Calleguas Creek Data Analysis in Support of TMDL Determination

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Disclaimer: This report represents the best professional judgment of the author acting solely as a private engineering consultant. The University of Florida has approved the investment of time associated with this effort, but does NOT take any responsibility for the methods employed or associated conclusions.

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Calleguas Creek TMDL
Algal Computations

Executive Summary

Dr. Warwick recommended, and representatives from Larry Walker and Associates conducted, a field data collection exercise designed to aid in establishing the current environmental conditions within portions of the Calleguas Creek watershed in Ventura County, California. Specifically, a 48-hour Lagrangian based water quality survey was conducted in mid-June 2000 on a sensitive reach of Conejo Creek. Data collected included nutrient concentrations, specifically dissolved inorganic nitrogen (DIN) and phosphorus (DIP), along with frequent systematic collection of dissolved oxygen (DO) and temperature.

Results from this intensive field data collection effort clearly demonstrate a minimum nighttime DO value of 4.28 mg/L which represents a violation of the established in-stream standard of 5.0 mg/L. A spreadsheet modeling exercise was conducted to determine a loading scenario that would result in compliance with the established in-stream DO standard. The reduced loading scenario focused upon achieving reductions in the major upstream point source discharge (Hill Canyon WWTP). Several conservative assumptions were incorporated into the analysis yielding a conservatively low effluent concentration estimate. Prediction indicates that the DO standard of 5.0 mg/L can be met, for the conditions monitored, by establishing a Total Kjeldahl Nitrogen (TKN) WWTP effluent concentration of 3.5 mg-N/L (conservatively low estimate). Removing most of the aforementioned conservative assumptions and using values more representative of mean conditions yields a maximum required TKN WWTP effluent concentration of 5.0 mg-N/L. A final recommendation is made to establish the TKN WWTP effluent limit at **4.0 mg-N/L** with this value including an estimated 25% margin of safety (MOS).

The detailed field data were also used to estimate the magnitude of the attached algal (periphyton) community within this reach. The derived estimate indicates that the amount of attached algae (12.9 g-AFDM/m^2) does not violate the quantitative characterization of an algal aesthetics standard (22.5 g-AFDM/m^2). Additional data analysis clearly indicates that extreme reductions of current in-stream nutrient concentrations (DIN = 6.92 mg-N/L and DIP = 1.63 mg-P/L) down to levels near the half-saturation concentrations (DIN=0.025 mg-N/L and DIP=0.005 mg-P/L) would be needed to substantially limit the amount of periphyton biomass via nutrient control. Data collected from two other locations, Simi Creek and Revolon Slough, also indicated a lack of aesthetics violation (17.7 g-AFDM/m^2 and 15.8 g-AFDM/m^2, respectively), however with a lower margin of safety. The number of assumptions required to compute these estimates most certainly warrants a future study to collect field observations of attached algal coverage for verification.

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General Assumption

I have tried to consistently use kinetics and characterizations reported in Caupp et al. (1997) and related support studies. These studies were performed on periphyton in the Truckee River, Nevada. The Truckee River is a relatively shallow, fast moving system, with relatively low nutrient concentrations. I believe that Caupp's report and the substantial amount of prior field, laboratory, and computer simulation work was generally well done. I have tried to consistently use the noted reference for all rates thereby avoiding mixing information from different systems. Extensive periphyton data was collected in the Truckee River during 1986. I will mail a complete copy of this information for your review that will clearly show a high degree of both temporal and spatial variability. I will summarize some very rough average values for the Nixon, Nevada location.

Ammonia = 0.10 mg-N/L
Unionized Ammonia = 0.005 mg-N/L
Nitrate = 0.40 mg-N/L
SRP (Soluble Reactive Phosphorus) = 0.050 mg-P/L
Periphyton = 270 mg-Chl a/m^2
Periphyton = 40 g-AFDM/m^2
Ratio = 150 g-AFDM/g-Chl a

Aesthetics

Assume that the acceptable level is **150. mg-Chl a/m^2**.

