CONCEPTUAL APPROACH FOR DEVELOPING NUTRIENT TMDLS FOR SAN FRANCISCO BAY AREA WATERBODIES

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INTRODUCTION

This report describes the California Regional Water Quality Control Board, San Francisco Bay Region's (Regional Board's) approach to resolving nutrient-related water quality problems in Bay Area waters. The report begins with a general introduction to the problem and continues with a more technical discussion of nutrient-related water quality problems. The report then describes our Regional Board's proposed technical approach to addressing nutrient-related water quality impairment through the Total Maximum Daily Load (TMDL) process, and concludes with discussions of possible implementation approaches, stakeholder involvement, and TMDL schedules.

PROBLEM DESCRIPTION

Nutrients—specifically the primary plant growth nutrients nitrogen and phosphorus—are essential for life and are ubiquitous in the environment. Because of their key role in ecosystem function, excessive levels of nutrients affect aquatic systems in a wide range of ways. Many types of human activities—particularly those associated with human or animal waste disposal or fertilizer application—can result in excessive loading of nutrients to waterbodies, and for this reason nutrient-related impairment is a widespread problem. Approximately 40% of rivers and streams nationwide are listed as impaired by nutrients in a recent USEPA National Water Quality Inventory (USEPA, 1998).

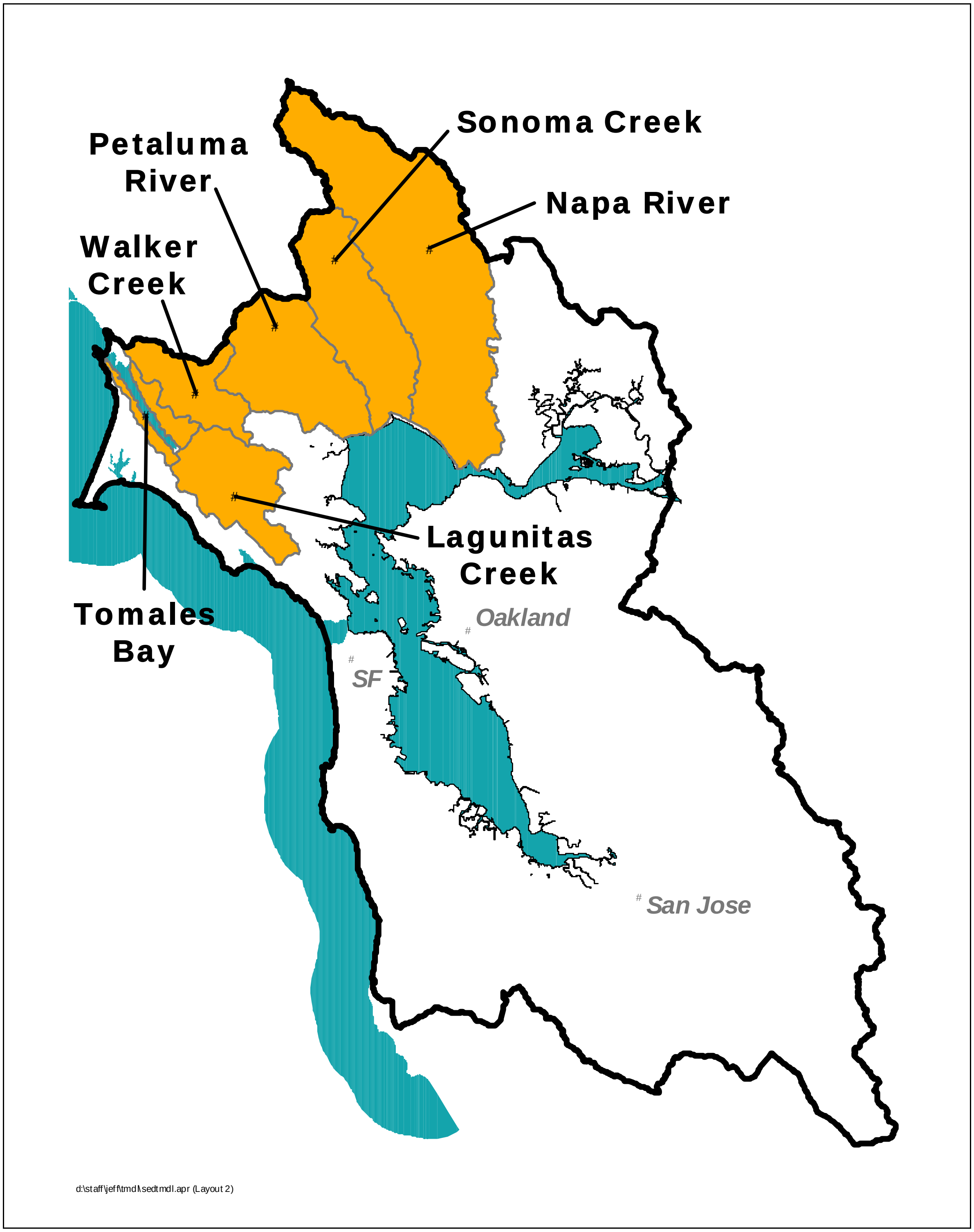
Six Bay Area waterbodies and their tributaries are on the 303(d) list as impaired by excessive nutrients: Napa River, Sonoma Creek, Petaluma River, Walker Creek, Lagunitas Creek, and Tomales Bay (Figure 1). The total watershed area of the listed waterbodies is 718 square miles, or about fifteen percent of the total land area within the jurisdiction of the Regional Board. The listed streams provide habitat for salmon, steelhead, and several other at-risk species. Tomales Bay also provides habitat for at-risk species, in addition to supporting an important commercial fishery.

