User's Guide
for
QUAL2K Dissolved Oxygen Modeling
of
Upper Oyster Creek
(Segment 1245, Assessment Units 02 & 03)

Prepared for:
TMDL Program
Texas Commission on Environmental Quality
Austin, Texas

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INTRODUCTION

Background

The Texas Commission on Environmental Quality (TCEQ) first identified the impairment to the intermediate aquatic life use for Upper Oyster Creek (Segment 1245) in the *1996 Texas Water Quality Inventory and 303(d) List* (TCEQ, 1996). The specific uses assigned to Upper Oyster Creek are contact recreation, intermediate aquatic life use, and domestic water supply. The TCEQ has assessed dissolved oxygen concentrations as being less than optimal for attainment of Segment 1245’s intermediate aquatic life use. The *2004 Texas Water Quality Inventory and 303(d) List* (TCEQ, 2004) considered six separate assessment units for the segment and reported that each assessment unit contained depressed dissolved oxygen concentrations. The 2004 inventory and list also included Segment 1245 under category 5c, which indicated that additional data would be collected before a TMDL was scheduled. Those additional data were collected in years 2003–2005. The most recently approved 303(d) list (2008) included the segment under category 5a (equivalent to the former priority ranking of “U”), indicating a TMDL is underway. The 2008 303(d) list (TCEQ, 2008) also indicated a consolidation of the number of the separate assessment units from six to three and indicated that each assessment unit contained depressed dissolved oxygen concentrations.

Two total maximum daily loads (TMDLs) for dissolved oxygen in portions of Upper Oyster Creek (Segment 1245) were developed with allocations based on predictions from a steady state, water quality model referred to as QUAL2K. The TMDLs were developed for assessment units (AUs) 1245_02 and 1245_03 with adoption by the Texas Commission on Environmental Quality (TCEQ) Commission on July 29, 2010 and approval by the U.S. Environmental Protection Agency (EPA) on September 21, 2010 (TCEQ, 2010). To address the depressed dissolved oxygen in AU 1245_01, an Aquatic Life Use-Attainability Analysis (ALUAA) was performed. The findings of the ALUAA resulted in a revision of the dissolved oxygen criteria for this AU under the 2010 Texas Water Quality Standards and TMDL development was not required.

Purpose

This report provides an overview documentation of the QUAL2K model developed for and applied to AU 1245_02 and AU 1245_03. Further, the report includes instructions to guide the user in making modification of model input data allowing the evaluation of both new wastewater treatment plants (WWTFs) and expansions of existing WWTFs. Finally, how to access relevant graphical and tabular model predictions of dissolved oxygen (DO) is provided so that results from execution of the model can be evaluated against the relevant DO criterion. Thus, this user’s guide provides the mechanism to extend the shelf life of the adopted TMDL through instructions on how to create proper input data to allow assessment of new and modified WWTFs in AUs 1245_02 and 1245_03.

OVERVIEW OF MODEL AND TMDL

Overview of QUAL2K

QUAL2K is a relatively recent model that was developed to provide a modernized version of QUAL2E, a long standing EPA supported model that cannot be operated under present personal-computer operating systems. QUAL2K is supported by EPA's Watershed and Water Quality Modeling Support Center. In Chapra et al. (2006) the model is described as containing the following characteristics. QUAL2K provides for the prediction of water quality in river and stream systems by representing the channel in a one dimensional, longitudinal manner with the assumption of vertical and lateral complete mixing. The model allows branching tributaries, provides non-uniform, steady flow hydraulics, and water quality variables are simulated on a diel time scale. An Excel workbook serves as the interface for QUAL2K. Model execution, input and output are all implemented from within Excel. Visual Basic for Applications (VBA) serves as Excel's macro language for implementing all interface functions, and numerical calculations are implemented in Fortran 90. QUAL2K version 2.06 was applied to develop this TMDL.

The technical support documents (Hauck and Bing, 2008; Hauck, 2008) and the TMDL (TCEQ, 2010) all refer to the model being QUAL2K version 2.04. Notes documenting the development and application of QUAL2K to Segment 1245 clearly indicate that the model version changed from 2.04 to 2.06 on or about May 30, 2006 when a slightly modified version of the model was received from Dr. Chapra at Tufts University. Further, the Fortran executable version of the model and the Excel workbook interface are all clearly labeled as version 2.06. In 2006 QUAL2K was still a relatively new model and the TIAER modeling team was discovering some minor errors in how the model operated. These errors were being corrected through communications between the modeling team and a graduate student of Dr. Chapra, Mr. Hua Tao, who was also a co-author of their model documentation reports (Chapra et al., 2006; Chapra et al., 2007). These interactions eventually lead to the TIAER modeling team procuring the QUAL2K version 2.06, which included the added capability of allowing the user to describe a reaeration equation of the form allowing input of the Texas reaeration equation specifically developed by a predecessor agency to TCEQ for applications in the State.

QUAL2K is a river and stream water quality model that is intended to represent a modernized version of the QUAL2E model. QUAL2K is similar to QUAL2E in the following respects as quoted directly from the QUAL2K version 2.07 documentation report (Chapra et al., 2007):

- One dimensional. The channel is well-mixed vertically and laterally.
- Branching. The system can consist of a mainstem river with branched tributaries.
- Steady state hydraulics. Non-uniform, steady flow is simulated.
- Diel heat budget. The heat budget and temperature are simulated as a function of meteorology on a diel time scale.

- Diel water-quality kinetics. All water quality variables are simulated on a diel time scale.
- Heat and mass inputs. Point and non-point loads and withdrawals are simulated.

The QUAL2K framework includes the following new elements (taken from Chapra et al. (2006) & Chapra et al. (2007)):

- Software Environment and Interface. QUAL2K is implemented within the Microsoft Windows environment. Numerical computations are programmed in Fortran 90. Excel is used as the graphical user interface. All interface operations are programmed in the Microsoft Office macro language: Visual Basic for Applications (VBA).
- Model segmentation. QUAL2E segments the system into river reaches comprised of equally spaced elements. QUAL2K also divides the system into reaches and elements. However, in contrast to QUAL2E, the element size for QUAL2K can vary from reach to reach. In addition, multiple loadings and withdrawals can be input to any element.
- Carbonaceous BOD speciation. QUAL2K uses two forms of carbonaceous BOD to represent organic carbon. These forms are a slowly oxidizing form (slow CBOD) and a rapidly oxidizing form (fast CBOD).
- Anoxia. QUAL2K accommodates anoxia by reducing oxidation reactions to zero at low oxygen levels. In addition, denitrification is modeled as a first-order reaction that becomes pronounced at low oxygen concentrations.
- Sediment-water interactions. Sediment-water fluxes of dissolved oxygen and nutrients can be simulated internally rather than being prescribed. That is, oxygen (SOD) and nutrient fluxes are simulated as a function of settling particulate organic matter, reactions within the sediments, and the concentrations of soluble forms in the overlying waters.
- Bottom algae. The model explicitly simulates attached bottom algae. These algae have variable stoichiometry.
- Light extinction. Light extinction is calculated as a function of algae, detritus and inorganic solids.
- pH. Both alkalinity and total inorganic carbon are simulated. The river's pH is then computed based on these two quantities.
- Pathogens. A generic pathogen is simulated. Pathogen removal is determined as a function of temperature, light, and settling.
- Reach specific kinetic parameters. QUAL2K allows you to specify many of the kinetic parameters on a reach-specific basis.
- Weirs and waterfalls. The hydraulics of weirs as well as the effect of weirs and waterfalls on gas transfer are explicitly included.

TMDL Application of QUAL2K

Application of QUAL2K followed the sequential steps of establishing the ability of the model of AUs 1245_02 and 1245_03 to reasonably predict dissolved oxygen and other relevant water quality parameters and, once the validity of the model was established, model operation to determine the allowable loadings of municipal WWTFs. In places within this report, AUs 1245_02 and 1245_03 will be referred to as the Upper Reach of Upper Oyster Creek, signifying that portion of Segment 1245 upstream of the lowermost dam (Dam # 3) on the creek system.

Validation of QUAL2K

A QUAL2K model was developed for the Upper Reach that represented the hydraulic, physical, biological, and chemical characteristics of AUs 1245_02 and 1245_03, major tributaries, and the WWTFs discharging into the Upper Reach (Figure 1). The model validation step establishes model reliability, acceptability, and robustness for use in developing the TMDL allocations. The QUAL2K model was developed using separate calibration and verification steps, which collectively are referred to as validation, and which can be defined as follows:

- Calibration—the first stage testing and tuning of a model to a set of observational data, such that the tuning results in a consistent and rational set of theoretically defensible input parameters.
- Verification—Subsequent testing of a calibrated model to additional observational data to further examine model validity, preferably under different external conditions from those used during calibration (Thomann and Mueller 1987).

Hence, calibration was performed as a systematic procedure of selecting model input parameters resulting in model predictions that best match observational or measured data. Within the separate verification step, the input parameters defining such things as kinetic rates were kept at the values used in the calibration step and separate sets of observational data were used for comparison purposes.

It is not the intent herein to go into the QUAL2K validation for the Upper Reach. The reader is directed to the TMDL report (TCEQ, 2010) for an overview of this validation process and to the technical support document (Hauck and Bing, 2008) for a more in-depth discussion of the validation process. However, the conclusion reached from the validation process was that the QUAL2K model of the Upper Reach provided sufficiently good predictions of all relevant water quality constituents for use in determining TMDL allocations.

Pollutant Load Allocation Process

To determine maximum allowable loadings from WWTFs in the Upper Reach, the validated QUAL2K model was applied. For this task of the pollutant load allocation, the model application was identical to a waste load evaluation process wherein the maximum allowable loading of oxygen demanding pollutants from WWTFs was determined under the critical combination of water temperature and steady-state, low flow.

The QUAL2K model of the Upper Reach was applied using the existing segmentation and kinetic rates developed during the model validation process. Applications of QUAL2K were made for low-flow conditions when minimum dissolved oxygen

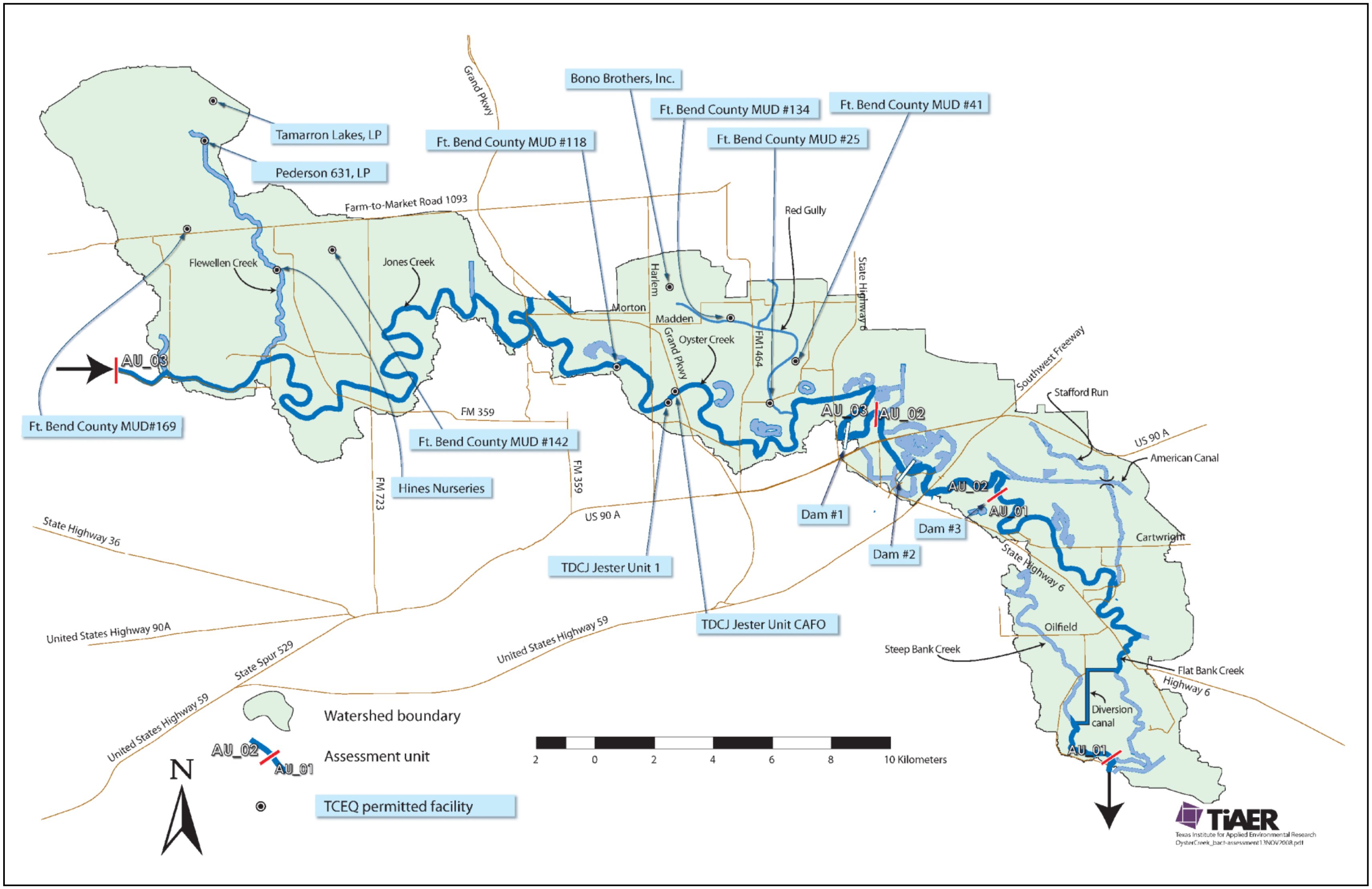


Figure 1. Entire Upper Oyster Creek (Segment 1245) showing all TCEQ permitted dischargers. The QUAL2K modeled area is west or upstream of Dam # 3 and includes the entirety of AUs 1245_02 and 1245_03; depicted as AU_02 and AU_03 on the map.

concentrations would occur. In order to properly establish the conditions for future model applications that will be assisted through this guidance manual, considerable information describing pertinent conditions follow immediately that was be taken directly from the approved TMDL (TCEQ, 2010) (Note that table numbers were changed for those in the TMDL to be consistent within this report.).

Defining Allocation Critical Flow

The specification of headwater flows in the Upper Reach was based on "Critical low-flow values for dissolved oxygen for the eastern and western Texas ecoregions" —Table 5 of SWQS (not reproduced here)—which provides for determination of critical low flow based on 24-hour average dissolved oxygen criteria and average stream bedslope (TCEQ, 2000). The critical low-flow values in the SWQS apply whenever the values are larger than the 7-day, 2-year low flow (7Q2). Therefore, values in this table and stream bedslope were used to determine the critical low flow for the main stem and tributaries to the Upper Reach of Segment 1245. Based on bedslope and survey information for the main stem provided by Fort Bend County Drainage District, the critical low flow from the SWQS was determined to be 0.085 cms (3.0 cfs) for the Upper Reach.

Critical low-flow determination for the headwater Upper Reach was, however, further complicated by the need to account for:

- the absence of gauged daily streamflow records at any location in the Upper Reach,
- the pumping of Brazos River water at the Shannon Pump Station, and
- the procedure to meet demands at the Second Lift Station when possible from rainfall runoff and to curtail pumping at the Shannon Pump Station during runoff conditions.

The absence of historical streamflow records was also encountered in developing the adopted bacteria TMDL for Upper Oyster Creek (TCEQ 2007) and addressed by applying the Soil & Water Assessment Tool (SWAT; Arnold et al. 1998) to predict daily streamflow at several locations within both the Upper Oyster Creek for the 12-year period of 1993–2004. The calibration and application of SWAT to Upper Oyster Creek is provided in Section 4–Bacteria Allocation Tool Development of the bacteria TMDL technical support document (Hauck and Du 2006).

The hydrologic predictions from application of SWAT to Upper Oyster Creek watershed were evaluated to determine the critical low flows in the Upper Reach. To determine the 7Q2 flow, the predicted daily flow data from SWAT for the period 1993–2004 were used as input for a TCEQ program developed to compute 7Q2 and harmonic means flows (7Q2HM). SWAT results for the following two locations were used:

- a location just below the Shannon Pump Station and
- a location immediately above the Second Lift Station.

