11.0 NUTRIENT REDUCTION ALTERNATIVES

This section discusses five different nutrient reduction alternatives that could be applied in the basin to aid in reduction of nutrient loading to the lake. Most alternatives are aimed at preventing or reducing nitrogen and phosphorous in groundwater, and ultimately into lake waters. The reduction alternatives discussed in this section include phytoremediation, permeable reactive treatment walls, pretreatment of storm water runoff/infiltration, implementation of best management practices, and implementation of awareness programs. The first two alternatives address nutrients that have already been released into groundwater. The following three alternatives address prevention of the release of nutrients into groundwater. Nutrient reduction alternatives are evaluated based on effectiveness, implementability, and cost.

11.1 Phytoremediation

11.1.1 Description

Phytoremediation is the use of plants to remove, contain, or render harmless environmental contaminants in soil and groundwater. It is a promising technology that addresses cleanup of a number of contaminants, including nutrients. The key physiological processes in phytoremediation include: stimulation of microorganism-based transformation by plant exudates and leachates, and by fluctuating oxygen regimes, slowing of contaminant transport from the vegetated zone due to adsorption and increased evapotranspiration, and plant uptake, followed by metabolism or accumulation (Best and Lee 2003). Phytoremediation takes advantage of the unique and selective uptake capabilities of plant root systems, together with the translocation, bioaccumulation, and contaminant storage/degradation abilities of the entire plant body (Hinchman 1998).

Plant-based soil remediation systems can be viewed as biological, solar-driven systems with an extensive, self-extending uptake network (the root system) that enhances the below-ground ecosystem for subsequent productive use. Examples of simpler phytoremediation systems that have been used for years are constructed or engineered wetlands, often using cattails to treat acid mine drainage or municipal sewage (Hinchman 1998). Physically, plants slow the movement of contaminants in soil, by reducing runoff and increasing evapotranspiration and by adsorbing compounds to their roots. Once a wetland or upland phytoremediation system is in place, its biological components are naturally self-sustaining, powered by plant photosynthesis (Best and Lee 2003).

There are a number of different types of phytoremediation mechanisms. These include the following (CPEO 2002):

- Rhizosphere biodegradation. In this process, the plant releases natural substances through its roots, supplying nutrients to microorganisms in the soil. The microorganisms enhance biological degradation.
- Phyto-stabilization. In this process, chemical compounds produced by the plant immobilize contaminants, rather than degrade them.

- Phyto-accumulation (also called phyto-extraction). In this process, plant roots sorb the contaminants along with other nutrients and water. The contaminant mass is not destroyed but ends up in the plant shoots and leaves. This method is used primarily for wastes containing metals. At one demonstration site, water-soluble metals are taken up by plant species selected for their ability to take up large quantities of lead (Pb). The metals are stored in the plant's aerial shoots, which are harvested and either smelted for potential metal recycling or recovery or are disposed of as hazardous waste. As a general rule, readily bioavailable metals for plant uptake include cadmium, nickel, zinc, arsenic, selenium, and copper. Moderately bioavailable metals are cobalt, manganese, and iron. Lead, chromium, and uranium are not very bioavailable. Lead can be made much more bioavailable by the addition of chelating agents to soils. Similarly, the availability of uranium and radio-cesium 137 can be enhanced using citric acid and ammonium nitrate, respectively.
- Hydroponic Systems for Treating Water Streams (Rhizofiltration). Rhizofiltration is similar to phyto-accumulation, but the plants used for cleanup are raised in greenhouses with their roots in water. This system can be used for *ex-situ* groundwater treatment, that is, groundwater is pumped to the surface to irrigate these plants. Typically hydroponic systems utilize an artificial soil medium, such as sand mixed with perlite or vermiculite. As the roots become saturated with contaminants, they are harvested and disposed of.
- Phyto-volatilization. In this process, plants take up water containing organic contaminants and release the contaminants into the air through their leaves.
- Phyto-degradation. In this process, plants actually metabolize and destroy contaminants within plant tissues.
- Hydraulic Control. In this process, trees indirectly remediate contamination by controlling groundwater movement. Trees act as natural pumps when their roots reach down towards the water table and establish a dense root mass that takes up large quantities of water. A poplar tree, for example, pulls out of the ground 30 gallons of water per day, and a cottonwood can absorb up to 350 gallons per day (CPEO 2002.