The listed waterbodies support a range of aquatic habitat-related beneficial uses, including warm freshwater, cold freshwater, marine, spawning, and migration habitats. Preservation of rare or endangered species is a designated beneficial use for all of the listed waterbodies, and all also support contact and non-contact recreation. Nutrients pose a demonstrated threat to all of these aquatic habitat and recreational uses in at least some portions of each of the listed waterbodies.

WATER QUALITY PROBLEMS ASSOCIATED WITH NUTRIENT ENRICHMENT

Adverse impacts of excessive nutrient loading can be placed into two general categories: toxic effects and eutrophication. Toxic effects can apply to aquatic life inhabiting the waterbody or to humans consuming the water. Eutrophication is the excessive and undesirable growth of algae and aquatic plants caused by excessive levels of nutrients. Eutrophication effects typically occur at somewhat lower nutrient concentrations than

Figure 1. Bay Area watersheds listed as impaired by nutrients.



toxic effects. Either of these modes of water quality impairment can affect the entire aquatic food web, from algae and other microscopic organisms, through benthic macroinvertebrates (principally aquatic insect larvae), through fish, to the mammals and birds at the top of the web.

Toxic effects

Nutrient toxicity can result from either of two forms of nitrogen: un-ionized ammonia and nitrate. Un-ionized ammonia (NH_3) is acutely toxic to a wide range of aquatic life at very low concentrations. Un-ionized ammonia is typically not measured directly, but is calculated as a function of measured total ammonia (NH_3 plus NH_4^+), pH, and temperature. High pH and high temperatures favor the un-ionized form, with this form constituting less than 10% of total ammonia under temperature and pH conditions generally encountered in central and northern California. The toxicology of un-ionized ammonia is rather complicated, but in general toxicity increases at low temperatures and low pH (USEPA, 1999a). Thus, while the *concentration* of un-ionized ammonia increases with high temperatures and high pH, the *toxicity at a given concentration* decreases. *The net result of these two opposing effects is that un-ionized ammonia toxicity problems tend to be more severe in the summer months.* Salmonid fish are particularly sensitive to un-ionized ammonia. Total ammonia concentrations as low as 2 mg-N/L[*] may result in un-ionized ammonia toxicity to salmonids under summer conditions (USEPA, 1999a). Based on these considerations and on available monitoring data, un-ionized ammonia has been identified as a potential problem in listed Bay Area streams.

Concerns over nitrate toxicity are usually based upon chronic human health problems associated with drinking water. The widely accepted threshold for chronic human toxicity in drinking water is 10 mg-N/L, and this is the Basin Plan objective for nitrate. Surface waters in listed Bay Area waterbodies are rarely if ever directly used for drinking, but they may contribute to adjacent ground water that is used for domestic water supply. A growing body of literature indicates that nitrate may also be chronically toxic to aquatic life—especially fish and amphibian eggs—at levels as low as 1.1 mg-N/L (Kincheloe et al., 1979; Crunkilton, 2000). Nitrate concentrations in listed Bay Area water bodies have been observed to exceed this value. Toxicity of nitrate to different forms of aquatic life is not well understood, and more research is needed to determine if this is a problem in the listed waterbodies.

