CHAPTER 17
SURFACE WATER QUALITY

UPDATE CHRONOLOGY

NOVEMBER 30, 2005—VERSION 1

A NAPA COUNTY STREAM IN FLOOD

PURPOSE

This chapter describes the baseline conditions for surface water quality of Napa County. In addition to summarizing surface water quality conditions, this chapter documents the methodology, construction, data sources, algorithms, calibration, and application of a regional surface water quality model developed for the Napa County BDR.

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LIST OF ACRONYMS AND ABBREVIATIONS

AD	MIKE 11 Advection and Dispersion module
Basin Plan	Water quality control plan
BAT	Best available technology
BCT	Best conventional pollutant control technology
BDR	Baseline Data Report
BMP	Best management practice
Caltrans	California Department of Transportation
CCR	California Code of Regulations
CEQA	California Environmental Quality Act
CFR	Code of Federal Regulations
CIMIS	California Irrigation Management Information System
Corps	United States Army Corp of Engineers
County	Napa County
CTR	California Toxics Rule
CWA	Federal Clean Water Act
DFG	California Department of Fish and Game
DHS	California Department of Health Services
EPA	U.S. Environmental Protection Agency
General Construction Permit	NPDES General Permit for Construction Activities
General Industrial Permit	NPDES General Permit for Discharges of Storm Water Associated with Industrial Activities excluding Construction Activities
HD	DHI's MIKE 11 hydraulic model
MGD	Million gallons per day
MS4	Municipal separate storm sewer system
Napa RCD	Napa County Resource Conservation District
NCFCWCD	Napa County Flood Control and Water Conservation District
NOI	Notice of intent
NPDES	National Pollutant Discharge Elimination System
NRCA	National Resources Conservation Agency
NRCS	Natural Resources Conservation Service
NSD	Napa Sanitation District
PWA	Pacific Watershed Associates
RWQCB	Regional Water Quality Control Board
SeaGIS	Soil erosion module
SFEI	San Francisco Estuary Institute
SIP	State Implementation Program
ST11	Mike 11 sediment transport module
SWMP	Stormwater Management Plan
SWPPP	Storm water pollution prevention plan
SWRCB	State Water Resources Control Board
SWRF	Soscol Water Recycling Facility
TM	MIKE 11 Temperature module
TMDL	Total maximum daily load
USLE	Universal Soil Loss Equation
WDR	Waste discharge requirements
WER	Water-Effect Ratio
WICC	Watershed Information Center and Conservancy
WQ	MIKE 11 Water Quality module
WWTP	Waste water treatment plant

INTRODUCTION

This chapter describes the baseline conditions for surface water quality of Napa County in support of the Napa County Baseline Data Report (BDR). In addition to summarizing surface water quality conditions, this chapter documents the methodology, construction, data sources, algorithms, calibration, and application of a regional surface water quality model developed for the Napa County BDR.

The water quality studies supporting the BDR were designed to establish baseline conditions by which countywide projects and programs could be assessed and evaluated for their planning benefits, constraints, and environmental impacts.

It is important to note that the surface water quality analysis and model were conducted and developed in support of the BDR with the understanding that they would be applied to future planning efforts. More specifically, the water quality studies supporting the BDR were designed to establish baseline conditions by which countywide projects and programs could be assessed and evaluated for their planning benefits, constraints, and environmental impacts. Consulting water quality scientists from DHI Water & Environment led the Jones & Stokes/EDAW team in conducting the water quality task of the BDR.

The supporting technical report (*Napa BDR Surface Water Hydrology Modeling Report*) of the BDR includes complete documentation of the surface water quality model and its results.

Coniferous forests and volcanic geology in the Napa River watershed

SPECIALIZED TERMS USED

Adsorption: The process of a substance bonding to the surface of a solid body. For example, soluble forms of metals and other water quality pollutants can adsorb to the surface of fine sediment particles, thus becoming a lesser threat to aquatic organisms. Desorption is the opposite process of adsorption.

Loading: The quantity of a single pollutant from all contributing point and non-point sources.

Coastal wetlands: Lands within the coastal zone which may be covered periodically or permanently with shallow water and include saltwater marshes, freshwater marshes, open or closed brackish water marshes, swamps, mudflats, and fens.

Cohesive sediment: A mixture of clay, silt, sand, and organic matter, commonly referred to as mud. Cohesive sediments can be transported long distances in water when in suspension.

Coliform bacteria: A group of bacteria that live in the lower intestines of warm-blooded animals and are present in feces. Presence of coliform bacteria in water is a common indicator of fecal contamination.

Desorption: The process in which substances such as chemicals or metals, which are bound to a solid body such as sediment particles, become unbound and subsequently released to the surrounding environment or water body. Absorption is the opposite of desorption.

Dilution credit: Dilution credit may be granted under conditions of a waste discharge permit when the receiving water is of a substantial volume to dilute the discharge or effluent.

Dissolved oxygen: The volume of oxygen that is contained in water. The amount of oxygen that can be held by the water depends on the water temperature, salinity, and pressure.

Eutrophication: The increase of nutrients, such as nitrogen and phosphorus, to a level which alters ecosystem functioning. Eutrophic conditions promote excessive plant growth, reduce dissolved oxygen levels for aquatic life, complicate water treatment processes, and degrade the aesthetic value of the water body.

Impaired: Not meeting standards. Under Section 303(d) of the Clean Water Act, impaired waters are those that do not meet water quality standards, even after point sources of pollution have been controlled.

Intermittent stream: A stream that has flowing water during certain times of the year, when groundwater provides water for stream flow. During dry periods, intermittent streams may not have flowing water.

Mixing zone: As defined in waste discharge permits, mixing zones are an area of the receiving water body within which water quality criteria may be exceeded, as long as the criteria are met at the boundary of the mixing zone.

Non-point source pollution: Pollution that originates from many diffuse sources over large areas and is not traceable to any single discrete source. Non-point source pollution enters a water system from areas such as drainage or runoff from agricultural fields, airborne pollution from cropdusting, or runoff from urban areas (construction sites, etc.).

Non-stormwater discharge: Any discharge to the municipal storm drain system that is not composed entirely of stormwater, such as condensation from air-conditioning.

Perennial stream: A stream that has flowing water year-round during a typical year. The water table is located above the streambed for most of the year; thus, groundwater is the primary source of water for stream flow.

Perennial wetlands: Areas saturated with water year-round.

pH: A numeric measure of the hydrogen-ion concentration in a solution. The neutral, or acceptable, range for water in the environment is 6.5 to 8.5. At values less than 6.5, the water is considered acidic; above 8.5 it is considered alkaline or basic.

Point source pollution: Pollution that originates at a point source, defined by the Clean Water Act as "any discernable, confined and discrete conveyance, including but not limited to any pipe ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft from which pollutants are or may be discharged." (33 CFR 1362[14]).

Seasonal wetlands: Areas inundated with water only during periods of rainfall or other precipitation, whereas perennial wetlands are saturated with water year-round.

Stormwater discharge: Surface runoff and drainage associated with rain and other precipitation events.

Waters of the State: Any surface water or groundwater, including saline waters, within the boundaries of the state of California. While all waters of the United States that are within the borders of California are also waters of the State, the converse is not true—waters of the United States is a subset of waters of the state. This particularly applies to isolated wetlands, which are regulated under state law, but not federal.

Waters of the United States: Navigable surface waters and all tributary surface waters to navigable surface waters. Waters of the United States are also considered to be all waters that are currently used, were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters that are subject to the ebb and flow of the tide, including wetlands. Groundwater is not considered a water of the United States. The definition of a wetland and tidal waters can be found at 33 CFR 328.3(b) and 33 CFR 328.3(f), respectively.

Wetlands: Areas "inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" (33 CFR 328.3, 40 CFR 230.3).

POLICY CONSIDERATIONS

A variety of federal, state and local regulations and agencies are involved in management of water quality in Napa County. In particular, Napa County falls within the jurisdiction of two Regional Water Quality Control Boards (RWQCBs). Areas of the County draining into the San Francisco Bay (i.e., Napa Valley) are within the boundaries of the San Francisco Bay RWQCB, while the remainder of the County is within the boundaries of the Central Valley RWQCB.

FEDERAL POLICIES

CLEAN WATER ACT

The Clean Water Act (CWA) is the primary federal law that protects the quality of the nation's surface waters, including lakes, rivers, and coastal wetlands. It operates on the principle that all pollutant discharges into the nation's waters are unlawful unless specifically authorized by a permit; permit review is the CWA's primary regulatory tool. The following paragraphs provide additional detail on specific sections of the CWA and how they pertain to water quality in Napa County.

CWA PERMITS FOR FILL PLACEMENT IN WATERS AND WETLANDS

CWA Section 404 regulates the discharge of dredged and fill materials into "waters of the United States," which include oceans, bays, rivers, streams, lakes, ponds, and wetlands. A definition of waters of the United States as relevant to Napa County includes the following.

- Waters currently used, used in the past, or potentially used for interstate or foreign commerce, as well as waters for which the use, degradation, or destruction could affect interstate or foreign commerce.
- All tidally influenced waters.
- Tributaries to, and adjacent wetlands of, the above two categories.

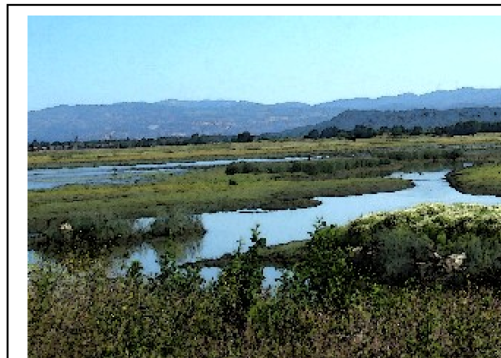
In general, most intermittent and perennial water bodies are considered waters of the United States unless they are isolated (e.g., vernal pools).

Project proponents must obtain a permit from the United States Army Corp of Engineers (Corps) for all discharges of dredged or fill material into waters of the United States, including wetlands, before proceeding with a proposed activity. Before any actions are carried out, a delineation of waters of the United States must completed, following Corps protocols (Environmental Laboratory 1987), to determine whether the project area encompasses wetlands or other waters of the United States that qualify for protection under the CWA. These waters may include any or all of the following.

- Areas within the ordinary high water mark of a stream, including non-perennial streams (streams that do not flow year-round) with a defined bed and bank and any stream channel that conveys natural runoff, even if it has been realigned or modified.
- Seasonal and perennial wetlands, including coastal wetlands.

Wetlands are defined for regulatory purposes as areas "inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" (33 Code of Federal Regulations [CFR] 328.3, 40 CFR 230.3).

Corps provides authorization through regional and nationwide general permits and individual permits, depending on project size and characteristics. Individual Section 404 permits may only be issued for the least environmentally damaging practicable project alternative. That is, authorization of a proposed discharge is prohibited if there is a more practicable alternative that would have less adverse impacts and lacks other significant adverse consequences.



Wetlands are areas inundated or saturated by surface or ground water often enough to support wetland vegetation.

