Addendum to Technical Support Document:

Upper Oyster Creek (Segment 1245) Dissolved Oxygen TMDL

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TR0805

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Texas Commission on Environmental Quality
TMDL Team

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ACRONYMS AND ABBREVIATIONS

AU	Assessment unit
BMP	Best management practice
BRA	Brazos River Authority
CAFO	Confined animal feeding operation
CBOD	Carbonaceous biochemical oxygen demand
Chla	Chlorophyll-α
cms	Cubic meters per second
DO	Dissolved Oxygen
GCWA	Gulf Coast Water Authority
hr	Hour
LA	Load allocation
MGD	Million gallons per day
mg/L	Milligrams per liter
MOS	Margin of safety
MUD	Municipal utility district
NO_2+NO_3-N	Nitrite – Nitrate Nitrogen
NH_3-N	Ammonia Nitrogen
PO_4-P	Ortho-Phosphate Phosphorus
TCEQ	Texas Commission on Environmental Quality
TDCJ	Texas Department of Criminal Justice
TMDL	Total maximum daily load
TPDES	Texas Pollution Discharge Elimination System
Total-P	Total phosphorus
µg/L	Micrograms per litter
WLA	Waste load allocation
WWTF	Wastewater treatment facility

SECTION 1

INTRODUCTION

1.1 Report Scope

Texas Commission on Environmental Quality (TCEQ) is leading an effort to assess the water quality of classified Segment 1245 of Oyster Creek, known as "Upper Oyster Creek." Segment 1245 was placed on the State of Texas 2002 303(d) list as not supporting its aquatic life use due to low dissolved oxygen concentrations. Segment 1245 is located within the Brazos River Basin, southwest of Houston, Texas in northern Fort Bend County. The segment begins at the Gulf Coast Water Authority (GCWA) Shannon Pump Station on the Brazos River and continues through Jones Creek to its confluence with Oyster Creek, through Oyster Creek to its confluence with Flat Bank Creek, through Flat Bank Creek to its confluence with the diversion canal, through the diversion canal to its confluence with Steep Bank Creek, and finally through Steep Bank Creek to its confluence with the Brazos River (Figure 1-1). Segment 1245 extends approximately 54 miles, and its watershed contains four incorporated areas: Fulshear, Sugar Land, Stafford, and Missouri City.

1.2 Report Purpose and Organization

The TCEQ contracted with the Texas Institute for Applied Environmental Research (TIAER) to conduct the appropriate studies to (1) acquire data and information necessary to identify pollutant sources and support modeling and assessment activities; (2) perform the assessment activities necessary to allocate the loadings of the constituent of concern; and (3) assist TCEQ in preparing a total maximum daily load (TMDL). A report titled *Technical Support Document: Upper Oyster Creek (Segment 1245) Dissolved Oxygen TMDL* (Hauck and Bing, 2008) was developed that provided information on historical data; watershed properties; dissolved oxygen assessment monitoring to confirm the State of Texas 2002 Section 303(d) listing of impairment due to low dissolved oxygen concentrations; verification and application of a dissolved oxygen model; and development of the TMDL load allocation.

Subsequent to the development of the technical support document for the TMDL and prior to approval of a TMDL for dissolved oxygen for Segment 1245, three events occurred that necessitated this addendum. First, TCEQ has embarked on an approach requiring that TMDLs be developed for each impaired assessment unit within a segment rather than for the segment as a whole. Second, assessment unit 1245_01 (AU_01), the most downstream assessment unit in Segment 1245 for the reach below Dam #3 (Figure 1-1), will be the subject of a Use Attainability Analysis (UAA) evaluating the aquatic life use supported by this portion of the segment. Since the aquatic life use designation will define the dissolved oxygen criteria applicable to AU_01, the present TMDL will not include that assessment unit. Third, the U.S. Environmental Protection Agency (EPA) approved a portion of the Texas Surface Water Quality Standards (TNRCC, 2000) that defines the critical low flow for eastern and southern ecoregions of Texas based on stream bedslope and 24-hour (hr) average dissolved oxygen criteria, which has implications on the computer modeling presented in Hauck and Bing (2008) and the actual TMDL load allocations developed from that modeling.

This addendum report is not intended to be entirely self-contained, but rather provides additional information to Hauck and Bing (2008) that addresses the need to develop the TMDL on an assessment unit basis, to exclude AU_01 from TMDL load allocations as a result of the planned UAA on that reach of the segment, and to incorporate the influences of the EPA recent approval of Table 5 in the Texas Surface Water Quality Standards that adds to the determination of critical low flow for Segment 1245. The approach taken within this addendum is to include the same sections and section headings as found in Hauck and Bing (2008) and to provide changes and additions to each section resulting from the three events mentioned in the previous paragraph.

SECTION 1

FIGURES

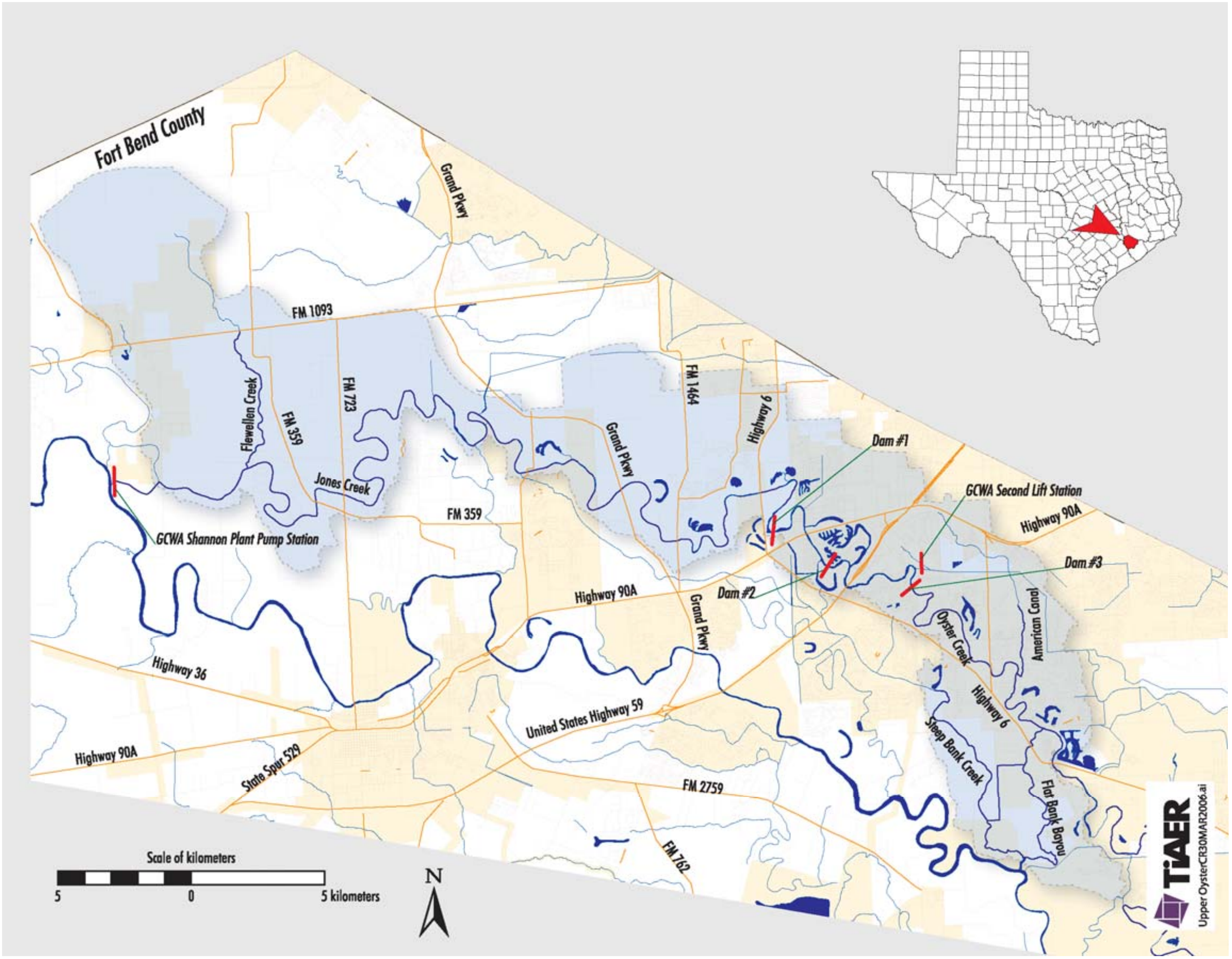

Figure 1-1 Relevant geographical references in Upper Oyster Creek

SECTION 2

WATERSHED PROPERTIES AND HYDROLOGY

2.1 Discussion of Changes to Section 2

Several changes have occurred pertaining to facilities permitted to discharge wastewater into Segment 1245 since the technical support document was written. Most changes are minor and pertain to changes in permit expiration date and previously pending permits for facilities that have now been granted permits. All these facilities were included in the TMDL load allocation process within the previous report based on their pending permits. Two changes of consequence occurred. First, the City of Missouri Wastewater Treatment Facility (WWTF) at the writing of this addendum has a pending permit amendment that includes final expansion phases involving increased discharge and more stringent limits on certain parameters. Second, Fort Bend County Municipal Utility District (MUD) # 41 WWTF has been granted a permit amendment that decreased the final permitted discharge limit from 0.86 million gallons per day (MGD) to 0.50 MGD with other limits remaining the same. The text and associated table and figure from Section 2.5 (Permitted Wastewater Discharges) of the technical support document are repeated below as Section 2.2 with necessary changes reflected.

2.2 Permitted Wastewater Discharges

Under the Texas Pollution Discharge Elimination System (TPDES), 17 facilities within Segment 1245 hold permits to discharge wastewater (Table 2-1, Figure 2-1). Two additional facilities hold permits without provisions that allow discharge of wastewater—the Texas Department of Criminal Justice (TDCJ) holds a permit for a confined animal feeding operation (CAFO) with land application of solid and liquid waste and Bono Brothers, Inc. holds a permit for beneficial land application of sewage sludge and domestic septage. For completeness these two facilities are also included in Table 2-1. Finally, Hines Nurseries, in addition to holding a permit for internal discharge of a small amount of treated human waste, also holds a permit to discharge storm/irrigation waters. All entities holding active TPDES discharge permits are domestic wastewater (sewage) treatment facilities. From 2005 to 2007, the reported average daily domestic wastewater discharge to Upper Oyster Creek was 12.8 MGD, which is well below the permitted daily flow of 31.6 MGD. A number of facilities have recently become operational and no monitored discharge information is provided for these facilities. Increasing discharge limits for some municipal permittees within the segment and adding new discharge permits in recent years indicate a steadily increasing wastewater loading into the segment commensurate with the rapid urbanization of the watershed.

The City of Sugar Land, City of Missouri City, and Fort Bend County WCID # 2 permits allow the largest discharge of the wastewater facilities at over 5 MGD each. The other wastewater facilities with permitted wastewater discharges of greater than 1 MGD are Quail Valley Utility District, and Fort Bend County MUDs #s 25, 118, and 142. As indicated in Table 2-1, several facilities are designed such that effluent enters a polishing pond prior to final discharge. Based on TCEQ evaluations of the facilities with polishing ponds, the final effluent from each facility will be at background levels of five-day carbonaceous biochemical oxygen demand (1.3 mg/L) and ammonia nitrogen (0.050 mg/L).

In 2001 TIAER staff reviewed the TPDES permit files to identify enforcement actions or other persistent problems with permitted discharge facilities within Segment 1245. This review was updated in 2005 and October 2008 by reviewing the discharge monitoring reports (DMR) from the Permit Compliance System (PCS) downloaded from the USEPA Envirofacts Data Warehouse (EPA, 2005 & 2008). No enforcement actions were uncovered in the screening; however, some self-reporting, operation, and administration violations were noted in the files. The TDCJ facility has had some minor violations regarding uncertified personnel, operational requirements, and final effluent limitations; however, these violations surfaced during an annual inspection and were completely resolved within the required time frame. The TDCJ facility underwent a $4.5 million expansion during 2001-2002. Imperial Sugar Corporation resolved a recurring violation on the annual certification of accuracy for pumping capacity used to measure flow, which was observed on biannual inspections in 1996 and 1998, though this facility has ceased operation and discharge since late in 2003. A violation of the fecal coliform bacteria daily maximum, 7-day average, and daily average criteria by Missouri City occurred in August 2000. The problem was resolved immediately, and subsequent fecal readings indicated no long-term concerns. No other fecal coliform effluent quality violations were reported since that time.

Because efforts to improve water quality problems have a long history in Upper Oyster Creek, a number of significant changes and improvements have occurred, which likely improved water quality. Kolbe (1992) reports:

- Prior to 1975 the City of Sugar Land operated three wastewater treatment facilities (WWTFs) that discharged into the Upper Reach; but, beginning in 1975, these facilities were closed and the sewage was piped to the Brazos River Authority's (BRA) Sugar Land Regional WWTP, which does not discharge in Segment 1245. (Note: Since 1991 the City of Sugar Land has operated a WWTF that discharges into Steep Bank Creek in the Lower Reach.)
- The Hines Horticulture direct discharge was removed in 1990 and reduced to storm water overflow releases and a very small internal domestic wastewater discharge that does not go to receiving waters.
- Wastewater treatment at the TDCJ unit has been improved since the late 1980s. Feedlot runoff has been controlled through coverage under a general permit since roughly that same time.

In addition, changes have been made to mitigate the effects of the previously permitted discharges from the Imperial Sugar facility. After June 1996, Imperial Sugar's major discharges were delivered to the BRA regional WWTF for treatment and subsequent discharge outside the watershed. Kolbe (1992) states that from 1987 through 1990 Imperial Sugar discharged an average of 17 to 21 MGD of wastewater at elevated temperature, which was allowed in their permits. In 2003, the facility ceased any discharge to Upper Oyster Creek.