Eutrophication

Nutrient supply is a primary limiting factor for plant growth in aquatic systems. Under natural conditions, competition for nutrients keeps concentrations low, and most organisms are therefore adapted to low nutrient conditions. High nutrient levels disrupt aquatic systems by promoting explosive growth of a limited variety of opportunistic organisms—algae or weedy plant species—that are capable of rapid nutrient uptake and

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[*] Concentrations given in this report are expressed as elemental equivalents. That is, mg-N/L refers to milligrams per liter *as nitrogen*, and mg-P/L refers to milligrams per liter *as phosphorus*.

growth. These organisms can overrun aquatic habitat, deplete oxygen, and in some cases release toxic substances.

The Regional Board's Water Quality Control Plan (Basin Plan) contains a narrative water quality objective for biostimulatory substances, specifying that they shall not "cause nuisance" or "adversely affect beneficial uses." This objective applies to nutrients, since eutrophication is synonymous with nutrient-induced biostimulation. Nutrient-induced biostimulation, or eutrophication, impairs aquatic habitat uses through broad impacts on the entire biological community. Recreational uses are impaired through aesthetic problems associated with algae or aquatic plant growth.

Different manifestations of eutrophication occur in different types of waterbodies. In lakes, estuaries, and slow-flowing rivers, suspended algae (phytoplankton) are often the primary problem. Small, flowing streams tend to be dominated by attached algae (periphyton) and associated floating algal mats, or by rooted or floating plants (macrophytes). Phytoplankton is the primary indicator in the brackish, estuarine portions of these streams. In marine systems such as Tomales Bay, either phytoplankton or attached marine macroalgae may be the primary concern.

Preliminary data indicate that periphyton growth in freshwater streams is the most prevalent type of eutrophication problem in Bay Area waterbodies (Figures 2 and 3). For this reason, this report focuses mainly on periphyton. However, many of the principles discussed apply to other types of nuisance growth.

Many interacting factors determine periphyton growth rates. Some of the most important factors (illustrated in Figure 4) are:

- External nutrient loading—nutrients entering the stream via surface runoff, groundwater seepage, or precipitation—is the primary source of nutrients for algal growth. The form of nutrients entering the water also affects algal growth rates. Dissolved inorganic nutrients are generally more available to algae, and tend to have a greater stimulatory effect on algal growth than organic and particulate forms of nutrients.
- Internal loading can also be a significant nutrient source. Internal loading is the release of nutrients stored in the sediment or in decaying biomass back into the water column, where it is again available for algal uptake.
- Light is essential for photosynthesis, and therefore the shade provided by riparian vegetation can be a major limiting factor on algae growth in streams.
- Streamflow can influence algal growth in two ways. Very low flows have been shown to inhibit algal growth by limiting nutrient transport to and into growing algal masses (Stevenson, 1997). Extremely high flows inhibit biomass accumulation by detaching algae and transporting it downstream.
- Grazing of algae by benthic macroinvertebrates is important in controlling the accumulation of algal biomass, and under some circumstances can prevent excessive algal growth even when nutrient and light conditions are optimal for growth (Biggs, 2000).

All of these factors vary a great deal from location to location, complicating efforts to predict periphyton growth, and underscoring the need to collect site-specific data for algal modeling. External nutrient loading and light availability are the factors that are most easily controlled, and are therefore the factors that will receive the most attention in the TMDL technical analysis.

Periphyton growth in Bay Area streams occurs primarily from late spring though early autumn. This is the period when temperatures and light levels are optimal for algal growth, and when scouring high flow conditions are absent. However, it is also the period when external nutrient loads are lowest. Loading through surface runoff is low or completely absent in the summer months, so external loading occurs almost exclusively through groundwater seepage. Limited loading combined with rapid uptake by the growing mass of algae tends to result in declining nutrient concentrations throughout the summer months. Eventually nutrient concentrations may become so low that they limit further algal growth. The exact nutrient levels at which algal growth limitation begins to occur vary, but are generally less than 0.5 mg/L for total nitrogen and 0.1 mg/L for total phosphorus (Bowie et al., 1985). If nutrient concentrations fall to limiting levels early in the season, only a modest standing crop of algae will be produced; if limiting concentrations do not occur until later, or if nutrient levels remain high all summer, large, problematic quantities of algal biomass may develop (Biggs, 2000; Dodds and Welch, 2000).

Whether nitrogen or phosphorus limits algal growth is a function of the ratio of these elements in the water. Algae utilize nitrogen and phosphorus at a ratio of about 7:1 by mass. A ratio of these elements significantly narrower than 7:1 means that there is a greater supply of phosphorus than nitrogen, relative to algal needs, and nitrogen is limiting growth. A wider ratio than 7:1 implies the opposite: phosphorus limits growth. A ratio close to 7:1 suggests that either or both elements may be limiting. Nitrogen appears to be the limiting nutrient in most Bay Area freshwater systems. This issue can have major implications for load reduction strategies, since different nutrient sources can be relatively higher in one of these elements than the other.

