TETRA TECH, INC.
10306 Eaton Place, Suite 340
Fairfax, VA 22030
Telephone (703) 385-6000
FAX (703) 385-6007
Email: MortoMi@tetratech-ffx.com

MEMORANDUM

DATE: June 28, 2002
TO: Tom Henry and Larry Merrill, U.S. EPA Region III
FROM: Mike Morton, Tetra Tech, Inc.
SUBJECT: *Response to DARA Comments on Revised Christina River TMDL*

Attached are my responses to the issues raised by Hall & Associates (March 28, 2002 letter to EPA Region III) regarding the Revised Christina River Basin TMDL and the impacts on the Downingtown Area Regional Authority (DARA) wastewater treatment plant.

Response to DARA comments on Revised Christina River TMDL

U.S. Environmental Protection Agency
Region III

June 7, 2002

It appears the primary point of contention revolves around the water quality model's ability to simulate periphyton biomass and the associated daily range of dissolved oxygen (DO) due to photosynthesis and respiration. More specifically, the comments from Gallagher and Knorr focused primarily on the phosphorus half-saturation constant (KHPm) used in the model. It appears that neither Gallagher or Knorr was aware of the 1997 field study (Davis 1998) in which a laboratory algal assay determined a value for KHPm of 0.132 mg/L. This site-specific phosphorus half-saturation constant was used as the basis for formulating the periphyton kinetics in the water quality model. A literature search indicates that the algal phosphorus half-saturation constant can range from 0.001 to 1.520 mg/L (see Table 1 below).

Table 1. Literature values for phosphorus half-saturation constant.

Algal Species	Half-saturation Constant (mg/L)	Reference
Asterionella formosa	0.002	Holm & Armstrong, 1981
Asterionella japonica	0.014	Thomas & Dodson, 1968
Biddulphia sinensis	0.016	Quasim et al., 1973
Ceratualina bergonii	0.003	Finenko & Krupatkina, 1974
Chaetoceros curvisetus	0.074 - 0.105	Finenko & Krupatkina, 1974
Chaetoceros socialis	0.001	Finenko & Krupatkina, 1974
Chlorella pyrenoidosa	0.380 - 0.475	Jeanjean, 1969
Cyclotella nana	0.055	Fuhs et al., 1972
Cyclotella nana	0.001	Fogg, 1973
Dinobryon cylindricum	0.076	Lehman (unpublished)
Dinobryon sociale	0.047	Lehman (unpublished)
Euglena gracilis	1.520	Dlum, 1966
Microcystis aeruginosa	0.006	Holm & Armstrong, 1981
Nitzschia actinastreoides	0.095	Von Muller, 1972
Pediastrum duplex	0.105	Lehman (unpublished)
Pithophora oedogonia	0.980	Spenser & Lembi, 1981
Scenedesmus obliquus	0.002	Fogg, 1973
Scenedesmus sp.	0.002 - 0.050	Rhee, 1973
Thalossiosira fluviatilis	0.163	Fogg, 1973

As a part of his review, Knorr performed a statistical analysis of the model periphyton biomass data presented in Table 9-5 of the model report and concluded that the biomass projected by the model was significantly different from the biomass measured in 1985. Unfortunately, the model periphyton biomass values reported in Table 9-5 were from an early draft calibration report, not the final calibration. The ranges of model periphyton biomass from the final model calibration (during the period 8/1/1997 - 8/31/1997) are presented in the corrected table below:

Table 9-5. Comparison of model periphyton with 1985 measurements (Knorr and Fairchild 1987).

