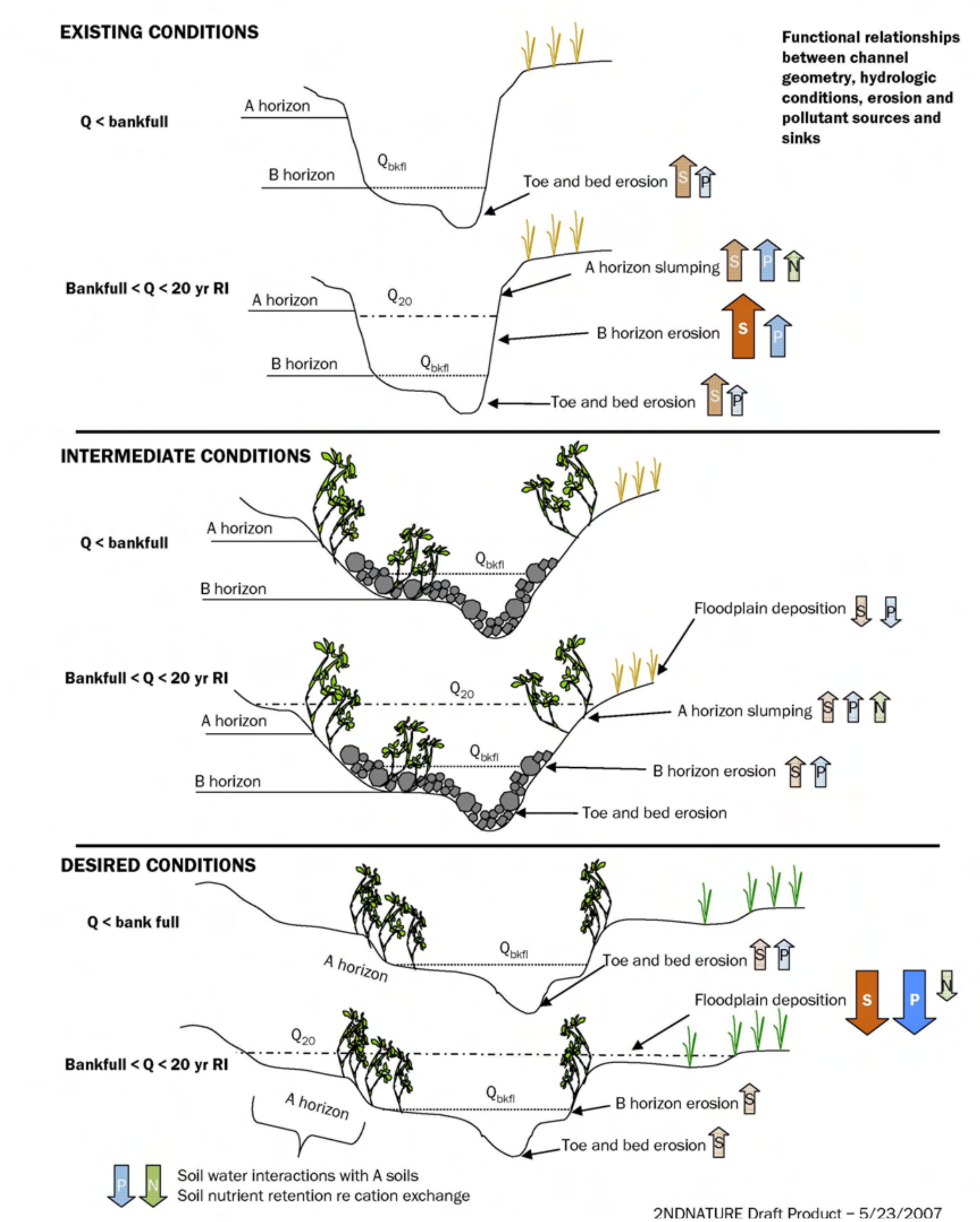


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Figure 6. Three channel conditions as they relate to channel morphology, hydrology and erosion potential under two flow conditions

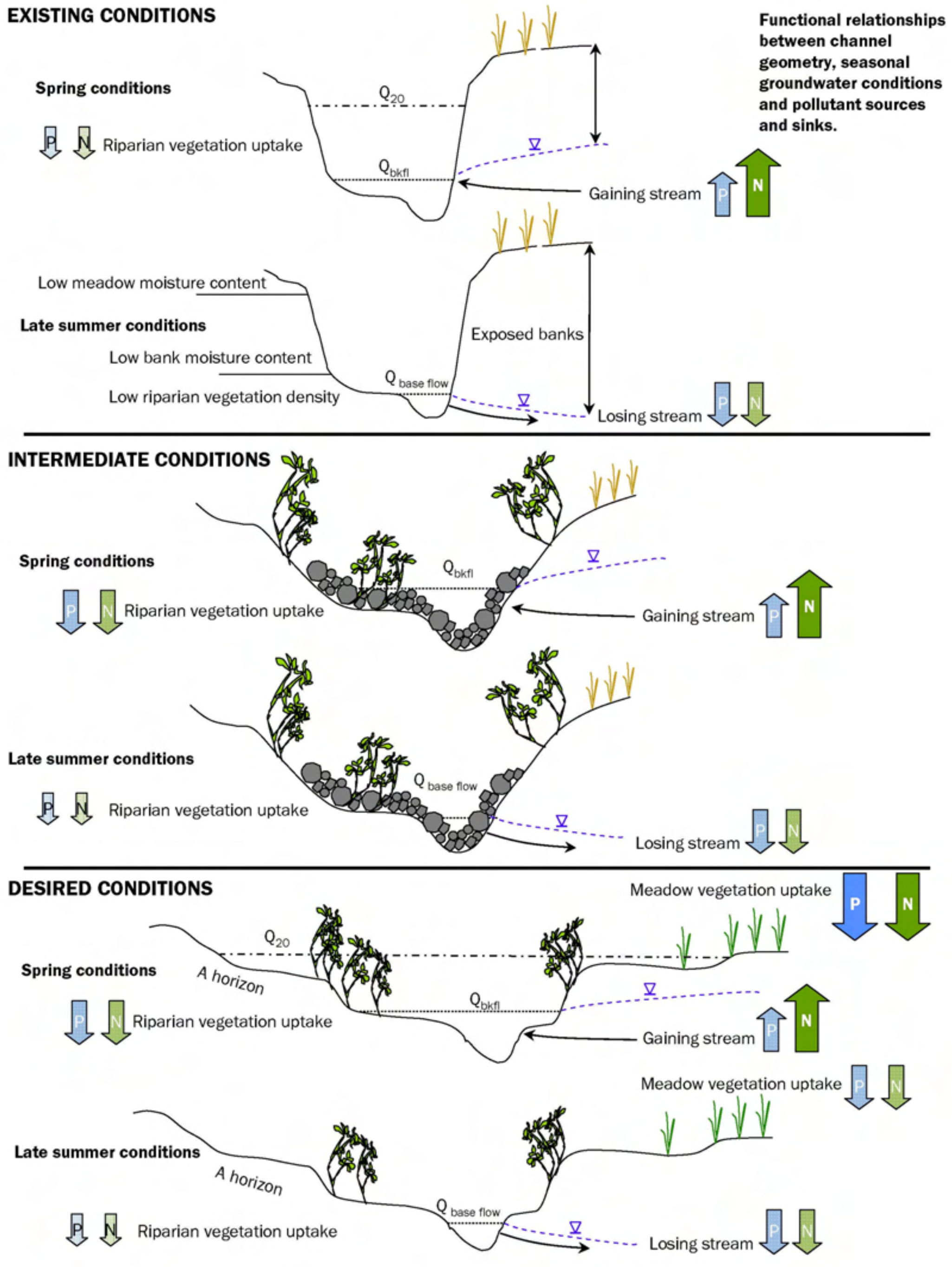

Figure 7. Three channel conditions as they relate to spring conditions and typical late summer conditions in relation to groundwater levels and vegetation

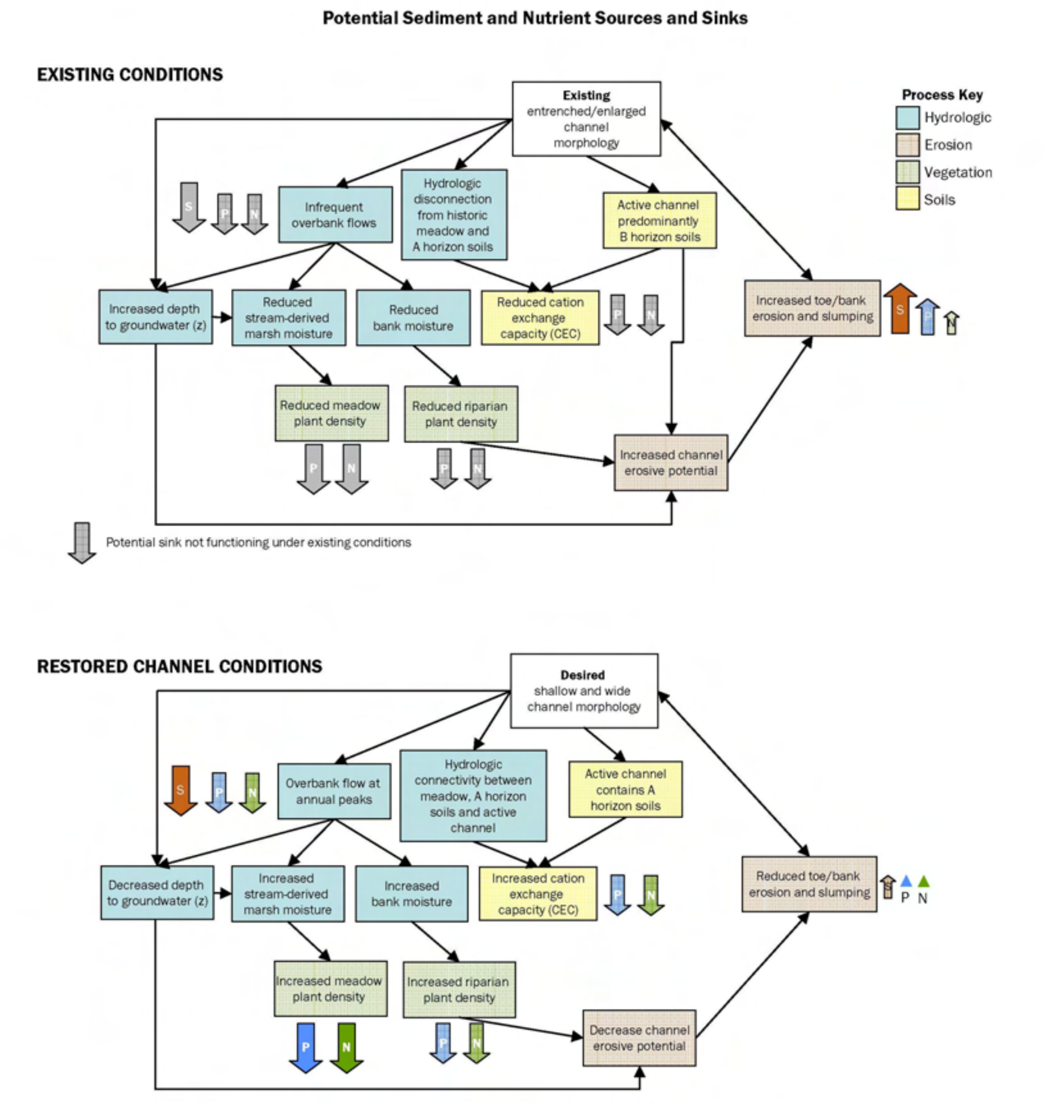

Figure 8. Conceptual models linking major channel processes acting as sediment sources and sinks under existing conditions and restored channel conditions. Under both conditions, positive feedback cycles are present, linking the channel morphology to processes that promote the persistence of that morphology.

As displayed in Figures 6 and 7, the primary source and sink processes assumed to be acting under the three channel conditions are:

- *Existing conditions*:
    - Moderate to high sediment and associated nutrient loads are generated from toe, bed and bank erosion and terrace slumping due to majority of flow conditions contained within the channel.
    - Sediment and nutrient losses from the water channel via particle settling and riparian/meadow vegetation uptake are minimal due to infrequent overbank flows. Depressed water table that impairs riparian vegetation density and survival.
    - Majority of soil/water interactions occur with B horizon soils. Minimal nutrient uptake occurs due to the low CEC of B horizon soils.

- *Protected bank conditions*:
    - Sediment and nutrient sources from toe, bed and bank erosion and terrace slumping are minimized even during high flow conditions.
    - Channel morphology remains similar to existing conditions, characterized by infrequent overbank flow events. No change occurs in sediment and nutrient sinks as a result of flood plain deposition.
    - A slight increase in nutrient uptake occurs through riparian revegetation plantings, assuming survival. Channel morphology limits seasonal bank and adjacent meadow moisture, which will directly influence vegetation density, survival and associated nutrient uptake.
    - Minimal nutrient removal occurs through soil water interactions due to low CEC of channel armor (riprap) and/or B soils.

- *Restored channel conditions*:
    - Low sediment and nutrient loads are generated from toe, bed and bank erosion due to lower bank angles, higher frequency of overbank flow, and a reduced sheer stress on bed and banks. Frequent floodplain interaction deposits sediment and nutrients on the flood plain.
    - Increased seasonal groundwater levels improve soil moisture content of banks and adjacent meadow. The presence of riparian vegetation assists in stabilizing banks. Resulting meadow and riparian vegetation uptake is a relatively large N and P nutrient sink.
    - Moderate nutrient retention occurs through soil water interactions with A horizon soil with high CEC.

Figure 8 presents two conceptual models to compare the major fluvial processes within the two bookend stream conditions – existing and restored channel. These conceptual models demonstrate the interrelatedness between channel morphologic, hydrologic, erosive, vegetative and soil-related processes. In restored channel conditions, frequent overbank flows and a shallow channel with low bank angles promote sediment deposition, shear stress reduction within the stream, and riparian and meadow vegetation survival. All of these processes can act as important sediment and nutrient sinks within the stream system. Riparian and meadow vegetation also contribute to bank stability, in turn reducing bed and bank erosion and helping to maintain a more stable channel with relatively lower sediment generation. These processes do not function as efficiently in an entrenched or enlarged channel with steep, exposed banks.

Under both channel conditions, there are feedback loops operating. An impaired channel morphology results in a repressed groundwater table and reduced surrounding soil moisture. This in turn limits vegetation survival and nutrient uptake, making the channel banks more susceptible to erosion. This cycle continues to perpetuate sediment inputs from the channel banks and prevents the maximization of potential nutrient and sediment sinks. On the other hand, a desired channel morphology supports groundwater recharge, bank moisture and floodplain deposition. These in turn maximize vegetation growth and channel bank and bed stability, creating a more sustainable stream system. A conceptual model for the protected bank condition is not presented, but Figure 8 displays the potential primary and secondary effects of an entrenched and/or enlarged channel morphology.

While several specific PCOs to control bank sediment sources may be effective at decreasing sediment and the associated low nutrient loads directly from channel sources, these PCOs vary in their ability to simultaneously provide possible sinks for sediment and nutrients originating upstream and upslope. This influences the overall benefit of the stream erosion PCOs, and should be considered in their cost/benefit analysis.

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Ferguson, J.W. and R.G. Qualls. 2005. Biological available phosphorus loading to Lake Tahoe. Final report submitted to Lahontan regional Water Quality Control Bd., South Lake Tahoe, CA.

Appendix B

Stream Channel Erosion Pollutant Control Options Screening

by Valley & Mountain Consulting

				Literature-Based Load Reduction Estimates				Data Sources for Quantifying Effectiveness			
Identified PCO*	**Specific PCOs/Strategies***	**Screening Rationale**	**Preferred PCO**	**SS Load Reduction**	**Lit Source(s)**	**TP Load Reduction**	**Lit Source(s)**	**Design Standards**	**Empirical Data**	**BSTEM Modeling**	**Interpolation**
Peak flow and duration management	Manage flows (with on- or off-channel storage and releases);	No regulating facilities on basin streams of adequate size to affect large peak flows.	N					N	N	?	N
	Restore in-stream hydrologic characteristics;	Vague description; unlikely to have substantial WQ benefit in existing incised channels.	N								
	Constructed wetlands;	Unlikely that areas of constructed wetlands would be adequate to reduce peak flows enough for beneficial WQ response; Possibly applicable in some settings.	N	69%; 14% Urban, 56% non-urban	Knight et al., 1993; Reinelt and Horner 1995	55%; 80 %	Knight et al., 1993; Reinhelt and Horner 1995	N	Y	N	N
Tributary/outfall treatments	Modify local hydraulics to reduce shear stress	Only applies to localized spots; can be represented by more general bank and/or bed protection PCOs for this analysis.	N					Y	N	N	N
Streamside land use buffers	Prevent vegetation removal and/or soil compaction along streambanks;	Unlikely to have substantial WQ benefit individually and little information upon which to quantify --but, may be represented by bank strengthening with vegetation scenario in BSTEM.	N					N	N	N	?
	Alleviate compacted soils;	Unlikely to have substantial WQ benefit individually and little information upon which to quantify --but, may be represented by bank protection scenarios in BSTEM.	N					N	N	N	?
	Increase SEZ setbacks;	Unlikely to have substantial WQ benefit individually and little information upon which to quantify; possibly applicable in some settings and probably would be coupled with other bank treatments or channel restoration.	N					N	N	N	N
	Remove recreation activities;	Unlikely to have substantial WQ benefit individually and little information upon which to quantify; possibly applicable in some settings and probably would be coupled with other bank treatments or channel restoration.	N					N	N	N	N
	Designate riparian conservation areas;	Unlikely to have substantial WQ benefit individually and little information upon which to quantify; possibly applicable in some settings and probably would be coupled with other bank treatments or channel restoration.	N					N	N	N	N
	Transfer development from SEZs;	Unlikely to have substantial WQ benefit individually and little information upon which to quantify; possibly applicable in some settings and probably would be coupled with other bank treatments or channel restoration.	N					N	N	N	N
	Buyout coverage and relocate SEZ properties;	Unlikely to have substantial WQ benefit individually and little information upon which to quantify; possibly applicable in some settings and probably would be coupled with other bank treatments or channel restoration.	N					N	N	N	N
Floodplain constriction / fill removal	Restore floodplain area;	Likely to have substantial WQ benefit, but probably would need to be coupled with other bank treatments or channel restoration.	Y	23 to 91 %; 8 to 93%	Phillips, 1989; van der Lee et al., 2004			N	Y	N	?
	Transfer development from SEZs;	Unlikely to have substantial WQ benefit individually and little information upon which to quantify; possibly applicable in some settings and probably would be coupled with other bank treatments or channel restoration.	N					N	N	N	N
	Buyout and relocation of SEZ properties;	Unlikely to have substantial WQ benefit individually and little information upon which to quantify; possibly applicable in some settings and probably would be coupled with other bank treatments or channel restoration.	N					N	N	N	N
	Remove impervious coverage in SEZs and setbacks;	Unlikely to have substantial WQ benefit individually and little information upon which to quantify; possibly applicable in some settings and probably would be coupled with other bank treatments or channel restoration.	N					N	N	N	?
	Remove earthfill and other structures confining flow in channel	Only applies to localized spots; applicable in some settings.	Y					N	?	N	?
Channel constriction removal	Replace outdated, under-sized culverts	Only applies to localized spots--but unlikely to reduce peak flows enough for beneficial WQ response; applicable in some settings.	N					Y	?	N	?
	Replace outdated, under-sized bridges	Only applies to localized spots--but unlikely to reduce peak flows enough for beneficial WQ response; applicable in some settings.	N					Y	N	N	?
Bank Protection-stone	Install streambank stabilization--(rigid)	Likely to have substantial WQ benefit individually and can be coupled with other PCOs; will constitute a bank protection scenario in BSTEM.	Y					Y	?	Y	Y
Bank Protection-flexible geotech mattresses	install streambank stabilization—(flexible)	Likely to have substantial WQ benefit individually and can be coupled with other PCOs; may be represented by other bank protection scenarios in BSTEM.	Y					Y	?	N	?
Bank Protection-LWD / rootwad revetment	Install streambank stabilization—(Anchored LWD);	Likely to have substantial WQ benefit individually and can be coupled with other PCOs; not readily represented in BSTEM.	Y					Y	?	N	?
	Restore woody debris assemblages	Vague description; potential WQ benefits difficult to predict.	N					N	?	N	N
Bank Protection- anchored shrub/brush revetment	Install streambank stabilization—(Anchored shrub)	Vague description; potential WQ benefits difficult to predict.	N					N	?	N	N
Bank Protection- stacked sod revetment	Install streambank stabilization—(Anchored sod)	Likely to have substantial WQ benefit individually and can be coupled with other PCOs; may be represented by other bank strengthening scenarios in BSTEM.	Y	Generally stable 2-5 years after implementation Trout Creek	Swanson H+G 2004			N	Y	N	Y
Bank Strengthening- wet meadow vegetation	Restore streambank vegetation herbaceous-- (via soil improvements, soil moisture increases) wet meadow 'sod' growing on banks	Likely to have substantial WQ benefit individually and can be coupled with other PCOs; will constitute a bank strengthening scenario in BSTEM.	Y	90% decrease in erodibility and number of failures; 84% decrease in migration rate	Micheli and Kirchner 2002 a and b			N	Y	Y	Y

				Literature-Based Load Reduction Estimates				Data Sources for Quantifying Effectiveness			
Identified PCO*	**Specific PCOs/Strategies***	**Screening Rationale**	**Preferred PCO**	**SS Load Reduction**	**Lit Source(s)**	**TP Load Reduction**	**Lit Source(s)**	**Design Standards**	**Empirical Data**	**BSTEM Modeling**	**Interpolation**
Bank Strengthening-woody riparian vegetation	Restore streambank vegetation woody--(via soil improvements, soil moisture or stream dynamics-seed beds)	Likely to have substantial WQ benefit individually and can be coupled with other PCOs; will constitute a bank strengthening scenario in BSTEM.	Y	44 to 60% decrease bank erosion with Rip forest vs Ag banks	Micheli et al., 2004			N	Y	Y	Y
Grade Control Structure-non porous material	Install keyed sheet pile/concrete sills etc.	Likely to have substantial WQ benefit when coupled with other PCOs where bed and bank stabilization are both needed; WQ benefits difficult to predict with BSTEM.	Y					Y	Y	N	Y
Grade Control Structure-porous rock material	Install keyed boulder/cobble wiers, riffles, etc.	Likely to have substantial WQ benefit when coupled with other PCOs where bed and bank stabilization are both needed; WQ benefits difficult to predict with BSTEM.	Y					Y	Y	N	?
Grade Control Structure-porous rock and LWD	Install keyed boulder/LWD jams;	Vague description; potential WQ benefits difficult to predict.	N					N	?	N	N
	Restore woody debris assemblages	Vague description; potential WQ benefits difficult to predict.	N					N	?	N	?
Channel fill with bank toe stabilization	Recreate hydrologic connectivity in streams, meadows, and wetlands--Raise streambed elevation within incised channel	Likely to have substantial WQ benefit individually and can be coupled with other PCOs; will constitute a stabilization scenario in BSTEM.	Y					N	N	Y	Y
Bank lowering +floodplain excavation	Recreate hydrologic connectivity in streams, meadows, and wetlands--Excavate bank to create connected active floodplain	Likely to have substantial WQ benefit individually and can be coupled with other PCOs; may be represented by BSTEM.	Y	23 to 91 %; 8 to 93%	Phillips, 1989; van der Lee et al., 2004	60% increase in nutrient retention	Narinesingh, 1995	N	Y	?	?
Bank lowering +angle reduction	Recreate hydrologic connectivity in streams, meadows, and wetlands--Excavate and contour bank to reduce angle and/or improve bank vegetation	Likely to have substantial WQ benefit individually and can be coupled with other PCOs; may be represented by BSTEM.	Y	23 to 91 %; 8 to 93%	Phillips, 1989; van der Lee et al., 2004	60% increase in nutrient retention	Narinesingh, 1995	N	Y	?	?
Channel reconstruction	Reconstruct natural geomorphic characteristics;	Likely to have substantial WQ benefit and can incorporate other PCOs; WQ benefits difficult to predict with BSTEM.	Y	reduced mid-winter 50%; increased snowmelt 60%	Susfalk 2006 (only 1 year)			N	?	N	?
	Restore sinuosity to channelized streams;	Likely to have substantial WQ benefit when coupled with other PCOs; will consitute a channel slope reduction scenario in BSTEM.	Y					N	?	Y	Y
	Recreate hydrologic connectivity in streams, meadows, and wetlands	Likely to have substantial WQ benefit and can incorporate other PCOs; WQ benefits difficult to predict with BSTEM.	Y	23 to 91 %; 8 to 93%	Phillips, 1989; van der Lee et al., 2004			N	Y	N	Y
Channel restoration	Restore natural geomorphic characteristics through construction and restored processes;	Likely to have substantial WQ benefit and can incorporate other PCOs; WQ benefits difficult to predict with BSTEM and uncertain as system responds.	Y					N	?	N	?
	Restore sinuosity to channelized streams;	Likely to have substantial WQ benefit when coupled with other PCOs; will consitute a channel slope reduction scenario in BSTEM.	Y					N	?	?	Y
	Reestablish hydrologic connectivity in streams, meadows, and wetlands	Likely to have substantial WQ benefit and can incorporate other PCOs; WQ benefits difficult to predict with BSTEM and uncertain as system responds.	Y	23 to 91 %; 8 to 93%	Phillips, 1989; van der Lee et al., 2004			N	Y	N	Y
Trout versus Upper Truckee	Non-incised versus Incised stream			(20-34) vs (13-41)	Stubblefield et al., 2005	(13-32) vs (17-28)	Stubblefield et al., 2005				
Trout Creek	functioning stream			20-34 %	Stubblefield et al., 2005	17 to 28%	Stubblefield et al., 2005				
Ijssel versus Waal	Larger, more functional FP versus less			(93-8)	van der Lee et al., 2004	(18-5)	van der Lee et al., 2004				
Trout Marsh	functioning marsh			51-77 %	Stubblefield et al., 2005	43-66%	Stubblefield et al., 2005				
Yellow River	functioning marsh/delta			74%; 82%	Shi et al 2003; Syvitski et al 2005						
Ganges	functioning marsh/delta			30 to 40%; 55%	Goodbred and Juehi 1998; Syvitski et al 2005						
Amazon	functioning marsh/delta			20%	Shi et al 2003						

Appendix C

Stream Channel Erosion Bank Stability and Toe Erosion Modeling Methods

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RESEARCH APPROACH and METHODS

To evaluate potential reduction in fine-sediment loadings emanating from streambanks, it was necessary to analyze the discrete process that control streambank erosion under existing and mitigated conditions. These processes include hydraulic erosion of bank-toe sediments, mass failure of upper-bank materials and the reinforcing effects of vegetation, if present. All of these processes can be modeled using the Bank-Stability and Toe-Erosion Model (BSTEM) developed by the USDA-ARS, National Sedimentation Laboratory (Simon *et al*., 1999; 2000) and has been previously used successfully in the Tahoe Basin to model the influence of riparian vegetation on bank stability along a reach of the Upper Truckee River (Simon *et al*., 2006).

The general research approach was to quantify fine-sediment loadings from streambank erosion for existing conditions and then to investigate the reduction in loadings by simulating various mitigation techniques. To accomplish this, the following tasks were outlined:

1. Select critical erosion sites within watersheds known to produce substantial quantities of fine-sediment from streambank-erosion processes.
2. Quantify annual loadings from streambank erosion for existing conditions at these critical erosion sites by simulating toe-erosion and bank-stability processes with the BSTEM over the course of an annual hydrograph.
3. Quantify annual loadings from streambank erosion for mitigated conditions at these critical erosion sites by simulating toe-erosion and bank-stability processes with the BSTEM over the course of the same annual hydrograph.
4. Compare loadings reductions for the modeled sites and extrapolate results to the remainder of the channel system and to other watershed sin the Tahoe Basin.

Bank Stability and Toe-Erosion Model (BSTEM)

The original BSTEM model (Simon *et al*. 1999) allowed for 5 unique layers, accounted for pore-water pressures on both the saturated and unsaturated parts of the failure plane, and the confining pressure from streamflow. The enhanced BSTEM (Version 4.1) includes a sub-model to predict bank-toe erosion and undercutting by hydraulic shear. This is based on an excess shear-stress approach that is linked to the geotechnical algorithms. Complex geometries resulting from simulated bank-toe are used as the new input geometry for the geotechnical part of the bank-stability model. If a failure is simulated, that new bank geometry can be exported back into either sub-model to simulate conditions over time by running the sub-models iteratively with different flow and water-table conditions. In addition, the enhanced bank-stability sub-model allows the user to select between cantilever and planar-failure modes and allows for inclusion of the mechanical, reinforcing effects of riparian vegetation (Simon and Collison, 2002; Micheli and Kirchner, 2002; Pollen and Simon 2005).

Bank-Toe Erosion Sub-Model

The Bank-Toe Erosion sub-model can be used to estimate erosion of bank and bank-toe materials by hydraulic shear stresses. The effects of toe protection can also be incorporated. The model calculates an average boundary shear stress from channel geometry and flow parameters using a rectangular-shaped hydrograph defined by flow depth and flow duration, and considers critical shear stress and erodibility of separate zones with potentially different materials at the bank and bank toe. The bed elevation is fixed because the model does not incorporate, in any way, the simulation of sediment transport.

Toe erosion by hydraulic shear is calculated using an excess shear approach. The average boundary shear stress (τ_o) acting on each node of the bank material is calculated using:

$$\tau_o = \gamma_w R S \tag{1}$$

where τ_o = average boundary shear stress (Pa), γ_w = unit weight of water (9.81 kN/m^3), R = local hydraulic radius (m) and S = channel slope (m/m).

The average boundary shear stress exerted by the flow on each node is determined by dividing the flow area at a cross-section into segments that are affected only by the roughness of the bank or bed and then further subdividing to determine the flow area affected by the roughness of each node. The line dividing the bed- and bank- affected segments is assumed to bisect the average bank angle and the average bank toe angle (Figure 1). The hydraulic radius of the flow on each segment is the area of the segment (A) divided by the wetted perimeter of the segment (P_n). Fluid shear stresses along the dividing lines are neglected when determining the wetted perimeter.

An average erosion rate (in m/s) is computed for each node by utilizing an excess-shear stress approach (Partheniades, 1965). This rate is then integrated with respect to time to yield an average erosion distance (in cm; Figure 1). This method is similar to that employed in the CONCEPTS model (Langendoen, 2000) except that erosion is assumed to occur normal to the local bank angle, not horizontally:

$$E = k \, \Delta t \, (\tau_0 - \tau_c) \tag{2}$$

where E = erosion distance (cm), k = erodibility coefficient (cm^3/N-s), Δt = time step (s), τ_0 = average boundary shear stress (Pa), and τ_c = critical shear stress (Pa).

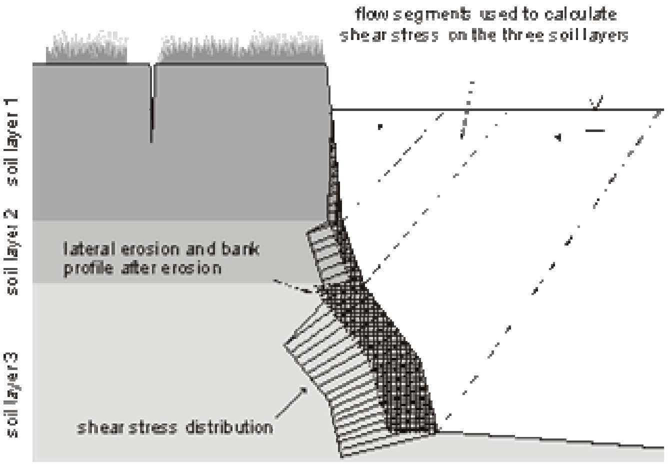


Figure 1. Segmentation of local flow areas and hydraulic radii.

Resistance of bank-toe and bank-surface materials to erosion by hydraulic shear is handled differently for cohesive and non-cohesive materials. For cohesive materials the relation developed by Hanson and Simon (2001) using a submerged jet-test device (Hanson, 1990) is used:

$$k = 0.2\ \tau_c^{-0.5} \qquad (3)$$

The Shields (1936) criteria is used for resistance of non-cohesive materials as a function of roughness and particle size (weight), and is expressed in terms of a dimensionless critical shear stress:

$$\tau^* = \tau_o / (\rho_s - \rho_w)\, g\, D \qquad (4)$$

where τ^* = critical dimensionless shear stress; ρ_s = sediment density (kg/m^3); ρ_w = water density (kg/m^3); g = gravitational acceleration (m/s^2); and D = characteristic particle diameter (m).

Bank Stability Sub-Model

The bank stability sub-model combines three limit equilibrium-methods to calculate a Factor of Safety (F_s) for multi-layered streambanks. The methods simulated are horizontal layers (Simon and Curini, 1998; Simon *et al*., 2000), vertical slices for failures with a tension crack (Morgenstern and Price, 1965) and cantilever failures (Thorne and Tovey, 1981).

For planar failures the Factor of Safety (F_s) is given by:

$$F_s = \frac{\sum_{i=1}^{I}\left(c_i' L_i + S_i \tan\phi_i^b + \left[W_i \cos\beta - U_i + P_i \cos(\alpha - \beta)\right]\tan\phi_i'\right)}{\sum_{i=1}^{I}\left(W_i \sin\beta - P_i \sin[\alpha - \beta]\right)} \qquad (5)$$

where c_i' = effective cohesion of ith layer (kPa), L_i = length of the failure plane incorporated within the ith layer (m), S_i = force produced by matric suction on the unsaturated part of the failure surface (kN/m), W_i = weight of the ith layer (kN), U_i = the hydrostatic-uplift force on the saturated portion of the failure surface (kN/m), P_i = the hydrostatic-confining force due to external water level (kN/m), β = failure-plane angle (degrees from horizontal), α = bank angle (degrees from horizontal), and I = the number of layers.

For planar failures with a tension crack F_s is determined by the balance of forces in horizontal and vertical directions for each slice and in the horizontal direction for the entire failure block. F_s is given by:

$$F_s = \frac{\cos\beta \sum_{j=1}^{J}\left(c_j' L_j + S_j \tan\phi_j^b + \left[N_j - U_j\right]\tan\phi_j'\right)}{\sin\beta \sum_{j=1}^{J}\left(N_j\right) - P_j} \qquad (6)$$

The cantilever shear failure algorithm is a further development of the method employed in the CONCEPTS model (Langendoen, 2000). The F_s is given by:

$$F_s = \frac{\sum_{i=1}^{I} \left(c'_i L_i + S_i \tan \phi_i^b - U_i \tan \phi_i' \right)}{\sum_{i=1}^{I} \left(W_i - P_i \right)} \qquad (7)$$

The model is easily adapted to incorporate the effects of geotextiles or other bank stabilization measures that affect soil strength. This version of the model assumes hydrostatic conditions below the water table, and a linear interpolation of matric suction above the water table.

Vegetation Effects

The reinforcing effect of riparian vegetation was accounted for where applicable. This was achieved by adding cohesion to certain bank layers to simulate the effect of root-reinforcement on streambank stability. Root-reinforcement estimates were obtained using the RipRoot model (Pollen and Simon, 2005; Pollen, 2006), which takes into account a distribution of different diameter roots, with corresponding tensile strengths determined for each species, acting over a failure plane. RipRoot estimates the reinforcement provided by roots crossing the shear plane, based on an algorithm that allows progressive loading of the streambank, breaking of roots and associated redistribution of stresses as root breakage or pullout occurs.

Site Selection

Critical erosion sites were selected from the three watersheds known to contribute the greatest amounts of fine sediment by streambank processes; Upper Truckee River, Blackwood Creek and Ward Creek (Simon, 2006). A summary of site characteristics for the modeled streambanks is shown in Table 1, all of which have actively eroding streambanks.