Oxygen depletion is an important effect of excessive algal growth due to its direct negative impact on aquatic life. Most native aquatic organisms found in streams are adapted to high levels of dissolved oxygen, and when oxygen levels fall, these organisms must either leave the system or die. Factors that consume oxygen in aquatic systems include decomposition, biological oxidation of ammonia to nitrate (nitrification), and respiration. In pristine streams these processes are fairly slow relative to reoxygenation from the atmosphere, and dissolved oxygen levels remain near equilibrium with the atmosphere, that is, near 100% saturation. Excessive nutrient loading can drastically accelerate algal-related oxygen-consuming processes—respiration by living algal cells, and decomposition of dead algal material—causing severe oxygen depletion.

Dissolved oxygen monitoring efforts must account for the natural fluctuations that result from algal production of oxygen as a by-product of photosynthesis. Photosynthesis occurs only during daylight hours, while oxygen-consuming processes occur 24 hours a day. As a result, daytime oxygen levels are often high—sometimes supersaturated—in nutrient-impaired systems. Concentrations typically peak late in the afternoon when photosynthetic oxygen production dominates, and are lowest in the pre-dawn hours, when respiration and decomposition are dominant (Figure 5). In seriously impaired streams, oxygen levels can range from 0% to over 200% saturation over a 24-hour period. For this reason, daytime dissolved oxygen measurements are of limited value in assessing nutrient problems. Pre-dawn measurements are better, and continuous or semi-continuous monitoring is ideal.

In some waterbodies, even continuous dissolved oxygen measurements may not be sufficient to evaluate impairment. In shallow, rapidly flowing streams, reaeration can be so rapid that dissolved oxygen in the water column remains high even when profuse periphyton growth smothers bottom habitat, impairing the important benthic component of the stream community. In these cases it may be possible to detect algal impairment of habitat through biological indicators, such as benthic macroinvertebrate community structure.

Summary of potential nutrient-related water quality problems in listed Bay Area waterbodies

- Attached algae, or periphyton, is the most common indicator of eutrophication in Bay Area streams. Excessive periphyton growth impairs aquatic habitat by depleting dissolved oxygen and by smothering bottom habitat.
- Total ammonia concentrations as low as 2 mg-N/L may result in acutely toxic concentrations of un-ionized ammonia. Salmonids are particularly sensitive to un-ionized ammonia toxicity.
- Nitrate can be toxic to fish and amphibian eggs and juveniles, but the level at which toxicity occurs is not well documented. Some studies suggest toxicity at concentrations as low as 1.1 mg-N/L. Further research is needed to clarify this issue.

Figure 2. Green algae periphyton and semi-attached floating algal mats in Sonoma Creek.

Figure 3. Diatom growth, another form of periphyton, in Sonoma Creek.