The plants most used and studied in phytoremediation are poplar trees. In Iowa, the EPA demonstrated that poplar trees acted as natural pumps to keep toxic herbicides, pesticides, and fertilizers out of the streams and groundwater (CPEO 2002).

11.1.2 Effectiveness

Phytoremediation can be applied in terrestrial and aquatic environments. It can be used as a preparatory or finishing step for other cleanup technologies. Plants are aesthetically pleasing, and these systems are relatively self-sustaining leading to long-term effectiveness (Best and Lee 2003).

The following study is a good example of the benefits of phytoremediation in the reduction of nutrients in groundwater. A USEPA study conducted in Iowa demonstrated the usage of phytoremediation by planting poplar trees along a stream bank between a cornfield and the stream. These trees acted as natural pumps to keep toxic herbicides, pesticides, and fertilizers out of the streams and groundwater. After three years, while the nitrate concentration in groundwater at the edge of the cornfield was measured at 150 mg/L, the groundwater among the poplar trees along the stream bank had nitrate concentration of only 3 mg/L (AEC 2002a).

11.1.3 Implementability

The implementability, risks, and limitation of phytoremediation technology are described below. Before implementing phytoremediation technology, detailed information is needed to determine the kinds of soil used for phytoremediation projects. Water movement, reductive oxygen concentrations, root growth, and root structure all affect the growth of plants and should be considered when implementing phytoremediation. They plant type should be carefully evaluated to determine the most productive for the circumstances. There are a number of limitations to phytoremediation as follows:

- The depth of the contaminants limits treatment. The treatment zone is determined by plant root depth. In most cases, it is limited to shallow soils, streams, and groundwater. Pumping the water out of the ground and using it to irrigate plantations of trees may treat contaminated groundwater that is too deep to be reached by plant roots (CPEO 2002).
- Generally, the use of phytoremediation is limited to sites with lower contaminant concentrations and contamination in shallow soils, streams, and groundwater. However, researchers are finding that the use of trees (rather than smaller plants) allows them to treat deeper contamination because tree roots penetrate more deeply into the ground (CPEO 2002).
- Climatic or seasonal conditions may interfere or inhibit plant growth, slow remediation efforts, or increase the length of the treatment period (AEC 2002a).
- Phytoremediation will likely require a large surface area of land for remediation (AEC 2002a).
- If contaminant concentrations are too high, plants may die (CPEO 2002).
- The success of remediation depends on establishing a selected plant community. Introducing new plant species can have widespread ecological ramifications. The plant community should be studied beforehand and monitored. Additionally, the establishment of the plants may require several seasons of irrigation. It is important to consider extra mobilization of contaminants in the soil and groundwater during this start-up period (CPEO 2002).

11.1.4 Cost

Phytoremediation is an innovative cleanup technology that is low-tech. Construction estimates for phytoremediation are approximately $200,000/acre and $20,000/acre for operations and maintenance (AEC 2002a).

Because conditions vary between each contaminated site, phytoremediation is not feasible in every case. Before a remediation project can begin, all of the site specific factors must be taken into account, and a decision must be made based upon the most suitable available technology. With time and increasing numbers of successful implementations, bioremediation and phytoremediation will be considered proven technologies, rather than innovative technologies (Frazar 2000). Additional information can be obtained from a number of companies who specialize in implementing phytoremediation technology.

