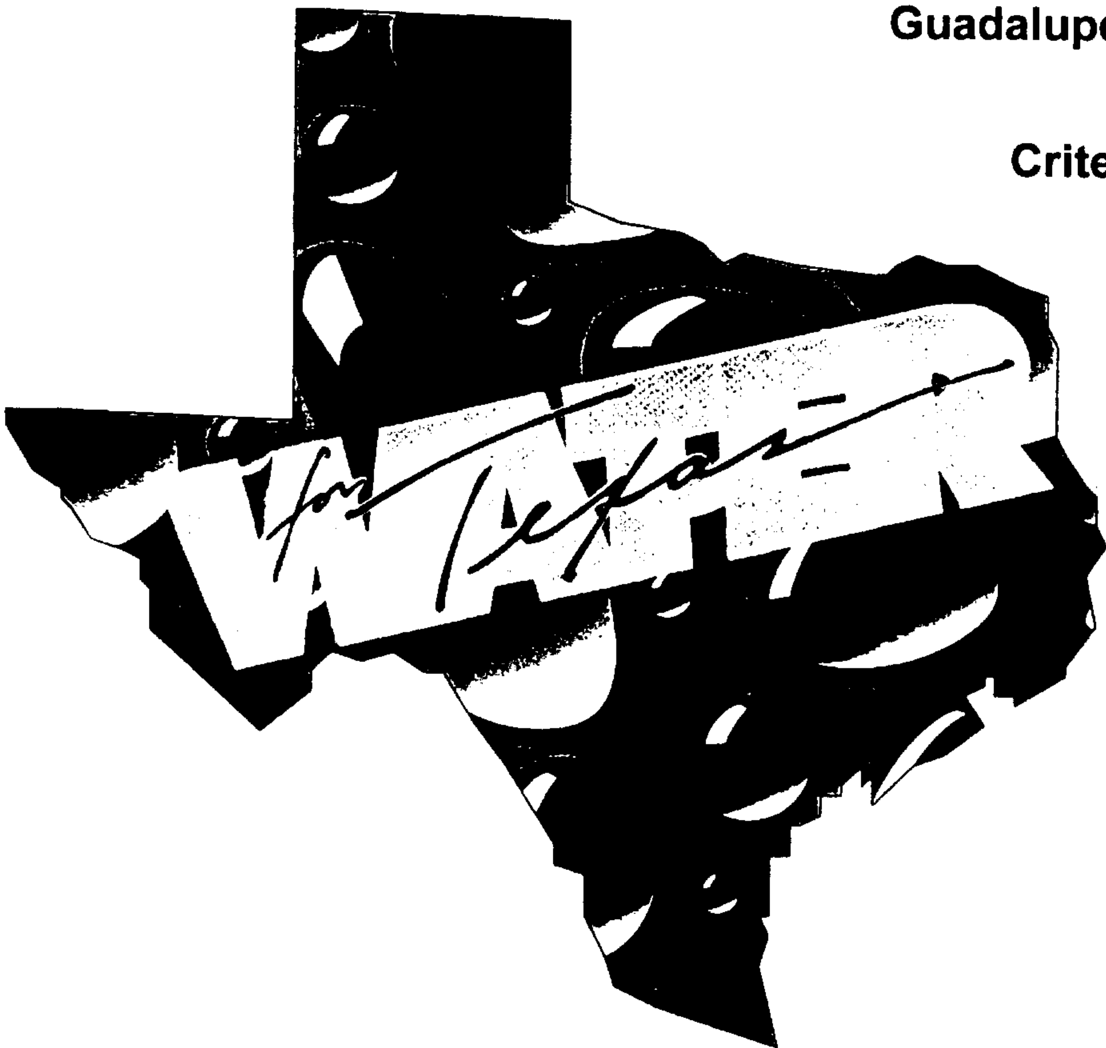
TRANS-TEXAS WATER PROGRAM

West Central Study Area

Phase II

Guadalupe - San Antonio River Basin Environmental Criteria Refinement



San Antonio River Authority

San Antonio Water System

Edwards Aquifer Authority

Guadalupe-Blanco River Authority

Lower Colorado River Authority

Bexar Metropolitan Water District

Nueces River Authority

Canyon Lake Water Supply Corporation

Bexar-Medina-Atascosa Counties WCID No. 1

Texas Natural Resource Conservation Commission

Texas Parks and Wildlife Department

Texas Water Development Board

March 1998

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PHASE 2

ENVIRONMENTAL CRITERIA REFINEMENT

San Antonio River Authority
San Antonio Water System
Edwards Aquifer Authority
Guadalupe-Blanco River Authority
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Nueces River Authority
Canyon Lake Water Supply Corporation
Bexar-Medina-Atascosa Counties WCID No. 1
Texas Natural Resource Conservation Commission
Texas Parks and Wildlife Department
Texas Water Development Board

3/26/98

Paul Price
3/30/98

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March 1998

STATE OF TEXAS
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REGISTERED
PROFESSIONAL ENGINEER

Samuel K Vaugh
3/25/98

GUADALUPE-SAN ANTONIO RIVER BASIN
ENVIRONMENTAL CRITERIA REFINEMENT

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES

1.0 INTRODUCTION

The general environmental criteria applicable to the evaluation of alternative water supply projects have been evolving throughout the course of the Trans-Texas Water Program. The criteria governing run-of-the-river or direct diversions moved from that promulgated in the beginning which excluded drought contingency provisions, through a two-zoned alternative criteria using moving averages of monthly streamflow to trigger drought contingency provisions, to the three-zoned Environmental Water Needs Criteria of the Consensus Planning Process, or "Consensus Criteria," which uses daily streamflows to trigger drought contingency provisions.