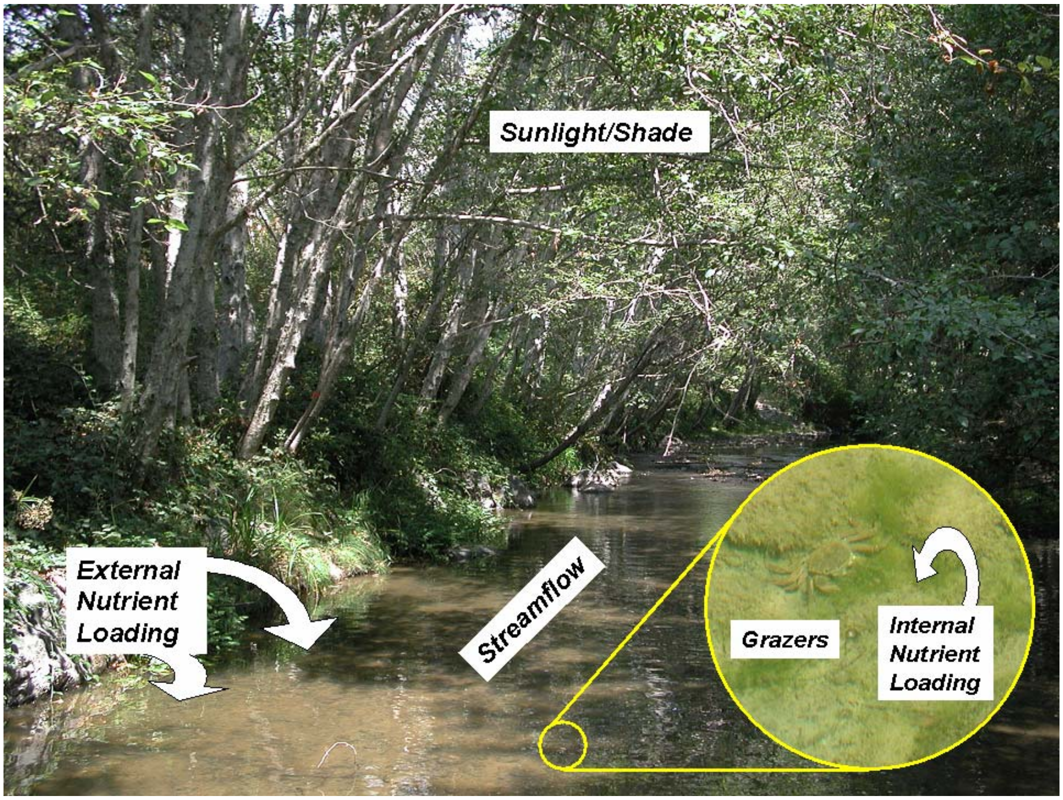

Figure 4. Factors affecting periphyton growth in streams.

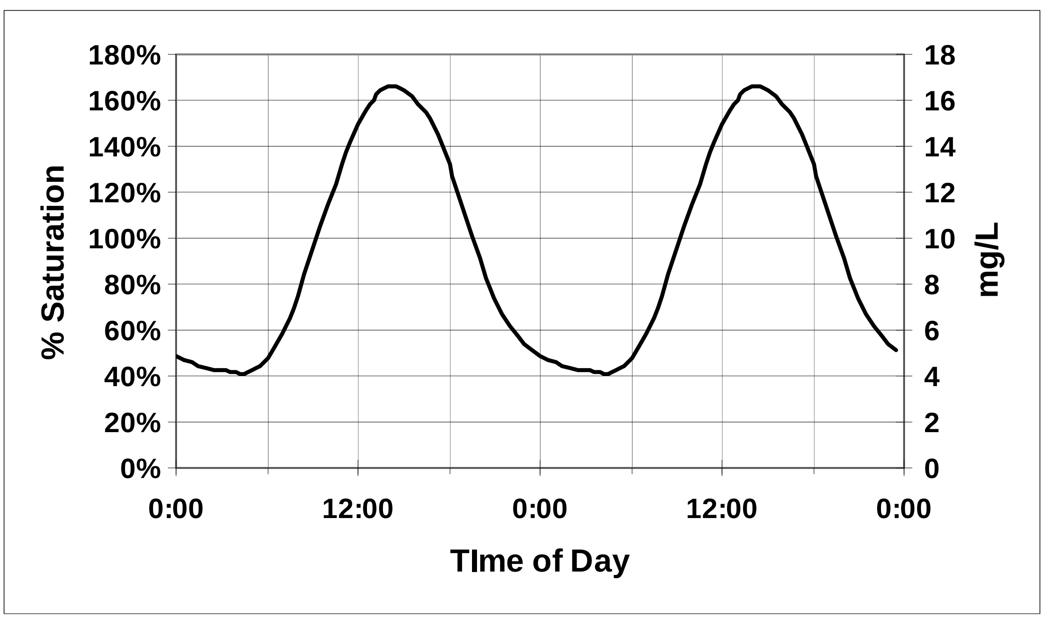

Figure 5. Typical dissolved oxygen curve in an impaired stream.

TECHNICAL APPROACHES FOR DEVOLOPING NUTRIENT TMDLs

Specific technical approaches and levels of effort will vary among the listed waterbodies, depending on such factors as degree of impairment and watershed complexity. However, all nutrient TMDLs will share the following components:

- Confirm the nature and degree of impairment.
- Establish numeric water quality targets necessary to support beneficial uses.
- Evaluate nutrient inputs and sources.
- Determine nutrient load reductions necessary to achieve numeric targets.
- Implement measures to control nutrient loads and limit the effects of nutrients in the listed waterbodies.

Technical approaches are subject to modification as new information and technical tools become available. We are working closely with the statewide Nutrient TMDL Workgroup and others to ensure that our nutrient TMDL efforts reflect the best available science.