CWA Water Quality Certification

Under CWA Section 401, applicants for a federal license or permit to conduct activities that may result in the discharge of a pollutant into waters of the United States must obtain certification from the state in which the discharge would originate, or, if appropriate, from the interstate water pollution control agency with jurisdiction over affected waters at the point where the discharge would originate. All projects that have a federal component and may affect the quality of the state's waters (including projects that require federal agency approval, such as issuance of a Section 404 permit) must also comply with CWA Section 401. Section 401 certification or waiver is under the jurisdiction of the relevant RWQCB; in the case of Napa County, California's Region 2, San Francisco Bay RWQCB, or Region 5, Central Valley RWQCB, depending on location in the County.

CWA Permits for Point and Nonpoint Source Discharges

CWA Section 402 regulates point and nonpoint source discharges to surface waters through the National Pollutant Discharge Elimination System (NPDES) program, administered by the U.S. Environmental Protection Agency (EPA). In California, the State Water Resources Control Board (SWRCB) is authorized by the EPA to oversee the NPDES program through the RWQCBs (see related discussion under "Porter-Cologne Water Quality Control Act" below). The NPDES program provides for both general permits (those that cover a number of similar or related activities) and individual permits.

General Construction Permit. Most construction projects that disturb 1 acre of land or more are required to obtain coverage NPDES General Permit for Construction Activities (General Construction Permit), which requires the applicant to file a public notice of intent (NOI) to discharge stormwater and to prepare and implement a storm water pollution prevention plan (SWPPP). The SWPPP includes a site map and a description of proposed construction activities, along with demonstration of compliance with relevant local ordinances and regulations, and an overview of the best management practices (BMPs) that will be implemented to prevent soil erosion and discharge of other construction-related pollutants that could contaminate nearby water resources. The permit holder is further required to conduct monitoring and reporting to ensure that BMPs are correctly implemented and effective in controlling the discharge of stormwater-related pollutants.

General Caltrans Permit. Projects constructed in California Department of Transportation (Caltrans) facilities or rights-of-way must comply with the requirements of Caltrans' statewide NPDES permit, which has requirements similar to those of the General Construction Permit.

General Industrial Permit. Stormwater discharges from industrial facilities are subject to the permitting requirements of the NPDES General Permit for Discharges of Storm Water Associated with Industrial Activities excluding Construction Activities (General Industrial Permit). The regulations defining *discharges of storm water associated with industrial activities* identify 11 categories of industrial activities that require permit coverage. Authorization for continued and future stormwater discharge under the General Industrial Permit requires each facility operator to submit an NOI. All stormwater discharges from industrial sites must meet all applicable provisions of Sections 301 and 402 of CWA. For example, discharges from an industrial site must not cause or contribute to a violation of any applicable water quality standards, which include all federal receiving water standards and all state standards under the region's Basin Plan, the guiding policy document adopted by the governing RWQCB and approved by the SWRCB. These provisions require control of pollutant discharges using the best available technology (BAT) that is economically achievable and the best conventional pollutant control technology (BCT) to prevent and reduce pollutants and to meet CWA water quality standards.

The General Industrial Permit generally requires facility operators to do the following.

- Eliminate unauthorized non-stormwater discharges.
- Develop, retain on site, and implement a SWPPP to identify sources of pollution and to prescribe BMPs to reduce or prevent pollutant discharges and authorized nonstormwater discharges.
- Perform monitoring of stormwater discharges and authorized non-stormwater discharges from industrial facilities (e.g., storm drains leaving the facility).

Areas of industrial activity where surface runoff must be controlled and treated include all storage areas and storage tanks, shipping and receiving areas, fueling areas, vehicle and equipment storage/maintenance areas, material handling and processing areas, waste treatment and disposal areas, dust- or particulate-generating areas, cleaning and rinsing areas, and all other areas of industrial activity that are potential pollutant sources. Any changes to the industrial site or activity require an update of the SWPPP and may necessitate the implementation of new control measures.

Other General Permits. The SWRCB has adopted several other general permits under the NPDES program, including permits for the discharges of aquatic pesticides for vector and aquatic weed control. The San Francisco Bay RWQCB has adopted general permits for discharges from surface water treatment facilities for potable supply and discharges from aggregate mining and sand washing facilities. The Central Valley RWQCB has adopted general permits for dewatering and other low threat discharges to surface waters, and discharge of groundwater or surface water from cleanup of petroleum pollution to surface water or groundwater. It has also adopted a conditional waiver for discharges from irrigated lands, and is in the process of developing a more comprehensive NPDES program to address agricultural runoff.

Municipal Stormwater Permits. The RWQCBs issue NPDES permits for municipal separate storm sewer systems (MS4s). Small MS4s (municipalities with populations of 100,000 or less, and non-traditional MS4s such as campuses) are covered under a general permit issued by the SWRCB. Under MS4 permits, the permittees are required to initiate a Stormwater Management Program and prepare a Stormwater Management Plan (SWMP). The SWMP must contain components addressing public education, public participation, illicit discharge and connection elimination, construction site stormwater runoff and control, post-construction stormwater management, and pollution prevention/good housekeeping. Permittees must reduce stormwater pollution to the maximum extent practicable, prepare annual reports, and in the case of medium to large MS4s, conduct chemical monitoring. Often multiple MS4s will become co-permittees; the Stormwater Management Programs in Napa County are discussed under Local Regulations, below.

Individual NPDES Permits. All point source discharges to waters of the United States not covered by a general permit are required to apply for an individual NPDES permit with the RWQCB. The RWQCB then issues waste discharge requirements (WDRs) and monitoring provisions to ensure compliance with CWA standards.

Considerations in Granting NPDES Permits. Under the NPDES permit process, the SWRCB or RWQCB has the authority to identify mixing zones and grant corresponding dilution credits in establishing and determining compliance with effluent limitations. A *mixing zone* is an area of the receiving water within which water quality criteria may be exceeded, as long as the criteria are met at the boundary of the mixing zone. A *dilution credit* may be granted when the receiving water has a substantial volume of water with which to dilute the effluent. It is expressed as a ratio of receiving water to effluent (for example, 20:1, or 20 parts receiving water to 1 part effluent), and effectively reduces the concentration of contaminants when determining whether water quality criteria can be met.

The allowance of mixing zones and dilution credits is discretionary and is determined on a case-by-case basis. Factors considered include variations in the receiving water flow or volume, aquatic toxicity, and human health criteria and objectives. Mixing zones may not be allowed at or near any drinking water intake and are prohibited from the following activities, although other limitations may also apply.

- Compromising the integrity of the entire water body.
- Causing acutely toxic conditions to aquatic life passing through the mixing zone or restricting the passage of aquatic life.
- Producing objectionable color, odor, taste, or turbidity.
- Dominating the receiving water body.

The RWQCB or SWRCB will deny or limit a mixing zone and dilution credit as necessary to protect the beneficial use of state waters.

TOTAL MAXIMUM DAILY LOADS

Under CWA Section 303(d) and California's Porter-Cologne Water Quality Control Act of 1969 (discussed below), the State of California is required to establish beneficial uses of state waters and to adopt water quality standards to protect those beneficial uses. Section 303(d) establishes the Total Maximum Daily Load (TMDL) process to assist in guiding the application of state water quality standards, requiring the states to identify waters whose water quality is "impaired" (affected by the presence of pollutants or contaminants) and to establish a *TMDL* or the maximum quantity of a particular contaminant that a waterbody can assimilate without experiencing adverse effects on the beneficial use identified. TMDLs are generally stakeholder driven processes that involve investigation of sources and their loading (pollution input), make load allocations, and identify an implementation plan and schedule. Where stakeholder processes are not effective, TMDLs can be established by the RWQCBs or the EPA. TMDLs specific to Napa County are discussed in more detail below.

STATE POLICIES

PORTER-COLOGNE WATER QUALITY CONTROL ACT

OVERVIEW

The Porter-Cologne Water Quality Control Act, passed in 1969, articulates the federal CWA (see "Clean Water Act" above) for California. It established the SWRCB and divided the state into nine regions, each overseen by an RWQCB. The SWRCB is the primary state agency responsible for protecting the quality of the state's surface and groundwater supplies, but much of its daily implementation authority is delegated to the nine RWQCBs, which are responsible for implementing CWA Sections 401, 402, and 303(d). In general, the SWRCB manages statewide regulation of water quality, while the RWQCBs focus exclusively on water quality within their regions. As previously mentioned, areas of the County draining into the San Francisco Bay are within the boundaries of the San Francisco Bay RWQCB (Region 2), while the remainder of the County is within the boundaries of the Central Valley RWQCB (Region 5).

BASIN PLANS AND WATER QUALITY OBJECTIVES

The Porter-Cologne Act provides for the development and periodic review of water quality control plans (basin plans) that designate beneficial uses of California's major rivers and groundwater basins and establish narrative and numerical water quality objectives for those waters. Beneficial uses represent the services and qualities of a water body (i.e., the reasons why the water body is considered valuable), while water quality objectives represent the standards necessary to protect and support those beneficial uses. Basin plans are primarily implemented by using the NPDES permitting system and the issuance of WDRs to regulate waste discharges so that water quality objectives are met (see discussion of the NPDES system in the "Clean Water Act" section above). Basin plans are updated every 3 years, and provide the technical basis for determining waste discharge requirements and taking regulatory enforcement actions if deemed necessary.

The Porter-Cologne Act provides for the development and periodic review of water quality control plans (basin plans) that designate beneficial uses of California's major rivers and groundwater basins and establish narrative and numerical water quality objectives for those waters.

Basin plans have been adopted for the Sacramento and San Joaquin River Basin (Region 5 Basin Plan, Central Valley Regional Water Quality Control Board 1995) and for the San Francisco Bay Region (Region 2 Basin Plan, San Francisco Bay Regional Water Quality Control Board 1995).

Water Quality Objectives by Region. Both Region 2 and 5 RWQCBs have set water quality objectives for all surface waters in their respective regions for the following substances and parameters: ammonia, bacteria, biostimulatory substances, chemical constituents, color, dissolved oxygen, floating material, oil and grease, pH, radioactivity, salinity, sediment, settleable material, suspended material, tastes and odors, temperature, toxicity, and turbidity. In addition, Region 2 has adopted standards for bioaccumulation, population and community ecology, sulfides, and constituents of concern for municipal and agricultural water supplies, while Region 5 has adopted standards for pesticides. Specific objectives for concentrations of chemical constituents are also applied to bodies of water based on their designated beneficial uses (Central Valley Regional Water Quality Control Board 1995, San Francisco Bay Regional Water Quality Control Board 1995).

Water quality objectives applicable to all groundwaters have been set for bacteria, chemical constituents, radioactivity, tastes and odors, and in Region 5, for toxicity (Central Valley Regional Water Quality Control Board 1995, San Francisco Regional Water Quality Control Board 1995).

The SWRCB is also considering adopting objectives for sediment quality.

Site-Specific Water Quality Objectives. Due to site-specific variations in water chemistry, the toxicity of a contaminant to aquatic life may deviate from adopted water quality objectives in a particular water body. As a result, various water bodies may require more or less protection to achieve optimal water quality. For this reason, the SWRCB and EPA allow *site-specific water quality objectives*. At this time in California, the only way to obtain a site-specific water quality objective is through an amendment to the relevant basin plan.