Table 1. General site characteristics for modeled streambanks

Stream	Location (km)	Bank height (m)	Special characteristics
Blackwood Creek	1.94	3.0	No top-bank vegetation
	2.39	2.4	Lemmon's willow (moderate)
Upper Truckee River	4.51	2.6	Meadow vegetation
	8.45	1.9	Mixed meadow and woody vegetation
	13.1	2.7	Golf course with lodgepole pine
Ward Creek	2.48	14.9	14.9 m steep, terrace slope adjacent to channel; coarse material at toe; Mature conifers
	3.60	1.3	Meadow vegetation

Input Data

As in any deterministic model, input data are required that define the appropriate force and resistance mechanisms that control processes. For the BSTEM, two groups of data are required: (1) data that quantify the driving and resisting forces for erosion by hydraulic shear and, (2) geotechnical data that define the gravitational forces that control mass failure (Table 2). Geotechnical and hydraulic-resistance data were collected in 2002 along the Upper Truckee River and Ward Creek as part of an earlier study and supplemented with additional data along these streams and along Blackwood Creek in 2006. Apparent cohesion (c_a) and friction angle (ϕ) of *in situ* bank sediments were obtained using a borehole shear test device (BST). Bulk unit weight (γ) was obtained from core samples of known volume that were processed (weighed) in the sediment laboratory at NSL. Pore-water pressure at the time of geotechnical testing was obtained with miniature, digital tensiometers and used to calculate effective cohesion (c'). For cohesionless materials (sands and gravels) critical shear stress (τ_c) was obtained from the particle-size distribution of a sample using a Shields-type approach. The erodibility coefficient (k) was then obtained from a relation developed by Hanson and Simon (2001). For cohesive sediments, a submerged jet-test device was employed *in situ* which provides data on τ_c and k.

Table 2. Summary of input requirements for the BSTEM

Sub-Model			
Toe erosion (hydraulic)		**Bank stability (geotechnical)**	
Driving	**Resisting**	**Driving**	**Resisting**
Flow depth (y)	Critical shear stress (τ_c)	Bank height (H)	Effective cohesion (c')
Channel gradient (S)	Erodibility coefficient (k)	Bank slope (a)	Effective friction angle (ϕ)
Flow duration (h)		Bulk unit weight (γ)	Bulk unit weight (γ)
			Vegetation (c_r)
		Pore-water pressure (μ)	Matric suction (μ)

Derivation of Hydraulic Data

To provide for the driving, hydraulic forces, an annual hydrograph was required. It was decided to use a typical high-flow year that contained series of high flow events and long durations to represent a worst-case scenario. Calendar year 1995 was selected for this purpose. In addition, the rain-on snow event of January 1, 1997 was added to the end of the 1995 data set. Stage data from four USGS gauging stations were discretized into individual events of given duration to be used as input into the toe-erosion sub-model (Figure (2). Data from gauging station 103366610 was used for the two downstream-most sites on the Upper Truckee River while data from station 103366092 was used for the more upstream site at the golf course (Table 1; Figure 2). A 48-hour flow duration was used for the January 1, 1997 event with depths ranging from 0.64 m at the Ward Creek site, 1.55 m at the Blackwood Creek sites, and 1.8 m for the Upper Truckee River sites. Details of the mean flow depths and durations for each event are provided in Table 3.

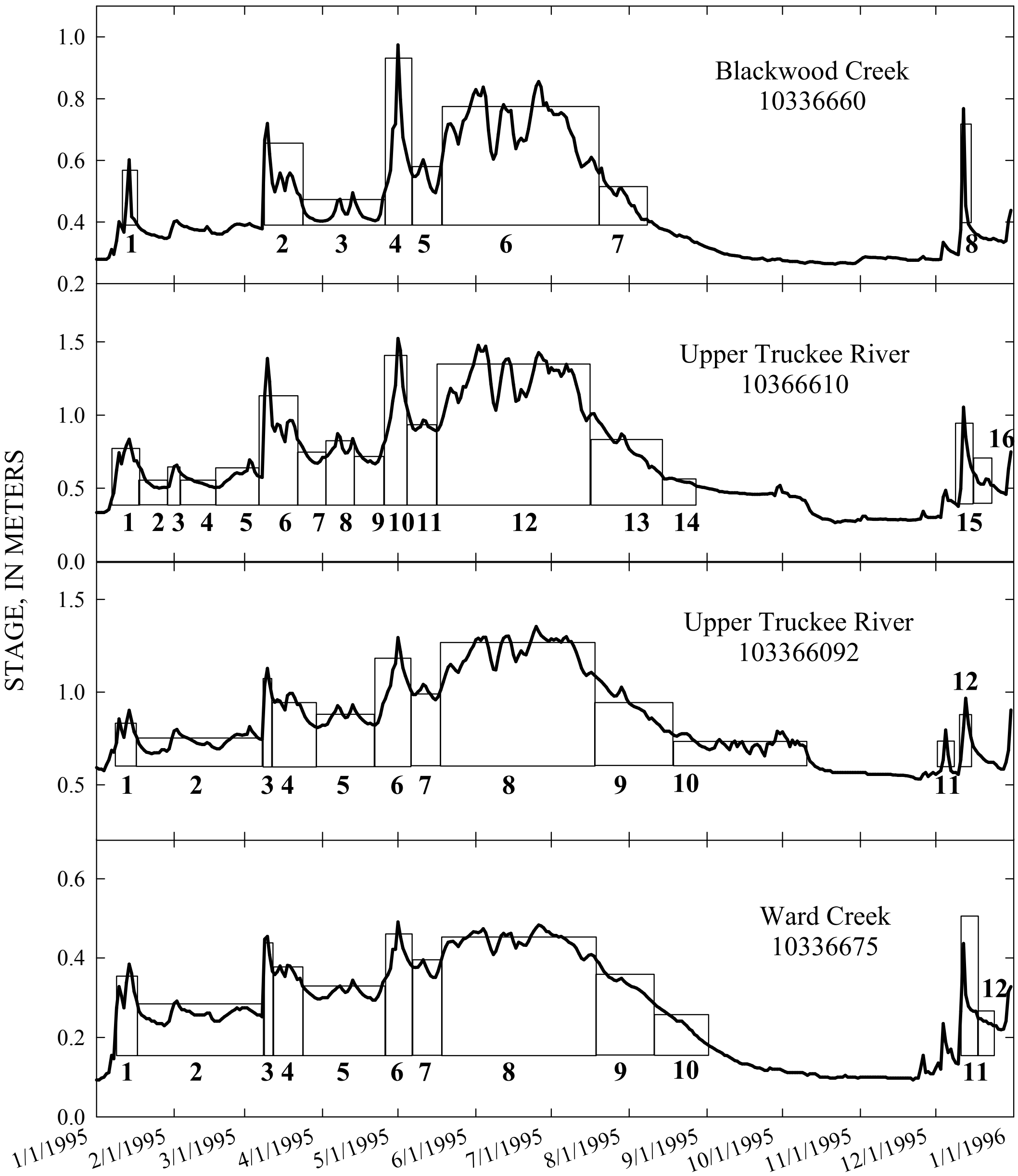


Figure 2. Discretized 1995 hydrographs for four USGS gauging stations used as input into the toe-erosion sub-model of BSTEM.

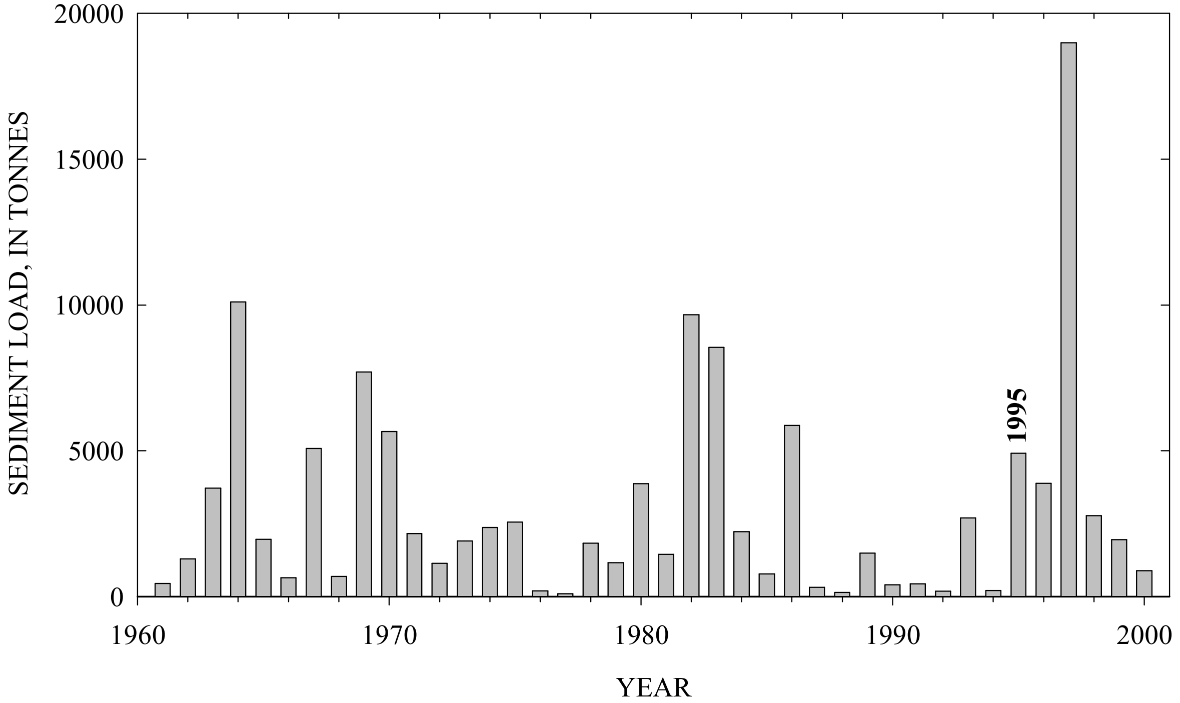


Figure 3. Annual, suspended-sediment loads for Blackwood Creek (10336660).

Table 3. Flow events discretized from 1995 hydrographs (Figure 2).

Blackwood Creek
Bank height (m) 2.35
Gage number 10336660

Event #	**Dates**		**Duration**	**Depth**
	Begin	**End**	**(h)**	**(m)**
	1-Jan	10-Jan	216	<0.2
1	10-Jan	17-Jan	168	0.36
	17-Jan	9-Mar	1224	<0.2
2	9-Mar	23-Mar	336	0.43
3	23-Mar	26-Apr	816	0.26
4	26-Apr	5-May	216	0.70
5	5-May	18-May	312	0.37
6	18-May	19-Jul	1488	0.57
7	19-Jul	10-Aug	528	0.30
	10-Aug	12-Dec	2976	<0.2
8	12-Dec	14-Dec	48	0.52
	14-Dec	31-Dec	408	<0.2

Upper Truckee River D-S
Bank height (m) 2.55
Gage 10336610

Event #	**Dates**		**Duration**	**Depth**
	Begin	**End**	**(h)**	**(m)**
	1-Jan	7-Jan	144	<0.5m
1	7-Jan	20-Jan	312	0.79
2	20-Jan	30-Jan	240	0.53
3	30-Jan	7-Feb	192	0.65
4	7-Feb	18-Feb	264	0.53
5	18-Feb	8-Mar	432	0.62
6	8-Mar	24-Mar	384	1.20
7	24-Mar	3-Apr	240	0.72
8	3-Apr	17-Apr	336	0.84
9	17-Apr	26-Apr	216	0.67
10	26-Apr	6-May	240	1.40
11	6-May	17-May	264	0.92
12	17-May	19-Jul	1512	1.38
13	19-Jul	14-Aug	624	0.85
14	14-Aug	1-Sep	432	0.55
	1-Sep	9-Dec	2376	<0.5m
15	9-Dec	17-Dec	192	0.95
16	17-Dec	28-Dec	264	0.54
	28-Dec	31-Dec	72	<0.5

Upper Truckee River U-S

Bank height (m) 2.71
Gage 113366092

Event #	Dates		Duration	Depth
	Begin	**End**	**(h)**	**(m)**
	1-Jan	8-Jan	168	<0.28
1	8-Jan	22-Jan	336	0.41
2	22-Jan	8-Mar	1080	0.34
3	8-Mar	15-Mar	168	0.68
4	15-Mar	24-Mar	216	0.53
5	24-Mar	22-Apr	696	0.48
6	22-Apr	8-May	384	0.80
7	8-May	18-May	240	0.60
8	18-May	17-Jul	1440	0.85
9	17-Jul	17-Aug	744	0.56
10	17-Aug	10-Oct	1296	0.33
	10-Aug	4-Dec	2784	<0.28
11	4-Dec	7-Dec	72	0.35
	7-Dec	10-Dec	72	<0.28
12	10-Dec	18-Dec	192	0.52
	18-Dec	31-Dec	312	<0.28

Ward Creek

Bank height[1] (m) 14.9
Gage 10336675

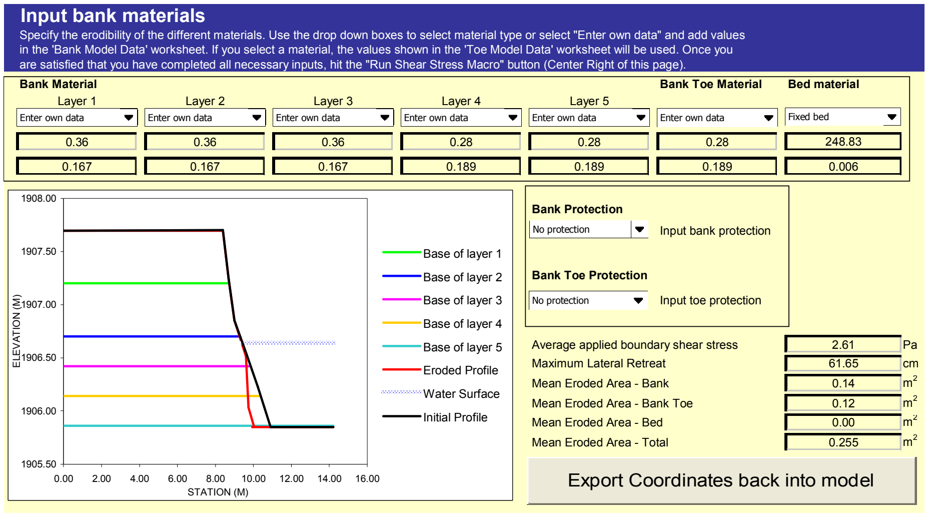
Event #	Dates		Duration	Depth
	Begin	**End**	**(h)**	**(m)**
	1-Jan	8-Jan	168	<0.15m
1	8-Jan	19-Jan	264	0.34
2	19-Jan	9-Mar	1176	0.26
3	9-Mar	13-Mar	96	0.43
4	13-Mar	23-Mar	240	0.37
5	23-Mar	25-Apr	792	0.32
6	25-Apr	7-May	288	0.44
7	7-May	17-May	240	0.38
8	17-May	18-Jul	1488	0.46
9	18-Jul	14-Aug	648	0.34
10	14-Aug	30-Aug	384	0.24
	30-Aug	10-Dec	2448	-
11	10-Dec	17-Dec	168	0.38
12	17-Dec	27-Dec	240	0.24
	27-Dec	31-Dec	96	-

[1] Bank height includes adjacent terrace slope

OPERATION of BSTEM MODEL

The BSTEM model was run in a series of iterative steps until all of the flow events were simulated:

1. The effects of the first flow event was simulated using the toe-erosion sub model to determine the amount (if any) of hydraulic erosion and the change in geometry in the bank-toe-region (Figure 4).



Input bank materials

Specify the erodibility of the different materials. Use the drop down boxes to select material type or select "Enter own data" and add values in the 'Bank Model Data' worksheet. If you select a material, the values shown in the 'Toe Model Data' worksheet will be used. Once you are satisfied that you have completed all necessary inputs, hit the "Run Shear Stress Macro" button (Center Right of this page).

Bank Material Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Bank Toe Material	Bed material
Enter own data	Enter own data	Enter own data	Enter own data	Enter own data	Enter own data	Fixed bed
0.36	0.36	0.36	0.28	0.28	0.28	248.83
0.167	0.167	0.167	0.189	0.189	0.189	0.006

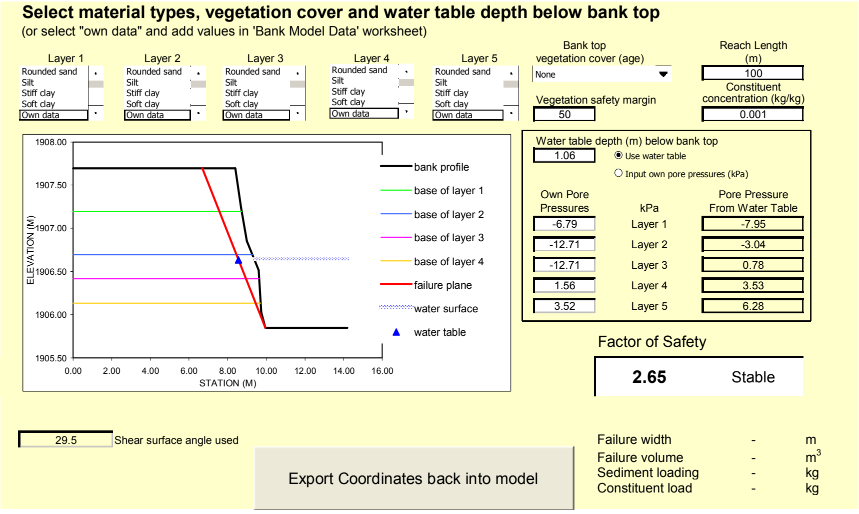
Bank Protection: No protection — Input bank protection

Bank Toe Protection: No protection — Input toe protection

Average applied boundary shear stress	2.61	Pa
Maximum Lateral Retreat	61.65	cm
Mean Eroded Area - Bank	0.14	m^2
Mean Eroded Area - Bank Toe	0.12	m^2
Mean Eroded Area - Bed	0.00	m^2
Mean Eroded Area - Total	0.255	m^2

Figure 4. Example results from toe-erosion sub-model of first flow event and resulting hydraulic erosion.

2. The new geometry was exported into the bank-stability sub-model to test for the relative stability of the bank. Water-table elevation was set to the elevation of the flow in the channel (Figure 5).



Select material types, vegetation cover and water table depth below bank top
(or select "own data" and add values in 'Bank Model Data' worksheet)

Layer 1	Layer 2	Layer 3	Layer 4	Layer 5
Rounded sand Silt Stiff clay Soft clay Own data	Rounded sand Silt Stiff clay Soft clay Own data	Rounded sand Silt Stiff clay Soft clay Own data	Rounded sand Silt Stiff clay Soft clay Own data	Rounded sand Silt Stiff clay Soft clay Own data

Bank top vegetation cover (age): None
Vegetation safety margin: 50
Reach Length (m): 100
Constituent concentration (kg/kg): 0.001

Water table depth (m) below bank top: 1.06
● Use water table
○ Input own pore pressures (kPa)

Own Pore Pressures	kPa	Pore Pressure From Water Table
-6.79	Layer 1	-7.95
-12.71	Layer 2	-3.04
-12.71	Layer 3	0.78
1.56	Layer 4	3.53
3.52	Layer 5	6.28

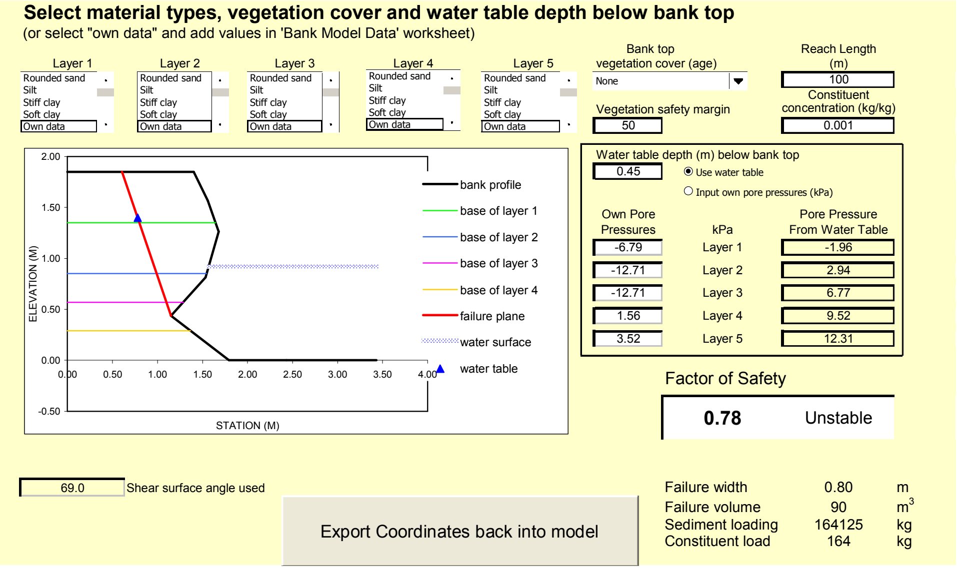
Factor of Safety: **2.65** Stable

29.5 Shear surface angle used

Failure width	-	m
Failure volume	-	m^3
Sediment loading	-	kg
Constituent load	-	kg

Figure 5. Example results from the bank-stability sub-model following the first flow event. This simulation shows a stable bank.

a. If the factor of safety (F_s) was greater than 1.0, geometry was not updated and the next flow event was simulated.
b. If F_s was less than 1.0, failure was simulated and the resulting failure plane became the geometry of the bank for simulation of toe erosion for the next flow event in the series.
c. If the next flow event had an elevation lower than the previous one, the bank-stability sub-model was run again using the new flow elevation while maintaining the higher groundwater level to test for stability under drawdown conditions (Figure 6). If F_s was less than 1.0, failure was simulated and the new bank geometry was exported into the toe-erosion sub-model for the next flow event.


Select material types, vegetation cover and water table depth below bank top
(or select "own data" and add values in 'Bank Model Data' worksheet)

Layer 1	Layer 2	Layer 3	Layer 4	Layer 5
Own data	Own data	Own data	Own data	Own data

Bank top vegetation cover (age): None
Vegetation safety margin: 50
Reach Length (m): 100
Constituent concentration (kg/kg): 0.001

Water table depth (m) below bank top: 0.45
● Use water table
○ Input own pore pressures (kPa)

Own Pore Pressures	kPa	Pore Pressure From Water Table
-6.79	Layer 1	-1.96
-12.71	Layer 2	2.94
-12.71	Layer 3	6.77
1.56	Layer 4	9.52
3.52	Layer 5	12.31

Factor of Safety
0.78 Unstable

69.0 Shear surface angle used

Failure width	0.80	m
Failure volume	90	m^3
Sediment loading	164125	kg
Constituent load	164	kg

Figure 6. Example results from the bank-stability sub-model showing an unstable bank under drawdown conditions. In this case, the bank geometry exported to simulate the next flow event is represented by the failure plane (in red) and the original bank toe.

3. The next flow event in the series is simulated.

Volumes of sediment erosion by hydraulic and geotechnical processes, and the number of mass failures were noted for each flow event and bank-stability simulation. As the bank-stability sub-model provides calculations of the amount of failed material in two dimensions (m^2), a reach length of 100 m was assumed for all simulations to provide eroded volumes in m^3.Values were summed for all events to obtain the amount of erosion under the prevailing conditions. This process was then repeated to simulate the effects of bank-toe protection and vegetation as stabilizing factors. For bank-toe protection, it was assumed that 256 mm boulders had been placed 1.0 - 1.5 m up the bank toe. To simulate the reinforcing effects of bank-top vegetation, 3.0 – 23 kPa of cohesion was added (depending on the type of vegetation) to the upper 0.5 to 1.0 m of the bank (Table 4). Comparison of the volumes of erosion and the number of mass failures under the different scenarios provided a means of calculating the potential reduction in streambank loadings.

Table 4. Root reinforcement and surcharge values for Upper Truckee Creek, Ward Creek and Blackwood Creek sites.

Site	Species	Rooting depth (m)	Root-reinforcement (kPa)	Surcharge
Upper Truckee 4.51	Wet meadow sedges and grasses	0.5	16.3	0.0
Upper Truckee 8.45	Wet meadow sedges and grasses with 5-10 year old Lemmon's willow, Coyote willow, X willow	0.5	9.15	0.0
Upper Truckee 13.1	5-10 year old Lemmon's willow, Coyote willow, X willow	1.0	3.02	0.0
Ward 2.45	30 year old Lodgepole Pine	1.0	23.4	1.2
Blackwood 1.94	No bank top vegetation	-	-	-
Blackwood 2.39	5 year old Lemmon's willow	0.63	3.02	0.0

RESULTS OF BANK-MODEL SIMULATIONS

Model simulations were carried out iteratively for the sites listed in Table 1 and for the flow events shown in Figure 2 and Table 2. An example set of results for the Upper Truckee River at km 13.1 is provided in Table 5, showing hydraulic erosion and geotechnical stability for the series of flow events. For this site and under existing conditions, 1288 m^3 of material was eroded from the streambank representing 12 periods of hydraulic erosion and 4 mass failures, with toe erosion representing just 7% of the total bank erosion in the reach. With the addition of toe protection which virtually eliminated hydraulic erosion at the bank toe, total bank erosion was reduced by about 89% to 137 m^3 over the same period.

Similar results were obtained for all other paired simulations (Table 6) with median and average load reductions of 87% and 86%, respectively with the addition of toe protection. These findings highlight the important relation between hydraulic erosion at the toe that steepens bank slopes and subsequent mass-bank stability. In the simulations conducted here under existing conditions, toe erosion accounted for an average of 13.6% of the total streambank erosion, yet control of that process resulted in a total reduction of almost 90%.

Table 5. Iterative modeling results for the Upper Truckee River (km 13.1) for existing conditions and with toe protection.

Existing Conditions (assuming 100m reach)

Event #	Toe erosion	Shear stress	Amount	FS SW=GW	Failure	Amount	FS Drawdown	Failure	Amount	Shear emergence	Failure Angle	Total Erosion	Total fines
1995		**Pa**	**m^3**			**m^3**			**m^3**	**m**	**degrees**	**m^3**	**m^3**
1	**Yes**	6.57	0.7	1.22	No	0	1.21	No	0	1912.03	40	0.70	0.13
2	**Yes**	6.32	8.5	0.95	**Yes**	362	-	-	0	1911.88	40	371	67.4
3	**Yes**	8.12	1.4	1.56	No	0	1.49	No	0	1911.91	34	1.40	0.25
4	**Yes**	5.34	0.3	1.47	No	0	1.45	No	0	1911.88	34	0.30	0.05
5	**Yes**	2.53	0.2	1.29	No	0	-	No	0	1911.88	34	0.20	0.04
6	**Yes**	7.08	3.5	0.99	**Yes**	194	1.37	No	0	1911.88	44/32	198	35.9
7	**Yes**	6.55	0.5	1.48	No	0	-	-	0	1911.98	32	0.50	0.09
8a	**Yes**	7.89	64	0.91	**Yes**	194	-	-	0	1911.88	46	258	47.0
8b	**Yes**	7.89	8.7	0.97	**Yes**	185	1.29			1911.88	44.5/32	194	35.3
9	**Yes**	6.46	1.1	1.41	No	0	1.35	No	0	1911.94	34.5	1	0.20
10	No	3.04	0	1.51	No	0	1.49	No	0	1911.94	34.5	0	0.0
11	No	3.13	0	1.50	No	0	1.47	No	0	1911.94	34.5	0	0.0
12	**Yes**	5.18	0	1.35	No	0	1.28	No	0	1911.91	34.5	0	0.0
1/1/1997	**Yes**	13.8	1.6	1.03	No	0	0.35	**Yes**	262	1911.88	34.5	264	48.0
TOTALS	**12**		**90.5**		**3**	**935**		**1**	**262**			**1288**	**234**

Toe Protection (assuming 100 m reach)

Event #	Toe erosion	Shear stress	Amount	FS SW=GW	Failure	Amount	FS Drawdown	Failure	Amount	Shear emergence	Failure Angle	Total Erosion	Total fines
1995		**Pa**	**m^3**			**m^3**			**m^3**	**m**	**degrees**	**m^3**	**m^3**
1	No	6.57	0	1.41	No	0	1.40	No	0	1912.10	40	0	0
2	No	6.32	0	1.44	No	0	-	-	0	1912.10	40	0	0
3	No	8.12	0	1.31	No	0	1.25	No	0	1912.10	40	0	0
4	No	5.34	0	1.36	No	0	1.34	No	0	1912.10	40	0	0
5	No	2.53	0	1.38	No	0	-	-	0	1912.10	40	0	0
6	No	7.08	0	1.27	No	0	1.19	No	0	1912.10	40	0	0
7	No	6.55	0	1.33	No	0	-	-	0	1912.10	40	0	0
8	No	7.89	0	1.26	No	0	1.13	No	0	1912.10	40	0	0
9	No	6.46	0	1.34	No	0	1.30	No	0	1912.10	40	0	0
10	No	3.04	0	1.45	No	0	-	-	0	1912.10	40	0	0
11	No	3.13	0	1.44	No	0	1.43	No	0	1912.10	40	0	0
12	No	5.18	0	1.36	No	0	1.32	No	0	1912.10	40	0	0
1/1/1997	**Yes**	13.8	0.1	1.19	No	0	0.28	**Yes**	137	1912.10	40	137	25.0
TOTALS	**1**		**0.1**		**0**	**0**		**1**	**137**			**137**	**25.0**

Table 5. Percentage of fine material (<0.063 mm) comprising the banks of the modeled reaches. Values represent an average from samples collected at each site.

Stream	Location (rkm)	Material finer than 0.063 mm (%)
Blackwood Creek	1.94	24.8
	2.39	16.9
Upper Truckee River	4.51	14.2
	8.45	13.8
	13.1	18.2
Ward Creek	2.48	6.4
	3.60	5.8

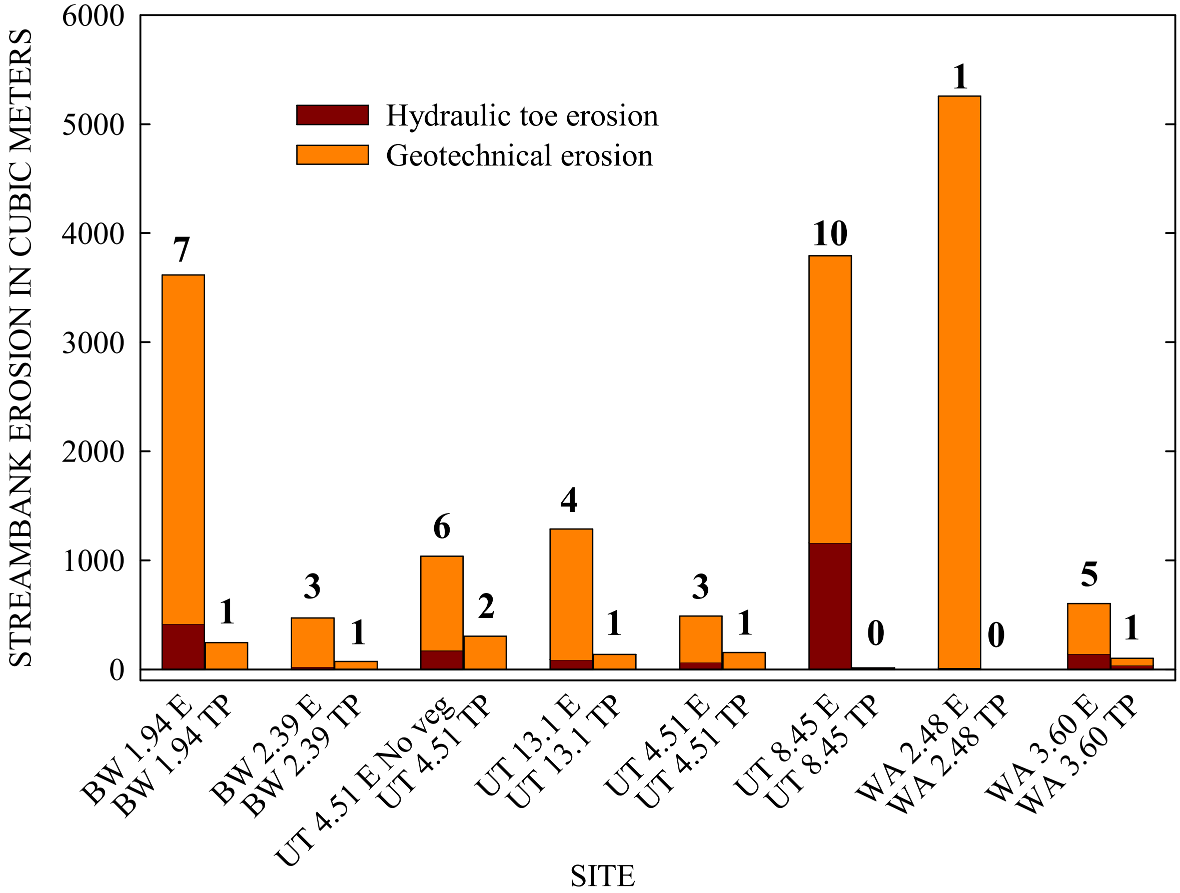


Figure 7. Simulated volumes of streambank erosion by hydraulic and geotechnical processes assuming a 100 m-long reach for 1995 and Jan. 1-2, 1997 under existing conditions (E), and with toe protection (TP). Numbers in bold refer to the frequency of bank failures for each scenario.

Table 6.