SECTION 2

TABLES

Table 2-1 Permitted facilities, permit limits, and related information for Upper Oyster Creek watershed

TCEQ Permit No. / EPA Permit No.	Facility Name & Location (Assessment Unit-AU)	Permit Expiration Date	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)
WQ0013873-001 TX0114855	City of Missouri City[6] **(AU_01)**	Dec. 1, 2008	1.047	6.0	5.0	12.0	1.5	5.0	No
WQ0012833-002 TX0096881	City of Sugar Land **(AU_01)**	Dec. 1, 2008	4.303	10.0	10.0	15.0	3.0	5.0	No
WQ0012003-001 TX0077178	Fort Bend County MUD # 25 **(AU_03)**	Dec. 1, 2010	0.781	1.6	5.0	5.0	1.0	5.0	No
WQ0012475-001 TX0089249	Fort Bend County MUD # 41 **(AU_03)**	Dec. 1, 2012	0.306	0.50	10.0	15.0	3.0	5.0	No
WQ0013951-001 TX0116386	Fort Bend County MUD # 118 **(AU_03)**	Dec. 1, 2008	0.214	1.2	5.0	12.0	1.5	5.0	No
WQ0014715-001 TX0128791	Fort Bend County MUD # 134 **(AU_03)**	Dec. 1, 2011	—[2]	0.30	7.0	15.0	2.0	4.0	Yes
WQ0014408-001 TX0125555	Fort Bend County MUD # 142 **(AU_03)**	Dec. 1, 2009	0.102	1.2	5.0	5.0	2.0	6.0	Yes
WQ0014692-001 TX0128635	Fort Bend County MUD # 182 **(AU_03)**	Dec. 1, 2008	—[2]	0.8	7.0	15.0	1.0	5.0	Yes
WQ0010086-001 TX0021458	Fort Bend County WCID # 2 **(AU_01)**	Dec. 1, 2009	3.847	6.0	10.0	15.0	2.0	6.0	No
WQ003015-000 TX0103608	Hines Nurseries Inc.[3]	Dec. 1, 2008	NA	0.0035	30.0	90.0	—	—	No
WQ0012937-001 TX0090484	Palmer Plantation MUD 001 **(AU_01)**	Dec. 1, 2008	0.309	0.60	10.0	15.0	3.0	5.0	No
WQ0014758-001 TX0129216	Pederson 631, LP **(AU_03)**	Dec. 1, 2011	0.027	0.60	10.0	15.0	2.0	6.0	Yes
WQ0011046-001 TX0035220	Quail Valley UD **(AU_01)**	Dec. 1, 2008	1.543	4.0	10.0	15.0	4.0/3.0[5]	6.0/5.0[5]	No

TCEQ Permit No. / EPA Permit No.	Facility Name & Location (Assessment Unit-AU)	Permit Expiration Date	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)
WQ0014100-001 TX0119199	Sienna Plantation MUD # 1 **(AU_01)**	Dec. 1, 2012	0.133	0.902	10.0	15.0	2.0	6.0	No
WQ0014064-001 TX0117358	Stafford Mobile Home Park, Inc. **(AU_01)**	Dec. 1, 2008	0.027	0.10	10.0	15.0	3.0	5.0	No
WQ0011475-001 TX0031674	TDCJ Jester Unit # 1 – WWTF **(AU_03)**	Dec. 1, 2008	0.210	0.315	10.0	15.0	3.0	5.0	No
WQ0014745-001 TX0129119	TMI, Inc. **(AU_03)**	Dec. 1, 2011	—[2]	0.50	10.0	15.0	3.0	6.0	Yes
WQ0003742-000 TXL005004	Bono Brothers, Inc. [1]	Feb. 10, 2010	NA	NA	—	—	—	—	NA
TXG920522[4]	TDCJ Jester (Swine CAFO) [1]	Jul. 20, 2009	NA	NA	—	—	—	—	NA
Total			12.849	31.6205					

Notes: [1] Permit does not contain a discharge provision
[2] No monitored discharge information available for this facility when the TMDL was developed.
[3] Discharge outfall is internal to the facility and no wastewater is discharged to a receiving stream. Permit also includes storm water discharge not to exceed 1.0 MGD
[4] Concentrated Animal Feeding Operation (CAFO) general permit number; State-Only CAFO permit with no EPA Permit No.
[5] Quail Valley UD operates under seasonal permit limits. First number is the limit for Dec-Feb; the second number is for Mar-Nov.
[6] The permit limits in this table for City of Missouri City are pending as of September 16, 2008, but expected to be implemented. Present limits are: Discharge = 3 MGD; 5-day CBOD = 10 mg/L; Total Suspended Solids = 15 mg/L; Ammonia-N = 3 mg/L; and Dissolved Oxygen = 5 mg/L..

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

SECTION 2

FIGURES

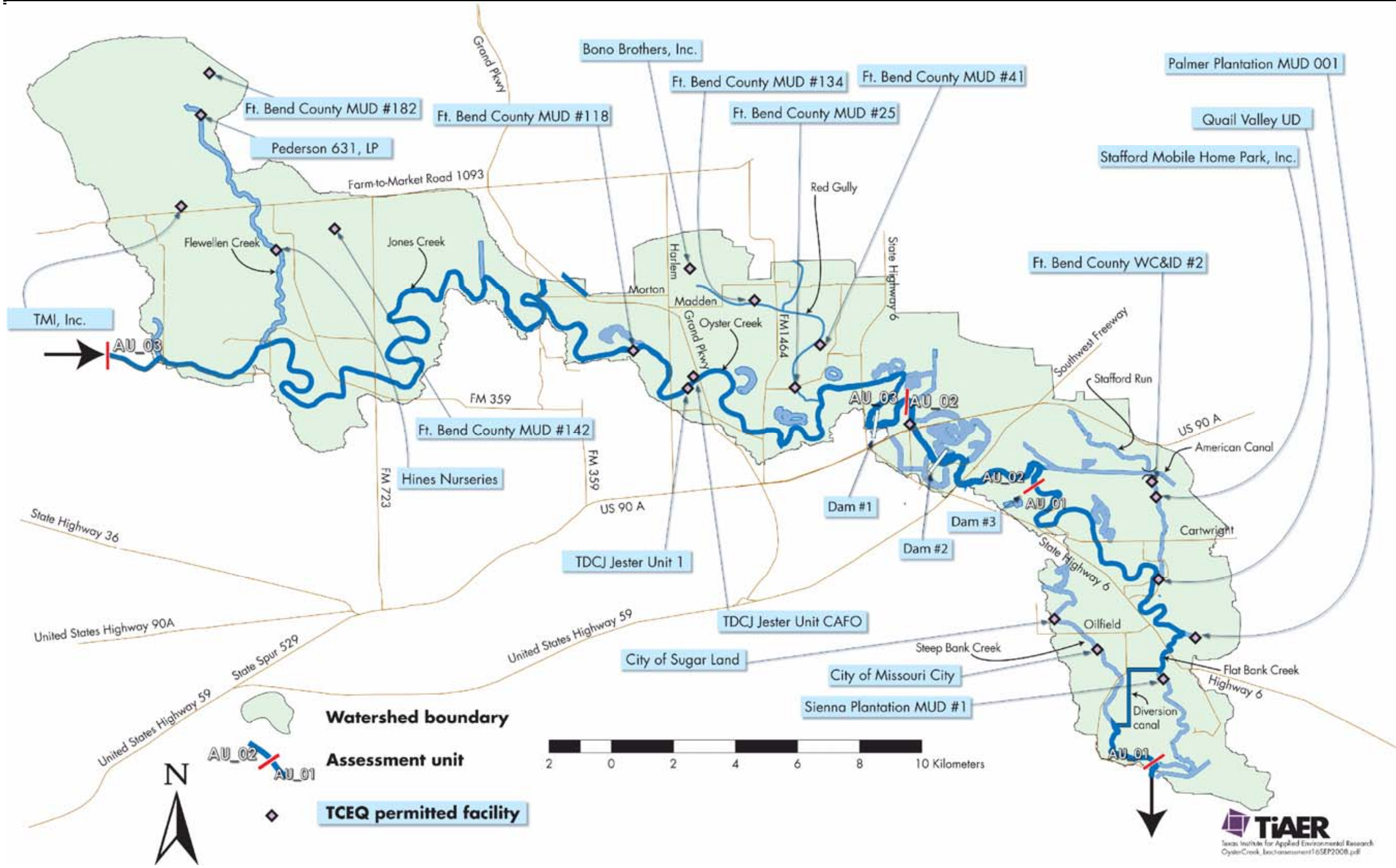

Figure 2-1 Upper Oyster Creek with locations of permitted facilities

SECTION 3

ASSESSMENT OF AQUATIC LIFE USE SUPPORT

3.1 Discussion of Changes to Section 3

The major changes to this section included in this addendum pertain to the assessment units. Within recent TCEQ assessments, the number of AUs in Segment 1245 has been reduced from six to three. Previous AU_01 remains new AU_01; AUs 02, 03, and 04 are now largely incorporated into new AU_02, and previous AUs 05 and 06 are now largely incorporated into AU_03. The assessment methodology presented in this addendum to Section 3 also follows the most recent assessment guidance provided by TCEQ (TCEQ, 2007 & 2008). For reasons of continuity this section from the technical support document is provided in its entirety with the AU and assessment method changes reflected as necessary in text, tables, and figures.

3.2 Background

The 2002 Texas 303(d) list included Segment 1245 under Category 5c ─ additional data and information will be collected before a TMDL is scheduled. To address the need for additional dissolved oxygen data, monitoring surveys were performed at eight stations along Upper Oyster Creek during the years of 2003 – 2005.

From winter 2003 through summer 2005, TIAER conducted 24-hr dissolved oxygen (DO) assessment surveys at selected stations on Upper Oyster Creek to determine whether or not present DO concentrations support the segment's aquatic life use.

This report section is based on Adams et al. (2007) wherein the original DO assessment results are provided.

3.3 Assessment Stations

From previous assessments, the Texas Commission on Environmental Quality (TCEQ) had divided Segment 1245 into six assessment units, but beginning with the 2006 water quality assessment (TCEQ, 2007a) the number of assessment units was reduced to three. For the present DO assessment, each assessment unit was established with either two or three stations (Figure 3-1):

- Assessment unit 1 (AU_01): From the confluence with the Brazos River upstream to Dam #3 (stations 12074 and 12077)
- Assessment unit 2 (AU_02): From Dam #3 upstream to Harmon Street crossing in Sugar Land (stations 12079, 12082, and 12083)
- Assessment unit 3 (AU_03): From Harmon Street crossing in Sugar Land upstream to the end of the segment (stations 12086, 12087, and 12090)

3.4 Methodology

The DO assessment for Upper Oyster Creek utilized the methodology prescribed by the TCEQ, Surface Water Quality Monitoring Program in their publication *2008 Guidance for Assessing and Reporting Surface Water Quality*, March 19, 2008 (TCEQ, 2008), which contains the same assessment guidance for DO as the previous guidance document (TCEQ, 2007b).

All data used in the assessment were collected under a quality assurance project plan that ensures the data are of a known and appropriate quality (TIAER, 2002; TIAER, 2004; TIAER 2005). A description of the methodology and data requirements for application of the assessment is as follows.

3.4.1 Constraints on Sampling Events

A minimum of ten 24-hr measurement events within a two- to five-year period are required to assess the aquatic life use. Measurement interval for DO data should be no more than once every 15 minutes and no less than once per hour. For this assessment, data were collected at a 15-minute interval. From the data of each 24-hr event an average DO concentration and an absolute minimum DO concentration are obtained. A streamflow measurement should be obtained with each 24-hr event.

When there are less than 10 sample events, water quality data can not be assessed for impairments of aquatic life. However, with four to nine sets Tier 1 primary concerns can be ascertained.

No more than two thirds of the events should occur in any year. The events must be spaced over an Index Period representing warm-weather seasons (March 15 – October 15) with annually between one half to two thirds of the measurements occurring during the Critical Period (July 1 – September 30). A period of about one month (or four weeks) must separate each 24-hr sampling event.

3.4.2 Assessment Criteria

The supporting criteria for the segment designated intermediate aquatic life use consist of 24-hr average and absolute minimum concentrations. The criteria for protection of intermediate aquatic life use are:

- 24-hr average DO concentration $\geq$ 4.0 mg/L
- 24-hr absolute minimum DO concentration $\geq$ 3.0 mg/L

and to protect fish spawning during any of the first 6 months of the year when average water temperature is between 63 and 73 °F (17.2 and 22.8 °C):

- 24-hr average DO concentration $\geq$ 5.0 mg/L
- 24-hr absolute minimum DO concentration $\geq$ 4.0 mg/L

3.4.3 Assessment of Exceedances

Whether an assessment unit supports the DO criteria is based on the number of exceedances that occur in the data set (with DO criteria an "exceedance" actually refers to DO concentrations that fall *below* the established criteria) based on the binomial method for establishing required number of exceedances for nonsupport of designated uses as described in TCEQ (2008). The assessment is conducted separately for the 24-hr average DO concentration data and the 24-hr minimum DO concentration data. If a DO concentration (either average or minimum depending upon which is being assessed) for a sample event is less than the relevant criterion, the event is counted as an exceedance. Based on the number of samples in exceedance and total number of samples, the assessment unit is considered *fully supporting*, *concern for near non-attainment but supporting,* or *not supporting* (Table 3-2). The assessment must indicate that *both* the 24-hr average and 24-hr minimum DO criteria are being fully supported for the assessment unit to be considered as fully supporting.

3.4.4 Flow Conditions

Streamflow at the time of a 24-hr DO measurement event is a consideration in the assessment method. A sample event is excluded from assessment if the streamflow is less than the seven-day, two-year low flow (7Q2) determined from statistical analysis of streamflow data for freshwater streams, including Upper Oyster Creek (TCEQ, 2008). If the assessment indicates an AU is not supporting due to exceedances of the 24-hr average criterion, then for streams located in the eastern and southern regions of Texas, in which upper Oyster Creek is included, confirmation of apparent DO impairment is performed (TCEQ, 2008). The confirmation is performed by excluding individual 24-hr average DO exceedances obtained under measured streamflow less than the critical low flow based on streambed slope as obtained from Table 5 of the Texas State Water Quality Standards (TNRCC, 2000), and then reassessing the data using Table 3-2. Because of the importance of low flow characterization to the assessment of aquatic life use support, further discussion of low flow conditions of Upper Oyster Creek are provided.

The hydrology of Upper Oyster Creek is a response to rainfall-runoff from a combination of an urban and rural land use watershed, likely shallow groundwater interactions, and several anthropogenic modifications, which include pumping, damming, and municipal WWTF effluents. AU_01, itself, contains two reasonably distinct hydrologic sections. An upper portion, which is defined from immediately above the confluence with Stafford Run upstream to Dam #3, contains as a major modification the presence of the dam, which at low flow interrupts the normal hydrologic pathway except for minimal seepage. A lower portion, which is defined from the downstream end of the stream segment to the confluence with Stafford Run, contains as the major anthropogenic modification significant WWTP effluents.

The hydrology of Upper Oyster Creek reach in AU_02 and AU_03 is often dominated by the GCWA's use of this reach as a conveyance channel for water pumped via the Shannon Pump Station from the Brazos River into the headwaters of Upper Oyster Creek. Limited water delivery points occur along AU_02 and AU_03, and most of the water is pumped out of the system at the Second Lift Station into the American Canal for an ultimate destination in the

Texas City area. Minimum flows occur in this reach when pumping is not occurring and several days have elapsed since rainfall runoff. With this combination of circumstances, the streamflow may approach that of the effluents from the point source dischargers. Measurement of such reduced flows, however, is extremely difficult, if not impossible, because of the pooled and impounded nature of much of AU_03 and especially AU_02, which results in very low velocities at low flows. Historically the occurrence of no pumping is most common in the winter when water demands are the least, though such occurrences may happen at any time of year when repairs are required by the GCWA.

Because of the southeast Texas location of Upper Oyster Creek and the slight slopes of its streambed, the slope-based (bedslope) definition of critical-low flow is applicable for this DO assessment. The Fort Bend County Drainage District (District) provided elevation and stream distance information for AU_01 and AU_03 that were used to determine bed slope (Jalowy, 2004 & 2005). TCEQ guidance indicates that bedslope can be calculated from US Geological Survey 1:24,000 topographic maps based on contour line crossings of the stream (TCEQ, 2003); however, for this study it was considered that actual detailed survey information would provide a more accurate means of calculating bedslope than USGS maps.

The District's information for AU_01 begins 3,300 feet upstream of the Brazos River and ends at Dulles Avenue just downstream of Dam #3. That entire stretch of the channel (55,100 ft) was divided by the District into three separate design gradients. Their design gradients are as follows:

- From the beginning flowline elevation to Highway 6 the slope is 0.050 %. Therefore, the change in elevation is 0.5 m/km.
- The channel slope from Highway 6 to F.M. 1092 is 0.041 %, or 0.41 m/km.
- The channel slope from F.M. 1092 to Dulles Avenue is 0.032 %, or 0.32 m/km.

The full gradient length is 55,100 ft with an elevation change of 23.65 ft, which gives an overall slope of 0.43 m/km. For a DO criterion of 4.0 mg/L, the critical low flow based on the overall bedslope is 0.5 cfs from Table 5 of TNRCC (2000).

For AU_02 the approach taken to determine the critical low flow from Table 5 of TNRCC (2000) was based on an "effective" slope rather than actual bedslope. Dams #2 and #3 provide constant backwater influences throughout AU_02, which results in a minimal "effective" slope that was considered to be ≤ 0.1 m/km, the minimum bedslope in Table 5. For a bedslope of 0.1 m/km and a DO criterion of 4.0 mg/L, the critical low flow from Table 5 of TNRCC (2000) was determined to 3.0 cfs for AU_02.

For AU_03 District survey information for the portion of Jones Creek that constitutes the upper half of AU_03 was used to calculate an average bedslope of 0.009 % or 0.09 m/km. For a DO criterion of 4.0 mg/L, the bedslope adjusted critical low flow was determined to be 3.0 cfs for AU_03.

TCEQ determination of 7Q2 flow for Upper Oyster Creek based strictly on hydrologic data (personal communication, Ms. Kenda Smith, TCEQ, November 2004) and bedslope adjusted critical low flow determined from Table 5 of TNRCC (2000) are found in Table 3-1.