Site-specific water quality objectives adjust the adopted water quality objective to account for over- or under-protectiveness based on site-specific information and federal and state scientific guidance.

Site-specific water quality objectives adjust the adopted water quality objective to account for over- or under-protectiveness based on site-specific information and federal and state scientific guidance. Three EPA-published procedures and a number of other procedures allowed by EPA can be used to establish these site-specific objectives. Of these procedures, the most common is the Water-Effect Ratio (WER) Procedure (U.S. Environmental Protection Agency 1994, 2001), which adjusts objectives to account for a site's water chemistry. The *WER* is the ratio of the toxicity of a chemical in site water to the chemical's toxicity in laboratory water, based on established standards for lab water.

As mentioned above, site-specific water quality objectives may be granted through the Basin Plan amendment process, which tends to be a time consuming proposition. The SWRCB is currently considering whether to extend this authority to individual NPDES permits. In either case, a process exists whereby a site-specific water quality objective may be sought to allow for a higher discharge limit than would otherwise be possible.

WASTE DISCHARGE REQUIREMENTS

The Porter-Cologne Act provides for the issuance of WDRs. This requirement is very similar to the NPDES program under the federal CWA, and in most cases the two processes are combined by the RWQCBs. However, the Porter-Cologne Act definition of discharge is somewhat broader than the CWA; in addition, waters of the State include certain water bodies that are not waters of the United States. As a result, certain discharges are solely regulated under the Porter-Cologne Act. The SWRCB has adopted general WDRs for land application of biosolids; discharges to isolated wetlands; and land discharge of groundwater or surface water from cleanup of petroleum pollution.

POLICY FOR IMPLEMENTATION OF TOXICS STANDARDS FOR INLAND SURFACE WATERS, ENCLOSED BAYS, AND ESTUARIES OF CALIFORNIA

The State Implementation Program (SIP) (State Water Resources Control Board 2000) established new standards for a variety of toxic pollutants. This state policy for water quality control applies to discharges of toxic pollutants into California's inland surface waters, enclosed bays, and estuaries, subject to regulation under the Porter-Cologne Water Quality Control Act and the federal CWA. Such regulation may occur through the issuance of NPDES permits, the issuance or waiver of WDRs, or other regulatory approaches.

The goal of the SIP is to establish a standardized approach for permitting discharges of toxic pollutants to non-ocean surface waters in a manner that promotes statewide consistency. The SIP is a tool to be used in conjunction with watershed management approaches and, where appropriate, the development of TMDLs to ensure that water quality standards are met and the beneficial uses are protected.

The SIP establishes implementation provisions for priority pollutant criteria promulgated by the EPA through the National Toxics Rule and the California Toxics Rule (CTR), and for priority pollutant objectives established by the RWQCBs in their respective basin plans. The CTR promulgates the following criteria.

- Ambient aquatic life criteria for 23 priority toxics.
- Ambient human health criteria for 57 priority toxics.
- A compliance schedule provision that authorizes the state to issue schedules of compliance for new or revised NPDES permit limits based on the federal criteria when certain conditions are met.

The state must use these criteria together with the state's existing water quality standards when controlling pollution in inland waters and enclosed bays and estuaries. California's RWQCBs are currently considering whether to include CTR standards in their Basin Plans as a streamlining measure.

DRINKING WATER STANDARDS

Title 22 of the California Code of Regulations (CCR) outlines drinking water standards in the State of California. Maximum contaminant levels (MCLs) for various contaminants are identified, and are made enforceable regulatory standards under the federal Safe Drinking Water Act. MCL standards must be met by all public drinking water systems to which they apply. Primary MCLs can be found in 22 CCR Sections 64431–64444. Specific regulations for lead and copper are in 22 CCR Section 64670 *et seq*. Secondary MCLs that address the taste, odor, and appearance of drinking water are found in 22 CCR Section 64449.

RECLAIMED WATER STANDARDS

Title 22 of the California Code of Regulations (CCR) outlines reclaimed water standards in the State of California, and reclaimed water is primarily regulated by the California Department of Health Services (DHS), in coordination with the RWQCBs.

DHS has produced *The Purple Book*, which contains California health laws related to reuse of disinfected tertiary recycled water. Disinfected tertiary recycled water is defined as filtered and subsequently disinfected wastewater that exhibits extremely low levels of coliform bacteria and turbidity. The following are allowable uses for disinfected tertiary recycled water.

- Food crops, including all edible root crops, where the recycled water comes into contact with the edible portion of the crop.
- Parks and playgrounds, schoolyards, residential landscaping, and unrestricted access golf courses.
- Industrial cooling that involves the use of a cooling tower.
- Flushing toilets and urinals, priming drain traps, industrial process that that may come into contact with workers, structural firefighting, decorative fountains, commercial laundries, consolidation of backfill around potable water pipelines, car washes.
- Any other irrigation use not prohibited.

The following limitations and requirements apply.

- Irrigation within 50 feet of any domestic water supply well is prohibited unless certain conditions are met.
- Surface impoundments of tertiary treated disinfected effluent within 100 feet of any domestic water supply well are prohibited.
- All irrigation runoff shall be confined to the recycled water use area, unless the runoff does not pose a public health threat and is authorized by the regulatory agency.
- Spray, mist, or runoff from reuse shall not contaminate dwellings, outdoor eating areas, food handling facilities, and drinking water fountains.
- No cross connections with domestic water systems are allowed. Proposed irrigation systems utilizing wastewater must be entirely separate from irrigation systems using domestic supplies, and all pipes used for water recycling must be colored purple or utilize another marking system that clearly distinguishes recycled water from potable water.
- Disinfected tertiary recycled water shall be sampled at least once daily for total coliform, and continuously for turbidity using a continuous turbidity meter.
- All use areas where recycled water is used that are accessible to the public shall be posted with signs that indicate that recycled water is in use.
- The supplier of reclaimed water must file an engineering report that indicates the means for compliance with regulations and a contingency plan to prevent untreated or inadequately treated wastewater from delivery to a use area.
- Training of personnel, system maintenance, and operating records and reports are required. The treatment system must be equipped with alarms in the event of a treatment system failure. The law also outlines standards for system reliability.
- Backflow prevention devices are required such that effluent does not reach potable supplies or otherwise expose humans.

Disinfected tertiary treated effluent may be used for groundwater recharge of domestic water supply aquifers by surface spreading provided the effluent is of a quality that fully protects human health at all times. For groundwater recharge projects, DHS make recommendations to the RWQCB based on the relevant aspects of the project, including effluent quality and quantity, spreading area operations, soil characteristics, hydrogeology, residence time, and distance to withdrawal.

As described below, Napa Sanitation District provides recycled water for various uses throughout the County during the dry season.

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CALIFORNIA FISH AND GAME CODE SECTIONS 1601–1607 (LAKE- OR STREAMBED ALTERATION AGREEMENT PROGRAM)

Under Sections 1601–1607 of the California Fish and Game Code, the California Department of Fish and Game (DFG) regulates projects that affect the flow, channel, or banks of rivers, streams, and lakes. Sections 1601 and 1603 require public agencies and private individuals, respectively, to notify and enter into a streambed or lakebed alteration agreement with DFG before beginning construction of a project that will have either of the following results.

- Divert, obstruct, or change the natural flow or the bed, channel, or bank of any river, stream, or lake.
- Use materials from a streambed.

Section 1601 contains addition prohibitions against the disposal or deposition of debris, waste, or other material containing crumbled, flaked, or ground pavement where it can pass into any river, stream, or lake.

Sections 1601–1607 may apply to any work undertaken within the 100-year floodplain of any body of water or its tributaries, including intermittent stream channels. In general, however, it is construed as applying to work within the active floodplain and/or associated riparian habitat of a wash, stream, or lake that provides benefit to fish and wildlife. Sections 1601–1607 typically do not apply to drainages that lack a defined bed and banks, such as swales, or to very small bodies of water and wetlands such as vernal pools.

IMPAIRED WATER BODIES IN NAPA COUNTY

The SWRCB, in compliance with the CWA, Section 303(d) has prepared a list of impaired water bodies in the State of California (State Water Resources Control Board 2003). The Napa River and its tributaries have been listed under Section 303(d) as water quality impaired for nutrients, pathogens, and sedimentation/siltation. The Putah Creek Watershed/Lake Berryessa is listed as water quality impaired for mercury. San Pablo Bay, into which the Napa River drains, has been listed as impaired for chlordane, DDT, diazinon, dieldrin, dioxins and furans, exotic species, mercury, nickel, PCBs, and selenium.

The TMDLs for the Napa River are currently under development.

The County's Conservation, Development and Planning Department is responsible for land use matters in the County, including (as relevant to water quality) conformance of forest management practices where applicable in County Code, implementation of the County's conservation regulations countywide, and vineyard or agriculture related erosion control municipal watersheds.

NAPA RIVER NUTRIENT TMDL

The San Francisco Bay RWQCB has begun the process of developing a TMDL for nutrients in the Napa River basin. The process to date has involved use of a watershed-based scientific approach and study to assess the nature and degree of impairment and evaluate nutrient inputs and sources. Once the study is confirmed by the RWQCB, numeric water quality targets will be established as necessary to support beneficial uses, load reduction targets, and implementation measures to control nutrient loads and limit the adverse effects of nutrients in the river system.

NAPA RIVER PATHOGENS TMDL

The San Francisco Bay RWQCB has also begun development of a TMDL for pathogens in the Napa River. A project report released in June 2005 identifies pollutant sources, numeric targets, load allocations, and an implementation plan (San Francisco Bay Regional Water Quality Control Board 2005a). At this time, the RWQCB is scoping the California Environmental Quality Act (CEQA) process for the TMDL, and plans to adopt a Basin Plan amendment for the TMDL in 2006.

NAPA RIVER SEDIMENT TMDL

The Napa River TMDL for sediment is on a parallel path with the TMDL for pathogens. A project report was released in June 2005 that identified pollutant sources, numeric targets, load allocations, and an implementation plan (San Francisco Bay Regional Water Quality Control Board 2005b). As with the pathogen TMDL, the RWQCB is presently scoping the CEQA process for the TMDL.

LOCAL POLICIES

NAPA COUNTY STORMWATER MANAGEMENT PROGRAM

The County is a co-permittee on an MS4 municipal stormwater NPDES permit along with the cities of Napa, St. Helena, and Calistoga, and the town of Yountville. A SWMP in support of the County's stormwater management program was completed in 2003, which outlines the County's approach to compliance with the requirements of the NPDES permit and addresses the program areas required under the MS4 permit (described under Municipal Stormwater Permits, above). It also includes a voluntary water quality monitoring program. The program is funded through a Joint Powers Authority administered by the Napa County Flood Control and Water Conservation District. Stormwater is also managed under Napa County Ordinance 1240, Stormwater Management and Discharge Control, administered by the Napa County Department of Public Works.

See also http://www.co.napa.ca.us/GOV/Departments/DeptPage.asp?DID=17500&LID=1098 (Napa County 2004a).