Stream	**Loads (T)**				**Total Cost**			**Unit Cost**		
	Existing	**Toe Protection**			**Toe Protection**			**($/T of Load Reduction)**		
		All	High only	H + M	All	High only	H + M	All	High only	H + M
Blackwood Creek	4432	585	2920	623	$ 8,159,449	$ 403,543	$ 6,840,551	**$ 2,121**	**$ 267**	**$ 1,796**
		86.8%	34.1%	85.9%				86.8%	34.1%	85.9%
Upper Truckee River	5691	751	3789	914	$ 20,911,417	$ 2,601,378	$ 10,735,138	**$ 4,233**	**$ 1,368**	**$ 2,247**
		86.8%	33.4%	83.9%				86.8%	33.4%	83.9%
Ward Creek	2956	390	910	451	$ 6,358,661	$ 1,731,594	$ 3,120,669	**$ 2,478**	**$ 846**	**$ 1,246**
		86.8%	69.2%	84.7%				86.8%	69.2%	84.7%
Totals	**13079**				**$ 35,429,528**	**$ 4,736,516**	**$ 20,696,358**			

Table 7. BSTEM Model Results*

River	River Station (km)	Condition	Toe Erosion	Failure Erosion	Toe Erosion	Toe Erosion Change		Failure events			Total Sediment Eroded		Eroded Fines		Load Reduction			
			m^3	m^3	%	m^3	%	at peak	at drawdown	Total	m^3	m^3/km	m^3	m^3/km	m^3	%	Average	Median
Existing versus Toe Protection																		
Blackwood	1.94	Existing	418.0	3199.0	11.6			4	3	7	3617	36170	897	8970	3373	93.3	84.3	84.2
Blackwood	1.94	Toe Protection	0.0	244.0	0.0	-418.0	11.6	0	1	1	244	2440	61	610				
Blackwood	2.39	Existing	26.7	445.0	5.7			2	1	3	472	4720	80	797	398	84.3		
Blackwood	2.39	Toe Protection	0.0	74.0	0.0	-26.7	5.7	1	0	1	74	740	13	125				
Upper Truckee	4.51	Existing, No Vegetation	171.0	866.0	16.5			3	3	6	1037	10370	147	1470	733	70.7		
Upper Truckee	4.51	Toe Protection	0.0	304.0	0.0	-171.0	16.5	0	2	2	304	3040	43	430				
Upper Truckee	4.51	Existing-Veg	66.0	424.0	13.5			2	1	3	490	4900	70	700	336	68.6		
Upper Truckee	4.51	Toe Protection-Veg	0.0	154.0	0.0	-66.0	13.5	0	1	1	154	1540	22	220				
Upper Truckee**	8.45	Existing	1161.0	2633.0	30.6			7	3	10	3794	37940	535	5350	3792	99.9		
Upper Truckee**	8.45	Toe Protection	2.2	0.0	100	-1158.8	30.5	0	0	0	2	22	0	3				
Upper Truckee	13.10	Existing	90.5	1197.0	7.0			3	1	4	1288	12880	234	2340	1151	89.4		
Upper Truckee	13.10	Toe Protection	0.1	137.0	0.07	-90.4	7.0	0	1	1	137	1370	25	250				
Ward	2.48	Existing-Side Slope	14.2	5242.0	0.3			1	0	1	5256	52562	336	3360	5256	100.0		
Ward	2.48	Toe Protection-Side Slope	0.0	0.0	0.0	-14.2	0.3	0	0	0	0	0	0	0				
Ward	3.60	Existing	143.0	461.0	23.7			5	0	5	604	6040	35	350	502	83.1		
Ward	3.60	Toe Protection	36.0	66.0	35.3	-107.0	17.7	0	1	1	102	1020	6	59				
Other Selected PCOs																		
Blackwood	1.94	Bed-Slope Reduction	227.0	1873.0	12.1	-191.0	5.3	4	2	6	2100	21000	521	5210	1517	41.9	47.9	
Upper Truckee	13.10	Bed-Slope Reduction	12.5	583.0	2.1	-78.0	6.1	2	1	3	595	5950	108	1080	693	53.8		
Upper Truckee	4.51	Top-bank Vegetation	66.0	424.0	13.5	-105.0	10.1	2	1	3	490	4900	70	700	547	52.7		
Upper Truckee	4.51	Toe Protection + Vegetation	0.0	154.0	0	-66.0	13.5	0	1	1	154	1540	22	220	883	85.1		

* BSTEM modeling conducted by National Sedimentation Lab (A. Simon, 2007) for full annual 1995 flows and January 1997 event flood flows.

** Results for existing condition at UTR 8.45km appear unrealistically high; perhaps due to cantilever sod block retention time at toe that can't be readily modeled in BSTEM; percent reduction would be unrealistically high and is excluded from analysis.

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BSTEM Model Results*

River	River Station (km)	Condition	Toe Erosion	Failure Erosion	Toe Erosion	Toe Erosion Change		Failure events			Total Sediment Eroded		Eroded Fines		Load Reduction			
			m^3	m^3	%	m^3	%	at peak	at drawdown	Total	m^3	m^3/km	m^3	m^3/km	m^3	%	Mean	Median
Existing versus Toe Protection																		
Blackwood	1.94	Existing	418.0	3199.0	11.6			4	3	7	3617	36170	897	8970	3373	93.3	84.3	84.2
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Upper Truckee	13.10	Toe Protection	0.1	137.0	0.07	-90.4	7.0	0	1	1	137	1370	25	250				
Ward	2.48	Existing-Side Slope	14.2	5242.0	0.3			1	0	1	5256	52562	336	3360	5256	100.0		
Ward	2.48	Toe Protection-Side Slope	0.0	0.0	0.0	-14.2	0.3	0	0	0	0	0	0	0				
Ward	3.60	Existing	143.0	461.0	23.7			5	0	5	604	6040	35	350	502	83.1		
Ward	3.60	Toe Protection	36.0	66.0	35.3	-107.0	17.7	0	1	1	102	1020	6	59				
Other Selected PCOs																		
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Upper Truckee	4.51	Top-bank Vegetation	66.0	424.0	13.5	-105.0	10.1	2	1	3	490	4900	70	700	547	52.7		
Upper Truckee	4.51	Toe Protection + Vegetation	0.0	154.0	0	-66.0	13.5	0	1	1	154	1540	22	220	883	85.1		

* BSTEM modeling conducted by National Sedimentation Lab (A. Simon, 2007) for full annual 1995 flows and January 1997 event flood flows.

Appendix D

Stream Channel Erosion Load Reduction Analysis Worksheets

by Valley & Mountain Consulting

	Existing	Tier 1 - Channel Restoration: Fine Sediment Loads and Cost Summary			
	Fine-Sediment Load (MT)*	Fine-Sediment Load (MT)	Load Reduction (%)	Total Cost ($)	Cost per Metric Ton Reduced Fine Sediment ($/MT)
Stream	All Reaches	High' & 'Moderate' reaches treated	High' & 'Moderate' reaches treated	High' & 'Moderate' reaches treated	High' & 'Moderate' reaches treated
Blackwood Creek	4,432	2,593	41.5%	$ 52,034,650	$ 28,301
Upper Truckee River	5,828	2,812	51.7%	$ 135,514,210	$ 44,938
Ward Creek	2,953	1,746	40.9%	$ 21,772,510	$ 18,042
Subtotal (B,U,W)	**13,213**	**7,152**	**44.7%**	**209,321,370**	**$30,427**
General Creek	117	69	41.2%	$ 21,028,610	$ 436,242
Third	133	74	44.7%	$ 1,618,297	$ 27,221
Totals/Averages	**26,675**	**14,446**	**44.1%**	**$ 441,289,648**	**$97,528**

* Modeled or measured for 1995 year, plus Jan 1997 event

	Existing	Tier 1- Channel Restoration: Total Phosphorus Loads and Cost Summary			
	Total Phosphorus Load (MT)*	Total Phosphorus Load (MT)	Load Reduction (%)	Total Cost ($)	Cost per Metric Ton Reduced TP ($/MT)
Stream	All Reaches	High' & 'Moderate' reaches treated	High' & 'Moderate' reaches treated	High' & 'Moderate' reaches treated	High' & 'Moderate' reaches treated
Blackwood Creek	0.7	0.4	41.5%	$ 47,725,650	$ 186,189,334
Upper Truckee River	0.9	0.4	51.7%	$ 135,514,210	$ 295,643,686
Ward Creek	0.4	0.3	40.9%	$ 23,738,282	$ 118,695,428
Subtotal (B,U,W)	**2.0**	**1.1**	**44.7%**	**206,978,142**	**$200,176,149**
General Creek	0.0	0.0	41.2%	$ 2,883,120	$ 2,870,013,244
Third	0.0	0.0	44.7%	$ 4,273,186	$ 179,083,482
Totals/Averages	**4.1**	**2.2**	**44.1%**	**$ 214,134,448**	**$641,633,554**

Streambank Fine Sediment Source Information (Simon and others 2003; Simon 2006)										Existing Loads: Stream Average Percent Fines			Existing Loads: Specific Percent Fines	
RGA River Station (km)	Bank Erosion (Left)	Bank Erosion (Right)	Bank Instability Percent (Left)	Bank Instability Percent (Right)	Combined Bank Percent Failing (%)	Unit Length (km)	Distributed Average Percent Failing (%)	Length-Weighted Percent Failing (%)	Relative Contribution of Fines from Banks (H, M, L)	"High" Existing Bank Erosion of Fines (m3)	"Moderate" Existing Bank Erosion of Fines (m3)	"Severity Rated" Existing Bank Erosion of Fines (m3)	Typical Bank Percent Fines (%)	"Reach Specific" Existing Bank Erosion of Fines (m3)
8.29	None	None	0-10%	0-10%	5.0%									
8.19	Fluvial	None	0-10%	26-50%	21.5%	0.10	13.3%	1.3%	M	119	11	11	5.8%	4
7.69	Fluvial	Fluvial	11-25%	11-25%	18.0%	0.50	19.8%	9.9%	L	886	79	8	0.0%	0
7.18	Fluvial	Fluvial	11-25%	11-25%	18.0%	0.51	18.0%	9.2%	L	823	73	7	26.0%	11
7.17	Fluvial	Mass Wasting	11-25%	76-100%	53.0%	0.01	35.5%	0.4%	H	32	3	32	26.0%	33
6.84	None	Mass Wasting	0-10%	11-25%	11.5%	0.33	32.3%	10.6%	L	955	85	8	26.6%	13
6.51	None	Mass Wasting	0-10%	51-75%	34.0%	0.33	22.8%	7.5%	M	673	60	60	22.1%	78
6.03	None	Mass Wasting	0-10%	26-50%	21.5%	0.48	27.8%	13.3%	M	1195	106	106	20.0%	126
5.55	None	Fluvial	0-10%	26-50%	21.5%	0.48	21.5%	10.3%	M	926	82	82	7.9%	38
5.08	None	Mass Wasting	0-10%	51-75%	34.0%	0.47	27.8%	13.0%	M	1170	104	104	23.5%	145
4.15	Fluvial	Fluvial	26-50%	11-25%	25.5%	0.93	29.8%	27.7%	M	2482	221	221	3.6%	47
3.95	None	Mass Wasting	0-10%	76-100%	46.5%	0.20	36.0%	7.2%	H	646	57	646	21.4%	557
2.80	Mass Wasting	None	51-75%	0-10%	34.0%	1.15	40.3%	46.3%	M	4152	369	369	12.3%	269
1.97	Fluvial	Mass Wasting	26-50%	11-25%	25.5%	0.83	29.8%	24.7%	M	2215	197	197	24.8%	289
1.77	Fluvial	Mass Wasting	11-25%	51-75%	40.5%	0.20	33.0%	6.6%	H	592	53	592	16.6%	396
0.32	Mass Wasting	None	51-75%	0-10%	34.0%	1.45	37.3%	54.0%	M	4845	430	430	16.3%	416
0.00	None	None	26-50%	26-50%	38.0%	0.32	36.0%	11.5%	M	1033	92	92	16.3%	89
8.29						**8.29**		**15.8%**	**Volume (m3)**	**22743**	**2021**	**2965**		**2511**
									Weight (kN)**	393458	34959	51288		43447
									Weight (MT)	**40133**	**3566**	**5231**		**4432**
									Volume/Kilometer (m3/km)	2743	244	358		303
									Metric Ton/Kilometer (MT/km)	4841	430	631		535
									Treated Length (km)					
									Percent Total Load Reduction (%)					
									Cost of Treatment ($)					
									Cost per Metric Ton Reduced Load (%/MT)					

* Uses average bulk unit weight of bank sediment from Simon and others 2003 (17.3 kN/m3)

High	0.41	4.9%
Moderate	6.54	78.9%
	6.95	

Reduced Loads: Channel Restoration

RGA River Station (km)	Maximum Treatment Bank Erosion of Fines (m3)	Focused Treatment Bank Erosion of Fines (m3)	Combined H&M Treatment Bank Erosion of Fines (m3)
	All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated
8.29			
8.19	2	4	2
7.69	0	0	0
7.18	7	11	11
7.17	19	19	19
6.84	8	13	13
6.51	45	78	45
6.03	73	126	73
5.55	22	38	22
5.08	84	145	84
4.15	27	47	27
3.95	324	324	324
2.80	156	269	156
1.97	168	289	168
1.77	230	230	230
0.32	241	416	241
0.00	51	89	51
8.29	**1459**	**2098**	**1469**
	25243	36293	25421
	2575	**3702**	**2593**
	176	253	177
	311	447	313
	8.3	0.4	7.0
	41.9%	16.5%	41.5%

Average Percent Reduction for Treatment **41.9**

"Slope Reduction" PCO…from BSTEM 0.581

Costs: Channel Restoration

Cost of Maximum Treatment ($)	Cost of Focused Treatment ($)	Cost of H&M Treatment ($)
All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated
$ 748,700		$ 748,700
$ 3,743,500		
$ 3,818,370		
$ 74,870	$ 74,870	$ 74,870
$ 2,470,710		
$ 2,470,710		$ 2,470,710
$ 3,593,760		$ 3,593,760
$ 3,593,760		$ 3,593,760
$ 3,518,890		$ 3,518,890
$ 6,962,910		$ 6,962,910
$ 1,497,400	$ 1,497,400	$ 1,497,400
$ 8,610,050		$ 8,610,050
$ 6,214,210		$ 6,214,210
$ 1,497,400	$ 1,497,400	$ 1,497,400
$ 10,856,150		$ 10,856,150
$ 2,395,840		$ 2,395,840
$ 62,067,230	$ 3,069,670	$ 52,034,650
$ 33,426	$ 4,207	$ 28,301

Cost per m **$ 7,487

Used "Reconstruction" cost, since mostly Public Lands

Reduced Total Phosphorus Loads: Channel Restoration

Stream	Maximum Treatment Bank Erosion of Fines (m3)	Focused Treatment Bank Erosion of Fines (m3)	Combined H&M Treatment Bank Erosion of Fines (m3)
Blackwood	All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated
Reduced Sediment Load (MT)	2575	3702	2593
Existing Fine Sediment Load (MT)	4432	4432	4432
Reduced TP Load (MT)	**0.39**	**0.56**	**0.39**
Existing TP Load (MT)	**0.67**	**0.67**	**0.67**
Percent TP Load Reduction (%)	41.9%	16.5%	41.5%
Cost of Treatment ($)	$ 62,067,230	$ 3,069,670	$ 52,034,650
Cost per Ton Reduced TP (%/MT)	$ 219,909,837	$ 27,674,737	$ 186,189,334

Multiplier for Percent TP Content of Sediment 0.000152

95% C.I. for Percent TP Content of Sediment 0.096-0.197 %

(Source: Ferguson 2005; Ferguson and Qualls 2005)

Streambank Fine Sediment Source Information (Simon and others 2003; Simon 2006)										Existing Loads: Stream Average Percent Fines			Existing Loads: Specific Percent Fines	
RGA River Station (km)	Bank Erosion (Left)	Bank Erosion (Right)	Bank Instability Percent (Left)	Bank Instability Percent (Right)	Combined Bank Percent Failing (%)	Unit Length (km)	Distributed Average Percent Failing (%)	Length-Weighted Percent Failing (%)	Relative Contribution of Fines from Banks (H, M, L)	"High" Existing Bank Erosion of Fines (m3) *	"Moderate" Existing Bank Erosion of Fines (m3)	"Severity Rated" Existing Bank Erosion of Fines (m3)	Typical Bank Percent Fines (%)	"Reach Specific" Existing Bank Erosion of Fines (m3)
24.19	Fluvial	Fluvial	0-10%	0-10%	5.0%									
23.01	None	Fluvial	0-10%	11-25%	11.5%	1.18	8.3%	9.7%	L	185	68	6.8	6.1%	2.9
22.54	None	Mass Wasting	0-10%	11-25%	11.5%	0.47	11.5%	5.4%	L	103	38	3.8	6.3%	1.7
21.77	None	None	0-10%	0-10%	5.0%	0.77	8.3%	6.4%	L	121	44	4.4	6.3%	2.0
21.40	Fluvial	Fluvial	0-10%	0-10%	5.0%	0.37	5.0%	1.9%	L	35	13	1.3	6.3%	0.6
20.75	Mass Wasting	Mass Wasting	0-10%	11-25%	11.5%	0.65	8.3%	5.4%	L	102	38	3.8	6.5%	1.7
19.94	Mass Wasting	Fluvial	51-75%	0-10%	34.0%	0.81	22.8%	18.4%	M	351	129	129.0	12.3%	111.1
19.26	Fluvial	Mass Wasting	0-10%	26-50%	21.5%	0.68	27.8%	18.9%	M	359	132	132.1	14.8%	136.8
18.57	None	Mass Wasting	0-10%	51-75%	34.0%	0.69	27.8%	19.1%	M	365	134	134.0	14.8%	138.9
17.99	Fluvial	Fluvial	0-10%	0-10%	5.0%	0.58	19.5%	11.3%	L	215	79	7.9	14.8%	8.2
17.78	None	Mass Wasting	0-10%	25-50%	21.5%	0.21	13.3%	2.8%	M	53	19	19.5	17.3%	23.5
16.90	Fluvial	Fluvial	11-25%	0-10%	11.5%	0.88	16.5%	14.5%	L	277	102	10.2	13.4%	9.5
16.40	Fluvial	Fluvial	11-25%	11-25%	18.0%	0.50	14.8%	7.4%	L	140	52	5.2	13.4%	4.8
15.78	None	None	0-10%	0-10%	5.0%	0.62	11.5%	7.1%	L	136	50	5.0	13.4%	4.7
15.277	None	Fluvial	0-10%	26-50%	21.5%	0.50	13.3%	6.7%	M	127	47	46.7	13.4%	43.6
14.77	None	Mass Wasting	0-10%	76-100%	46.5%	0.51	34.0%	17.2%	H	328	121	328.4	9.4%	188.4
14.10	Fluvial	None	0-10%	0-10%	5.0%	0.67	25.8%	17.3%	L	329	121	12.1	21.0%	17.8
13.52	None	Mass Wasting	0-10%	76-100%	46.5%	0.58	25.8%	14.9%	H	285	105	284.5	18.2%	316.0
13.15	None	Mass Wasting	0-10%	50-75%	34.0%	0.37	40.3%	14.9%	M	284	104	104.2	18.2%	132.8
12.07	None	Mass Wasting	0-10%	0-10%	5.0%	1.08	19.5%	21.1%	L	401	147	14.7	18.4%	18.9
11.21	Fluvial	Mass Wasting	0-10%	51-75%	34.0%	0.86	19.5%	16.8%	M	319	117	117	18.4%	150.8
10.84	Mass Wasting	Fluvial	51-75%	0-10%	34.0%	0.37	34.0%	12.6%	M	240	88	88.1	18.5%	114.0
10.04	None	Fluvial	0-10%	11-25%	11.5%	0.80	22.8%	18.2%	L	347	127	12.7	16.3%	14.5
8.46	None	Mass Wasting	0-10%	76-100%	46.5%	1.58	29.0%	45.8%	H	873	321	872.9	14.1%	751.0
7.14	None	Mass Wasting	0-10%	0-10%	27.5%	1.32	37.0%	48.8%	M	930	342	341.9	23.0%	549.2
5.84	None	None	0-10%	0-10%	5.0%	1.30	16.3%	21.1%	L	402	148	14.8	18.4%	19.1
5.06	Fluvial	Mass Wasting	26-50%	26-50%	38.0%	0.78	21.5%	16.8%	M	319	117	117.4	13.9%	114.2
4.10	Fluvial	Fluvial	0-10%	0-10%	5.0%	0.96	21.5%	20.6%	L	393	144	14.4	14.4%	14.6
2.94	Mass Wasting	None	51-75%	0-10%	34.0%	1.16	19.5%	22.6%	M	431	158	158	23.0%	254.9
1.96					20.0%	0.99	27.0%	26.6%	M	507	186	186	11.6%	151.2
1.63					12.0%	0.33	16.0%	5.2%	L	99	37	3.7	11.6%	3.0
0.00					5.0%	1.63	8.5%	13.8%	L	264	97	9.7	3.5%	2.4
24.19						**24.19**		**20.2%**	**Volume (m3)**	**9322**	**3425**	**3191**		**3303**
									Weight (kN)**	161267	59258	55203		57136
									Weight (MT)	**16449**	**6044**	**5631**		**5828**
									Volume/Kilometer (m3/km)	385	142	132		137
									Metric Ton/Kilometer (MT/km)	680	250	233		241
									Treated Length (km)					
									Percent Total Load Reduction (%)					
									Cost of Treatment ($)					
									Cost per Metric Ton Reduced Load (%/MT)					

* Uses 1905 m3/km [average eroded fines for 4.51 km, no veg (1470 m3/km) and 13.1 km (2340 m3/km)].
** Uses average bulk unit weight of bank sediment from Simon and others 2003 (17.3 kN/m3)

High	2.67	11.0%
Moderate	8.74	36.1%
	11.41	

	Reduced Loads: Channel Restoration			Costs: Channel Restoration		
RGA River Station (km)	Maximum Treatment Bank Erosion of Fines (m3)	Focused Treatment Bank Erosion of Fines (m3)	Combined H&M Treatment Bank Erosion of Fines (m3)	Cost of Maximum Treatment ($)	Cost of Focused Treatment ($)	Cost of H&M Treatment ($)
	All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated	All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated
24.19						
23.01	1.4	2.9	2.9	$ 14,020,760		
22.54	0.8	1.7	1.7	$ 5,584,540		
21.77	0.9	2.0	2.0	$ 9,149,140		
21.40	0.3	0.6	0.6	$ 4,396,340		
20.75	0.8	1.7	1.7	$ 7,723,300		
19.94	51.3	111.1	51.3	$ 9,624,420		$ 9,624,420
19.26	63.2	136.8	63.2	$ 8,079,760		$ 8,079,760
18.57	64.2	138.9	64.2	$ 8,198,580		$ 8,198,580
17.99	3.8	8.2	8.2	$ 6,891,560		
17.78	10.9	23.5	10.9	$ 2,495,220		$ 2,495,220
16.90	4.4	9.5	9.5	$ 10,456,160		
16.40	2.2	4.8	4.8	$ 5,941,000		
15.78	2.2	4.7	4.7	$ 7,366,840		
15.277	20.1	43.6	20.1	$ 5,976,646		$ 5,976,646
14.77	87.0	87.0	87.0	$ 6,024,174	$ 6,024,174	$ 6,024,174
14.10	8.2	17.8	17.8	$ 7,960,940		
13.52	146.0	146.0	146.0	$ 6,891,560	$ 6,891,560	$ 6,891,560
13.15	61.4	132.8	61.4	$ 4,396,340		$ 4,396,340
12.07	8.7	18.9	18.9	$ 12,832,560		
11.21	69.7	150.8	69.7	$ 10,218,520		$ 10,218,520
10.84	52.7	114.0	52.7	$ 4,396,340		$ 4,396,340
10.04	6.7	14.5	14.5	$ 9,505,600		
8.46	347.0	347.0	347.0	$ 18,773,560	$ 18,773,560	$ 18,773,560
7.14	253.7	549.2	253.7	$ 15,684,240		$ 15,684,240
5.84	8.8	8.8	19.1	$ 15,446,600		
5.06	52.8	114.2	52.8	$ 9,267,960		$ 9,267,960
4.10	6.7	14.6	14.6	$ 11,406,720		
2.94	117.8	254.9	117.8	$ 13,783,120		$ 13,783,120
1.96	69.8	151.2	69.8	$ 11,703,770		$ 11,703,770
1.63	1.4	3.0	3.0	$ 3,873,532		
0.00	1.1	2.4	2.4	$ 19,355,778		
24.19	**1526**	**2617**	**1594**			
	26397.0	45274	27572			
	2692.5	**4618**	**2812**			
	63.1	108	66			
	111.3	191	116			
	24.2	2.7	11.4			
	53.8%	20.8%	51.7%			
				$ 287,425,580	$ 31,689,294	$ 135,514,210
				$ 91,671	$ 26,191	$ 44,938

Reduced Total Phosphorus Loads: Channel Restoration			
Stream	Maximum Treatment Bank Erosion of Fines (m3)	Focused Treatment Bank Erosion of Fines (m3)	Combined H&M Treatment Bank Erosion of Fines (m3)
Upper Truckee River	All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated
Reduced Sediment Load (MT)	2692	4618	2812
Existing Fine Sediment Load (MT)	5828	5828	5828
Reduced TP Load (MT)	**0.41**	**0.70**	**0.43**
Existing TP Load (MT)	**0.89**	**0.89**	**0.89**
Percent TP Load Reduction (%)	53.8%	20.8%	51.7%
Cost of Treatment ($)	$ 287,425,580	$ 31,689,294	$ 135,514,210
Cost per Ton Reduced TP (%/MT)	$ 603,096,094	$ 172,309,486	$ 295,643,686

Average Percent Reduction for Treatment	**53.8**
Slope Reduction from BSTEM	0.462

Cost per m **$ 11,882

Uses "Reconstruction" costs since dominantly public land; could be more costly where private parcels must be acquired.

Multiplier for Percent TP Content of Sediment	0.000152
95% C.I. for Percent TP Content of Sediment	0.096-0.197 %

(Source: Ferguson 2005; Ferguson and Qualls 2005)

Streambank Fine Sediment Source Information (Simon and others 2003; Simon 2006)										Existing Loads: Stream Average Percent Fines			Existing Loads: Specific Percent Fines	
RGA River Station (km)	Bank Erosion (Left)	Bank Erosion (Right)	Bank Instability Percent (Left)	Bank Instability Percent (Right)	Combined Bank Percent Failing (%)	Unit Length (km)	Distributed Average Percent Failing (%)	Length-Weighted Percent Failing (%)	Relative Contribution of Fines from Banks (H, M, L)	"High" Existing Bank Erosion of Fines (m3)	"Moderate" Existing Bank Erosion of Fines (m3)	"Severity Rated" Existing Bank Erosion of Fines (m3)	Typical Bank Percent Fines (%)	"Reach Specific" Existing Bank Erosion of Fines (m3)
6.55	None	Fluvial	0-10%	26-50%	24.0%				L				24.4%	
6.45	Fluvial	Fluvial	0-10%	11-25%	11.5%	0.10	17.8%	1.8%	L	58.9	6.1	0.6	27.7%	2.9
6.42	None	None	0-10%	0-10%	5.0%	0.04	8.3%	0.3%	L	10.7	1.1	0.1	17.5%	0.3
6.27	None	Fluvial	0-10%	11-25%	11.5%	0.15	8.3%	1.2%	L	40.4	4.2	0.4	27.1%	2.0
6.17	Fluvial	None	11-25%	0-10%	11.5%	0.10	11.5%	1.2%	L	39.9	4.2	0.4	13.1%	0.9
6.10	Fluvial	None	11-25%	0-10%	11.5%	0.07	11.5%	0.7%	L	25.2	2.6	0.3	16.2%	0.7
5.94	None	Mass Wasting	0-10%	76-100%	49.0%	0.16	30.3%	4.9%	H	166.2	17.3	17	19.2%	57
5.87	None	Fluvial	0-10%	0-10%	5.0%	0.07	27.0%	1.9%	L	63.9	6.7	0.7	9.7%	1.1
5.81	Fluvial	Fluvial	0-10%	11-25%	11.5%	0.06	8.3%	0.5%	L	17.4	1.8	0.2	0.2%	0.0
5.53	Fluvial	Fluvial	11-25%	0-10%	11.5%	0.28	11.5%	3.2%	L	107.7	11.2	1.1	21.0%	4.1
5.36	None	Fluvial	0-10%	26-50%	21.5%	0.17	16.5%	2.8%	M	92.5	9.6	9.6	33.0%	54.9
5.12	Fluvial	Mass Wasting	0-10%	26-50%	21.5%	0.24	21.5%	5.1%	M	170.3	17.7	17.7	18.5%	56.6
4.74	None	Mass Wasting	0-10%	76-100%	49.0%	0.38	35.3%	13.5%	H	454.5	47.3	47	22.9%	187
4.52	Fluvial	Fluvial	11-25%	11-25%	18.0%	0.22	33.5%	7.3%	L	245.6	25.6	2.6	16.6%	7.3
4.25	Mass Wasting	None	26-50%	0-10%	21.5%	0.27	19.8%	5.4%	M	180.5	18.8	18.8	16.6%	53.7
4.06	Fluvial	Fluvial	11-25%	11-25%	18.0%	0.19	19.8%	3.8%	L	127.0	13.2	1.3	10.2%	2.3
3.64	Mass Wasting	Fluvial	51-75%	26-50%	50.5%	0.42	34.3%	14.3%	H	480.2	50.0	480	5.8%	439
3.51	Fluvial	Mass Wasting	11-25%	51-75%	40.5%	0.14	45.5%	6.2%	H	207.2	21.6	207	6.1%	198
3.28	None	Mass Wasting	0-10%	0-10%	5.0%	0.23	22.8%	5.1%	L	173.0	18.0	1.8	6.1%	1.9
2.64	None	Fluvial	0-10%	0-10%	5.0%	0.64	5.0%	3.2%	L	107.6	11.2	1.1	6.1%	1.2
2.38	Fluvial	Mass Wasting	11-25%	51-75%	40.5%	0.26	22.8%	5.9%	H	196.8	20.5	197	6.4%	197
2.08	Fluvial	Fluvial	0-10%	0-10%	5.0%	0.30	22.8%	6.8%	L	227.4	23.7	2.4	19.7%	8.1
1.97	Fluvial	Fluvial	0-10%	0-10%	5.0%	0.11	5.0%	0.6%	L	19.0	2.0	0.2	17.1%	0.6
1.55	Fluvial	Fluvial	0-10%	0-10%	5.0%	0.43	5.0%	2.1%	L	71.5	7.5	0.7	17.1%	2.2
1.42	Mass Wasting	Fluvial	26-50%	0-10%	21.5%	0.13	13.3%	1.7%	M	57.3	6.0	6.0	14.4%	14.8
1.29	None	Mass Wasting	0-10%	51-75%	34.0%	0.12	27.8%	3.4%	M	115.7	12.1	12.1	14.7%	30.6
1.14	None	Fluvial	0-10%	11-25%	11.5%	0.15	22.8%	3.5%	L	116.9	12.2	1.2	14.7%	3.1
1.12	Mass Wasting	Fluvial	26-50%	0-10%	21.5%	0.01	16.5%	0.2%	M	8.1	0.8	0.8	14.7%	2.2
1.11	Fluvial	Fluvial	26-50%	0-10%	21.5%	0.02	21.5%	0.3%	M	10.8	1.1	1.1	15.0%	2.9
0.78	Mass Wasting	Fluvial	51-75%	11-25%	40.5%	0.33	31.0%	10.3%	H	346.0	36.0	36	22.5%	140
0.63	Fluvial	Mass Wasting	0-10%	26-50%	21.5%	0.15	31.0%	4.6%	M	155.1	16.2	16.2	11.5%	32.1
0.51	None	Fluvial	0-10%	11-25%	11.5%	0.12	16.5%	2.0%	M	68.5	7.1	7.1	9.7%	11.9
0.44	Mass Wasting	Mass Wasting	76-100%	11-25%	53.0%	0.07	32.3%	2.2%	H	75.5	7.9	75.5	9.7%	115
0.25	Mass Wasting	Fluvial	26-50%	26-50%	38.0%	0.18	45.5%	8.3%	M	277.9	29.0	29.0	7.9%	39.5
0.09	None	None	0-10%	0-10%	5.0%	0.25	21.5%	5.5%	L	183.2	19.1	1.9	7.9%	2.6
6.55						**6.55**		**3.8%**	**Volume (m3)**	**4698**	**489**	**1196**		**1674**
									Weight (kN)**	81282	8467	20688		28952
									Weight (MT)	**8291**	**864**	**2110**		**2953**
									Volume/Kilometer (m3/km)	717	75	182		255
									Metric Ton/Kilometer (MT/km)	1265	132	322		451
									Treated Length (km)					
									Percent Total Load Reduction (%)					
									Cost of Treatment ($)					
									Cost per Metric Ton Reduced Load (%/MT)					

H	1.76	26.9%
M	1.41	21.5%
H&M	3.17	

* Uses average bulk unit weight of bank sediment from Simon and others 2003 (17.3 kN/m3)

Reduced Loads: Channel Restoration

Costs: Channel Restoration

RGA River Station (km)	Maximum Treatment Bank Erosion of Fines (m3)	Focused Treatment Bank Erosion of Fines (m3)	Combined H&M Treatment Bank Erosion of Fines (m3)	Cost of Maximum Treatment ($)	Cost of Focused Treatment ($)	Cost of Combined H&M Treatment ($)
	All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated	All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated
6.55						
6.45	1.7	2.9	2.9	$ 677,773		
6.42	0.2	0.3	0.3	$ 265,753		
6.27	1.1	2.0	2.0	$ 1,001,209		
6.17	0.5	0.9	0.9	$ 709,361		
6.10	0.4	0.7	0.7	$ 447,728		
5.94	33.3	33.3	33.3	$ 1,122,755	$ 1,122,755	$ 1,122,755
5.87	0.6	1.1	1.1	$ 483,437		
5.81	0.0	0.0	0.0	$ 430,561		
5.53	2.4	4.1	4.1	$ 1,913,146		
5.36	31.9	54.9	31.9	$ 1,145,416		$ 1,145,416
5.12	32.9	56.6	32.9	$ 1,619,239		$ 1,619,239
4.74	108.7	108.7	108.7	$ 2,634,868	$ 2,634,868	$ 2,634,868
4.52	4.2	7.3	7.3	$ 1,498,379		
4.25	31.2	53.7	31.2	$ 1,867,824		$ 1,867,824
4.06	1.4	2.3	2.3	$ 1,314,344		
3.64	254.9	254.9	254.9	$ 2,865,599	$ 2,865,599	$ 2,865,599
3.51	115.2	115.2	115.2	$ 930,479	$ 930,479	$ 930,479
3.28	1.1	1.9	1.9	$ 1,554,002		
2.64	0.7	1.2	1.2	$ 4,396,940		
2.38	114.5	114.5	114.5	$ 1,767,566	$ 1,767,566	$ 1,767,566
2.08	4.7	8.1	8.1	$ 2,042,933		
1.97	0.3	0.6	0.6	$ 778,031		
1.55	1.3	2.2	2.2	$ 2,923,969		
1.42	8.6	14.8	8.6	$ 883,096		$ 883,096
1.29	17.8	30.6	17.8	$ 852,195		$ 852,195
1.14	1.8	3.1	3.1	$ 1,049,964		
1.12	1.3	2.2	1.3	$ 100,945		$ 100,945
1.11	1.7	2.9	1.7	$ 103,005		$ 103,005
0.78	81.3	81.3	81.3	$ 2,281,217	$ 2,281,217	$ 2,281,217
0.63	18.6	32.1	18.6	$ 1,022,496		$ 1,022,496
0.51	6.9	11.9	6.9	$ 848,761		$ 848,761
0.44	66.6	66.6	66.6	$ 478,630	$ 478,630	$ 478,630
0.25	22.9	39.5	22.9	$ 1,248,421		$ 1,248,421
0.09	1.5	2.6	2.6	$ 1,741,471		
6.55	**972**	**1115**	**990**			
	16821	19289	17121			
	1716	**1968**	**1746**			
	148	170	151			
	262	300	266			
	6.6	1.8	3.2			
	41.9%	33.4%	40.9%			
				$ 45,001,511	$ 12,081,113	$ 21,772,510
				$ 36,369	$ 12,258	$ 18,042

Reduced Total Phosphorus Loads: Channel Restoration

Stream	Maximum Treatment Bank Erosion of Fines (m3)	Focused Treatment Bank Erosion of Fines (m3)	Combined H&M Treatment Bank Erosion of Fines (m3)
Ward Creek	All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated
Reduced Sediment Load (MT)	1716	1968	1746
Existing Fine Sediment Load (MT)	2953	2953	2953
Reduced TP Load (MT)	**0.26**	**0.30**	**0.27**
Existing TP Load (MT)	**0.45**	**0.45**	**0.45**
Percent TP Load Reduction (%)	41.9%	33.4%	40.9%
Cost of Treatment ($)	$ 45,001,511	$ 12,081,113	$ 21,772,510
Cost per Ton Reduced TP (%/MT)	$ 239,271,696	$ 80,642,255	$ 118,695,428

Average Percent Reduction for Treatment	**41.9**
Slope Reduction BSTEM	0.581

Cost per m **$ 6,867

Multiplier for Percent TP Content of Sediment	0.000152
95% C.I. for Percent TP Content of Sediment	0.096-0.197 %

(Source: Ferguson 2005; Ferguson and Qualls 2005)