3.5 DO Assessment

3.5.1 Water Temperature and Streamflow During Events

Sampling stations, beginning date of sampling, streamflow and 24-hr average water temperature for each sampling event are listed in Table 3-3. In addition, the 24-hr average temperatures for surveys occurring during the first six months of the year are provided in Table 3-3. Therefore, Table 3-3 can also be used to determine which events should be used for DO assessment based on streamflow at or above the 7Q2 values in Table 3-1, presence or absence of required streamflow measurement for the event, and whether the temperature-based DO criteria to protect fish spawning applies for the event.

It can be seen from the distribution of dates in Table 3-3 that the minimum frequency and duration of sampling requirements are met by the data set. The events span two seasons (Spring and Summer), and include a 3-year period from May of 2003 to September of 2005. No more than two thirds of the samples are from the same year. All of the sampling dates occurred within the Index Period (March 15 – October 15) and one half or more of the sample events in each year occurred during the Critical Period (3 of 5 in year 2003, 3 of 6 in year 2004, and 3 of 5 in year 2005).

Gray shaded values in Table 3-3 are temperatures that fall within the range of 17.2 °C to 22.8 °C during the first six months of the year. Sampling events with temperatures shaded gray were evaluated against the higher DO criteria of 5.0 mg/L average 24-hr DO and 4.0 mg/L absolute minimum 24-hr DO.

All measured flows were above the 7Q2 flows and the bedslope adjusted critical low flows (Table 3-1), so all the sample sets with measured flows could be used for the DO assessment.[1] There were two dates (5/19/2003 and 8/11/2003) at station 12077 during which flow was too low to be measured. Due to lack of flow data for these dates, these sampling events cannot be used for the DO assessment. On 7/1/2004 there was backwater from a flooding event on the Brazos River that prevented flow measurements from being taken at both stations (12077 and 12074) in AU_01 of Upper Oyster Creek. Starting 9/29/2004 a 24-hr DO event was conducted only at

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[1] Station 12077 presented a challenge regarding measurement of low streamflows, because the entire stream channel along that reach was mildly pooled, which prohibited measurement at lower flows. Beginning September 2003, station 18211(location of a small riffle) was established about 1 km downstream from station 12077 as an alternative location for streamflow measurement when flow could not be measured at station 12077. Twenty-four hr DO assessment, however, could not be moved to station 18211. Unacceptable exposure of instrumentation to vandalism at this station would occur, because its location was adjacent to a heavily trafficked walking and jogging trail. Also, refined 7Q2 flows were determined as part of the TMDL allocation process. Though these refined flows were greater at some stations than those developed by TCEQ in 2004, all measured flows collected during the DO monitoring were larger than these refined 7Q2 flows resulting in no changes to the assessment.

stations 12074, 12077, and 12090 to replace the event missed at 12074 and 12077 due to backwater conditions and the missing July 2003 event data from failed instrumentation at station 12090. Because pumping had stopped from both the Shannon Pump and the Second Lift Stations prior to and during the September 2005 monitoring survey, flow was not attainable at any station in AU_02 and AU_03. Therefore, data from these stations were not included in this assessment.

Prior to 2005 flow could not be measured at stations 12083 and 12079, because these stations are located in reservoir-like impoundment areas between small dams where extremely low velocities do not allow accurate measurement of flow. Based on contiguous streamflow and proximity of stations 12083 and 12079 to station 12082, where flow could be measured (see Figure 3-1), it was assumed that the flow at station 12082 reasonably represented the flow at the other two stations. All streamflows at station 12082 were well above the critical low flows in Table 3-1. For the 2005 monitoring period, acoustic Doppler technology allowed flow measurements to be made at these low velocity stations. As shown in Table 3-3, only one event on 6/8/2005 at station 12083 did not yield a flow measurement. However, because a flow measurement was obtained at station 12082 during the same monitoring period, this event was included in the assessment. For all events and stations where flow was measurable, streamflows were above critical low flow, which allows all such data to be used in this assessment.

3.5.2 Assessment Results

Table 3-4 shows the 24-hr average and absolute minimum DO concentrations for all sampling dates and stations. Based on the sample size and the number of exceedances, the aquatic life use assessment by station is provided in the last row in Table 3-4. The DO concentrations in red font do not meet the DO criteria. The values shaded in gray are samples that are subject to the higher DO criteria based on average water temperature and time of year. It can be seen that all events during the period of higher restrictions meet the higher criteria. The values that are shaded in yellow in Table 3-4 are samples that should not be used in the assessment due to absence of streamflow data.

All stations, except 12087, were assessed as *not supporting* the intermediate aquatic life use. Station 12087 was found to be in *full support* of the intermediate aquatic life use.

Figures 3-2 ─ 3-9 graphically show the pattern of DO at each station. The blue and red lines represent the 24-hr DO average and absolute minimum limitation respectively. Values that are in exceedance of the criteria are circled. All sampling data are shown on the figures regardless of whether or not the data point was used in the DO assessment due to flow limitations.

3.6 Findings and Discussions

In general, the assessment found that the Upper Oyster Creek system is *not supporting* of the intermediate aquatic life use; however, there was one area of exception – station 12087. DO concentrations were particularly low during the second year, especially at stations 12082, 12083 and 12086 where both 24-hr average and absolute minimum DO concentrations were frequently in exceedance (Table 3-4).

To complete the assessment at the AU level, which is the spatial level used by the TCEQ, the data from each monitoring station was aggregated by location into one of the three AUs of Segment 1245. The assessment was then performed on the aggregated data sets for each AU using Table 3-2. A summary of assessment findings regarding support of the intermediate aquatic life use is as follows for the three AUs:

- AU_01, 24-hr average: *fully supporting*
- AU_01, 24-hr minimum: *not supporting*
- **AU_01, final assessment:** ***not supporting***

- AU_02, 24-hr average: *not supporting*
- AU_02, 24-hr minimum: *not supporting*
- **AU_02, final assessment:** ***not supporting***

- AU_03, 24-hr average: *not supporting*
- AU_03, 24-hr minimum: *not supporting*
- **AU_03, final assessment:** ***not supporting***

These assessment findings were based on eliminating all data for which a flow measurement had not been obtained, which are the data highlighted in yellow in Table 3-4. If these data had been included in the analysis, the same conclusion is reached that all three AUs do not support the intermediate aquatic life use based on DO exceedances. At station 12079, however, the 24-hr minimum assessment would have indicated concern for non-attainment but supporting.

The fact that most exceedances in AU_01 (both stations 12074 and 12077) are caused by DO concentrations below the minimum criterion while the average DO concentrations are acceptable (Table 3-4) indicates a system influenced by aquatic plant growth. During daylight hours a large increase in DO occurs as oxygen is released into the water by the photosynthetic process. At night, however, when photosynthesis is not occurring, respiration of the large aquatic plant population depletes much of the DO. Therefore, there are large daily swings in DO concentration resulting in high 24-hr average DOs, but low 24-hr absolute minimum DO concentrations.

Diel variations in DO concentrations are not nearly as pronounced in AU_02 and AU_03 as in AU_01. In these other assessment units, exceedances often included both average and minimum DO concentrations from the same event.

Four supplementary DO assessment events were conducted during the winter (February 2003, December 2003, January 2004, and February 2004). No DO exceedances occurred with any of these events. Historical data from the 1980s and 1990s indicated occurrences of low DO concentrations within AU_02 during the winter when GCWA pumping was often lowest. Past winter DO excursions occurred when significantly greater amounts of point source effluents were present in the area of AU_02. While these recent winter surveys portend that present condition in Segment 1245 are not conducive to low winter DO concentrations, the data are inadequate to definitively reach that conclusion.

As indicated in Table 3-4 and Figures 3-2 ─ 3-9, the data from the 24-hour DO assessment surveys for the Index Period of 2003 showed pronounced differences in the number of criteria exceedances at stations 12082, 12083, and 12086 when compared to the data for the Index Period of 2004. Concerns over these differences resulted in the third year of data collection in 2005. Also, within some assessment units and during some surveys, the measured exceedances were only 0.1 to 0.2 mg/L below the criteria. Some steering committee members at their December 9, 2004 public meeting noted the small magnitudes of some exceedances and that ignoring these small exceedances would result in more stations supporting the segment's aquatic life use.

Regarding observation of some stakeholders that the measured exceedances for some surveys were only slightly (0.1 to 0.2 mg/L) below the criteria, review of Table 3-4 also indicates a roughly equal number of non-exceedances that are at or only slightly above the criteria. While it is both unfortunate that the measured values occasionally were very near the criteria and acknowledged that these slight differences are within the instrumentation accuracy, the roughly equal number of slight exceedances and slight non-exceedances must be presumed to offset one another in lieu of any contrary information. That is while some of the slight exceedances might actually not have been exceedances, some of the slight non-exceedances might actually have been exceedances.

SECTION 3

TABLES

Table 3-1 Seven-day, two-year low flow (7Q2) assessment showing TCEQ determined 7Q2 and bedslope adjusted critical low flow from Table 5 of TNRCC (2000).

Station Id	TCEQ Determined 7Q2 Flow (cfs)	Bedslope Adjusted Critical Low Flow (cfs)
12074	6.77	0.5
12077	0.1	0.8
12079	0.86	3.0
12082	0.73[a]	3.0
12083	0.86	3.0
12086	0.86	3.0
12087	0.38	3.0
12090	0.1	3.0

a. Based on Gulf Coast Water Authority information, it is estimated that 15 % of the flow at station 12083 is diverted through Brooks Lake, thus effectively bypassing station 12082, and that flow reenters Oyster Creek before station 12079.

Table 3-2 Assessment table using binomial method. Source: TCEQ (2008)

Figure B-1. Binomial Method for Listing and Delisting Conventional Parameter Use-Attainment and Concerns

Use this look-up table for the following use-attainment assessment methods:

Aquatic Life Use:	**General Use:**
-DO grab minimum	-Temperature
-24-Hour DO average	-High / Low pH
-24-Hour DO minimum	- Enterococcus for Segments 1006 and 1007

Fully Supporting (FS), **No Concern (NC)**, **Concern for Near Non-attainment but Supporting(CN)**, **Not Supporting (NS)**. **Note that fewer samples than illustrated are not assessed (NA)**. ***Exceedance ratios less than that indicated (≤10%) by the thick line can be delisted.***

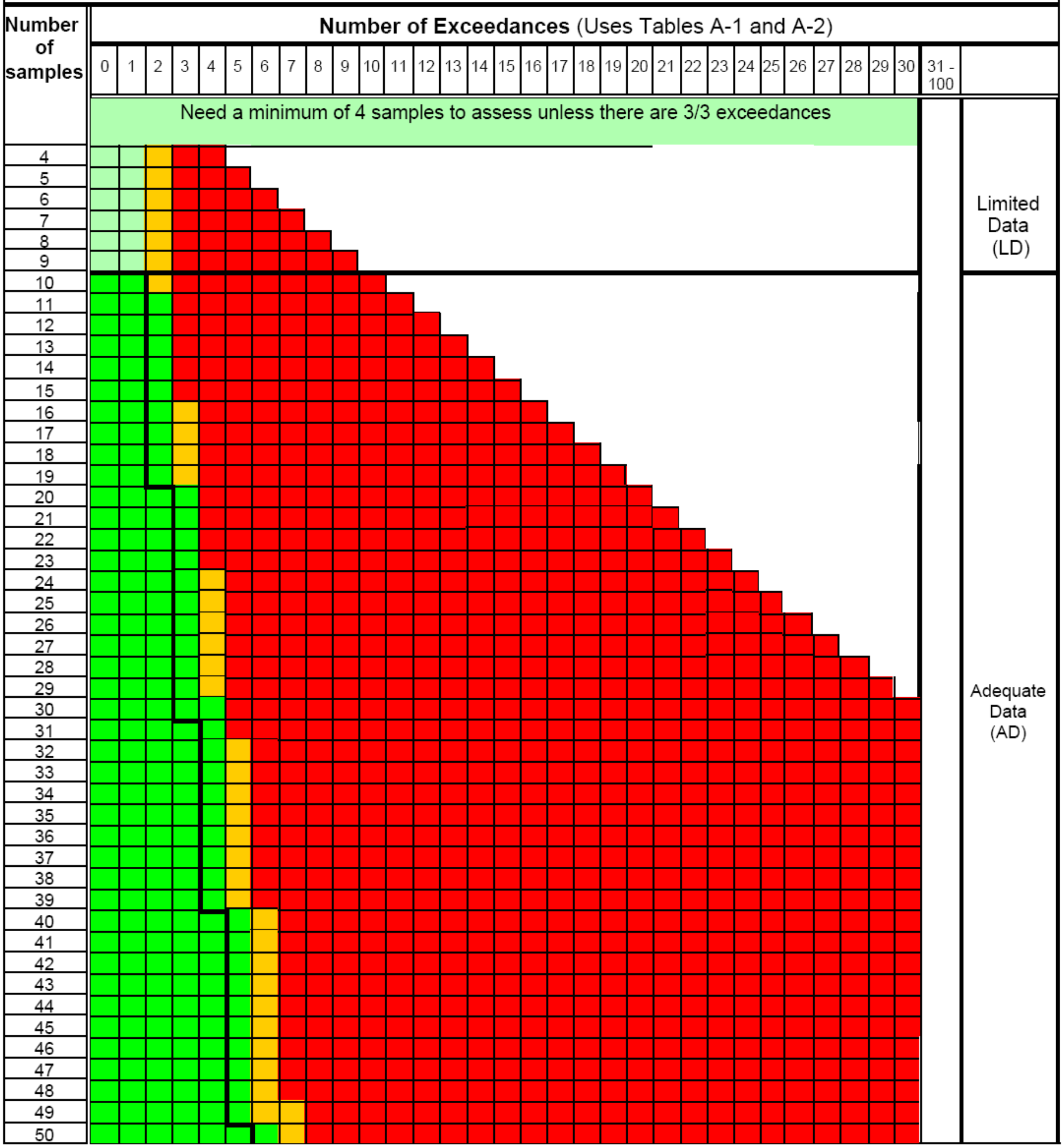


Table 3-3 Sample stations, dates of sampling, and the flow rate at each station for the 24-hr DO assessment (NA – not applicable, NM – not measured, MD – missing data; gray shaded temperatures indicate that DO criteria to protect fish spawning pertain because of time of year and water temperature.)

Beginning Date of 24-hr Event	Stations (assessment units)															
	12090 (3)		12087 (3)		12086 (3)		12083 (2)		12082 (2)		12079 (2)		12077 (1)		12074 (1)	
	Flow	Temp	Flow	Temp	Flow	Temp	Flow	Temp	Flow	Temp	Flow	Temp	Flow	Temp	Flow	Temp
	cfs	°C	cfs	°C	cfs	°C	cfs	°C	cfs	°C	cfs	°C	cfs	°C	cfs	°C
5/19/2003	214	30.0	111	30.2	189	29.5	NM	30.7	122	30.6	NM	30.2	NM	28.1	14.7	28.9
6/16/2003	114	28.1	113	28.6	104	29.4	NM	28.7	83.0	29.2	NM	29.4	53.4	28.9	51.8	27.5
7/14/2003	MD	NA	42.1	NA	144	NA	NM	NA	87.9	NA	NM	NA	66.0	NA	162	NA
8/11/2003	85.2	NA	97.1	NA	89.8	NA	NM	NA	77.7	NA	NM	NA	NM	NA	30.0	NA
9/9/2003	114	NA	109	NA	103	NA	NM	NA	72.9	NA	NM	NA	3.2	NA	22.8	NA
3/23/2004	126	20.4	110	20.6	105	20.6	NM	20.8	57.8	20.9	NM	21.3	5.8	20.5	25.3	21.4
4/20/2004	124	22.5	112	23.3	109	23.2	NM	23.8	61.7	24.0	NM	23.5	2.6	23.3	13.9	24.2
5/25/2004	128	27.8	79.1	28.3	68.8	28.4	NM	29.0	59.8	29.0	NM	28.8	7.6	28.3	24.3	27.5
7/1/2004	31.9	NA	94.1	NA	189	NA	NM	NA	124	NA	NM	NA	NM[a]	NA	NM[a]	NA
8/2/2004	141	NA	66.9	NA	91.1	NA	NM	NA	178	NA	NM	NA	51.2	NA	58.3	NA
8/30/2004	121	NA	86.2	NA	90.4	NA	NM	NA	77.8	NA	NM	NA	8.9	NA	51.5	NA
9/29/2004	118	NA	NM	NA	NM	NA	NM	NA	NM	NA	NM	NA	2.0	NA	12.7	NA
5/3/2005	117	22.8	115	22.7	138	23.3	126	23.2	88.7	23.2	127	23.1	2.5	24.2	12.0	23.6
6/8/2005	126	30.5	113	30.8	113	30.7	NM	31.1	45.5	30.6	115	31.0	3.0	31.0	14.9	29.8
7/13/2005	112	NA	83.0	NA	104	NA	108	NA	48.9	NA	94.1	NA	2.2	NA	11.4	NA
8/17/2005	125	NA	133	NA	140	NA	88.0	NA	55.8	NA	104	NA	4.1	NA	23.0	NA
9/20/2005	NM[b]	NA	NM[b]	NA	NM[b]	NA	NM[b]	NA	NM[b]	NA	NM[b]	NA	3.8	NA	10.0	NA

a. Not measured due to backwater from the Brazos River flooding.
b. Not measured, water velocities too low due to no pumping at the Shannon Pump and Second Lift Stations prior to and during event.