NAPA COUNTY CONSERVATION, DEVELOPMENT, AND PLANNING DEPARTMENT

The County's Conservation, Development and Planning Department is responsible for land use matters in the County, including (as relevant to water quality) conformance of forest management practices where applicable in County Code, implementation of the County's conservation regulations countywide, and vineyard or agriculture related erosion control municipal watersheds. Land disturbing activities (grading and earthwork) in Municipal water supply watersheds are regulated under County Ordinance 1219, which identifies standards for watershed protection, including erosion control procedures, monitoring and inspection requirements.

The Department's watershed program is primarily expressed through the Watershed Information Center and Conservancy (WICC) Board of Napa County and through their website (www.napawatersheds.org) (Watershed Information Center and Conservancy of Napa County 2005). Information contained in this Baseline Data Report will be used to support the WICC mission and the overall management and protection of watershed resources throughout Napa County.

NAPA COUNTY DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

The County's Department of Environmental Planning is responsible for multiple water quality related issues in the County, including management and oversight of small public water systems, public wastewater systems, recreational health (including public water contact areas), hazardous materials and wastes, storage tanks, toxic site mitigation and emergency response, and groundwater protection.

More information is available at http://www.co.napa.ca.us/Gov/Departments/DeptDefault.asp?DID=40500 (Napa County 2004b).

NAPA SANITATION DISTRICT

Napa Sanitation District (NSD) provides wastewater collection, treatment and disposal services to the residents and businesses in the City of Napa and surrounding unincorporated areas of Napa County. NSD is an independent local agency governed by three elected officials from the City of Napa and County, as well as two public appointees. It services 33,000 connections within approximately 23 square miles of service area, with a network of approximately 250 miles of underground sewer pipelines and six lift stations. Wastewater is treated at the Soscol Water Recycling Facility (SWRF), which provides secondary and tertiary biological physical-chemical treatment with a dry weather treatment design capacity of 15.4 million gallons per day (MGD).

NSD's NPDES permit allows discharge to the Napa River from November 1 through April 30 (the wet season period). From May 1 through October 31 (the dry season period), discharge to the Napa River is prohibited and wastewater is either stored in stabilization ponds or treated and beneficially reused for landscape irrigation in industrial parks, golf courses, pasturelands, and vineyards. See also http://www.napasanitationdistrict.com/ (Napa Sanitation District 2005).

NAPA COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT

While the Napa County Flood Control and Water Conservation District (NCFCWCD) is primarily charged with flood protection in the County, it also provides management and monitoring of groundwater, and assistance to the community in complying with NPDES requirements, and watershed maintenance activities among other services. See also http://www.napaflooddistrict.org (Napa County Flood Control and Water Conservation District n.d.).

NAPA COUNTY CONSERVATION REGULATIONS

Napa County enacted conservation regulations in 1991 to address erosion control and protection of the County's streams and waterways. The intent of these regulations is to protect lands from excessive soil loss and maintain or improve water quality of watercourses by minimizing soil erosion from earthmoving, land disturbing and grading activities. Compliance with the regulations is site specific and required prior to initiating any earthmoving or land disturbing activities, and may take the form of an erosion control plan, standard erosion control measures or exemption. See also http://www.co.napa.ca.us/GOV/Departments/DeptPage.asp?DID=29000&LID=669 (Napa County 2004c).

METHODOLOGY

DEFINITION OF STUDY AREA

The study area for the analysis of surface water quality was the entire area of Napa County.

GENERAL APPROACH

Analysis of the surface water hydrology of Napa County followed a general three-part approach.

- Step 1—Collection of existing baseline information.
- Step 2—Synthesis of baseline information to develop a descriptive overview and conceptual model of County conditions.
- Step 3—Development of a numeric surface water quality model.

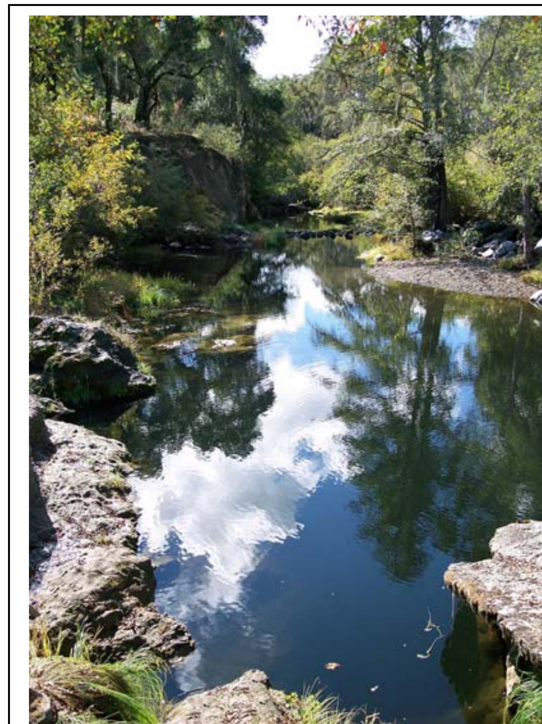
As part of Step 1, an extensive literature review and data collection effort was conducted to provide a scientifically valid background of water quality conditions in Napa County. Sources for information included but were not limited to local, state and federal agency reports; publicly available data; university research studies; professional engineering reports; and privately collected soils, climate, and water-use data throughout the County. A list of data sources used for this report can be found in the *References* section of this chapter.

The overview of baseline surface water quality conditions includes a description of the following water quality components.

- Sediment.
- Temperature.
- Nutrients (including Nitrogen and Phosphorus).
- Pathogens.

The general physical and chemical processes influencing these components are introduced, and Napa County specific issues related to these components are described. This overview also provides a basis for the modeling analysis, which has its own detailed technical methodology.

The surface water quality modeling analysis utilized the base MIKE SHE/MIKE11 model that was developed for the surface hydrology analysis outlined in Chapter 15. As described in Chapter 15, the



The overview of baseline surface water quality conditions includes a description of sediment, temperature, nutrients, and pathogens.

Erosion and incision of stream channels is an important source of sediment, in addition to more upland and hillside slopes.

In addition to natural process, anthropogenic influences can impact erosion and sediment. Fire management is one of these anthropogenic influences.

MIKE SHE/MIKE11 code has the capability of simulating the major flow components of the hydrologic cycle. In the case of surface water quality modeling, several additional modules were developed on this foundation, to simulate erosion, sediment transport, temperature, nutrients, and pathogens. The model is well suited for simulating water quality conditions in Napa County and evaluating how land use scenarios may influence the baseline conditions. An overview of the modeling approach for various water quality features is discussed immediately below. A more complete description of the models' data requirements, computational algorithms, and outputs is discussed later in this chapter and presented in detail in a supporting technical report (*Napa BDR Surface Water Hydrology Modeling Report*).

SURFACE WATER QUALITY MODELING

The primary objectives of the surface water quality modeling effort was to develop a tool that enables the assessment of surface water quality conditions for the Napa County watershed. One of the prime uses for the model will be to assess the water quality implications for different planning/land use scenarios. The models developed here will allow the comparison of the effects on surface water quality from various land management scenarios based upon a scientific process.

The baseline model was developed for localized environmental analyses, including characterizing temperature, nutrients, and pathogens.

In cases where existing water quality data was sparse or not available, engineering judgment (under consultation with professionals in the field and local people knowledgeable on these subjects) was applied to make certain decisions on the model and provide the best model input data available. The models are calibrated to the extent possible. It should be noted that model results will have less confidence in areas with sparse or limited data. The model will be applicable for impact analysis comparing baseline conditions to alternative land use scenarios.

EROSION AND SEDIMENT MODELING

The primary objective of the sediment modeling effort was to quantify the relative influence on erosion from potential land use scenarios, as well as, provide insight to the effectiveness of different erosion control approaches. The sediment delivery model was calibrated for existing conditions using the Universal Soil Loss Equation (USLE), as well as other information. In addition to the fine-sediment surface erosion/sediment delivery model, a hydraulic model can be used to route the pollutants delivered to the stream system through point sources.

OVERVIEW OF SURFACE WATER QUALITY IN NAPA COUNTY

This section presents an overview of surface water quality conditions in Napa County for the topics of erosion and sediment, temperature, nutrients, and pathogens. For each of these water quality topics, an introduction to the general subject is provided, then specific Napa County conditions are described.

EROSION AND SEDIMENT

PROCESSES AND BACKGROUND

In terms of erosion and sediment, watersheds are cascading systems in which a continuum of sedimentary processes naturally occurs. Sediments can be stored in place, eroded (i.e. initiated into movement downslope or downstream), transported, or deposited. A standard, though simplified, geomorphic approach describes watersheds in terms of three general zones: (1) a source zone of sediment production, (2) a transport zone where sediments are generally carried, and (3) a depositional zone typically occurring downstream in the basin where sediments are more likely to come to rest. While generally true, such a simple three-part classification obscures several of the erosive, transport, or depositional possibilities that can occur throughout the watershed. In closer detail, sediments can be variably eroded, stored, or transported throughout the entire system, whether in the farthest upstream tributaries, mid-watershed valleys and floodplains, or in the lower watershed estuaries and marshes.

There are several governing physical and biological conditions that influence erosion and sediment processes in a watershed. These generally include: the watershed's geologic structure and properties; local history of tectonism; general climatic conditions; watershed physiography and channel slopes; the density and orientation of the stream network; soils and vegetation; and multiple hydrologic variables including general water balance, rainfall, and runoff conditions.

On top of these physical influences, anthropogenic influences can then be considered for their relative impact on erosion and sediment processes. Typically, an intensification of human land uses (notably through agriculture, grazing, timber/forest management, fire management, mining, urbanization, or recreation) results in increased erosion.

Sometimes the links between land use and erosion create direct sequences, such as when a new land cover reduces infiltration, increases surface runoff and streamflow, increases the delivery of sediment to streams, increases in-channel bed/bank erosion and transport, ultimately resulting in increased sediment yield downstream. At other times, depending on the specific land use and setting, increases in surface erosion and delivery of sediment to the channel may occur without increases in streamflows. In such a case, increased erosion may lead to net channel aggradation, at least locally, because there is not adequate streamflow power to carry the material downstream.

COUNTY-SPECIFIC SEDIMENT ISSUES

This overview on sediment processes is Napa County is largely based on the following reports, as well as other supporting materials.

- The Universal Soil Loss Equation USLE: Special Applications for Napa County, California. (USDA 1994).
- Rainfall Runoff and Erosion in Napa Valley Vineyards: Effects of Slope, Cover and Surface Roughness. (Battany and Grismer 2000).
- Watershed Erosion and Sediment Yield Affecting Contaminant Transport. (L. J. Lane et al. 1983).
- Napa River Basin Limiting Factors Analysis, Final Technical Report. (Stillwater Sciences and W. Dietrich 2002).
- Napa River Sediment Total Maximum Daily Load. (Napolitano et al. 2005).
- Sediment and Stewardship Project 2002–05. (Blank et al. 2005).

Sediment load varies with geologic terrain, land uses, soil type, climate, and dams. Napolitano et al. (2005) provides estimates of sediment loading from different geomorphic and geologic terrain types in the Napa River Watershed, while Dietrich et al. (2002) related the relative influences of geology and land use in characterizing erosion and sediment sources. These reports suggest that more than half of the sediment delivered to the Napa River basin's stream channels comes from vineyard, grazing, or road land use areas; or from erosion of the bed and banks of the river and tributary reaches.