The Consensus Criteria governing new direct diversion projects is summarized in Figure 1-1 which defines three streamflow zones, the minimum flow to remain in the stream associated with each zone, and the two streamflow statistics (monthly median and 25th percentile) triggering the transition from one zone to another. Zone triggers and minimum flows to remain in the stream are to be computed from natural daily streamflows, however, the minimum flow associated with Zone 3 is to be the water quality standard used by the Texas Natural Resource Conservation Commission (TNRCC). The rules of the TNRCC generally define the water quality standard as the 7Q2 flow, the lowest average flow for 7 consecutive days which occurs with a recurrence interval of 2 years.[1] For reference, the Consensus Criteria is included as Appendix A. While the Consensus Criteria was developed from a statewide perspective, certain aspects may become quite restrictive when applied to springflow or treated effluent dominated streams such as the Guadalupe and San Antonio Rivers, respectively (Figure 1-2). For example, the water quality standard, below which no new diversions would be allowed, actually exceeds the natural 25th percentile streamflow in about half of the months of the year in these rivers.

As the sponsors of the Trans-Texas Water Program for the West Central Study Area prepare to embark on regional planning efforts with the objective of developing feasible, long-range water supply plans, it is imperative that the environmental criteria used to evaluate projects and plans adequately reflects the unique characteristics of the Guadalupe - San Antonio River