Organic matter is generally quantified as ash-free dry mass (AFDM). The ratio of photosynthetic biomass (expressed as AFDM) to Chlorophyll a is highly variable. A factor of 60 has been commonly used to represent communities growing in nutrient rich, unshaded conditions (Vollenweider, 1974; Summer and McIntire, 1982). Standard Methods (APHA, 1976) states a range from 50 to 200 for phytoplankton. The complete range of ratios between biomass and Chlorophyll a for the six sites sampled on the Truckee River in 1986 was from approximately 50 g-AFDM/g-Chl a to 600 g-AFDM/g-Chl a. Since all Chlorophyll a numbers with the exception of those presented for the Truckee River are for phytoplankton, I used the aforementioned ratio value of **150 g-AFDM/g-Chl a** which is for periphyton.

Then, the nuisance standard translates to **22.5 g-AFDM/m^2**.

Conejo Reach (California)

Physical Characteristics:

Average Depth = 0.79 ft = 0.241 m
Average Velocity = 1.7 ft/sec
Average Longitudinal Bottom Slope = 0.00331

Nutrient Characteristics:

Organic Nitrogen:
- Upstream: 0.90 mg-N/L
- Downstream: 0.80 mg-N/L
- Average: 0.85 mg-N/L

Ammonia Nitrogen:
- Upstream: 0.90 mg-N/L
- Downstream: 0.10 mg-N/L (half detection level of 0.20 mg-N/L)
- Average: 0.50 mg-N/L

Nitrate Nitrogen:
- Upstream: 6.23 mg-N/L
- Downstream: 6.62 mg-N/L
- Average: 6.42 mg-N/L

Organic Phosphorus:
- Upstream: 0.31 mg-P/L
- Downstream: 0.13 mg-P/L
- Average: 0.22 mg-P/L

Ortho-Phosphorus
- Upstream: 1.79 mg-P/L
- Downstream: 1.47 mg-P/L
- Average: 1.63 mg-P/L

Therefore:

Average DIN = 6.92 mg-N/L
Average DIP = 1.63 mg-P/L

Using Field Data Collection to Estimate Periphyton Biomass (P) and other in-stream Reaction Rates

Ideal Field Data Collection

1) Choose a reach where no significant loads enter between the upstream and downstream end of the reach.
2) The total travel time between the upstream and downstream end of the reach should be approximately 4 hours.
3) Dissolved oxygen, temperature, pH, and conductivity should be collected at both the upstream and downstream ends of the reach. Information should be stored every 15 minutes. Data collection should span a two-day period.
4) Water column samples should be collected at roughly equally spaced intervals throughout a 24-hour period, with the samples being phase lagged between the upstream and downstream locations by the travel time. The example shown below assumes a travel time of 4 hours.

Upstream Location	Downstream Location
7:00am	11:00am
11:30am	3:30pm
4:00pm	8:00pm
8:30pm	12:30am
7:00am	11:00am

These samples should be analyzed for the following parameters:

a. CBOD (20 day) or CBOD (5 day)
b. TKN – to be used to calculate Organic nitrogen
c. Ammonia nitrogen
d. Nitrate nitrogen
e. Total Phosphorus – to be used to calculate Organic phosphorus
f. Ortho-Phosphate

5) Estimate average depth of flow for the reach.
6) Estimate travel time (t_f) for the reach.
7) Estimate average longitudinal slope for the reach.
8) Estimate distance along channel for the reach.

Note: Item 4) is rather expensive so a compromise would be to collect separate samples for perhaps ammonia analysis. Then composite all five samples for each location (upstream and downstream) and run the remaining laboratory tests on the two composite samples.