Streambank Fine Sediment Source Information (Simon and others 2003; Simon 2006)											Existing Loads: Specific Percent Fines		Reduced
RGA ID	RGA River Station (km)	Bank Erosion (Left)	Bank Erosion (Right)	Bank Instability Percent (Left)	Bank Instability Percent (Right)	Combined Bank Percent Failing (%)	Unit Length (km)	Distributed Average Percent Failing (%)	Length-Weighted Percent Failing (%)	Relative Contribution of Fines from Banks (H, M, L)	Typical Bank Percent Fines (%)	"Reach Specific" Existing Bank Erosion of Fines (m3)	Typical Bank Percent Fines (%)
													All reaches treated
GC45	8.08	None	None	0-10%	0-10%	5.0%				L			
56-01	6.80	None	Fluvial	0-10%	0-10%	5.0%	1.28	5.0%	6.4%	L			
56-02	6.66	None	Fluvial	0-10%	0-10%	5.0%	0.14	5.0%	0.7%	L			
56-03	6.50	Mass Wasting	Fluvial	76-100%	11-25%	53.0%	0.16	29.0%	4.6%	H			
56-05	6.06	None	Fluvial	0-10%	11-25%	11.5%	0.44	32.3%	14.2%	L			
56-06	5.90	None	Fluvial	0-10%	26-50%	21.5%	0.16	16.5%	2.6%	M			
56-08	5.33	Fluvial	Fluvial	11-25%	11-25%	18.0%	0.57	19.8%	11.3%	L			
56-09	5.25	Fluvial	Fluvial	11-25%	11-25%	18.0%	0.08	18.0%	1.4%	L			
56-11	5.05	Fluvial	Fluvial	0-10%	11-25%	11.5%	0.20	14.8%	3.0%	L			
56-12	4.73	None	Mass Wasting	0-10%	76-100%	46.5%	0.32	29.0%	9.3%	H			
56-14	4.21	None	Fluvial	0-10%	0-10%	5.0%	0.52	25.8%	13.4%	L			
56-16	3.62	Fluvial	None	0-10%	0-10%	5.0%	0.59	5.0%	3.0%	L			
56-17	3.60	Fluvial	Mass Wasting	0-10%	26-50%	21.5%	0.02	13.3%	0.3%	M			
56-18	3.59	Fluvial	Fluvial	0-10%	11-25%	11.5%	0.01	16.5%	0.2%	L			
56-19	3.25	Fluvial	Mass Wasting	0-10%	76-100%	46.5%	0.34	29.0%	9.9%	H			
56-20	2.97	None	None	0-10%	0-10%	5.0%	0.28	25.8%	7.2%	L			
56-21	2.58	Fluvial	Mass Wasting	0-10%	51-75%	34.0%	0.39	19.5%	7.6%	M			
56-23	2.20	None	Mass Wasting	0-10%	76-100%	46.5%	0.38	40.3%	15.3%	H			
56-24	1.94	None	Fluvial	0-10%	26-50%	21.5%	0.26	34.0%	8.8%	M			
56-26	1.93	Fluvial	Fluvial	0-10%	0-10%	5.0%	0.01	13.3%	0.1%	L			
56-27	1.54	None	Mass Wasting	0-10%	51-75%	34.0%	0.39	19.5%	7.6%	M			
56-28	1.17	None	Mass Wasting	0-10%	11-25%	11.5%	0.37	22.8%	8.4%	L			
56-29	0.95	Fluvial	Mass Wasting	11-25%	76-100%	53.0%	0.22	32.3%	7.1%	H			
56-30	0.89	Fluvial	Mass Wasting	0-10%	11-25%	11.5%	0.06	32.3%	1.9%	L			
56-32	0.71	None	Fluvial	0-10%	11-25%	11.5%	0.18	11.5%	2.1%	L			
56-34	0.57	None	None	0-10%	0-10%	5.0%	0.14	8.3%	1.2%	L			
56-36	0.30	None	Fluvial	0-10%	0-10%	5.0%	0.27	5.0%	1.4%	L			
56-37	0.01	Mass Wasting	None	26-50%	0-10%	21.5%	0.29	13.3%	3.8%	M			
TOTALS	**8.08**						**8.07**		**5.0%**	**Volume (m3)**			
										Weight (kN)**			
										Weight (MT)		**117**	**68.0**
										Volume/Kilometer (m3/km)		0	
										Metric Ton/Kilometer (MT/km)		14	8
										Treated Length (km)			8.1
										Percent Total Load Reduction (%)			41.9%
										Cost of Treatment ($)			
										Cost per Metric Ton Reduced Load (%/MT)			

Average Percent Re
Treatment

Slope Reduction
Using average of Bla

High	1.42	17.6%
Moderate	1.51	18.7%
H&M	2.93	

Loads: Channel Restoration			Costs: Channel Restoration			Reduced Total Phosphorus Loads: Channel Restoration			
RGA ID	Focused Treatment Bank Erosion of Fines (m3)	Combined H&M Treatment Bank Erosion of Fines (m3)	Cost of Maximum Treatment ($)	Cost of Focused Treatment ($)	Cost of H&M Treatment ($)	Stream	Maximum Treatment Bank Erosion of Fines (m3)	Focused Treatment Bank Erosion of Fines (m3)	Combined H&M Treatment Bank Erosion of Fines (m3)
	Only "High" reaches treated	"High & Moderate" reaches treated	All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated	General Creek	All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated
GC45									
56-01			$ 9,167,900						
56-02			$ 1,004,780						
56-03			$ 1,148,320	$ 1,148,320	$ 1,148,320				
56-05			$ 3,157,880						
56-06			$ 1,148,320		$ 1,148,320				
56-08			$ 4,090,890						
56-09			$ 574,160						
56-11			$ 1,435,400						
56-12			$ 2,296,640	$ 2,296,640	$ 2,296,640				
56-14			$ 3,732,040						
56-16			$ 4,234,430						
56-17			$ 143,540		$ 143,540				
56-18			$ 71,770						
56-19			$ 2,440,180	$ 2,440,180	$ 2,440,180				
56-20			$ 2,009,560						
56-21			$ 2,799,030		$ 2,799,030				
56-23			$ 2,727,260	$ 2,727,260	$ 2,727,260				
56-24			$ 1,866,020		$ 1,866,020				
56-26			$ 71,770						
56-27			$ 2,799,030		$ 2,799,030				
56-28			$ 2,655,490						
56-29			$ 1,578,940	$ 1,578,940	$ 1,578,940				
56-30			$ 430,620						
56-32			$ 1,291,860						
56-34			$ 1,004,780						
56-36			$ 1,937,790						
56-37			$ 2,081,330		$ 2,081,330				
TOTALS						Reduced Sediment Load (MT)	68	88	69
	87.8	**68.8**				Existing Fine Sediment Load (MT)	117	117	117
						Reduced TP Load (MT)	**0.01**	**0.01**	**0.01**
	11	9				**Existing TP Load (MT)**	**0.02**	**0.02**	**0.02**
	1.4	2.9							
	25.0%	41.2%				Percent TP Load Reduction (%)	41.9%	25.0%	41.2%
			$ 57,899,730	$ 10,191,340	$ 21,028,610	Cost of Treatment ($)	$ 57,899,730	$ 10,191,340	$ 21,028,610
			$ 1,181,073	$ 348,422	$ 436,242	Cost per Ton Reduced TP (%/MT)	$ 7,770,215,511	$ 2,292,249,213	$ 2,870,013,244

duction for
41.9
0.581
ckwood and Ward model results.

Cost per m **$ 7,177
Use average BW and Ward costs.

Multiplier for Percent TP Content of Sediment 0.000152
95% C.I. for Percent TP Content of Sediment 0.096-0.197 %
(Source: Ferguson 2005; Ferguson and Qualls 2005)

Streambank Fine Sediment Source Information (Simon and others 2003; Simon 2006)											Existing Loads: Specific Percent Fines	
RGA ID	RGA River Station (km)	Bank Erosion (Left)	Bank Erosion (Right)	Bank Instability Percent (Left)	Bank Instability Percent (Right)	Combined Bank Percent Failing (%)	Unit Length (km)	Distributed Average Percent Failing (%)	Length-Weighted Percent Failing (%)	Relative Contribution of Fines from Banks (H, M, L)	Typical Bank Percent Fines (%)	"Reach Specific" Existing Bank Erosion of Fines (m3)
18-09	8.10	Fluvial	Fluvial	11-25%	0-10%	12.5%		6.3%	0.0%	L		
18-08	7.61	Fluvial	Fluvial	26-50%	0-10%	21.5%	0.49	17.0%	8.3%	M		
18-6	5.84	None	None	0-10%	0-10%	5.0%	1.77	13.3%	23.4%	L		
18-7	5.39	None	None	0-10%	0-10%	5.0%	0.45	5.0%	2.3%	L		
18-05	4.87	Fluvial	None	11-25%	0-10%	12.5%	0.52	8.8%	4.6%	L		
18-4a	3.49	None	None	0-10%	0-10%	5.0%	1.38	8.8%	12.1%	L		
18-4b	3.08	None	None	0-10%	0-10%	5.0%	0.41	5.0%	2.1%	L		
18-04	2.97	Fluvial	Fluvial	26-50%	0-10%	21.5%	0.11	13.3%	1.4%	M		
18-03	1.15	Fluvial	None	11-25%	0-10%	12.5%	1.82	17.0%	31.0%	L		
18-02	0.59	Fluvial	Fluvial	11-25%	0-10%	12.5%	0.57	12.5%	7.1%	L		
18-01	0.05	Mass Wasting	Fluvial	11-25%	11-25%	18.0%	0.54	15.3%	8.3%	L		
TOTALS	**8.10**						**8.05**		**9.1%**	**Volume (m3)**		
										Weight (kN)**		
										Weight (MT)		**133**
										Volume/Kilometer (m3/km)		
										Metric Ton/Kilometer (MT/km)		16
										Treated Length (km)		
										Percent Total Load Reduction (%)		
										Cost of Treatment ($)		
										Cost per Metric Ton Reduced Load (%/MT)		

High	0	
Mode	0.60	0.073962733
H&M	0.6	

Reduced Loads: Channel Restoration (84.3% reduction) | **Costs: Channel Restoration ($984/m)**

RGA ID	Typical Bank Percent Fines (%)	Focused Treatment Bank Erosion of Fines (m3)	Combined H&M Treatment Bank Erosion of Fines (m3)	Cost of Maximum Treatment ($)	Cost of Focused Treatment ($)	Cost of Combined Treatment ($)
	All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated	All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated
18-09						
18-08				$ 1,331,005		$ 1,331,005
18-6				$ 4,810,045		
18-7				$ 1,223,100		
18-05				$ 1,413,904		
18-4a				$ 3,750,296		
18-4b				$ 1,114,380		
18-04				$ 287,293		$ 287,293
18-03				$ 4,952,468		
18-02				$ 1,537,573		
18-01				$ 1,471,253		
TOTALS						
	69.3	**133.0**	**73.5**			
	9		9			
	8.1	0.0	0.6			
	47.9%	0.0%	44.7%			
				$ 21,891,316	$ -	$ 1,618,297
				$ 343,625	$ -	$ 27,221

Average Percent Reduction for Treatment **47.9**
Slope Reduction 0.521
Using average of BW, UTR, and Ward model results.

Cost per m **$ 2,718
Using small stream costs.

Reduced Total Phosphorus Loads: Channel Restoration

Stream	Maximum Treatment Bank Erosion of Fines (m3)	Focused Treatment Bank Erosion of Fines (m3)	Combined H&M Treatment Bank Erosion of Fines (m3)
Third Creek	All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated
Reduced Sediment Load (MT)	69	133	74
Existing Fine Sediment Load (MT)	133	133	133
Reduced TP Load (MT)	**0.01**	**0.02**	**0.01**
Existing TP Load (MT)	**0.02**	**0.02**	**0.02**
Percent TP Load Reduction (%)	47.9%	0.0%	44.7%
Cost of Treatment ($)	$ 21,891,316	$ -	$ 1,618,297
Cost per Ton Reduced TP (%/MT)	$ 2,260,690,555	N/A	$ 179,083,482

Multiplier for Percent TP Content of Sediment 0.000152
95% C.I. for Percent TP Content of Sediment 0.096-0.197 %
(Source: Ferguson 2005; Ferguson and Qualls 2005)

Stream	Existing	Tier 2 Mixed Treatments: Fine Sediment Loads and Cost Summary			
	Fine-Sediment Load (MT)*	Fine-Sediment Load (MT)	Load Reduction (%)	Total Cost ($)	Cost per Metric Ton Reduced Load ($/MT)
	All Reaches				
Blackwood Creek	4,432	1,275	71.2%	$ 13,580,120	$ 4,303
Upper Truckee River	5,828	2,094	64.1%	$ 29,618,842	$ 7,933
Ward Creek	2,953	919	68.9%	$ 6,478,889	$ 3,185
Totals/Averages	**13,213**	**4,288**	**68.1%**	**$ 49,677,851**	**$5,140**

* Modeled or measured for 1995 year, plus Jan 1997 event

Stream	Existing	Tier 2 Mixed Treatments: Total Phophorus Loads and Cost Summary			
	Total Phosphorus Load (MT)*	Total Phosphorus Load (MT)	Load Reduction (%)	Total Cost ($)	Cost per Metric Ton Reduced TP ($/MT)
	All Reaches				
Blackwood Creek	0.67	0.19	71.2%	$ 13,580,120	$ 28,306,130
Upper Truckee River	0.89	0.32	64.1%	$ 29,618,842	$ 52,187,544
Ward Creek	0.45	0.14	68.9%	$ 6,478,889	$ 20,954,357
Totals/Averages	**2.01**	**0.65**	**68.1%**	**$ 49,677,851**	**$33,816,010**

Streambank Fine Sediment Source Information (Simon and others 2003; Simon 2006)										Existing Loads: Stream Average Percent Fines			Existing Loads
RGA River Station (km)	Bank Erosion (Left)	Bank Erosion (Right)	Bank Instability Percent (Left)	Bank Instability Percent (Right)	Combined Bank Percent Failing (%)	Unit Length (km)	Distributed Average Percent Failing (%)	Length-Weighted Percent Failing (%)	Relative Contribution of Fines from Banks (H, M, L)	"High" Existing Bank Erosion of Fines (m3)	"Moderate" Existing Bank Erosion of Fines (m3)	"Severity Rated" Existing Bank Erosion of Fines (m3)	Typical Bank Percent Fines (%)
8.29	None	None	0-10%	0-10%	5.0%								
8.19	Fluvial	None	0-10%	26-50%	21.5%	0.10	13.3%	1.3%	M	119	11	11	5.8%
7.69	Fluvial	Fluvial	11-25%	11-25%	18.0%	0.50	19.8%	9.9%	L	886	79	8	0.0%
7.18	Fluvial	Fluvial	11-25%	11-25%	18.0%	0.51	18.0%	9.2%	L	823	73	7	26.0%
7.17	Fluvial	Mass Wasting	11-25%	76-100%	53.0%	0.01	35.5%	0.4%	H	32	3	32	26.0%
6.84	None	Mass Wasting	0-10%	11-25%	11.5%	0.33	32.3%	10.6%	L	955	85	8	26.6%
6.51	None	Mass Wasting	0-10%	51-75%	34.0%	0.33	22.8%	7.5%	M	673	60	60	22.1%
6.03	None	Mass Wasting	0-10%	26-50%	21.5%	0.48	27.8%	13.3%	M	1195	106	106	20.0%
5.55	None	Fluvial	0-10%	26-50%	21.5%	0.48	21.5%	10.3%	M	926	82	82	7.9%
5.08	None	Mass Wasting	0-10%	51-75%	34.0%	0.47	27.8%	13.0%	M	1170	104	104	23.5%
4.15	Fluvial	Fluvial	26-50%	11-25%	25.5%	0.93	29.8%	27.7%	M	2482	221	221	3.6%
3.95	None	Mass Wasting	0-10%	76-100%	46.5%	0.20	36.0%	7.2%	H	646	57	646	21.4%
2.80	Mass Wasting	None	51-75%	0-10%	34.0%	1.15	40.3%	46.3%	M	4152	369	369	12.3%
1.97	Fluvial	Mass Wasting	26-50%	11-25%	25.5%	0.83	29.8%	24.7%	M	2215	197	197	24.8%
1.77	Fluvial	Mass Wasting	11-25%	51-75%	40.5%	0.20	33.0%	6.6%	H	592	53	592	16.6%
0.32	Mass Wasting	None	51-75%	0-10%	34.0%	1.45	37.3%	54.0%	M	4845	430	430	16.3%
0.00	None	None	26-50%	26-50%	38.0%	0.32	36.0%	11.5%	M	1033	92	92	16.3%
8.29						**8.29**		**15.8%**	**Volume (m3)**	**22743**	**2021**	**2965**	
									Weight (kN)*	393458	34959	51288	
									Weight (MT)	**40133**	**3566**	**5231**	
									Volume/Kilometer (m3/km)	2743	244	358	
									Metric Ton/Kilometer (MT/km)	4841	430	631	
									Treated Length (km)				
									Percent Total Load Reduction (%)				
									Average Cost of Treatment ($/m)				
									Cost per Metric Ton Reduced Load (%/MT)				

* Uses average bulk unit weight of bank sediment from Simon and others 2003 (17.3

: Specific Percent Fines		Reduced Loads: Mixed Treatments		Costs: Mixed Treatments		Reduced Total Phosphorus Loads: Mixed Treatments	
RGA River Station (km)	"Reach Specific" Existing Bank Erosion of Fines (m3)	Treatment Type	Mixed Treatments Bank Erosion of Fines (m3)	Unit Cost of Treatment ($/m)	Total Cost of Mixed Treatments ($)	Stream	Mixed Treatments Bank Erosion of TP
			Using BSTEM results for similar treatment and site			Blackwood Creek	
8.29			4	$0	$0		
8.19	4	Stone Toe HS	1	$420	$42,000		
7.69	0		11	$0	$0		
7.18	11		33	$0	$0		
7.17	33	Stone Toe	5	$700	$7,000		
6.84	13		78	$0	$0		
6.51	78	Stone Toe HS	31	$420	$138,600		
6.03	126	Stone Toe HS	49	$420	$201,600		
5.55	38	Stone Toe/Reduce Slope	14	$4,094	$1,964,880		
5.08	145	Stone Toe/Reduce Slope	53	$4,094	$1,923,945		
4.15	47	Stone Toe HS	18	$420	$390,600		
3.95	557	Stone Toe	87	$700	$140,000		
2.80	269	Stone Toe	42	$700	$805,000		
1.97	289	Stone Toe	45	$700	$581,000		
1.77	396	Stone Toe	62	$700	$140,000		
0.32	416	Stone Toe/Reduce Slope	153	$4,094	$5,935,575		
0.00	89	Stone Toe/Reduce Slope	33	$4,094	$1,309,920		
8.29	**2511**		**723**			Reduced Sediment Load (MT)	1275
	43447		12503				
	4432		**1275**			Existing Fine Sediment Load (MT)	4432
	303		87			**Reduced TP Load (MT)**	**0.19**
	535		154			**Existing TP Load (MT)**	**0.67**
		H+M	7.0				
			71.2%			Percent TP Load Reduction (%)	71.2%
					$ 13,580,120	Cost of Treatment ($)	$ 13,580,120
					$ 4,303	Cost per Metric Ton Reduced TP (%/MT)	$ 28,306,130

kN/m3)

Treatment	Reduced Load %	Cost $/m
Stone Toe	0.157	700
Stone Toe HS	0.393	420
Stone Toe/Reduce Slope	0.369	4094
Reduce Slope	0.581	7487

Multiplier for Percent TP Content of Sediment	0.000152
95% C.I. for Percent TP Content of Sediment	0.096-0.197 %

(Source: Ferguson 2005; Ferguson and Qualls 2005)

Streambank Fine Sediment Source Information (Simon and others 2003; Simon 2006)										Existing Loads: Stream Average Percent Fines			Existing Loads: Specific Percent Fines	
RGA River Station (km)	Bank Erosion (Left)	Bank Erosion (Right)	Bank Instability Percent (Left)	Bank Instability Percent (Right)	Combined Bank Percent Failing (%)	Unit Length (km)	Distributed Average Percent Failing (%)	Length-Weighted Percent Failing (%)	Relative Contribution of Fines from Banks (H, M, L)	"High" Existing Bank Erosion of Fines (m3)	"Moderate" Existing Bank Erosion of Fines (m3)	"Severity Rated" Existing Bank Erosion of Fines (m3)	Typical Bank Percent Fines (%)	"Reach Specific" Existing Bank Erosion of Fines (m3)
24.19	Fluvial	Fluvial	0-10%	0-10%	5.0%									
23.01	None	Fluvial	0-10%	11-25%	11.5%	1.18	8.3%	9.7%	L	185	68	6.8	6.1%	2.9
22.54	None	Mass Wasting	0-10%	11-25%	11.5%	0.47	11.5%	5.4%	L	103	38	3.8	6.3%	1.7
21.77	None	None	0-10%	0-10%	5.0%	0.77	8.3%	6.4%	L	121	44	4.4	6.3%	2.0
21.40	Fluvial	Fluvial	0-10%	0-10%	5.0%	0.37	5.0%	1.9%	L	35	13	1.3	6.3%	0.6
20.75	Mass Wasting	Mass Wasting	0-10%	11-25%	11.5%	0.65	8.3%	5.4%	L	102	38	3.8	6.5%	1.7
19.94	Mass Wasting	Fluvial	51-75%	0-10%	34.0%	0.81	22.8%	18.4%	M	351	129	129.0	12.3%	111.1
19.26	Fluvial	Mass Wasting	0-10%	26-50%	21.5%	0.68	27.8%	18.9%	M	359	132	132.1	14.8%	136.8
18.57	None	Mass Wasting	0-10%	51-75%	34.0%	0.69	27.8%	19.1%	M	365	134	134.0	14.8%	138.9
17.99	Fluvial	Fluvial	0-10%	0-10%	5.0%	0.58	19.5%	11.3%	L	215	79	7.9	14.8%	8.2
17.78	None	Mass Wasting	0-10%	25-50%	21.5%	0.21	13.3%	2.8%	M	53	19	19.5	17.3%	23.5
16.90	Fluvial	Fluvial	11-25%	0-10%	11.5%	0.88	16.5%	14.5%	L	277	102	10.2	13.4%	9.5
16.40	Fluvial	Fluvial	11-25%	11-25%	18.0%	0.50	14.8%	7.4%	L	140	52	5.2	13.4%	4.8
15.78	None	None	0-10%	0-10%	5.0%	0.62	11.5%	7.1%	L	136	50	5.0	13.4%	4.7
15.277	None	Fluvial	0-10%	26-50%	21.5%	0.50	13.3%	6.7%	M	127	47	46.7	13.4%	43.6
14.77	None	Mass Wasting	0-10%	76-100%	46.5%	0.51	34.0%	17.2%	H	328	121	328.4	9.4%	188.4
14.10	Fluvial	None	0-10%	0-10%	5.0%	0.67	25.8%	17.3%	L	329	121	12.1	21.0%	17.8
13.52	None	Mass Wasting	0-10%	76-100%	46.5%	0.58	25.8%	14.9%	H	285	105	284.5	18.2%	316.0
13.15	None	Mass Wasting	0-10%	50-75%	34.0%	0.37	40.3%	14.9%	M	284	104	104.2	18.2%	132.8
12.07	None	Mass Wasting	0-10%	0-10%	5.0%	1.08	19.5%	21.1%	L	401	147	14.7	18.4%	18.9
11.21	Fluvial	Mass Wasting	0-10%	51-75%	34.0%	0.86	19.5%	16.8%	M	319	117	117	18.4%	150.8
10.84	Mass Wasting	Fluvial	51-75%	0-10%	34.0%	0.37	34.0%	12.6%	M	240	88	88.1	18.5%	114.0
10.04	None	Fluvial	0-10%	11-25%	11.5%	0.80	22.8%	18.2%	L	347	127	12.7	16.3%	14.5
8.46	None	Mass Wasting	0-10%	76-100%	46.5%	1.58	29.0%	45.8%	H	873	321	872.9	14.1%	751.0
7.14	None	Mass Wasting	0-10%	0-10%	27.5%	1.32	37.0%	48.8%	M	930	342	341.9	23.0%	549.2
5.84	None	None	0-10%	0-10%	5.0%	1.30	16.3%	21.1%	L	402	148	14.8	18.4%	19.1
5.06	Fluvial	Mass Wasting	26-50%	26-50%	38.0%	0.78	21.5%	16.8%	M	319	117	117.4	13.9%	114.2
4.10	Fluvial	Fluvial	0-10%	0-10%	5.0%	0.96	21.5%	20.6%	L	393	144	14.4	14.4%	14.6
2.94	Mass Wasting	None	51-75%	0-10%	34.0%	1.16	19.5%	22.6%	M	431	158	158	23.0%	254.9
1.96					20.0%	0.99	27.0%	26.6%	M	507	186	186	11.6%	151.2
1.63					12.0%	0.33	16.0%	5.2%	L	99	37	3.7	11.6%	3.0
0.00					5.0%	1.63	8.5%	13.8%	L	264	97	9.7	3.5%	2.4
24.19						**24.19**		**20.2%**	**Volume (m3)**	**9322**	**3425**	**3191**		**3303**
									Weight (kN)*	161267	59258	55203		57136
									Weight (MT)	**16449**	**6044**	**5631**		**5828**
									Volume/Kilometer (m3/km)	385	142	132		137
									Metric Ton/Kilometer (MT/km)	680	250	233		241
									Treated Length (km)					
									Percent Total Load Reduction (%)					
									Average Cost of Treatment ($/m)					
									Cost per Metric Ton Reduced Load (%/MT)					

* Uses 1905 m3/km [average eroded fines for 4.51 km, no veg (1470 m3/km) and 13.1 km (2340 m3/km)].

** Uses average bulk unit weight of bank sediment from Simon and others 2003 (17.3 kN/m3)

Reduced Loads: Mixed Treatments			Costs: Mixed Treatments		Reduced Total Phosphorus Loads: Mixed Treatments	
RGA River Station (km)	Treatment Type	Mixed Treatments Bank Erosion of Fines (m3)	Unit Cost of Treatment ($/m)	Total Cost of Mixed Treatments ($)	Stream	Mixed Treatments Bank Erosion of TP
		Using BSTEM results for similar treatment and site			Upper Truckee River	
24.19						
23.01		2.9	$ -	$0		
22.54		1.7	$ -	$0		
21.77		2.0	$ -	$0		
21.40		0.6	$ -	$0		
20.75		1.7	$ -	$0		
19.94	Stone Toe HS	43.6	$ 420	$340,200		
19.26	Stone Toe HS	53.7	$ 420	$285,600		
18.57	Stone Toe HS	54.5	$ 420	$289,800		
17.99		8.2	$ -	$0		
17.78	Stone Toe	3.7	$ 700	$147,000		
16.90		9.5	$ -	$0		
16.40		4.8	$ -	$0		
15.78		4.7	$ -	$0		
15.277	Stone Toe	6.8	$ 700	$352,100		
14.77	Stone Toe/Reduce Slope	69.5	$ 6,291	$3,189,537		
14.10		17.8	$ -	$0		
13.52	Stone Toe	49.6	$ 700	$406,000		
13.15	Stone Toe/Reduce Slope	49.0	$ 6,291	$2,327,670		
12.07		18.9	$ -	$0		
11.21	Stone Toe/Reduce Slope	55.6	$ 6,291	$5,410,260		
10.84	Wet/Woody Veg	53.9	$ 336	$124,320		
10.04		14.5	$ -	$0		
8.46	Stone Toe/Reduce Slope	277.1	$ 700	$1,106,000		
7.14	Stone Toe/Reduce Slope	202.7	$ 6,291	$8,304,120		
5.84		19.1	$ -	$0		
5.06	Stone Toe HS	44.8	$ 420	$327,600		
4.10		14.6	$ -	$0		
2.94	Stone Toe	40.0	$ 700	$812,000		
1.96	Stone Toe/Reduce Slope	55.8	$ 6,291	$6,196,635		
1.63		3.0	$ -	$0		
0.00		2.4	$ -	$0		
24.19		**1187**			Reduced Sediment Load (MT)	2094
		20530				
		2094			Existing Fine Sediment Load (MT)	5828
		49			**Reduced TP Load (MT)**	**0.32**
		87			**Existing TP Load (MT)**	**0.89**
	H+M only	11.4				
		64.1%			Percent TP Load Reduction (%)	64.1%
				$ 29,618,842	Cost of Treatment ($)	$ 29,618,842
				$ 7,933	Cost per Ton Reduced TP (%/MT)	$ 52,187,544

Treatment	Reduced Load %	Cost $/m
Stone Toe	0.157	700
Stone Toe HS	0.393	420
Stone Toe/Reduce Slope	0.369	6291
Reduce Slope	0.462	11882
Reduce Slope/Wet Meadow	0.473	6109
Wet and Woody Veg	0.473	336
Anchored Shrub/Woody Riparian	0.66	916

Multiplier for Percent TP Content of Sediment	0.000152
95% C.I. for Percent TP Content of Sediment	0.096-0.197 %
(Source: Ferguson 2005; Ferguson and Qualls 2005)	

Streambank Fine Sediment Source Information (Simon and others 2003; Simon 2006)										Existing Loads: Stream Average Percent Fines			Existing Loads: Specific Percent Fines	
RGA River Station (km)	Bank Erosion (Left)	Bank Erosion (Right)	Bank Instability Percent (Left)	Bank Instability Percent (Right)	Combined Bank Percent Failing (%)	Unit Length (km)	Distributed Average Percent Failing (%)	Length-Weighted Percent Failing (%)	Relative Contribution of Fines from Banks (H, M, L)	"High" Existing Bank Erosion of Fines (m3)	"Moderate" Existing Bank Erosion of Fines (m3)	"Severity Rated" Existing Bank Erosion of Fines (m3)	Typical Bank Percent Fines (%)	"Reach Specific" Existing Bank Erosion of Fines (m3)
6.55	None	Fluvial	0-10%	26-50%	24.0%				L				24.4%	
6.45	Fluvial	Fluvial	0-10%	11-25%	11.5%	0.10	17.8%	1.8%	L	58.9	6.1	0.6	27.7%	2.9
6.42	None	None	0-10%	0-10%	5.0%	0.04	8.3%	0.3%	L	10.7	1.1	0.1	17.5%	0.3
6.27	None	Fluvial	0-10%	11-25%	11.5%	0.15	8.3%	1.2%	L	40.4	4.2	0.4	27.1%	2.0
6.17	Fluvial	None	11-25%	0-10%	11.5%	0.10	11.5%	1.2%	L	39.9	4.2	0.4	13.1%	0.9
6.10	Fluvial	None	11-25%	0-10%	11.5%	0.07	11.5%	0.7%	L	25.2	2.6	0.3	16.2%	0.7
5.94	None	Mass Wasting	0-10%	76-100%	49.0%	0.16	30.3%	4.9%	H	166.2	17.3	17	19.2%	57
5.87	None	Fluvial	0-10%	0-10%	5.0%	0.07	27.0%	1.9%	L	63.9	6.7	0.7	9.7%	1.1
5.81	Fluvial	Fluvial	0-10%	11-25%	11.5%	0.06	8.3%	0.5%	L	17.4	1.8	0.2	0.2%	0.0
5.53	Fluvial	Fluvial	11-25%	0-10%	11.5%	0.28	11.5%	3.2%	L	107.7	11.2	1.1	21.0%	4.1
5.36	None	Fluvial	0-10%	26-50%	21.5%	0.17	16.5%	2.8%	M	92.5	9.6	9.6	33.0%	54.9
5.12	Fluvial	Mass Wasting	0-10%	26-50%	21.5%	0.24	21.5%	5.1%	M	170.3	17.7	17.7	18.5%	56.6
4.74	None	Mass Wasting	0-10%	76-100%	49.0%	0.38	35.3%	13.5%	H	454.5	47.3	47	22.9%	187
4.52	Fluvial	Fluvial	11-25%	11-25%	18.0%	0.22	33.5%	7.3%	L	245.6	25.6	2.6	16.6%	7.3
4.25	Mass Wasting	None	26-50%	0-10%	21.5%	0.27	19.8%	5.4%	M	180.5	18.8	18.8	16.6%	53.7
4.06	Fluvial	Fluvial	11-25%	11-25%	18.0%	0.19	19.8%	3.8%	L	127.0	13.2	1.3	10.2%	2.3
3.64	Mass Wasting	Fluvial	51-75%	26-50%	50.5%	0.42	34.3%	14.3%	H	480.2	50.0	480	5.8%	439
3.51	Fluvial	Mass Wasting	11-25%	51-75%	40.5%	0.14	45.5%	6.2%	H	207.2	21.6	207	6.1%	198
3.28	None	Mass Wasting	0-10%	0-10%	5.0%	0.23	22.8%	5.1%	L	173.0	18.0	1.8	6.1%	1.9
2.64	None	Fluvial	0-10%	0-10%	5.0%	0.64	5.0%	3.2%	L	107.6	11.2	1.1	6.1%	1.2
2.38	Fluvial	Mass Wasting	11-25%	51-75%	40.5%	0.26	22.8%	5.9%	H	196.8	20.5	197	6.4%	197
2.08	Fluvial	Fluvial	0-10%	0-10%	5.0%	0.30	22.8%	6.8%	L	227.4	23.7	2.4	19.7%	8.1
1.97	Fluvial	Fluvial	0-10%	0-10%	5.0%	0.11	5.0%	0.6%	L	19.0	2.0	0.2	17.1%	0.6
1.55	Fluvial	Fluvial	0-10%	0-10%	5.0%	0.43	5.0%	2.1%	L	71.5	7.5	0.7	17.1%	2.2
1.42	Mass Wasting	Fluvial	26-50%	0-10%	21.5%	0.13	13.3%	1.7%	M	57.3	6.0	6.0	14.4%	14.8
1.29	None	Mass Wasting	0-10%	51-75%	34.0%	0.12	27.8%	3.4%	M	115.7	12.1	12.1	14.7%	30.6
1.14	None	Fluvial	0-10%	11-25%	11.5%	0.15	22.8%	3.5%	L	116.9	12.2	1.2	14.7%	3.1
1.12	Mass Wasting	Fluvial	26-50%	0-10%	21.5%	0.01	16.5%	0.2%	M	8.1	0.8	0.8	14.7%	2.2
1.11	Fluvial	Fluvial	26-50%	0-10%	21.5%	0.02	21.5%	0.3%	M	10.8	1.1	1.1	15.0%	2.9
0.78	Mass Wasting	Fluvial	51-75%	11-25%	40.5%	0.33	31.0%	10.3%	H	346.0	36.0	36	22.5%	140
0.63	Fluvial	Mass Wasting	0-10%	26-50%	21.5%	0.15	31.0%	4.6%	M	155.1	16.2	16.2	11.5%	32.1
0.51	None	Fluvial	0-10%	11-25%	11.5%	0.12	16.5%	2.0%	M	68.5	7.1	7.1	9.7%	11.9
0.44	Mass Wasting	Mass Wasting	76-100%	11-25%	53.0%	0.07	32.3%	2.2%	H	75.5	7.9	75.5	9.7%	115
0.25	Mass Wasting	Fluvial	26-50%	26-50%	38.0%	0.18	45.5%	8.3%	M	277.9	29.0	29.0	7.9%	39.5
0.09	None	None	0-10%	0-10%	5.0%	0.25	21.5%	5.5%	L	183.2	19.1	1.9	7.9%	2.6
6.55						**6.55**		**3.8%**	**Volume (m3)**	**4698**	**489**	**1196**		**1674**
									Weight (kN)*	81282	8467	20688		28952
									Weight (MT)	**8291**	**864**	**2110**		**2953**
									Volume/Kilometer (m3/km)	717	75	182		255
									Metric Ton/Kilometer (MT/km)	1265	132	322		451
									Treated Length (km)					
									Percent Total Load Reduction (%)					
									Average Cost of Treatment ($/m)					
									Cost per Metric Ton Reduced Load (%/MT)					