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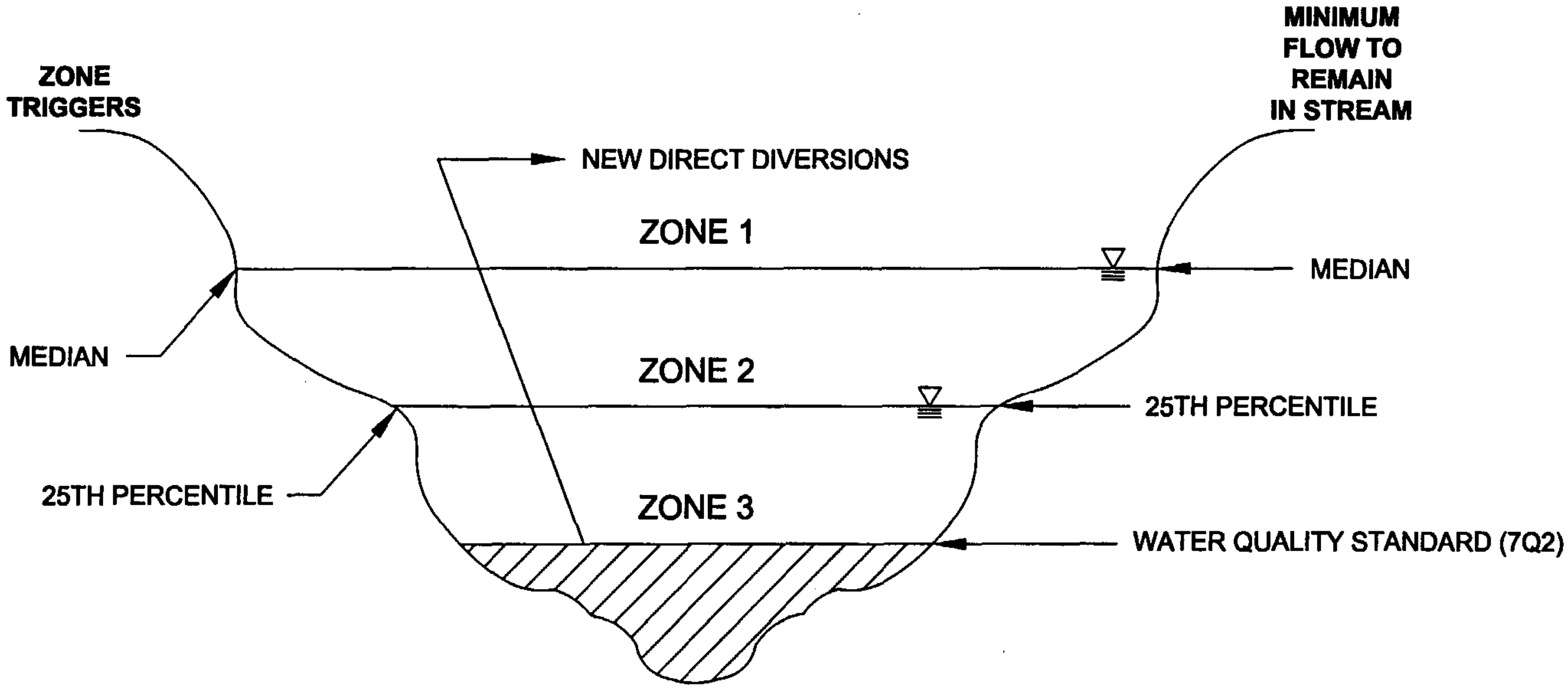
[1] TNRCC, "Permanent Rule Changes, Texas Surface Water Quality Standards," Sections 307.1 - 307.10, July 13, 1995.



NO NEW DIRECT DIVERSIONS ALLOWED

NOTES:

1) STATISTICS BASED ON NATURAL DAILY STREAMFLOW.
2) NEW DIRECT DIVERSIONS IN ALL ZONES SUBJECT TO SENIOR WATER RIGHTS.