Table 3-4 24-hr average and absolute minimum DO concentrations for all sampling dates and stations, the number of sample sets that exceed the DO criteria, and the use attainment assessment based on the binomial method (MD – Missing Data; NM – Not Measured; FS – Fully Supporting; NS – Not Supporting; yellow shading indicates DO values were not be used due to absence of flow measurements; gray shading indicates values subject to spawning DO criteria)

Beginning Date of 24-hr DO event	Stations (assessment units)															
	12090 (3)		12087 (3)		12086 (3)		12083 (2)		12082 (2)		12079 (2)		12077 (1)		12074 (1)	
	Avg	Min	Avg	Min	Avg	Min	Avg	Min	Avg	Min	Avg	Min	Avg	Min	Avg	Min
	mg/L	Mg/L	mg/L	mg/L	mg/L	mg/L	Mg/L	Mg/L	Mg/L	mg/L	Mg/L	mg/L	Mg/L	mg/L	mg/L	mg/L
5/19/2003	**3.4**	**2.0**	5.7	4.9	6.6	5.2	5.9	4.8	6.5	5.4	7.2	6.0	7.0	0.4	6.6	4.1
6/16/2003	**3.9**	3.0	4.6	4.2	5.0	4.7	4.1	3.4	4.4	3.4	4.7	3.8	6.2	4.0	4.3	**2.9**
7/14/2003	MD	MD	6.2	5.9	5.4	4.7	5.8	4.8	6.1	3.9	6.2	4.9	6.8	**2.9**	5.0	3.8
8/11/2003	5.0	4.5	4.6	4.1	4.2	4.0	**3.5**	**2.9**	**3.6**	**2.5**	4.2	3.4	6.9	2.3	4.4	**2.8**
9/9/2003	5.6	5.3	5.8	5.4	5.7	5.4	4.5	4.3	4.4	3.5	5.2	3.6	7.6	**2.2**	4.1	**2.5**
3/23/2004	7.6	7.4	7.5	7.3	7.0	6.9	6.4	6.2	6.4	5.9	5.6	5.3	9.7	4.1	7.1	6.1
4/20/2004	6.8	6.6	6.7	6.5	6.4	6.3	5.8	5.5	5.6	5.3	6.0	5.7	8.3	**1.9**	6.7	5.3
5/25/2004	4.9	4.6	5.0	4.6	4.5	4.3	4.8	4.2	4.8	4.4	5.4	4.7	8.3	**2.5**	4.9	3.4
7/1/2004	**3.2**	**2.8**	**3.0**	**2.7**	**2.5**	**2.4**	**1.8**	**1.2**	**2.4**	**1.9**	**3.2**	**2.4**	4.1	3.3	4.4	3.5
8/2/2004	4.6	**2.8**	4.6	3.9	**3.9**	3.6	**2.7**	**2.1**	**3.5**	**2.1**	4.7	3.2	5.0	3.4	**3.6**	**1.7**
8/30/2004	5.4	5.2	4.8	4.3	**3.5**	**2.8**	**1.8**	**1.4**	**2.8**	**2.0**	4.5	3.4	7.4	3.5	5.6	3.8
9/29/2004	6.3	6.0	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	9.0	**1.4**	6.9	5.3
5/03/2005	7.9	6.9	7.5	7.0	7.4	7.2	6.6	5.4	6.7	5.9	7.5	6.9	7.8	**2.0**	9.2	7.0
6/08/2005	5.0	4.9	4.8	4.1	4.4	4.2	4.2	**2.4**	5.9	3.9	6.3	3.4	7.1	**1.2**	6.3	4.2
7/13/2005	**3.4**	**1.3**	5.0	3.4	5.2	4.6	4.7	3.4	5.8	3.9	4.7	**2.9**	5.4	**0.9**	4.8	3.3
8/17/2005	4.6	4.2	4.2	4.0	**3.9**	3.7	**3.3**	3.0	**3.1**	**1.8**	4.7	**2.9**	8.2	**1.3**	4.0	3.0
9/20/2005	3.4	1.7	8.6	6.8	5.0	3.1	7.1	3.0	7.3	4.8	5.4	4.1	7.8	**0.6**	**3.3**	**1.8**
Exceedances (24 hr Avg)	4/15		1/15		4/15		5/15		5/15		1/15		0/14		2/16	
Assessment (24 hr Avg)	NS		FS		NS		NS		NS		FS		FS		FS	
Exceedances (24 hr Min)	4/15		1/15		2/15		5/15		5/15		3/15		10/14		5/16	
Assessment (24 hr Min)	NS		FS		FS		NS		NS		NS		NS		NS	
Final Assessment	**NS**		**FS**		**NS**		**NS**		**NS**		**NS**		**NS**		**NS**	

SECTION 3

FIGURES

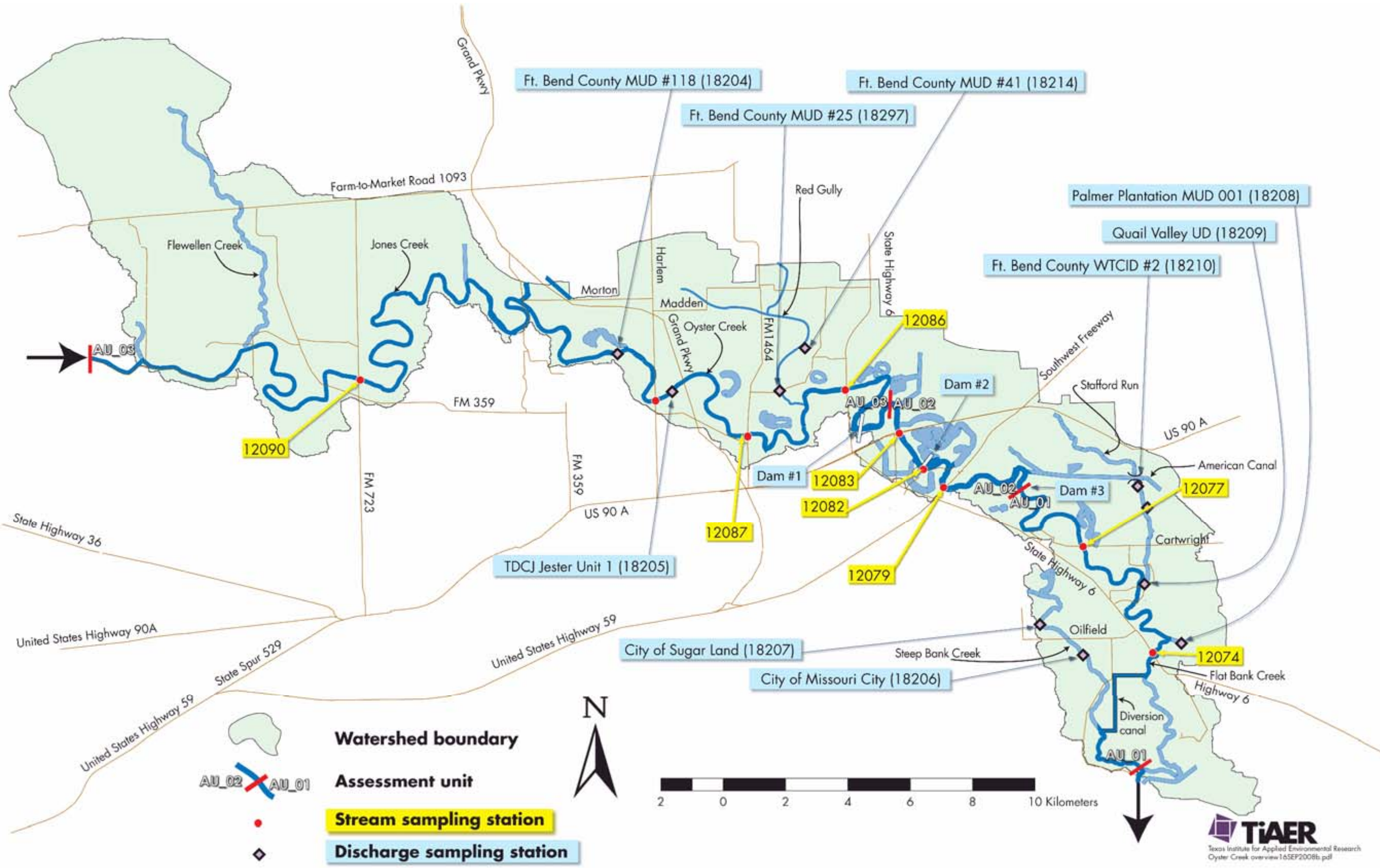


Figure 3-1 Upper Oyster Creek watershed (Segment 1245) with assessment stations

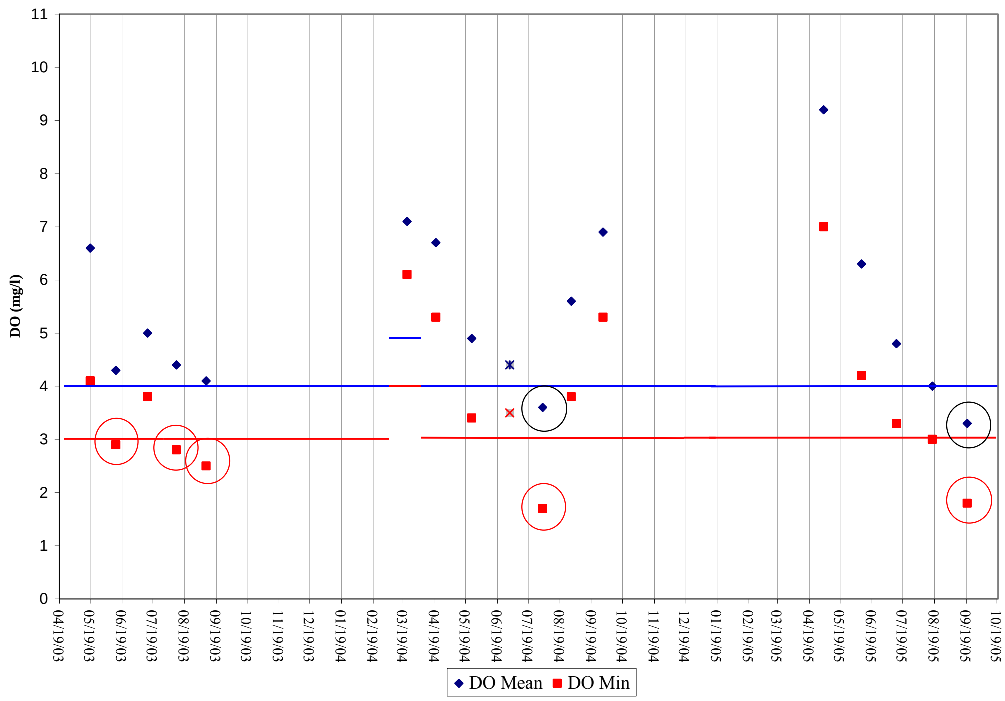


Figure 3-2 **Station 12074 (AU_01) 24-hr average and absolute minimum DO, showing average (blue line) and minimum (red line) criteria (Values in exceedance are circled; values that could not be used in the assessment are marked with an "x")**

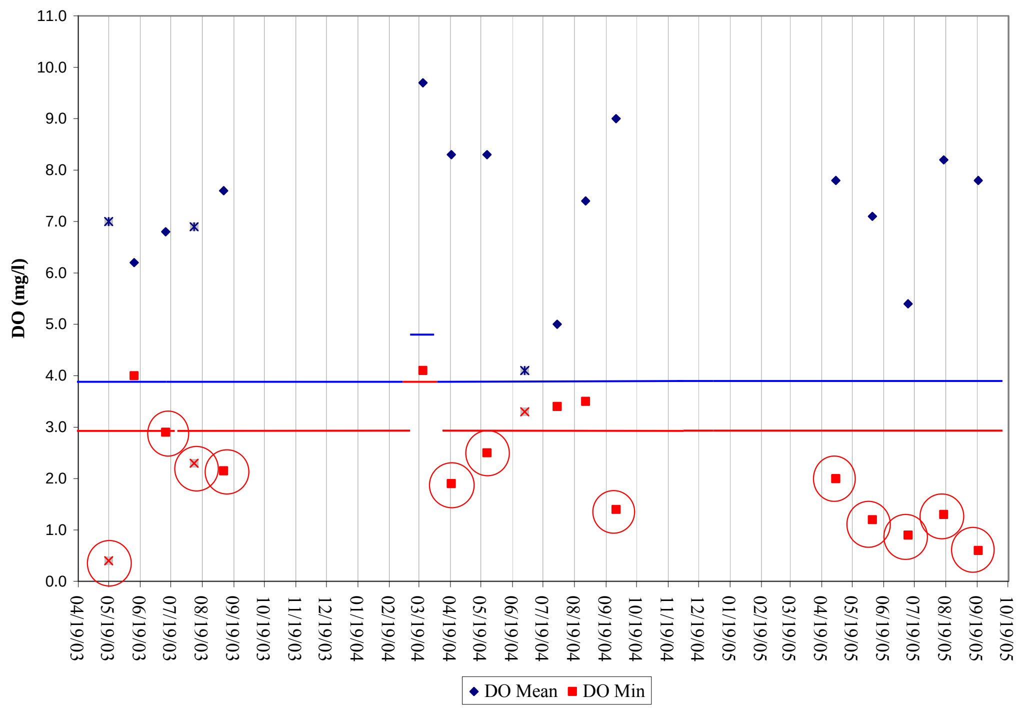


Figure 3-3 **Station 12077 (AU_01) 24-hr average and absolute minimum DO, showing average (blue line) and minimum (red line) criteria (Values in exceedance are circled; values that could not be used in the assessment are marked with an "x")**

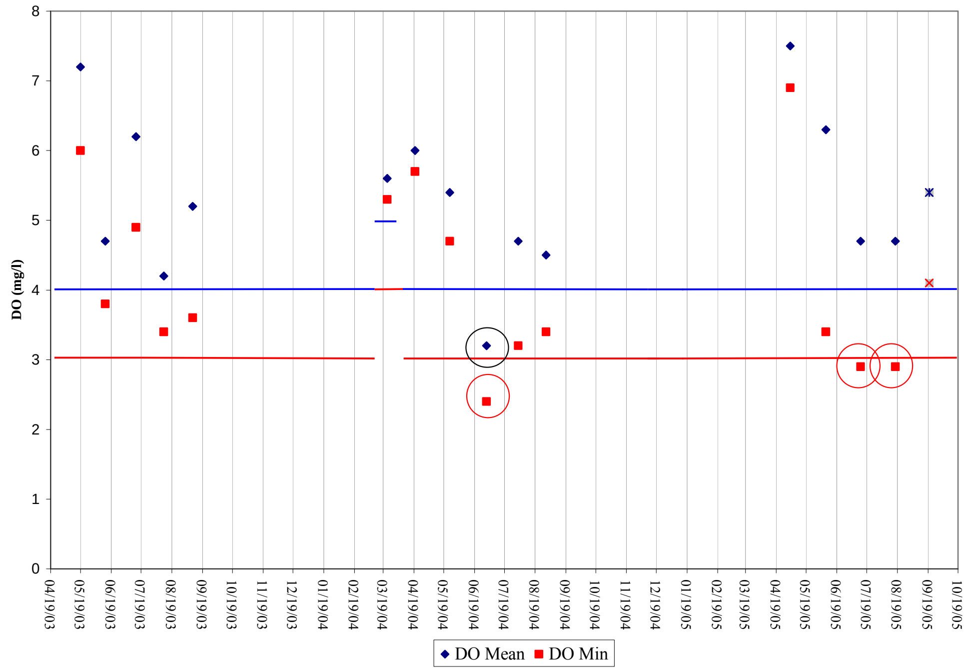


Figure 3-4 **Station 12079 (AU_02) 24-hr average and absolute minimum DO, showing average (blue line) and minimum (red line) criteria (Values in exceedance are circled; values that could not be used in the assessment are marked with an "x")**