* Uses average bulk unit weight of bank sediment from Simon and others 2003 (17.3 kN/m3)

	Reduced Loads: Mixed Treatments		Costs: Mixed Treatments	
RGA River Station (km)	Treatment Type	Mixed Treatments Bank Erosion of Fines (m3) Using BSTEM results for similar treatment and site	Unit Cost of Treatment ($/m)	Total Cost of Mixed Treatments ($)
6.55				
6.45		2.9	$0	$0
6.42		0.3	$0	$0
6.27		2.0	$0	$0
6.17		0.9	$0	$0
6.10		0.7	$0	$0
5.94	Stone Toe	9.0	$700	$114,450
5.87		1.1	$0	$0
5.81		0.0	$0	$0
5.53		4.1	$0	$0
5.36	Stone Toe/Reduce Slope	20.2	$3,784	$631,088
5.12	Stone Toe/Reduce Slope	20.9	$3,784	$892,149
4.74	Stone Toe/Reduce Slope	69.0	$3,784	$1,451,729
4.52		7.3	$0	$0
4.25	Stone Toe HS	21.1	$420	$114,240
4.06		2.3	$0	$0
3.64	Stone Toe/Reduce Slope	161.9	$3,784	$1,578,855
3.51	Stone Toe	31.1	$700	$94,850
3.28		1.9	$0	$0
2.64		1.2	$0	$0
2.38	Stone Toe	30.9	$700	$180,180
2.08		8.1	$0	$0
1.97		0.6	$0	$0
1.55		2.2	$0	$0
1.42	Stone Toe HS	5.8	$420	$54,012
1.29	Stone Toe HS	12.0	$420	$52,122
1.14		3.1	$0	$0
1.12	Stone Toe HS	0.8	$420	$6,174
1.11	Stone Toe	0.5	$700	$10,500
0.78	Stone Toe	22.0	$700	$232,540
0.63	Stone Toe HS	12.6	$420	$62,538
0.51	Stone Toe HS	4.7	$420	$51,912
0.44	Stone Toe/Reduce Slope	42.3	$3,784	$263,710
0.25	Stone Toe/Reduce Slope	14.6	$3,784	$687,840
0.09		2.6	$0	$0
6.55		**521**		
		9009		
		919		
		79		
		140		
	H+M	3.2		
		68.9%		
				$ 6,478,889
				$ 3,185

Treatment	Reduced Load %	Cost $/m
Stone Toe	0.157	700
Stone Toe HS	0.393	420
Stone Toe/Reduce Slope	0.369	3784

Stream	Existing	Tier 3- Bank Protection: Fine Sediment Loads and Cost Summary			
	Fine-Sediment Load (MT)*	Fine-Sediment Load (MT)	Load Reduction (%)	Total Cost ($)	Cost per Metric Ton Reduced Fine Sediment ($/MT)
	All Reaches	"High" & "Moderate" reaches treated	"High" & "Moderate" reaches treated	"High" & "Moderate" reaches treated	"High" & "Moderate" reaches treated
Blackwood Creek	4,432	732	83.5%	$ 4,865,000	$ 1,315
Upper Truckee River	5,828	1,103	81.1%	$ 7,983,500	$ 1,690
Ward Creek	2,953	525	82.2%	$ 2,219,420	$ 914
Subtotal (B,U,W)	**13,213**	**2,360**	**82.3%**	**15,067,920**	**$1,306**
General Creek	117	21	82.4%	$ 2,051,000	$ 21,274
Third	133	23	82.4%	$ 416,780	$ 3,803
Totals/Averages	**26,675**	**4,765**	**82.3%**	**$ 32,603,620**	**$5,050**

* Modeled or measured for 1995 year, plus Jan 1997 event

Stream	Existing	Tier 3- Bank Protection: Total Phosphorus Loads and Cost Summary			
	Total Phosphorus Load (MT)*	Total Phosphorus Load (MT)	Load Reduction (%)	Total Cost ($)	Cost per Metric Ton Reduced TP ($/MT)
	All Reaches	"High" & "Moderate" reaches treated	"High" & "Moderate" reaches treated	"High" & "Moderate" reaches treated	"High" & "Moderate" reaches treated
Blackwood Creek	0.67	0.11	83.5%	$ 4,865,000	$ 8,652,298
Upper Truckee River	0.89	0.17	81.1%	$ 7,983,500	$ 6,773,628
Ward Creek	0.45	0.08	82.2%	$ 2,219,420	$ 13,182,409
Subtotal (B,U,W)	**2.01**	**0.36**	**82.3%**	**15,067,920**	**$9,536,111**
General Creek	0.02	0.00	82.4%	$ 2,883,120	$ 331,990,903
Third	0.02	0.00	82.4%	$ 416,780	$ 292,052,147
Totals/Averages	**4.05**	**0.72**	**82.3%**	**$ 18,367,820**	**$110,364,583**

Streambank Fine Sediment Source Information (Simon and others 2003; Simon 2006)										Existing Loads: Stream Average Percent Fines			Existing Loads: Specific Percent Fines	
RGA River Station (km)	Bank Erosion (Left)	Bank Erosion (Right)	Bank Instability Percent (Left)	Bank Instability Percent (Right)	Combined Bank Percent Failing (%)	Unit Length (km)	Distributed Average Percent Failing (%)	Length-Weighted Percent Failing (%)	Relative Contribution of Fines from Banks (H, M, L)	"High" Existing Bank Erosion of Fines (m3)	"Moderate" Existing Bank Erosion of Fines (m3)	"Severity Rated" Existing Bank Erosion of Fines (m3)	Typical Bank Percent Fines (%)	"Reach Specific" Existing Bank Erosion of Fines (m3)
8.29	None	None	0-10%	0-10%	5.0%									
8.19	Fluvial	None	0-10%	26-50%	21.5%	0.10	13.3%	1.3%	M	119	11	11	5.8%	4
7.69	Fluvial	Fluvial	11-25%	11-25%	18.0%	0.50	19.8%	9.9%	L	886	79	8	0.0%	0
7.18	Fluvial	Fluvial	11-25%	11-25%	18.0%	0.51	18.0%	9.2%	L	823	73	7	26.0%	11
7.17	Fluvial	Mass Wasting	11-25%	76-100%	53.0%	0.01	35.5%	0.4%	H	32	3	32	26.0%	33
6.84	None	Mass Wasting	0-10%	11-25%	11.5%	0.33	32.3%	10.6%	L	955	85	8	26.6%	13
6.51	None	Mass Wasting	0-10%	51-75%	34.0%	0.33	22.8%	7.5%	M	673	60	60	22.1%	78
6.03	None	Mass Wasting	0-10%	26-50%	21.5%	0.48	27.8%	13.3%	M	1195	106	106	20.0%	126
5.55	None	Fluvial	0-10%	26-50%	21.5%	0.48	21.5%	10.3%	M	926	82	82	7.9%	38
5.08	None	Mass Wasting	0-10%	51-75%	34.0%	0.47	27.8%	13.0%	M	1170	104	104	23.5%	145
4.15	Fluvial	Fluvial	26-50%	11-25%	25.5%	0.93	29.8%	27.7%	M	2482	221	221	3.6%	47
3.95	None	Mass Wasting	0-10%	76-100%	46.5%	0.20	36.0%	7.2%	H	646	57	646	21.4%	557
2.80	Mass Wasting	None	51-75%	0-10%	34.0%	1.15	40.3%	46.3%	M	4152	369	369	12.3%	269
1.97	Fluvial	Mass Wasting	26-50%	11-25%	25.5%	0.83	29.8%	24.7%	M	2215	197	197	24.8%	289
1.77	Fluvial	Mass Wasting	11-25%	51-75%	40.5%	0.20	33.0%	6.6%	H	592	53	592	16.6%	396
0.32	Mass Wasting	None	51-75%	0-10%	34.0%	1.45	37.3%	54.0%	M	4845	430	430	16.3%	416
0.00	None	None	26-50%	26-50%	38.0%	0.32	36.0%	11.5%	M	1033	92	92	16.3%	89
8.29						**8.29**		**15.8%**	**Volume (m3)**	**22743**	**2021**	**2965**		**2511**
									Weight (kN)*	393458	34959	51288		43447
									Weight (MT)	**40133**	**3566**	**5231**		**4432**
									Volume/Kilometer (m3/km)	2743	244	358		303
									Metric Ton/Kilometer (MT/km)	4841	430	631		535
									Treated Length (km)					
									Percent Total Load Reduction (%)					
									Cost of Treatment ($)					
									Cost per Metric Ton Reduced Load (%/MT)					

* Uses average bulk unit weight of bank sediment from Simon and others 2003 (17.3 kN/m3)

Reduced Fine Sediment Loads: Bank Protection

RGA River Station (km)	Maximum Treatment Bank Erosion of Fines (m3)	Focused Treatment Bank Erosion of Fines (m3)	Combined H&M Treatment Bank Erosion of Fines (m3)
	All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated
8.29			
8.19	1	4	1
7.69	0	0	0
7.18	2	11	11
7.17	5	5	5
6.84	2	13	13
6.51	12	78	12
6.03	20	126	20
5.55	6	38	6
5.08	23	145	23
4.15	7	47	7
3.95	87	87	87
2.80	42	269	42
1.97	45	289	45
1.77	62	62	62
0.32	65	416	65
0.00	14	89	14
8.29	**394**	**1679**	**415**
	6821	29053	7180
	696	**2963**	**732**
	48	203	50
	84	357	88
	8.3	0.4	7.0
	84.3%	33.1%	83.5%

Costs: Bank Protection

RGA River Station (km)	Cost of Maximum Treatment ($)	Cost of Focused Treatment ($)	Cost of H&M Treatment ($)
	All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated
8.29			
8.19	$ 70,000		$ 70,000
7.69	$ 350,000		
7.18	$ 357,000		
7.17	$ 7,000	$ 7,000	$ 7,000
6.84	$ 231,000		
6.51	$ 231,000		$ 231,000
6.03	$ 336,000		$ 336,000
5.55	$ 336,000		$ 336,000
5.08	$ 329,000		$ 329,000
4.15	$ 651,000		$ 651,000
3.95	$ 140,000	$ 140,000	$ 140,000
2.80	$ 805,000		$ 805,000
1.97	$ 581,000		$ 581,000
1.77	$ 140,000	$ 140,000	$ 140,000
0.32	$ 1,015,000		$ 1,015,000
0.00	$ 224,000		$ 224,000
	$ 5,803,000	$ 287,000	$ 4,865,000
	$ 1,553	$ 195	$ 1,315

Reduced Total Phosphorus Loads: Bank Protection

Stream	Maximum Treatment Bank Erosion of Fines (m3)	Focused Treatment Bank Erosion of Fines (m3)	Combined H&M Treatment Bank Erosion of Fines (m3)
Blackwood Creek	All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated
Reduced Sediment Load (MT)	696	2963	732
Existing Fine Sediment Load (MT)	4432	4432	4432
Reduced TP Load (MT)	**0.11**	**0.45**	**0.11**
Existing TP Load (MT)	**0.67**	**0.67**	**0.67**
Percent TP Load Reduction (%)	84.3%	33.1%	83.5%
Cost of Treatment ($)	$ 5,803,000	$ 287,000	$ 4,865,000
Cost per Ton Reduced TP (%/MT)	$ 10,219,304	$ 1,286,057	$ 8,652,298

Average Percent Reduction for Treatment	**84.3**
	0.157
**Cost per m	**$ 700**
Multiplier for Percent TP Content of Sediment	0.000152
95% C.I. for Percent TP Content of Sediment	0.096-0.197 %

(Source: Ferguson 2005; Ferguson and Qualls 2005)

Streambank Fine Sediment Source Information (Simon and others 2003; Simon 2006)									Existing Loads: Stream Average Percent Fines			Existing Loads: S
RGA River Station (km)	Bank Erosion (Left)	Bank Erosion (Right)	Bank Instability Percent (Left)	Bank Instability Percent (Right)	Combined Bank Percent Failing (%)	Unit Length (km)	Distributed Average Percent Failing (%)	Length-Weighted Percent Failing (%)	Relative Contribution of Fines from Banks (H, M, L)	"High" Existing Bank Erosion of Fines (m3) *	"Moderate" Existing Bank Erosion of Fines (m3)	"Severity Rated" Existing Bank Erosion of Fines (m3)	Typical Bank Percent Fines (%)
24.19	Fluvial	Fluvial	0-10%	0-10%	5.0%								
23.01	None	Fluvial	0-10%	11-25%	11.5%	1.18	8.3%	9.7%	L	185	68	6.8	6.1%
22.54	None	Mass Wasting	0-10%	11-25%	11.5%	0.47	11.5%	5.4%	L	103	38	3.8	6.3%
21.77	None	None	0-10%	0-10%	5.0%	0.77	8.3%	6.4%	L	121	44	4.4	6.3%
21.40	Fluvial	Fluvial	0-10%	0-10%	5.0%	0.37	5.0%	1.9%	L	35	13	1.3	6.3%
20.75	Mass Wasting	Mass Wasting	0-10%	11-25%	11.5%	0.65	8.3%	5.4%	L	102	38	3.8	6.5%
19.94	Mass Wasting	Fluvial	51-75%	0-10%	34.0%	0.81	22.8%	18.4%	M	351	129	129.0	12.3%
19.26	Fluvial	Mass Wasting	0-10%	26-50%	21.5%	0.68	27.8%	18.9%	M	359	132	132.1	14.8%
18.57	None	Mass Wasting	0-10%	51-75%	34.0%	0.69	27.8%	19.1%	M	365	134	134.0	14.8%
17.99	Fluvial	Fluvial	0-10%	0-10%	5.0%	0.58	19.5%	11.3%	L	215	79	7.9	14.8%
17.78	None	Mass Wasting	0-10%	25-50%	21.5%	0.21	13.3%	2.8%	M	53	19	19.5	17.3%
16.90	Fluvial	Fluvial	11-25%	0-10%	11.5%	0.88	16.5%	14.5%	L	277	102	10.2	13.4%
16.40	Fluvial	Fluvial	11-25%	11-25%	18.0%	0.50	14.8%	7.4%	L	140	52	5.2	13.4%
15.78	None	None	0-10%	0-10%	5.0%	0.62	11.5%	7.1%	L	136	50	5.0	13.4%
15.277	None	Fluvial	0-10%	26-50%	21.5%	0.50	13.3%	6.7%	M	127	47	46.7	13.4%
14.77	None	Mass Wasting	0-10%	76-100%	46.5%	0.51	34.0%	17.2%	H	328	121	328.4	9.4%
14.10	Fluvial	None	0-10%	0-10%	5.0%	0.67	25.8%	17.3%	L	329	121	12.1	21.0%
13.52	None	Mass Wasting	0-10%	76-100%	46.5%	0.58	25.8%	14.9%	H	285	105	284.5	18.2%
13.15	None	Mass Wasting	0-10%	50-75%	34.0%	0.37	40.3%	14.9%	M	284	104	104.2	18.2%
12.07	None	Mass Wasting	0-10%	0-10%	5.0%	1.08	19.5%	21.1%	L	401	147	14.7	18.4%
11.21	Fluvial	Mass Wasting	0-10%	51-75%	34.0%	0.86	19.5%	16.8%	M	319	117	117	18.4%
10.84	Mass Wasting	Fluvial	51-75%	0-10%	34.0%	0.37	34.0%	12.6%	M	240	88	88.1	18.5%
10.04	None	Fluvial	0-10%	11-25%	11.5%	0.80	22.8%	18.2%	L	347	127	12.7	16.3%
8.46	None	Mass Wasting	0-10%	76-100%	46.5%	1.58	29.0%	45.8%	H	873	321	872.9	14.1%
7.14	None	Mass Wasting	0-10%	0-10%	27.5%	1.32	37.0%	48.8%	M	930	342	341.9	23.0%
5.84	None	None	0-10%	0-10%	5.0%	1.30	16.3%	21.1%	L	402	148	14.8	18.4%
5.06	Fluvial	Mass Wasting	26-50%	26-50%	38.0%	0.78	21.5%	16.8%	M	319	117	117.4	13.9%
4.10	Fluvial	Fluvial	0-10%	0-10%	5.0%	0.96	21.5%	20.6%	L	393	144	14.4	14.4%
2.94	Mass Wasting	None	51-75%	0-10%	34.0%	1.16	19.5%	22.6%	M	431	158	158	23.0%
1.96					20.0%	0.99	27.0%	26.6%	M	507	186	186	11.6%
1.63					12.0%	0.33	16.0%	5.2%	L	99	37	3.7	11.6%
0.00					5.0%	1.63	8.5%	13.8%	L	264	97	9.7	3.5%
24.19						**24.19**		**20.2%**	**Volume (m3)**	**9322**	**3425**	**3191**	
									Weight (kN)*	161267	59258	55203	
									Weight (MT)	**16449**	**6044**	**5631**	
									Volume/Kilometer (m3/km)	385	142	132	
									Metric Ton/Kilometer (MT/km)	680	250	233	
									Treated Length (km)				
									Percent Total Load Reduction (%)				
									Cost of Treatment ($)				
									Cost per Metric Ton Reduced Load (%/MT)				

* Uses 1905 m3/km [average eroded fines for 4.51 km, no veg (1470 m3/km) and 13.1 km (2

** Uses average bulk unit weight of bank sediment from Simon and others 2003 (17.3 kN/m3)

pecific Percent Fines		Reduced Loads: Bank Protection			Costs: Bank Protection			Reduced Total Phosphorus Loads: Bank Protection			
RGA River Station (km)	"Reach Specific" Existing Bank Erosion of Fines (m3)	Maximum Treatment Bank Erosion of Fines (m3)	Focused Treatment Bank Erosion of Fines (m3)	Combined H&M Treatment Bank Erosion of Fines (m3)	Cost of Maximum Treatment ($)	Cost of Focused Treatment ($)	Cost of H&M Treatment ($)	Stream	Maximum Treatment Bank Erosion of Fines (m3)	Focused Treatment Bank Erosion of Fines (m3)	Combined H&M Treatment Bank Erosion of Fines (m3)
		All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated	All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated	Upper Truckee River	All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated
24.19											
23.01	2.9	0.5	2.9	2.9	$ 826,000						
22.54	1.7	0.3	1.7	1.7	$ 329,000						
21.77	2.0	0.3	2.0	2.0	$ 539,000						
21.40	0.6	0.1	0.6	0.6	$ 259,000						
20.75	1.7	0.3	1.7	1.7	$ 455,000						
19.94	111.1	17.4	111.1	17.4	$ 567,000		$ 567,000				
19.26	136.8	21.5	136.8	21.5	$ 476,000		$ 476,000				
18.57	138.9	21.8	138.9	21.8	$ 483,000		$ 483,000				
17.99	8.2	1.3	8.2	8.2	$ 406,000						
17.78	23.5	3.7	23.5	3.7	$ 147,000		$ 147,000				
16.90	9.5	1.5	9.5	9.5	$ 616,000						
16.40	4.8	0.8	4.8	4.8	$ 350,000						
15.78	4.7	0.7	4.7	4.7	$ 434,000						
15.277	43.6	6.8	43.6	6.8	$ 352,100		$ 352,100				
14.77	188.4	29.6	29.6	29.6	$ 354,900	$ 354,900	$ 354,900				
14.10	17.8	2.8	17.8	17.8	$ 469,000						
13.52	316.0	49.6	49.6	49.6	$ 406,000	$ 406,000	$ 406,000				
13.15	132.8	20.9	132.8	20.9	$ 259,000		$ 259,000				
12.07	18.9	3.0	18.9	18.9	$ 756,000						
11.21	150.8	23.7	150.8	23.7	$ 602,000		$ 602,000				
10.84	114.0	17.9	114.0	17.9	$ 259,000		$ 259,000				
10.04	14.5	2.3	14.5	14.5	$ 560,000						
8.46	751.0	117.9	117.9	117.9	$ 1,106,000	$ 1,106,000	$ 1,106,000				
7.14	549.2	86.2	549.2	86.2	$ 924,000		$ 924,000				
5.84	19.1	3.0	3.0	19.1	$ 910,000						
5.06	114.2	17.9	114.2	17.9	$ 546,000		$ 546,000				
4.10	14.6	2.3	14.6	14.6	$ 672,000						
2.94	254.9	40.0	254.9	40.0	$ 812,000		$ 812,000				
1.96	151.2	23.7	151.2	23.7	$ 689,500		$ 689,500				
1.63	3.0	0.5	3.0	3.0	$ 228,200						
0.00	2.4	0.4	2.4	2.4	$ 1,140,300						
24.19	**3303**	**519**	**2228**	**625**				Reduced Sediment Load (MT)	915	3932	1103
	57136	8970.4	38550	10811							
	5828	**915.0**	**3932**	**1103**				Existing Fine Sediment Load (MT)	5828	5828	5828
	137	21.4	92	26				**Reduced TP Load (MT)**	**0.14**	**0.60**	**0.17**
	241	37.8	163	46				**Existing TP Load (MT)**	**0.89**	**0.89**	**0.89**
		24.2	2.7	11.4							
		84.3%	32.5%	81.1%				Percent TP Load Reduction (%)	84.3%	32.5%	81.1%
					$ 16,933,000	$ 1,866,900	$ 7,983,500	Cost of Treatment ($)	$ 5,803,000	$ 287,000	$ 4,865,000
					$ 3,447	$ 985	$ 1,690	Cost per Ton Reduced TP (%/MT)	$ 7,770,847	$ 995,940	$ 6,773,628

340 m3/km)].
)

Average Percent Reduction for Treatment **84.3**
0.157

Cost per m **$ 700

Multiplier for Percent TP Content of Sediment 0.000152
95% C.I. for Percent TP Content of Sediment 0.096-0.197 %
(Source: Ferguson 2005; Ferguson and Qualls 2005)

Streambank Fine Sediment Source Information (Simon and others 2003; Simon 2006)										Existing Loads: Stream Average Percent Fines			Existing Loads: Specific Percent Fines		Reduc
RGA River Station (km)	Bank Erosion (Left)	Bank Erosion (Right)	Bank Instability Percent (Left)	Bank Instability Percent (Right)	Combined Bank Percent Failing (%)	Unit Length (km)	Distributed Average Percent Failing (%)	Length-Weighted Percent Failing (%)	Relative Contribution of Fines from Banks (H, M, L)	"High" Existing Bank Erosion of Fines (m3)	"Moderate" Existing Bank Erosion of Fines (m3)	"Severity Rated" Existing Bank Erosion of Fines (m3)	Typical Bank Percent Fines (%)	"Reach Specific" Existing Bank Erosion of Fines (m3)	Maximum Treatment Bank Erosion of Fines (m3)
															All reaches treated
6.55	None	Fluvial	0-10%	26-50%	24.0%				L				24.4%		
6.45	Fluvial	Fluvial	0-10%	11-25%	11.5%	0.10	17.8%	1.8%	L	58.9	6.1	0.6	27.7%	2.9	0.5
6.42	None	None	0-10%	0-10%	5.0%	0.04	8.3%	0.3%	L	10.7	1.1	0.1	17.5%	0.3	0.1
6.27	None	Fluvial	0-10%	11-25%	11.5%	0.15	8.3%	1.2%	L	40.4	4.2	0.4	27.1%	2.0	0.3
6.17	Fluvial	None	11-25%	0-10%	11.5%	0.10	11.5%	1.2%	L	39.9	4.2	0.4	13.1%	0.9	0.1
6.10	Fluvial	None	11-25%	0-10%	11.5%	0.07	11.5%	0.7%	L	25.2	2.6	0.3	16.2%	0.7	0.1
5.94	None	Mass Wasting	0-10%	76-100%	49.0%	0.16	30.3%	4.9%	H	166.2	17.3	17	19.2%	57	9.0
5.87	None	Fluvial	0-10%	0-10%	5.0%	0.07	27.0%	1.9%	L	63.9	6.7	0.7	9.7%	1.1	0.2
5.81	Fluvial	Fluvial	0-10%	11-25%	11.5%	0.06	8.3%	0.5%	L	17.4	1.8	0.2	0.2%	0.0	0.0
5.53	Fluvial	Fluvial	11-25%	0-10%	11.5%	0.28	11.5%	3.2%	L	107.7	11.2	1.1	21.0%	4.1	0.6
5.36	None	Fluvial	0-10%	26-50%	21.5%	0.17	16.5%	2.8%	M	92.5	9.6	9.6	33.0%	54.9	8.6
5.12	Fluvial	Mass Wasting	0-10%	26-50%	21.5%	0.24	21.5%	5.1%	M	170.3	17.7	17.7	18.5%	56.6	8.9
4.74	None	Mass Wasting	0-10%	76-100%	49.0%	0.38	35.3%	13.5%	H	454.5	47.3	47	22.9%	187	29.4
4.52	Fluvial	Fluvial	11-25%	11-25%	18.0%	0.22	33.5%	7.3%	L	245.6	25.6	2.6	16.6%	7.3	1.1
4.25	Mass Wasting	None	26-50%	0-10%	21.5%	0.27	19.8%	5.4%	M	180.5	18.8	18.8	16.6%	53.7	8.4
4.06	Fluvial	Fluvial	11-25%	11-25%	18.0%	0.19	19.8%	3.8%	L	127.0	13.2	1.3	10.2%	2.3	0.4
3.64	Mass Wasting	Fluvial	51-75%	26-50%	50.5%	0.42	34.3%	14.3%	H	480.2	50.0	480	5.8%	439	68.9
3.51	Fluvial	Mass Wasting	11-25%	51-75%	40.5%	0.14	45.5%	6.2%	H	207.2	21.6	207	6.1%	198	31.1
3.28	None	Mass Wasting	0-10%	0-10%	5.0%	0.23	22.8%	5.1%	L	173.0	18.0	1.8	6.1%	1.9	0.3
2.64	None	Fluvial	0-10%	0-10%	5.0%	0.64	5.0%	3.2%	L	107.6	11.2	1.1	6.1%	1.2	0.2
2.38	Fluvial	Mass Wasting	11-25%	51-75%	40.5%	0.26	22.8%	5.9%	H	196.8	20.5	197	6.4%	197	30.9
2.08	Fluvial	Fluvial	0-10%	0-10%	5.0%	0.30	22.8%	6.8%	L	227.4	23.7	2.4	19.7%	8.1	1.3
1.97	Fluvial	Fluvial	0-10%	0-10%	5.0%	0.11	5.0%	0.6%	L	19.0	2.0	0.2	17.1%	0.6	0.1
1.55	Fluvial	Fluvial	0-10%	0-10%	5.0%	0.43	5.0%	2.1%	L	71.5	7.5	0.7	17.1%	2.2	0.3
1.42	Mass Wasting	Fluvial	26-50%	0-10%	21.5%	0.13	13.3%	1.7%	M	57.3	6.0	6.0	14.4%	14.8	2.3
1.29	None	Mass Wasting	0-10%	51-75%	34.0%	0.12	27.8%	3.4%	M	115.7	12.1	12.1	14.7%	30.6	4.8
1.14	None	Fluvial	0-10%	11-25%	11.5%	0.15	22.8%	3.5%	L	116.9	12.2	1.2	14.7%	3.1	0.5
1.12	Mass Wasting	Fluvial	26-50%	0-10%	21.5%	0.01	16.5%	0.2%	M	8.1	0.8	0.8	14.7%	2.2	0.3
1.11	Fluvial	Fluvial	26-50%	0-10%	21.5%	0.02	21.5%	0.3%	M	10.8	1.1	1.1	15.0%	2.9	0.5
0.78	Mass Wasting	Fluvial	51-75%	11-25%	40.5%	0.33	31.0%	10.3%	H	346.0	36.0	36	22.5%	140	22.0
0.63	Fluvial	Mass Wasting	0-10%	26-50%	21.5%	0.15	31.0%	4.6%	M	155.1	16.2	16.2	11.5%	32.1	5.0
0.51	None	Fluvial	0-10%	11-25%	11.5%	0.12	16.5%	2.0%	M	68.5	7.1	7.1	9.7%	11.9	1.9
0.44	Mass Wasting	Mass Wasting	76-100%	11-25%	53.0%	0.07	32.3%	2.2%	H	75.5	7.9	75.5	9.7%	115	18.0
0.25	Mass Wasting	Fluvial	26-50%	26-50%	38.0%	0.18	45.5%	8.3%	M	277.9	29.0	29.0	7.9%	39.5	6.2
0.09	None	None	0-10%	0-10%	5.0%	0.25	21.5%	5.5%	L	183.2	19.1	1.9	7.9%	2.6	0.4
6.55						**6.55**		**3.8%**	**Volume (m3)**	**4698**	**489**	**1196**		**1674**	**263**
									Weight (kN)*	81282	8467	20688		28952	4545
									Weight (MT)	**8291**	**864**	**2110**		**2953**	**464**
									Volume/Kilometer (m3/km)	717	75	182		255	40
									Metric Ton/Kilometer (MT/km)	1265	132	322		451	71
									Treated Length (km)						6.6
									Percent Total Load Reduction (%)						84.3%
									Cost of Treatment ($)						
									Cost per Metric Ton Reduced Load (%/MT)						

Average Percent Re
Treatment

* Uses average bulk unit weight of bank sediment from Simon and others 2003 (17.3 kN/m3)

d Loads: Bank Protection			Costs: Bank Protection		
RGA River Station (km)	Focused Treatment Bank Erosion of Fines (m3)	Combined H&M Treatment Bank Erosion of Fines (m3)	Cost of Maximum Treatment ($)	Cost of Focused Treatment ($)	Cost of H&M Treatment ($)
	Only "High" reaches treated	"High & Moderate" reaches treated	All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated
6.55					
6.45	2.9	2.9	$ 69,090		
6.42	0.3	0.3	$ 27,090		
6.27	2.0	2.0	$ 102,060		
6.17	0.9	0.9	$ 72,310		
6.10	0.7	0.7	$ 45,640		
5.94	9.0	9.0	$ 114,450	$ 114,450	$ 114,450
5.87	1.1	1.1	$ 49,280		
5.81	0.0	0.0	$ 43,890		
5.53	4.1	4.1	$ 195,020		
5.36	54.9	8.6	$ 116,760		$ 116,760
5.12	56.6	8.9	$ 165,060		$ 165,060
4.74	29.4	29.4	$ 268,590	$ 268,590	$ 268,590
4.52	7.3	7.3	$ 152,740		
4.25	53.7	8.4	$ 190,400		$ 190,400
4.06	2.3	2.3	$ 133,980		
3.64	68.9	68.9	$ 292,110	$ 292,110	$ 292,110
3.51	31.1	31.1	$ 94,850	$ 94,850	$ 94,850
3.28	1.9	1.9	$ 158,410		
2.64	1.2	1.2	$ 448,210		
2.38	30.9	30.9	$ 180,180	$ 180,180	$ 180,180
2.08	8.1	8.1	$ 208,250		
1.97	0.6	0.6	$ 79,310		
1.55	2.2	2.2	$ 298,060		
1.42	14.8	2.3	$ 90,020		$ 90,020
1.29	30.6	4.8	$ 86,870		$ 86,870
1.14	3.1	3.1	$ 107,030		
1.12	2.2	0.3	$ 10,290		$ 10,290
1.11	2.9	0.5	$ 10,500		$ 10,500
0.78	22.0	22.0	$ 232,540	$ 232,540	$ 232,540
0.63	32.1	5.0	$ 104,230		$ 104,230
0.51	11.9	1.9	$ 86,520		$ 86,520
0.44	18.0	18.0	$ 48,790	$ 48,790	$ 48,790
0.25	39.5	6.2	$ 127,260		$ 127,260
0.09	2.6	2.6	$ 177,520		
6.55	**550**	**298**			
	9511	5148			
	970	**525**			
	84	45			
	148	80			
	1.8	3.2			
	67.1%	82.2%			
			$ 4,587,310	$ 1,231,510	$ 2,219,420
			$ 1,843	$ 621	$ 914

duction for

		84.3	**Cost per m	**$ 700**	
		0.157			

Reduced Total Phosphorus Loads: Bank Protection			
Stream	Maximum Treatment Bank Erosion of Fines (m3)	Focused Treatment Bank Erosion of Fines (m3)	Combined H&M Treatment Bank Erosion of Fines (m3)
Ward Creek	All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated
Reduced Sediment Load (MT)	464	970	525
Existing Fine Sediment Load (MT)	2953	2953	2953
Reduced TP Load (MT)	**0.07**	**0.15**	**0.08**
Existing TP Load (MT)	**0.45**	**0.45**	**0.45**
Percent TP Load Reduction (%)	84.3%	67.1%	82.2%
Cost of Treatment ($)	$ 5,803,000	$ 287,000	$ 4,865,000
Cost per Ton Reduced TP (%/MT)	$ 15,335,688	$ 952,191	$ 13,182,409

Multiplier for Percent TP Content of Sediment	0.000152
95% C.I. for Percent TP Content of Sediment	0.096-0.197 %

(Source: Ferguson 2005; Ferguson and Qualls 2005)

Streambank Fine Sediment Source Information (Simon and others 2003; Simon 2006)										Existing Loads: Specific Percent Fines		Reduced Loads: Bank Protection		
RGA River Station (km)	Bank Erosion (Left)	Bank Erosion (Right)	Bank Instability Percent (Left)	Bank Instability Percent (Right)	Combined Bank Percent Failing (%)	Unit Length (km)	Distributed Average Percent Failing (%)	Length-Weighted Percent Failing (%)	Relative Contribution of Fines from Banks (H, M, L)	Typical Bank Percent Fines (%)	"Reach Specific" Existing Bank Erosion of Fines (m3)	Maximum Treatment Bank Erosion of Fines (m3)	Focused Treatment Bank Erosion of Fines (m3)	Combined H&M Treatment Bank Erosion of Fines (m3)
												All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated
8.08	None	None	0-10%	0-10%	5.0%				L					
6.80	None	Fluvial	0-10%	0-10%	5.0%	1.28	5.0%	6.4%	L					
6.66	None	Fluvial	0-10%	0-10%	5.0%	0.14	5.0%	0.7%	L					
6.50	Mass Wasting	Fluvial	76-100%	11-25%	53.0%	0.16	29.0%	4.6%	H					
6.06	None	Fluvial	0-10%	11-25%	11.5%	0.44	32.3%	14.2%	L					
5.90	None	Fluvial	0-10%	26-50%	21.5%	0.16	16.5%	2.6%	M					
5.33	Fluvial	Fluvial	11-25%	11-25%	18.0%	0.57	19.8%	11.3%	L					
5.25	Fluvial	Fluvial	11-25%	11-25%	18.0%	0.08	18.0%	1.4%	L					
5.05	Fluvial	Fluvial	0-10%	11-25%	11.5%	0.20	14.8%	3.0%	L					
4.73	None	Mass Wasting	0-10%	76-100%	46.5%	0.32	29.0%	9.3%	H					
4.21	None	Fluvial	0-10%	0-10%	5.0%	0.52	25.8%	13.4%	L					
3.62	Fluvial	None	0-10%	0-10%	5.0%	0.59	5.0%	3.0%	L					
3.60	Fluvial	Mass Wasting	0-10%	26-50%	21.5%	0.02	13.3%	0.3%	M					
3.59	Fluvial	Fluvial	0-10%	11-25%	11.5%	0.01	16.5%	0.2%	L					
3.25	Fluvial	Mass Wasting	0-10%	76-100%	46.5%	0.34	29.0%	9.9%	H					
2.97	None	None	0-10%	0-10%	5.0%	0.28	25.8%	7.2%	L					
2.58	Fluvial	Mass Wasting	0-10%	51-75%	34.0%	0.39	19.5%	7.6%	M					
2.20	None	Mass Wasting	0-10%	76-100%	46.5%	0.38	40.3%	15.3%	H					
1.94	None	Fluvial	0-10%	26-50%	21.5%	0.26	34.0%	8.8%	M					
1.93	Fluvial	Fluvial	0-10%	0-10%	5.0%	0.01	13.3%	0.1%	L					
1.54	None	Mass Wasting	0-10%	51-75%	34.0%	0.39	19.5%	7.6%	M					
1.17	None	Mass Wasting	0-10%	11-25%	11.5%	0.37	22.8%	8.4%	L					
0.95	Fluvial	Mass Wasting	11-25%	76-100%	53.0%	0.22	32.3%	7.1%	H					
0.89	Fluvial	Mass Wasting	0-10%	11-25%	11.5%	0.06	32.3%	1.9%	L					
0.71	None	Fluvial	0-10%	11-25%	11.5%	0.18	11.5%	2.1%	L					
0.57	None	None	0-10%	0-10%	5.0%	0.14	8.3%	1.2%	L					
0.30	None	Fluvial	0-10%	0-10%	5.0%	0.27	5.0%	1.4%	L					
0.01	Mass Wasting	None	26-50%	0-10%	21.5%	0.29	13.3%	3.8%	M					
8.08						**8.07**		**5.0%**	**Volume (m3)**					
									Weight (kN)*					
									Weight (MT)		**117**	**18.4**	**77.7**	**20.6**
									Volume/Kilometer (m3/km)		0			
									Metric Ton/Kilometer (MT/km)		14	2	10	3
									Treated Length (km)			8.1	1.4	2.9
									Percent Total Load Reduction (%)			84.3%	33.6%	82.4%
									Cost of Treatment ($)					
									Cost per Metric Ton Reduced Load (%/MT)					