Lagrangian Dissolved Oxygen Equation (Warwick and McDonnell, 1985)

A simplified dissolved oxygen mass balance equation is shown immediately below

$$\frac{DC}{Dt_f} \cong \frac{\Delta C}{\Delta t} \cong \frac{C_{down} - C_{up}}{t_f} \cong K_a\left(C_s - C_{avg}\right) + O_P - R_C \qquad \text{(Eq. 1)}$$

where: C_{down} = concentration of dissolved oxygen at downstream location (mg-O_2/L), at a time t_f later than that for the upstream observation;

C_{up} = concentration of dissolved oxygen at upstream location (mg-O_2/L);

C_{avg} = average (over t_f time period and distance) concentration of dissolved oxygen (mg-O_2/L);

t_f = travel time between upstream and downstream ends (days);

K_a = reaeration rate coefficients (day^{-1});

C_s = saturation dissolved oxygen concentration (mg-O_2/L);

O_P = average (over t_f time period and distance) rate of periphyton oxygen production (mg-O_2/L/day); and

R_C = average (over t_f time period and distance) community respiration = (mg-O_2/L/day).

$$C_{avg} = \frac{C_{down} + C_{up}}{2}$$

Dissolved Oxygen Analysis Protocol

Step 1) Using physical reach characterizations estimate the reaeration coefficient (K_a):

$$K_a = 0.054 * V * S \qquad \text{(Eq. 2)}$$

where K_a = reaeration coefficient (day^{-1}) at 25°C;

V = average reach velocity (ft/day); and

S = average longitudinal bottom slope.

$$\mathbf{K_a = 26.25\ day^{-1}}$$

Step 2) Using nighttime profiles (pairings of upstream and downstream observed DO, phase shifted by travel time) estimate R_C through simulation solution of equations (one per profile). See Excel Spreadsheet.

Step 3) Using daytime profiles (pairings of upstream and downstream observed DO, phase shifted by travel time) estimate $O_{P(max)}$. This should occur during the middle of the day (~ noon to 3:00pm). See Excel Spreadsheet.

Step 4) Compute ratio of g-O_2 produced to g-AFDM.

<u>WASP Values</u> (Ambrose, et al., 1991)

28 (ug-C/ug-Chl a) and 32/12 = 2.67 (mg-O_2/mg-C) yields

0.075 mg-O_2/ug-Chl a = 75 mg-O_2/mg-Chl a = 0.01333 g-Chl a/g-O_2

<u>The Ratio Final Used</u>

150 (g-AFDM/g-Chl a) * 0.0133 (g-Chl a/g-O_2) = **2.00 g-AFDM/g-O_2**

Step 5) Assuming that $O_{P(max)}$ is NOT light limited, thereby giving a full accounting of active periphyton biomass, convert to biomass (P) using a ratio calculated in Step 4).

$$P(g-AFDM/m^2) = \frac{O_{P(\max)}(mg-O_2/L/day)}{GMAX(1/day)} * Depth(m) * 2.00\left(\frac{g-AFDM}{g-O_2}\right)$$

(Eq.3)

GMAX (at 20^{o}C) = 3.5 day^{-1} (Caupp, et al., 1991 and 1997)

Periphyton Growth Limitations

Nutrients

The two expressions shown immediately below describe the degree of periphyton growth limitation that will occur as a result of the local abundance of nutrients. These expressions were used by Caupp, et al. (1991 and 1997).

$$L(DIP) = \frac{DIP}{0.005 + DIP}$$, where DIP = Orthophosphate (mg-P/L)

DIP = 1.63 mg-P/L (Conejo, CA)

L(DIP) = 0.997

$$L(DIN) = \frac{DIN}{0.025 + DIN}$$, where DIN = Ammonia + Nitrate (mg-N/L)

DIN = 6.92 mg-N/L (Conejo, CA)

L(DIN) = 0.996 (THIS IS THE MOST LIMITING, though just barely)