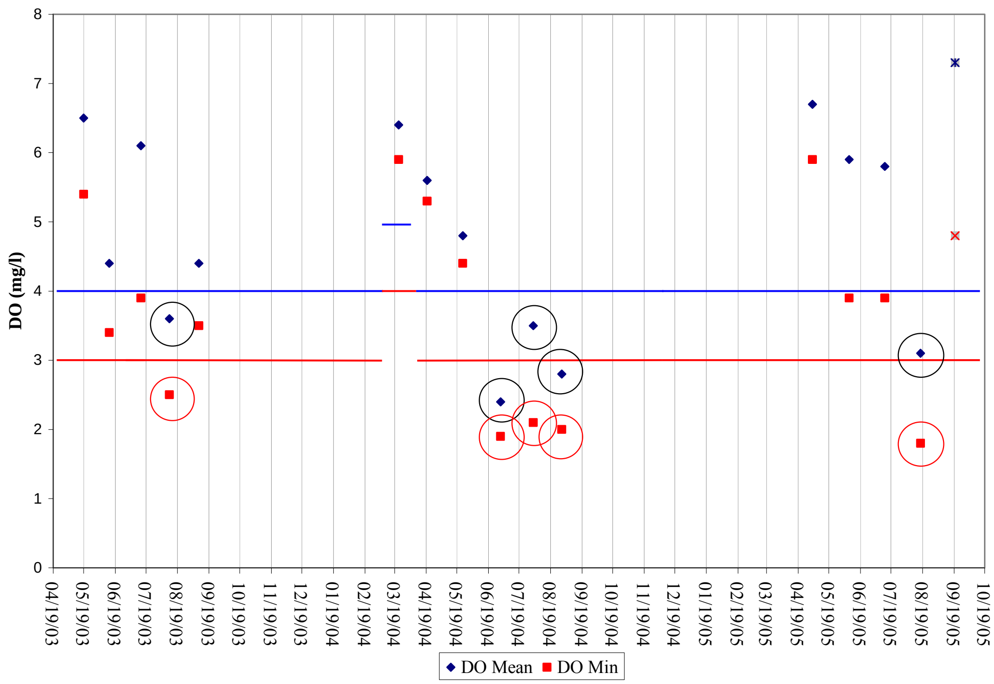


Figure 3-5 **Station 12082 (AU_02) 24-hr average and absolute minimum DO, showing average (blue line) and minimum (red line) criteria (Values in exceedance are circled; values that could not be used in the assessment are marked with an "x")**

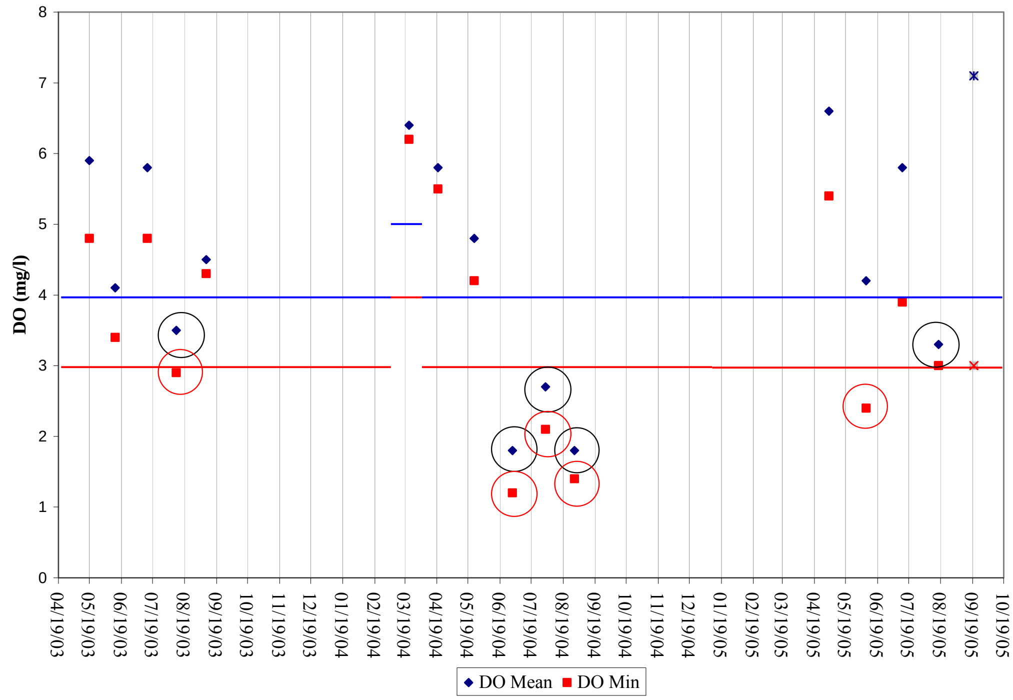


Figure 3-6 **Station 12083 (AU_02) 24-hr average and absolute minimum DO, showing average (blue line) and minimum (red line) criteria (Values in exceedance are circled; values that could not be used in the assessment are marked with an "x")**

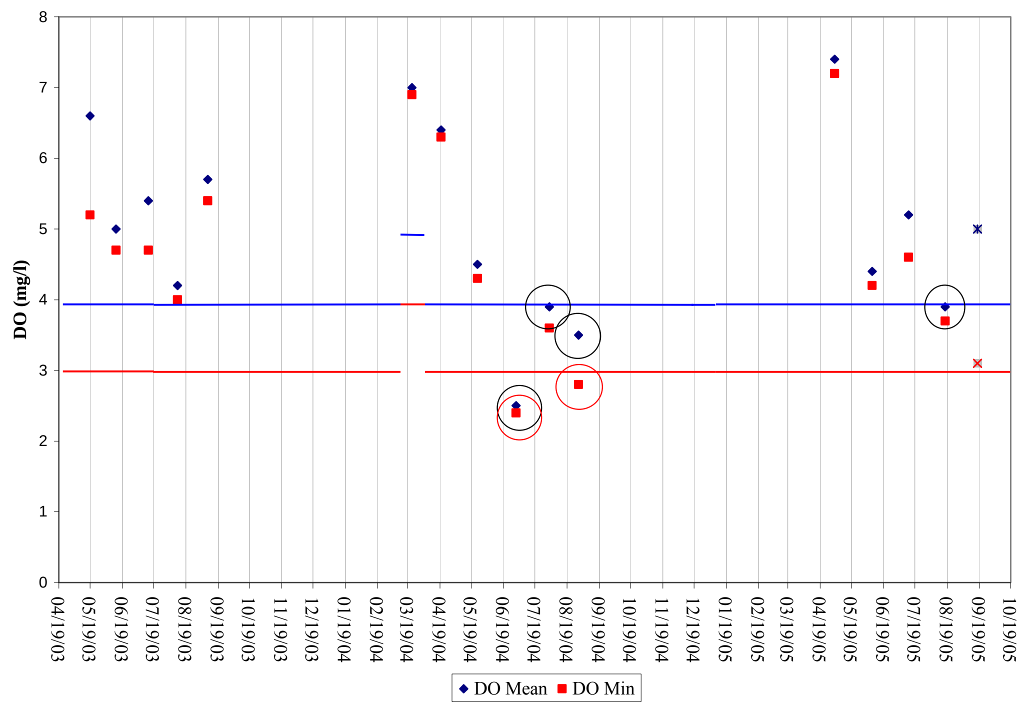


Figure 3-7 **Station 12086 (AU_03) 24-hr average and absolute minimum DO, showing average (blue line) and minimum (red line) criteria (Values in exceedance are circled; values that could not be used in the assessment are marked with an "x")**

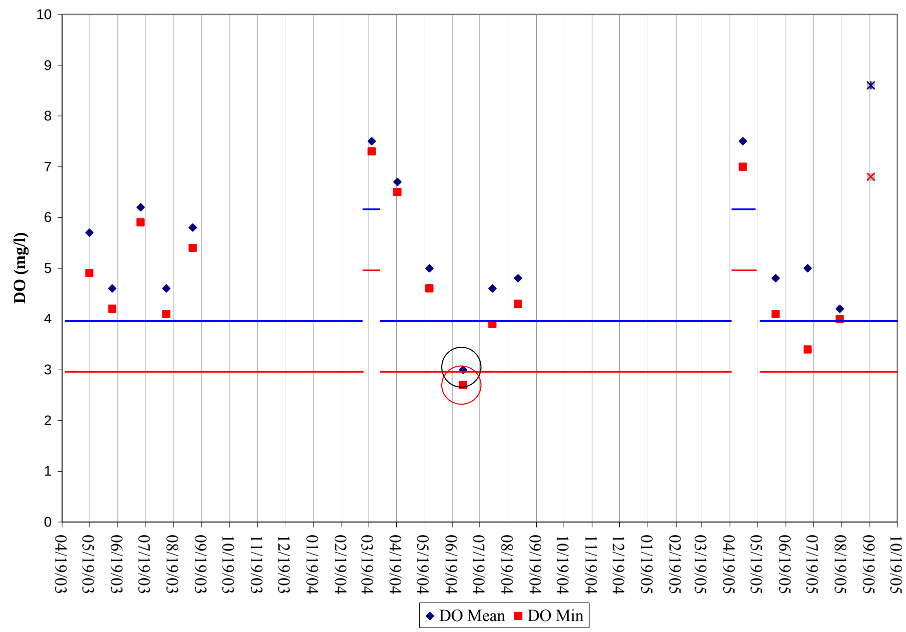


Figure 3-8 **Station 12087 (AU_03) 24-hr average and absolute minimum DO, showing average (blue line) and minimum (red line) criteria (Values in exceedance are circled; values that could not be used in the assessment are marked with an "x")**

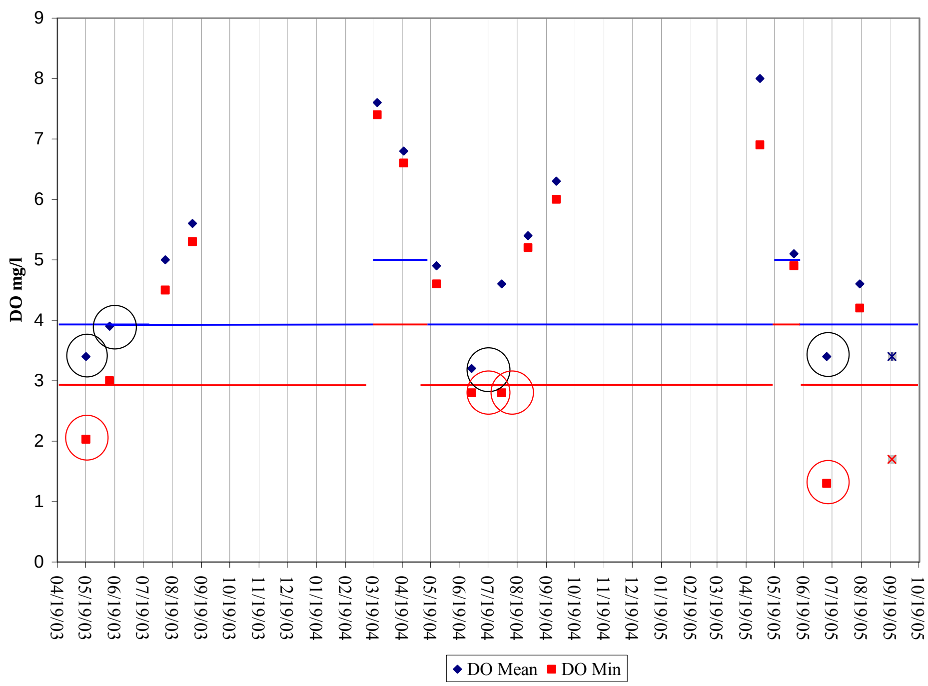


Figure 3-9 **Station 12090 (AU_03) 24-hr average and absolute minimum DO, showing average (blue line) and minimum (red line) criteria (Values in exceedance are circled; values that could not be used in the assessment are marked with an "x")**

SECTION 4

INVESTIGATIONS OF THE RELATIONSHIPS BETWEEN DO AND OTHER VARIABLES

4.1 Discussion of Changes to Section 4

No changes were necessary to Section 4 from the technical support document.

SECTION 5

SELECTION AND VALIDATION OF THE DISSOLVED OXYGEN MODEL

5.1 Discussion of Changes to Section 5

Because of hydrologic distinctions imposed by Dam #3 and the pumping of water at the Shannon Pump Station, the technical support document contained a dissolved oxygen modeling approach that separated Segment 1245 into a Lower Reach and an Upper Reach. The Lower Reach was defined as beginning at the confluence of the segment with the Brazos River and continuing upstream to Dam #3, which is also the exact definition of AU_01. The Upper Reach was defined as beginning at Dam #3 and proceeding upstream to the segment terminus at the Shannon Pump Station, which includes the entirety of AU_02 and AU_03.

Because the planned UAA activities for AU_01 mean that a TMDL will not be developed for that AU at this time, the previous modeling efforts of the Lower Reach are no longer necessary to the development of the dissolved oxygen TMDL for Segment 1245. The previous modeling efforts of the Upper Reach, however, remain relevant to the development of the TMDL for AU_02 and AU_03.

Within the context explained above, Section 5 in the technical support document requires minimal changes, other than the discretion of the reader to ignore the portions of the section that contain reference to the Lower Reach. The minimal changes required regard figures that did not include reference to AU_02 and AU_03 as they are now defined. The revised map showing the 21 stream stations and 9 active permitted discharges monitored during the two intensive DO surveys used to provide model validation data is provided in Figure 5-1. The segmentation of the QUAL2K model for the Upper Reach with AU_02 and AU_03 shown is provided in Figure 5-2. These minor changes to these two figures constitute the changes required within this addendum for Section 5.