Impairment Assessment and Numeric Targets

We will examine three general indicators of nutrient impairment in order to assess impairment and establish numeric water quality targets:

- Water column nutrient concentrations
- Algal densities
- Water column dissolved oxygen concentrations

The first step in impairment assessment is to identify locations within the listed waterbodies where nutrient problems occur or are likely to occur. We will accomplish this through reviewing existing data, conducting screening level monitoring studies, interviewing stakeholders, and conducting visual reconnaissance. More detailed monitoring will then be conducted, focusing on identified problem reaches, but also including less-impacted reaches in order to provide a basis of comparison and possibly establish reference conditions. Monitored parameters will include nutrient concentrations, riparian canopy density, stream flow, periphyton growth, and dissolved oxygen. We will assess periphyton growth both quantitatively, measuring the amount of algal biomass (either as ash-free dry weight or chlorophyll-a) per unit of stream bottom area, and in a semi-quantitative manner using USEPA's rapid field assessment procedure (USEPA, 1999b). Dissolved oxygen will be measured on a continuous 24-hour basis, or, when this is not practical, early morning sampling will be conducted.

Impacts of excessive nutrient loading in aquatic systems vary seasonally. Eutrophication is primarily a warm season phenomenon, so algal and dissolved oxygen sampling will be done from late spring through early fall. Nutrient toxicity can occur at any time of year, so nutrient concentrations will be monitored on a year-round basis.

We will begin numeric target development concurrently with impairment assessment. Basin Plan water quality objectives are an obvious starting point for developing numeric targets for toxic constituents. The Basin Plan objective of 0.025 mg-N/L (annual median) for un-ionized ammonia is based on somewhat outdated USEPA guidance. Recent USEPA guidance recommends pH and temperature-based criteria ranging from 0.01 to 0.21 mg-N/L un-ionized ammonia (USEPA, 1999a). We will develop targets to address toxic effects of un-ionized ammonia based on the latest USEPA guidance and on other relevant scientific information.

The Basin Plan objective of 10 mg-N/L for nitrate is based on drinking water concerns, and may not be sufficiently stringent to protect aquatic life. Funding is currently being sought to conduct a study of nitrate toxicity to California steelhead (Chris Rose, Central Coast Regional Water Quality Control Board, personal communication), and any proposed nitrate target will likely reflect the results of this and other relevant studies.

Targets for eutrophication impacts will focus on responses to excessive nutrient inputs—dissolved oxygen concentration and algal growth—rather than on the causative nutrient concentrations. Numerous studies have found that setting numeric targets for nutrient concentrations can be difficult or impossible due to the temporal issues and site-specific factors discussed above (Dodds et al., 1997; Biggs, 2000). Despite these difficulties, it may be appropriate to establish summer nutrient concentration targets to supplement algal biomass and dissolved oxygen targets. These nutrient targets would be based on locally-observed algal growth responses to nutrient concentrations.

We will base targets for dissolved oxygen concentration on the Basin Plan objectives of 5.0 mg/L minimum for warm water habitat and 7.0 mg/L for cold water habitat. These values are based on well-accepted scientific considerations, and are generally protective of beneficial uses. Targets may deviate from these values—either higher or lower—based on site-specific considerations. In shallow, well-aerated streams dissolved oxygen in the water column may fail to reflect excessive oxygen consumption and oxygen depletion on the stream bottom, with resulting adverse impacts on benthic organisms. In these cases, algal biomass may provide a more useful target than dissolved oxygen.

Targets for algal biomass can be based either on nuisance considerations or on habitat impairment. Nuisance targets of 100-200 mg/m^2 algal chlorophyll-a have been proposed for other California nutrient TMDLs and for general stream management programs (Biggs, 2000; Dodds and Welch, 2000; Larry Walker Associates, 2001). This range represents an adequate starting point, but may be refined or modified based on stakeholder input, user surveys, or other considerations.

Setting algal targets based on habitat impairment is more problematic. Estimates in the scientific literature for the quantity of periphyton algae that results in habitat impairment generally range from 50 mg/m^2 to over 200 mg/m^2 chlorophyll-a (Dodds et al., 1997; Biggs, 2000). One approach to refining this range may be to examine correlations between algal biomass and other indicators of habitat impairment, such as benthic macroinvertebrate community composition. Macroinvertebrate community composition (factors such as species diversity and presence or absence of pollutions-sensitive groups) is widely acknowledged to be an important indicator of stream habitat quality and ecological function, and is currently being monitored through the Regional Board's Surface Water Ambient Monitoring Program (SWAMP), and by a number of other Bay area entities. If a relationship between algal densities and invertebrate data can be established, it may be possible to set algal targets at a level where the invertebrate data indicate habitat impairment. It is not clear if it will be possible to establish this type of causal relationship, especially with the time and resource constraints faced by the TMDL program. We will also consider other approaches to linking algal densities to habitat impairment. The USEPA Region IX Nutrient Criterion Regional Technical Assistance Group is currently considering the development of algal standards specific to streams in the California-Nevada-Arizona region, and numeric target development for TMDLs in the San Francisco Bay Region may reflect the findings of this group.

