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Developing a Nutrient Management Plan for Napa River Watershed

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Introduction

Implementation of section 303(d) of the 1972 Clean Water Act has prompted states to develop lists of impaired waters that do not meet set water quality standards. The law requires that jurisdictions establish priority rankings for waters on the lists and develop total maximum daily loads (TMDLs) for these waters. By definition, a TMDL specifies the maximum amount of a pollutant that a waterbody can receive without violating water quality standards and disrupting the beneficial uses of the watershed.

In California alone, 509 watersheds have been identified as impaired and in need of TMDL establishment. The Napa River Watershed, located in northern California is one of the listed watersheds. World renowned for its wine, the Napa Valley has experienced rapid agricultural and urban growth within the past few decades. Repercussions of this development can be seen throughout the Napa River Watershed, which was identified as impaired by extensive nutrient, pathogen and sediment loading by the EPA in 1998. The focus of this project is to specifically address the nutrient impairment in the river.

Background

Napa River extends 88 km (55 mi) from the headwaters at Mt. St. Helena to San Pablo Bay. Spanning 2.59 sq km (426 sq mi), the Napa River Watershed and its 47 tributaries are spawning grounds for the endangered Chinook Salmon and Steelhead Trout, and provide habitat for dozens of other threatened and endangered birds, mammals, reptiles, fish and plants.

Figure 1: Napa River Watershed Location

Nutrient loading from anthropogenic activity has led to eutrophication throughout the watershed. Eutrophication is the increased growth of plant and algal matter due to a high influx of nutrients. Once these plants die, their decomposition process removes oxygen from the water thereby creating an anaerobic environment. Fish and other organisms dependent on oxygen for survival are often debilitated or killed as a result. Additionally, eutrophication damages its aesthetic quality of the water adversely affecting beneficial uses such as recreational activities.


Figure 2: Eutrophication in the Napa River

Sources contributing to the excess loading of nutrients consist of a combination of point sources, such as wastewater treatment plant effuent, and non-point sources, such as faulty septic system seepage, fertilizer run-off from agricultural lands, and accretion from livestock land uses. This project focuses on quantifying

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source contributions and developing a nutrient load reduction management plan.

Field Investigations

Water quality samples were collected by the San Francisco Regional Water Quality Control Board (RWQCB) at 23 sites throughout the watershed in January and June of 2003. Samples were analyzed for a suite of nutrient indicators, which helped determine nitrogen as the limiting nutrient. Total dissolved nitrogen data was then analyzed to determine which sample sites exceeded nutrient target levels, and to observe trends of nitrogen concentration in tributaries versus the main river stem.

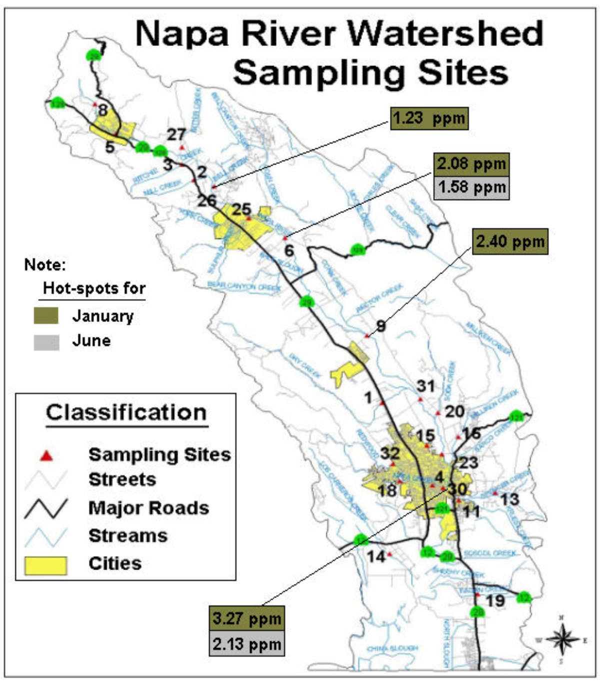

Figure 3: Sample site locations and measured TDN concentrations for January and June 2003

Preliminary total dissolved nitrogen (TDN) water quality objectives established by the RWQCB are 0.2 mg/L (0.2 ppm) TDN during the dry season, and 1.0 mg/L (1 ppm) TDN during the wet. A comparison of the TDN levels indicated that water quality targets along the main river stem were exceeded at all sample sites except the northernmost. In the tributaries, TDN concentrations mostly remained below water quality targets in the wet season, but exceeded the target levels at almost all sites during the dry season. These initial findings served as a benchmark for the development of nutrient load reduction scenarios.

Source Analysis

Point sources in the Napa River Watershed include:

- **Wastewater Treatment Plants (WWTPs)**
  Within the Napa Watershed, each of the four main cities, Calistoga, St. Helena, Yountville and Napa have their own WWTP. These WWTPs have no regulatory nutrient requirements for wastewater effluent, but specific dilution ratios must be attained before wet season discharge can take place.