SECTION 5

FIGURES

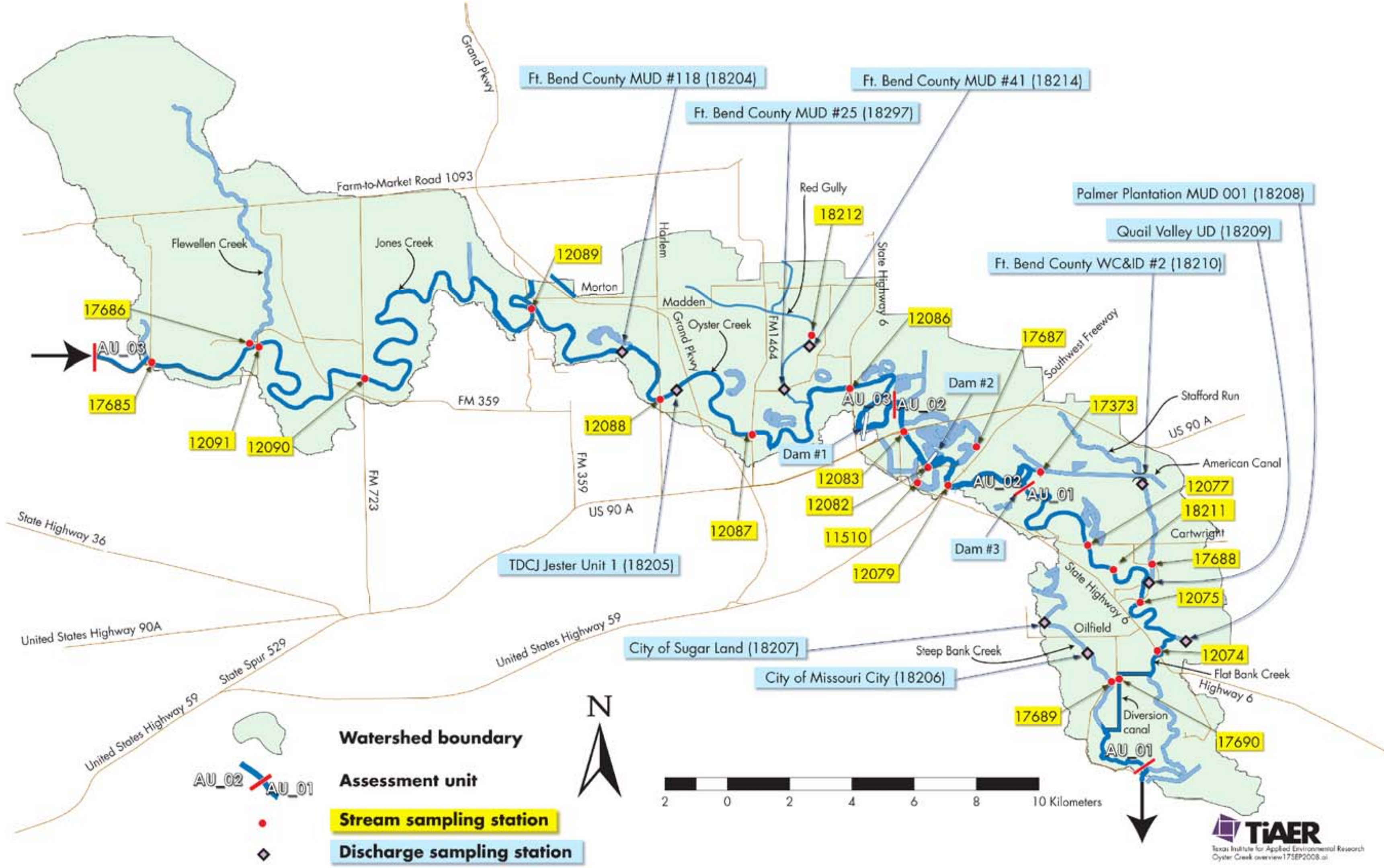


Figure 5-1 Map of Upper Oyster Creek showing monitoring stations and active point source discharges during model support surveys

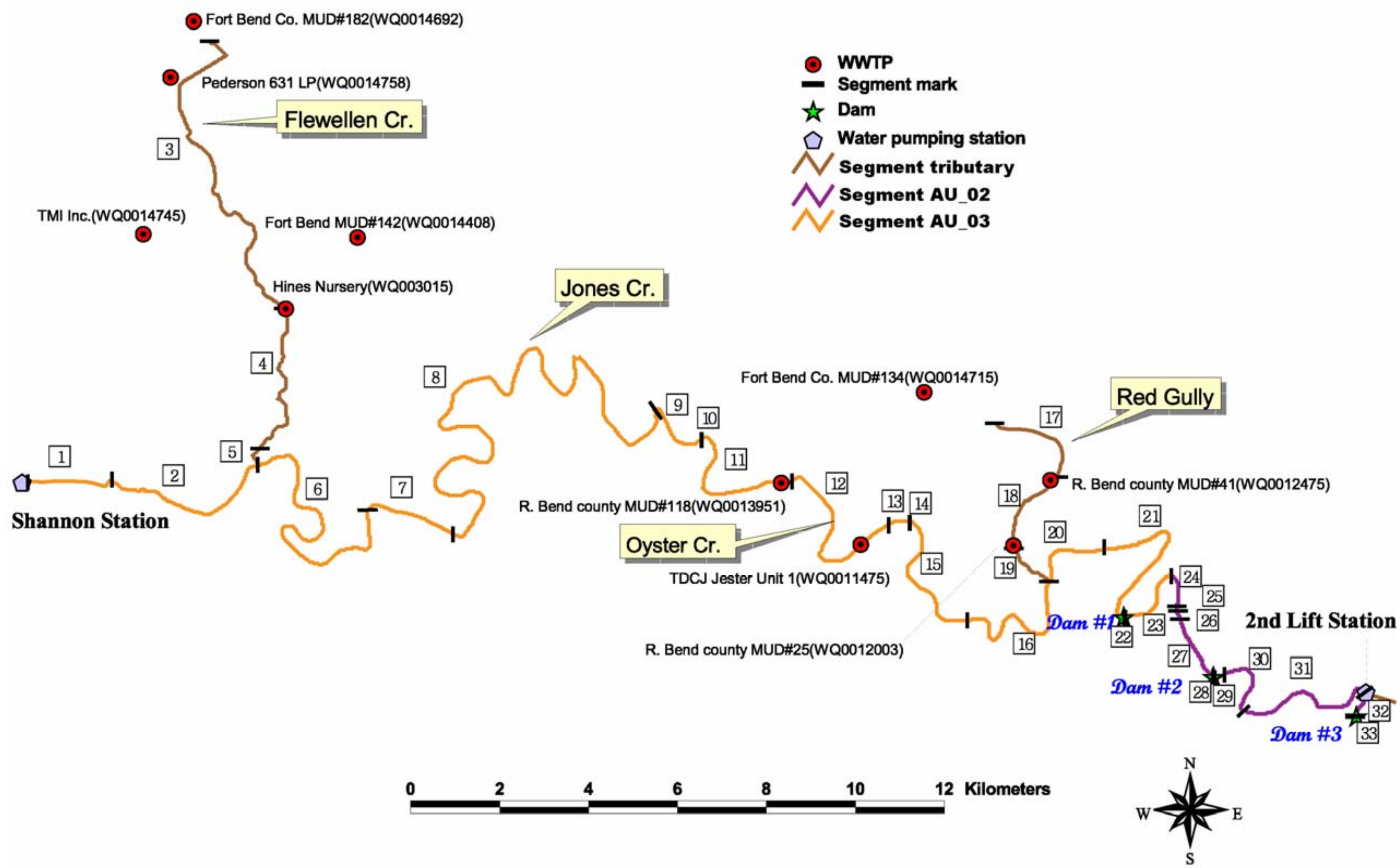


Figure 5-2 QUAL2K segmentation of Upper Reach, Upper Oyster Creek

SECTION 6

DEVELOPMENT OF TMDL ALLOCATION

6.1 Discussion of Changes to Section 6

Within this report section is presented the development of the dissolved oxygen TMDL allocation for AU_02 and AU_03. As developed in portions of Sections 2 (Watershed Properties and Hydrology) and Section 4 (Investigations of the Relationships between DO and Other Variables) of Hauck and Du (2008), the water quality, hydrology, hydraulics, and several related parameters provide complexities to the understanding of DO impairments and exceedances in Upper Oyster Creek. Further as presented in Section 1 (Introduction) of this report, the planned UAA activities in AU_01 preclude TMDL development at this time in that assessment unit. Hence, the TMDL allocations presented in this section reflect exclusion of AU_01 from the TMDL allocation due to the planned UAA, the assessment unit approach for allocations in AU_02 and AU_03, changes in WWTFs reflected in Table 2-1 of this report, and implications of EPA approval of Table 5 of the Texas Surface Water Quality Standards on determination of critical low flow.

Though portions of this section do not require updating in this addendum and hence could be excluded herein, the section will be presented in its entirety for purposes of continuity given that this is the critical section of the technical support document and this addendum to that report.

6.2 TMDL Allocation

The TMDL represents the maximum amount of pollutants that the stream can receive without exceeding the water quality standard. For purposes of DO allocation, the TMDL allocation is defined by the following simple equation:

$$TMDL = \Sigma\, WLA + \Sigma\, LA + MOS$$

where,

WLA is waste load allocation for point (TPDES-regulated) source reductions,
LA is the load allocation for nonpoint source reductions, and
MOS is the margin of safety.

For DO exceedances, the pollutants most closely related to the impairment are carbonaceous biochemical oxygen demand (CBOD) and ammonia as nitrogen (NH_3-N).

Predominately the dissolved oxygen exceedances appeared to occur under flow conditions that approached steady state conditions as opposed to dynamic flow conditions under the influence of rainfall runoff. The TMDL allocation process, therefore, emphasized regulated point source contributions from WWTFs and contributions from the Brazos River water pumped into the system.

For the TMDL allocation process as defined in the equation above, WLA and LA included various sources of five-day CBOD ($CBOD_5$) and NH_3-N. WLA was defined as contributions from WWTFs. For AU_03, LA was defined as critical low-flow background contributions from the watershed of AU_03 and from the pumped Brazos River water. For downstream AU_02, LA was defined as critical low-flow background contributions from the watershed of AU_02 plus the contributions entering AU_02 in Oyster Creek from upstream AU_03.

Because this TMDL allocation is for the critical low-flow condition, the allocations are not intended to characterize allowable loadings for regulated and unregulated storm water sources. Regulated storm water discharges are included in the Phase II permits for entities in the Upper Reach. This TMDL presumes that implementation of best management practices (BMPs) identified in each of these permits will not cause or contribute to violation of water quality standards during the critical low-flow period. Therefore, the WLA for these permittees during the critical low-flow period is the WLA identified in this document.

6.3 WLA for AU_02 and AU_03

To determine maximum allowable loadings from WWTFs in the Upper Reach, the validated QUAL2K models of that reach were 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.

6.3.1 Input Data Requirements

QUAL2K was applied using the existing segmentation and kinetic rates developed during the model validation process. Certain areas of model input, however, required updating to reflect the conditions under which the TMDL allocation for the point sources was performed. Applications of QUAL2K were made for low-flow conditions when minimum DO concentrations could occur.

6.3.1.1 Headwater and Diffuse Sources Flow

For unclassified streams in Segment 1245 that are tributaries to Upper Oyster Creek, the critical low flow specification is based on Table 5 of the Texas Surface Water Quality Standards (TNRCC, 2000), which provides for determination of critical low flow based on designated aquatic life use and average stream bedslope. Therefore Table 5 was used to determine the critical low flow used for the headwater flow of each tributary to the Upper Reach that are represented in QUAL2K (Table 6-1).

Critical low flow determination for the headwater to the Upper Reach was complicated by the pumping of Brazos River water at the Shannon Pump Station, 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 recent gauged streamflow records in Upper Oyster Creek, and the need to take into account channel bedslope. As will be developed in the immediately following paragraphs, the determination of headwater for the Upper Reach at the upstream terminus of AU_03 is required on, in essence, a monthly basis and is the greater of the critical low flow from bedslope computations, the 7Q2 flow, and the 10th percentile flow (i.e., the flow that is exceeded 90 % of the time) determined on a monthly basis.

As discussed in Section 3.4.3 (Flow Conditions) of this addendum report, the bedslope of the Jones Creek portion of AU_03, representing the upstream most portion of the Upper Reach, was calculated to be a little less than 0.1 m/km. Considerations of bedslope in Table 5 of TNRCC (2000) results in a critical low-flow value of 0.085 cms (3.0 cfs) for conditions of a bedslope of 0.1 m/km and an intermediate aquatic life use with a 24-hr average DO criterion of 4.0 mg/L.

To determine the 7Q2 flow, the hydrologic predictions from application of SWAT to Upper Oyster Creek watershed were evaluated for the Upper Reach. As mentioned in Section 2 of Hauck and Bing (2008), SWAT was applied to determine the daily streamflows needed to complete the bacteria TMDL. This application of SWAT is explained in Hauck and Du (2006); Section 4. To determine 7Q2 flow, the predicted daily flow data from SWAT for the period 1993 – 2004 were used as input to the TCEQ program 7Q2HM, which is a TCEQ program developed to compute 7Q2 and harmonic mean flows. SWAT results for the following two locations were used: (i) a location just below the Shannon Pump Station and (ii) 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), which 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.[2] Because the critical low flow 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 DO.

For the determination of low flows in the seasonal analysis, the 10th percentile flow 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 greater of the 10th percentile flow for that month, the bedslope related flow, and the 7Q2 (Table 6-2). Because 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. The amount of the diffuse source for each month was calculated as follows:

Diffuse Source = Flow at Outlet (2nd Lift Station) – Flow at Headwater – Tributary Headwater Flows (Flewellen Creek + Red Gully, Table 6-1) – Average WWTF Discharges Used in SWAT

[2] The critical low flow at the outlet of the Upper Reach at Dam #3 is effectively zero; however, within the pool of Dam #3 is the intake for the Second Lift Station where the critical low flow is greater.

The diffuse sources computation ensures a water balance of each monthly critical low flow by taking into account mainstem and tributary headwater flow specifications in the model. Further, the computation corrects for the presence of WWTF discharges, which were incorporated into the SWAT modeling, by subtracting these discharges. As previously discussed, within QUAL2K each WWTF discharge is specified in the input, and therefore these discharges should not be incorporated into the computation of diffuse sources.

6.3.1.2 Stream Water Temperature

To perform the seasonal analysis, monthly water temperatures also need to be considered. All available historical water temperature data for Segment 1245 AU_02 and AU_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 data set was dominated by instantaneous temperature measurements, though 24-hr average water temperature data also populated the database, especially in recent years as a result of the DO assessment surveys discussed in Section 3. The seasonal analysis of temperature followed TCEQ guidance, which 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 process involves the following computations and decisions (also see Table 6-3):

- On a monthly basis determine average water temperature and standard deviation using available data.
- Use the average (avg), standard deviation (std), and the t-distribution tabular value (ν) in guidance provided by TCEQ to compute the 90th percentile temperature ($T_{90} = Tavg + STD \cdot \nu$). [For relatively small data sets as encountered for Segment 1245, TCEQ recommends using the computations described above to estimate the 90th percentile water temperature or finding a nearby USGS gauging station with a long record of water temperature data. Because the nearest USGS stations with temperature data were for systems that did not seem to represent the physical stream conditions found in Upper Oyster Creek, the decision was made to use the t-distribution method.] A monthly 90th percentile temperature is the temperature exceeded 10 percent of the time for the month being evaluated.
- Define the temperature for the three hottest months as the average of the average temperature for the months with the three hottest 90th percentile temperatures plus the average of the standard deviations of the same three months (for Segment 1245 the hottest months for water temperature were June, July, and August).
- For the remaining 9 months use the computed 90th percentile temperature.
- Within the first 6 months of the year, additional considerations are required for evaluating the higher DO criteria that are effective to protect during the spawning season when average water temperatures are between 17.2° C (63.0° F) and 22.8° C (73.0° F). First determine the month(s) with average water temperatures within the range provided above, which for this situation is only the month of March (Table 6-3). If the 90th percentile temperature for March is less than 22.8° C, then use that temperature to define

water temperature for the applications of QUAL2K in evaluating spawning season DO criteria. Because the March 90th percentile temperature is 22.6° C, which meets the requirement, that temperature becomes the specified temperature for evaluating the spawning season DO criteria.

An additional complexity with temperature definition in the application of QUAL2K was that unlike QUALTX, where a water temperature can be user specified, QUAL2K predicts water temperature based on head budget equations and input of hourly air temperature, dew point, cloud cover, and wind speed data. Data obtained from the National Climatic Data Center website for Sugar Land for the years 2001 – 2005 were used to develop the required meteorological data input. For each month, the 90th percentile of 24-hr data was determined for air temperature and dew point temperature, and cloud cover and wind speed was based on median values of 24-hr data. During actual applications of QUAL2K, adjustments were made to the air temperature and dew point temperature input data until the average predicted water temperature was within a couple of a tenths of a degree C of the desired water temperature. Wind speed and cloud cover were not adjusted. This water temperature refinement was accomplished by adjusting the hourly air and dew point temperature data (increasing or decreasing) a constant amount and inspecting the predicted water temperatures along Upper Oyster Creek and its tributaries. Through adjustments to air temperature and dew point temperature, an average daily water temperature within a maximum of a couple of tenths of a degree C of the desired temperature could be readily obtained after typically three or four simulations.