Source Assessment

We will use watershed models to estimate nutrient loading as a function of land use, topography, soils, vegetation, meteorology, and related factors. Models will be calibrated by comparing predicted nutrient concentrations to those actually observed in our monitoring studies. Available models range from simple to highly complex. In cases where the level of nutrient-related impairment is low, and especially when implementation measures for concurrent sediment and/or pathogen TMDLs will result in substantial reductions in nutrient loading, simpler, less data-intensive approaches may be appropriate. Simple modeling approaches include the Metropolitan Washington Council of Governments' Simple Method, USEPA's Screening Procedure, and the USGS Regression Method.

In situations where nutrient problems are more severe, or where a number of significant nonpoint nutrient sources exist, we may need to employ more complex models. USGS's HSPF (Hydrologic Simulation Program Fortran) model has been widely used for nutrient loading assessments, and can estimate loads and resultant in-stream concentrations over time frames ranging from hours to an entire year. Other potentially useful models include USDA's SWAT (Soil and Water Assessment Tool) and the proprietary WARMF (Watershed Analysis Risk Management Framework). Both HSPF and SWAT can be incorporated into USEPA's BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) modeling environment, which allows integration of watershed models and in-stream process models within a geographic information system (GIS) framework. All of these more complex models have relatively high data input requirements and require considerable effort to develop and calibrate. We are currently evaluating some of these models for use in the Napa River and Sonoma Creek TMDL projects.

Linkage Analysis and Load Allocation

Linking source reduction management activities to in-stream responses is a very challenging aspect of nutrient TMDL development. For unionized ammonia and nitrate, the loading models discussed above will be used to estimate loads under different management scenarios, and predicted in-stream concentrations of these parameters will be compared to the targets to evaluate whether targets are being exceeded.

As discussed above, algal response to nutrient loading is a function of many factors. An assortment of sophisticated computer models have been developed to predict growth of algae in plankton-dominated systems such as lakes, large rivers, and estuaries (Bowie et al., 1985). Unfortunately, no such models exist for periphyton growth. The scientific literature quantifying responses of periphyton to nutrients is rather limited, but is increasing. A few simple predictive models to estimate periphyton growth based on nutrient concentrations, duration of exposure to nutrients, and level of light exposure have been developed for various parts of the world (Dodds and Welch, 2000; Biggs, 2000). We expect to be able to modify one or more of these models for local application, based on nutrient and algal data collected in the listed waterbodies and throughout the region. We can then estimate the maximum total nutrient load that will result in attainment of algal targets by linking the algal growth predictive model with the nutrient loading models. Separate wet season and dry season allocations may be developed to reflect seasonal variability in nutrient loads and processes.

TMDL IMPLEMENTATION

We will begin developing implementation strategies concurrently with analytical TMDL tasks. When significant nutrient-related impairment is identified, control measures will be proposed to reduce adverse impacts. Some potential nutrient implementation measures are given in Table 1. The table shows that there is a great deal of overlap between nutrient control activities and implementation measures for sediments and for pathogens. For this reason, nutrient implementation planning will be conducted in close coordination with sediment and pathogen TMDL projects.

Nutrient impacts can be reduced by reducing nutrient loading and/or through measures that increase the shading provided by riparian vegetation. In some cases it may be impossible to reduce nutrient loading sufficiently to control algal growth, and riparian shading may be the only means to achieve algal biomass and/or dissolved oxygen targets. Riparian shading provides the additional benefit of reducing summertime water temperatures, an important limiting factor for cold water fish habitat. Reduced water temperatures also reduce un-ionized ammonia concentrations by shifting the chemical equilibrium toward the non-toxic ionized form.

Monitoring throughout the course of implementation will allow us to assess the effectiveness of nutrient control measures and to practice an adaptive implementation approach. We plan to monitor in-stream nutrient concentrations, dissolved oxygen levels, and algal growth at key points in the watersheds throughout the implementation process. Monitoring will allow us to move beyond observational science to experimental science, and will allow us to refine numeric targets and loading estimates as more data are collected.