The results from 7Q2HM indicated that the 7Q2 for any given year typically occurred during the fall, winter, and early spring (October–March). The 7Q2 did not coincide with the occurrence of maximum water temperatures in the system (June – September). The 7Q2 value just below the Shannon Pump Station was 0.009 cms and above the Second Lift Station was 0.117 cms. Because the 7Q2 did not occur at the same time as critical high water temperatures (i.e., during the summer), a seasonal analysis was necessary for the QUAL2K application to the Upper Reach to determine the combination of low flow and temperature that caused the lowest dissolved oxygen.

For the determination of low flows in the seasonal analysis, the 10^{th} percentile flow (i.e., the flow that is exceeded 90 percent of the time) was determined on a monthly basis using the 1993–2004 SWAT daily predictions. Critical low flow was determined for each month of the year as the greatest of the 10^{th} percentile flow for that month, the flow obtained from Table 5 of the SWQS, and the 7Q2 (Table 1). The computations indicated differences in the monthly critical low flows between the headwater (just below the Shannon Pump Station) and the outlet (near the Second Lift Station). QUAL2K was operated using the "diffuse source" option to provide the necessary water balance, which considered pumped flows, headwater flows, and the average WWTF discharges used in the SWAT model.

Defining Allocation Critical Water Temperature

To perform the seasonal analysis, monthly water temperatures also needed to be considered. All available historical water temperature data for Segment 1245_02 and 1245_03 were obtained from the TCEQ water quality database for the period 1988 - 2006. For station 12083 in the immediate vicinity of the formerly operating Imperial Sugar facility, temperature data prior to 1996 were excluded from subsequent analyses. Prior to 1996, Imperial Sugar discharged heated effluent into Oyster Creek, which would have improperly biased data in the vicinity of this discharge.

The seasonal analysis of temperature followed TCEQ guidance. The guidance requires that a single, reasonable value be computed to represent the temperature for the three months with highest temperatures and that a reasonable high temperature be determined for each of the remaining nine months. The resulting critical water temperatures, which are defined as the monthly 90^{th} percentile temperatures (i.e., the temperature that is exceeded 10 percent of the time for the month being evaluated) except for the three hottest months, are provided with footnote explanations in Table 2.

Defining WLA and LA Inputs

The municipal WWTFs were represented in the input data to QUAL2K at full permitted discharge and at existing permit limits for NH_3-N, $CBOD_5$, and dissolved oxygen (Table 3). TCEQ's default multiplier of 2.3 was employed to convert $CBOD_5$ to ultimate CBOD (CBODu) as needed for input to QUAL2K. Total phosphorus (total-P) in effluent was assumed to be 5 mg/L for all facilities, which was considered a somewhat conservative number since the highest total-P concentration measured during the intensive surveys for model validation was 4.3 mg/L and most facilities were discharging between about 3.5 and 4.0 mg/L of total-P.

Based on the intensive survey data for the WWTFs, 94 percent of the total-P was considered to be in the soluble form as orthophosphate phosphorus (PO_4-P) and the remainder as organic-P. Organic-N and nitrite + nitrate nitrogen (NO_2+NO_3-N) effluent concentrations were based on TCEQ guidance for estimating these constituents using permitted values of $CBOD_5$ and NH_3-N. Several recent facilities in the Upper Reach have polishing ponds. Polishing ponds have been evaluated by TCEQ to produce effluent from the ponds that is at background levels of CBOD and NH_3-N with dissolved oxygen at approximately 5 mg/L (personal communications with Mr. Mark Rudolph, P.E., TCEQ, June 2007).

Table 1. Monthly headwater and diffuse sources flows information for Upper Reach

All flows in units of cubic meters/second (cms)

Location	Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Headwater	10th percentile flow	0.014	0.026	0.016	0.146	0.392	1.247	2.463	2.546	0.072	0.016	0.011	0.012
	Critical low flow [maximum of Table 5 (0.085 cms), 7Q2 (0.009 cms) and 10th percentile flow]	0.085	0.085	0.085	0.146	0.392	1.247	2.463	2.546	0.085	0.085	0.085	0.085
2nd Lift Station [1]	10th percentile flow	0.019	0.010	0.004	0.666	1.045	2.109	2.601	2.420	0.999	0.050	0.032	0.021
	Critical low flow [maximum of Table 5 (0.085 cms), 7Q2 (0.117 cms) and 10th percentile flow]	0.117	0.117	0.117	0.666	1.045	2.109	2.601	2.420	0.999	0.117	0.117	0.117
Diffuse Sources [2]	Computed by water balance [3]	-0.097	-0.096	-0.097	0.390	0.524	0.739	0.014	-0.246	0.794	-0.089	-0.090	-0.091

Notes: [1] The 2nd Lift Station withdrawal location is used to define the most downstream location for critical flow determination, though physically the most downstream location is at Dam #3.

[2] Negative diffuse sources flow is an abstraction or withdrawal.

[3] Water balance considered flow at the 2nd Lift Station less headwater flow at Shannon Pump Station less headwater flows from Flewellen Creek and Red Gully less average WWTF discharges used in SWAT.

Table 2. Monthly water temperature information for Upper Reach

Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average (°C) [a]	12.5	15.3	19.9	23.1	26.8	29.6	29.8	30.1	28.9	24.2	19.7	14.3
Standard Deviation (°C)	3.4	2.7	2.1	2.2	2.6	1.5	2.0	1.7	1.9	2.5	2.8	4.3
Sample Size (n)	41	62	36	39	99	64	70	129	30	31	50	41
90th percentile (°C) [b]	16.9	18.8	22.6	26.0	30.2	N/A	N/A	N/A	31.4	27.5	23.3	19.9
3 hottest months temperature (°C)						31.6 [c]						

Notes:

[a] Water temperature data are for Segment 1245 for years 1988-2006 obtained from the TCEQ web site <www.tceq.state.tx.us/compliance/monitoring/crp/data/samplequery.html>.

[b] 90th percentile estimated using Avg + STD x t-value assuming a normal or t-distribution using a one-tailed test.

[c] Calculated using Avg of months 6, 7 and 8 + Avg of their STD values, and the 3 hottest months (6, 7, 8) are selected by the 90th percentile temperature.

Table 3. Permitted facilities, existing permit limits, and related information for the Upper Reach of Upper Oyster Creek watershed **(Note: This table of permitted facilities represents active dischargers at the time of TMDL development. Because of ongoing urbanization in the watershed, this list is dated and incomplete.)**

TCEQ Permit No. / EPA Permit No.	Facility Name & Location [1] (Assessment Unit- AU)	Monthly Average Discharge 2005-2007 (MGD)	Final Permitted Discharge (MGD)	5-Day CBOD (mg/L)	Total Suspended Solids (mg/L)	Ammonia-N (mg/L)	Dissolved Oxygen (mg/L)	Polishing Pond (Yes Or No)
WQ0012003-001 TX0077178	Fort Bend County MUD # 25 **(AU_03)**	0.781	1.6	5.0	5.0	1.0	5.0	No
WQ0012475-001 TX0089249	Fort Bend County MUD # 41 **(AU_03)**	0.306	0.50	10.0	15.0	3.0	5.0	No
WQ0013951-001 TX0116386	Fort Bend County MUD # 118 **(AU_03)**	0.214	1.2	5.0	12.0	1.5	5.0	No
WQ0014715-001 TX0128791	Fort Bend County MUD # 134 **(AU_03)**	— [2]	0.30	7.0	15.0	2.0	4.0	Yes
WQ0014408-001 TX0125555	Fort Bend County MUD # 142 **(AU_03)**	0.102	1.2	5.0	5.0	2.0	6.0	Yes
WQ0014758-001 TX0129216	Pederson 631, LP **(AU_03)**	0.027	0.60	10.0	15.0	2.0	6.0	Yes
WQ0014692-001 TX0128635	Tamarron Lakes, LP **(AU_03)**	— [2]	0.8	7.0	15.0	1.0	5.0	Yes
WQ0011475-001 TX0031674	TDCJ Jester Unit # 1 – WWTF **(AU_03)**	0.210	0.315	10.0	15.0	3.0	5.0	No
WQ0014745-001 TX0129119	Fort Bend County MUD # 169 (formerly TMI, Inc.) **(AU_03)**	— [2]	0.50	10.0	15.0	3.0	6.0	Yes

Notes: NA = Not applicable; MGD = million gallons per day; 5-Day CBOD = five-day carbonaceous biochemical oxygen demand.

[1] List of permits at time document was originally drafted (November 2008).

[2] No monitored discharge information available for this facility when the TMDLs were developed.

The facilities with polishing ponds are indicated as such in the last column of Table 3. For modeling purposes, the effluent from facilities with polishing ponds was assigned background concentrations for ultimate CBOD and NH_3-N, organic-N of 1 mg/L, and a chlorophyll-α concentration of 79.2 µg/L. The chlorophyll-α selected was the average of the chlorophyll-α concentration measured at the outfall from the holding pond of Quail Valley UD WWTF during the two model support surveys in the Lower Reach. This chlorophyll-α value was used because the facilities with polishing ponds in the Upper Reach were not operational during the intensive surveys conducted for this project. The Quail Valley facility uses a pond that is similar to those ponds, and gave the best available measured data for this study. To be conservative and in lieu of any information, NO_2+NO_3-N and PO_4-P were left at high concentrations assuming no nutrient removal by the ponds.

The mainstem headwater and diffuse source input flow data to QUAL2K to define LA contributions were defined as previously discussed in the section titled "Defining Allocation Critical Flow." Tributary headwater flows were defined in the models based on the critical low flow determined from the SWQS (see Table 4). Headwater water quality input data for the mainstem and tributaries of the Upper Reach were obtained from various sources. For ultimate CBOD (CBODu), organic nitrogen, NH_3-N, nitrite plus nitrate nitrogen (NO_2+NO_3-N), dissolved oxygen as percent saturation (DO % saturation), and chlorophyll-α (Chla), the default background concentrations used in TCEQ waste load evaluations were specified unless adequate (i.e., more than a couple of data points) site specific information were available. Portions of the necessary water quality data from the headwaters of the mainstem of the Upper Reach were obtained from monitoring stations in the Brazos River in proximity to the Shannon Pump Station. The Brazos River water quality data were obtained from the TCEQ Surface Water Quality Monitoring Information System (SWQMIS) database.

The default background concentration for total phosphorus of 0.02 mg/L was separated as required in QUAL2K into organic P and PO_4-P components based on ratios determined from survey data sets for model validation and water quality data for the Brazos River. The headwater water quality input for QUAL2K is summarized in Table 5. Flewellen Creek is not included in Table 5, because no headwater flow contribution is associated with this tributary. Diffuse sources were given the same water quality characteristics as Red Gully (Table 5).

Table 4. Tributaries to Upper Reach, designated aquatic life use, bedslope, critical low flow, and dissolved oxygen (DO) criteria

Tributary Name	Designated Aquatic Life Use	Bedslope (m/km)	Critical Low Flow (cms)	General 24-hour Average/Minimum DO Criteria (mg/L)	Spawning-Season 24-hour Avg/Minimum DO Criteria (mg/L)
Flewellen Cr.	No Significant	1.1	0.0000	2 / 2	2 / 2
Red Gully	Intermediate	0.1[a]	0.0850	4 / 3	5 / 4

[a] The bedslope of 0.1 m/km used for Red Gully to determine the critical low flow from Table 5 of TNRCC (2000) is not the actual average bedslope of the creek, but rather reflects the constant backwater effects from Oyster Creek that greatly reduces the effective slope of the lower portion of Red Gully where DO minimums occur. This approach represents the same manner in which TCEQ has accounted for the backwater effect on Red Gully in waste load evaluations.

Table 5. Headwater water quality input to QUAL2K for mainstem, tributaries, and diffuse sources. [Note: Flewellen Creek has no headwater flow (see Table 4) and is not included in this table.]

Constituent	Upper Reach Headwater	Red Gully	Diffuse Sources
DO (% sat.)	80	80	80
CBODu (mg/L)	3.0	3.0	3.0
Organic-N (mg/L)	0.5	0.5	0.5
NH_3-N (mg/L)	0.05	0.05	0.05
NO_2+NO_3-N (mg/L)	0.585	0.200	0.200
Organic-P (mg/L)	0.021	0.019	0.019
PO_4-P (mg/L)	0.025	0.001	0.001
Chla (µg/L)	2 / 8.7 [a]	2	2

[a] The chlorophyll-α data for the Brazos River in the vicinity of the Shannon Pump Station showed a seasonal component, though no other input parameters exhibited this characteristic for the Brazos River. Based on analysis of these data, a concentration of 2 µg/L of chlorophyll-α was used for the months of November through April and a concentration of 8.7 µg/L for May through October.

Allowance for Future Growth

The allowance for future growth specified in the TMDL provides a basis for some of the common application of the QUAL2K model of AUs 1245_02 and 1245_03 that may be required. The entire text on Allowance for Future Growth" from the TMDL (TCEQ, 2010) is provided for ease of reference:

> The TMDL allocations for 1245_02 and 1245_03 of the Upper Reach do not preclude nor prevent consideration of expansions to WWTFs and addition of new WWTFs. Any expansions and additional facilities need to be evaluated on a permit-by-permit basis. This evaluation will be conducted through the appropriate QUAL2K model or an updated replacement model. Additional allowable loadings, if any, under new permits and amendments for permit expansions will be determined subject to the outcome of the modeling and predicted dissolved oxygen concentrations using information specific to each WWTF as well as the QUAL2K analysis that supports these TMDLs. For this reason, an explicit value for the allowance for future growth cannot be assigned for an entire assessment unit or segment.
>
> Further, the TMDL allocations are not intended to restrict or limit the GCWA pumping of Brazos River water into the Upper Reach at the Shannon Pump Station and associated

loadings of NH3-N and CBOD5. Based on QUAL2K seasonal-analysis results for the Upper Reach (Table 8; *table not provided in this report*), a comparison can be made of model-predicted minimum 24-hour average dissolved oxygen concentrations for June – August to the minimum dissolved oxygen concentrations for September.

Both sets of predictions were made with comparable model inputs except for headwater inflow. This comparison indicates that higher dissolved oxygen concentrations occur under the higher pumping rates experienced in the June – August scenario than the lower rates in September. These QUAL2K results indicate that any future increases to the critical headwater pumped flows from the Brazos River due to increased water demands on the GCWA system should improve dissolved oxygen conditions in the Jones Creek/Oyster Creek portion of the Upper Reach.

The three-tiered antidegradation policy in the water quality standards prohibits an increase in loading that would cause or contribute to degradation of an existing use. The antidegradation policy applies to both point and nonpoint source pollutant discharges. In general, antidegradation procedures establish a process for reviewing individual proposed actions to determine if the activity will degrade water quality. The TMDLs in this document will result in protection of existing beneficial uses and conform to Texas' antidegradation policy.

OPERATING THE QUAL2K MODEL

Setting Up and Running QUAL2K

QUAL2K uses an Excel workbook as the interface for both input to the model and output from the model. Numerical computations are implemented in Fortran 90 through an executable file. Both the workbook and executable must be in the same directory for the model to run. These two files have the following names:

- Excel Workbook: **UOC_QUAL2K_v2.06.xlsm**
- Fortran 90 Executable: **Q2KFortran2_06.exe**

It should be noted that in executing the model, some additional files are automatically created to exchange information with the Excel workbook. The Excel workbook, Fortran executable, and all model input files listed in Table 6 are provided with the initial submission of this manual.

Step 1: Create a directory (e.g., **C:\QUAL2K**) to contain the Excel Workbook (**UOC_QUAL2K_v2.06**) and Fortran 90 executable (**Q2KFotran2_06.exe**). For this example, the directory is called QUAL2K (i.e., **C:\QUAL2K**).

Step 2: Create a subdirectory to contain data input files. For this example the subdirectory is called **UOC_DataFile**. (i.e., **C:\QUAL2K\UOC_DataFiles**).

Step 3: The names of the QUAL2K input files used in developing the TMDL allocation are provided Table 6. Move a copy of all input files into subdirectory **C:\QUA2K\UOC_DataFiles**.

Table 6. QUAL2K input file names and description from development of the TMDL allocation (the file name of the critical September condition used in TMDL allocation development is highlighted in yellow).