11.2 Permeable Reactive Treatment Walls

11.2.1 Description

A permeable reactive treatment wall is a type of barrier wall that allows the passage of groundwater while causing the degradation or removal of nutrients and other pollutants. A permeable reaction wall is installed across the flow path of a contaminant plume, allowing the groundwater portion of the plume to move through the wall while prohibiting the movement of or remediating the contaminants by employing such materials as sorbents and microbes (Figure 5-1). Sorbents that can be used in permeable reactive walls to remove pollutants include such diverse materials such as straw, newspaper, raw cotton, jute pellets, vegetable oil, compost, wood mulch, and sawdust. Permeable reactive treatment walls are generally intended for long-term operation to control migration of contaminants in groundwater (AEC 2002b).

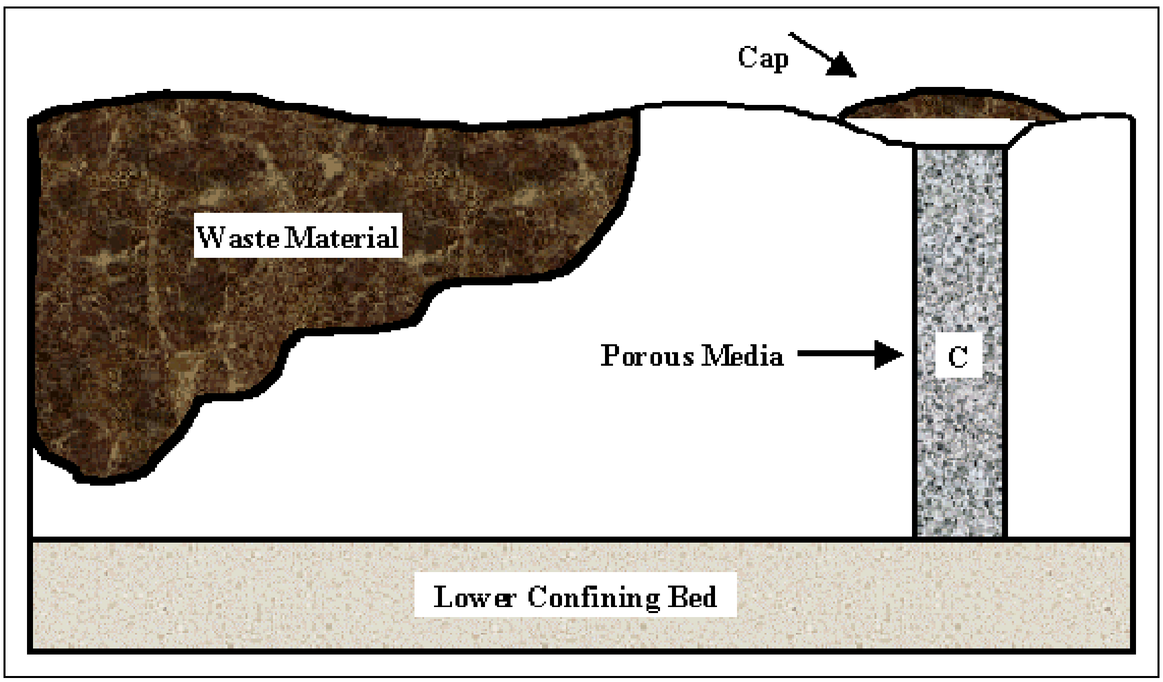

Figure 11-1. Typical Permeable Treatment Wall (Cross-Section) (AEC 2002b).

Field trials conducted by the University of Waterloo, Ontario, Canada demonstrated the use of nitrate-reactive permeable subsurface barriers to passively attenuate nitrate from septic systems. These barriers were installed as layers below an otherwise conventional septic system infiltration beds and as a vertical wall intercepting a horizontally flowing septic system plume. The barriers contained waste cellulose solids (wood mulch, sawdust and leaf compost), which provided a carbon source for heterotrophic denitrification. A field trial was also conducted on agricultural runoff where a nitrate barrier in the form of a containerized reactor was used to treat farm field drainage water. Field trials were conducted over a 5 to 10 year period (Robertson et al. 2000).