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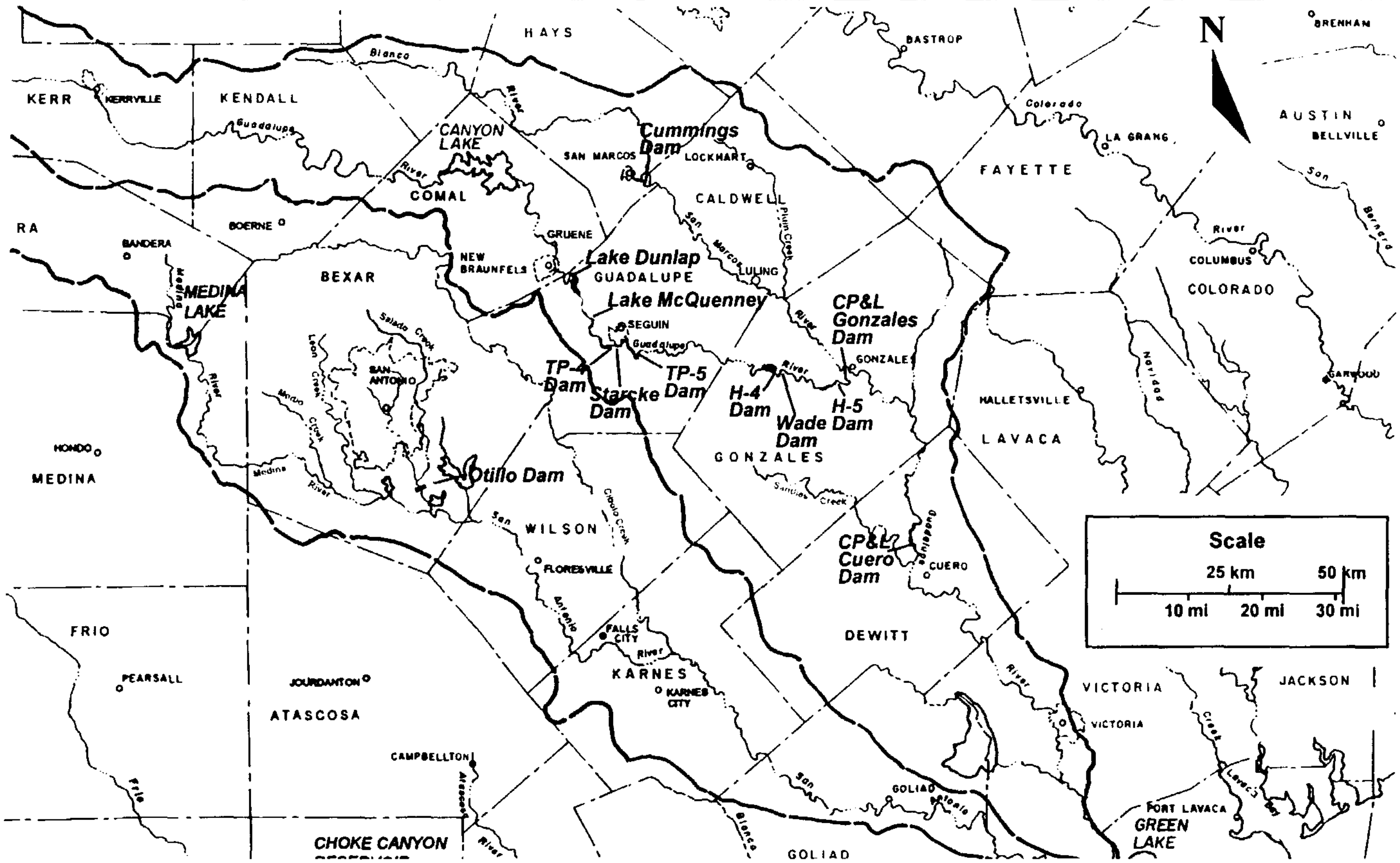
CONSENSUS CRITERIA FOR NEW DIRECT DIVERSIONS

FIGURE 1-1



Legend

- River Basin Boundary
- Reservoir

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MAP OF GUADALUPE-SAN ANTONIO RIVER BASIN

FIGURE 1-2

98-11

Basin. Furthermore, the environmental criteria should, to the extent possible, facilitate the selection and implementation of the most economically and environmentally feasible plan(s).

This Technical Memorandum summarizes discussions and technical analyses comprising a process by which refinement of the statewide Consensus Criteria has been considered for the Guadalupe - San Antonio River Basin. The intent is to make the Consensus Criteria more suitable for planning purposes and approximate criteria for permitting projects at some point in the future. Note that the intended goal of this process was not to reassess all aspects of the Consensus Criteria, but to refine the selection of appropriate desired minimum instream flows for Zones 2 and 3 as these will likely have the greatest effects on dependable water supply during drought. The environmental criteria refinement process was keyed to the participation of state and local sponsors on an Environmental Criteria Subcommittee (ECS) with technical support from HDR Engineering, Inc. (HDR) and Paul Price Associates, Inc. (PPA). Notes summarizing discussions during the ECS meetings are included as Appendix G. Technical analyses performed in support of the environmental criteria refinement process are presented in the following sections of this Technical Memorandum and include:

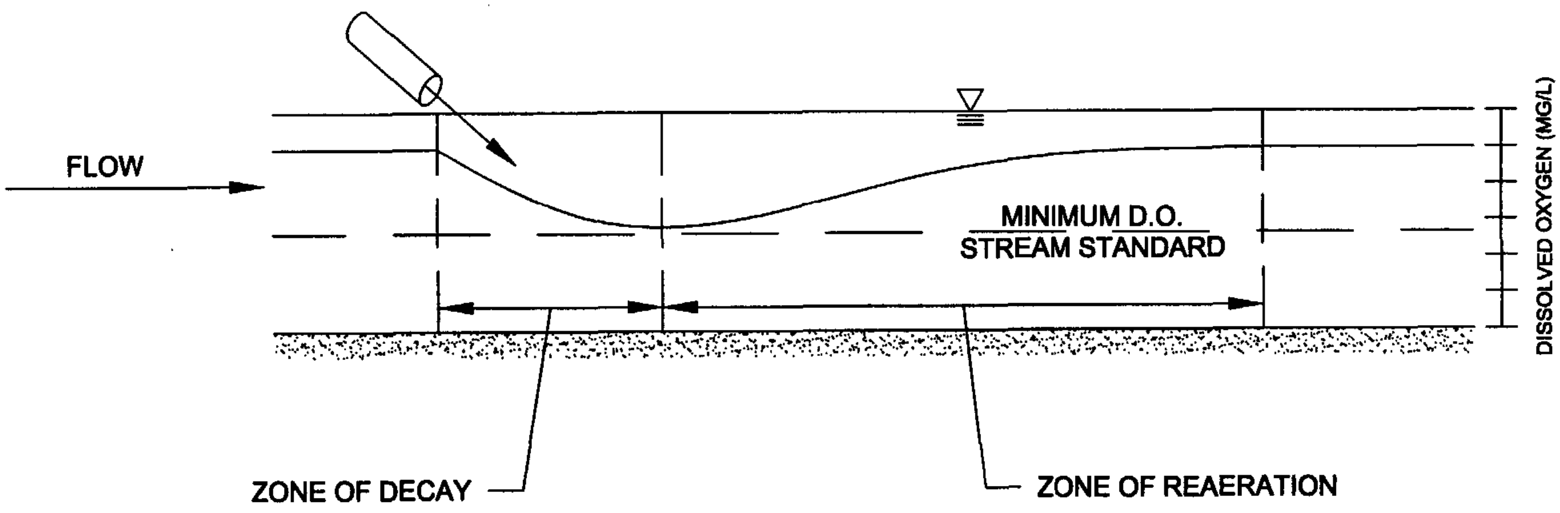
- Development and application of water quality models of the Guadalupe and San Antonio Rivers focusing on simulation of dissolved oxygen subject to various effluent loading and streamflow conditions (Section 2);
- Summary and interpretation of pertinent biological studies potentially providing insight into the selection of minimum instream flows (Section 3); and
- Performance of sensitivity analyses illustrating the effects of Zone 2 and 3 triggers and minimum flows on water availability, firm yield with off-channel storage, project cost, instream flows, and freshwater inflows to the Guadalupe Estuary (Section 4).

2.0 WATER QUALITY MODELING

For Zone 3 of the environmental criteria refinement, the focus of this study is on the interaction of streamflow, wastewater discharges, and dissolved oxygen levels in the streams of the study area. Figure 2-1 depicts the typical dissolved oxygen "sag" behavior in a stream after the introduction of a wasteload with organic materials, such as those found in municipal or industrial wastewater. Initially, just downstream of the discharge point, the biologic decay of the organic waste is of dominant importance. In this region, bacteria utilize oxygen in the conversion of organic carbonaceous and nitrogenous compounds from the waste stream which leads to declining dissolved oxygen levels. The central question in water quality analysis is whether the minimum of the dissolved oxygen sag curve will fall below the minimum acceptable stream standard. Table 2-1 presents a summary of the dissolved oxygen standards for the streams and rivers in the study area.