File Name	Description
UOC_Upper_Mon1.q2k	Critical conditions for January
UOC_Upper_Mon2.q2k	Critical conditions for February
UOC_Upper_Mon13_spawning.q2k	Critical conditions for March (spawning temperatures)
UOC_Upper_Mon4.q2k	Critical conditions for April
UOC_Upper_Mon5.q2k	Critical conditions for May
UOC_Upper_Mon678_Hottest3.q2k	Critical conditions for 3 hottest months (June-August)
UOC_Upper_Mon9_High_T.q2k	Critical conditions for September (Critical TMDL case)
UOC_Upper_Mon10.q2k	Critical conditions for October
UOC_Upper_Mon11.q2k	Critical conditions for November
UOC_Upper_Mon12.q2k	Critical conditions for December

Step 4: Make sure copies of the workbook, Fortran executable, and all input files are kept in a separate location as a back-up of original files. In the event that files become modified or corrupted, these files will allow reinstallation of model functionality.

Step 5: Open Microsoft Excel 2007 and make sure the macro security level is set at the proper setting. To set the security level, left click on the **Excel Office Button** (extreme upper left of screen); next click on **Excel Options**; then click on **Trust Center**; then **Trust Center Settings**; then to **Macro Settings**; and select the following level [**Disable all macros except digitally signed macros**] (Figure 2). (**Note:** Based on our experiences, the required security setting level to allow execution of QUAL2K has been the source of some inconsistency under Microsoft Office 2007. It may be necessary to use the lowest security setting in Excel [**enable all macros**…] on your system for the program to execute.)

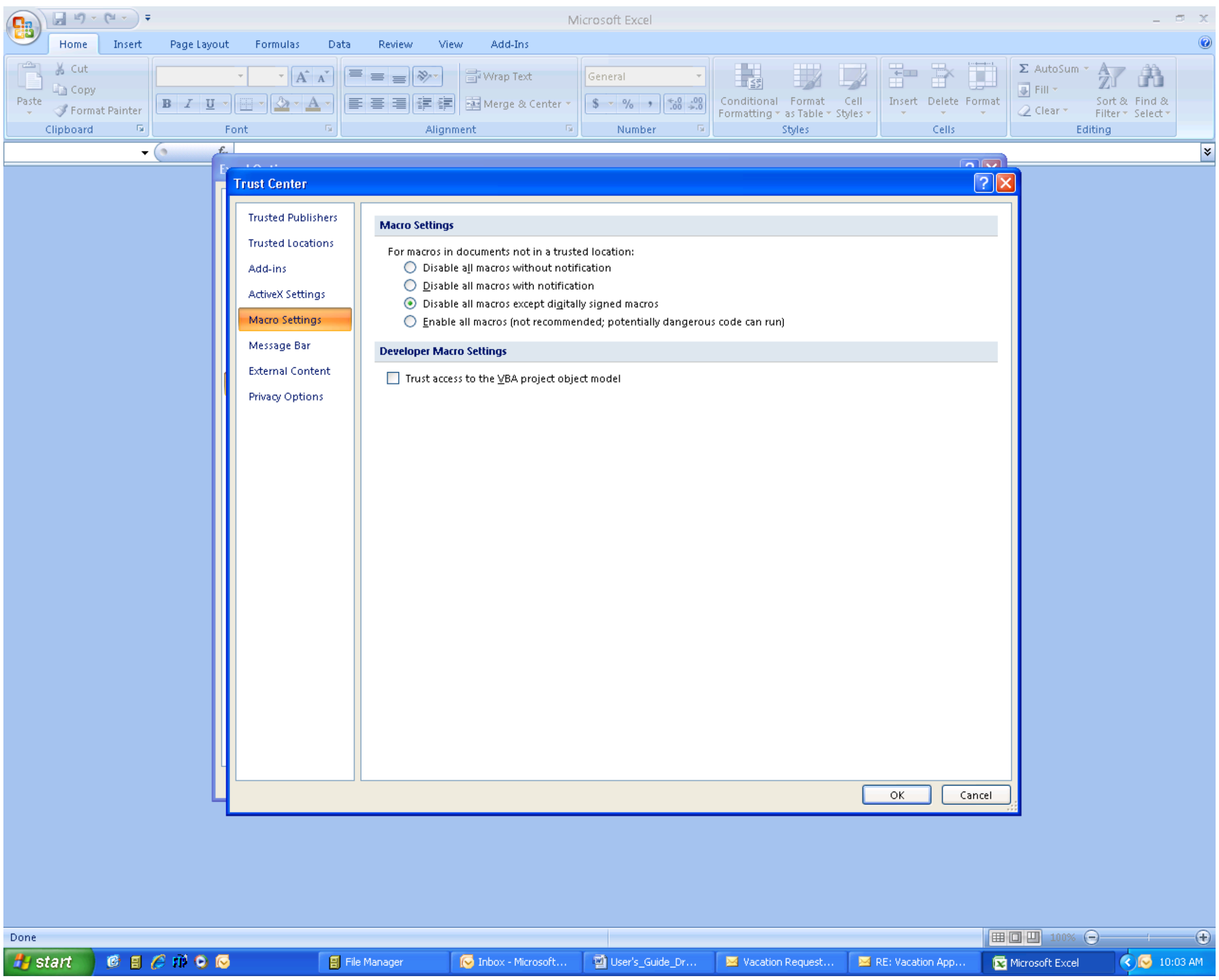


Figure 2. The Excel Trust Center dialogue box. In order to run QUAL2K, the level of security enabling digitally signed macros is required. If the model fails to execute at this security level, try the lowest level of security enabling all macros.

Step 6: Open **UOC_QUAL2K_v2.06.xslm.** Depending on how your Excel program is set a dialogue box might open with a security warning regarding the macros in the Excel file. For the model to execute, you must enable macros. (**Note: UOC_QUAL2K_v2.o6.xslm** is preloaded with the input data from file **UOC_Upper_Mon9_High_T.q2k**, the critical TMDL condition.)

Step 7: Go to the first worksheet in **UOC_QUAL2K_v2.06.xslm**, which will have the name **QUAL2K**, and go to **cell B10** and make sure that the path is set to where you want data files to be located that are used in program execution. The path is set in **cell B10** as described in the steps above: **C:\QUAL2K\UOC_DateFiles** as show in Figure 3.

Step 8: For this example, change the name in **Cell B9** to **Practice_Operation** (Figure 3).

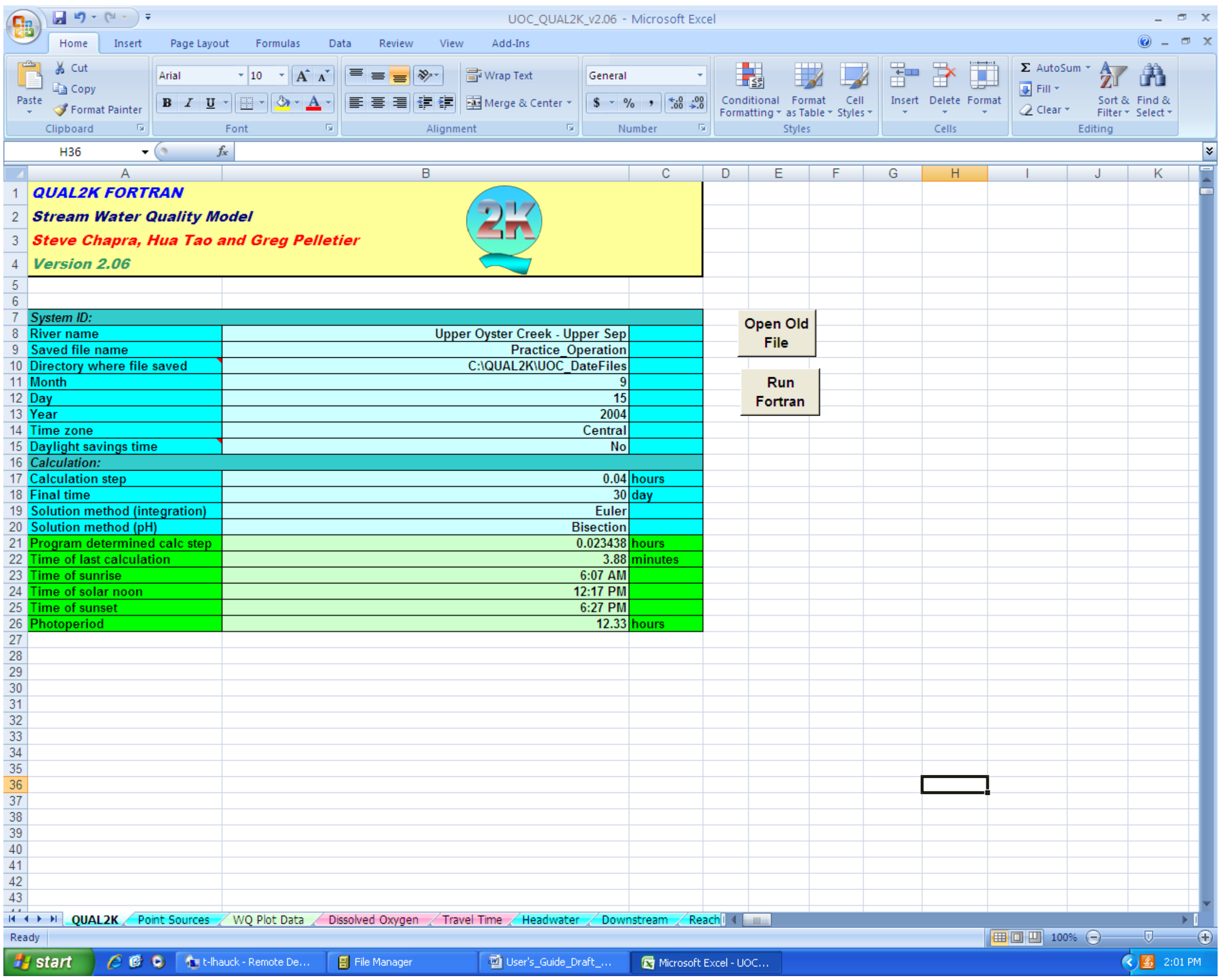


Figure 3. **Worksheet QUAL2K** showing the file path in **Cell B10**

Step 9: Click the **Run Fortran** button to initialize program execution.

If the program does not work correctly, the most common error is that the file path in **cell B10** was mistyped or does not exist (Figure 4). Enter correct file path if this is error occurs.

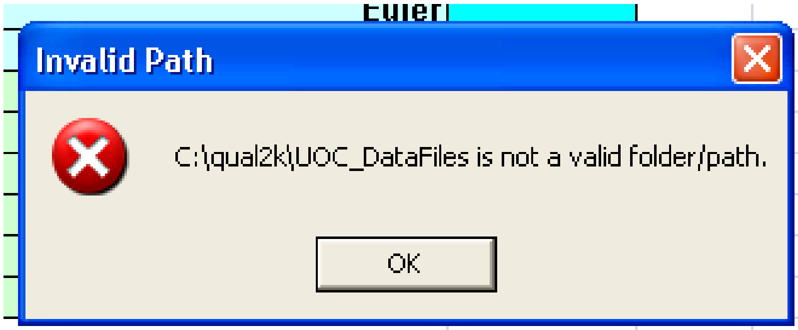


Figure 4. Error message that occurs if the file path in **cell B10** is in error or does not exist.

If the program works correctly a window will open showing progress of the Fortran computations (Figure 5).

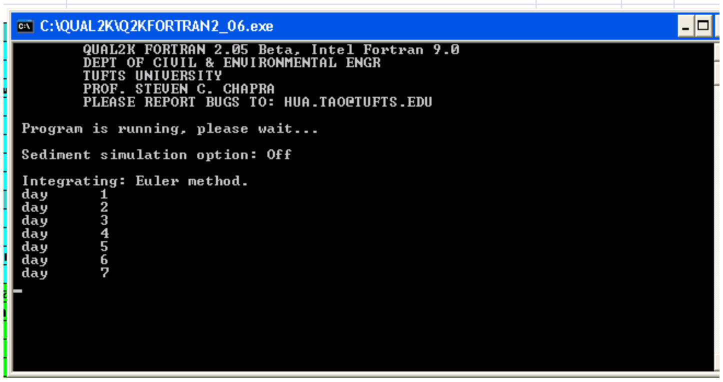


Figure 5. Window displayed when model computations are being executed in Fortran. The model is set to run for 30 days to allow stabilization of algae growth. Note that line 1 in the display box indicates that QUA2L version 2.05 is being run. Version 2.06 was obtained from Dr. Chapra to allow inclusion of the Texas reaeration equation, and this banner was not updated with that version of release. We are running a limited release version.

The QUAL2K model of the Upper Reach is set to operate for 30 simulated days. This period of time allows the periphytic algae or bottom algae to reach an equilibrium biomass. After the window counts down all 30 days, several seconds will transpire before a dialogue box appears indicating successful execution of the program (Figure 6).

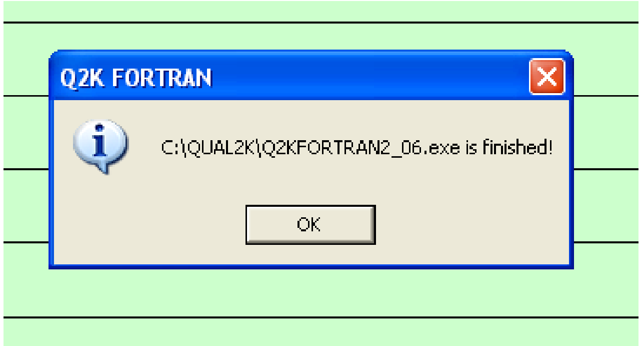


Figure 6. Dialogue box after a successful model simulation

Left clicking on the **OK** button in the box will bring up another dialogue box (Figure 7), which directs the Excel plots of physical and water quality constituents by water body. The default is for the main stem (AUs 1245_02 and 1245_03).

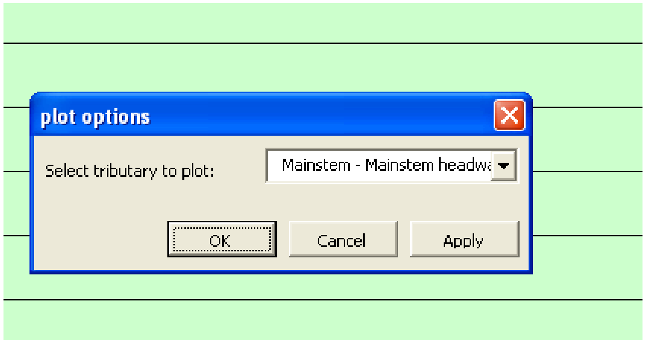


Figure 7. Dialogue box that determines the tributary displayed in the water quality plots.

Pressing the down-arrow pulldown in the box displays the three options for the plots in this application—Mainstem, tributary 1 (Flewellen Creek), and tributary 2 (Red Gully); (Figure 8).

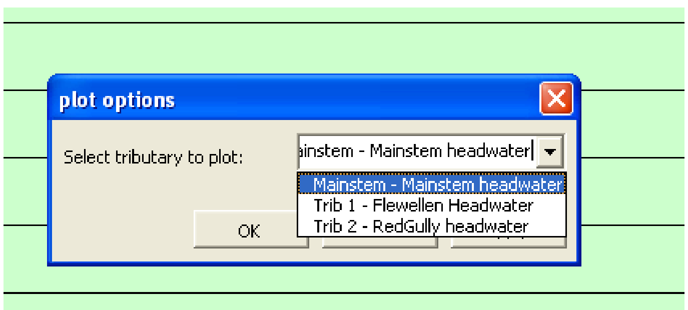


Figure 8. Display of three options for plots

Choosing either the **OK** or **Apply** button will activate development of plots for the selected water body; however, only clicking on **OK** will remove the dialogue box to allow other activities to occur within the workbook.

To switch the plots from one water body to another, press the button in the upper left corner of any plot (Figure 9), which will cause the plot options dialogue box to be re-displayed.

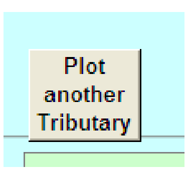


Figure 9. Switch to develop plots for another water body

Step 10: Return to **Worksheet QUAL2K** (Figure 3) and click on the **Open Old File** button. Browse to get to the directory: **C:\QUAL2K\UOC_DataFiles**. A new file will have been created with the name specified in **Cell B9**, which for the display in Figure 3 would be named:

Practice_Operation
Click on the **Cancel** button to return to **Worksheet QUAL2K**.