Average Percent Reduction for Treatment **84.3**

0.157

Costs: Bank Protection

Cost of Maximum Treatment ($)	Cost of Focused Treatment ($)	Cost of H&M Treatment ($)
All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated
$ 894,180		
$ 98,000		
$ 112,000	$ 112,000	$ 112,000
$ 308,000		
$ 112,000		$ 112,000
$ 399,000		
$ 56,000		
$ 140,000		
$ 224,000	$ 224,000	$ 224,000
$ 364,000		
$ 413,000		
$ 14,000		$ 14,000
$ 7,000		
$ 238,000	$ 238,000	$ 238,000
$ 196,000		
$ 273,000		$ 273,000
$ 266,000	$ 266,000	$ 266,000
$ 182,000		$ 182,000
$ 7,000		
$ 273,000		$ 273,000
$ 259,000		
$ 154,000	$ 154,000	$ 154,000
$ 42,000		
$ 126,000		
$ 98,000		
$ 189,000		
$ 203,000		$ 203,000
$ 5,647,180	$ 994,000	$ 2,051,000
$ 57,256	$ 25,285	$ 21,274

Reduced Total Phosphorus Loads: Bank Protection

Stream	Maximum Treatment Bank Erosion of Fines (m3)	Focused Treatment Bank Erosion of Fines (m3)	Combined H&M Treatment Bank Erosion of Fines (m3)
General Creek	All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated
Reduced Sediment Load (MT)	18	78	21
Existing Fine Sediment Load (MT)	117	117	117
Reduced TP Load (MT)	**0.00**	**0.01**	**0.00**
Existing TP Load (MT)	**0.02**	**0.02**	**0.02**
Percent TP Load Reduction (%)	84.3%	33.6%	82.4%
Cost of Treatment ($)	$ 5,803,000	$ 287,000	$ 4,865,000
Cost per Ton Reduced TP (%/MT)	$ 387,075,378	$ 48,030,064	$ 331,990,903

**Cost per m	**$ 700**

Multiplier for Percent TP Content of Sediment	0.000152
95% C.I. for Percent TP Content of Sediment	0.096-0.197 %

(Source: Ferguson 2005; Ferguson and Qualls 2005)

Streambank Fine Sediment Source Information (Simon and others 2003; Simon 2006)										Existing Loads: Specific Percent Fines	
RGA River Station (km)	Bank Erosion (Left)	Bank Erosion (Right)	Bank Instability Percent (Left)	Bank Instability Percent (Right)	Combined Bank Percent Failing (%)	Unit Length (km)	Distributed Average Percent Failing (%)	Length-Weighted Percent Failing (%)	Relative Contribution of Fines from Banks (H, M, L)	Typical Bank Percent Fines (%)	"Reach Specific" Existing Bank Erosion of Fines (m3)
8.10	Fluvial	Fluvial	11-25%	0-10%	12.5%		6.3%	0.0%	L		
7.61	Fluvial	Fluvial	26-50%	0-10%	21.5%	0.49	17.0%	8.3%	M		
5.84	None	None	0-10%	0-10%	5.0%	1.77	13.3%	23.4%	L		
5.39	None	None	0-10%	0-10%	5.0%	0.45	5.0%	2.3%	L		
4.87	Fluvial	None	11-25%	0-10%	12.5%	0.52	8.8%	4.6%	L		
3.49	None	None	0-10%	0-10%	5.0%	1.38	8.8%	12.1%	L		
3.08	None	None	0-10%	0-10%	5.0%	0.41	5.0%	2.1%	L		
2.97	Fluvial	Fluvial	26-50%	0-10%	21.5%	0.11	13.3%	1.4%	M		
1.15	Fluvial	None	11-25%	0-10%	12.5%	1.82	17.0%	31.0%	L		
0.59	Fluvial	Fluvial	11-25%	0-10%	12.5%	0.57	12.5%	7.1%	L		
0.05	Mass Wasting	Fluvial	11-25%	11-25%	18.0%	0.54	15.3%	8.3%	L		
8.10						**8.05**		**9.1%**	**Volume (m3)**		
									Weight (kN)*		
									Weight (MT)		**133**
									Volume/Kilometer (m3/km)		
									Metric Ton/Kilometer (MT/km)		16
									Treated Length (km)		
									Percent Total Load Reduction (%)		
									Cost of Treatment ($)		
									Cost per Metric Ton Reduced Load (%/MT)		

Reduced Loads: Bank Protection				Costs: Bank Protection		
RGA River Station (km)	Maximum Treatment Bank Erosion of Fines (m3)	Focused Treatment Bank Erosion of Fines (m3)	Combined H&M Treatment Bank Erosion of Fines (m3)	Cost of Maximum Treatment ($)	Cost of Focused Treatment ($)	Cost of H&M Treatment ($)
8.10						
7.61				$ 342,790		$ 342,790
5.84				$ 1,238,790		
5.39				$ 315,000		
4.87				$ 364,140		
3.49				$ 965,860		
3.08				$ 287,000		
2.97				$ 73,990		$ 73,990
1.15				$ 1,275,470		
0.59				$ 395,990		
0.05				$ 378,910		
8.10						
	17.6	**133.0**	**23.4**			
	2		3			
	8.1	0.0	0.6			
	84.3%	0.0%	82.4%			
				$ 5,637,940	$ -	$ 416,780
				$ 48,837	$ -	$ 3,803

Average Percent Reduction for Treatment	**84.3**	**Cost per m	**$ 700**
	0.157		

Reduced Total Phosphorus Loads: Bank Protection			
Stream	Maximum Treatment Bank Erosion of Fines (m3)	Focused Treatment Bank Erosion of Fines (m3)	Combined H&M Treatment Bank Erosion of Fines (m3)
Third Creek	All reaches treated	Only "High" reaches treated	"High & Moderate" reaches treated
Reduced Sediment Load (MT)	18	133	23
Existing Fine Sediment Load (MT)	133	133	133
Reduced TP Load (MT)	**0.00**	**0.02**	**0.00**
Existing TP Load (MT)	**0.02**	**0.02**	**0.02**
Percent TP Load Reduction (%)	86.8%	0.0%	82.4%
Cost of Treatment ($)	$ 5,803,000	$ 287,000	$ 4,865,000
Cost per Ton Reduced TP (%/MT)	$ 330,702,605	N/A	$ 292,052,147

Multiplier for Percent TP Content of Sediment	0.000152
95% C.I. for Percent TP Content of Sediment	0.096-0.197 %

(Source: Ferguson 2005; Ferguson and Qualls 2005)

Appendix E

Stream Channel Erosion Pollutant Control Options Cost Estimates

by ENTRIX, Inc.

Cost Estimation of Stream Channel Erosion Treatments

Prepared for:

Valley and Mountain Consulting
IWQMS to Support Lake Tahoe TMDL

Prepared by:

Entrix, Inc.
1048 Ski Run Boulevard
South Lake Tahoe, CA

May 2007

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Appendix B: Exhibits

B.1 – Engineered Bank Stabilization
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1.0 Introduction

As part of the overall Total Maximum Daily Load (TMDL) efforts currently ongoing within the Lake Tahoe Basin, Stream Channel Erosion reduction is being investigated to determine its overall contribution, and potential benefit to Lake Tahoe. The Stream Channel group identified Pollutant Control Options (PCOs) to reduce stream bank fine sediment sources of sediment in these streams and Lake Tahoe. To properly assess each of the PCOs as components of alternatives for the TMDL, general cost estimates of each PCO are required for a cost/benefit analysis. This memorandum develops general cost estimates of the treatment per uniform implementation reach (1,000 lineal feet) of each identified PCO.

2.0 Description/Purpose

This memorandum provides a general cost overview of different stream erosion treatment types within the Lake Tahoe Basin that are part of the PCOs considered for the water quality TMDL. Additionally, the memorandum addresses estimated Operations and Maintenance (O & M) costs over an assumed 20-year life span of each improvement. The cost estimates can be used to compare construction costs for implementing a project along and/or within a stream channel, along with the anticipated O & M costs over a 20-year period. The cost estimates developed in association with this document are general in nature, and are intended to provide a general cost estimate rather than an “exact” determination of costs. Each project has many variables, some of which cannot be accounted for in the general nature of this document. However, the estimates allow for the comparison between different treatment types, and consistent general cost estimating for evaluation of various potential treatments basin-wide.

3.0 Methods

The cost estimating for this effort are general in nature and use existing available construction costs for similar type work in the Lake Tahoe Basin geographic region, and constructed within the past ten years. This similar type work however is not for stream channels of the size and flow of the three study streams (Upper Truckee, Ward and Blackwood), as a stream of these sizes have not had significant restoration/repair/enhancement performed within the Lake Tahoe Basin. In order to estimate costs on an accurate basis, within this local (Tahoe Basin), previously constructed projects, and unit costs were used to determine an estimate of cost for the various improvements. Since the three study streams are of different size and flow than the previously constructed projects, this memorandum will provide a means to estimate cost increases based on these size/flow differences. In general, the cost estimates provided within the tables of this document are for channels consisting of a 100 year design flow of between

150 and 200 cubic feet per second (cfs), or were for Erosion Control and other types of projects ongoing in the Tahoe Basin.

The cost estimates are all expressed in year 2008 construction costs, to most accurately compare costs. Inflationary costs have been applied to the Tahoe Basin existing data, using the inflationary rate of construction costs in the region (over the past 4 years the inflation rate has been approximately 15% per year). Furthermore, these cost estimates are expressed on a consistent spatial implementation scale, using typical 1,000 linear feet of channel as the 'implementation area'. While the key fine sediment pollutant source streams are the Upper Truckee River, Blackwood Creek or Ward Creek, cost estimates are also needed that can be applied to other streams in the basin. Since the size, location, flow, etc. of channels is drastically different; the cost estimates are a "blended" rate for the channel types, and not specific to any one channel in particular. Based on available data, ratios/equations are provided to adjust the general cost estimates for given treatments, on given flow channels. Additionally, the values of cost within the tables are for construction activities requiring minimal construction access requirements (ease of access to construct the given improvement). The cost estimates provided (from existing projects completed) typically were constructed within 500 feet of a public right-of-way (paved roadway) which required minor tree removal, grading and stabilized access construction. Given the general difficulty in constructing any stream/river restoration aspect within the Tahoe Basin, this minimal assumption is based on the general types of access required on previous example projects (Lower West Side, Angora SEZ, Erosion Control Projects). A correlation/equation is provided to adjust the general costs to better represent more difficult access or other construction "obstacles".

A brief description of how to correlate costs to a particular stream is provided as a conceptual rough estimate of cost (to be used only for project funding estimates, not for actual construction costs). The estimates will allow for ease of comparison between the treatment options, but will not provide detail cost estimating for implementing any one of these PCOs, on any particular channel within the Lake Tahoe Basin. The estimates do allow for a comparison between the alternative PCOs, including general percentage difference in cost between the options.

In order perform a cursory review of the estimates provided within this document and quality assurance/quality review process was provided. This process included a peer review of all data and assumptions of the costs estimated in the attached table, along with a comparison between the planning level estimates available for Ward Creek. The comparison between this document and the Ward Creek planning estimates showed that when the estimation procedures used in this document are followed, the estimates fall within the estimate ranges of the planning efforts.

The general cost estimates developed are summarized in a table attached to this memorandum.

4.0 Estimation of costs for differing channel sizes

In general, and as discussed above, the cost estimates provided within the tables of this document are for channels consisting of a 100 year design flow of between 150 and 200 cubic feet per second (cfs). Generally the streams within the Tahoe Basin consist of flows within close proximity to this general range; however, the key fine sediment load source streams are significantly larger than this assumed flow, which effects the overall cost of each PCO. To more closely represent the likely cost of alternative treatments on streams of different scale, the general cost estimates based on the channel sizes and flows for previously constructed projects herein must be adjusted. In order to perform this 100 year design flow for the channel in questions will be required to be estimated in a general nature (i.e. no detailed HEC modeling required, a good estimate will suffice for the nature of this preliminary estimating activity). Once this value is known the cost difference between the estimate in this document, and for the proposed channel, is a simple correlation based on a 10 percentage difference in 100 year design flows. For an example, please see below (Ward Creek Watershed Assessment, for California Tahoe Conservancy, February 2007, by Hydroscience and River Run Consulting – 100 year flow 2,670 cfs)):

- Assumed 100 year flow for this document = 175 cfs
- Estimate 100 year flow for channel in question = 2,670 cfs

Therefore the channel in question is approximately 15.26 times larger (in 100-year flow value) than the channel values for this document. Based on a 10 percent increase correlation (10% of 15.26 is 1.526, or 152.6%) the estimated values to be multiplied by 252.6% (100% + 152.6%) or 2.526 to attain a more accurate estimate of costs, see below:

- Keyed Boulder LDW Jams (document cost) = $219,463
- Estimate for 2,670 cfs channel = 2.526 * $219,463 = $554,363.50

Furthermore, since the main objective of this report/memorandum is for use on the three major channels in Tahoe (Ward, Blackwood and Upper Truckee) we have investigated the “best known” values of these channels 100-year flows. Ward is stated above, and Blackwood is estimated at 4,820 cfs (Swanson Hydrology and Geomorphology, Blackwood Creek Stream Restoration Project – Final Design Report, April 2003 for the USFS-LTBMU), which will provide a multiplier of 2.754. Upper Truckee is estimated at 7,650 cfs (Entrix, Inc., Upper Truckee River Process and Functions Report, February 2003, for the State of California), which will provide a multiplier of 4.371.

5.0 Estimation of cost for differing access conditions

Given the general difficulty in constructing any stream/river restoration aspect within the Tahoe Basin, the standard access assumption is based on the type of access required and access issues on previous example projects (Lower West Side, Angora SEZ, and Erosion Control Projects-see appendix A). To properly determine the estimated construction cost for a given project, its proposed construction activity is compared to these previous projects. There is no "exact science" or equation that can provide this information; therefore sound judgment and estimation from an experienced engineer or knowledgeable individual familiar with Tahoe Basin construction requirements is needed. Ideally this would be a collaborative effort of several experienced members of the team to collectively agree on a general degree of difficulty, higher or lower than these previous projects

These experienced team members will then estimate a degree of difficulty, for construction access, greater or lower than the example projects and provide a general percentage number (i.e. 50% harder, or 30% easier). Once this percentage is determined it will then be applied to the cost determined in section 4 (estimate determined based on channel size) to determine the estimated cost, based on construction access requirements, please see below for example:

First Example (greater difficulty):

- Degree of difficulty difference for example channel = 30% greater
- Estimate for 2,670 cfs channel = $554,363.50
- Therefore: $373,087 * 1.3 = $720,672.60

Second Example (lower difficulty):

- Degree of difficulty difference for example channel = 30% greater
- Estimate for 300 cfs channel = $554,363.50
- Therefore: $373,087 * 0.7 = $388,054.50

6.0 Estimation of cost for efforts in future

To accurately compare and estimate these costs at the time of TMDL preparation, the cost estimates are all based on year 2008 construction costs. However, the implementation schedule may span many years, and more accurate estimates of future efforts can be made using a similar extrapolation, based on the anticipated year for construction of the given project. The value determined from the general table by type of treatment, as adjusted for stream size and degree of difficulty, would need to be further modified for future projects, see below for an example:

- Estimated Value Year in document = 2008
- Estimated Year of construction to occur = 2012

- Estimated inflation rate (construction costs) = i = 15%
- Future Value = F

- Present Value = P = $720,672.60 (from example 1 above)
- Number of years in the future = n (this case is 4 years)

$$F = P * (1+ i)^n$$

$$F = (\$720,672.60) * (1 + 0.15)^4 = \$1,260,461.00$$

7.0 Results/Discussion

Table 1 illustrates the cost estimate values for the identified PCOs. As stated earlier in this document, the estimates are based on varying engineering judgment and existing construction costs within the Tahoe Basin over the past 10 years. The table is broken down into several columns, as follows:

- Identified PCO:
    - General PCO category

- Specific PCO's/Stratagies:
    - Example of typical or representative PCO under that General category

- Detailed Description of Improvement:
    - More refined description of PCO features, focused on elements that affect costs (see also, the attached exhibits for example details).

- Description of Application in 1,000 LF of Channel:
    - Assumptions used to clarify how the specific PCO would be applied per 1,000 LF of stream channel.

- Construction Cost per 1,000 LF of Channel (in 2008 dollar value):
    - Estimated cost, in2008 dollars

- References for Development of Cost Estimate:
    - Cited cost information used to determine/estimate costs for the given PCO.

Treatment Descriptions				Implementation Costs for Small to Moderate Tahoe Streams						Implementation Costs for Large Tahoe Streams				Cross Check
Identified PCO*	**Specific PCOs/Strategies***	**Details of Features**	**Representative Application per 1,000 LF of Channel**	**Construction Cost per 1,000 LF of Channel (2008 $ value)**	**Referenced Project Costs**	**Operations and Maintenance Costs ($/20-year)**	**Total 20-year Cost ($)**	**Small Tahoe Stream 20-year Cost per Foot ($/ft)**	**Small Tahoe Stream 20-year Cost per Meter ($/m)**	**Ward Total 20-year Cost ($/m)**	**Blackwood Total 20-year Cost ($/m)**	**Upper Truckee Total 20-year Cost ($/m)**	**Stream Size Escalation used?**	**Reasonable relative to recent cost estimates? (Too High? Too Low?)**
Grade Control Structure-porous rock material	Keyed boulder/cobble weirs, riffles, etc.	See exhibit 3 and/or 6; will require channel dewatering; does not include cost of other biotechnical or geotechnical bank treatments that may be added	Within a 1,000 LF channel reach there is assumed to be 20 locations (every 50 LF of channel) requiring this type of grade control.	$179,921	rock cut off wall - EDOT Angora SEZ, 2005 - 76.40/LF - each location will require 30LF of wall, twice as large = $4,600/ location; channel diversion - $40,000 engineers estimate (2008 $$)	O & M will not be present over a 20 year life if rock is sized properly to not be mobile during a 100 year storm event. If large event occurs, and moves rocks, then minor repair would be necessary	$ 179,921	$180	$590	$ 590	$ 590	$ 590	No	Good estimate. Locations will require several mobilizations. Several diversions or one long diversion.
Grade Control Structure-porous rock and LWD	Keyed boulder/LWD jams;	Engineered/constructed large woody debris jams with boulders (See exhibit 4); does not include cost of other biotechnical or geotechnical bank treatments that may be added	Within a 1,000 LF channel reach there is assumed to be 20 locations (every 50 LF of channel) requiring this type of grade control.	$219,463	rock cut off wall - EDOT Angora SEZ, 2005 - 76.40/LF - each location will require 30LF of wall + 20 LF root wad revetment @ $181/LF = $5,900/ location; channel diversion - $40,000 engineers estimate (2008 $$)	Woody debris will have a useful life of approximately 20 years in a stream environment. O & M would consist of complete reconstruction if still warranted in the locations placed = $220,000	$ 219,463	$219	$720	$ 720	$ 720	$ 720	No	Good estimate. Locations will require several mobilizations. Several diversions or one long diversion.
	Restore woody debris assemblages	Similar to exhibit 4, which was previously existing (natural or manmade) which requires additional work and/or upgrading; does not include cost of other biotechnical or geotechnical bank treatments that may be added	Within a 1,000 LF channel reach there is assumed to be 20 locations (every 50 LF of channel) requiring this type of grade control.	$109,732	50% of effort below - augmenting exist. material: rock cut off wall - EDOT Angora SEZ, 2005 - 76.40/LF - each location will require 30LF of wall + 20 LF root wad revetment @ $181/LF = $5,900/ location; channel diversion - $40,000 engineers estimate (2008	Woody debris will have a useful life of approximately 20 years in a stream environment. O & M would consist of complete reconstruction if still warranted in the locations placed = $110,000	$ 109,732	$110	$360	$ 360	$ 360	$ 360	No	Good estimate. Access will contribute to cost as well as required equipment.
Channel fill with bank toe stabilization	Maintain hydrologic connectivity in streams, meadows, and wetlands-- Raise streambed elevation within incised channel	Raising of channel bed approximately 1.5 feet, with the installation of rock toe protection (See exhibit 2 and 5 - combination of the two exhibits)	Within a 1,000 LF channel reach there is assumed to be 1,000 LF of channel filling with bank toe protection (one side of channel, at outer bend) - approx. 275 CY (1.5'x5'x1,000')	$515,995	EDOT - Angora SEZ, 2005; Rock Slope Protection = 1/3 of rock work - $14.25/SF x 3 = 42.75/sf @ 6 SF/LF = $256.50/LF; gravel channel bed - EDOT Angora SEZ, 2005, $301/CY	O & M will not be present over a 20 year life if rock is sized properly to not be mobile during a 100 year storm event. If large event occurs, and moves rocks, then minor repair would be necessary	$ 515,995	$516	$1,693	$ 4,276	$ 4,662	$ 7,400	Yes	Good estimate. Difficult to cost with many unknowns.
Bank lowering +floodplain excavation	Maintain hydrologic connectivity in streams, meadows, and wetlands-- Excavate bank to create connected active floodplain	excavation of floodplain area (See exhibit 9)	Within a 1,000 LF channel reach there is assumed to be 1,000 LF of bank lowering and floodplain excavation (one side of channel, varies b/w right and left banks - 20 feet wide, and 4 feet deep) - 1,000'x20'x4' = 3,000 CY	$487,946	Excess Earth Material, removal and disposal - CSLT Lyons Ave - $72/CY - 2004; Flood plain grading, EDOT Angora SEZ 2005 - $8.32/CY; Channel Diversion - $40,000 Engineer estimate (2008 $$)	O & M will not be present over a 20 year life. If sediment deposition occurs, minor cleaning may be necessary if inhibits vegetation growth.	$ 487,946	$488	$1,601	$ 4,044	$ 4,409	$ 6,997	Yes	Good Estimate. Based on Ward Cr estimate of $500,000(660/lf)-$100000($1325/lf) and a size of channel cost reduction of 2.5 of assumed channel and annual cost increases.
Bank lowering +angle reduction	Maintain hydrologic connectivity in streams, meadows, and wetlands-- Excavate and contour bank to reduce angle and/or improve bank vegetation	Similar to exhibit 9, without the flat floodplain. This area would be graded on a slight slope (5:1 or less) to tie into the existing ground	Within a 1,000 LF channel reach there is assumed to be 1,000 LF of bank lowering and angle reduction (one side of channel - 20 feet wide) - 200'x20'x2' = 300 CY	$81,575	Excess Earth Material, removal and disposal - CSLT Lyons Ave - $72/CY - 2004; Flood plain grading, EDOT Angora SEZ 2005 - $8.32/CY; Channel Diversion - $40,000 Engineer estimate (2008 $$)	O & M will not be present over a 20 year life. If sediment deposition occurs, minor cleaning may be necessary if inhibits vegetation growth.	$ 81,575	$82	$268	$ 676	$ 737	$ 1,170	Yes	Good estimate. Could be low. Access, required equipment,and required diversion will have a large impact on cost.
Channel reconstruction	Restore natural geomorphic characteristics through construction;	See exhibits 10 and 11 - channel reconstructed based on accessibility, land ownership, and geomorphic principles	Within a 1,000 LF channel reach there is assumed that the entire length of channel will be reconstructed - construction of varying channel elements, and new channel segments at new grades	$828,575	NTCD - Incline Creek Restoration, 1999; $67/LF - extreme small channel - typ channels 3 times size of incline - $200/LF; continuous dewatering of channel - engineers estimate of $125,000	O & M will not be present over a 20 year life. If a major event occurs, potential damage may occur to channel requiring targeted repair.	$ 828,575	$829	$2,718	$ 6,867	$ 7,487	$ 11,882	Yes	Good Estimate. Based on Middle Reach estimate of $2175/lf with good access, this is $2365/lf with unknown access
	Restore sinuosity to channelized streams;	See exhibits 10 and 11 - channel reconstructed based on accessibility, land ownership, and geomorphic principles	Within a 1,000 LF channel reach there is assumed that the entire length of channel will be reconstructed - construction of sinuous channel alignment	$828,575	NTCD - Incline Creek Restoration, 1999; $67/LF - extreme small channel - typ channels 3 times size of incline - $200/LF; continuous dewatering of channel - engineers estimate of $125,000	O & M will not be present over a 20 year life. If a major event occurs, potential damage may occur to channel requiring targeted repair.	$ 828,575	$829	$2,718	$ 6,867	$ 7,487	$ 11,882	Yes	Good Estimate. Based on Middle Reach estimate of $2175/lf with good access, this is $2365/lf with unknown access
	Maintain hydrologic connectivity in streams, meadows, and wetlands	See exhibits 10 and 11 - channel reconstructed based on accessibility, land ownership, and geomorphic principles	Within a 1,000 LF channel reach there is assumed that the entire length of channel will be reconstructed - construction of new channel alignment with connection to wetland areas - construction of 10,000 SF of wetland area - 1,000'x10'x3' = 1,000 CY	$967,157	NTCD - Incline Creek Restoration, 1999; $67/LF - extreme small channel - typ channels 3 times size of incline - $200/LF; Excess Earth Material, removal and disposal - CSLT Lyons Ave - $72/CY - 2004; Flood plain grading, EDOT Angora SEZ 2005 - $8.32/CY;con	O & M will not be present over a 20 year life. If a major event occurs, potential damage may occur to channel requiring targeted repair.	$ 967,157	$967	$3,173	$ 8,015	$ 8,739	$ 13,870	Yes	Good estimate. Compares well with Middle Reach and construction of wetland
Channel restoration *	Restore natural geomorphic characteristics through construction and restored processes;	See exhibits 10 and 11 - channel reconstructed based on geomorphic principles	The entire 1,000 LF reach should be restored to properly restore the channel; acquisition of five parcels within reach necessary for proper restoration practices	$1,949,825	NTCD - Incline Creek Restoration, 1999; $67/LF - extreme small channel - typ channels 3 times size of incline - $200/LF; 2007 Development right of property = $95,000 + property value of $100,000/acre = $195,000/parcel; continuous dewatering of channel - e	O & M will not be present over a 20 year life. If a major event occurs, potential damage may occur to channel requiring targeted repair.	$ 1,949,825	$1,950	$6,397	$ 16,159	$ 17,618	$ 27,962	Yes	Good Estimate. Compares well with Middle reach cost and reasonable cost of aquiring parcels. Dewatering difficult to estimate, but would not change estimate by more than 5%
	Restore sinuosity to channelized streams;	See exhibits 10 and 11 - channel reconstructed based on geomorphic principles	The entire 1,000 LF reach should be restored to properly restore the channel; acquisition of five parcels within reach necessary for proper restoration practices	$1,949,825	NTCD - Incline Creek Restoration, 1999; $67/LF - extreme small channel - typ channels 3 times size of incline - $200/LF; 2007 Development right of property = $95,000 + property value of $100,000/acre = $195,000/parcel; continuous dewatering of channel - e	O & M will not be present over a 20 year life. If a major event occurs, potential damage may occur to channel requiring targeted repair.	$ 1,949,825	$1,950	$6,397	$ 16,159	$ 17,618	$ 27,962	Yes	Good Estimate. Compares well with Middle reach cost and reasonable cost of aquiring parcels. Dewatering difficult to estimate, but would not change estimate by more than 5%
	Maintain hydrologic connectivity in streams, meadows, and wetlands	See exhibits 9, 10 and 11 - channel reconstructed based on geomorphic principles	The entire 1,000 LF reach should be restored to properly restore the channel; acquisition of five parcels within reach necessary for proper restoration practices	$2,088,407	NTCD - Incline Creek Restoration, 1999; $67/LF - extreme small channel - typ channels 3 times size of incline - $200/LF; Excess Earth Material, removal and disposal - CSLT Lyons Ave - $72/CY - 2004; Flood plain grading, EDOT Angora SEZ 2005 - $8.32/CY; 20	O & M will not be present over a 20 year life. If a major event occurs, potential damage may occur to channel requiring targeted repair.	$ 2,088,407	$2,088	$6,852	$ 17,307	$ 18,870	$ 29,949	Yes	Good Estimate. Compares well with Middle reach cost and reasonable cost of aquiring parcels. Dewatering difficult to estimate, but would not change estimate by more than 5%

* Channel Restoration costs would be expected to be similar to Channel Reconstruction for areas already in public ownership, not requiring acquisitions.