As the wasteload is transported downstream and the decay processes consume much of the initial wasteload, the D.O. levels in the stream begin to recover. In this region, the dominant process becomes the reaeration of dissolved oxygen from the atmosphere. Obviously, the volume of the wasteload and the strength (concentration) of the organic materials it contains are of crucial importance in determining the magnitude of the sag and how far downstream it extends.

Of equal importance is the flow of water in the receiving stream. The amount of streamflow is important for several reasons. First are the direct dilution and dispersion effects which spread out the wasteload and reduce the severity of the minimum of the sag. Secondly, streamflow has a direct influence on the process of reaeration. Reaeration is predominantly related to the velocity and depth of the stream which are highly dependent upon streamflow as will be discussed in more detail herein. Therefore, the choice of an appropriate streamflow for evaluation of the potential effects of a wasteload is crucial. For the springflow-dominated river segments of this study (Guadalupe and San Marcos Rivers), the 7Q2 streamflows normally used to evaluate wasteload impacts are high as compared to other Texas streams.



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TYPICAL DISSOLVED OXYGEN PROFILE IN A RECEIVING STREAM NEAR A WASTELOAD INPUT
FIGURE 2-1

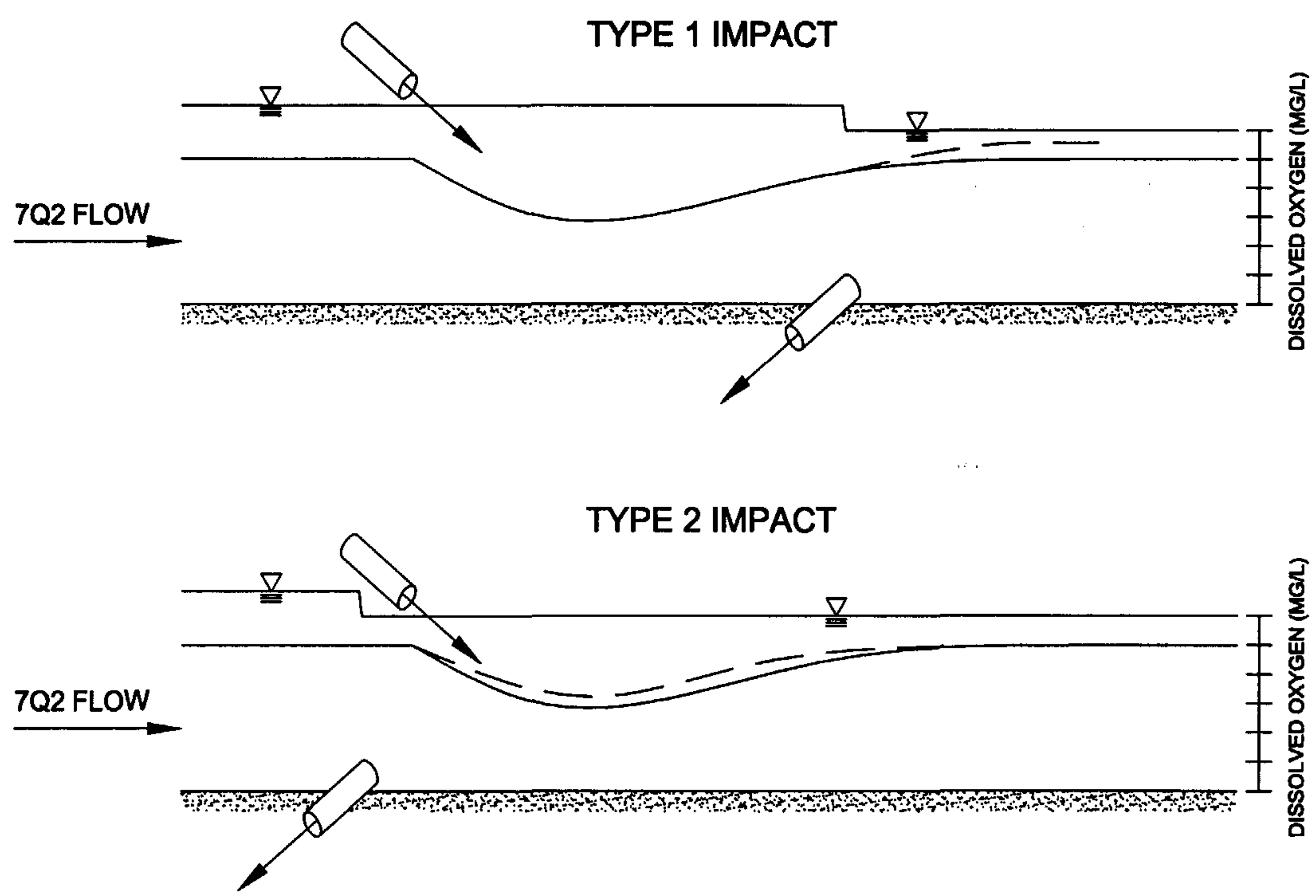
Table 2-1
Use Classification and Dissolved Oxygen Criteria for Select Segments on the Guadalupe and San Antonio Rivers