Therefore, both nutrient limitations terms are very close to each other and very close to 1.00 . A value of 1.00 indicates that there is no nutrient limitation. Since both values are very close to 1.00, the current concentrations of available nutrients (DIN and DIP) are NOT limiting significantly algal growth in this reach. Limitation is therefore likely a result of other factors like the availability of substrate. Caupp, et al. (1991 and 1997) found substrate an important growth limitation factor for periphyton. Only a significant decrease in DIN or DIP will result in lower biomass levels of periphyton in Conejo reach. For example, if DIN=0.025 mg-N/L the value of L(DIN) would equal 0.50, indicating that the rate of periphyton growth would be limited to 50% of the maximum growth rate by the amount of DIN. Or if DIP=0.005 mg-P/L then the value of L(DIP) would equal 0.50, indicating that the rate of periphyton growth would be limited to 50% of the maximum growth rate by the amount of DIP. This nutrient limitation is NOT additive, since only the smallest L value, either L(DIN) or L(DIP), is applied to limit growth.

Eq. 3 (see previous page) is written using the maximum photosynthetic period and therefore assumes that there is no light limitation (shallow depths and maximum incident solar radiation). This coupled with effectively no nutrient limitation results in a GMAX value which will only be temperature corrected to the average temperature occurring during the period of maximum photosynthetic activity.

Conejo Reach Results

$O_{P(max)}$ = 138.3. mg-O_2/L/day on 6/12/00 (See attached Excel Spreadsheet)

$O_{P(max)}$ = 141.9. mg-O_2/L/day on 6/13/00 (See attached Excel Spreadsheet)

Use $O_{P(max)}$ = 140. mg-O_2/L/day

Average Depth = 0.79 ft = 0.241 m

Average Temperature at maximum photosynthesis period = 26.2°C

$$GMAX = 3.50\ day^{-1} * (1.066)^{(26.2-20)} = \mathbf{5.22\ day^{-1}}$$

Then **P = 12.9 g-AFDM/m²** (Below Aesthetics Standard of 22.5 g-AFDM/m²)

Therefore: Average estimated periphyton biomass level in the Conejo reach does NOT violate nuisance standard. Algal biomass is highly variable in both time and space. Periodic direct quantitative observation of attached algal biomass is highly recommended to verify estimates made herein.

Single Station Analysis

Two additional locations were monitored for DO at different dates. No nutrient data was collected in concert with this DO data. A more simplistic analysis was performed to estimate the rate of maximum photosynthetic activity ($O_{P(max)}$) at each station using the equations shown immediately below from Thomann and Mueller (1987)

$$O_{P(avg)}(mg-O_2/L/day) = \frac{0.50K_a\left[1-e^{-K_a}\right]}{\left(1-e^{-0.5K_a}\right)^2} * \Delta DO(mg/L) \qquad \text{(Eq. 4a)}$$

$$O_{P(\max)}(mg-O_2/L/day) = \frac{O_{P(avg)}(mg-O_2/L/day) * \pi}{(2f)} \qquad \text{(Eq. 4b)}$$

where: ΔDO = range in DO from minimum to maximum during a 24-hour period (mg/L);

f = duration of photoperiod (days). A value of 15 hours or 0.625 days was used.

Simi Station Results

$O_{P(max)}$ = 238.8. mg-O_2/L/day on 6/07/00 (See attached Excel Spreadsheet)

Average Depth = 0.63 ft = 0.192 m

Average Temperature at maximum photosynthesis period = 26.1°C

$$GMAX = 3.50\ day^{-1}*(1.066)^{(26.1-20)} = \mathbf{5.17\ day^{-1}}$$

Then **P = 17.7 g-AFDM/m²** (Below Aesthetics Standard of 22.5 g-AFDM/m²)

Therefore: Average estimated periphyton biomass level in the Simi Station does NOT violate nuisance standard. Algal biomass is highly variable in both time and space. Periodic direct quantitative observation of attached algal biomass is highly recommended to verify estimates made herein.

Revolon Station Results

$O_{P(max)}$ = 208.9. mg-O_2/L/day on 6/07/00 (See attached Excel Spreadsheet)

Average Depth = 0.55 ft = 0.168 m

Average Temperature at maximum photosynthesis period = 23.69°C

$$GMAX = 3.50\ day^{-1}*(1.066)^{(23.7-20)} = \mathbf{4.43\ day^{-1}}$$

Then **P = 15.8 g-AFDM/m²** (Below Aesthetics Standard of 22.5 g-AFDM/m²)

Therefore: Average estimated periphyton biomass level in the Revolon Station does NOT violate nuisance standard. Algal biomass is highly variable in both time and space. Periodic direct quantitative observation of attached algal biomass is highly recommended to verify estimates made herein.