Site ID	River Mile	1985 Periphyton Biomass (ug chlorophyll-*a* / cm^2)	EFDC Grid Cell	Model Periphyton (ug chlorophyll-*a* / L)	Water Depth (m)	Model Periphyton Biomass (ug chlorophyll-*a* / cm^2)
1	109.3	6.2 - 10.2	54,69	74 - 97	0.30	1.6 - 2.0
2	NA	8.0 - 16.5	NA	NA	NA	NA
3	106.2	8.5 - 13.0	54,64	59 - 72	0.33	1.3 - 1.7
4	102.4	9.0 - 17.0	54,58	351 - 601	0.36	8.2 - 14.0
5	101.2	11.5 - 21.0	54,56	396 - 662	0.37	9.1 - 15.2
6	96.1	8.0 - 14.3	54,50	93 - 169	0.35	3.6 - 6.5

The purpose of citing the Knorr and Fairchild periphyton biomass was to demonstrate that the model predictions were in the ballpark with historical information. One cannot reasonably expect that the model, which was developed using 1997 conditions, to exactly agree with field measurements made 12 years earlier in 1985. It is also important to understand a statement from the Knorr and Fairchild (1987) paper:

> *"High current velocities, however, may have caused erosion of accumulated algal cells, reducing standing crop below levels otherwise sustainable by ambient light and nutrient supply. Storm events on 16 and 27 July, and on 1 August during the 23 day incubation period, monitored by fluctuating discharge at USGS gaging station 01480870 located at site 5, provide additional evidence of probable scouring of the pots during the study."*

This statement implies that the periphyton biomass measured in 1985 may have been substantially lowered by three storm events. This confounds attempts to directly compare the 1997 model periphyton predictions with the 1985 observations. The time to establish maximum periphyton biomass following a scouring storm event typically ranges from 20 to 120 days (Biggs 2000). Knorr's use of the Crystal Ball Monte Carlo analysis was interesting, however, the exercise was moot due to the different hydraulic and nutrient loading conditions in 1985 and 1997.

Our responses to individual comments are presented below.

<u>Comments</u>

A. Periphyton Model Fundamentally Flawed

The model developed by EPA to evaluate compliance with dissolved oxygen standards in the Christina River Basin predicts periphyton growth as the primary factor affecting minimum DO levels in the receiving water. This projection of minimum DO was used to mandate more restrictive TP, CBOD, and ammonia limits. DARA has already notified the Agency that periphyton projections made to compare the TMDL loading with other allocation scenarios are fundamentally flawed for the following reasons:

- *No periphyton measurements were made to calibrate the model or to verify calibration of the periphyton growth subroutine, thus the model results are sheer guesswork.*

Response: Direct instream measurements of periphyton biomass were not made during the recent (1995-1997) field studies in the Christina River Basin. However, as part of the August 1997 field study (Davis 1998), a laboratory algal assay analysis was conducted which estimated periphyton biomass productivity at eight locations in the Christina River Basin, including two stations on East Branch Brandywine Creek. This algal assay analysis indicated an algal biomass of 12 ug/L (dry weight) at the station upstream of DARA and 187 ug/L (dry weight) downstream of DARA. In addition, diel DO measurements from August 1997 show the diel DO swing downstream of DARA is about 6 to 7 mg/L, and the diel DO swing upstream of DARA is about 2 mg/L. The water quality model projects these diel DO swings very well (see Figure 9-17 in the model report). This is clear evidence based on field observations that increased nutrients from the DARA discharge are stimulating periphyton growth and the diel DO swing. The fact that the model projects this diel DO swing indicates that the periphyton kinetics formulated in the model are scientifically credible.

- *Site-specific periphyton data for the East Branch of Brandywine Creek from Knorr and Fairchild (1987), cited in the model documentation as the basis for periphyton biomass projections, demonstrate that the model does not accurately represent periphyton growth in the East Branch of Brandywine Creek. The model greatly under-predicts periphyton biomass upstream of the DARA outfall and over-predicts periphyton biomass downstream of the outfall.*

Response: The model documentation does not claim that the Knorr and Fairchild (1987) study was used as the basis for periphyton biomass projections. The Knorr and Fairchild periphyton biomass, measured in 1985, represented the only in-situ measurements available for comparison to the model periphyton biomass predictions. The Knorr and Fairchild data were not used to develop any coefficients in the model. The purpose of citing the Knorr and Fairchild periphyton biomass was to show that the model predictions were in the ballpark with historical information. One cannot reasonably expect that the model, which was developed using 1997 conditions, to exactly agree with field measurements made 12 years earlier in 1985.