Non-point sources in the Napa River Watershed include:

- **Runoff from Agriculture/Livestock**
  Nutrient sources produced by these land uses include inorganic fertilizers, manure, organic amendments applied during cultivation, waste accumulation from grazing animals, and soluble nutrients released during the decomposition and mineralization of plant litter. Storm and irrigation runoff, erosion, and shallow groundwater flows help transport nutrients from agriculture and pastureland to the Napa River and its tributaries.

- **Runoff from Urban Land Sources**
  Potential sources of nutrients include fertilizer runoff from lawns and landscaping, organic debris from gardens and parks, detergents used to wash cars or driveways, and trash such as food wastes. Domestic animal waste and human waste from areas inhabited by homeless also contribute to nutrient loads from urban land uses.

- **Septic System Effluent**
  Failures of septic system tanks or leach fields introduce nutrients into surface waters through groundwater contamination. Several areas where septic tanks are likely to be located have soil characterized by very slow infiltration rates and high runoff potential when thoroughly wet. Such traits increase the chance that septic systems will not operate as designed.

- **Atmospheric deposition**
  Atmospheric deposition may be assimilated in the soil and in vegetative uptake, with some portion reaching surface waters through the natural hydrologic cycle.

Linkage Analysis & Watershed Models

The key to the linkage analysis is a watershed model capable of simulating the physical and biogeochemical processes that affect river hydrology and water quality. The linkage analysis quantifies the changes in nutrient concentrations that occur between the sources and the river segments through subsequent attenuation and assimilation of those loads by transport through soil, vegetation, and other media, and through in stream processes such as mixing, biogeochemical reactions, and dilution. The watershed models used in this project were the Soil and Water Assessment Tool (SWAT) and the Watershed Analysis Risk Management Framework (WARMF).

Nutrient & Hydrological Model Results

Results from computer modeling simulations and data analysis are as follows:

- Simulated nutrient loads from identified sources were comparable between SWAT and WARMF.

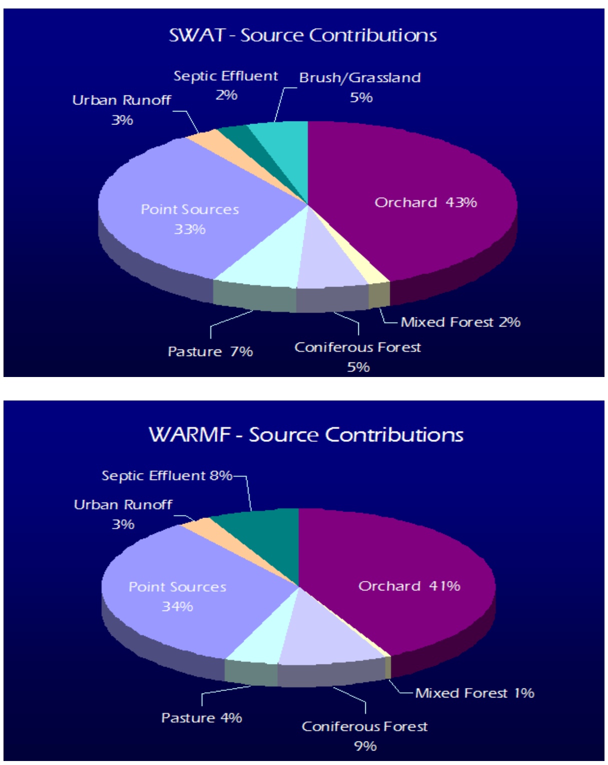

Figure 4: Source contribution comparison

- Simulated source contributions from both models were analyzed to identify subregions and subwatersheds contributing the largest nutrient loads. Best management practices (BMPs) were then formulated to account for these hotspots.

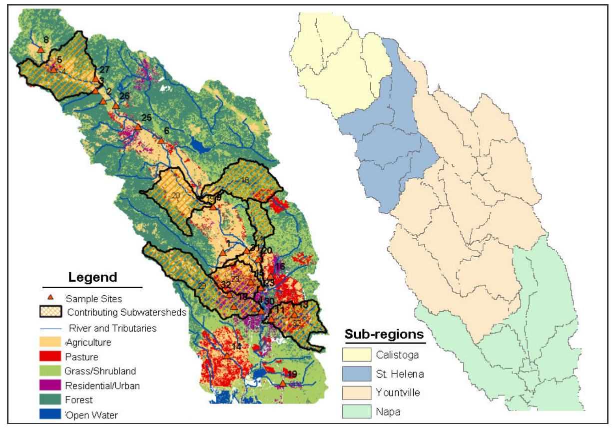

Figure 5: Subwatershed hotspots and sub-regional identification

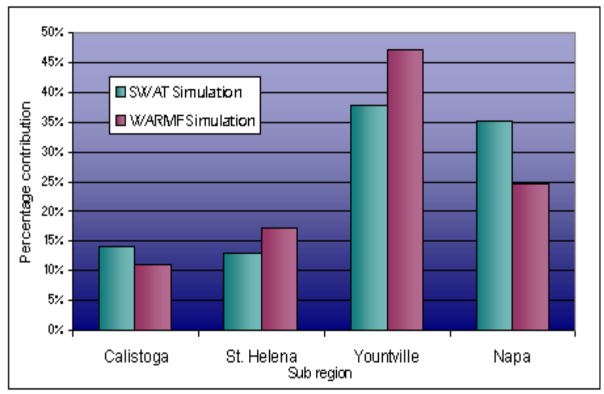

Figure 6: Contribution of nutrients from sub-regions

- The WARMF model indicates that the background nutrient concentrations in groundwater combined with residual nutrients in the river will prevent the water quality from achieving dry season target levels. The SWAT model was found to agree with the findings.