Dissolved Oxygen Standard

Extensive dissolved oxygen (DO) data (15-minute interval over a two-day period) was collected at four locations: Upstream Conejo, Downstream Conejo, Simi, and Revolon. Only the Upstream Conejo site had minimum DO values below the established standard of 5.0 mg/L. Specifically, minimum DO values for Upstream Conejo were 4.50 mg/L on 6/12/00 at 21:30 and 4.28 mg/L on 6/13/00 also at 21:30. In it important to note the minimum DO values at the Downstream Conejo site were 6.41 mg/L on 6/12/00 at 23:45 and 6.21 mg/L on 6/13/00 at 23:30. These data clearly indicate that the stream is recovering in this reach (i.e. minimum DO is increasing between the upstream and downstream sites).

Low values of DO typically occur during nighttime hours when the effect of algal communities is to lower DO due to respiration. Additionally, algal communities do not assimilate as much ammonium at night (no cell growth), leaving more ammonium available for nitrification to nitrate thereby creating an additional sink of DO. While the average ammonium concentration at the Upstream Conejo site was 0.90 mg-N/L, collected data demonstrates a clear diel variation in ammonium concentration with this behavior supporting the aforementioned discussion.

Table 1: Dissolved Oxygen extremes by location.

Dissolved	Upstream Conejo		Downstream Conejo	
Oxygen Values	6/12/00	6/13/00	6/12/00	6/13/00
Maximum	11.47	10.49	9.96	10.27
Minimum	4.50	4.28	6.41	6.21
Range	6.97	6.21	3.55	4.06

Another important aspect of the data in Table 1 is the reduction in range (maximum minus minimum) from the Upstream to the Downstream Conejo site. The magnitude of this range is a result of the size of the photosynthetic community (larger results in higher range) and the level of in-stream reaeration (larger results in a smaller range).

Dealing with DO Violations (Complex Method)

The following equation is designed to investigate critical (minimum) DO conditions that occur at night. Therefore no photosynthetic oxygen production is shown, only algal respiration.

$$D = D_o e^{-K_a t_f} + \left(\frac{L_o K_d}{(K_a - K_d)} \right) \left(e^{-K_d t_f} - e^{-K_a t_f} \right) + \qquad \text{(Eq. 5)}$$

(Term 1) (Term 2)

$$\left(\frac{N_o K_n}{(K_a - K_n)} \right) \left(e^{-K_n t_f} - e^{-K_a t_f} \right) +$$

(Term 3)

$$\left(\frac{O_R + S}{K_a} \right) \left(1.0 - e^{-K_a t_f} \right)$$

(Term 4)

where: D = dissolved oxygen deficit = C_s – C (mg-O_2/L);

D_o = dissolved oxygen deficit at upstream location (mg-O_2/L);

L_0 = ultimate (20-day) CBOD concentration at upstream location (mg-O_2/L);

K_d = deoxygenation rate coefficient (day^{-1});

N_0 = ultimate (20-day) NBOD concentration at upstream location (mg-O_2/L);

K_n = first-order nitrification rate coefficient (day^{-1});

O_R = average (over t_f time period and distance) rate of periphyton respiration (mg-O_2/L/day); and

S = sediment oxygen demand (mg-O_2/L/day).