Segment No.	Segment Name	Aquatic Life Uses	Domestic Water Supply	Recreation	Dissolved Oxygen+ Criteria (mg/l)
Guadalupe River Basin					
1803	Guadalupe River Below San Marcos	High	PS	CR	5.0
1804	Guadalupe River Below Comal River	High	PS	CR	5.0
1808	Lower San Marcos River	High	PS	CR	5.0
1814	Upper San Marcos River	Exceptional	PS	CR	6.0
San Antonio River					
1901	Lower San Antonio River	High	PS	CR	5.0
1903	Medina River Below Medina Diversion Lake	High	PS*	CR	5.0
1906	Lower Leon Creek	High	PS**	CR	5.0
1910	Salado Creek	High	PS/AP	CR	5.0
1911	Upper San Antonio River	High		CR	5.0

notes: from the Texas Natural Resource Conservation Commission. Texas Surface Water Quality Standards Sections 307.1-307.10 Effective: July 13, 1995. PS = Public Water Supply, AP = Aquifer Protection. CR = Contract Recreation
+ Minimum 24-hour means at any site within segment.
* For Segment 1903, the public water supply designation does not apply from the confluence with the San Antonio River to a point 2.5 kilometers upstream of the confluence.
** For Segment 1906, the public supply does not apply from the confluence of the Medina River to a point 4.8 kilometers upstream.

Figure 2-2 illustrates the potential effects of reducing flow in the receiving stream below the 7Q2 flow. In the upper portion of Figure 2-2, a diversion removes water downstream from a wasteload discharge at a point beyond the minimum of the dissolved oxygen sag curve. After the diversion, the flow remaining in the stream is below the 7Q2 flow. This downstream reduction in streamflow delays the recovery of dissolved oxygen levels in the stream, but does not cause the crucial minimum point to be lower. For the purposes of this study, this will be designated a "Type 1" impact of the diversion; it is the impact of the diversion relative to an upstream wasteload discharge.

The lower portion of Figure 2-2 shows a diversion taking place upstream of the D.O. sag curve minimum. In this case, the reduction in streamflow to a level below the 7Q2 flow will tend to amplify the severity of the D.O. sag curve. For the purposes of this study, this will be



LEGEND:

- — — ORIGINAL DISSOLVED OXYGEN PROFILE AT 7Q2
- —— DISSOLVED OXYGEN PROFILE AFTER DIVERSION SUCH THAT STREAMFLOW IS BELOW 7Q2