- The WARMF air quality sensitivity analysis indicates negligible contributions from wet and dry air deposition to nutrient loading into the river. The SWAT model also displayed no sensitivity to dry air deposition but did demonstrate a minor contribution of wet air deposition to nutrient loading.

Nutrient Load Reduction Management Options

Based on the results of water sample analyses, watershed model calculations, simulations of BMP scenarios, and cost-effectiveness evaluations, the following options for nutrient reduction management have been selected.

- Nutrient reductions from WWTPs can be achieved by increasing the dilution requirement currently in place between wastewater effluent and stream flow, or by adding microbial processes onto existing treatment facilities. The most cost effective biological treatment process evaluated during this project is the five-stage Bardenpho process, which lowers the TDN concentration in effluent to less than 5 mg/L.

- Faulty septic tanks located adjacent to the river and tributaries can be retrofitted with Nitrex filters, which lower TDN loading by 87%. For a typical residential septic system installation, the NitREX filter costs approximately $2,900. (Annual inspection of the tanks should also occur to ensure maintenance. In addition, educational materials on septic tank upkeep can be provided.)

- Agricultural load reductions can occur through modifications in fertilizer application use to obtain a sustainable rate of fertilization. Based on Agrotech Supply's vineyard drip system irrigation research, fertilizer application rates may be reduced to 42 kg/ha year from an initial rate of 84 kg/ha year. The reduction in the rate of fertilization would also reduce costs, under the assumption that the modified rate does not affect crop productivity. For the entire agricultural acreage in the Napa valley, the modification of fertilizer application could possibly reduce costs by approximately $700,000 per year.

- Structural stormwater BMPs may be implemented to reduce nutrient loads from urban and agricultural runoff. These BMPs involve the use of constucted wetlands, infiltration trenches and basins, sand filters, filter strips, or grass swales to filter sediments, pathogens, and nutrients from runoff. The approximate cost of percent reduction in nitrate varies based on the specific type of BMP implemented.

Recommended Nutrient Management Plan

The nutrient management plan was designed based on the most cost-effective scenarios, which when implemented together, achieve nutrient targets throughout the watershed. In order to determine the effectiveness of the scenarios, both SWAT and WARMF were used to simulate TDN levels that could be achieved with the implementation of specific BMPs.

According to the simulation models, in order to attain water quality target levels, nutrient loading of TDN in the Napa River Watershed would need to be reduced by approximately 50%. Specifically, the WARMF model recommends a 45.1% reduction in TDN loading throughout the entire watershed, and the SWAT model advises a 54.5% reduction.

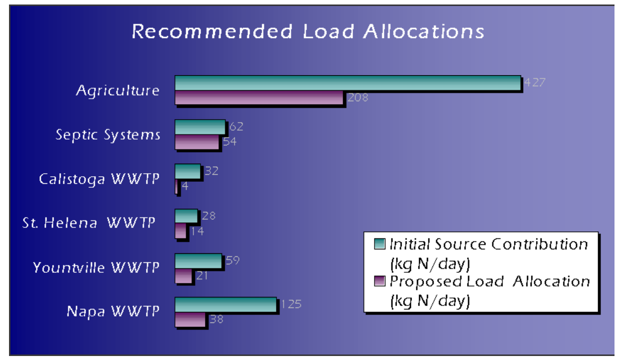

Figure 7: Proposed Land Use Reductions

It is our recommendation that a substantial reduction in nutrient loading occur at wastewater treatment plants. Based on simulation results, the Napa and Calistoga wastewater treatment plants have been shown to contribute significantly to TDN levels in the main river channel. Possible strategies for nutrient load reduction from the wastewater treatment plants may be to add microbial processes or to increase the dilution ratio of effluent. The latter strategy may require larger retention ponds in order to hold effluent in cases where a low stream flow precludes discharge.

In addition, it is recommended that nutrient reducing BMPs be primarily implemented in the Yountville region, which contributes the largest nutrient loads.

Finally, it is recommended that an additional investigation of irrigation management be conducted through another field study to understand the dynamics between soil nitrate concentrations and nutrient content in groundwater. Based upon a ten-year simulation in both models, soil nitrate concentrations alone cause the TDN concentrations in the main river channel to exceed the dry season target level of 0.2 mg/L. Since soil nitrate concentrations contribute to nutrient loading into the Napa River Watershed through groundwater infiltration, the target level of 0.2 mg/L in the dry season appears to be unattainable at this point.

This nutrient management plan is designed to contribute to the development of the Napa River Watershed nutrient TMDL reduction plan, which will be completed by the San Francisco Bay RWQCB by December 31, 2005.