Each of the four terms shown for Eq. 5 "tracks" a different aspect of an in-stream dissolved oxygen mass balance. Term 1 simulates the effect of the upstream dissolved oxygen boundary condition throughout the downstream spatial domain. Term 2 simulates the effect of the upstream ultimate CBOD boundary condition, as CBOD decays (i.e. is aerobically oxidized) it demands in-stream dissolved oxygen. Term 3 simulates, in a parallel fashion, the effect of the upstream ultimate NBOD boundary condition. Finally, Term 4 simulates the impact of a spatially distributed (i.e. uniform coverage over the entire downstream spatial domain) dissolved oxygen sink caused by attached algal respiration and oxidation of materials in the bottom sediments. Each term is impacted by the reaeration rate coefficient (K_a) therefore the importance of accurately assessing in-stream reaeration is obvious. Additionally, all terms are impacted by in-stream water column temperature, with higher temperatures consistently netting lower predictions of in-stream dissolved oxygen.

K_d Assumption

Caupp, et al. 1991 and 1997 used the following calibrated function to obtain estimates of K_d. This approach was used since no in-stream information was available to characterize the spatial decrease of ultimate (20-day) CBOD.

$$K_d = 0.050 day^{-1}(1.413)R^{-0.4562} \qquad \text{(Eq. 6)}$$

Where R = channel hydraulic radius (m), which is equal to the depth for wide channels. Using Eq. 6 with the average depth of 0.241 m for the studied reach of Conejo Creek results in a computed Kd value of **0.135 day^{-1}**.

K_n Estimation

The equation immediately below was used to estimate the value of the in-stream nitrification rate (K_n)

$$N = N_0 e^{-K_n t_f} \qquad \text{or} \qquad K_n = \frac{\ln\left(\frac{N_0}{N}\right)}{t_f}$$

where: N = ultimate (20-day) NBOD at downstream location = TKN (mg-N/L)*4.57 (mg-O_2/mg-N).

The attached spreadsheet shows the calibration to a value of **3.39 day^{-1}** for the K_n.

(O_R+S) Estimation

Solve Eq. 5 for (O_R+S)

The attached spreadsheet shows the calibration for the term (O_R+S) to match the most critical period of time (minimum DO at Upstream Conejo Site). This analysis is Lagrangian, meaning that a parcel of water is tracked through the system from the upstream boundary Upstream Conejo to the Downstream Conejo Site. The critical parcel of water begins at the

Upstream Conejo site at 21:30 on 6/13/00 (Critical DO = 4.28 mg/L) and proceeds downstream to the Downstream Conejo site and arrives at 03:00 on 6/14/00 (DO = 6.42 mg/L). Due to the substantially amount of temperature variation, a relatively small computational step size (delx=0.10 miles) was used to accurately capture the effect of temperature variation on all reaction rate coefficients. A Hill Canyon WWTP discharge value for ultimate CBOD of 7.5 mg-O_2/L was used.

Meeting a DO Target (5.0 mg/L)

The Hill Canyon WWTP discharge characteristics (DO and TKN) were adjusted to achieve a minimum DO value above 5.0 mg/L. It was assumed that (O_R+S) remains unchanged. The critical conditions will remain at night thereby causing O_p to again be zero. Note that the attached spreadsheet demonstrates that the minimum DO standard of 5.0 mg/L can be met by controlling effluent characteristics of the WWTP and does NOT require reducing the size of the periphyton community. The spreadsheet analysis shows that the minimum target DO value of 5.0 mg/L can be met with a WWTP discharge TKN concentration of 3.5 mg-N/L, ultimate CBOD concentration of 7.5 mg-O_2/L, and a DO concentration of 8.7 mg/L.

Margin of Safety (MOS)

Several conservative assumptions have been made throughout this analysis resulting in a significant Margin of Safety (MOS).

1) 100% of the stream flow is actually WWTP effluent (i.e. no dilution).
2) 100% of Organic-nitrogen (determined from TKN chemical oxidation analysis) is available for biological conversion to ammonia.
3) 100% of Ammonia-nitrogen is oxidized through nitrification, assumes no uptake of ammonia for periphyton cell synthesis (4.57 mg-O_2/mg-N).
4) Hill Canyon effluent analysis shows BOD_5 to be less than 5.0 mg-O_2/L, while a value of 5.0 was used to compute the ultimate CBOD number (7.5).
5) Hill Canyon effluent analysis shows average DO to be 9.5 mg/L, while the minimum recorded value of 8.7 mg/L was used in the computations.