- *Available data do not indicate that periphyton data will change significantly due to higher loadings from DARA. In fact, the projected TP levels under permitted loadings are lower than the conditions observed by Knorr and Fairchild, which confirmed periphyton levels did not increase significantly below DARA.*

Response: The field study conducted by Davis (1998) indicates that periphyton growth in the East Branch Brandywine Creek in the vicinity of DARA is phosphorus limited. The model kinetics were developed based on the Davis (1998) study which confirmed that periphyton levels do, indeed, increase downstream of DARA. As part of the August 1997 field study (Davis 1998), a laboratory algal assay analysis was conducted which estimated periphyton biomass at eight locations in the Christina River Basin, including two stations on East Branch Brandywine Creek. This algal assay analysis indicated an algal biomass of 12 mg/L (dry weight) at the station upstream of DARA and 187 ug/L (dry weight) downstream of DARA.

- *Knorr and Fairchild, the only periphyton data cited in the final report, concluded that phosphorus did not limit growth of periphyton in the East Branch of Brandywine Creek at ambient concentrations significantly less than the TMDL level. Consequently, increases in phosphorus concentration above the TMDL level would have little, if any, effect on periphyton biomass, contrary to the model's prediction.*

Response: As part of the Davis (1998) field study, a laboratory algal productivity analysis was conducted by PA DEP. The study concluded that the limiting nutrient for periphyton growth in all reaches was phosphorus. Also, the Davis study concluded that contributions of phosphorus from wastewater dischargers in the study reaches had a significant impact on downstream phosphorus concentrations and periphyton biomass. The water quality model was formulated based on the Davis (1998) study and supports the conclusions of that study.

1. Findings of Thomas W. Gallagher

(a) *Literature and field studies indicate that limiting nutrient levels for periphyton growth due to phosphorus range from 5 to 50 ug/L, far lower than ambient TP levels found during various studies used to develop the TMDL.*

Response: No reference was provided for this statement. Site-specific field studies in the Christina River Basin (Davis 1998) indicate that limiting phosphorus levels for periphyton growth are greater than 0.100 mg/L.

(b) *The periphyton predictions in the model are not credible. Given the level of phosphorus in the TMDL and alternative scenarios, there should be no significant effect on periphyton biomass under low flows or increased loadings.*

Response: Given the fact that the site-specific phosphorus half-saturation constant was estimated as 0.132 mg/L, the increased phosphorus loadings from DARA cause a predictable increase in periphyton biomass and diel DO range downstream of DARA.

(c) *The predicted changes in DO associated with phosphorus loading for the TMDL and alternative scenarios are unrealistic, inconsistent with the literature, and inconsistent with site-specific analysis of the East Branch Brandywine Creek.*

Response: Site-specific diel DO measurements were made during the 1997 field study (Davis 1998). These DO measurements are shown in Figure 9-17 in the model report. The measured DO swing downstream of DARA is about 6 to 7 mg/L, and the diel DO swing upstream of DARA is about 2 mg/L. As one can see from Figure 9-17, the water quality model provides a reasonable projection of these diel DO swings. The site-specific data collected in 1997 provides evidence that increased nutrients from the DARA discharge are stimulating periphyton growth and the diel DO swing. The fact that the model projects this diel DO swing indicates that the periphyton kinetics formulated in the model are realistic.