Channel incision as a sediment source generally occurs for two primary reasons: a reduced sediment supply, or an increased sediment transport capacity (e.g. increased peak flows). Many tributaries in the county are observed to be incising and widening as a result of bank erosion. Estimates show that these processes can represent a fairly large contribution to the sediment budget. Napolitano et al. (2005) found that channel incision and bank erosion contributed about 45,000 tons per year into the Napa River from the alluvial fan and valley areas. Incision rates vary substantially with location along the Napa River, although average rates of incision on the mainstream Napa River over the past four decades (0.5 cm/yr) is 50 times greater than natural background rates.

Other important sediment sources include mass wasting processes and landslides. Dietrich et al. (2002) found that landslides were considerable sources for sediment in the northern Napa River Watershed. Mass movements can occur following particularly large rainstorms, but more often occur towards the latter winter months in particularly wet seasons following much rain, when soils are saturated with high soil pore water pressure. Mass movements may involve shallow or deep-seated landsliding, small earthflows, or debris flows. Dietrich et al. (2002) provide maps and details on where mass wasting generally occurs in the Napa River Watershed. Napolitano et al. (2005) also provide estimates for percentages of coarse and fine sediment input to channels from colluvial stream bank, gullies, shallow landslides, and road crossing type erosive sources. In general, hillslope erosion is comprised of about 25% very fine gravel (greater than 2 mm to 11.2 mm), and 75% sand and finer sizes (less than 2 mm).

In terms of the influence of roads, Pacific Watershed Associates (PWA) (2003) evaluated the Carneros Creek, Dry Creek, and Sulfur Creek watersheds and found that about 20% of the road length is hydraulically connected to stream channels. Similar to hillslope sources, it is estimated that road surface erosion sources are 25% fine gravel and 75% sand and finer sizes (Napolitano et al. 2005).

The construction of several large dams between 1924 and 1959 on major tributaries in the eastern Napa River Watershed and northern headwater areas of the Napa River has affected sediment transport processes into the main Napa River by reducing the delivery of the coarse load sediments to the river (Stillwater Sciences and Dietrich 2002). In addition to the larger dams, many smaller dams also intercept coarse sediment supply and contribute to this overall trapping of coarse material. Thirty percent of the watershed drains into dams, such that ponds and reservoirs behind these dams capture a significant fraction of all sediment input to channels. The influence of dams was found to be prominent in Milliken Creek and much of the eastside of the Napa Watershed, where most of the sediment input was not delivered because of the many dams those areas drain into. In other tributaries (Carneros, Sulphur, and Ritchie Creeks), dams are much less prominent and therefore total sediment input should correspond approximately with total sediment yield at the confluence.

Historically, the Napa River system was more typically a gravel bed river that over time has become increasingly dominated by finer sediments (Napolitano et al. 2005). The source for these finer sediments is found from a variety of land use, infrastructure, and in-stream erosion sediment sources. The role of dams in trapping sediment (predominantly course materials) has not significantly reduced the degree to which finer sediments are being delivered to the watershed. As a result of this fine sedimentation, habitats for three species that rely more gravel substrate in the river (steelhead, Chinook salmon, and Californian freshwater shrimp) have been negatively affected through reduced gravel permeability (Stillwater Sciences and Dietrich 2002). The San Francisco Bay Regional Water Quality Control Board has released a technical report that proposes a total maximum daily load (TMDL) for the Napa River (Napolitano et al. 2005) calling for substantial reductions in the amount of fine sediment input from the watershed to improve the water quality and beneficial use of the river, including the spawning and rearing habitat for salmonid species.

Nutrients are present in waterbodies through natural sources. In addition, nutrients are introduced to waterbodies through human or animal waste disposal or agricultural application of fertilizers.

TEMPERATURE

PROCESSES AND BACKGROUND

Parameters that influence stream temperature include ambient air temperature, humidity, riparian vegetation, topography, surrounding land use, and flow conditions. Additionally, cold water seeps and groundwater inputs contribute to stream water temperatures. Among these parameters, direct solar radiation on the water surface is perhaps the most influential factor over water temperature. Consequently, shade provided by riparian vegetation often controls water temperature. Water

Pathogenic bacteria contained within fecal waste are the common source of waterborne diseases. High concentrations of indicator bacteria, resulting from poor waste management and disposal, can degrade water quality for human consumption, recreation, and wildlife use.

temperature influences a number of chemical processes within water bodies. For example, the dissolved oxygen capacity is inversely related to water temperature; as water temperature rises, the concentration of dissolved oxygen reduces. This affects the growth and decay rate of aquatic species that rely on high dissolved oxygen concentrations for survival. Streams in Mediterranean climates, such as in Napa County, experience naturally low summer flows that translate to higher water temperatures, resulting in watersheds that are susceptible to impacts of high water temperatures. Additionally, land development often results in removal of riparian shading, reduced cold-water inputs (i.e. altered groundwater supplies), and increased surface runoff. All of these factors alter channel geomorphology, which in turn creates conditions that cause water temperatures to rise and habitat to degrade.

The Napa River Watershed currently provides habitat for cold-water anadromous fish species, including steelhead trout and Chinook salmon (for further discussion on these species see Chapter 4, *Biological Resources*). Water temperature is a key constituent for assessing the quality of water within the Napa River Watershed. Steelhead and Chinook salmon are highly sensitive to temperature and require cold water throughout the majority of their life stages. As stated in Moyle (2002), optimal temperatures for growth and survival of Chinook salmon are 55°–64°F (13°–18°C) and mortality occurs at temperatures of 72°–73°F (22°–23°C). Optimal water temperature for growth and survival of steelhead trout are 59°–64°F (15°–18°C) and mortality occurs at 73°–81°F (23°–27°C) (Moyle 2002). Though not specific to the Napa River, these thresholds are generally accepted for assessing optimal habitat conditions for steelhead and Chinook salmon.

County-Specific Temperature Issues

The Napa River exhibits naturally warm waters compared to rivers in the Pacific Northwest. Consequently, salmonids residing in the Napa River Watershed may have adapted to warmer conditions than those observed elsewhere in their population range (Stillwater Sciences and Dietrich 2005). Temperature monitoring conducted by Stillwater Sciences and Dietrich (2005) concluded that mainstem and tributary temperatures are elevated to a level which can cause stress to salmonids, but not high enough to be acutely lethal. Elevated temperature conditions contribute to reduced habitat conditions for salmonids, particularly when combined with low summer base flows and aggraded channels.

Nutrients

Processes and Background

Nutrients, specifically nitrogen and phosphorus, are essential for life and play a primary role in ecosystem functions. Nitrogen and phosphorus are naturally occurring inorganic ions present within the atmosphere and in fixed forms within organic matter, such as plants and soils. In addition to naturally present concentrations, nutrients are introduced to waterbodies through human or animal waste disposal or agricultural application of fertilizers.

Nutrients are commonly the limiting factor for growth in aquatic systems. In freshwater streams of the Bay Area, nitrogen is the limiting nutrient (Krottje and Whyte 2003). Excessive levels of nutrients affect aquatic systems in a wide range of ways, including many types of human activities that can result in excessive loading of nutrients to water bodies. Excessive nutrient loading in streams can produce toxic or eutrophic conditions, both of which impair aquatic life. Eutrophication leads to increased algal growth and reduced oxygen levels in the water, thus reducing aesthetic quality and natural habitat. Nutrient toxicity is produced when concentrations of ammonia and nitrate, along with high pH and temperature, are at levels which negatively affect aquatic life.

County Specific Nutrient Issues

The Napa River is identified as impaired by nutrient loading according to Seciton 303(d) of the Clean Water Act, as discussed above in the *Policy Considerations* section. Wang et al. (2004) conducted an investigation of potential sources of nutrients within the watershed. The study identified numerous nutrient load contributors, including point sources such as wastewater treatment plants, and non-point sources such as septic system seepage, agricultural and urban runoff, and atmospheric deposition. As of the date of this document, the RWQCB has not established specific numeric nutrient targets for the Napa River Watershed. However, improved land management practices and upgraded sewage disposal systems would potentially reduce nutrient loads and therefore improve aquatic habitat in the watershed.

Pathogens

Processes and Background

Pathogens are microorganisms that cause diseases in other organisms. Bacteria are the primary indicator organisms of pathogens, particularly for the detection of waterborne diseases. Waterborne diseases threaten the health of recreational users of waters and wildlife. Pathogenic bacteria contained within fecal waste are the common source of waterborne diseases. Fecal contamination can be detected by bacterial indicators, such as total coliforms, fecal coliforms, Escherichia coli (E. coli), and fecal enterococci. High concentrations of these indicator bacteria, resulting from poor waste management and disposal, can degrade water quality for human consumption, recreation, and wildlife use.

High concentrations of fecal bacteria have been observed in the Napa River since the 1960s (Krottje and Tuden 2005). Consequently, the SFRWQCB identified the Napa River as impaired by excessive fecal bacteria according to Section 303(d) of the Clean Water Act. The following sources have been associated as contributors of significant pathogen loads in the watershed (Krottje and Tuden 2005).

- Faulty on-site sewage treatment systems (septic systems).
- Failing sanitary sewer lines.

- Municipal runoff.
- Cattle grazing.

COUNTY-SPECIFIC PATHOGEN ISSUES

Existing and ongoing bacterial water quality studies in the Napa River are summarized in Krottje and Tuden (2005). The general trend in past monitoring efforts indicates that urban runoff and failing septic systems are the primary pathogen source during wet weather months, while failing sanitary sewer lines and septic tanks may constitute the primary pathogen sources during the dry season (Krottje and Tuden 2005). Based on the conclusions of these studies and supplemental monitoring, the San Francisco Bay RWQCB is preparing a TMDL to address the pathogen impairment. As of the date of this document, the RWQCB has not established specific numeric targets for pathogens in the Napa River Watershed.

SURFACE WATER QUALITY MODELING

INTRODUCTION TO THE MODELING TASK

The purpose of the surface water quality modeling for the Napa County BDR is to develop a tool that enables the assessment of water quality conditions for the drainages within Napa County. One of the primary uses for the model will be to assess the water quality implications for different planning/land use scenarios. The models developed here will allow the comparison of the effects on water quality from various land management scenarios based upon a scientific process.

The combined groundwater and surface water model MIKE SHE –MIKE 11 gives a detailed description of the interaction between groundwater and surface water. The surface water model MIKE 11 (HD) provides the variation of water levels and water discharges in the river network taking into account the exchange of water between the groundwater and the surface water. Thus the interaction between groundwater and surface water is included when applying the MIKE11 HD model for the Napa BDR study. The results from the hydrodynamic simulations form the basis for the succeeding sediment, temperature and water quality simulations.

DHI's MIKE 11 hydraulic model (HD), Load Calculator, and SeaGIS are the three models that were used and integrated to provide a comprehensive surface water quality model for the BDR. These models are manually linked to enable complete representation of Napa County water quality conditions.

MODELING APPROACH

SEDIMENT MODEL

The sediment modeling is based on the following soil erosion and in-stream sediment transport modules.