CAUTION: Every time that QUAL2K is run, a data file with the extension "q2k" will be generated with the file name specified in **Cell B9** of **Worksheet QUAL2K** (Figure 3). Running the program will overwrite the previous version of the file with the name in **Cell B9**. If you do not want the previous file overwritten, the file name must be changed in **Cell B9**.

Now that you can run the QUAL2K model, the next section is devoted to the results generated from operating the model.

Graphical and Tabular Output

The Excel **Workbook UOC_QUAL2K_v2.06** contains both tabular and graphical output of a completed run of QUAL2K in separate worksheets (Tables 7 and 8). Each worksheet listed in Table 7 provides tabular results with model predicted parameters in columns and each row representing an element, and each worksheet in Table 8 provides a longitudinal plot of a parameter. For the graphical results, only one water body is shown at a time (main stem, Flewellen Creek, or Red Gully) and a different water body is plotted by clicking on the box **Plot Another Tributary** (Figure 9).

Table 7. List and description of worksheets containing tabular results of QUAL2K model output.

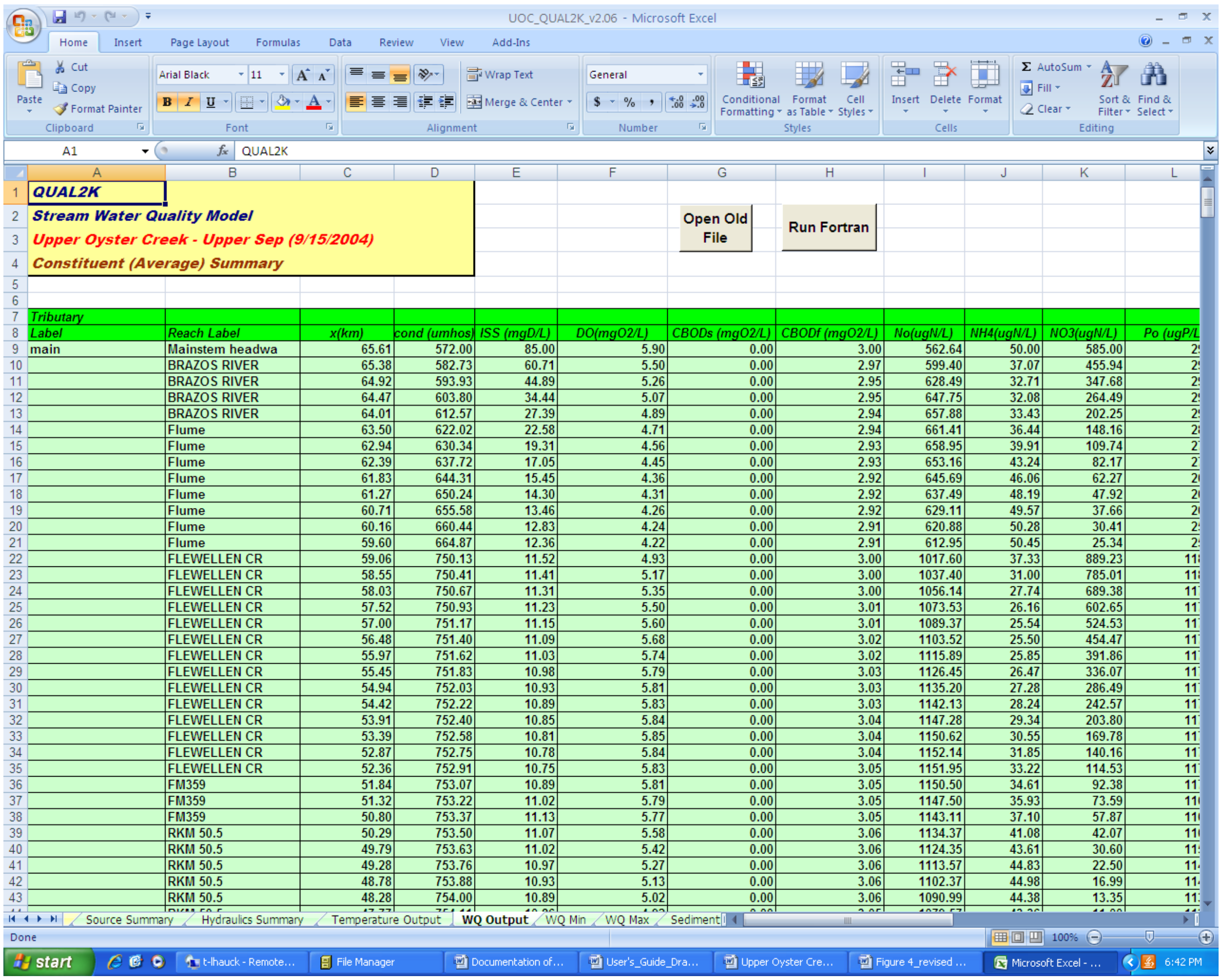
Worksheet Name	Description
WQ Output	Daily average water quality concentrations by model element
Source Summary	Flow of inflows and abstractions; water quality of inflows, all by model element
Hydraulic Summary	Hydraulics and reaeration by model element
Temperature output	Average, minimum, and maximum temperature by model element
WQ Min	24-hour minimum water quality results by model element
WQ Max	24-hour maximum water quality results by model element
Sediment Fluxes	SOD and nutrient fluxes by model element
Diel Output	Detailed time series of water quality results at user specified location (element)

Table 8. List of worksheets containing longitudinal graphical results of QUAL2K model output. (Where applicable the plots contain 24-hour average, minimum and maximum values)

Dissolved Oxygen	Flow	Velocity	Depth
Reaeration	Temperature	Conductivity	ISS
Detritus	CBOD slow	CBOD fast	CBODu
Organic N	NH4	NO3	Organic P
Inorganic P	Phytoplankton	Bottom Algae mgA per m2	Bottom Algae mgC per m2
Alkalinity	pH	Pathogens	NH3
Total N	Total P	TSS	SOD
CH4 Sed Flux	NH4 Sed Flux	NO3 Sed Flux	Inorganic P Sed Flux

As evident from the listed worksheets in Tables 7 and 8, the presentation of results is extensive and includes some information that are superfluous to the dissolved oxygen assessment. In particular the QUAL2K model for Upper Oyster Creek was not calibrated for alkalinity, pH, and pathogens so results for those three constituents should be ignored. The model was operated using the option that did not simulate slow carbonaceous biochemical oxygen demand (CBOD slow). Finally, QUAL2K provides predictions of both 24-hour average and minimum DO, though the TMDL addresses only average DO concentrations. While the model was validated for 24-hour minimum DO concentrations, under the construct of the TMDL only the 24-hour average DO concentrations should be considered when evaluating permitted dischargers.

For decisions by the user regarding 24-hour average dissolved oxygen the most pertinent model outputs are found in the worksheet of tabular results (**Worksheet WQ Output**) and the worksheet containing the longitudinal plot of dissolved oxygen results (**Worksheet Dissolved Oxygen**). **Worksheet WQ Output** contains far too many rows and columns to be provided in a legible form in this manual; however, an excerpt is provided in Figure 10 for Upper Oyster Creek AUs 1245_01 and 1245_02 representing the critical September conditions.



Tributary Label	Reach Label	x(km)	cond (umhos)	ISS (mgD/L)	DO(mgO2/L)	CBODs (mgO2/L)	CBODf (mgO2/L)	No(ugN/L)	NH4(ugN/L)	NO3(ugN/L)
main	Mainstem headwa	65.61	572.00	85.00	5.90	0.00	3.00	562.64	50.00	585.00
	BRAZOS RIVER	65.38	582.73	60.71	5.50	0.00	2.97	599.40	37.07	455.94
	BRAZOS RIVER	64.92	593.93	44.89	5.26	0.00	2.95	628.49	32.71	347.68
	BRAZOS RIVER	64.47	603.80	34.44	5.07	0.00	2.95	647.75	32.08	264.49
	BRAZOS RIVER	64.01	612.57	27.39	4.89	0.00	2.94	657.88	33.43	202.25
	Flume	63.50	622.02	22.58	4.71	0.00	2.94	661.41	36.44	148.16
	Flume	62.94	630.34	19.31	4.56	0.00	2.93	658.95	39.91	109.74
	Flume	62.39	637.72	17.05	4.45	0.00	2.93	653.16	43.24	82.17
	Flume	61.83	644.31	15.45	4.36	0.00	2.92	645.69	46.06	62.27
	Flume	61.27	650.24	14.30	4.31	0.00	2.92	637.49	48.19	47.92
	Flume	60.71	655.58	13.46	4.26	0.00	2.92	629.11	49.57	37.66
	Flume	60.16	660.44	12.83	4.24	0.00	2.91	620.88	50.28	30.41
	Flume	59.60	664.87	12.36	4.22	0.00	2.91	612.95	50.45	25.34
	FLEWELLEN CR	59.06	750.13	11.52	4.93	0.00	3.00	1017.60	37.33	889.23
	FLEWELLEN CR	58.55	750.41	11.41	5.17	0.00	3.00	1037.40	31.00	785.01
	FLEWELLEN CR	58.03	750.67	11.31	5.35	0.00	3.00	1056.14	27.74	689.38
	FLEWELLEN CR	57.52	750.93	11.23	5.50	0.00	3.01	1073.53	26.16	602.65
	FLEWELLEN CR	57.00	751.17	11.15	5.60	0.00	3.01	1089.37	25.54	524.53
	FLEWELLEN CR	56.48	751.40	11.09	5.68	0.00	3.02	1103.52	25.50	454.47
	FLEWELLEN CR	55.97	751.62	11.03	5.74	0.00	3.02	1115.89	25.85	391.86
	FLEWELLEN CR	55.45	751.83	10.98	5.79	0.00	3.03	1126.45	26.47	336.07
	FLEWELLEN CR	54.94	752.03	10.93	5.81	0.00	3.03	1135.20	27.28	286.49
	FLEWELLEN CR	54.42	752.22	10.89	5.83	0.00	3.03	1142.13	28.24	242.57
	FLEWELLEN CR	53.91	752.40	10.85	5.84	0.00	3.04	1147.28	29.34	203.80
	FLEWELLEN CR	53.39	752.58	10.81	5.85	0.00	3.04	1150.62	30.55	169.78
	FLEWELLEN CR	52.87	752.75	10.78	5.84	0.00	3.04	1152.14	31.85	140.16
	FLEWELLEN CR	52.36	752.91	10.75	5.83	0.00	3.05	1151.95	33.22	114.53
	FM359	51.84	753.07	10.89	5.81	0.00	3.05	1150.50	34.61	92.38
	FM359	51.32	753.22	11.02	5.79	0.00	3.05	1147.50	35.93	73.59
	FM359	50.80	753.37	11.13	5.77	0.00	3.05	1143.11	37.10	57.87
	RKM 50.5	50.29	753.50	11.07	5.58	0.00	3.06	1134.37	41.08	42.07
	RKM 50.5	49.79	753.63	11.02	5.42	0.00	3.06	1124.35	43.61	30.60
	RKM 50.5	49.28	753.76	10.97	5.27	0.00	3.06	1113.57	44.83	22.50
	RKM 50.5	48.78	753.88	10.93	5.13	0.00	3.06	1102.37	44.98	16.99
	RKM 50.5	48.28	754.00	10.89	5.02	0.00	3.06	1090.99	44.38	13.35

Figure 10. Snapshot of **Worksheet WQ Output** for the critical condition scenario of September.

For the September conditions, the longitudinal plot of dissolved oxygen for the main stem of Upper Oyster Creek from **Worksheet Dissolved Oxygen** is provided in Figure 11.

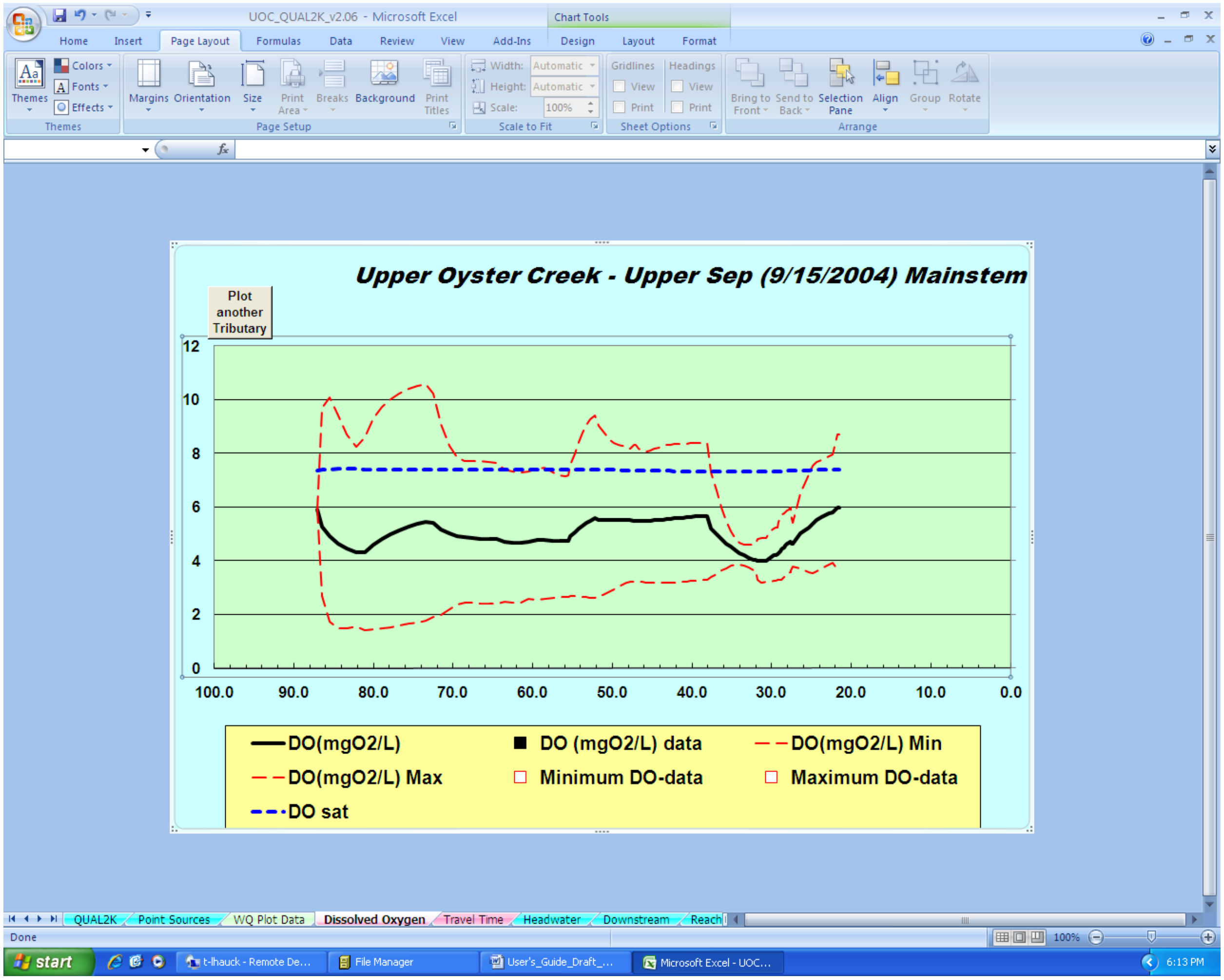


Figure 11. Dissolved oxygen plot for Main Stem of Upper Oyster Creek representing the critical condition scenario of September (Worksheet Dissolved Oxygen).

While the graphical representations available in the workbook that can be generated separately for the main stem of Upper Oyster Creek, Flewellen Creek, and Red Gully are useful, ultimately evaluations may require review and evaluation of the actual predicted DO concentration found in tabular form in **Worksheet WQ Output**. In developing the TMDL, it was found useful to cut & paste relevant columns from **Worksheet WQ Output** into a separate Excel Workbook for additional post processing, including locating the minimum 24-hour average dissolved oxygen concentration by water body.

Input File and Tabular Input

As discussed previously, for this exercise of applying the existing QUAL2K model of the Upper Reach (AUs 1245_02 and 1245_02), the input files already exist to operate the model for the seasonal analysis. These input files should be stored both in a secure backup location in case a file mistakenly gets overwritten or becomes corrupted and also in directory: **C:\QUAL2K\UOC_DataFiles**. How to modify model input will be the subject of the next chapter, but for now the purpose is to familiarize the user with the basic input structure.