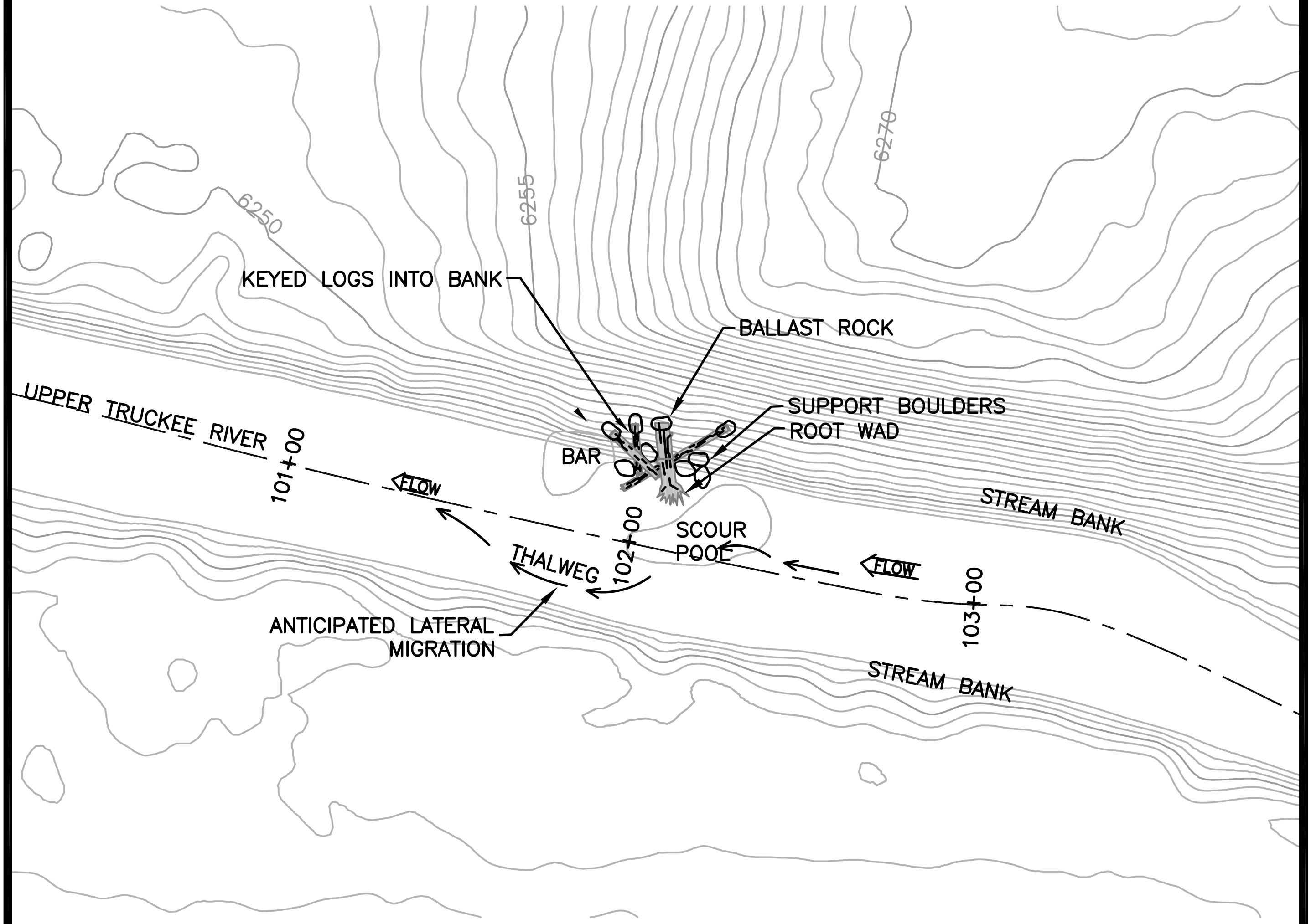
Treatment Descriptions				Implementation Costs for Small to Moderate Tahoe Streams						Implementation Costs for Large Tahoe Streams				Cross Check
Identified PCO*	Specific PCOs/Strategies*	Details of Features	Representative Application per 1,000 LF of Channel	Construction Cost per 1,000 LF of Channel (2008 $ value)	Referenced Project Costs	Operations and Maintenance Costs ($/20-year)	Total 20-year Cost ($)	Small Tahoe Stream 20-year Cost per Foot ($/ft)	Small Tahoe Stream 20-year Cost per Meter ($/m)	Ward Total 20-year Cost ($/m)	Blackwood Total 20-year Cost ($/m)	Upper Truckee Total 20-year Cost ($/m)	Stream Size Escalation used?	Reasonable relative to recent cost estimates? (Too High? Too Low?)
	Remove earthfill and other structures confining flow in channel	Removal and disposal of earthen material, large woody debris, rock, and other items within channel; requires flow diversion of channel	Within a 1,000 LF channel reach there is assumed to be one channel blockage, and approximately 250 CY of earthen material to remove	$71,482	Excess Earth Material, removal and disposal - CSLT Lyons Ave - $72/CY - 2004; Channel Diversion - $40,000 Engineer estimate (2008 $$)	Should not require any O & M over a typical 20-year period. Will only require O & M if major storm event occurs - blockage may occur and require complete re-do of procedure	$ 71,482	$71	$235	$ 592	$ 646	$ 1,025	Yes	Removal of material cost is accurate. Diversion cost could be alittle high. Cost dependent on ability to access and divert flow.
Channel constriction removal	Replace outdated, under-sized culverts	remove and replace existing culverts - increase size; requires flow diversion of channel	Within a 1,000 LF channel reach there is assumed to be one culvert replacement - 100 LF in length, requiring a twin (2) 72" Dia. Culverts to be installed to convey 100 year flood flow	$134,940	CSLT - Glorene - 2004 const bid - 30" RCP @ $115/LF = 38% of cost of one 72" Dia culvert: 72" Dia culvert = $300/LF; Channel Diversion - $30,000 engineers estimate (2008 $$), assuming easy access to diversion.	Should not require any O & M over a typical 20-year period. Will only require O & M if major storm event occurs, with large sediment delivery, pipes may become clogged - requiring cleaning (typically less than $5,000 per cleaning)	$ 144,940	$145	$476	$ 1,201	$ 1,310	$ 2,079	Yes	Pipe cost slightly high and diversion slightly high. Assumed easy access to diversion. Amended from $172,924 to $134,940
	Replace outdated, under-sized bridges	Remove and replace existing bridges - could be done with conspan or bridge structure; requires flow diversion of channel	Each channel will only require one bridge replacement per creek/river. Conspan assumed for costs, with width of 30 foot width (2 traffic lanes)	$485,616	EDOT - Angora SEZ - 2 lane conspan structure, 2005 construction = $293,000; Channel Diversion - $40,000 engineers estimate (2008 $$)	Should not require any O & M over a typical 20-year period. Bridge inspections should be done when bridge has reached 50% of its design life, every other year (will not happen in first 20 years)	$ 485,616	$486	$1,593	$ 4,024	$ 4,388	$ 6,964	Yes	Mistake in cost estimate equation. Assumptions are correct. Amended from $637,704 to $485,616
Bank Protection-stone	Streambank stabilization-- (rigid)	Boulder placement along streambank toe (4 feet high, max); doesnot include possible need for grade control in actively degrading areas	Within a 1,000 LF channel reach there is assumed to be 1,000 LF of bank protection (one side of channel at outer bend)	$213,380	EDOT - Angora SEZ - 2005 Construction - Rock Slope Protection = 50% of bank protection - $14.25/SF x 2 = 28.50/sf @ 4 SF/LF = $114/LF	Should not require any O & M over a typical 20-year period. Will only require O & M if major storm event occurs and destroys/moves toe - would require re-construction and/or repair to damaged section	$ 213,380	$213	$700	$ 700	$ 700	$ 700	No	Good Estimate. Based on Angora project cost. Would need grade control added in areas of active degradation (additive cost)
Bank Protection-flexible geotech mattresses	Streambank stabilization—(flexible)	Bank protection using geotechnical support materials (2 foot below flowline to 1 foot above 100 year flow elevation - 6 feet high, typ.); doesnot include possible need for grade control in actively degrading areas	Within a 1,000 LF channel reach there is assumed to be 1,000 LF of bank protection (one side of channel at outer bend) = 24 SF/LF of channel (with overlapping material)	$182,436	Apalachee/EDOT 2007 bid - Revegetation - $1.40/SF; coir fabric - $4.34/SY; design channel shaping - $4.73/LF = $6.61/SF	Should not require any O & M over a typical 20-year period, once vegetation is established. Will only require O & M if major storm event occurs and destroys/moves toe - would require re-construction and/or repair to damaged section	$ 182,436	$182	$599	$ 1,512	$ 1,648	$ 2,616	Yes	Good estimate. Channel access and bank flow diversion could seriously affect cost.
Bank Protection-LWD / rootwad revetment	Streambank stabilization—(Anchored LWD);	Large Woody Debris and root wads anchored into channel embankment (see exhibit 1);doesnot include possible need for grade control in actively degrading areas	Within a 1,000 LF channel reach there is assumed to be 1,000 LF of bank protection (one side of channel at outer bend)	$275,278	EDOT - Angora SEZ - root wad revetment, 2005 construction = $181/LF	Woody debris and root wads will have a useful life of approximately 20 years in a stream environment.	$ 275,278	$275	$903	$ 903	$ 903	$ 903	No	Good Estimate. Based on access dificulties of Ward Cr. Est. is lower than Ward Cr. Low Est. by 30%
	Restore woody debris assemblages	Similar to exhibit 1, which was previously existing (natural or manmade) which requires additional work and/or upgrading; doesnot include possible need for grade control in actively degrading areas	Within a 1,000 LF channel reach there is assumed to be1,000 LF of bank protection to restore (one side of channel at outer bend)	$136,879	EDOT - Angora SEZ, 2005 construction = $181/LF - Estimate 50% of effort or cost of construction of new = $90/LF	Woody debris will have a useful life of approximately 20 years in a stream environment.	$ 136,879	$137	$449	$ 449	$ 449	$ 449	No	Good Estimate. Based on previous project costs. Assuming much of the materials on already on site. If anything alittle low. Access could raise cost.
Bank Protection- anchored shrub/brush revetment	Streambank stabilization—(Anchored shrub)	Stabilization of Streambanks through the use of salvaged sod in conjunction with willow transplants/staking; doesnot include possible need for grade control in actively degrading areas	Within a 1,000 LF channel reach there is assumed to be 1,000 LF of bank protection (one side of channel at outer bend)	$86,264	EDOT - Angora SEZ, 2005; salvaged sod & Willows - 56.72/LF	O & M will consist of yearly visual inspections of both willow health, and stacked sod - to determine if bank failure has occurred. Potential over a 20 year period for 10% of channel embankment and 10% of willows will need attention = $18,000	$ 104,264	$104	$342	$ 864	$ 942	$ 1,495	Yes	Good Estimate. Based on previous project costs. Assuming much of the materials on already on site. If anything alittle low. Access could raise cost.
Bank Protection- stacked sod revetment	Streambank stabilization—(Anchored sod)	Reconstruction of channel embankments (See exhibits 8, 10 and 11); doesnot include possible need for grade control in actively degrading areas	Within a 1,000 LF channel reach there is assumed to be 1,000 LF of bank protection (one side of channel at outer bend)	$172,528	Salvaged sod & Willows - EDOT Angora SEZ, 2005 - 56.72/LF - stacking for bank armoring = 2 times value: $113.44/LF	O & M will consist of yearly visual inspections of both willow health, and stacked sod - to determine if bank failure has occurred. Potential over a 20 year period for 10% of channel embankment and 10% of willows will need attention = $35,000	$ 207,528	$208	$681	$ 1,720	$ 1,875	$ 2,976	Yes	Estimate at 2x the cost of Angora SEZ estimate; larger streams and higher banks require scaling if assumed as primary bank treatment
Bank Strengthening- wet meadow vegetation	Restore streambank vegetation herbaceous-- (via soil improvements, soil moisture increases) wet meadow 'sod' growing on banks	Restoration of disturbed streambanks - tilling soil, revegetation (or sod salvage and placement), planting, etc. (these measures do NOT include the cost that may be required for increasing the soil moisture/groundwater table through overbanking and/or low	Within a 1,000 LF channel reach there is assumed to be 1,000 LF of bank protection (one side of channel at outer bend)	$86,264	Salvaged sod & Willows - EDOT Angora SEZ, 2005 - 56.72/LF; revegetation of area is = effort	O & M will consist of yearly visual inspections of both willow health, and stacked sod - to determine if bank failure has occurred. Potential over a 20 year period for 10% of channel embankment and 10% of willows will need attention = $16,000 (if not maj	$ 102,264	$102	$336	$ 336	$ 336	$ 336	No	Good Estimate. Based on known project costs on Angora SEZ. Assuming SOD comes from close proximity of project area. Cost would go up if it was propagated.
Bank Strengthening-woody riparian vegetation	Restore streambank vegetation woody--(via soil improvements, soil moisture or stream dynamics-seed beds)	See Exhibit 8 - may or may not require sod revetment (these costs are independent of cost of other measures that may be needed to keep the hydrology suitable for woody rip vegetation - but can have lower water table than sod, once established)	Within a 1,000 LF channel reach there is assumed to be 1,000 LF of bank protection (total for both sides of channel)	$86,264	Salvaged sod & Willows - EDOT Angora SEZ, 2005 - 56.72/LF	O & M will consist of yearly visual inspections of both willow health, and stacked sod - to determine if bank failure has occurred. Potential over a 20 year period for 10% of channel embankment and 10% of willows will need attention = $16,000 (if not maj	$ 102,264	$102	$336	$ 336	$ 336	$ 336	No	Good Estimate. Based on local project costs.
Grade Control Structure-non porous material	Keyed sheet pile/concrete sills, etc.	Construction of permanent, non movable grade control through the use of vinyl sheet pile, or concrete cut off walls; will require channel dewatering; does not include cost of other biotechnical or geotechnical bank treatments that may be added	Within a 1,000 LF channel reach there is assumed to be twenty locations requiring this type of grade control - 30 LF of sheet pile installation per location at 50 LF stationing	$254,006	Vinyl sheet pile - EDOT Angora SEZ, 2005 - $96/LF - shallow, easy access for Angora - will require 2.5 times effort on avg. stream - $240/LF; channel diversion - $35,000 engineers estimate (2008 $$)	O & M will not be present over a 20 year life (vinyl sheet pile anticipated life span is 50 years)	$ 254,006	$254	$833	$ 833	$ 833	$ 833	No	Estimate is close. Reduced multiplier from 3 to 2.5 and diversion from $40k to $35k b/c of ease of access, however a long diversion. Amended from $302.807 to $254,006

Treatment Descriptions				Implementation Costs for Small to Moderate Tahoe Streams						Implementation Costs for Large Tahoe Streams				Cross Check
Identified PCO*	Specific PCOs/Strategies*	Details of Features	Representative Application per 1,000 LF of Channel	Construction Cost per 1,000 LF of Channel (2008 $ value)	Referenced Project Costs	Operations and Maintenance Costs ($/20-year)	Total 20-year Cost ($)	Small Tahoe Stream 20-year Cost per Foot ($/ft)	Small Tahoe Stream 20-year Cost per Meter ($/m)	Ward Total 20-year Cost ($/m)	Blackwood Total 20-year Cost ($/m)	Upper Truckee Total 20-year Cost ($/m)	Stream Size Escalation used?	Reasonable relative to recent cost estimates? (Too High? Too Low?)
Grade Control Structure-porous rock material	Keyed boulder/cobble weirs, riffles, etc.	See exhibit 3 and/or 6; will require channel dewatering; does not include cost of other biotechnical or geotechnical bank treatments that may be added	Within a 1,000 LF channel reach there is assumed to be 20 locations (every 50 LF of channel) requiring this type of grade control.	$179,921	rock cut off wall - EDOT Angora SEZ, 2005 - 76.40/LF - each location will require 30LF of wall, twice as large = $4,600/ location; channel diversion - $40,000 engineers estimate (2008 $$)	O & M will not be present over a 20 year life if rock is sized properly to not be mobile during a 100 year storm event. If large event occurs, and moves rocks, then minor repair would be necessary	$ 179,921	$180	$590	$ 590	$ 590	$ 590	No	Good estimate. Locations will require several mobilizations. Several diversions or one long diversion.
Grade Control Structure-porous rock and LWD	Keyed boulder/LWD jams;	Engineered/constructed large woody debris jams with boulders (See exhibit 4); does not include cost of other biotechnical or geotechnical bank treatments that may be added	Within a 1,000 LF channel reach there is assumed to be 20 locations (every 50 LF of channel) requiring this type of grade control.	$219,463	rock cut off wall - EDOT Angora SEZ, 2005 - 76.40/LF - each location will require 30LF of wall + 20 LF root wad revetment @ $181/LF = $5,900/ location; channel diversion - $40,000 engineers estimate (2008 $$)	Woody debris will have a useful life of approximately 20 years in a stream environment. O & M would consist of complete reconstruction if still warranted in the locations placed = $220,000	$ 219,463	$219	$720	$ 720	$ 720	$ 720	No	Good estimate. Locations will require several mobilizations. Several diversions or one long diversion.
	Restore woody debris assemblages	Similar to exhibit 4, which was previously existing (natural or manmade) which requires additional work and/or upgrading; does not include cost of other biotechnical or geotechnical bank treatments that may be added	Within a 1,000 LF channel reach there is assumed to be 20 locations (every 50 LF of channel) requiring this type of grade control.	$109,732	50% of effort below - augmenting exist. material: rock cut off wall - EDOT Angora SEZ, 2005 - 76.40/LF - each location will require 30LF of wall + 20 LF root wad revetment @ $181/LF = $5,900/ location; channel diversion - $40,000 engineers estimate (2008	Woody debris will have a useful life of approximately 20 years in a stream environment. O & M would consist of complete reconstruction if still warranted in the locations placed = $110,000	$ 109,732	$110	$360	$ 360	$ 360	$ 360	No	Good estimate. Access will contribute to cost as well as required equipment.
Channel fill with bank toe stabilization	Maintain hydrologic connectivity in streams, meadows, and wetlands-- Raise streambed elevation within incised channel	Raising of channel bed approximately 1.5 feet, with the installation of rock toe protection (See exhibit 2 and 5 - combination of the two exhibits)	Within a 1,000 LF channel reach there is assumed to be 1,000 LF of channel filling with bank toe protection (one side of channel, at outer bend) - approx. 275 CY (1.5'x5'x1,000')	$515,995	EDOT - Angora SEZ, 2005; Rock Slope Protection = 1/3 of rock work - $14.25/SF x 3 = 42.75/sf @ 6 SF/LF = $256.50/LF; gravel channel bed - EDOT Angora SEZ, 2005, $301/CY	O & M will not be present over a 20 year life if rock is sized properly to not be mobile during a 100 year storm event. If large event occurs, and moves rocks, then minor repair would be necessary	$ 515,995	$516	$1,693	$ 4,276	$ 4,662	$ 7,400	Yes	Good estimate. Difficult to cost with many unknowns.
Bank lowering +floodplain excavation	Maintain hydrologic connectivity in streams, meadows, and wetlands-- Excavate bank to create connected active floodplain	excavation of floodplain area (See exhibit 9)	Within a 1,000 LF channel reach there is assumed to be 1,000 LF of bank lowering and floodplain excavation (one side of channel, varies b/w right and left banks - 20 feet wide, and 4 feet deep) - 1,000'x20'x4' = 3,000 CY	$487,946	Excess Earth Material, removal and disposal - CSLT Lyons Ave - $72/CY - 2004; Flood plain grading, EDOT Angora SEZ 2005 - $8.32/CY; Channel Diversion - $40,000 Engineer estimate (2008 $$)	O & M will not be present over a 20 year life. If sediment deposition occurs, minor cleaning may be necessary if inhibits vegetation growth.	$ 487,946	$488	$1,601	$ 4,044	$ 4,409	$ 6,997	Yes	Good Estimate. Based on Ward Cr estimate of $500,000(660/lf)-$100000($1325/lf) and a size of channel cost reduction of 2.5 of assumed channel and annual cost increases.
Bank lowering +angle reduction	Maintain hydrologic connectivity in streams, meadows, and wetlands-- Excavate and contour bank to reduce angle and/or improve bank vegetation	Similar to exhibit 9, without the flat floodplain. This area would be graded on a slight slope (5:1 or less) to tie into the existing ground	Within a 1,000 LF channel reach there is assumed to be 1,000 LF of bank lowering and angle reduction (one side of channel - 20 feet wide) - 200'x20'x2' = 300 CY	$81,575	Excess Earth Material, removal and disposal - CSLT Lyons Ave - $72/CY - 2004; Flood plain grading, EDOT Angora SEZ 2005 - $8.32/CY; Channel Diversion - $40,000 Engineer estimate (2008 $$)	O & M will not be present over a 20 year life. If sediment deposition occurs, minor cleaning may be necessary if inhibits vegetation growth.	$ 81,575	$82	$268	$ 676	$ 737	$ 1,170	Yes	Good estimate. Could be low. Access, required equipment,and required diversion will have a large impact on cost.
Channel reconstruction	Restore natural geomorphic characteristics through construction;	See exhibits 10 and 11 - channel reconstructed based on accessibility, land ownership, and geomorphic principles	Within a 1,000 LF channel reach there is assumed that the entire length of channel will be reconstructed - construction of varying channel elements, and new channel segments at new grades	$828,575	NTCD - Incline Creek Restoration, 1999; $67/LF - extreme small channel - typ channels 3 times size of incline - $200/LF; continuous dewatering of channel - engineers estimate of $125,000	O & M will not be present over a 20 year life. If a major event occurs, potential damage may occur to channel requiring targeted repair.	$ 828,575	$829	$2,718	$ 6,867	$ 7,487	$ 11,882	Yes	Good Estimate. Based on Middle Reach estimate of $2175/lf with good access, this is $2365/lf with unknown access
	Restore sinuosity to channelized streams;	See exhibits 10 and 11 - channel reconstructed based on accessibility, land ownership, and geomorphic principles	Within a 1,000 LF channel reach there is assumed that the entire length of channel will be reconstructed - construction of sinuous channel alignment	$828,575	NTCD - Incline Creek Restoration, 1999; $67/LF - extreme small channel - typ channels 3 times size of incline - $200/LF; continuous dewatering of channel - engineers estimate of $125,000	O & M will not be present over a 20 year life. If a major event occurs, potential damage may occur to channel requiring targeted repair.	$ 828,575	$829	$2,718	$ 6,867	$ 7,487	$ 11,882	Yes	Good Estimate. Based on Middle Reach estimate of $2175/lf with good access, this is $2365/lf with unknown access
	Maintain hydrologic connectivity in streams, meadows, and wetlands	See exhibits 10 and 11 - channel reconstructed based on accessibility, land ownership, and geomorphic principles	Within a 1,000 LF channel reach there is assumed that the entire length of channel will be reconstructed - construction of new channel alignment with connection to wetland areas - construction of 10,000 SF of wetland area - 1,000'x10'x3' = 1,000 CY	$967,157	NTCD - Incline Creek Restoration, 1999; $67/LF - extreme small channel - typ channels 3 times size of incline - $200/LF; Excess Earth Material, removal and disposal - CSLT Lyons Ave - $72/CY - 2004; Flood plain grading, EDOT Angora SEZ 2005 - $8.32/CY;con	O & M will not be present over a 20 year life. If a major event occurs, potential damage may occur to channel requiring targeted repair.	$ 967,157	$967	$3,173	$ 8,015	$ 8,739	$ 13,870	Yes	Good estimate. Compares well with Middle Reach and construction of wetland
Channel restoration *	Restore natural geomorphic characteristics through construction and restored processes;	See exhibits 10 and 11 - channel reconstructed based on geomorphic principles	The entire 1,000 LF reach should be restored to properly restore the channel; acquisition of five parcels within reach necessary for proper restoration practices	$1,949,825	NTCD - Incline Creek Restoration, 1999; $67/LF - extreme small channel - typ channels 3 times size of incline - $200/LF; 2007 Development right of property = $95,000 + property value of $100,000/acre = $195,000/parcel; continuous dewatering of channel - e	O & M will not be present over a 20 year life. If a major event occurs, potential damage may occur to channel requiring targeted repair.	$ 1,949,825	$1,950	$6,397	$ 16,159	$ 17,618	$ 27,962	Yes	Good Estimate. Compares well with Middle reach cost and reasonable cost of aquiring parcels. Dewatering difficult to estimate, but would not change estimate by more than 5%
	Restore sinuosity to channelized streams;	See exhibits 10 and 11 - channel reconstructed based on geomorphic principles	The entire 1,000 LF reach should be restored to properly restore the channel; acquisition of five parcels within reach necessary for proper restoration practices	$1,949,825	NTCD - Incline Creek Restoration, 1999; $67/LF - extreme small channel - typ channels 3 times size of incline - $200/LF; 2007 Development right of property = $95,000 + property value of $100,000/acre = $195,000/parcel; continuous dewatering of channel - e	O & M will not be present over a 20 year life. If a major event occurs, potential damage may occur to channel requiring targeted repair.	$ 1,949,825	$1,950	$6,397	$ 16,159	$ 17,618	$ 27,962	Yes	Good Estimate. Compares well with Middle reach cost and reasonable cost of aquiring parcels. Dewatering difficult to estimate, but would not change estimate by more than 5%
	Maintain hydrologic connectivity in streams, meadows, and wetlands	See exhibits 9, 10 and 11 - channel reconstructed based on geomorphic principles	The entire 1,000 LF reach should be restored to properly restore the channel; acquisition of five parcels within reach necessary for proper restoration practices	$2,088,407	NTCD - Incline Creek Restoration, 1999; $67/LF - extreme small channel - typ channels 3 times size of incline - $200/LF; Excess Earth Material, removal and disposal - CSLT Lyons Ave - $72/CY - 2004; Flood plain grading, EDOT Angora SEZ 2005 - $8.32/CY; 20	O & M will not be present over a 20 year life. If a major event occurs, potential damage may occur to channel requiring targeted repair.	$ 2,088,407	$2,088	$6,852	$ 17,307	$ 18,870	$ 29,949	Yes	Good Estimate. Compares well with Middle reach cost and reasonable cost of aquiring parcels. Dewatering difficult to estimate, but would not change estimate by more than 5%

* Channel Restoration costs would be expected to be similar to Channel Reconstruction for areas already in public ownership, not requiring acquisitions.

8.0 Conclusion

The information provided herein will provide the Stream Channel Erosion Source Control Group of the Lake Tahoe TMDL general costs for various stream channel erosion PCOs, and Operations and Maintenance costs over a 20-year period, on the range of streams within the Basin. Means to adjust general costs (and O & M costs) to represent streams of varied size, projects with varied access conditions, and projects that may be implemented over time are provided. While the document covers a wide range of options, with multiple correlations to better estimate the costs of improvements, the estimates developed through this document are general in nature. The intent is to provide a comparative analysis between differing treatment types, along with a general idea of what the overall cost of construction will be. Throughout the course of planning, and design, of a given project, more detailed estimates shall be developed at each stage to better refine the overall costs of a given project.



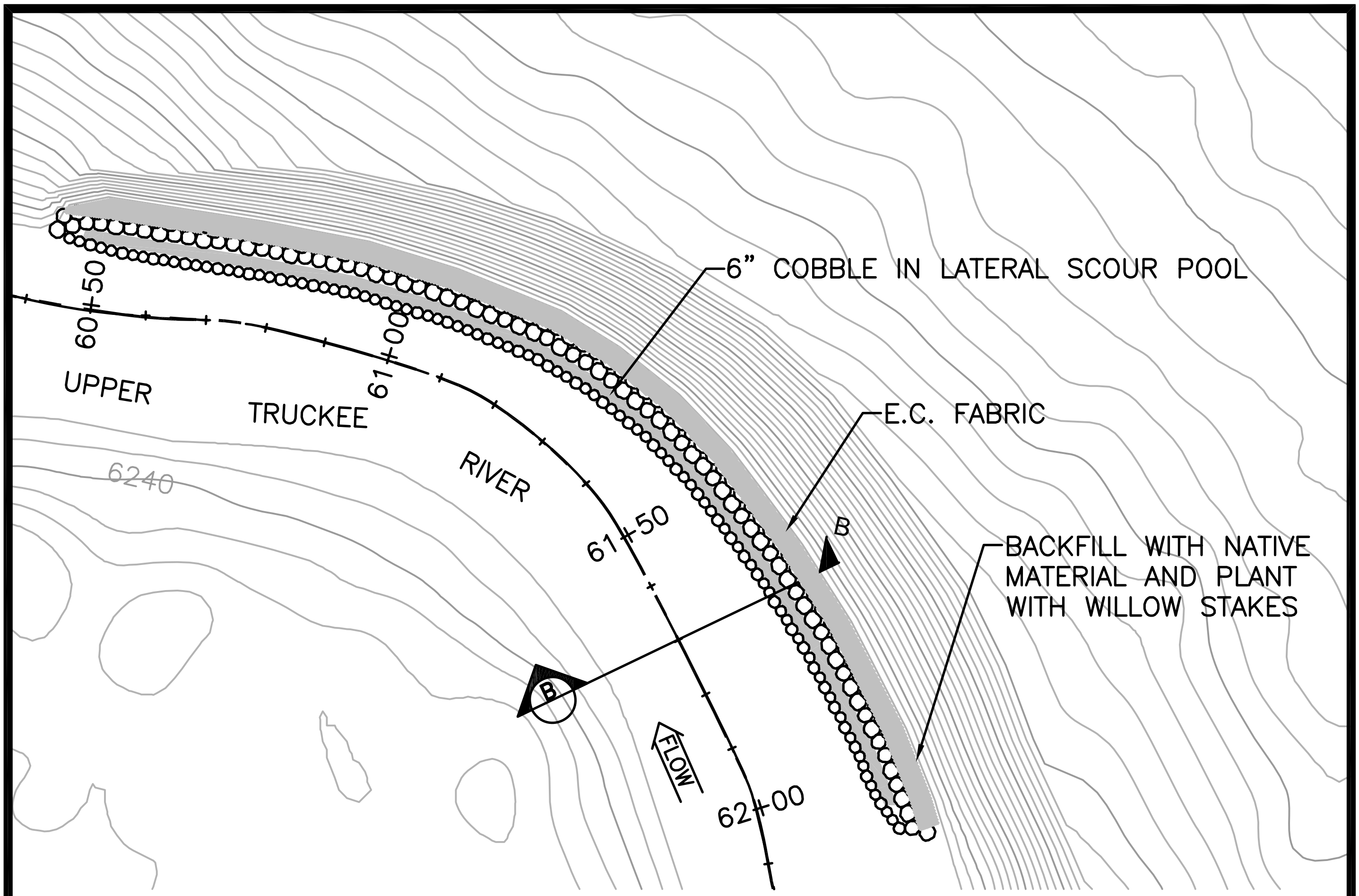
ENTRIX

1048 Ski Run Boulevard
South Lake Tahoe, CA 96150
(530) 542-0201 Main

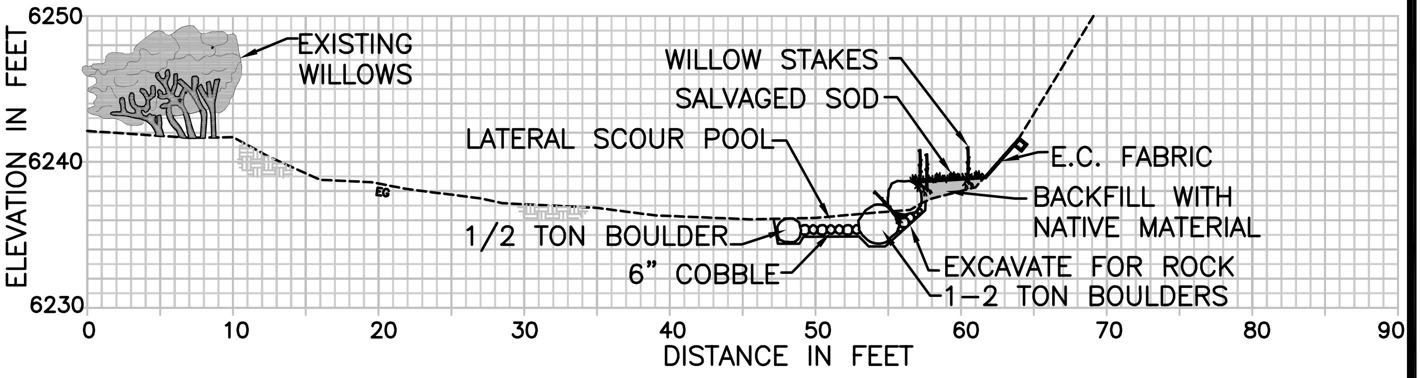
BIOENGINEERED BANK STABILIZATION
NOT TO SCALE

DATE: 03/07
PROJECT NO.: 3114201
BY: SHP

FIGURE
EXHIBIT 1



PLAN VIEW



SECTION B-B

ENTRIX

1048 Ski Run Boulevard
South Lake Tahoe, CA 96150
(530) 542-0201 Main

RS 60+00-62+00 BANK STABILIZATION
NOT TO SCALE

DATE: 03/07

PROJECT NO.: 3114201

BY: SHP

FIGURE

EXHIBIT 2

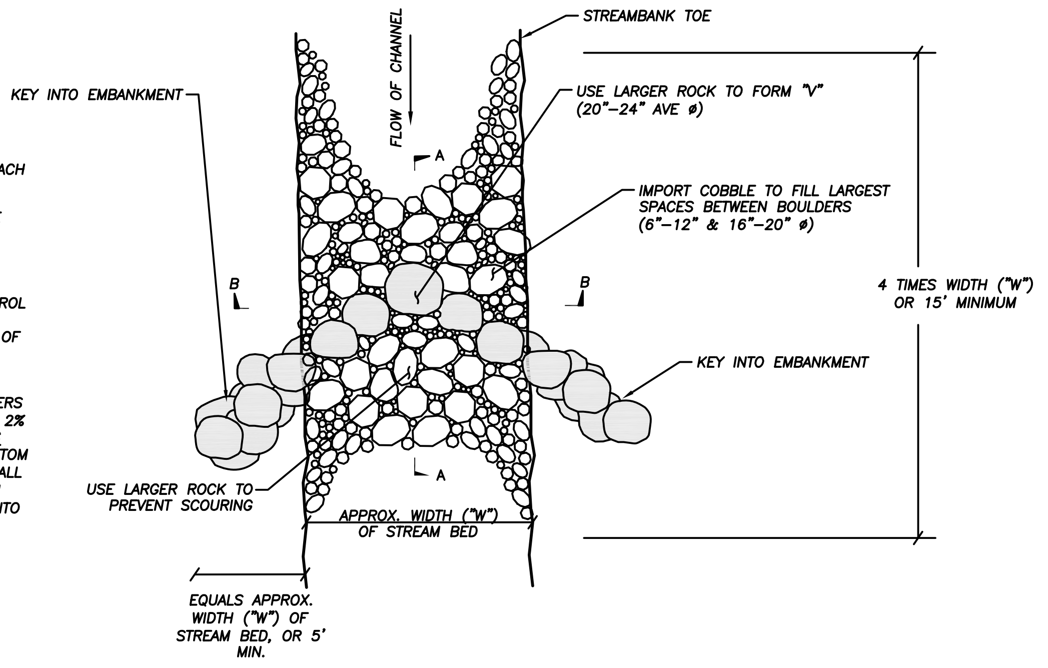
NOTES:

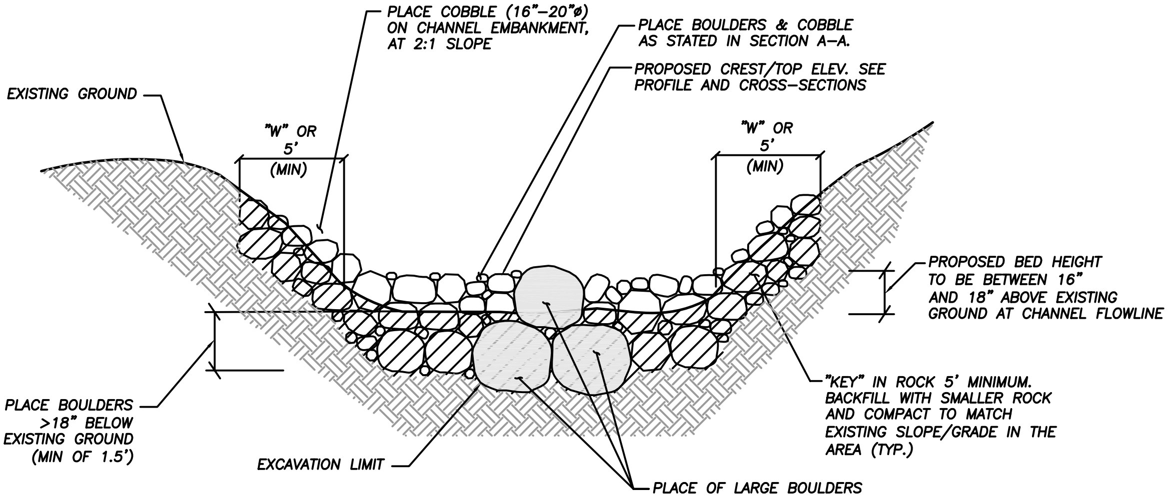
TOTAL VOLUME 5± CY OF ROCK AT EACH GRADE CONTROL STRUCTURE

GRADE CONTROL STRUCTURES WILL BE LOCATED WITHIN 25' OF PROPOSED LOCATION IN PLAN SHEET C-1

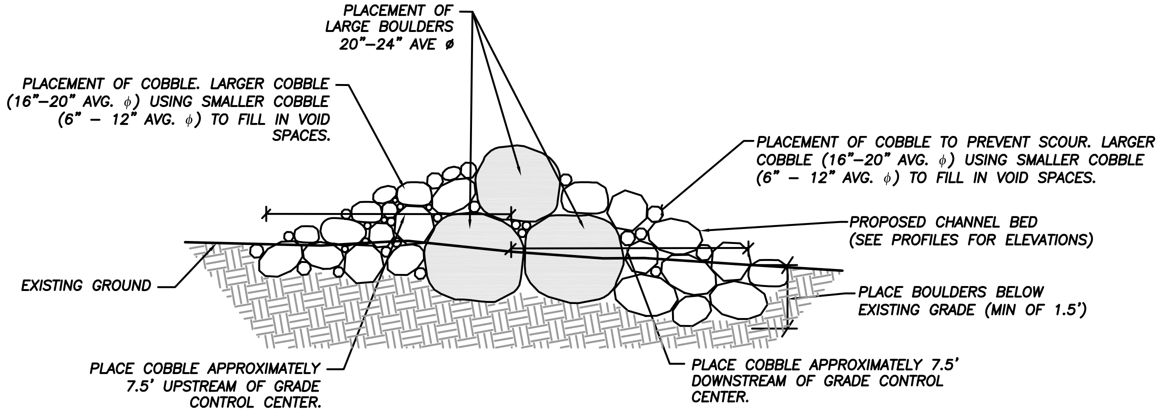
LARGE BOULDERS (20"-24" AVE ø) PLACED TO FROM "V" IN GRADE CONTROL STRUCTURE SHALL BE PLACED (VERTICAL/ELEVATION) STARTING AT ℄ OF CHANNEL 16"-18" BELOW EXISTING GROUND.

THE ELEVATION OF THE LARGE BOULDERS (20"-24" AVE ø) SHALL INCREASE AT 2% ± GOING AWAY FROM THE CHANNEL ℄ AND INTO THE EMBANKMENT. THE BOTTOM OF THE ROCK IN THE CHANNEL ℄ SHALL BE APPROXIMATELY 0.25' LOWER THAN THE LAST ROCK PLACED (FURTHEST INTO EMBANKMENT).