- Soil erosion module (SeaGis).
- Mike 11 sediment transport module (ST)

Fine sediment load is calculated from Soil Erosion Assessment (USLE based) using GIS (SeaGIS) model. Results for annual sediment loads are distributed in grids over the basin. Sediment loads are then delivered to river system through source points (using MIKE 11 ST). Source points and the annual loading for each point are determined from the MIKE 11 network and subbasin delineations.

Sediment loading is then converted to time-series by assuming a distribution function in the form Q^P, where Q is the runoff from each catchment and P is an exponent larger than unity (the number 1); typically P=5/3 is used in connection with USLE (USDA 1994).

Using MIKE 11 ST, sediment is delivered in time-series sequences (volume/time) to the MIKE 11 network through the source points, while sediment transport in the river is calculated from a selected sediment transport formula. Feedbacks enable the riverbed condition to be updated for changes in sediment transport. This gives a full representation of the sediment budget (delivery, transport, deposition and erosion) in the river system.

SURFACE WATER QUALITY MODEL

The integrated in-stream surface water quality model consists of four modules.

- ArcGis Load calculator to establish watershed loads.
- MIKE 11 Advection and Dispersion module (AD).
- MIKE 11 Temperature module (TM).
- MIKE 11 Water Quality module (WQ).

Delivery of constituents to the stream network was modeled by coupling the MIKE SHE surface water model with the ArcGIS Load Calculator. The MIKE 11 HD, AD, TM and WQ modules were used to determine the fate and transport of the constituents through the stream network (Figure 17-1).

The resultant in-stream water quality model simulates the transport and fate of the following constituents, each of which shall be determined.

Storm-swollen stream carrying a high sediment load.

- Temperature.
- Nitrate.
- Total Phosphorus.
- Coliforms (e.g., *E.coli*).

The dynamic coupling between the overland and subsurface flows (MIKE SHE-MIKE11) for the loading and water quality modeling provides a tool for analyzing current water quality conditions and assessing water quality outcomes in light of potential land use changes in the watershed.

MODELING COMPONENTS

HYDRODYNAMICS FOR WATER QUALITY ANALYSIS

MIKE 11 Hydrodynamic Module (HD) is a one-dimensional model typically used in studies related to flood forecasting and simulation of flood control measures, operation and design of irrigation and surface channel systems and in studies of tides and storm surges in rivers and estuaries. Results from the hydrodynamic simulations form the basis for succeeding advection dispersion and water quality simulation.

The model is based on the vertically integrated equations of conservation of continuity and momentum (i.e. the Saint Venant equations [17-1 and 17-2]), which read as follows.

Equation 17-1:

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = q$$

Equation 17-2:

$$\frac{\partial Q}{\partial t} + \frac{\partial \left(a \frac{Q^2}{A} \right)}{\partial x} + gA\frac{\partial h}{\partial x} + \frac{n^2 g Q|Q|}{AR^{4/3}} = 0$$

where

Q = discharge, m^3s^{-1} A = flow area, m^2.

q = lateral inflow, m^2s^{-1}.

H = stage above datum, m.

n = Manning n resistance factor, $sm^{-1/3}$.

R = hydraulic or resistance radius, m.

α = momentum distribution coefficient.

These equations are solved using an implicit finite difference scheme by applying a Double Sweep algorithm. The computational grid comprises alternating *Q* (discharge) and *H* (water level) points. Cross-sectional data are given at H-points, whereas Q-points are automatically placed midway between neighboring H-points and at hydraulic structures.

A wide range of structures (e.g. culverts, weirs or under-flow gates) and their operation rules can be simulated. The data required for a hydrodynamic simulation are the following.

- Model extent
- Topographic description
- Channel and floodplain roughness coefficients
- Time step and duration of simulation
- Type and frequency of output
- Recorded measurements of water levels and discharges for initial and boundary conditions and for calibration.

SEDIMENT LOAD MODULE

The sediment load calculation is a two-step process. The first step calculates the soil loss for individual areas (defined as grid cells) using the USLE formula. The second step computes the transported soil erosion reaching the catchment outlets. This is calculated using a Soil Erosion Assessment GIS based module (SeaGIS). The USDA Universal Soil Loss Equation was developed specifically for Napa County conditions and applications (1994) and was used to develop the sediment load module.

The SeaGIS model is used to evaluate how land use changes and/or erosion control policies will affect the overall soil erosion transport in the basin. It can help quantify potential outcomes of activities such as new vineyards or road construction. Of particular application for land management purposes, the SeaGIS model can evaluate where sediment loading can most effectively be reduced.

Channel incision is represented in the MIKE 11 model through bathymetry (cross-sections). Channel incision and the associated sediment supply should not be handled as an external forcing mechanism in the model (source point) because the sediment comes from the model bathymetry itself. Incision and widening are resulting from the model, while loading from the basin is prescribed.

DATA FOR SEDIMENT MODELING

Several data sources were referenced in developing the sediment analysis and modeling. Information on dam locations was combined with information provided in Napolitano et al. (2005) regarding the trapping of fine sediments in County dams in the process of constructing the MIKE 11 model. Major dams have been included in the model because they impact the hydrograph.

Structures like weirs are handled in the sediment transport calculations by essentially calculating the sediment transport from the upstream and downstream conditions. MIKE 11 can hence pass sediment over a weir and/or through a culvert.

For in channel sediment analysis, information on sediment particle sizes is important. Particle size distribution data is given in Napolitano et al. 2005 for different land types. The particle sizes are classified into four groups.

- Coarse bed material (greater than 64 mm)
- Spawning gravel (11.2–64 mm)
- Fine bed material (2–11 mm)
- Suspended load (less than 2 mm)

The suspended load classification of less than 2 mm does not offer optimal precision, as there are many important distinctions in the properties of sediments smaller than 2 mm in size. Part of the eroded material may be cohesive (grain size below 0.06 mm), which could require simulation of cohesive sediment. However, cohesive sediment, requires very low flow velocities to deposit, and it is therefore estimated that cohesive material would have a very limited interaction with the riverbed except perhaps in the vicinity of the bay. In addition, the transport characteristics of 0.2 mm and 2 mm sand vary greatly in terms of erosion/sedimentation and transport in a river channel. It is therefore emphasized that the particle size distribution should be continued down to the cohesive limit of 0.06 mm. If particle size distribution data exists for grain sizes below 2 mm, it would benefit the modeling effort. We are at present investigating whether there is particle size distribution data for the material smaller than 2 mm.

A predicted median grain size distribution map for the river system is provided in Stillwater Sciences and Dietrich (2002, Map 7). The map was prepared based on the channel gradient. A similar map can be developed with the MIKE 11 model, based on the sediment loading and the transport in the river system. Comparison of these maps would support the calibration of the MIKE 11 ST model for existing conditions, while changes in the substrate resulting from changes in erosion and land use policies can be quantified with the calibrated model. At this point it is not known what substrate data is available for the river channel. The predicted substrate from the grain size distribution map is based on assumptions, while actual measured data is likely to show a somewhat different and also more complex picture.

It is not anticipated that enough data will be available to form a complete picture of the substrate, which is why the use of the predicted grain size map is necessary. It is also stressed that actual data will be preferred over the estimated map. Hence, if collected data shows a different map than the estimated, that data will be used instead.

Permeability data was reported in Table 7 of Napolitano et al. 2005. This data can be used to estimate the amount of fine sediments for the sediment transport model. However, the underlying substrate must be determined from measured data or indirectly from the permeability curve in Figure 3 in Napolitano et al. 2005 in order to do this.

The following five primary sediment sources are influenced by anthropogenic activities (from Napolitano et al 2005, Figure 19).

- Roads.
- Channel incision.
- Gullies and landslides.
- Sheetwash.
- Fine sediment thru dams.

CONSTITUENT LOAD CALCULATOR

The Load Calculator is a tool that determines constituent loads to the stream network from the watershed. It can be applied as a stand-alone tool for calculating average mass fluxes of constituents for individual sub-catchments (e.g. kg/catchment/year) or on a raster grid basis (e.g. kg/grid/year). Optionally, the tool can provide the constituents load input data for the MIKE 11 ECOLab model (Figure 17-1).

Land Use is a principal factor in calculating constituent loads.

Constituent loads may include both point and non-point sources. All loads are initially calculated as constant mass fluxes for each sub-catchment. However, when applying the Load Calculator with the Mike11 ECOLab model, there are several ways to translate the constant mass fluxes into mass flux time series depending on runoff time series or any other known temporal variations.

The Load Calculator uses ArcGIS to assess non-point and point sources of constituents. The model integrates the results from the MIKE SHE model with GIS databases, as well as transport and decay of constituents in a watershed. Due to the integration with MIKE SHE, the model is able to simulate flows and load distribution within the three different model layers: overland flow, streamflow, and groundwater.

Distance specific decay or retention of constituents can be included, taking into account the distance between the location of the constituents' sources and the presumed outlet in the river network in MIKE 11. Transport and decay of constituents through the watershed is modeled in the program as a first order decay process. The decay of the constituents is assumed to depend on the distance from each cell to the nearest downstream point in the river. The model is directly and automatically coupled to the MIKE 11 river water quality model and can be calibrated interactively with MIKE 11 water quality module.

The Load Calculator is a tool that determines constituent loads to the stream network from the watershed.

The Load Calculator estimates a wide range of situations such as the following.

- Quantification of non-point or diffuse sources of constituents and to identify potential affected areas.
- Estimation of constituent loads originating from urban sources such as industries, households, sewers and treatment facilities.
- Visualization and understanding of the "path" or route followed by the constituents from the point of generation until they reach the final outlet.
- Estimation of the quantity of constituents that actually reach the receiving body.

The model provides an understanding of spatial relationships between the data and therefore helps define the impacts of anthropologic and natural activities on the surface water quality of the receiving water bodies. Linking the surface water quality models to GIS improves pre- and post- processing of the data and therefore provides a strong integrated tool for environmental decision-making and watershed management.

Figure 17-2 shows the principal influences of the Load Calculator model. Both non-point and point sources can be included in the model set-up. The transport of each constituent from the source to the river network and further on towards the river outlet is calculated using grid maps.

For each constituent, a distance specific first-order decay or detention can be specified. The resulting accumulated loads of each constituent in the river system can be compared with corresponding values of the total transport estimated from measured concentrations and water discharges at different monitoring stations within the river network.

The input data required is either in the format of a shape or a grid file that is applied directly as input. The following inputs and file formats are used.

- Digital elevation model (grid).
- Distance theme (grid).
- Runoff theme (grid).
- Population theme (polygon shape).
- Land use (polygon shape).
- Industrial point sources (point shape).
- Run off estimation

The model requires four maps with related databases as input to the Load Calculator.

- 'Catchment.shp' (includes catchment runoff information).
- 'Nonpoint.shp' (includes livestock and fertilizer use information).
- 'Domestic.shp' (includes population originating loads).
- 'Industry.shp' (includes industrial loads).

The general formula is for the load calculations (calculated on a cell by cell basis) is the following.

Equation 17-3:

$Load_{xl} = EMC_{xl} * Runoff_l * CellArea$

where

EMC = The Estimated Mean Concentration in the runoff water (mg/l).