11.2.2 Effectiveness

Field trials conducted by the University of Waterloo have demonstrated that reactive barriers using waste cellulose solids, which act as carbon sources for heterotrophic denitrification, can be used to achieve long-term, passive, in situ attenuation of nitrate originating from a variety of sources (fertilizer, septic/sewage, agricultural/pasture drainage). Nitrate removal rates ranged from 0.7 to 32 mg/L per day, were temperature dependent, and did not significantly diminish over the monitoring period. Mass-balance calculations and visual inspection indicated that a substantial portion of the initial carbon remained in the barriers after six to seven years of operation, suggesting that such barriers can be readily designed to provide a decade or more of nitrate treatment without carbon replenishment. (Robertson et al. 2000)

11.2.3 Implementability

Permeable reactive barriers have the potential to provide virtually complete single-pass nitrate removal using materials that are low cost and, in most cases, locally available. They require little maintenance and should be ideally suited for use on both a large and small scale. Reactive barriers have been more recently installed to treat nitrate contamination from a fertilizer facility and have also been incorporated into a commercially available wastewater treatment system (Robertson et al. 2000).

There are a number of factors that may limit the applicability and effectiveness of permeable reactive treatment walls. Though projected to last at least 10 years without having to be replaced, permeable treatment walls may lose their reactive capacity, requiring replacement of the reactive medium earlier than anticipated. The depth and width of the barrier may be a limiting factor depending upon the area in need of treatment. The subsurface lithology must have a continuous aquitard at a depth that is within the vertical limits of trenching equipment. The volume cost of the treatment medium may be a limiting factor depending upon the availability of the materials used. Biological activity or chemical precipitation may limit the permeability of the treatment wall (AEC 2002b). Selection of a carbon source for this project in a permeable reactive treatment wall is expected to be governed by site-specific factors, such as the hydraulic retention time in the barrier, permeability requirements, acceptable frequency of maintenance, and local availability of materials (Robertson et al. 2000).

11.2.4 Cost

Complete cost data are still not available because most sites have been demonstration scale and may have been over designed to provide a safety margin (AEC 2002b). However, costs to install and maintain permeable reactive treatment walls should be low due to minimal required maintenance, the use of locally available materials, and long-term operation (Robertson et al. 2000). A cost-limiting factor could include availability of locally available materials and reactive media.

11.3 Pretreatment of Storm water Runoff

Collection and infiltration of storm water runoff has become a popular means of reducing surface water runoff into Lake Tahoe, by preventing most suspended sediments and pollutants from reaching lake waters. Though considered highly effective and beneficial in preventing direct flow of suspended sediments and pollutants into the lake, infiltration of untreated runoff could potentially affect the quality of groundwater, and indirectly, the quality of lake water which is being fed by groundwater. Accumulation of nutrient and pollutant rich sediments in infiltration systems (basins, trenches, dry wells, and wetlands) creates a potential point source for groundwater (Whitney 2003).

Infiltration systems convey surface water to groundwater regardless of quality, and if left untreated, storm water flows may negatively affect groundwater. Currently, water quality standards that are applied to pollutant concentrations in storm water runoff does not take into consideration protection of groundwater that lies beneath. Revision of this standard may be considered in the future (Whitney 2003).

A study is currently being conducted by the South Tahoe Public Utility District (STPUD) to study the impact of storm water infiltration on the quality of groundwater (Whitney 2003). The results of this study may change the way infiltration basins are used in the future, including possible changes in design, addition or storm water pretreatment, monitoring of groundwater, or reduction in number (Whitney 2003).

New technology in the area of storm water management has led to the development of several products that may prove useful in both controlling and treating storm water runoff and infiltration, protecting the quality of groundwater and surface water at the same time. Below is a description of several new technologies that can be used for the pretreatment of storm water runoff before it enters an infiltration system.

11.3.1 Description

StormFilter®

StormFilter® is a passive, flow-through storm water filtration system appropriate for treating runoff from parking lots, industrial sites, and roadways. It consists of rechargeable media cartridges housed in an underground concrete vault. The vault is composed of three bays: a pretreatment bay, a filter bay, and an outlet bay. Heavy solids are removed at the pretreatment bay. Flow then passes through the media filled cartridges that trap particulates and adsorb dissolved materials such as orthophosphate, metals, and hydrocarbons. Treated water empties into an under-drain manifold that discharges to an outlet bay. The StormFilter® design is well suited for areas where space is limited and treatment requirements are high (LRWQCB 2001).