By going to **Worksheet QUAL2K** and pressing the **Open Old File** button, the user can browse to bring in an input file from directory: **C:\QUAL2K\UOC_DataFiles**. When the user selects the desired input file and clicks the **Open** button, **Workbook UOC_QUAL2K_v2.06** will be automatically updated with the information contained in the selected input file.

Reminder: The user is given a reminder caution that once an input file is opened, **Worksheet QUAL2K** will be updated and **Cell B9** will contain the name of the selected input file. When the model is run, this input file will be overwritten with any changes the user has made to model input. If any model input changes are made by the user, it is advisable to change the file name in **Cell B9.**

Several worksheets contain the model input that is contained in an input file (Table 9). Until the next chapter, suffice it to know that each of these worksheets is updated with the information contained in an opened input file with the extension q2k. The user has the latitude to change any of the input data in any of these worksheets and those changes will be implemented in both the simulated output and in the file named in **Cell B9** once the **Run Fortran** button is pressed.

Table 9. List and description of worksheets containing tabular QUAL2K input data.

Worksheet Name	Description
QUAL2K	File names and general description of model operation and simulation period
Point Sources	Flow and water quality of sources (includes abstractions as well as point sources)
Headwater	Flow and water quality of headwaters of each water body
Downstream	Water quality prescribed as downstream boundary (not needed for this situation)
Reach	Physical description of model segmentation at the reach and element level
Reach Rates	Kinetic rates at the reach level (overrides global rates in Worksheet Rates)
Air Temperature	Hourly air temperature by reach
Dew Point Temperature	Hourly dew point temperature by reach
Wind Speed	Hourly wind speed by reach
Cloud Cover	Hourly cloud cover by reach
Shade	% of solar radiation blocked by vegetation and banks, by reach and hour
Rates	Globally applied kinetic rates (overridden by any rates in Worksheet Reach Rates)
Light and Heat	Global values for light sources and heat transfer computations
Diffuse Sources	Flow and water quality of diffuse sources (can be abstractions as well as inflows)

MODIFYING INPUT DATA FOR THE QUAL2K MODEL

Importing Input Data Files

As mentioned previously in this manual, the necessary input to run the QUAL2K model is found in files with the extension q2k. Several existing input files were created to perform the seasonal analysis in developing this TMDL (see Table 6). Each input file describes the critical conditions either for a particular month or for the three hottest months combined as required in TCEQ protocol for a seasonal analysis. The lowest predictions of 24-hour average dissolved oxygen occurred during the September critical conditions (**File UOC_Upper_Mon9_High_T.q2k**, which is also the preloaded input data in **Workbook UOC_QUAL2K_v2.06**.)

To import a new seasonal condition into **Workbook UOC_QUAL2K_v2.06,** a similar procedure is followed as discussed in Step 10 of the previous chapter that allowed viewing of the new input date file created after running the QUAL2K model.

Step 1: In **Worksheet QUAL2K** (Figure 3) click on the **Open Old File** button. Browse to get to the directory: **C:\QUAL2K\UOC_DataFiles**. If all the TMDL input files have been loaded into this directory and if the example was followed in the previous chapter, the list of input files (q2k extension) will appear as shown in Figure 12.

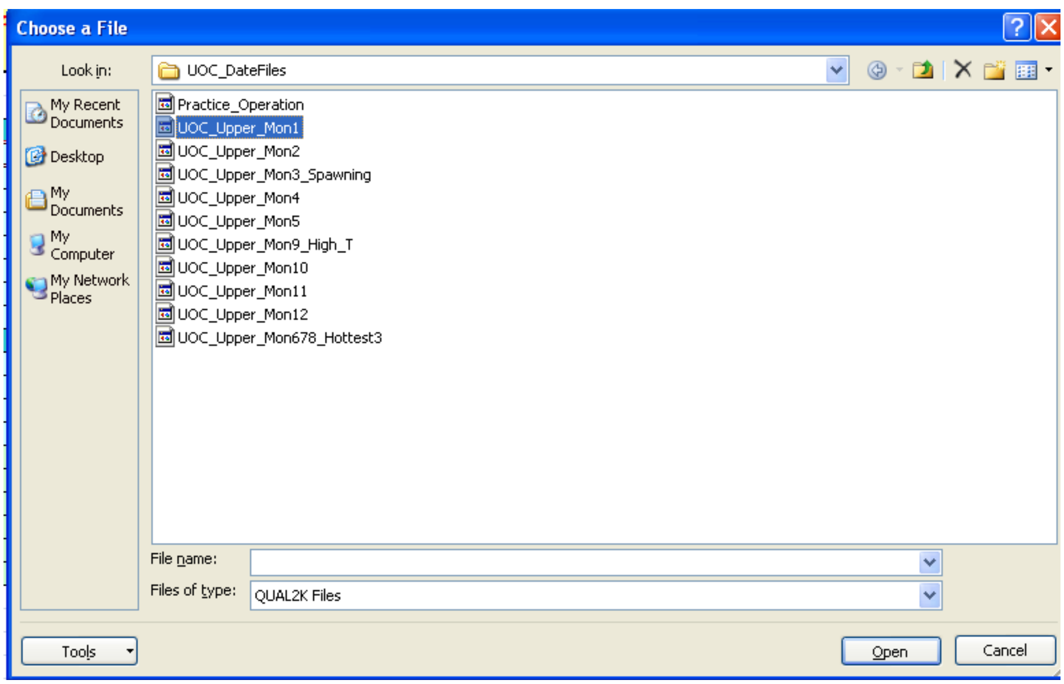


Figure 12. QUAL2K Model input files in directory **UOC_DataFiles**

Step 2: Left click on the desired input condition, for this example **UOC_Upper_Mon1**, (January critical conditions), and left click on **OPEN** results in the reading of the input file and populating of the appropriate Worksheets with the input data of the selected input file. The immediate confirmation of the new data is evident on **Worksheet QUAL2K** as **Cells B11** and **B12**, which will now show the Month and Day of the January scenario (Compare **Cells B11** and **B12** on Figures 3 and 13.) **Note:** The information in Green highlight on the worksheet describing length of photoperiod and related information will not be updated until the **Run Fortran** button is clicked and the simulation runs to successful completion.

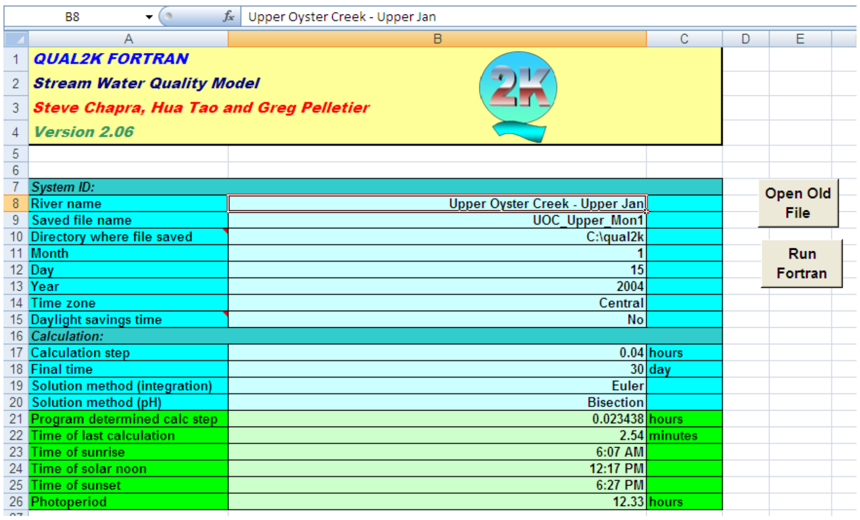


Figure 13. View of System ID information on Worksheet QUAL2K after opening file **UOC_Upper_Mon1.q2k.**

Step 3: For applications when the user is modifying the input data to the model, now is a good time to rename the Saved File Name in **Cell B9** to avoid overwriting the original input file when the simulation is initiated.

At this point the user should have loaded into **Workbook UOC_QUAL2K_v2.06** the desired scenario through the selected input file and taken the necessary action to create a new file name to receive input modifications that need to be made. Regrettably, there is no means to provide modified input data to each of the 10 seasonal scenarios evaluated for the TMDL other than opening each file individually, making the same modification to the needed worksheets within **Workbook UOC_QUAL2K_v2.06** and running the model each time.

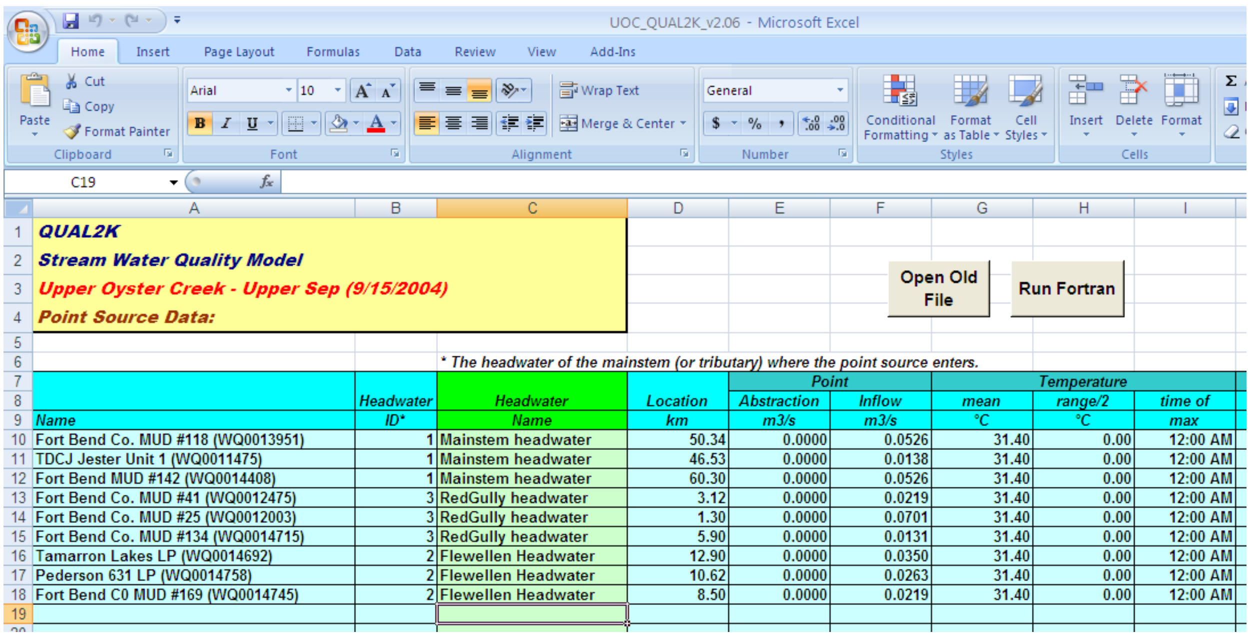
Pertinent Data Input Worksheets

For applying the QUAL2K model to evaluate WWTF expansions or new facilities, the only data input sheet where new information will need to be entered and old information changed is **Worksheet Point Sources**. Conceivably with changes in water demands on the water pumped from the Brazos River through Upper Oyster Creek, **Worksheet Headwater** could also require modification of input data for certain scenarios that would need to be evaluated in the future. Finally, if changes are required of the model segmentation of AU 1245_02, AU 1245_03, Flewellen Creek or Red Gully, those would need to be implemented in **Worksheet Reach** and **Worksheet Reach Rates**.

All other input worksheets listed in Table 9 should not require alteration as these worksheets contain either input data developed during the model verification process (e.g., kinetic rates) or information to describe the particular conditions required for each scenario of the seasonal analysis as previously listed in Table 6 (e.g., weather data).

Making Modifications to Point Sources

For applying the QUAL2K model to evaluate WWTF expansions or new facilities, the only data alterations will occur in **Worksheet Point Sources** (see partial view in Figure 14). Within this worksheet are described the characteristics of each point source considered in the model. New WWTFs will be added to **Worksheet Point Sources**.



Name	Headwater ID*	Headwater Name	Location km	Point Abstraction m3/s	Point Inflow m3/s	Temperature mean °C	Temperature range/2 °C	Temperature time of max
Fort Bend Co. MUD #118 (WQ0013951)	1	Mainstem headwater	50.34	0.0000	0.0526	31.40	0.00	12:00 AM
TDCJ Jester Unit 1 (WQ0011475)	1	Mainstem headwater	46.53	0.0000	0.0138	31.40	0.00	12:00 AM
Fort Bend MUD #142 (WQ0014408)	1	Mainstem headwater	60.30	0.0000	0.0526	31.40	0.00	12:00 AM
Fort Bend Co. MUD #41 (WQ0012475)	3	RedGully headwater	3.12	0.0000	0.0219	31.40	0.00	12:00 AM
Fort Bend Co. MUD #25 (WQ0012003)	3	RedGully headwater	1.30	0.0000	0.0701	31.40	0.00	12:00 AM
Fort Bend Co. MUD #134 (WQ0014715)	3	RedGully headwater	5.90	0.0000	0.0131	31.40	0.00	12:00 AM
Tamarron Lakes LP (WQ0014692)	2	Flewellen Headwater	12.90	0.0000	0.0350	31.40	0.00	12:00 AM
Pederson 631 LP (WQ0014758)	2	Flewellen Headwater	10.62	0.0000	0.0263	31.40	0.00	12:00 AM
Fort Bend C0 MUD #169 (WQ0014745)	2	Flewellen Headwater	8.50	0.0000	0.0219	31.40	0.00	12:00 AM

Figure 14. Opening view of **Worksheet Point Sources** showing WWTFs included in TMDL.

Worksheet Point Sources contains the input data that names the facility, gives its location within the model segmentation, and defines the quantity and quality characteristics of the effluent. For each quality characteristic the mean, one-half the range (range/2) and time of maximum value must be defined. For the TMDL the intra-day variability of effluents was ignored, so the value describing the range was set as zero (0.00) and the time of maximum value to 12:00 AM.

For a permit expansion, with the facility keeping the same name and discharge location, the discharge (called inflow (**Column F**) in the worksheet) and effluent quality parameters will need to be updated as needed to reflect the new conditions. For an entirely new facility, all the required information will need to be filled in describing the discharge.

The following is a list of columns of input data in the **Worksheet Point Sources**:

- Name – Provide the name by which the facility will be referenced
- Headwater ID – This identifying number into which the WWTF discharge enters. Enter 1 for Main Stem (AUs 1245_02 * 1245_03), 2 for Flewellen Creek, and 3 for Red Gully
- Headwater Name – either Mainstem UOC, Red Gully or Flewellen Creek. Filling in this information is optional – see Green color on column which signifies information filled in after the simulation is run.
- Location – The river kilometer where the discharge enters one of the three modeled creeks.
- Abstraction – Will be zero unless the facility withdraws water rather than discharges.
- Inflow (m^3/s) – Amount of discharge; this will typically be the full build-out permit limit.
- Temperature (°C) – Mean value, one-half the range (range/2) and time of maximum. Mean value set to the temperature determined for the particular seasonal scenario being run (see Table 2).[Default range set to 0.00, and time of maximum set to 12:00 AM]
- Specific conductance (µmhos) – Mean value, one-half the range (range/2) and time of maximum. [Default mean = 920.2, range set to 33.55, and time of maximum set to 12:00 AM. Specific conductance has no bearing on simulation results. Dissolved oxygen saturation values in QUAL2K are only a function of temperature and not salt content. The values provided were the mean values from WWTF effluent monitoring conducted to collect information for the model calibration and validation process.]
- Inorganic Suspended Sediment (mg/L) – Mean value, one-half the range (range/2) and time of maximum. Mean value set as total suspended sediment permit limit.[1] [Default range set to 0.00, and time of maximum set to 12:00 AM.]
- Dissolved Oxygen (mg/L) – Mean value, one-half the range (range/2) and time of maximum. Mean value set as permit limit. [Default range set to 0.00, and time of maximum set to 12:00 AM.]
- Slow CBOD (mg O_2/L) – Mean value, one-half the range (range/2) and time of maximum. Mean value set as 0.00; Slow CBOD is not included in this model application. [Default range set to 0.00, and time of maximum set to 12:00 AM.]
- Fast CBOD (mg O_2/L) – Mean value, one-half the range (range/2) and time of maximum. Mean value set as CBOD 5-day ($CBOD_5$) permit limit x 2.3, where 2.3 is the assumed conversions factor of $CBOD_5$ to ultimate CBOD. [Default range set to 0.00, and time of maximum set to 12:00 AM.]
- Organic N (µg N/L) – Mean value, one-half the range (range/2) and time of maximum. Mean value set as function of $CBOD_5$ and ammonia nitrogen (NH_3-N) permit limits. [Default range set to 0.00, and time of maximum set to 12:00 AM]
    - Organic N = 3000 µg/L if $CBOD_5$ < 11 mg/L or NH_3-N < 7 mg/L;

[1] The modeling philosophy undertaken was to set the Inorganic Suspended Sediment equal to the Total Suspended Sediment (TSS) permit limit. In QUAL2K, TSS includes inorganic suspended sediment, detritus and suspended algae biomass. Within the model detritus undergoes dissolution and eventually is exerted as CBOD. Because the CBOD permit limit includes dissolved and suspended CBOD fractions, it was considered double accounting to include TSS or some portion of TSS as detritus, since that portion of TSS that is exerted as CBOD is already included in the CBOD permit limit. Further the permit limit for CBOD is suggested as the input under the fast CBOD input.