Table 1. Potential nutrient management measures categorized by general nutrient source.

Potential Nutrient Source	Potential Management Measures
Agriculture, Ranching	• Establish stream setbacks[sp] • Enhance riparian corridor vegetation[sp] • Manage fertilizers to reduce loss via runoff or sub-surface flow
Existing Development	• Retrofit failing onsite sewage disposal systems or connect to treatment plant[p] • General stormwater management BMPs[sp]
Future Development	• Establish stream setbacks[sp] • Stormwater management BMPs[sp]
Confined Animal Facilities	• Retain stormwater on site[p] • Store manure on impermeable surfaces to reduce nutrient leaching[p] • Manage land application of waste to reduce nutrient leaching and runoff[p]
Domestic Wastewater Facilities	• Ensure adequate dry season storage and reuse to avoid dry season discharge[p] • Reduce the probability of accidental discharges[p]
Non-specific	• Enhance riparian canopy to provide shade[s]

[s] Indicates that this is also a sediment control measure.

[p] Indicates that this is also a pathogen control measure.

STAKEHOLDER INVOLVEMENT

Stakeholder involvement throughout the TMDL process is essential in order to: 1) educate stakeholders and regulators about land use practices, regulations, watershed problems, and potential solutions; 2) communicate the intentions of our agency; 3) share scientific information as it becomes available; and 4) provide incentives for pro-active problem solving by local entities. Involvement of government stakeholders is important in promoting regulatory coordination, ensuring efficient utilization of scarce staff and monetary resources, and developing a holistic, watershed-based approach to TMDLs.

Stakeholders we currently work with include the Napa Farm Bureau, Napa Resource Conservation District, Napa County, Sonoma Ecology Center, Sonoma Valley Vintners and Growers, North Bay Agricultural Alliance, Southern Sonoma County Resource Conservation District, Tomales Bay Watershed Council, Marin County Resource Conservation District, FishNet 4C, and the city and county governments in each watershed. Other stakeholders we work with include environmental groups, landowners, and interested members of the public.

ONGOING AND PLANNED TECHNICAL WORK

The San Francisco Estuary Institute (SFEI) is conducting a study of nutrient and pathogen loadings in the Napa River and Sonoma Creek watersheds under a contract with the Regional Board. Approximately 40 sites in the two watersheds were sampled in October 2002 and January 2003, and additional sampling will be conducted in early summer 2003. The study will help confirm impairment, establish spatial and temporal patterns of nutrient loading in these watersheds, and facilitate development and calibration of watershed loading models.

In the summer of 2003, Regional Board staff plan to sample at key points in the Napa River and Sonoma Creek watersheds in order to supplement the work being conducted by SFEI. Nutrient samples will be collected, continuous dissolved oxygen probes will be deployed, and periphyton biomass will be measured. We will attempt to sample at locations where related data, such as benthic macroinvertebrate community structure, are being collected by other entities.

Students from UC Santa Barbara's Bren School of Environmental Science and Management have begun developing a nutrient loading model for the Napa River watershed as a group Masters Degree project. The students are working under the guidance of Bren School faculty with extensive experience in watershed modeling, and in close coordination with Regional Board staff.

SFEI is currently seeking Proposition 50 funding for comprehensive, multi-pollutant monitoring and analysis in the Petaluma River watershed. A significant portion of this effort would be directed at nutrients.

SCHEDULE

TMDL development and early implementation is high priority for staff. We are actively working on Napa River and Sonoma Creek nutrient TMDL projects. We are also working with stakeholders in the other listed waterbodies to establish the foundations for future studies.

Completion dates for nutrient TMDLs are presented in Table 2. Completion dates are for proposed Basin Plan Amendments. A draft TMDL project report and implementation plan will typically be completed 6 to 12 months before the final completion date.

Table 2. Nutrient TMDL schedule.

Waterbody	TMDL Report*	Board Action**	Status
Napa River	June 2004	June 2005	Problem statement complete Preliminary monitoring study in progress
Sonoma Creek	June 2005	June 2006	Problem statement complete Preliminary monitoring study in progress
Tomales Bay	June 2006	June 2007	Preliminary stakeholder contact
Petaluma River	June 2006	June 2007	Preliminary stakeholder contact
Walker Creek	June 2006	June 2007	Preliminary stakeholder contact
Lagunitas Creek	June 2006	June 2007	Preliminary stakeholder contact

*TMDL report with implementation plan and recommended Board action
**Consideration of Basin Plan amendment to establish TMDL and implementation plan

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