StormTreat System™

The StormTreat System™ (STS) consists of a series of sedimentation chambers and constructed wetlands that effectively remove suspended sediments and total phosphorous. The wetlands are contained within a modular 2.9-meter-diameter recycled polyethylene tank. Influent is piped into sedimentation chambers where pollutants are removed through sedimentation and filtration. Storm water is then conveyed from the chambers to the surrounding wetland. The STS conveys flows directly to the subsurface of the wetland and through the root zone for improved filtration, adsorption, and biological uptake and conversion (LRWQCB 2001).

The STS is adaptable to a wide range of site conditions and watershed sites. Designers of the system claim that it can be used to treat runoff from highways, parking lots, and commercial, industrial, and residential areas. The system is designed as an offline system to treat first-flush flows; the manufacturer recommends 1-2 units for each acre of impervious surface (LRWQCB 2001).

11.3.2 Effectiveness

StormFilter®

StormFilter® has a high pollutant removal capacity that appears to be effective for removing dissolved pollutants and fine sediments. Seven different types of media are available for the filter cartridges. Of particular interest is an iron infused media capable of removing dissolved phosphorus. Independent studies suggest that high dissolved phosphorus removal rates are associated with the use of iron infused media. Pleated fabric and perlite are reportedly effective for removing fine sediments. Other media are well suited for removing hydrocarbons and soluble metals (LRWQCB 2001).

StormTreat System™

The STS is reported to be very effective for removing high percentages of total phosphorus, suspended sediment and other pollutants such as hydrocarbons and metals. The STS has a relatively large holding volume of 1,390 gallons. Flow rates and holding times can be controlled by manipulating an outlet control valve. The STS is also very adaptable to different soil types and groundwater conditions (LRWQCB 2001).

11.3.3 Implementability

StormFilter®

StormFilter® is made or sold in flexible configurations for easy installation. They are available as pre-cast vaults, cast-in-place units, and pre-cast filters designed to be installed in storm drain drop inlets. Cast-in-place units can be quite large, involving over 100 individual filter cartridges. Drop inlet units are designed to handle small flows at individual locations with one cartridge per unit (LRWQCB 2001).

There are a number of potential limitations to the StormFilter® technology including the possibility that additional pretreatment of storm water may be required to remove coarse sediment to prevent clogging of the StormFilter® cartridges. Yearly maintenance may be time consuming and expensive as each cartridge weighs roughly 150 pounds and must be replaced at least once per year. Smaller StormFilters® (such as the drop inlet units) may not be capable of filtering high flows. Further, Caltrans has reported unfavorable performance of the StormFilter® on some of their projects in Southern California (LRWQCB 2001).

StormTreat System™

A benefit to the STS technology is that it requires very low maintenance with only annual or more frequent inspections and replacement of influent line sediment control sacks. Sediment must be removed from the main chamber every three to five years, and plants and gravel must be replaced every 10-15 years (LRWQCB 2001).

Potential limitations to the STS technology are that it is relatively new, and has had limited testing in cold, snowy climates. Also, wetland efficiency may be limited during the winter season when vegetation is dormant (LRWQCB 2001).

11.3.4 Cost

StormFilter®

Though initial purchase and installation costs may be reasonable, yearly operation and maintenance costs may be expensive due to the cartridge replacement requirements. Additional information can be obtained on StormFilter® by contacting the manufacturer, Stormwater Management Inc., or going to their web site at www.stormwatermgt.com (LRWQCB 2001).

StormTreat System™

Costs for the STS system are mainly upfront costs for purchase and installation. Since the system requires little maintenance, operation and maintenance costs are expected to be minimal. Additional information can be obtained on STS by contacting the manufacturer, StormTreat Systems, Inc., or going to their web site at www.stormtreat.com (LRWQCB 2001).