Collectively these conservative assumptions amount to a qualitative estimate of a 25%-50% MOS on the prescribed WWTP TKN discharge level of **3.5 mg/L**. Using the value for the best reasonable estimate of TKN effluent concentration (5.0 mg-N/L), presented in the following section, yields a MOS value of 42.9% .

Best Reasonable TKN Estimate Analysis

An attempt was made to determine a reasonable upper limit to a prescribed WWTP TKN discharge concentration. This was accomplished by removing some of the conservative assumptions indicated above. The original conservative assumptions are reiterated with a following sentence explaining any change made to estimate a reasonable upper limit for Hill Canyon WWTP TKN concentration.

1) 100% of the stream flow is actually WWTP effluent (i.e. no dilution). NO CHANGE.
2) 100% of Organic-nitrogen (determined from TKN chemical oxidation analysis) is available for biological conversion to ammonia. Only 80% of TKN is assumed to be available for biological oxidation.
3) 100% of Ammonia-nitrogen is oxidized through nitrification, assumes no uptake of ammonia for periphyton cell synthesis (4.57 mg-O_2/mg-N). The amount of oxygen demanded by unit of ammonia reduction was decreased to 4.33 mg-O_2/mg-N to reflect some ammonia loss due to aquatic plant uptake (Haug and McCarty, 1972).
4) Hill Canyon effluent analysis shows BOD_5 to be less than 5.0 mg-O_2/L, while a value of 5.0 was used to compute the ultimate CBOD number (7.5). The mean Hill Canyon BOD_5 value of 3.1 mg-O_2/L was used to compute the ultimate CBOD number (4.65).
5) Hill Canyon effluent analysis shows average DO to be 9.5 mg/L, while the minimum recorded value of 8.7 mg/L was used in the computations. The average Hill Canyon DO value of 9.5 mg/L was used.

Based upon the analysis (see attached Excel spreadsheet), the amount of biologically oxidizable TKN in the Hill Canyon WWTP discharge should be 4.0 mg-N/L. Assuming that only 80% of TKN is available for biological oxidation (Item 2), yields an upper limit estimate for Hill Canyon WWTP effluent TKN concentration of **5.0 mg-N/L**. The conservative assumption of no dilution (100% WWTP effluent) remains. It is also recognized that nighttime stream temperatures may be a little higher later in the summer. These two issues (dilution and temperature) are assumed to offset with the estimated value for WWTP TKN effluent concentration (5.0 mg-N/L) then representing the author's best reasonable estimate of needed effluent quality.

Recommendations

1) Based upon the data collected and the analyses performed, the author would recommend establishing a WWTP TKN effluent concentration limit of **4.0 mg-N/L**, with an associated estimated MOS equal to **25%.**
2) Develop and implement an ongoing robust monitoring program to better characterize the in-stream effects of both point and non-point pollution source loads.
   a) Repeat on a monthly basis (during critical summer months) detailed data collection efforts for critical reaches, like the study performed recently on a section of Conejo Creek. (Steady state flow conditions)
   b) In a concurrent fashion with the detailed chemical data collection shown immediately above, also obtain detailed spatially representative estimates of algal biomass by direct field observation. (Steady state flow conditions)
   c) In a concurrent fashion with the detailed chemical data collection shown in item a), also perform direct field analysis of in-stream reaeration.
   d) Attempt to perform storm-event in-stream chemical sampling to characterize runoff related to non-point source loads and associated in-stream water quality impacts. (Nonsteady flow conditions)
3) Develop a more sophisticated data analysis approach to make better use of the improved quantity and quality of field data information. This may likely involve developing a computer model of the stream system that can simultaneously perform mass balance computations on dissolved oxygen, nitrogen and phosphorus species, and attached algae. Recent example of such a modeling approach can be found in Warwick, et al. (1997 and 1999) or Caupp, et al. (1997).

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