  - Organic N = 2000 µg/L if $CBOD_5$ < 11 mg/L and NH_3-N < 7 mg/L
  - Organic N = 1000 µg/L if $CBOD_5$ < 7 mg/L and NH_3-N < 7 mg/L
- Ammonia N (µg N/L) – Mean value, one-half the range (range/2) and time of maximum. Mean value set as NH_3-N permit limit expressed as µg/L. [Default range set to 0.00, and time of maximum set to 12:00 AM.]
- Nitrate + Nitrite N (µg N/L) – Mean value, one-half the range (range/2) and time of maximum. Mean value set = 20,000 µg/L – Organic N – NH_3-N. [Default range set to 0.00, and time of maximum set to 12:00 AM.]
- Organic P (µg/L) – Mean value, one-half the range (range/2) and time of maximum. Mean value determined from permit limits (expressed as µg/L) if phosphorus limits apply. Otherwise suggested value is 284 µg/L.[2] [Default range set to 0.00, and time of maximum set to 12:00 AM.]
- Inorganic P (µg/L) – Mean value, one-half the range (range/2) and time of maximum. Mean value determined from permit limits (expressed as µg/L) if phosphorus limits apply. Otherwise suggested value is 4716 µg/L (see Organic P footnote). [Default range set to 0.00, and time of maximum set to 12:00 AM.]
- Phytoplankton (µg A/L) – Mean value, one-half the range (range/2) and time of maximum. Suggest mean value = 0.00 unless discharge is from a polishing pond. For polishing pond effluent a seasonal value was used in the TMDL; 79.2 µg/L chlorophyll-a for the months of May – October and 16.0 µg/L chlorophyll-a for the months of November – April. [Default range set to 0.00, and time of maximum set to 12:00 AM.]
- Detritus (mg D/L) – Mean value, one-half the range (range/2) and time of maximum. Mean value set as 0.00; see explanation for Inorganic Suspended Sediment input. [Default range set to 0.00, and time of maximum set to 12:00 AM.]
- Pathogen Indicator (cfu/100mL) – Mean value, one-half the range (range/2) and time of maximum. Mean value set as 0.00; bacteria modeling not included in TMDL. [Default range set to 0.00, and time of maximum set to 12:00 AM.]
- Alkalinity (mg $CaCO_3$/L) – Mean value, one-half the range (range/2) and time of maximum. Suggested mean value = 200. **Caution**: Alkalinity is not part of the modeling nor is pH; however, the pH submodel cannot be turned off and an alkalinity value of 200 mg/L allows the pH computations to be successfully completed. [Default range set to 0.00, and time of maximum set to 12:00 AM.]
- pH (S.U.) – Mean value, one-half the range (range/2) and time of maximum. Suggested mean value = 7.77. **Caution**: pH model component cannot be turned off, but the predicted values should not be given any validity. [Default range set to 0.00, and time of maximum set to 12:00 AM.]

The QUAL2K model segmentation is provided in Figure 15 (western end of watershed) and Figure 16 (eastern end of watershed) to assist the user in finding a WWTF discharge location. Both maps contain the reach number, 0.5 river kilometer (RKM) marks, and labels at the even whole RKMs (e.g., 2, 4, and 6). The segmentation presented in Figures 15 and 16 represents a

[2] The suggested value of Organic P is based on an assumed effluent concentration of 5,000 µg/L (5 mg/L) and the ratio of Inorganic P (measured as PO_4-P) to Total P in the effluents of WWTFs measured during monitoring surveys to collect site specific information for model calibration and validation. Organic P = 5,000 x (1 – PO_4-P/Total P)

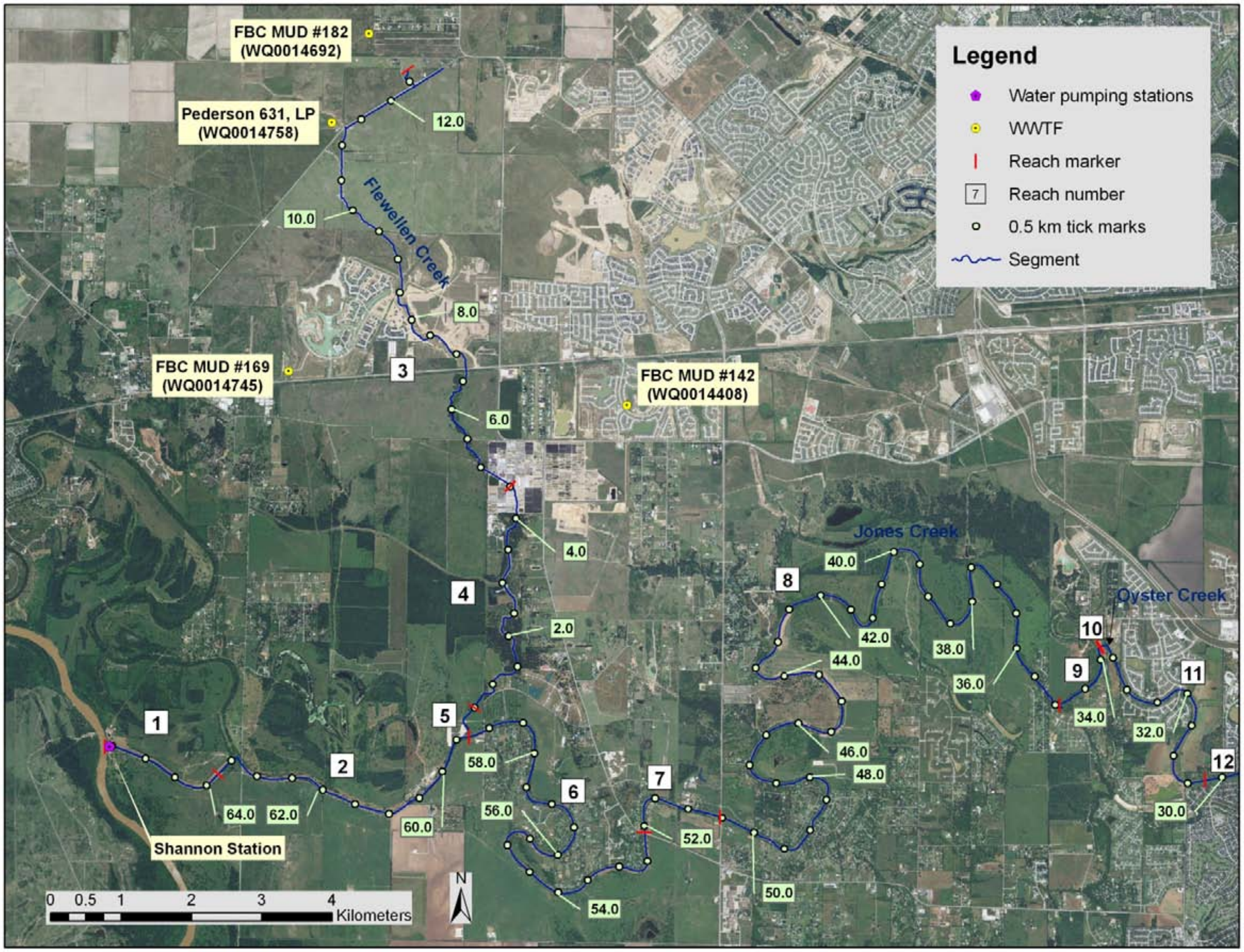


Figure 15. Segmentation for western portion of Upper Oyster Creek Model

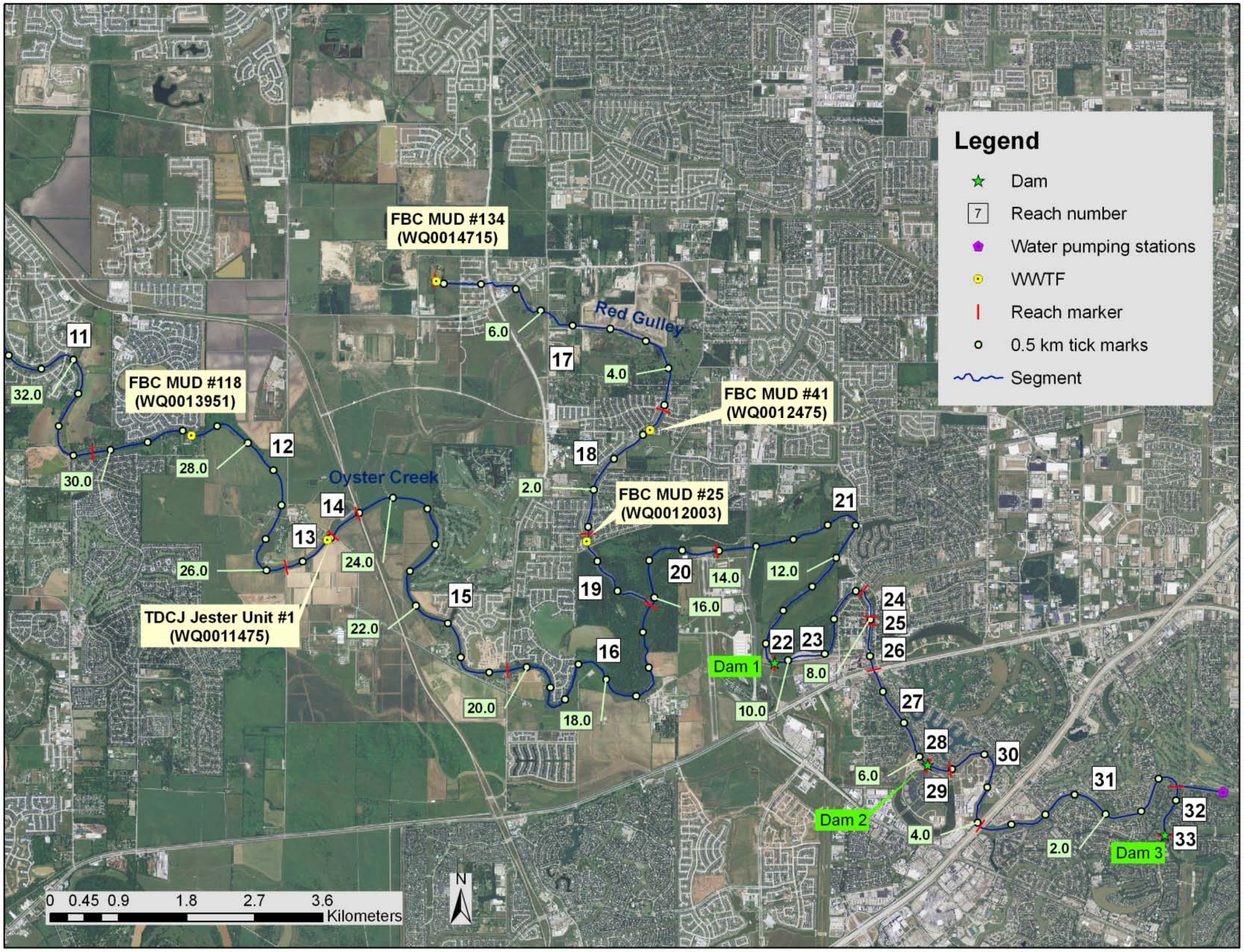


Figure 16. Segmentation for eastern portion of Upper Oyster Creek Model

refinement to the segmentation used in developing the TMDL. The new segmentation allows for more accurate geographic specification of locations than the original model and at the same time gives virtually identical results to the original model (see comparison in Table 10). Further the new segmentation was developed using the U.S. Geological Survey National Hydrography Dataset (NHD) Geographic Information System (GIS) rather than being based on the segmentation of the 1991 waste load evaluation for dissolved oxygen of Upper Oyster Creek (TWC, 1991). For Red Gully the segmentation reflects the present (Winter 2011) configuration of the stream, which has been modified in its channel course in its western most extremity near FBC MUD # 134 (Figure 16). The model, however, does not reflect the modified channel geometry and the series of added amenity lakes. The present model representation of Red Gully channel cross sections still reflects conditions of the original, non-modified channel.

Table 10. Comparison of minimum 24-hour average DO concentrations (mg/L) from the original and new QUAL2K segmentations of the Upper Reach stream system. Pink shading under new segmentation results indicates comparative difference >0.05 mg/L and <0.50 mg/L; yellow shading indicates comparative difference ≥0.50 mg/L.

(AU_02 = assessment unit 02; AU_03 = assessment unit 03)

Location	Jan	Feb	Mar	Apr	May	Jun-Aug	Sep	Oct	Nov	Dec
Original Segmentation Results										
Mainstem AU_02	7.70	7.20	6.43	5.50	5.30	4.66	4.23	6.00	6.01	6.89
Main stem AU_03	6.97	6.39	5.21	4.87	4.71	4.63	4.00	4.06	4.93	6.04
Flewellen Cr.	7.31	7.06	6.68	5.96	6.00	5.90	5.46	6.04	6.24	6.93
Red Gully	6.93	6.57	5.86	5.25	4.86	4.48	4.13	4.87	5.56	6.34
New Segmentation Results										
Mainstem AU_02	7.78	7.29	6.52	5.56	5.34	4.65	4.26	6.11	6.11	6.98
Main stem AU_03	6.88	6.39	5.21	4.87	4.69	4.62	3.99	4.05	4.93	6.04
Flewellen Cr.	6.20	6.08	5.90	5.71	5.94	5.87	5.46	5.87	5.81	6.02
Red Gully	6.98	6.61	5.88	5.26	4.85	4.46	4.12	4.86	5.57	6.38

An example addition of a hypothetical new WWTF with a discharge of 1.0 million gallons per day (0.0438 m^3/s) at RKM 10.0 of Flewellen Creek is provided in Figure 17 in red font.

QUAL2K
Stream Water Quality Model
Upper Oyster Creek - Upper Sep (9/15/2004)
Point Source Data:

Open Old File | Run Fortran

* The headwater of the mainstem (or tributary) where the point source enters.

				Point		Temperature			Specific Conducta	
	Headwater	Headwater	Location	Abstraction	Inflow	mean	range/2	time of	mean	range/2
Name	ID*	Name	km	m3/s	m3/s	°C	°C	max	umhos	umhos
Fort Bend Co. MUD #118 (WQ0013951)	1		28.88	0.0000	0.0526	31.40	0.00	12:00 AM	920.20	33.55
TDCJ Jester Unit 1 (WQ0011475)	1		25.07	0.0000	0.0138	31.40	0.00	12:00 AM	920.20	33.55
Fort Bend MUD #142 (WQ0014408)	1		43.17	0.0000	0.0526	31.40	0.00	12:00 AM	920.20	33.55
Fort Bend Co. MUD #41 (WQ0012475)	3		3.12	0.0000	0.0219	31.40	0.00	12:00 AM	920.20	33.55
Fort Bend Co. MUD #25 (WQ0012003)	3		1.30	0.0000	0.0701	31.40	0.00	12:00 AM	920.20	33.55
Fort Bend Co. MUD #134 (WQ0014715)	3		7.59	0.0000	0.0131	31.40	0.00	12:00 AM	920.20	33.55
Tamarron Lakes LP (WQ0014692)	2		12.75	0.0000	0.0350	31.40	0.00	12:00 AM	920.20	33.55
Pederson 631 LP (WQ0014758)	2		11.25	0.0000	0.0263	31.40	0.00	12:00 AM	920.20	33.55
Fort Bend Co. MUD #169 (WQ0014745)	2		8.34	0.0000	0.0219	31.40	0.00	12:00 AM	920.20	33.55
Hypothetical Facility # 1	2		10	0.0000	0.0438	31.40	0.00	12:00 AM	920.20	33.55

Figure 17. Opening view of **Worksheet Point Sources** showing hypothetical WWTF addition.