11.4 Groundwater Pumping

The use of groundwater as a drinking water source is different from the other remedies presented which are meant to reduce the nutrient concentrations. This alternative would not reduce nutrient concentrations, but rather divert nutrients that would otherwise reach the lake. Groundwater as a drinking water source is used only on a limited basis in the Tahoe Basin. STPUD obtains 100 percent of their drinking water from groundwater. The remaining regions obtain their drinking water from a combination of surface water intakes and groundwater. The nutrient concentrations found in groundwater in the Tahoe Basin are, for the most part, well below the drinking water standards. However, the nutrient concentrations could pose a threat to the lake. For this reason, using groundwater as a drinking water source should be considered as an alternative where feasible.

11.4.1 Effectiveness

South Lake Tahoe uses groundwater as a drinking water source. The groundwater modeling performed as part of this evaluation showed that groundwater in at least one area (subregion 3) was being diverted from the lake into a drinking water well (Section 4.5.4). This region did have elevated concentrations of nutrients in groundwater, but showed little nutrient loading to Lake Tahoe because the groundwater discharge rate was negligible. This illustrates that the use of groundwater as a drinking water source can divert nutrients that would otherwise reach the lake.

11.4.2 Implementability

If the groundwater is of good quality, the treatment standards for groundwater are not as stringent as those for the use of surface water. This alternative would provide a beneficial use to the community for drinking water and would be of benefit to the lake because fewer nutrients would migrate to the lake. The nutrient concentrations found in groundwater in the Tahoe Basin are below drinking water standards, however, if the wells are constructed to intercept the highest nutrient concentrations, then the well will likely draw other contaminants. If this alternative is to be used as a remedy, careful planning is necessary to meet both the needs of diverting nutrients from the lake and providing clean drinking water to the public. The wells would have to be placed in an aquifer which allows for enough pumping to supply drinking water to the population. For large municipal wells, pumping rate requirements range from about 500 to 4,000 gallons per minute (gpm). Small- and medium-sized community water systems may depend on water wells that produce from 100 to 500 gpm. Because the wells would have to be constructed in key locations for pumping, there is no guarantee that the wells will be able to be constructed in the best location to intercept nutrients.

11.4.3 Costs

Costs can vary widely depending on the amount of investigation that is required prior to placing the wells. A hydrogeological assessment to determine whether and where to locate a well should always be conducted. Well depth is another factor in the cost of the well. The amount of infrastructure that would have to be built to supply wells to the public should also be a consideration.

11.5 <u>Implementation of Best Management Practices</u>

Achieving wider implementation of existing best management practices (BMP) in the Lake Tahoe Basin is an important step toward improving lake clarity. Scientists have determined that implementing BMPs on existing development is one of the most critical steps toward improving water quality (TRPA 2003b). The development of new BMPs may not be necessary as there are a number of existing BMPs in place already, developed mainly for the protection of surface water quality. However, surface water BMPs do not always take into account the effects on groundwater, which could be negatively affected if not considered. In addition, some existing BMPs may need reevaluation to determine if they are effective or not.

Recent research indicates urbanized areas and roadways contribute a significant amount of sediment and nutrients responsible for water quality impairment at Lake Tahoe. To minimize the environmental impacts to water quality associated with urban runoff, several agencies in the Tahoe Basin are working to effectively control non-point source pollution by implementing BMPs. Lahontan Regional Water Quality Control Board (LRWQCB) and the Tahoe Regional Planning Agency, in cooperation with other agencies, have developed BMPs and a number of other guidelines and management plans specifically designed to protect water quality. Through greater implementation of these BMPs, taking into account the impacts on groundwater, pollution sources can be controlled and will have less of an impact on water quality and therefore, lake clarity.

11.5.1 Existing Best Management Practices

Lahontan BMPs and Management Plans

Lahontan RWQCB has developed storm water BMPs (LRWQCB 2001) for management of urban runoff and storm water treatment and has also developed a Water Quality Control Plan (LRWQCB 1995) to protect both surface water and groundwater. Implementation of these practices is important in reducing nutrient loading to the lake.