6.3.1.3 Water Quality Specification for Headwaters and Diffuse Sources

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-nitrate nitrogen (NO_2+NO_3-N), 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 headwater water quality data for 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 orthophosphate phosphorus (PO_4-P) components based on ratios determined from the model validation survey data sets and water quality data for the Brazos River. The headwater water quality input for QUAL2K are summarized in Table 6-4, and it should be noted that Flewellen Creek is not included in this table, because no headwater flow contribution is associated with these tributaries. Diffuse sources were given the same water quality characteristics as Red Gully (Table 6-4).

6.3.1.4 Point Source 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 DO (Table 2-1 of this addendum). TCEQ's default multiplier of 2.3 was employed to convert $CBOD_5$ to CBODu.

Total-P in effluent was assumed to be 5 mg/L for all facilities, which is 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 % of the total-P was considered to be in the soluble form as PO_4-P and the remainder as organic-P. Organic-N and NO_2+NO_3 effluent concentrations were based on TCEQ guidance for estimating these constituents based on permitted values of BOD_5 and NH_3-N. Several recent facilities in the Upper Reach have polishing ponds, which has been evaluated by TCEQ staff to produce effluent from the ponds that is at background levels of CBODu and NH_3-N with DO at approximately 5 mg/L (personal communications with Mr. Mark Rudolph, TCEQ, June 2007). The facilities with polishing ponds are indicated as such in the last column of Table 2-1. For modeling purposes, the effluent from facilities with polishing ponds was assigned background concentrations for CBODu and NH_3-N, organic-N of 1 mg/L, a chlorophyll-α concentration of 79.2 μg/L (the average of the chlorophyll-α concentration measured at the outfall from the holding pond of Quail Valley UD WWTF in AU_01 during the two model support surveys – the only facility operating at the time of the model support surveys that had anything similar to a polishing pond), and 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.

6.3.1.5 Definition of Other Inputs

As developed in Section 5 (Selection and Validation of the Dissolved Oxygen Model) in Hauck and Bing (2008), external factors to the model necessitated adjustments of one input factor for Upper Reach. Model input of settling velocities for inorganic suspended solids along the mainstem required different values for the calibration and verification periods. The sensitivity analysis in Figure 5-35 of Hauck and Bing (2008) indicated that higher settling velocities resulted in increased average DO concentrations in the lower portions of the reach, but only insignificant effects on minimum DO. To be conservative, the lower of the settling velocities specified for any location in the model segmentation in the calibration and verification input data sets were used in the model applications in this section.

6.3.2 Applications of QUAL2K

The validated QUAL2K model of the Upper Reach was applied to determine allowable loadings from municipal WWTFs using the same input data as determined during the model validation process except for the input of settling velocities for inorganic solids discussed above, which is needed to reflect conditions for assessing DO under critical conditions of temperature and flow. Each WWTF was evaluated within QUAL2K at its full permit limits. Subsequent model applications would be made if more stringent permit limits were required to meet DO criteria, and the permit limits would be adjusted until the criteria were not exceeded.

The focus was on 24-hr average DO criterion in AU_02, AU_03 and their tributaries. In the Upper Reach, as established in this report and in even more detail in Hauck and Bing (2008), the average DO criterion is important to the majority of exceedances in the assessment survey data sets.

Certain limitations on interpretations of the applications of QUAL2K to the variable of pH are necessary to individuals who may operate the models developed for this DO TMDL and closely evaluate model predictions. The user does not have the discretion as to whether or not to include pH in simulations—the model will always provide predictions of pH. No results have been provided within this report for pH, because pH levels are not a concern in Segment 1245 and no effort was made to calibrate and verify this parameter. Also, the necessary input data (e.g., alkalinity) were not collected to allow model calibration and verification of pH, and therefore little confidence can be placed in model predictions of pH. As a strong caution, the pH concentrations predicted by QUAL2K for these applications should not be considered meaningful or accurate.

6.3.2.1 Margin of Safety

A margin of safety (MOS) is required in the determination of maximum allowable pollutant loadings under the TMDL process. The MOS may be either implicit through use of conservative model assumptions to develop the allocations or explicit through assigning a portion of the total TMDL as the MOS and using the remainder for allocations. An implicit MOS, based on conservative model assumptions, is used in this TMDL that include. First, the evaluation was performed under full permitted limits during critical low flow conditions, which is an extremely unlikely combination of circumstances. Second, conservative assumptions were made regarding some model input parameters, such as the settling velocities for inorganic suspended solids at values from the calibration and verification cases that gave lower DO concentrations.

6.3.2.2 WLA for AU_02 and AU_03

Since a seasonal analysis was required for the Upper Reach, QUAL2K was operated under conditions of existing permit loading for water temperature and headwater, diffuse sources and tributary flow conditions for January, February, March, April, May, three hottest months (June – August), September, October, November, and December. The headwater and diffuse source flows for June were used in the simulation of the three hottest months, since these were the lowest monthly flows for June – August (Table 6-2). The DO results for March were evaluated against the 24-hr average DO criterion to protect spawning whereas results for all other months were evaluated against the general DO criterion. The minimum 24-hr average DO predicted for the mainstem AU_02, mainstem AU_03, Flewellen Creek, and Red Gully are provided in Table 6-5 for each condition. These model predictions indicate no exceedances of the 24-hr average DO criterion, though for the September scenario the minimum predicted DO concentration in AU_03 was at the criterion value of 4.0 mg/L (Table 6-5; Figure 6-1). The model predicted 24-hr average DO for the March spawning scenario and June – August scenario are provided in Figures 6-2 and 6-3 for AU_02, AU_03, Flewellen Creek, and Red Gully. The June – August scenario represents the critical summer conditions of temperature (Table 6-3) and the June headwater flow (Table 6-2), which is the lowest flow for the three months of June, July, and August.

The absence of any exceedance in the model predictions is a different finding from the original report and original QUAL2K seasonal analysis of the Upper Reach. The reason for the differences is two fold. First, the recent applicability of Table 5 of TNRCC (2000) to classified segments resulted in an increased headwater flow to the Upper Reach for the months of September – March as compared to the previous work and this increased flow was sufficient to avoid the exceedances for the months of March, October, and November. In the three months of March, October, and November, DO exceedances had been previously predicted immediately downstream of the headwater in the very upper portion of Jones Creek above the confluence with Flewellen Creek. With the additional headwater flow these exceedances were not predicted. Second, the decrease in permitted discharge into Red Gully from Fort Bend County MUD # 41 (reduced from 0.86 MGD to 0.50 MGD; Table 2-1) sufficiently decreased loadings of oxygen demanding substances to Red Gully that the previous slight DO excursion predicted for September was no longer predicted.

Based on the applications of QUAL2K, existing permit limits for WWTFs result in the pertinent 24-hr average DO criteria being meet in AU_02 and AU_03 of the Upper Reach and its major tributaries. A minimum 24-hr average DO prediction of 4.0 mg/L in AU_03 occurred under the conditions of the September scenario and higher DO predictions occurred for all other scenarios (Table 6-5), making September the critical period of streamflow and water temperatures.

The predicted minimum DO concentration under critical September conditions is the same as the 24-hr average DO criterion for Upper Oyster Creek (4.0 mg/L) indicating that present waste load allocations do not result in exceedances, but do result in DO concentrations at the criterion level. The critical area of lowest DO for the Upper Reach is immediately upstream of the upper terminus of AU_02 and in the very most downstream portions of AU_03 (Figure 6-1). The maximum allowable loadings by individual WWTFs for AU_03 are provided in Table 6-6. No WWTFs presently discharge into AU_02. A summary of the existing, maximum allowable loadings, and percent reductions (which are zero) for WWTFs or waste load allocations (WLAs) are provided in Table 6-7 for AU_02 and AU_03.

Applications of QUAL2K were not performed to investigate potential effectiveness of reduced WWTF total-P discharges in lessening aquatic vegetation and increasing 24-hr minimum DO concentrations. The model applications were not performed for two reasons. First, the aquatic vegetation in the Upper Reach is strongly dominated by macrophytes, and it is very unlikely that their abundance will be responsive to reductions in water column phosphorus. Second, exceedances of the absolute minimum dissolved oxygen criterion without contemporaneous exceedances of the 24-hour average criterion occurred in only 4 of 24 exceedances monitored during the assessment period in the years 2003-2005, indicating only limited concerns with minimum dissolved oxygen concentrations in the Upper Reach.

6.4 LA for AU_02 and AU_03

LA was defined as the allowable loading from critical low-flow background contributions within the watershed including any contributions from the pumped Brazos River water at the Shannon Pump Station, which is considered as headwater flow to the model. To determine the loadings from background contributions, a flow and associated constituent concentration must be known. Relevant pollutants for this dissolved oxygen TMDL, as previously discussed, are the oxygen demanding constituents of $CBOD_5$ and NH_3-N. For the Upper Reach, the headwater and diffuse source critical low flows varied by month (Table 6-2). Much of this variability is attributable to the seasonality of the pumped Brazos River water. Because September conditions resulted in the lowest dissolved oxygen concentrations, the critical low flows for September were used in determination of LA for the Upper Reach. LA was calculated from the critical low flows and background $CBOD_5$ and NH_3-N concentrations specified as input to QUAL2K (Table 6-4).

Because AU_03 ends at the headwaters of Upper Oyster Creek, its LA can readily be calculated from September scenario input data to QUAL2K by considering the headwater flows to the Upper Reach and Red Gully and the proportion of total diffuse source inflows that enter the stream within AU_03. Since AU_02 is not at the headwaters of Upper Oyster Creek, there is a component of LA that is transported into AU_02 by the flow entering AU_02 from upstream AU_03. This upstream inflowing component to LA was determined from QUAL2K output for the September scenario. Thus LA for $CBOD_5$ and NH_3-N may be defined as follows:

$LA_{(AU\_02)}$ = Diffuse Source + Upstream Loading (from QUAL2K)

and

$LA_{(AU\_03)}$ = Diffuse Source + Headwater(Upper Reach + Red Gully)

where sources are defined and computed in Table 6-8. The LA for AU_02 and AU_03 is summarized in Table 6-9.

6.5 TMDL Allocation Summary for AU_02 and AU_03

The TMDL allocations for AU_02 and AU_03 of Upper Oyster Creek (Segment 1245) were developed for the critical low-flow condition that was determined to be the September scenario from the QUAL2K model. For AU_02 and AU_03 the TMDL allocations for $CBOD_5$ NH_3-N are provided in Tables 6-10 and 6-11.

Because this TMDL allocation is for the critical low-flow condition, the allocations are not intended to characterize allowable loadings for regulated and unregulated storm water sources. Regulated storm water discharges will be included in Phase II permits. This TMDL presumes that implementation of BMPs identified in each of these permits will not cause or contribute to violation of water quality standards during the critical low-flow period. Therefore, the WLA for these permittees during the critical low-flow period is the WLA identified in this document. Monitoring of these discharges and evaluation of BMP effectiveness over time will determine if this presumption is correct or needs to be modified.

The TMDL allocations for AU_02 and AU_03 of Segment 1245 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 this TMDL. 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 $CBOD_5$ and NH_3-N. Based on QUAL2K seasonal-analysis results for the Upper Reach (Table 6-5), 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 for which 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 as a result of increased water demands on the GCWA system should improve dissolved oxygen conditions in the Jones Creek/Oyster Creek portion of the Upper Reach.

The complexity of Segment 1245 necessitates additional investigations to continue progress toward understanding dissolved oxygen and protecting the designated aquatic life use of the Upper Reach. Additional monitoring studies are recommended during the implementation process to obtain a better understanding of the conditions resulting in the dissolved oxygen exceedances.

SECTION 6

TABLES

Table 6-1 Tributaries of Upper Reach, designated aquatic life use, bedslope, critical low flow, and DO criteria

Tributary Name	Designated Aquatic Life Use	Bedslope (m/km)	Critical Low Flow (cms)	General 24-hr Average/Minimum DO Criteria (mg/L)	Spawning-Season 24-hr Average/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 6-2 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 [a]	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 [b]	Computed by water balance [c]	-0.097	-0.096	-0.097	0.390	0.524	0.739	0.014	-0.246	0.794	-0.089	-0.090	-0.091

[a] 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.

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

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

Table 6-3 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	61	36	39	99	64	70	129	30	31	50	41
90th percentile (°C) [b]	16.9	18.8	22.6	26.0	30.2	31.5	32.4	32.3	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 http://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 6-4 Headwater water quality input to QUAL2K for mainstem, tributaries, and diffuse sources. [Note: Flewellen Creek has no headwater flow (see Table 6-1) and is not included in this table.]

Constituent	Upper Reach Headwater	Red Gully	Diffuse Sources
Inorganic Solids (mg/L)	85	68	68
DO (% sat.)	80	80	80
Fast 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
PO4-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.

Table 6-5 QUAL2K simulated minimum 24-hr average DO concentrations under the existing permits limits in the Upper Reach

Location	Jan	Feb	Mar[a]	Apr	May	Jun-Aug	Sep	Oct	Nov	Dec
Mainstem AU_02	7.7	7.2	6.4	5.5	5.3	4.7	4.2	6.0	6.0	6.9
Mainstem AU_03	7.0	6.4	5.2	4.9	4.7	4.6	4.0	4.1	4.9	6.0
Flewellen Cr.	7.3	7.1	6.7	6.0	6.0	5.9	5.5	6.0	6.2	6.9
Red Gully	6.9	6.6	5.7	5.3	4.9	4.5	4.1	4.9	5.6	6.3

[a] March represents the spawning season due to monthly water temperature (Table 6-3) and the 24-hr average DO criterion is 5.0 mg/L during this period as compared to 4.0 mg/L for all others times of the year.

Table 6-6 WLA for Upper Reach, AU_03 by Individual WWTF

Facility	Final Permitted Discharge (MGD)	Allowable $CBOD_5$ Loading (kg/d)	Allowable NH_3-N Loading (kg/d)
Fort Bend County MUD #25	1.6	30.28	6.06
Fort Bend County MUD #41	0.5	18.93	5.68
Fort Bend County MUD #118	1.2	22.71	6.81
Fort Bend County MUD #134 *	0.3	1.48	0.06
Fort Bend County MUD #142 *	1.2	5.91	0.23
Fort Bend County MUD #182 *	0.8	3.94	0.15
Pederson 631, LP *	0.6	2.95	0.11
TDCJ Jester Unit #1	0.315	11.92	3.58
TMI, Inc. *	0.5	2.46	0.09
Total	**7.015**	**100.58**	**22.77**

* Facility includes a polishing pond system. The WLA for each facility with a polishing pond system was based on analyses by TCEQ. The permit discharge limits into the polishing pond system for each of these facilities is provided in Table 2-1. The WLAs in this table represent the loadings leaving the polishing pond system.

Table 6-7 Existing, maximum allowable loadings, and percent reductions for WWTFs (or WLA) in Upper Reach

Condition	Discharge (cms)	$CBOD_5$ (kg/d)	Ammonia N (kg/d)
Assessment Unit 02 (AU_02)			
Existing Permit Loading	0.000	0.0	0.00
Allowable Loading*	0.000	0.0	0.00
Percent Reduction	0%	0%	0%
Assessment Unit 03 (AU_03)			
Existing Permit Loading	7.015	100.58	22.77
Allowable Loading	7.015	100.58	22.77
Percent Reduction	0%	0%	0%

***** Assignment of no permitted loading in AU_02 reflects the present physical reality that no WWTFs discharge into this AU. The absence of permitted loading in this table is not intended to preclude future evaluation of a new WWTF desiring location in AU_02, which should be assessed using the appropriate QUAL2K model or an updated replacement model.