Making Modifications to Headwaters and Segmentation

While the main purpose of this User’s Guide is to guide direct the user toward making changes to model input to allow evaluation of changes in WWTF discharges, there may also be a need to change headwater and model segmentation for some applications.

The quantity and quality of headwaters are specified in **Worksheet Headwater** (Figure 18). The flow rate of headwater is specified in Column D (**Cell D11** for Upper Oyster Creek water from the Brazos River, **Cell D32** for Flewellen Creek, and **Cell D53** for Red Gully). Though constant concentrations (i.e., no intra-daily variation) were specified for each water quality parameter for the TMDL applications, the user is allowed to specify a value for each of the 24 hours of the day (**Columns D – AA**). Making any needed changes to the values on this worksheet will be reflected in the simulation once the **Run Fortran** button is clicked.

QUAL2K
Stream Water Quality Model
Upper Oyster Creek - Upper Sep (9/15/2004)
Headwater Data:

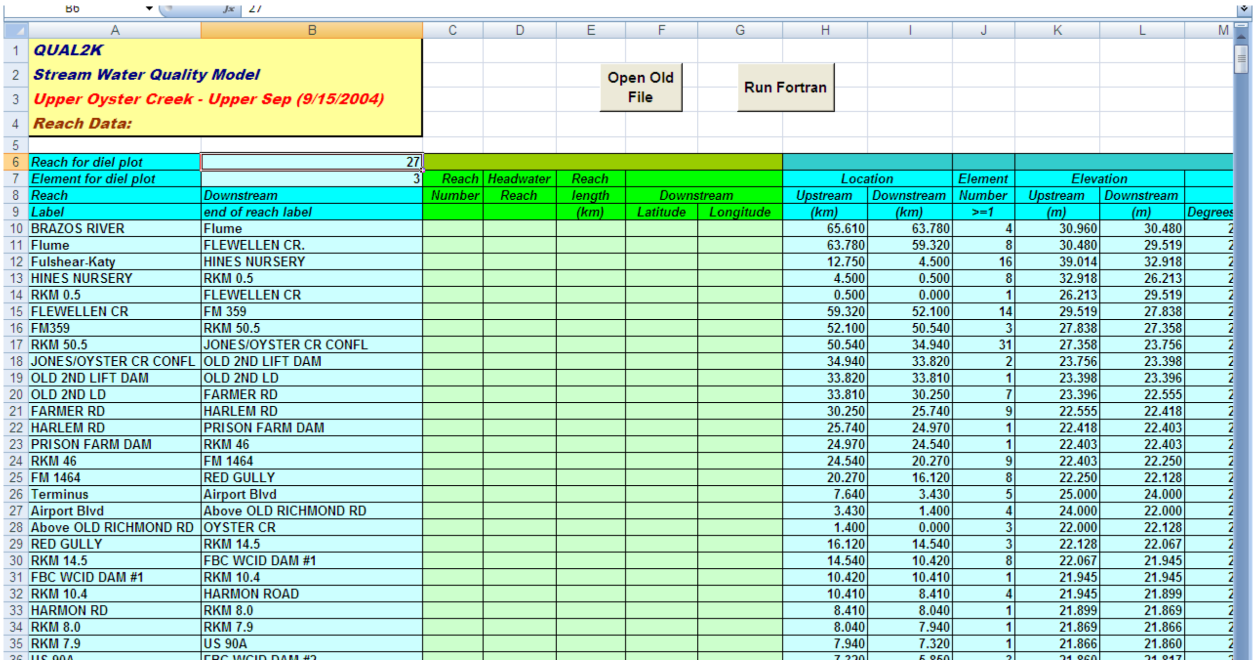
Open Old File | Run Fortran

Note: * required field

ID	Number of Headwaters*	3												
No. 1	Reach No.*	Headwater Name	Flow*	Elevation	Weir		Rating Curves						Manning Formula	
			Rate		Height	Width	Velocity		Depth		Channel	Manning	Bot Width	Sic
			(m^3/s)	(m)	(m)	(m)	Coefficient	Exponent	Coefficient	Exponent	Slope	n	m	Slo
	1	Mainstem headwat	0.085	30.960	0.0000	0.0000	0.2039	0.500	0.4721	0.400	0	0.0000	0.00	
	Headwater Water Quality	Units	12:00 AM	1:00 AM	2:00 AM	3:00 AM	4:00 AM	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00
	Temperature	C	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	
	Conductivity	umhos	572.00	572.00	572.00	572.00	572.00	572.00	572.00	572.00	572.00	572.00	572.00	5
	Inorganic Solids	mgD/L	85.00	85.00	85.00	85.00	85.00	85.00	85.00	85.00	85.00	85.00	85.00	
	Dissolved Oxygen	mg/L	5.90	5.90	5.90	5.90	5.90	5.90	5.90	5.90	5.90	5.90	5.90	
	CBODslow	mgO2/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	CBODfast	mgO2/L	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	
	Organic Nitrogen	ugN/L	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	5
	NH4-Nitrogen	ugN/L	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	
	NO3-Nitrogen	ugN/L	585.00	585.00	585.00	585.00	585.00	585.00	585.00	585.00	585.00	585.00	585.00	5
	Organic Phosphorus	ugP/L	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	
	Inorganic Phosphorus (SRP)	ugP/L	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	
	Phytoplankton	ugA/L	8.70	8.70	8.70	8.70	8.70	8.70	8.70	8.70	8.70	8.70	8.70	
	Detritus (POM)	mgD/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Pathogen	cfu/100 mL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Alkalinity	mgCaCO3/L	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	2
	pH	s.u.	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	
No. 2	Reach No.*	Headwater Name	Flow*	Elevation	Weir		Rating Curves						Manning Formula	
			Rate		Height	Width	Velocity		Depth		Channel	Manning	Bot Width	Sic
			(m^3/s)	(m)	(m)	(m)	Coefficient	Exponent	Coefficient	Exponent	Slope	n	m	Slo
	3	Flewellen Headwat	0.000	39.014	0.0000	0.0000	0.3197	0.500	0.5908	0.400	0	0.0000	0.00	
	Headwater Water Quality	Units	12:00 AM	1:00 AM	2:00 AM	3:00 AM	4:00 AM	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00
	Temperature	C	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	

Figure 18. Initial view of **Worksheet Headwater**.

The model segmentation is found in **Worksheet Reach** (Figure 19). If re-segmentation is required for a new application, considerable model expertise will be required for successful implementation of new input. The basics are provided in this manual and the user is also directed to the QUAL2K documentation (Chapra et al., 2007).



Row	A	B	C	D	E	F	G	H	I	J	K	L	M
6	Reach for diel plot	27											
7	Element for diel plot	3	Reach	Headwater	Reach			Location		Element	Elevation		
8	Reach	Downstream	Number	Reach	length	Downstream		Upstream	Downstream	Number	Upstream	Downstream	
9	Label	end of reach label			(km)	Latitude	Longitude	(km)	(km)	>=1	(m)	(m)	Degrees
10	BRAZOS RIVER	Flume						65.610	63.780	4	30.960	30.480	2
11	Flume	FLEWELLEN CR.						63.780	59.320	8	30.480	29.519	2
12	Fulshear-Katy	HINES NURSERY						12.750	4.500	16	39.014	32.918	2
13	HINES NURSERY	RKM 0.5						4.500	0.500	8	32.918	26.213	2
14	RKM 0.5	FLEWELLEN CR						0.500	0.000	1	26.213	29.519	2
15	FLEWELLEN CR	FM 359						59.320	52.100	14	29.519	27.838	2
16	FM359	RKM 50.5						52.100	50.540	3	27.838	27.358	2
17	RKM 50.5	JONES/OYSTER CR CONFL						50.540	34.940	31	27.358	23.756	2
18	JONES/OYSTER CR CONFL	OLD 2ND LIFT DAM						34.940	33.820	2	23.756	23.398	2
19	OLD 2ND LIFT DAM	OLD 2ND LD						33.820	33.810	1	23.398	23.396	2
20	OLD 2ND LD	FARMER RD						33.810	30.250	7	23.396	22.555	2
21	FARMER RD	HARLEM RD						30.250	25.740	9	22.555	22.418	2
22	HARLEM RD	PRISON FARM DAM						25.740	24.970	1	22.418	22.403	2
23	PRISON FARM DAM	RKM 46						24.970	24.540	1	22.403	22.403	2
24	RKM 46	FM 1464						24.540	20.270	9	22.403	22.250	2
25	FM 1464	RED GULLY						20.270	16.120	8	22.250	22.128	2
26	Terminus	Airport Blvd						7.640	3.430	5	25.000	24.000	2
27	Airport Blvd	Above OLD RICHMOND RD						3.430	1.400	4	24.000	22.000	2
28	Above OLD RICHMOND RD	OYSTER CR						1.400	0.000	3	22.000	22.128	2
29	RED GULLY	RKM 14.5						16.120	14.540	3	22.128	22.067	2
30	RKM 14.5	FBC WCID DAM #1						14.540	10.420	8	22.067	21.945	2
31	FBC WCID DAM #1	RKM 10.4						10.420	10.410	1	21.945	21.945	2
32	RKM 10.4	HARMON ROAD						10.410	8.410	4	21.945	21.899	2
33	HARMON RD	RKM 8.0						8.410	8.040	1	21.899	21.869	2
34	RKM 8.0	RKM 7.9						8.040	7.940	1	21.869	21.866	2
35	RKM 7.9	US 90A						7.940	7.320	1	21.866	21.860	2

Figure 19. Initial view of **Worksheet Reach**.

For the TMDL model applications, the hydraulics (e.g., relationships of water velocity and depth to streamflow) were specified using power equations, which is the same approach typically used by TCEQ for waste load evaluations using QUAL-TX. Power equations are used to relate mean velocity and depth to flow as follows:

$$U = aQ^b$$

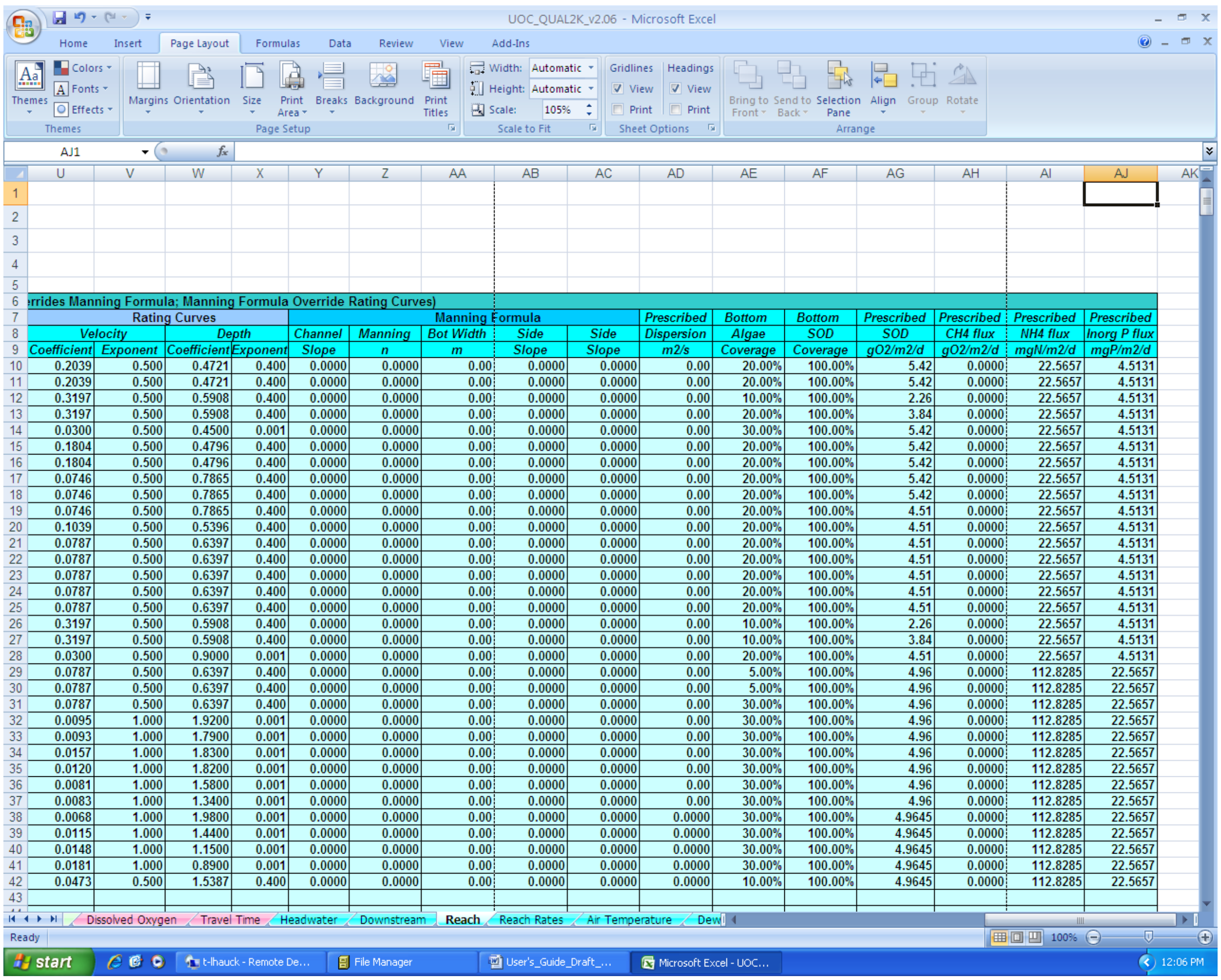
$$H = \alpha Q^\beta$$

where Q is flow, U is mean velocity, H is depth, and a, b, α, and β are empirical constants. Within Worksheet Reach this information is found input in **Columns U – X** by reach (Figure 20). Additional input in this worksheet in **Columns AG - AJ** is the sediment-water nutrient release rates as well as sediment oxygen demand (SOD) rates. (**Note:** QUAL2K contains a sediment-diagenesis submodel, which was not turned on for this TMDL as initial attempts to use the submodel gave unrealistic results.) Our experience with the model indicated that these rates were not temperature corrected internally during model operation and therefore these rates had to be input in this columns with the Arrhenius equation correction applied to change the rates from their 20ºC values to that of the average temperature for the specific simulation.

$$K_T = K_{20°C}\theta^{(T-20)}$$

where K is the rate, T is water temperature (°C), and θ is the temperature correction constant (a value of 1.074 was used for sediment-related rates). The sediment-related rates at 20°C are provided in Table 11, and the water temperature is the temperature associated with the particular seasonal run as found in Table 2, the point source (**Worksheet Point Sources**) and the headwater (**Worksheet Headwater**).