Unfortunately, no single BMP can address all storm water problems. Every BMP has limitations based on cost and pollutant removal efficiency as well as site-specific restrictions including available land, slope, soil type, and depth to groundwater. These limitations must be considered when selecting the appropriate BMP or group of BMPs to treat storm water at a particular location (LRWQCB 2001).

While erosion control and sediment reduction remain important goals, new and retrofitted BMPs must focus on the removal of bioavailable nutrients and fine particulates (silts and clays) if these efforts are to improve the clarity of Lake Tahoe (LRWQCB 2001). Reduction of nutrient loads to groundwater will also improve lake clarity.

Careful BMP selection, design, and implementation is essential for achieving the highest possible pollutant reduction. Monitoring of BMP projects will provide better information for use in improving storm water treatment in the Lake Tahoe Basin (LRWQCB 2001).

TRPA BMPs and Management Plans

TRPA has developed BMPs for management of soil erosion and urban runoff. In addition, TRPA has developed a Water Quality Management Plan, an Improved Fertilizer Management Program and a number of resource guides for the public. The goals of each are to protect water quality and to reduce the release of nutrients, sediments, and other pollutants into the lake. These programs are required to be implemented within the basin (TRPA 2003a).

TRPAs BMPs serve to compensate for land development within the Tahoe Basin and mainly address soil erosion control and management of surface runoff. All property owners in the Tahoe Basin are required to implement BMPs, whether they own residential or commercial properties. BMPs for residential properties commonly include roof dripline infiltration trenches, vegetation and mulch on bare areas, responsible irrigation and fertilization techniques, and gravel under decks. Depending on the size of the related parking area or amount of use and impervious area on site, BMPs for commercial or public service properties may include a storm water pre-treatment system with a sand/oil separator, detention basins, infiltration devices, roadside rock lined ditches or slope stabilization techniques (TRPA 2003a).

TRPA is currently developing an Improved Fertilizer Management Program to reduce the release of nutrients to groundwater and surface water through modified application, watering, and drainage control of landscaping and revegetated areas. This program applies to existing users for facilities that require regular fertilizer maintenance (i.e., parks, cemeteries, plant nurseries, recreational ball fields, golf courses, and residential yards) (TRPA 2003c).

Under this program, users will be required to submit a fertilizer management program for review and approval by TRPA. Criteria for the program shall include consideration of the following: type of fertilizer used to avoid release of excess nutrients, rate of application to avoid excessive application, frequency of application to minimize the use of fertilizer, appropriate watering schedules to avoid excessive leaching and runoff of nutrients, preferred plant materials to minimize the need for fertilizer, landscape design that minimizes the use and impacts of fertilizer application, critical areas where the use of fertilizer shall be avoided, design and maintenance of drainage control systems, surface and groundwater monitoring programs, and public outreach. Public outreach applies in particular to residential users, owners associations, and condominiums. Public outreach shall be required in conjunction with fertilizer sales in the Tahoe Basin (TRPA 2003c).

Wetland and Stream Environment Zone Infiltration

Like other treatment basins, wetlands and stream environment zones (SEZ) are engineered or natural landscape depressions designed to retain and treat storm water flows. Wetlands/SEZs, in contrast to detention basins, maintain a permanent pool of water. They are designed to capture runoff from the design storm and retain it until it is displaced by the next runoff event. Although many wetlands and SEZs offer nutrient removal by biological uptake and conversion, the primary mechanism for treatment is sedimentation. The permanent pool of water limits resuspension of accumulated sediment during high flow events (LRWQCB 2001).

Vegetative wetland storm water treatment can be used in any area where there is sufficient space and hydrologic conditions that support thick hydrophytic vegetation. Any location in need of treatment with access to a densely vegetated area should consider this option. In addition to providing treatment, wetland systems help also control runoff volumes. Wetland construction or development of existing wetlands or SEZ resources may require multiple local, state, and federal permits including, but not limited to, 401 water quality certification, 404 wetland permits, waterway disturbance permits, Basin Plan prohibition exemptions, and TRPA land use approvals (LRWQCB 2001).