SECTION A-A



SECTION B-B

ENTRIX

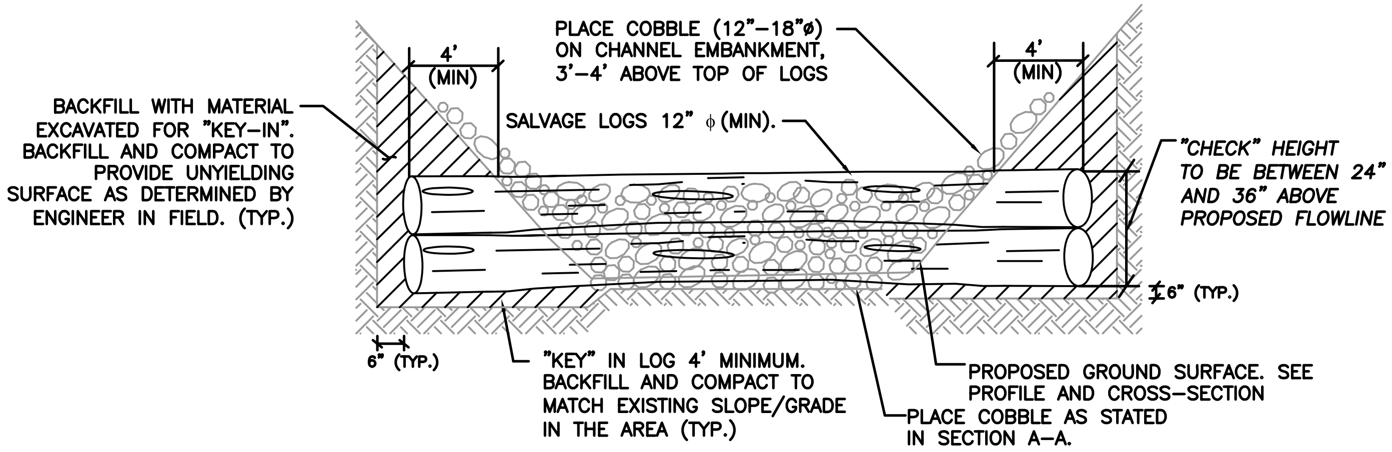
1048 Ski Run Boulevard
South Lake Tahoe, CA 96150
(530) 542-0201 Main

ROCK GRADE CONTROL
NOT TO SCALE

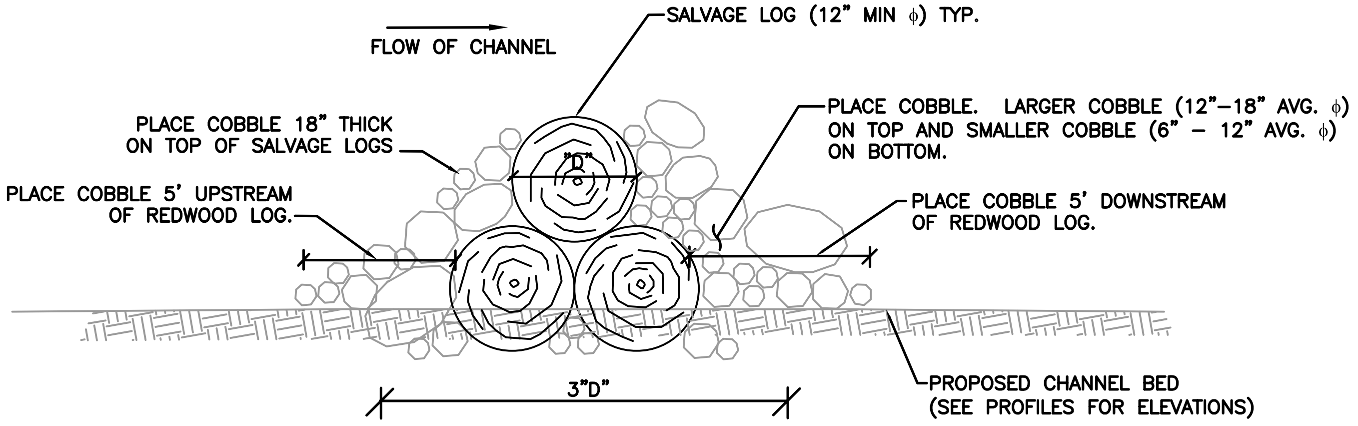
FIGURE

EXHIBIT
3

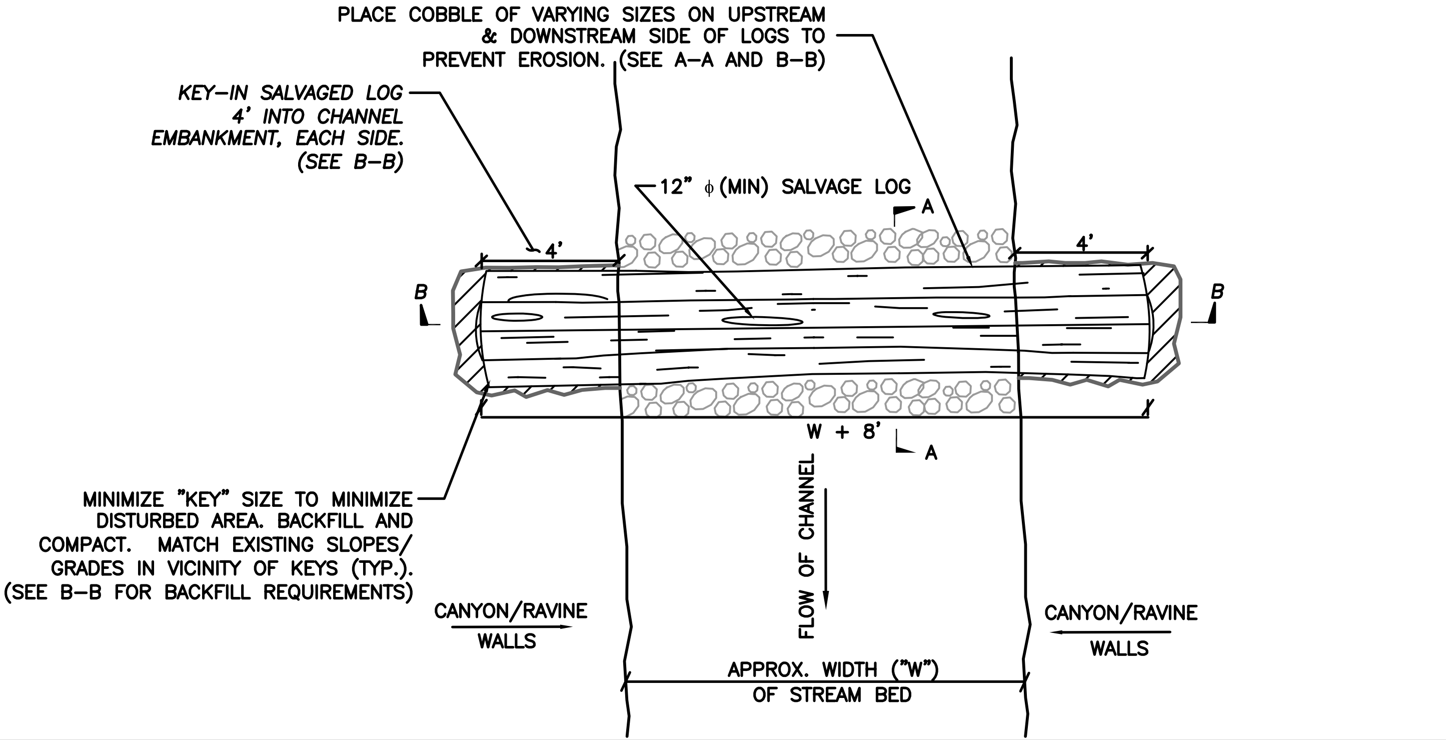
DATE: 03/07
PROJECT NO.: 3114201
BY: SHP



SECTION B-B



SECTION A-A

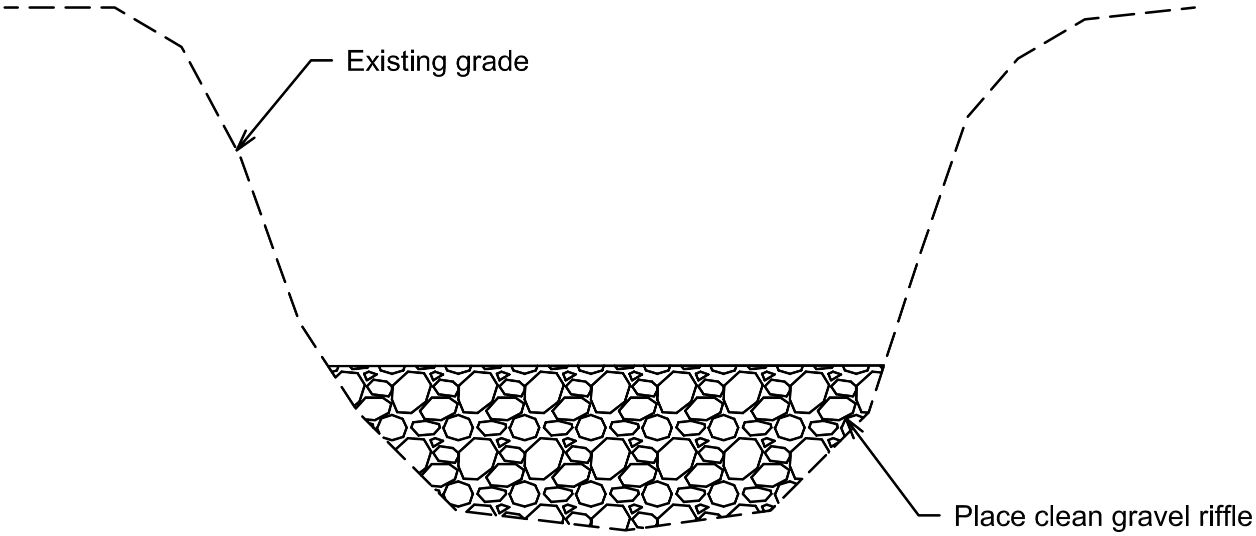


ENTRIX
1048 Ski Run Boulevard
South Lake Tahoe, CA 96150
(530) 542-0201 Main

LWD GRADE CONTROL STRUCTURE
NOT TO SCALE

DATE: 03/07
PROJECT NO.: 3114201
BY: SHP

FIGURE
EXHIBIT 4



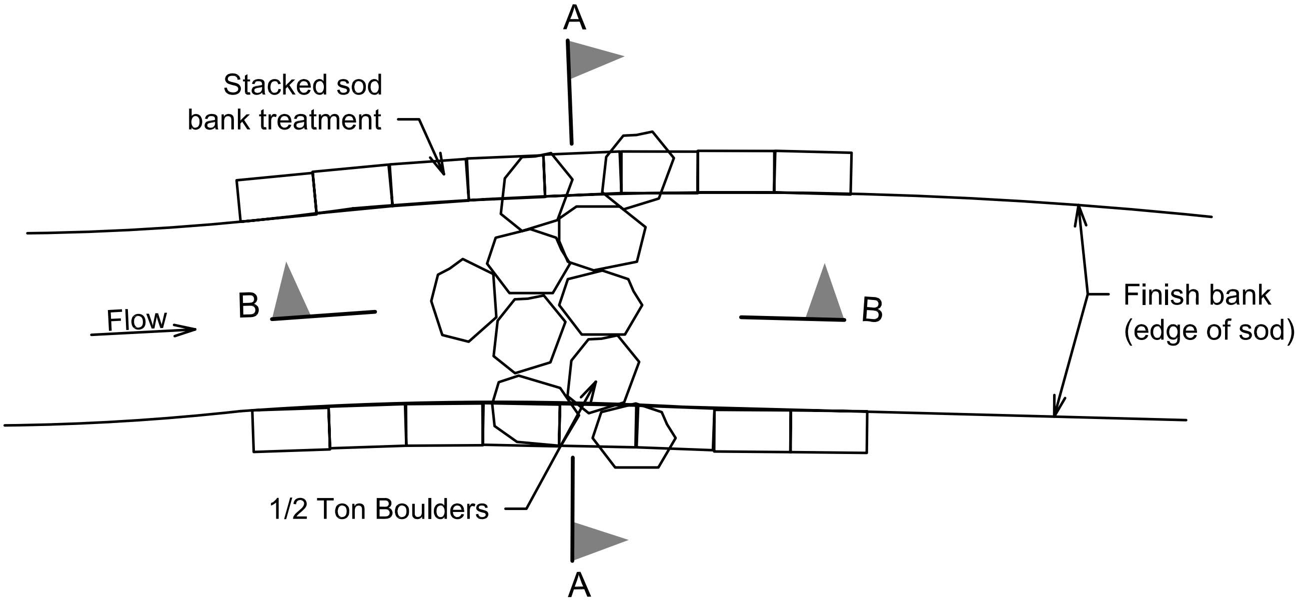
CLEAN GRAVEL RIFFLE

ENTRIX
1048 Ski Run Boulevard
South Lake Tahoe, CA 96150
(530) 542-0201 Main

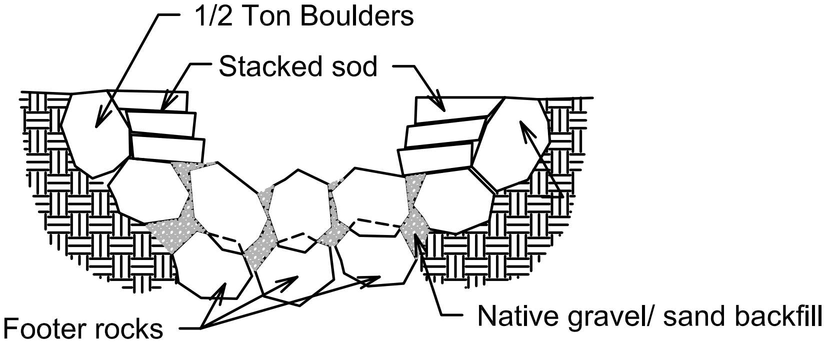
FILL EXISTING CHANNEL
NOT TO SCALE

FIGURE
EXHIBIT
5

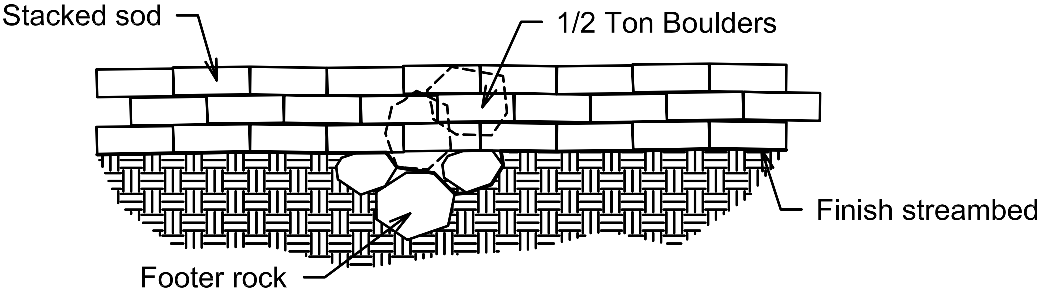
DATE: 03/07
PROJECT NO.: 3114201
BY: SHP



PLAN VIEW



SECTION A-A



SECTION B-B

NOT TO SCALE

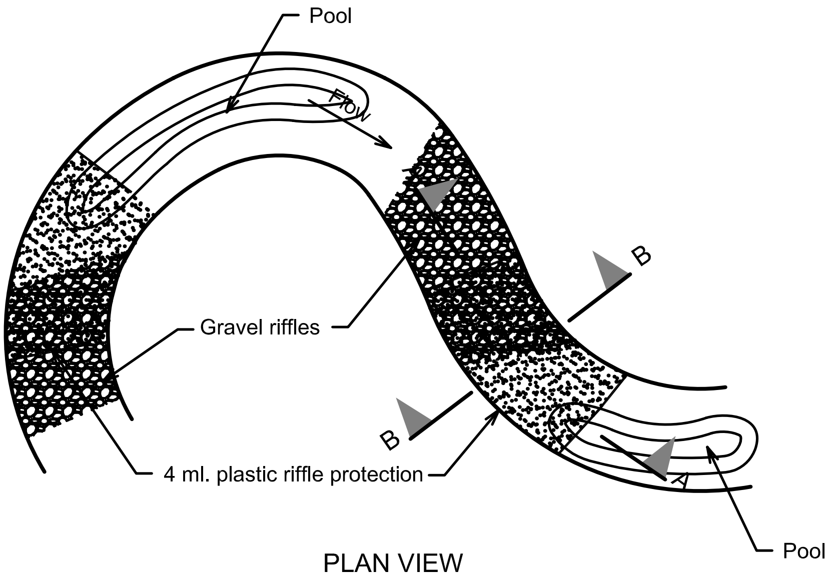
GRADE CONTROL

ENTRIX
1048 Ski Run Boulevard
South Lake Tahoe, CA 96150
(530) 542-0201 Main

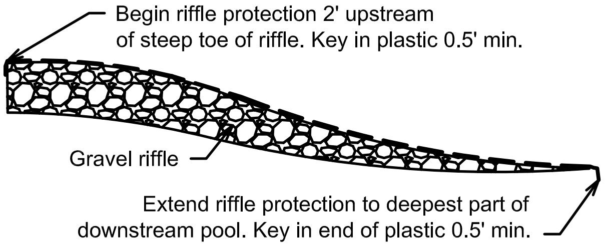
GRADE CONTROL STRUCTURE
NOT TO SCALE

FIGURE
EXHIBIT
6

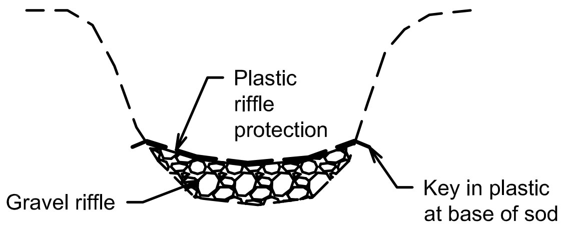
DATE:	PROJECT NO.:	BY:
03/07	3114201	SHP



PLAN VIEW



SECTION A-A



SECTION B-B

Notes: 1) Riffle protection plastic shall be 4 ml. except at pump outlet, where plastic shall be 6 ml.

2) Plastic shall be placed such that all pumped water flows on plastic at toes of riffles.

NOT TO SCALE

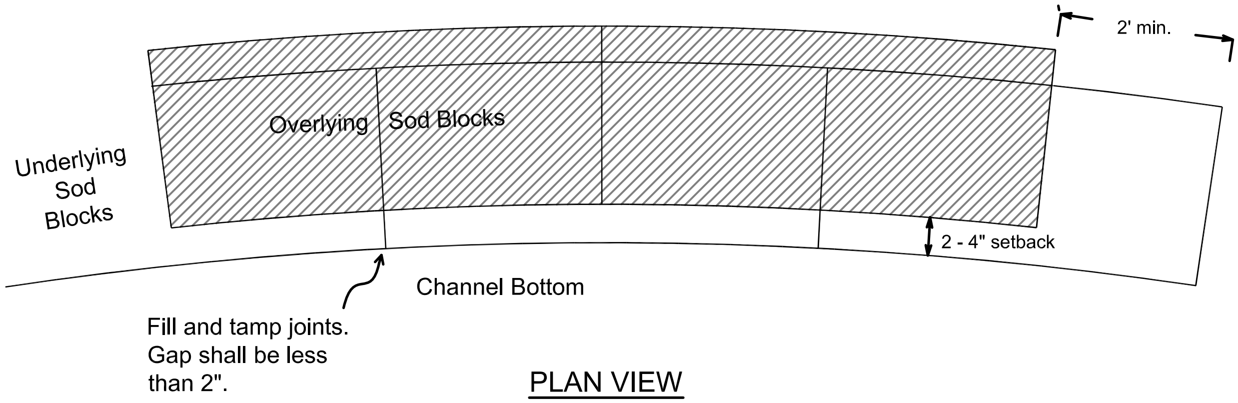
RIFFLE PROTECTION

ENTRIX
1048 Ski Run Boulevard
South Lake Tahoe, CA 96150
(530) 542-0201 Main

RIFFLE PROTECTION
NOT TO SCALE

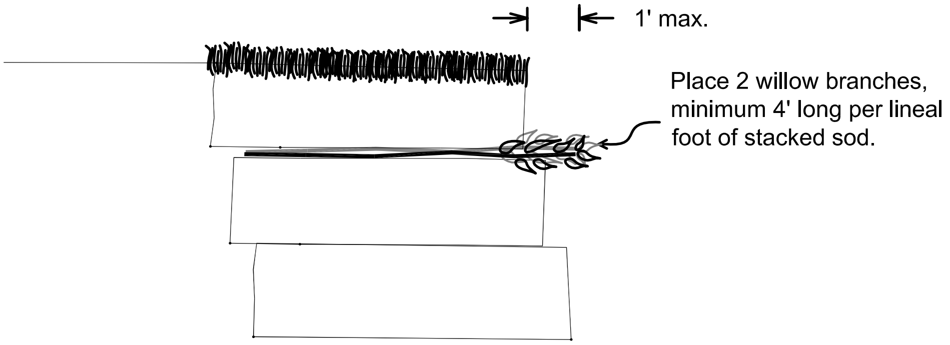
FIGURE
EXHIBIT
7

DATE: 03/07
PROJECT NO.: 3114201
BY: SHP



PLAN VIEW

SOD REVETMENT
JOINT PATTERN



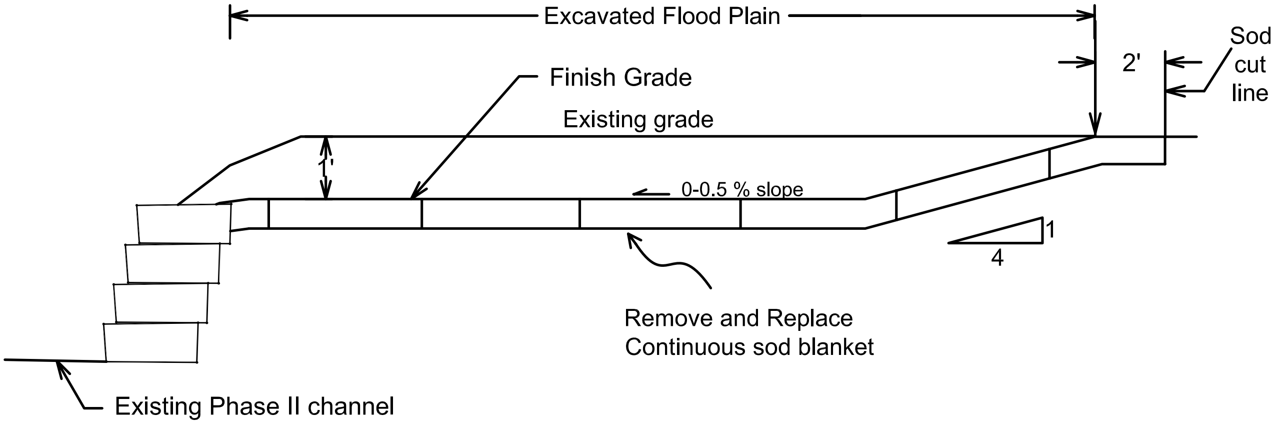
BRUSH LAYERING

ENTRIX
1048 Ski Run Boulevard
South Lake Tahoe, CA 96150
(530) 542-0201 Main

SOD REVETMENT/BRUSH LAYERING
NOT TO SCALE

FIGURE
EXHIBIT
8

DATE: 03/07
PROJECT NO.: 3114201
BY: SHP



FLOOD PLAIN (TYPICAL)

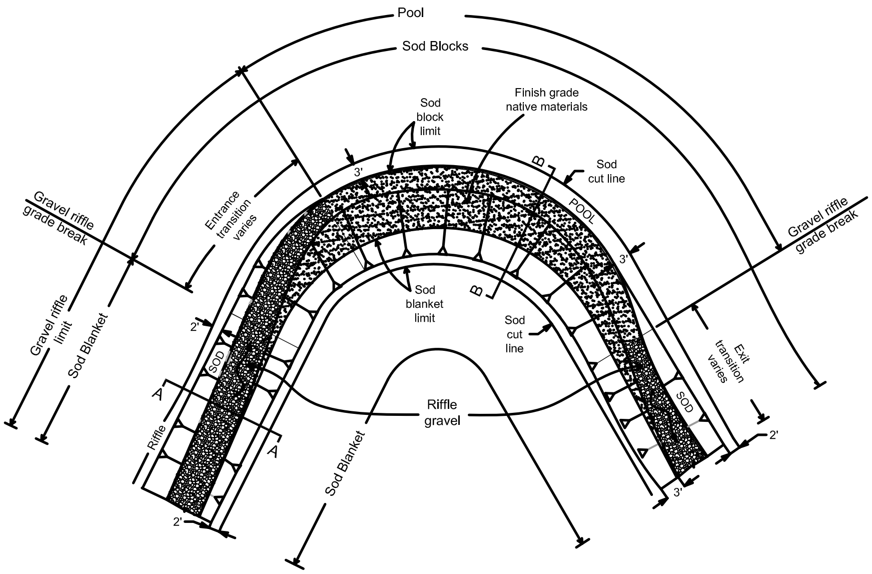
ENTRIX

1048 Ski Run Boulevard
South Lake Tahoe, CA 96150
(530) 542-0201 Main

FLOOD PLAIN EXCAVATION
NOT TO SCALE

DATE: 03/07
PROJECT NO.: 3114201
BY: SHP

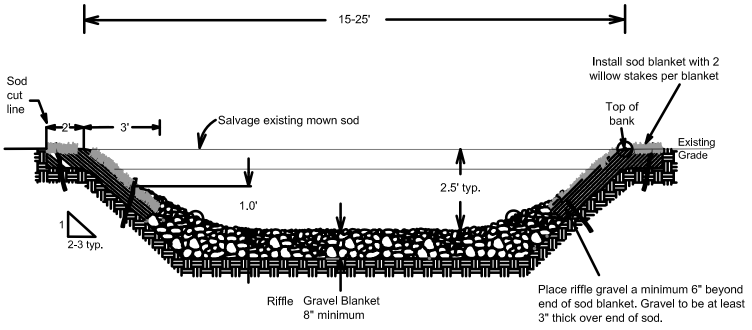
FIGURE
EXHIBIT
9



NOTES:

1. Riffle and sod revetment lengths vary. See Sheets 4-9 for limits.

TYPICAL REACH PLAN

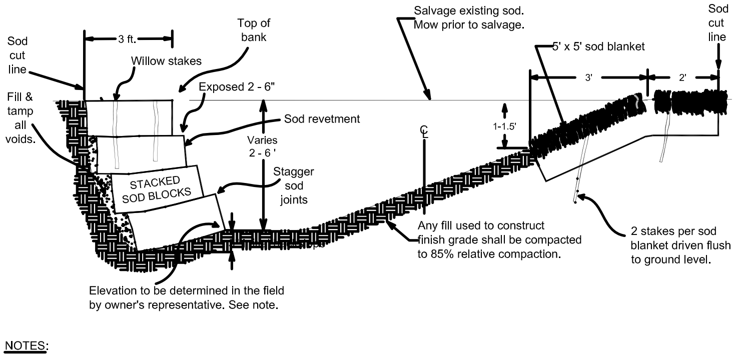


NOTES:

1. Dimensions shown are representative only. Dimensions shall conform to existing Phase II constructed channel.

2. Top of bank line shall be painted prior to grading, by the engineer.

TYPICAL RIFFLE
SECTION A-A



NOTES:

1. 0.75-1.5 inch diameter live willow 18-24" stakes.
2. 2"- 6" set back on sod blocks.
3. Sod blocks shall be approximately 10"-14" thick and 3' wide x 5' long.
4. Sod blanket shall be a minimum 5' wide x 5' long.
5. Compact each layer of sod with loader bucket or equal.
6. Sod cut line and top-of-bank line shall be painted, prior to grading, by the engineer.

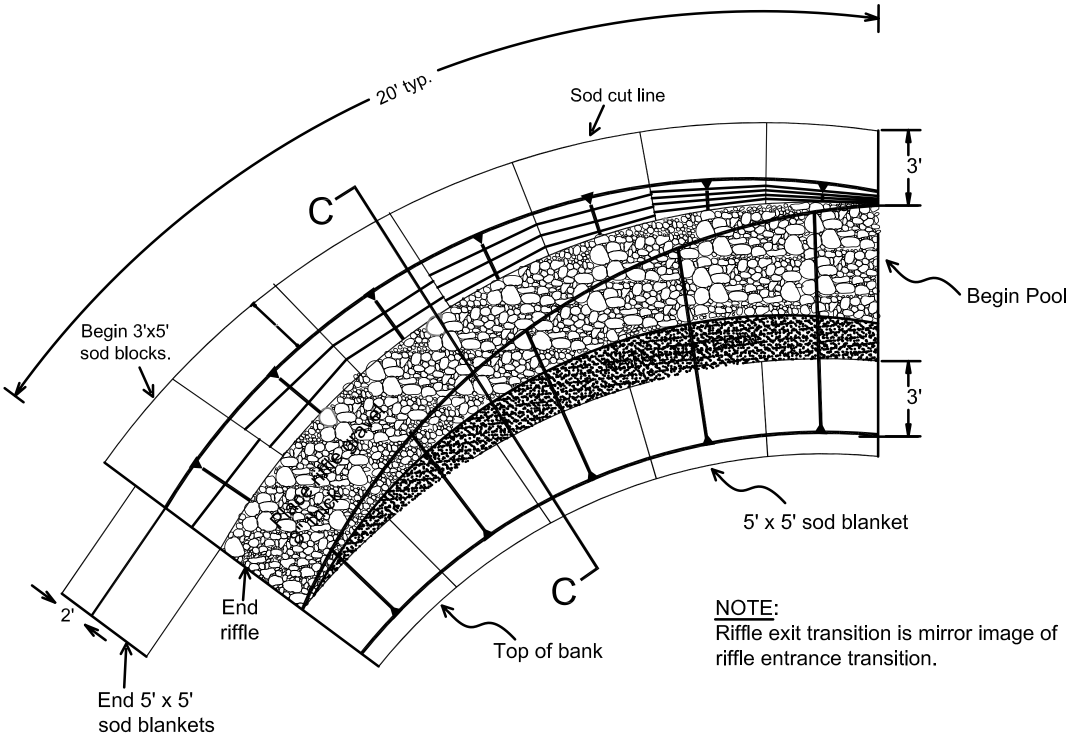
TYPICAL POOL
SECTION B-B

ENTRIX
1048 Ski Run Boulevard
South Lake Tahoe, CA 96150
(530) 542-0201 Main

REACH, RIFFLE AND POOL
NOT TO SCALE

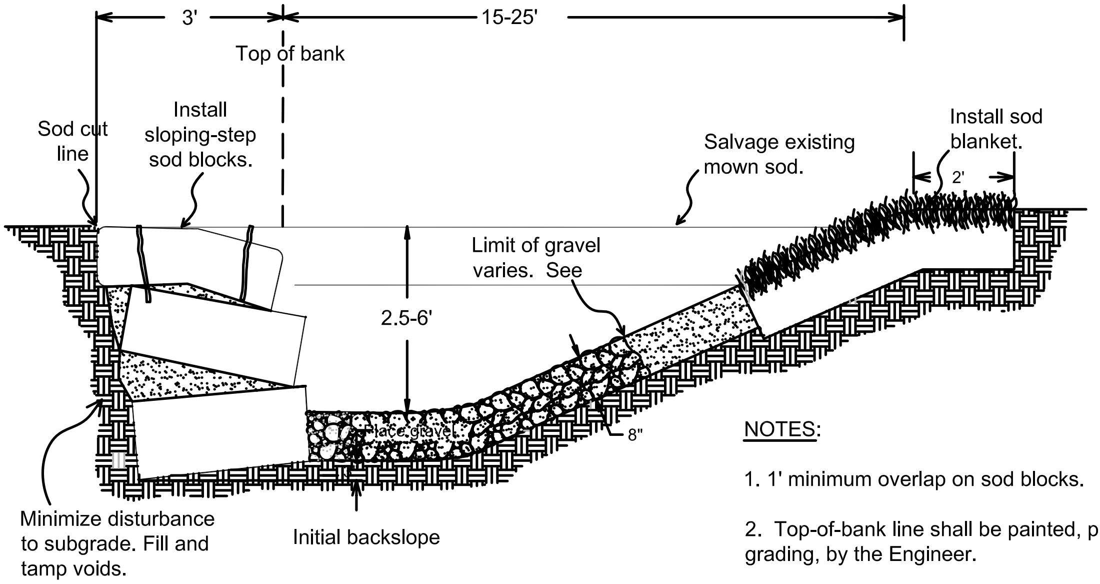
FIGURE
EXHIBIT
10

DATE: 03/07
PROJECT NO.: 3114201
BY: SHP



NOTE:
Riffle exit transition is mirror image of riffle entrance transition.

TYPICAL TRANSITION
PLAN



NOTES:

1. 1' minimum overlap on sod blocks.

2. Top-of-bank line shall be painted, prior to grading, by the Engineer.

TYPICAL TRANSITION
SECTION C-C

ENTRIX
1048 Ski Run Boulevard
South Lake Tahoe, CA 96150
(530) 542-0201 Main

TRANSITION
NOT TO SCALE

DATE: 03/07
PROJECT NO.: 3114201
BY: SHP

FIGURE
EXHIBIT 11

Particle Mass to Particle Number Conversion

Table A. Particle Size Fractions Used to Convert Particle Mass (<63 microns) to Total Number of Particles (< 20 microns) for Each Source Category

Atmospheric

							Tier	Setting			
	Calculations to convert PSD to weight and vice versa						Weight =	1 MT			
	Size (mm)	**Volume (mr**	**Total partic**	**weight**	**Actual Weight**	**Proportio**	**Actual**	**For particle**	**Particles(#)**	**checking**	Checking
0.5 to 1	0.75	0.2	3.66E+19	20.685	28.730	0.037	0.027	0.027	4.76E+16	0.027	0.0
1 to 2	1.5	1.8	1.21E+19	54.650	54.650	0.071	0.071	0.071	1.57E+16	0.071	0.1
2 to 4	3	14.1	9.18E+17	33.207	33.207	0.043	0.043	0.043	1.19E+15	0.043	0.0
4 to 8	6	113.1	9.00E+17	260.609	260.609	0.339	0.339	0.339	1.17E+15	0.339	0.3
8 to 16	12	904.8	8.84E+16	204.797	204.797	0.267	0.267	0.267	1.15E+14	0.267	0.3
16 to 32	20	4188.8	1.73E+16	185.975	185.975	0.242	0.242	0.242	2.26E+13	0.242	0.2
32 to 63			0.00E+00	0.000	0.000	0.000	0	0	0	0.000	0.0
		Total	5.06E+19	760	**767.97**	**1.00**	**0.99**	**0.99**	**6.59E+16**	0.990	1.0

Urban

						1.000		
Size range (μm)	Diameter (μm)	Volume (μm^3)	Particles (#)	Weight (MT)	Proportion	Conc-Steep Tier 1	Particles (#)	Checking
0.5 to 1	0.75	0.2	2.71E+20	153	0.033	0.03	5.84E+16	0.03
1 to 2	1.5	1.8	5.42E+19	245	0.053	0.05	1.17E+16	0.05
2 to 4	3	14.1	1.40E+19	505	0.109	0.11	3.01E+15	0.11
4 to 8	4	33.5	5.76E+18	494	0.106	0.11	1.24E+15	0.11
8 to 16	8	268.1	2.79E+18	1913	0.412	0.41	6.00E+14	0.41
16 to 32	16	2144.7	5.91E+16	325	0.070	0.07	1.27E+13	0.07
32 to <63	32	17157.3	2.30E+16	1010	0.217	0.22	4.95E+12	0.22
		Total	3.48E+20	4645	1	1	7.492E+16	1.00

Non-Urban (Forest)

						1		
Size range (μm)	Diameter (μm)	Volume (μm^3)	Particles (#)	Weight (MT)	Proportion	Setting A Tier 1	Particles (#)	Checking
0.5 to 1	0.75	0.2	3.17E+19	18	0.004	0.00	6.65E+15	0.00
1 to 2	1.5	1.8	6.75E+18	31	0.006	0.01	1.42E+15	0.01
2 to 4	3	14.1	1.67E+18	60	0.013	0.01	3.50E+14	0.01
4 to 8	6	113.1	6.44E+17	186	0.039	0.04	1.35E+14	0.04
8 to 16	12	904.8	2.96E+17	684	0.144	0.14	6.20E+13	0.14
16 to 32	24	7238.2	8.01E+16	1484	0.312	0.31	1.68E+13	0.31
32 to <63	39	31059.4	2.89E+16	2300	0.483	0.48	6.07E+12	0.48
		Total	4.12E+19	4764	1	1	8.641E+15	1.00

Stream channel erosion

						1		
Size range (μm)	Diameter (μm)	Volume (μm^3)	Particles (#)	Weight (MT)	Proportion		Particles (#)	Checking
0.5 to 1	0.75	0.2	1.29E+19	7	0.002	0.00	3.43E+15	0.00
1 to 2	1.5	1.8	2.76E+18	12	0.003	0.00	7.36E+14	0.00
2 to 4	3	14.1	6.82E+17	25	0.007	0.01	1.82E+14	0.01
4 to 8	6	113.1	2.62E+17	76	0.020	0.02	6.99E+13	0.02
8 to 16	12	904.8	1.20E+17	277	0.074	0.07	3.20E+13	0.07
16 to 32	32	17157.3	3.22E+16	1414	0.377	0.38	8.59E+12	0.38
32 to <63	50	65449.8	1.16E+16	1937	0.517	0.52	3.08E+12	0.52
		Total	1.67E+19	3749	1	1	4.462E+15	1.00