Table 6-8 Computations of components of $CBOD_5$ and NH_3-N daily loadings (LA) for AU_02 and AU_03 based on September critical condition

Description	**Value**
Conversion Factor (CF) to compute loading as kg/d	
CF = (cu. meter /sec) (mg/L) (86,400 sec/d) (1000 L/cu meter) / (1 x 10^6 mg/Kg)	86.4
Diffuse Source Distribution to AU_02 & AU_03	
Distributed over stream length of Upper Reach (km 21.47 to km 87.00)	65.53 km
Diffuse source length in AU_02 (km 21.47 to km 30.50)	9.03 km
Fraction of total length in AU_02 - $\mathbf{K_{(AU\_02)}}$	0.137799
Diffuse source length in AU_03 (km 30.50 to km 87.00)	56.50 km
Fraction of total length in AU_03 – $\mathbf{K_{(AU\_03)}}$	0.862201
Total Diffuse Source Flow (Table 6-2)	0.7941 cms
$CBOD_5$ concentration for diffuse source (Table 6-4)*	1.30 mg/L
$CBOD_5$ load = CF x Flow x Concentration	89.19 kg/d
AU_02 $CBOD_5$ Diffuse Source Load: $K_{(AU\_02)}$ x $CBOD_5$ load	12.29 kg/d
AU_03 $CBOD_5$ Diffuse Source Load: $K_{(AU\_03)}$ x $CBOD_5$ load	76.90 kg/d
NH_3-N concentration for diffuse source (Table 6-4)	0.050 mg/L
NH_3-N load = CF x Flow x Concentration	3.43 kg/d
AU_02 NH_3-N Diffuse Source Load: $K_{(AU\_02)}$ x NH_3-N load	0.47 kg/d
AU_03 NH_3-N Diffuse Source Load: $K_{(AU\_03)}$ x NH_3-N load	2.96 kg/d
Upstream Loadings (from QUAL2K output) into AU_02	
Streamflow from AU_03 entering AU_02	1.2222 cms
$CBOD_5$ concentration from AU_03 entering AU_02	1.34 mg/L
$CBOD_5$ load entering AU_2 = CF x Flow x Concentration	141.41 kg/d
NH_3-N concentration from AU_03 entering AU_02	0.131 mg/L
NH_3-N load entering AU_02 = CF x Flow x Concentration	13.83 kg/d
Headwater Loading from Upper Reach and Red Gully into AU_03	
Headwater flow to Upper Reach (Table 6-2)	0.0850 cms
Headwater flow to Red Gully (Table 6-1)	0.0850 cms
$CBOD_5$ concentration for headwater sources (Table 6-4)*	1.30 mg/L
$CBOD_5$ load = CF x Total Headwater Flows x Concentration	19.09 kg/d
NH_3-N concentration for diffuse source (Table 6-4)	0.050 mg/L
NH_3-N load = CF x Flow x Concentration	0.73 kg/d

* $CBOD_5$ concentration = fast CBODu / 2.3 = 3.0 mg/L / 2.3 = 1.30 mg/L

Table 6-9 Estimated background $CBOD_5$ and NH_3-N daily loadings (LA) and critical low flow for AU_02 and AU_03

Description	Value
Assessment Unit 02 (AU_02):	
Critical low flow (cms) *	1.3316
Background $CBOD_5$ Load (kg/d)	153.70
Background NH_3-N Load (kg/d)	14.30
Assessment Unit 03 (AU_03):	
Critical low flow (cms) *	0.8547
Background $CBOD_5$ Load (kg/d)	96.00
Background NH_3-N Load (kg/d)	3.69

* Critical low flow includes all model specified headwater and diffuse source inputs

Table 6-10 TMDL summary for $CBOD_5$ (AU_02 and AU_03)

Source Category	Existing Loading (kg/d)	Allowable Loading (kg/d)	Percent Reduction (%)
Assessment Unit 02 (AU_02)			
Waste Load Allocation*	0.00	0.00	0
Load Allocation	153.70	153.70	0
Total Loading	153.70	153.70	0
Assessment Unit 03 (AU_03)			
Waste Load Allocation	100.58	100.58	0
Load Allocation	96.00	96.00	0
Total Loading	196.58	196.58	0

***** Assignment of no permitted loading in AU_02 reflects the present physical reality that no WWTFs discharge into this AU. The absence of permitted loading in this table is not intended to preclude future evaluation of a new WWTF desiring location in AU_02, which should be assessed using the appropriate QUAL2K model or an updated replacement model.

Table 6-11 TMDL summary for NH_3-N (AU_02 and AU_03)

Source Category	Existing Loading (kg/d)	Allowable Loading (kg/d)	Percent Reduction (%)
Assessment Unit 02 (AU_02)			
Waste Load Allocation*	0.00	0.00	0
Load Allocation	14.30	14.30	0
Total Loading	14.30	14.30	0
Assessment Unit 03 (AU_03)			
Waste Load Allocation	22.77	22.77	0
Load Allocation	3.69	3.69	0
Total Loading	26.46	26.46	0

***** Assignment of no permitted loading in AU_02 reflects the present physical reality that no WWTFs discharge into this AU. The absence of permitted loading in this table is not intended to preclude future evaluation of a new WWTF desiring location in AU_02, which should be assessed using the appropriate QUAL2K model or an updated replacement model.

SECTION 6

FIGURES

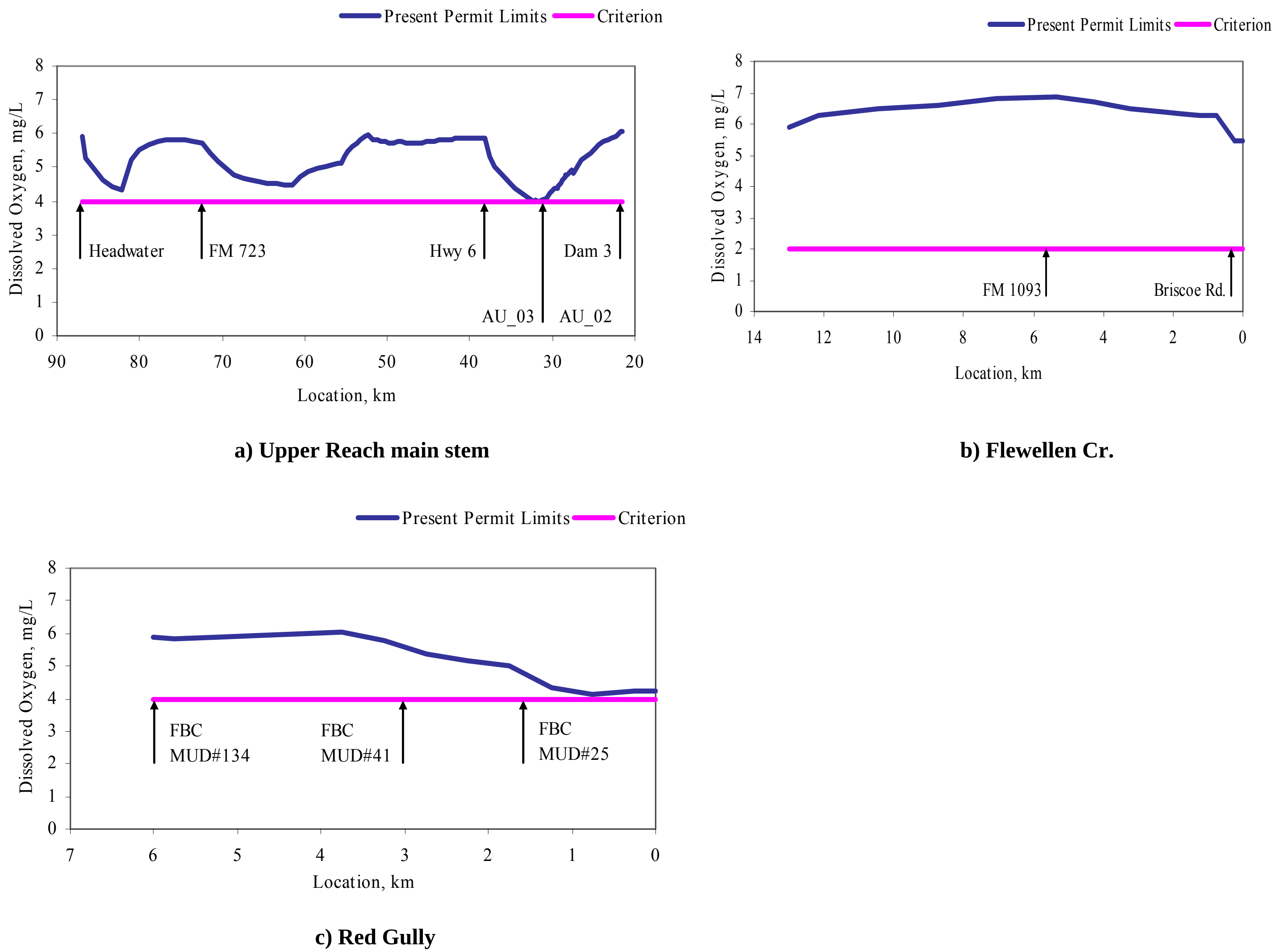
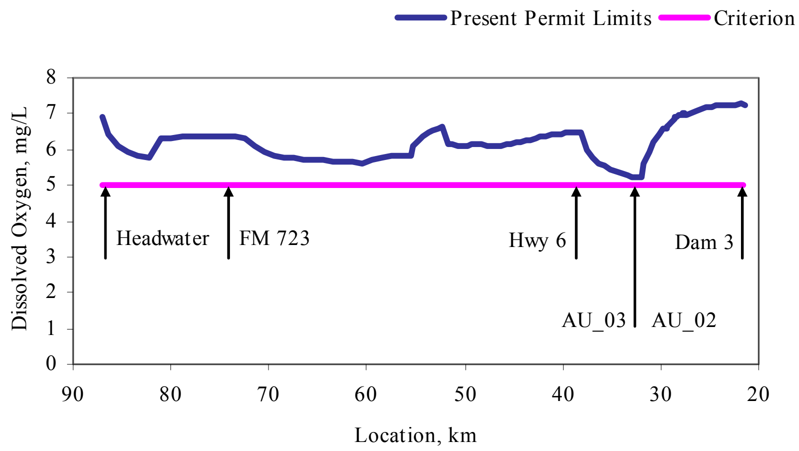
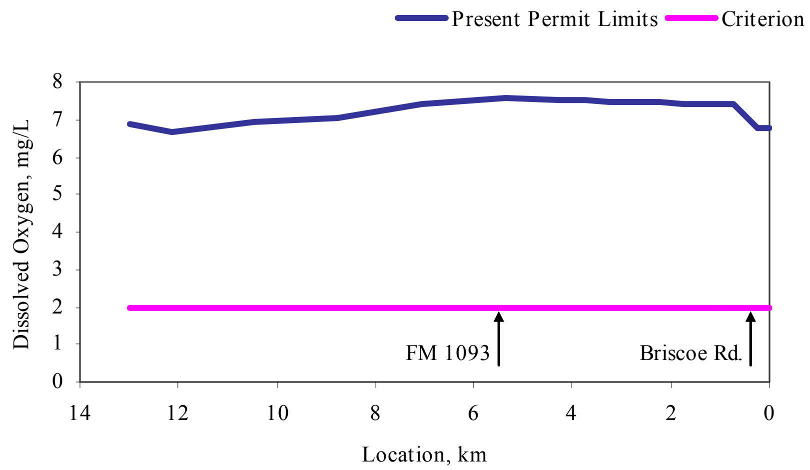


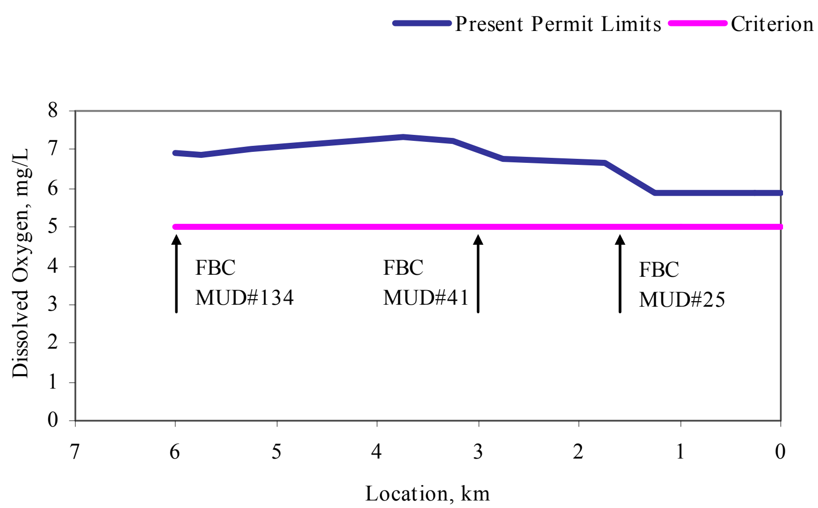
Figure 6-1 QUAL2K average dissolved oxygen predictions for Upper Reach during September conditions



a) Upper Reach main stem

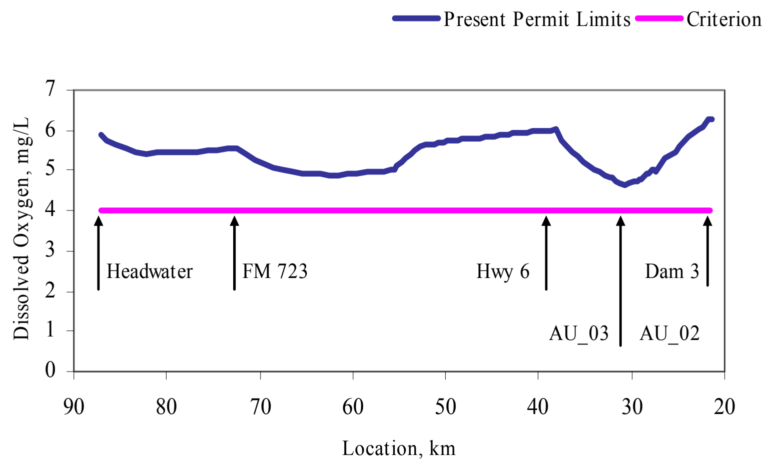


b) Flewellen Cr.

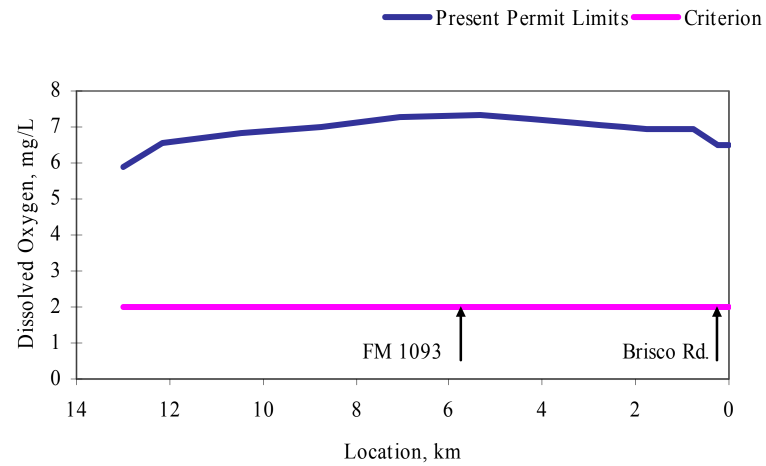


c) Red Gully

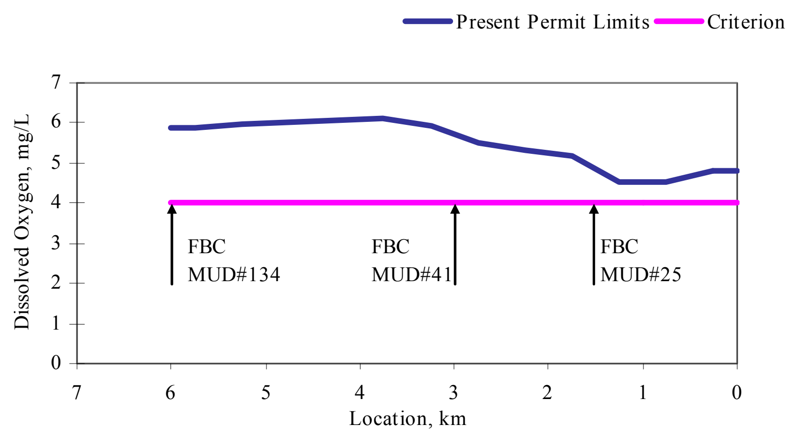
Figure 6-2 QUAL2K average dissolved oxygen predictions for Upper Reach during spawning conditions (March)



a) Upper Reach main stem



b) Flewellen Cr.



c) Red Gully

Figure 6-3 QUAL2K average dissolved oxygen predictions for Upper Reach during June-August low flow and high temperature conditions

SECTION 7

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