(d) *The model used a phosphorus Michaelis constant for periphyton of 132 ug/L, over 100 times greater than that for suspended algae (without any scientifically defensible justification), and compensated for this by modifying the carbon:chlorophyll ratio to match the diurnal variation during the calibration period. The same data fit could have been obtained using more realistic model coefficients and would not have had unrealistic periphyton growth projections.*

Response: The Michaelis constant (i.e., phosphorus half-saturation constant) of 0.132 ug/L was derived from a field study conducted during August 1997 (Davis 1998). The commentor may not understand the use of the carbon-to-chlorophyll ratio in the water quality model. Algal biomass is computed in the model in units of carbon. The carbon-to-chlorophyll ratio has absolutely no bearing on any internal computations of algal growth or dissolved oxygen levels. The purpose of the carbon-to-chlorophyll ratio is to convert the algal biomass in carbon units to chlorophyll units for model output.

(e) *The model was developed without sufficient data to link nutrients, periphyton, and dissolved oxygen.*

Response: The model was developed based on a field data collected primarily from 1995 to 1998. In addition, a special field study conducted in 1997 (Davis 1998) to measure community photosynthetic and respiration rates in selected reaches of East Branch Brandywine Creek, West Branch Brandywine Creek, West Branch Red Clay Creek, and White Clay Creek. As part of the Davis (1998) field study, a laboratory algal productivity analysis was conducted by PA DEP. The study concluded that the limiting nutrient for periphyton growth in all reaches was phosphorus. Also, the study concluded that contributions of phosphorus from wastewater dischargers in the study reaches had a significant impact on downstream phosphorus concentrations and photosynthesis rates. The study recommended that pollution control strategies directed toward maintaining dissolved oxygen concentrations in these stream reaches should address the impact of phosphorus loads from wastewater discharges on the photosynthesis and respiration processes of instream periphyton.

2. Findings of Don Knorr

(a) *EPA's use of the information contained in Knorr and Fairchild (1987) is biased and incorrect.*

Response: The algal biomass from the 1985 field study by Knorr and Fairchild (1987) was included in Table 9-5 of the Christina Model Report to show that the predicted model periphyton was in the ball park of historical measurements.

(b) *The TMDL model predictions in the calibration report are significantly different than the data contained in Knorr and Fairchild (1987) and demonstrate that the model is inadequate for predicting periphyton biomass.*

Response: The information contained in Knorr and Fairchild (1987) was not used for calibrating the model. The information was presented as a simple side-by-side comparison of the predicted model periphyton biomass and biomass measured in the field to demonstrate that the model was computing biomass in a ballpark range consistent with historical field observations . In fact, the conditions during the 1985 field survey and the 1997 calibration periods were significantly different, so one would not expect the model biomass to exactly replicate the measurements made in 1985.

(c) *Knorr and Fairchild determined that phosphorus was not limiting to periphyton growth. This finding contradicts the TMDL model, which assumed that phosphorus was limiting periphyton at all sites.*

Response: The more recent field study conducted in August 1997 (Davis 1998) concluded that phosphorus was the limiting nutrient. Information from the 1997 field survey was used as the basis for developing periphyton kinetics in the water quality model.

(d) *The calculation error is likely due to the use of an invalid phosphorus half-saturation constant for periphyton growth. The study results suggest a half-saturation constant of 1.5 ug/L. The value used in the model is 132 ug/L, nearly 100 times higher.*

Response: The phosphorus half-saturation constant of 0.132 mg/L was derived from a site-specific laboratory algal assay study conducted in August 1997 (Davis 1998).

References

Biggs, B.J.F. 2000. New Zealand Periphyton Guideline: Detecting, Monitoring, and Managing Enrichment of Streams. Prepared for the Ministry for the Environment. 122 p. June 2000.

Davis, J.F. 1998. Measurement of Community Photosynthetic and Respiration Rates for Selected Reaches of the Christina Watershed. Prepared for Pennsylvania Department of Environmental Protection and Delaware Department of Natural Resources and Environmental Control. March 1998.

Knorr, D.F. and G.W. Fairchild. 1987. Periphyton, benthic invertebrates and fishes as biological indicators of water quality in the East Branch Brandywine Creek. *Proceedings of the Pennsylvania Academy of Science*, 61(1):61-66.