Also, the amount (percentage) of the streambed bottom subject to sediment-related interactions is specified in **Column AF** and the amount of the bottom favorable to algae coverage is specified in **Column AE**. For this system, bottom algae where used to mimic the implications of the robust macrophyte population in the Upper Reach; for more discussion see Hauck & Bing (2008).


rrides Manning Formula; Manning Formula Override Rating Curves)

Row	Rating Curves: Velocity Coefficient (U)	Velocity Exponent (V)	Depth Coefficient (W)	Depth Exponent (X)	Manning Formula: Channel Slope (Y)	Manning n (Z)	Bot Width m (AA)	Side Slope (AB)	Side Slope (AC)	Prescribed Dispersion m2/s (AD)	Bottom Algae Coverage (AE)	Bottom SOD Coverage (AF)	Prescribed SOD gO2/m2/d (AG)	Prescribed CH4 flux gO2/m2/d (AH)	Prescribed NH4 flux mgN/m2/d (AI)	Prescribed Inorg P flux mgP/m2/d (AJ)
10	0.2039	0.500	0.4721	0.400	0.0000	0.0000	0.00	0.0000	0.0000	0.00	20.00%	100.00%	5.42	0.0000	22.5657	4.5131
11	0.2039	0.500	0.4721	0.400	0.0000	0.0000	0.00	0.0000	0.0000	0.00	20.00%	100.00%	5.42	0.0000	22.5657	4.5131
12	0.3197	0.500	0.5908	0.400	0.0000	0.0000	0.00	0.0000	0.0000	0.00	10.00%	100.00%	2.26	0.0000	22.5657	4.5131
13	0.3197	0.500	0.5908	0.400	0.0000	0.0000	0.00	0.0000	0.0000	0.00	20.00%	100.00%	3.84	0.0000	22.5657	4.5131
14	0.0300	0.500	0.4500	0.001	0.0000	0.0000	0.00	0.0000	0.0000	0.00	30.00%	100.00%	5.42	0.0000	22.5657	4.5131
15	0.1804	0.500	0.4796	0.400	0.0000	0.0000	0.00	0.0000	0.0000	0.00	20.00%	100.00%	5.42	0.0000	22.5657	4.5131
16	0.1804	0.500	0.4796	0.400	0.0000	0.0000	0.00	0.0000	0.0000	0.00	20.00%	100.00%	5.42	0.0000	22.5657	4.5131
17	0.0746	0.500	0.7865	0.400	0.0000	0.0000	0.00	0.0000	0.0000	0.00	20.00%	100.00%	5.42	0.0000	22.5657	4.5131
18	0.0746	0.500	0.7865	0.400	0.0000	0.0000	0.00	0.0000	0.0000	0.00	20.00%	100.00%	5.42	0.0000	22.5657	4.5131
19	0.0746	0.500	0.7865	0.400	0.0000	0.0000	0.00	0.0000	0.0000	0.00	20.00%	100.00%	4.51	0.0000	22.5657	4.5131
20	0.1039	0.500	0.5396	0.400	0.0000	0.0000	0.00	0.0000	0.0000	0.00	20.00%	100.00%	4.51	0.0000	22.5657	4.5131
21	0.0787	0.500	0.6397	0.400	0.0000	0.0000	0.00	0.0000	0.0000	0.00	20.00%	100.00%	4.51	0.0000	22.5657	4.5131
22	0.0787	0.500	0.6397	0.400	0.0000	0.0000	0.00	0.0000	0.0000	0.00	20.00%	100.00%	4.51	0.0000	22.5657	4.5131
23	0.0787	0.500	0.6397	0.400	0.0000	0.0000	0.00	0.0000	0.0000	0.00	20.00%	100.00%	4.51	0.0000	22.5657	4.5131
24	0.0787	0.500	0.6397	0.400	0.0000	0.0000	0.00	0.0000	0.0000	0.00	20.00%	100.00%	4.51	0.0000	22.5657	4.5131
25	0.0787	0.500	0.6397	0.400	0.0000	0.0000	0.00	0.0000	0.0000	0.00	20.00%	100.00%	4.51	0.0000	22.5657	4.5131
26	0.3197	0.500	0.5908	0.400	0.0000	0.0000	0.00	0.0000	0.0000	0.00	10.00%	100.00%	2.26	0.0000	22.5657	4.5131
27	0.3197	0.500	0.5908	0.400	0.0000	0.0000	0.00	0.0000	0.0000	0.00	10.00%	100.00%	3.84	0.0000	22.5657	4.5131
28	0.0300	0.500	0.9000	0.001	0.0000	0.0000	0.00	0.0000	0.0000	0.00	20.00%	100.00%	4.51	0.0000	22.5657	4.5131
29	0.0787	0.500	0.6397	0.400	0.0000	0.0000	0.00	0.0000	0.0000	0.00	5.00%	100.00%	4.96	0.0000	112.8285	22.5657
30	0.0787	0.500	0.6397	0.400	0.0000	0.0000	0.00	0.0000	0.0000	0.00	5.00%	100.00%	4.96	0.0000	112.8285	22.5657
31	0.0787	0.500	0.6397	0.400	0.0000	0.0000	0.00	0.0000	0.0000	0.00	30.00%	100.00%	4.96	0.0000	112.8285	22.5657
32	0.0095	1.000	1.9200	0.001	0.0000	0.0000	0.00	0.0000	0.0000	0.00	30.00%	100.00%	4.96	0.0000	112.8285	22.5657
33	0.0093	1.000	1.7900	0.001	0.0000	0.0000	0.00	0.0000	0.0000	0.00	30.00%	100.00%	4.96	0.0000	112.8285	22.5657
34	0.0157	1.000	1.8300	0.001	0.0000	0.0000	0.00	0.0000	0.0000	0.00	30.00%	100.00%	4.96	0.0000	112.8285	22.5657
35	0.0120	1.000	1.8200	0.001	0.0000	0.0000	0.00	0.0000	0.0000	0.00	30.00%	100.00%	4.96	0.0000	112.8285	22.5657
36	0.0081	1.000	1.5800	0.001	0.0000	0.0000	0.00	0.0000	0.0000	0.00	30.00%	100.00%	4.96	0.0000	112.8285	22.5657
37	0.0083	1.000	1.3400	0.001	0.0000	0.0000	0.00	0.0000	0.0000	0.00	30.00%	100.00%	4.96	0.0000	112.8285	22.5657
38	0.0068	1.000	1.9800	0.001	0.0000	0.0000	0.00	0.0000	0.0000	0.0000	30.00%	100.00%	4.9645	0.0000	112.8285	22.5657
39	0.0115	1.000	1.4400	0.001	0.0000	0.0000	0.00	0.0000	0.0000	0.0000	30.00%	100.00%	4.9645	0.0000	112.8285	22.5657
40	0.0148	1.000	1.1500	0.001	0.0000	0.0000	0.00	0.0000	0.0000	0.0000	30.00%	100.00%	4.9645	0.0000	112.8285	22.5657
41	0.0181	1.000	0.8900	0.001	0.0000	0.0000	0.00	0.0000	0.0000	0.0000	30.00%	100.00%	4.9645	0.0000	112.8285	22.5657
42	0.0473	0.500	1.5387	0.400	0.0000	0.0000	0.00	0.0000	0.0000	0.0000	10.00%	100.00%	4.9645	0.0000	112.8285	22.5657

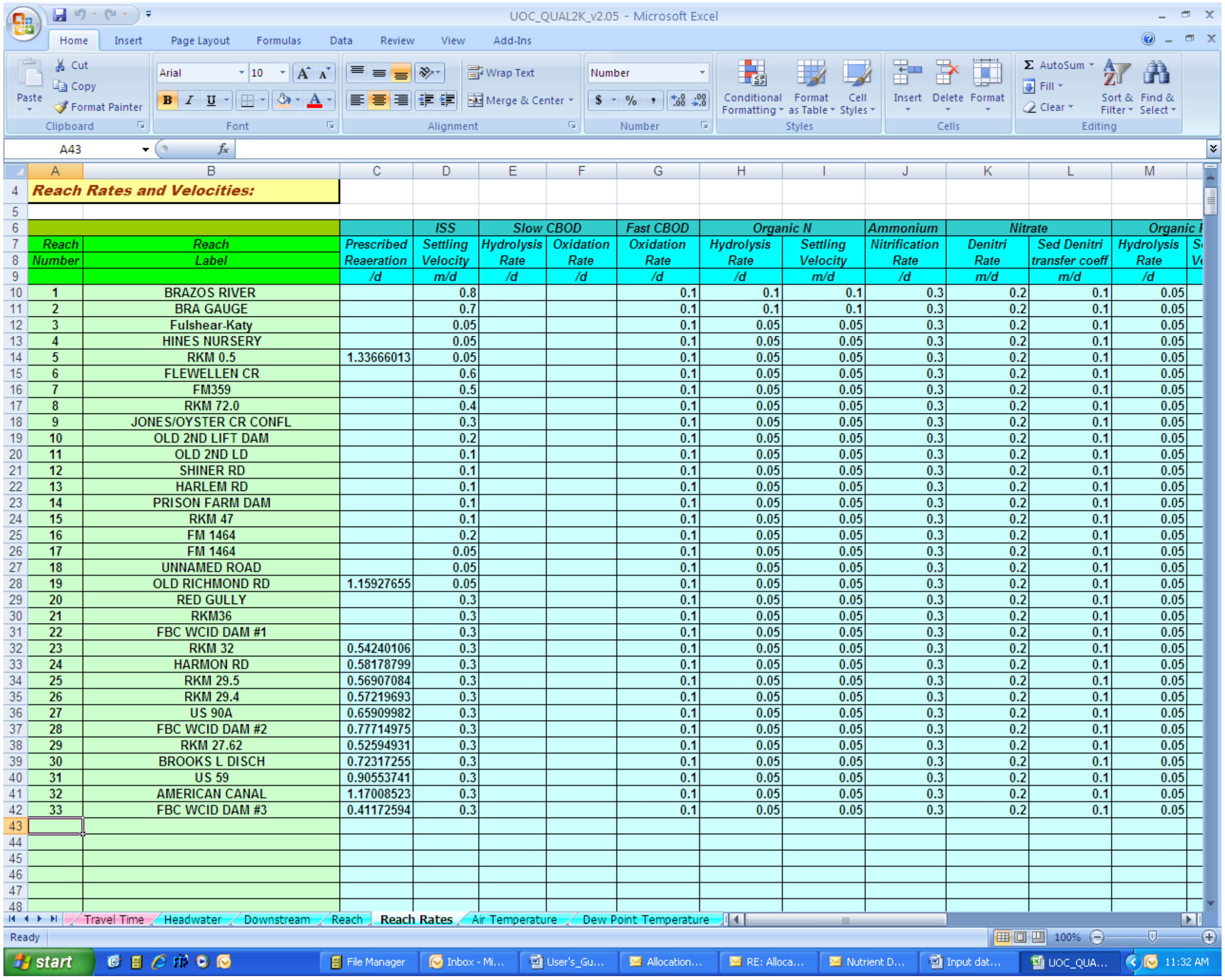
Figure 20. View of hydraulic and sediment interaction input data from Worksheet Reach.

Table 11. QUAL2K model sediment-related rates at a temperature of 20ºC

Sediment-Related Rates at 20°C				
Reach	*Prescribed*	*Prescribed*	*Prescribed*	*Prescribed*
Number	*SOD*	*CH4 flux*	*NH4 flux*	*Inorg P flux*
	gO2/m2/d	*gO2/m2/d*	*mgN/m2/d*	*mgP/m2/d*
1	2.40	0.00	10.00	2.00
2	2.40	0.00	10.00	2.00
3	1.00	0.00	10.00	2.00
4	1.70	0.00	10.00	2.00
5	2.40	0.00	10.00	2.00
6	2.40	0.00	10.00	2.00
7	2.40	0.00	10.00	2.00
8	2.40	0.00	10.00	2.00
9	2.40	0.00	10.00	2.00
10	2.00	0.00	10.00	2.00
11	2.00	0.00	10.00	2.00
12	2.00	0.00	10.00	2.00
13	2.00	0.00	10.00	2.00
14	2.00	0.00	10.00	2.00
15	2.00	0.00	10.00	2.00
16	2.00	0.00	10.00	2.00
17	1.00	0.00	10.00	2.00
18	1.70	0.00	10.00	2.00
19	2.00	0.00	10.00	2.00
20	2.20	0.00	50.00	10.00
21	2.20	0.00	50.00	10.00
22	2.20	0.00	50.00	10.00
23	2.20	0.00	50.00	10.00
24	2.20	0.00	50.00	10.00
25	2.20	0.00	50.00	10.00
26	2.20	0.00	50.00	10.00
27	2.20	0.00	50.00	10.00
28	2.20	0.00	50.00	10.00
29	2.20	0.00	50.00	10.00
30	2.20	0.00	50.00	10.00
31	2.20	0.00	50.00	10.00
32	2.20	0.00	50.00	10.00
33	2.20	0.00	50.00	10.00

If the segmentation is altered, **Worksheet Reach Rates** may also require modification (Figure 21). The numerous rates in this worksheet were developed from the model calibration and verification process. The user should have experience or access to such experience on operation of dissolved oxygen models before embarking on changing this aspect of the model. The user is directed to the QUAL2K documentation (Chapra et al., 2007) and the Upper Oyster Creek

QUAL2K application (Hauck and Bing, 2008) for additional assistance on the various rates required to successfully operate the model.



Reach Rates and Velocities:

Reach Number	Reach Label	Prescribed Reaeration /d	ISS Settling Velocity m/d	Slow CBOD Hydrolysis Rate /d	Slow CBOD Oxidation Rate /d	Fast CBOD Oxidation Rate /d	Organic N Hydrolysis Rate /d	Organic N Settling Velocity m/d	Ammonium Nitrification Rate /d	Nitrate Denitri Rate m/d	Nitrate Sed Denitri transfer coeff m/d	Organic P Hydrolysis Rate /d
1	BRAZOS RIVER		0.8			0.1	0.1	0.1	0.3	0.2	0.1	0.05
2	BRA GAUGE		0.7			0.1	0.1	0.1	0.3	0.2	0.1	0.05
3	Fulshear-Katy		0.05			0.1	0.05	0.05	0.3	0.2	0.1	0.05
4	HINES NURSERY		0.05			0.1	0.05	0.05	0.3	0.2	0.1	0.05
5	RKM 0.5	1.33666013	0.05			0.1	0.05	0.05	0.3	0.2	0.1	0.05
6	FLEWELLEN CR		0.6			0.1	0.05	0.05	0.3	0.2	0.1	0.05
7	FM359		0.5			0.1	0.05	0.05	0.3	0.2	0.1	0.05
8	RKM 72.0		0.4			0.1	0.05	0.05	0.3	0.2	0.1	0.05
9	JONES/OYSTER CR CONFL		0.3			0.1	0.05	0.05	0.3	0.2	0.1	0.05
10	OLD 2ND LIFT DAM		0.2			0.1	0.05	0.05	0.3	0.2	0.1	0.05
11	OLD 2ND LD		0.1			0.1	0.05	0.05	0.3	0.2	0.1	0.05
12	SHINER RD		0.1			0.1	0.05	0.05	0.3	0.2	0.1	0.05
13	HARLEM RD		0.1			0.1	0.05	0.05	0.3	0.2	0.1	0.05
14	PRISON FARM DAM		0.1			0.1	0.05	0.05	0.3	0.2	0.1	0.05
15	RKM 47		0.1			0.1	0.05	0.05	0.3	0.2	0.1	0.05
16	FM 1464		0.2			0.1	0.05	0.05	0.3	0.2	0.1	0.05
17	FM 1464		0.05			0.1	0.05	0.05	0.3	0.2	0.1	0.05
18	UNNAMED ROAD		0.05			0.1	0.05	0.05	0.3	0.2	0.1	0.05
19	OLD RICHMOND RD	1.15927655	0.05			0.1	0.05	0.05	0.3	0.2	0.1	0.05
20	RED GULLY		0.3			0.1	0.05	0.05	0.3	0.2	0.1	0.05
21	RKM36		0.3			0.1	0.05	0.05	0.3	0.2	0.1	0.05
22	FBC WCID DAM #1		0.3			0.1	0.05	0.05	0.3	0.2	0.1	0.05
23	RKM 32	0.54240106	0.3			0.1	0.05	0.05	0.3	0.2	0.1	0.05
24	HARMON RD	0.58178799	0.3			0.1	0.05	0.05	0.3	0.2	0.1	0.05
25	RKM 29.5	0.56907084	0.3			0.1	0.05	0.05	0.3	0.2	0.1	0.05
26	RKM 29.4	0.57219693	0.3			0.1	0.05	0.05	0.3	0.2	0.1	0.05
27	US 90A	0.65909982	0.3			0.1	0.05	0.05	0.3	0.2	0.1	0.05
28	FBC WCID DAM #2	0.77714975	0.3			0.1	0.05	0.05	0.3	0.2	0.1	0.05
29	RKM 27.62	0.52594931	0.3			0.1	0.05	0.05	0.3	0.2	0.1	0.05
30	BROOKS L DISCH	0.72317255	0.3			0.1	0.05	0.05	0.3	0.2	0.1	0.05
31	US 59	0.90553741	0.3			0.1	0.05	0.05	0.3	0.2	0.1	0.05
32	AMERICAN CANAL	1.17008523	0.3			0.1	0.05	0.05	0.3	0.2	0.1	0.05
33	FBC WCID DAM #3	0.41172594	0.3			0.1	0.05	0.05	0.3	0.2	0.1	0.05

Figure 21. Initial view of **Worksheet Reach Rates**

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