Properly designed wetland and SEZ storm water treatment systems have proven highly effective for removing bioavailable nutrients and fine sediment from urban runoff. Wetland treatment offers pollutant removal by infiltration, sedimentation, physical filtering, and biological uptake and conversion. SEZs can permanently remove bioavailable nitrogen and phosphorous from surface waters. Wetland and vegetated treatment systems can also be visually attractive and provide valuable habitat for migratory waterfowl (LRWQCB 2001).

Improper development or excessive pollutant loads can damage natural wetland systems and affect groundwater quality. Upsetting the natural nutrient and hydrologic balance of wetland areas by the introduction of storm water may threaten their integrity, reduce water quality benefits, and potentially impair beneficial uses. Some storm water experts have also raised concerns about potential effects on wildlife attracted to storm water wetlands. Limited nutrient removal capacities during the winter season when vegetation is dormant may be another possible disadvantage. Furthermore, decomposing wetland vegetation may release stored nutrients and other chemicals (such as heavy metals) to surface and groundwater. Pretreatment of runoff waters is highly recommended before release into a wetland or SEZ (LRWQCB 2001).

Wetland treatment efficiency is a function of pollutant load, and thus can be highly variable. In general, nutrient removal efficiency drops with decreased nutrient concentrations. Another factor influencing nutrient removal is the seasonal nature of nutrient-laden runoff. Unlike areas on the east coast of the United States where runoff occurs primarily during the growing season, much of the urban runoff in the Tahoe Basin occurs during the winter and early spring when vegetation is dormant (LRWQCB 2001).

A final drawback to the use of SEZs is that many of the SEZs in the Basin have been adversely affected through filling, excavation, and channelization of associated waterways. Furthermore, a large portion of the urbanized areas of the Basin (including most of the west and north shores) do not drain to an SEZ. Those SEZs that do receive urban runoff (such as those in the south shore area) are often incapable of treating the high pollutant loads found in urban runoff. Consequently, infiltration currently remains the primary method for removing fine sediment and bioavailable phosphorus from urban storm water (LRWQCB 2001).

11.6 Awareness Programs

Awareness programs to educate the public on how they can reduce nutrient loadings to soil and groundwater in their own backyards are another important step in the protection of groundwater and surface water quality. Public education about lawn fertilizer application in residential yards and pet dropping pickup in designated pet walking areas can reduce an overlooked yet contributing source of nutrients to groundwater. A number of public awareness programs are already in place for programs such as water conservation, storm water BMPs, and fertilizer management. A successful awareness program for water conservation is making an impact, as many residents currently conserve water. A public information officer with the South Lake Tahoe Chamber of Commerce is responsible for educating the public on water conservation (Wallace 2003).

TRPA has a designated Erosion Control Team (ECT) whose mission is to manage storm water runoff and reduce erosion from developed properties utilizing Best Management Practices (BMPs). By providing the public with quality technical assistance to facilitate the implementation of BMPs, the ECT aims to preserve water quality and the clarity of Lake Tahoe. Through education and assistance, the ECT is committed to heightening public awareness of the unique problems facing Lake Tahoe and to helping residents implement BMPs on their properties. By implementing BMPs, all property owners can help slow or reverse the loss of lake clarity. Through grant funding, the ECT is able to offer free BMP site evaluations, limited field crew implementation assistance and some discounted materials (TRPA 2003b).

TRPA also provides a Home Landscaping Guide for Lake Tahoe and Vicinity. This book, written by the University of Nevada Cooperative Extension, explains how homeowners can have a beautiful landscape while protecting Lake Tahoe. TRPA also is developing a more comprehensive Improved Fertilizer Management Program that outlines requirements for fertilizer application rates, watering frequency, site drainage, and plant choices and recommendations. The goals of these programs are to reduce nutrient loading to the groundwater, thereby protecting lake clarity (TRPA 2003b).