Runoff = The Runoff (mm)

X = Water quality component, TN, TP, BOD

l = Layer

For the decay calculations, the following is used.

Equation 17-4:

$$\text{DecayedLoad}_{xl} = \text{Load}_{xl} * e^{-\text{Distance}*\text{DecayRate}_{xl}*1.05^{(\text{WaterTemp}-20)}}$$

This procedure is carried out for every water quality component and layer. Each cell area will contribute to the river concentration based on distance from the river and land use. As illustrated in Figure 17-3, each watershed will have a discharge point.

The output from the load calculations will be time series for each discharge point, containing constituents discharge as a function of time.

ADVECTION AND DISPERSION MODULE

The MIKE 11 Advection and Dispersion Module (AD) simulates the advection and dispersion of conservative materials and materials using a first order decay. The module is based on the one-dimensional equation of conservation of mass of dissolved or suspended material. The equations are solved with a fully time- and space-centered finite difference scheme at all grid points ensuring that numerical dispersion is minimized. The resulting system of linear equations is solved using the Double Sweep algorithm.

The AD module requires the following.

- Dispersion coefficients.
- Initial and boundary concentrations.
- Mixing rates at model boundaries (optional), and first order decay rate (optional).
- Input results from an HD simulation.

This module is integrated with the MIKE 11 temperature (TM) and Water Quality modules (WQ), to provide a correct simulation of the spreading of the constituent as a basis for calculating the heat balance as well as the chemical and biological transformation processes.

TEMPERATURE MODULE

Modeling surface water temperature in detail requires describing the energy balance of heat balance for the water body. To compute the energy balance, the MIKE 11 TM includes the following elements.

- Heat balance/exchange (combination of physically based and empirical equations).
- Flows and system retention time.
- Physical system or geometry.
- Riparian vegetation (shading).
- Variations due to run-off and groundwater interaction.
- Inflow from tributaries and point sources (thermal loads).

A full heat balance including the most important terms for computing heat exchange between the water body and its surroundings is given bye the following equation and represented graphically in Figure 17-4.

Equation 17-5:

$$\Delta q = q_{trib} - q_c + q_s - q_{sr} + q_l - q_{lu} - q_a - q_e$$

where

Δq = change in the heat capacity of the water body;

q_{trib} = heat transfer from tributary inflow;

q_e = loss of energy due to evaporation;

q_c = convective heat transfer;

q_s = short-wave radiation;

q_{sr} = reflected short-wave radiation;

q_l = long-wave radiation above the sea surface;

q_{lu} = emittance of long-wave energy from the water body; and

q_a = loss of energy from outflow.

Chinook salmon require a specific range of temperatures for species survival.

Generally, time series data used for executing (and verifying) models should be expressed in hourly values, which capture day to night variations in discharge and temperature in sufficient detail. Hourly values should also be applied to meteorological data for simulating heat exchanges. To capture seasonal variations, data should be available for several weeks during winter, summer, spring, and autumn.

Specific data requirements for the TM include the following.

- Water temperature and discharge at the upstream boundaries and tributaries.
- Water temperatures along the river for calibration and verification.
- Relative humidity (in percent).
- Solar radiation expressed as number of sunny hours per day. (Data on solar radiation and/or information on cloud cover can be used after transformation).
- Air temperature.
- Shading (e.g. from DEM model and/or routines to compute local shading from vegetation).
- Model constants:
    - Longitudinal variation in wind shielding factor;
    - Longitude, latitude, altitude; and
    - Constants in Daltons and Beer's law (calibration parameters).

DATA FOR TEMPERATURE MODELING

Specific data requirements for temperature modeling include water temperature and meteorological data as detailed below.

- Water temperature and discharge at the upstream boundaries and tributaries.
- Water temperatures along the river for calibration and verification.
- Air temperature.
- Relative humidity (%).
- Solar radiation expressed as number of sunny hours per day. Data on solar radiation and/or information on cloud cover can be used after transformation.
- Air temperature, relative humidity, and solar radiation are discussed in detail within the meteorological data section below.

WATER TEMPERATURE DATA

Water temperature has been monitored as part of several different monitoring efforts. The most comprehensive data sets are from automatic or continuous temperature monitoring sensors. These devices were deployed and operated by Napa County Resource Conservation District (Napa RCD) (Napa County 2005) at four locations during July through October 2002 and at 10 sites from August 2003 to October 2004. The data were logged every 30 minutes.

Other temperature measurements include single measurements using an YSI meter. The YSI meter is a hand held instrument made by Yellow Springs Instrument Company that measures salinity, temperature, pH, and dissolved oxygen electronically from a probe lowered into the water.

Water temperature data were collected using this device from 1996 to 2001 for 19 sites (Napa County 2005), and from 2001 to 2005 for 15 sites (Napa County 2005).

Water temperature was also monitored extensively by Stillwater Sciences as part of the June 2002 Napa River Basin Limiting Factors Analysis (Stillwater Sciences 2002). Stream temperature was continuously monitored at 22 sites in 13 tributaries and 6 mainstem sites, over two dry seasons and one wet season (August 2000-October 2001) with 15-minute intervals.

The simulation period covers January 2000 through December 2003. Data coverage from that period is shown in Figure 17-5 below. The best data coverage in terms of number of stations and overlap with simulation period is from the June 2002 Napa River Basin Limiting Factors Analysis study (Stillwater Sciences 2002). This data was not available for this modeling effort. However, when available, the data will be very useful for calibration and verification of the water quality model.

METEOROLOGICAL DATA

Meteorological data was downloaded from the California Irrigation Management Information System (CIMIS) (2005). The CIMIS program manages a network of over 120 automated weather stations in the state of California. CIMIS was developed in 1982 by the California Department of Water Resource and the University of California at Davis to assist California's irrigators manages their water resources efficiently.

The following two CIMIS stations located within the Napa Valley watershed were included in the model.

- Station 77 Oakville, North Coast Valleys Region Napa County Central District.
- Station 113 Carneros, San Francisco Bay Region Napa County Central District.

Data for air temperature, relative humidity, solar radiation, net sun radiation, wind speed, and wind direction were available from CIMIS on an hourly basis for the simulation period (January 2000 to January 2004).

Data on air temperature, wind speed and direction were also available from Terra Spase (Terra Spase 2005). Terra Spase's spatial information products included a set of in-house tools and services which combined soil, weather, vine, and wine production data with statistical analysis, forecasting, and mapping tools. The data were collected in 15-minute intervals from four stations within the Napa Watershed. This data only covered the period from 2000 to 2002.

NUTRIENTS AND PATHOGENS MODULE

The MIKE 11 Water Quality module is known as ECOLab. ECOLab is integrated with the Advection Dispersion module of MIKE11 and can handle a wide range of water quality processes, ranging from simple first order decay to fully-dynamic eutrophication processes (Figure 17-6). ECOLab works dynamically with MIKE 11 HD to simulate the constituent dynamics in the stream network.

ECOLab is an equation solver designed for ecological modeling and designed to make the development of tailor-made models easy. ith a user-friendly interface, it can be adjusted to apply simple or complex ecological models designed by the user or based on predefined ecosystem models called ECOLab Templates.

In the ECOLab water quality module, the user can define an equation that is specific to a process in the study area. The ability to define the level of complexity and the specific equations used within the model helps to minimize uncertainties associated with the processes within the model domain.

NUTRIENTS: NITROGEN AND PHOSPHORUS

MIKE 11 ECOLab can be used for studies of general water quality describing the river water quality in areas influenced by human activities like transport and fate of specific nutrients (e.g. nitrogen and phosphorus). A number of transformation processes and interactive relationships that affect the date of the water quality constituents are taken into account. These transformations include the following.

- Degradation constants;
- Temperature coefficients;
- Sedimentation rates;
- Re-suspension rates;
- Critical velocities for sedimentation;
- Yield and uptake rates for ammonia/ammonium-N and phosphorus;
- Reaction orders, and rate constants for nitrification and de-nitrification; and
- Adsorption/desorption of phosphorus on suspended solids.

The processes and concentrations of the determinants are influenced by external factors such as temperature, incident solar radiation, and discharges.

DATA FOR NUTRIENTS MODELING

Monitoring data for nutrients in the Napa River Watershed is very limited. Most of the monitoring data is historic and sampling efforts were infrequent.

Only the most recent monitoring effort carried out by San Francisco Bay Regional Water Quality Control Board (RWQCB) provides a coherent and comprehensive set of nutrient data with sufficient coverage (McKee 2005). However, data is only available for a few selected dates, specifically four dates from October 2002 to May 2004. However, the San Francisco Bay RWQCB conducted two water quality sampling efforts in 2003, the first in January and the second in July. Samples were taken at 23 sites throughout the Napa River and its tributaries, 21 of which were located north of the tidal zone and were therefore the sites of interest. Nutrient data from these sampling events served as the baseline for the current nutrient loading and nutrient levels in the model.

Data collected during other monitoring events include the following.

- Nitrate, ammonia, phosphate, total dissolved nitrogen and total dissolved phosphorus data from Oct 2002 to May 2004 for 22 sites (McKee, 2005).
- Nitrate data from, 1998-2003 for 9 sites (DHS 2005)
- Nutrient data from 1970 to 2001 13 sites (USGS 2005).
- Nutrient data from 1988 to1993 for 9 sites (EPA 2005)

Data was also collected to support evaluation of non-point and point sources of nutrients. Contribution of nutrients in the model are either discretely piped into the river as point sources, or conveyed from the nonpoint sources to the river by run-off or groundwater seepage. The loads and waste loads that ultimately make it to the water bodies as in stream loading are attenuated to a degree by several physical and chemical factors. Point and non-point sources that are likely significant sources of nutrient loading to the Napa River include waste water treatment plants (WWTP), effluent from faulty septic systems, surface runoff and groundwater seepage from urban and agricultural land uses, and possibly atmospheric deposition. In summary, both point and non-point contributors have been identified as potential key sources of nutrient loading into the Napa River Watershed.

The following is a summary of collected non-point source related data.

Sedimentation, starvation, sunlight, pH, temperature plus competition with and predation from other microorganisms are factors involved in the decay of pathogenic bacteria from the aquatic environment.

- Run-off from agricultural activity:
  - Fertilizer application of nitrate and ammonia and phosphorus on a monthly basis kg/ha (Wang et al. (2004);
- Run-off from livestock;
  - Number of livestock in the Napa basin. Data collected from US department of Agriculture (Census 2002);
- Run-off from urban land sources:
  - Storm water and fertilizer application of nitrate and ammonia and phosphorus on a monthly basis kg/ha; where Calistoga; St. Helena; Yountville; and Napa City. Populations range from approximately 2,900 in Yountville to 72,590 in Napa City; with Calistoga and St. Helena housing 5190 and 5,950 people respectively. The population of the entire Napa County is approximately 124,280 (Bay Area Census, 2000);
- Septic system effluent seepage and run-off:
  - Nutrient loading from septic tanks was then estimated from septic effluent studies which document an average total nitrogen concentration of 42.5 mg/L and the amount of the effluent was estimated to be 50 gallon/day-person. During an average year, 5 to 15 percent of the septic tanks systems in the watershed are assumed to be failing (Wang et al. (2004);
- Atmospheric deposition:
  - The long-term mean of nitrogen concentration in rainfall in the Napa Watershed was calculated to be 0.62 mg N/L (Wang et al. (2004); and
- The initial groundwater nitrate concentration under agricultural land. (This was set to be 1.5 mg/L according to some field tests in similar areas and the others was set to be 0.1 mg/l (Wang et al. (2004)).

Point source data originates from WWTP data and includes nitrogen loading (nitrate, ammonia total organic nitrogen) from 1995–2001 kg/year for the four main treatment plants in Calistoga; St. Helena; Yountville; and Napa. Average nutrient concentrations from NPDES reports (included in Wang et al. [2004] were also utilized in the model.

PATHOGENS

The water quality sub-module for bacterial fate was applied for this project. Most pathogenic microorganisms are typically unable to multiply or survive for extensive periods in the aquatic environment. Sedimentation, starvation, sunlight, pH, temperature plus competition with and predation from other microorganisms are factors involved in the decay of pathogenic bacteria from the aquatic environment.

Escherichia coli (*E.coli*) is one of the dominant species in feces from human and warm-blooded animals. The organism itself is normally considered non-pathogenic, but is very often used as indicator for fecal constituents and therefore the potential for the presence of real pathogenic organisms.

Coliform bacteria die-off can be modeled very well by a first order decay. However, the die-off rate constant or decay rate is highly variable due to interaction by environmental factors on bacterial die-off. The main factors are assumed to be light, temperature and salinity.

DATA FOR PATHOGENS MODELING

Since the beginning of the 1960s, a number of water quality studies identified excessive bacteria densities in the Napa River. Most of these studies focused on the mainstem of the river. A study conducted by the California State Department of Public Health (1969) documented bacterial problems along the mainstem of the Napa River.

The Napa Sanitation District sampled fecal coliforms in the tidally influenced reaches of the Napa River in 1972 and 1973 (Krotje et al. 2005).

A study conducted by the University of California, Berkeley for the RWQCB from 1984 and 1985 ((Krotje et al. 2005) monitored *E. coli* levels at fifteen sites on the Napa River.

Two recent monitoring efforts investigated pathogen levels in the Napa River system (SFRWQCB/SFEI 2003, and SFRWQCB 2004).

- An on-going program implemented by the Napa County Department of Environmental Management initiated in December 2002 in response to a raw sewage spill in Napa.
- A study developed specifically in support of the Napa River Pathogen TMDL, cooperatively conducted by the Water Board and the San Francisco Estuary Institute (SFEI), with laboratory support from the EPA. The two complementary efforts have sufficient overlap in stations to allow each study to serve to verify data collected by the other.

The RWQCB conducted a supplemental sampling program in May and June 2004 in order to investigate pathogen sources near hotspots identified in the RWQCB/SFEI study (Krottje and Tuden 2005). The data collected reflected early dry-season conditions. The data from May-June 2004 was only available in summary form and therefore not used in the model.

Development of the water quality model was based on the following data set.

- Total and fecal coliform from 1998 to 2003 for 5 sites (DHS 2005).

- Total and fecal coliform from Dec 2002 to Aug 2005 for 7 sites (DHS 2005).
- *E.coli* from Oct 2002 to June 2003 for 23 sites (SFBRWQCB/SFEI 2003).
- *E.coli* from May to June 2004 for 17 sites (SFBRWQCB 2004).

MODEL CALIBRATION AND RESULTS

MODEL CALIBRATION

Model calibration is a critical step in developing the water quality analysis. The goal of the model calibration is to provide a reasonable estimate of the water quality parameters at the regional and subbasin level throughout a long-term simulation period. The accuracy is reflected in how well the observed temperature, concentrations of nutrients, bacteria numbers and sediment levels match the simulated results. To calibrate the models, simulated water quality parameters are compared to observed data at a number of available calibration target locations. The simulation and calibration period included January 2000 through December 2003.

The surface water quality model was calibrated to the greatest extent possible; however, the model results will have less confidence in areas with limited or no data.

The calibration and precision of model results depends on the quantity and quality of the input data. For the Napa County MIKE SHE/MIKE 11 models, limited ambient water quality data were available for calibration and verification. These calibration limitations can to some extent be addressed by collection of additional data. For the surface water quality model simulation the most significant limitations identified are the following.

- *Sediment.* The morphological behavior is controlled by the supply to and transport of sediment in the river system. Only limited data is available for the substrate that varies in time and space. The calibration of the sediment transport model will use the available data combined with engineering judgment.
- *Water temperature.* Automatic sampling of water temperature is available from monitoring stations in the Napa Valley covering the period 2002-2004. However, the most comprehensive monitoring of water temperature was carried out by Stillwater Sciences as part of the Limiting Factors report. This data is not presently available for calibration.
- *Nutrients.* Nutrient data is in general very sparse in the Napa Valley watershed. The calibration of nitrate and phosphorus will use the available monitoring data to the extent possible. Where data may be lacking and/or missing, engineering judgment will be applied to provide the best-input data for the models.
- *Pathogens.* Recent monitoring programs confirm elevated fecal coliform and *E. coli* levels in the river and its tributaries. The pathogen data collected as part of the pathogen TMDL implementation indicates that localized bacteria sources may be present that are difficult to identify. These sources can be difficult to address in the modeling when the origin of elevated bacteria level is unknown.

INITIAL RESULTS AND MODEL OUTPUT

Initial results of the modeling analysis are presented in a supporting technical report (*Napa BDR Surface Water Hydrology Modeling Report*). It is anticipated that the surface water quality model will be used to evaluate land use scenarios in support of a planned county General Plan Update. Results from that future analysis will also be documented for further model refinement and improvement. Those refinements will also be included in a supporting technical report update to the BDR when the Water Quality Modeling task is complete.

The results from the surface water quality simulation can be presented in various ways. Typically, the results will be extracted as time series from different locations along the streams illustrating the temporal variation of water quality for that stream segment. The data can be processed statistically (minimum, maximum, average, exceedance periods etc.) and presented in tables for single points/locations, river reaches, and/or at a sub-basin level. Using the data in tabulated form is a way of compressing the information into a few selected key parameters.

The spatial variation of the surface water parameters of temperature, nutrients, bacteria and sediments in the watershed can also be presented as maps. The results can furthermore be used to provide ecological or environmental classification maps for the whole watershed or sub-basins.

The GIS based Load calculator model provides an extensive approach to evaluate land use and other mapping characteristics that explain the spatial distribution of non-point and point sources of contamination (Figure 17-7). Linking the spatial data from the land to the water quality modeling allows examination of both the cause and effect processes. The load calculator results for non-point and point sources can be displayed as subbasin distributed GIS theme maps and in summary form.

MODEL ASSUMPTIONS AND LIMITATIONS

The surface water quality and sediment models are fully integrated with the hydrodynamic model and therefore any limitation or inaccuracy in the hydrodynamic model is inherited in any subsequent water quality modeling. A more detailed description of the limitation of the hydrologic and hydrodynamic modeling can be found in the surface water and ground water chapters of the BDR (Chapters 15 and 16).

Limitations of the mathematical models (like MIKE SHE/MIKE 11) arise from inherent limitations of numerical models, the limitation of detailed input and calibration data, and inaccuracies associated with

The model is intended for the regional analysis of Napa County's hydrologic system and can be used to help evaluate alternatives developed as part of the Napa County General Plan update.

An Eroded Streambank

available data. A computer model, by definition, is a simplification of the real-world physical system. The model is intended to represent the significant functions and inter-relations that occur in the natural system. However, no model can represent all the intricate details of the processes and inter-relations that could occur in a real-world system.

The accuracy of the surface water quality simulation depends on various factors and their associated uncertainties.

- *The in-stream hydrodynamic model.* The surface water quality model is fully integrated with the hydrodynamic model and any uncertainty in the simulation of water levels and discharges from tributaries will affect the outcome of the water quality model.
- *The exchange of overland, drain and groundwater flows between the MIKESHE and MIKE11 model.* The exchange of surface and subsurface flows can potentially have a significant effect on the surface water quality as groundwater may have very different levels (for example: nutrients) than the surface water.
- *The load estimation from non-point and point sources.* The load calculator is applied when no detailed catchment model is available or if data are insufficient to provide the basis for a detailed dynamic catchment model. Input data is simple GIS layers such as land use, agricultural statistics, population distribution, distribution of point sources and a digital elevation model.
- *The limitation of water quality monitoring data* to establish model boundary conditions with sufficient temporal and spatial variability.
- *The transport of water quality constituents in the surface water quality model.* The water quality constituents are transported with the flow and also via dispersion, which is the spreading (longitudinal and transversal) during the flow. The effect of all the dispersion processes is lumped into one parameter known as the dispersion coefficient. The dispersion coefficient can be calibrated if the necessary data is available, however, this is not possible for the Napa Valley model.
- *The water quality processes in the river system itself.* The water quality processes of the system often referred to as the self-purification capacity of the system. The most important self-purification processes are probably nitrification, de-nitrification, sedimentation/re-suspension and bacteria die-off. These processes can be parameterized and described mathematically, mostly as a combination of zero and first order processes.

CONCLUSIONS AND REPORT UPDATE RECOMMENDATIONS

A surface water model has been developed in MIKE SHE/MIKE 11 that simulates the major components of the hydrologic system active in Napa County. The established MIKE SHE surface hydrology water model was coupled to an in-stream surface water quality model which simulates the temperature variation in the surface water and the transport and fate of nutrients (nitrate and total phosphorus) and pathogens. The water quality analysis makes use of existing and available water quality information. The most recent and updated information on the general surface water quality in the Napa River basin is from initial technical reports to support the implementation of the TMDL program by RWQCB. The Napa River has been defined as water quality impaired and 303(d) listed for sediments, nutrient and bacteria the by EPA.

Loadings from the watershed (non-point and point sources) are assessed using a GIS-based load calculation tool. Different types of land use have different run-off concentrations of nutrients, organic matter, and bacteria. Predominant land uses includes; agriculture, residential, commercial, industrial, mixed (variety of land uses), transportation, open space, forest, and wetlands. The loadings from agricultural activity are likely the most dominant. The GIS based load estimation will be linked to the in-stream water quality model.

The developed model was sensitive to changes in land use and can be used in the future to determine the possible effects of various proposed projects or land use scenarios.

Limitations of the combined MIKE SHE/MIKE 11 modeling to assess the County's surface water quality arise from the inherent limitations of numerical mathematical models, the limitation of detailed input and calibration data, and inaccuracies associated with available data. If the model is to be used for purposes other than regional hydrology, hydraulic, or local hydrology studies, then additional data of the specific study area of interest may need to be collected to refine the sensitivity of the model. The major model limitation is the lack of ambient water quality monitoring data to calibrate and verify the surface water quality model. The model is fully applicable, however, for impact analyses comparing baseline conditions to future land use scenarios.

The Napa County MIKE SHE/MIKE 11 model is a dynamic model that can be refined and expanded as additional data becomes available and as new planning, management and policy questions are identified. Because the model is intended for the regional analysis of Napa County's hydrologic system, it can be used to help evaluate alternatives developed as part of the current updating of the Napa County General Plan.

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