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POTENTIAL IMPACTS OF DIVERSIONS ON THE D.O. BEHAVIOR IN A STREAM

FIGURE 2-2

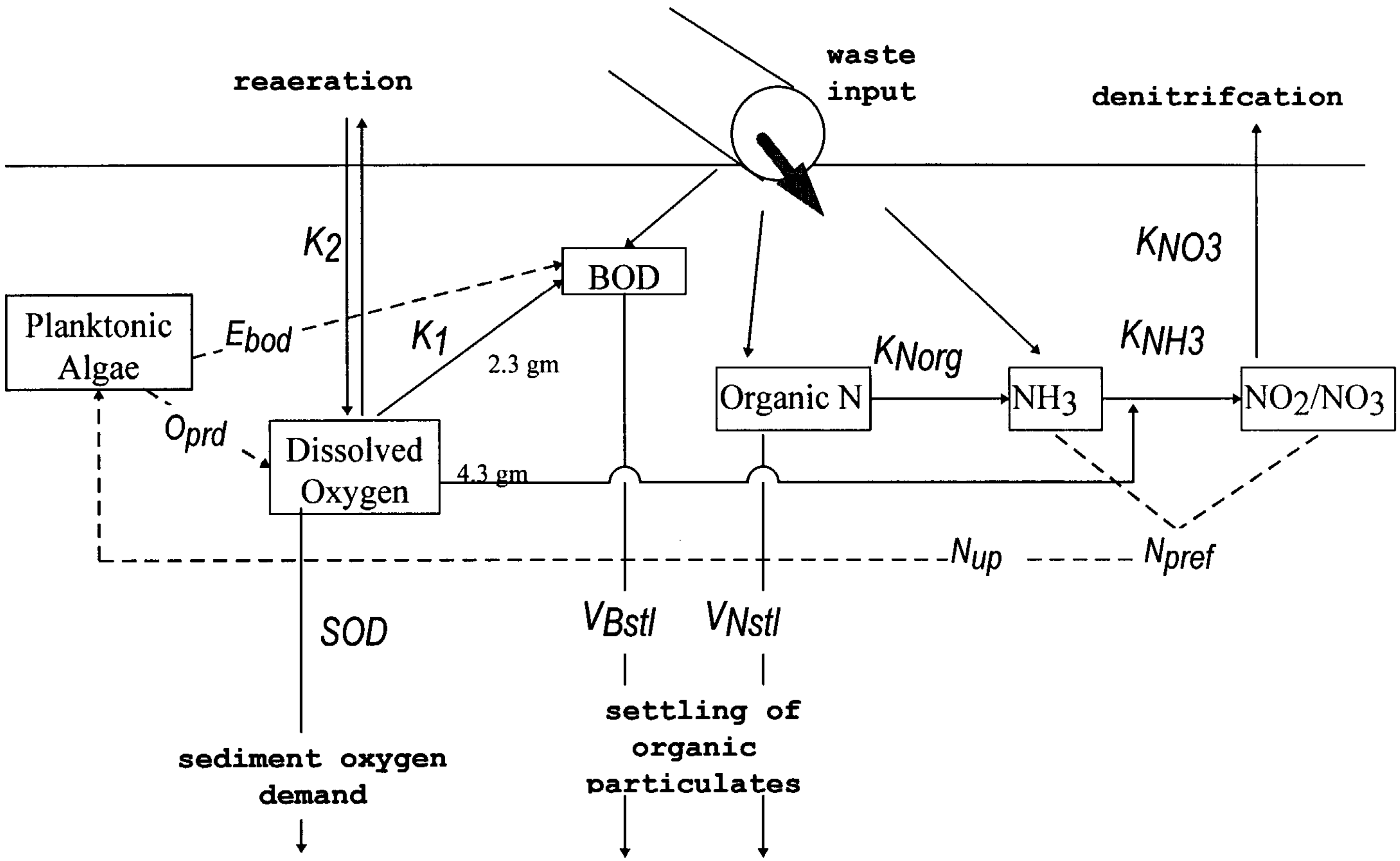
designated a "Type 2" diversion impact; it is generally the impact of the diversion relative to a downstream wasteload discharge. If the diversion takes place below the discharge point but upstream of the minimum of the D.O. sag curve it is still a "Type 2" impact with regard to its effect on the sag.

To evaluate the appropriateness of the 7Q2 flow as the minimum for Zone 3 of the environmental criteria, a methodology is needed which can integrate the impacts of the biologic decay process of wasteloads, the hydrologic behavior of the receiving stream, and the geographic relationships between the discharges of wasteloads and potential diversion sites of water. Such methodologies already exist and are generally referred to as *water quality models*. They are routinely used by state and federal agencies in the regulation of surface water quality and the evaluation of wasteload impacts on receiving streams.

2.1 Water Quality Modeling

The D.O. sag curve results from two dominant processes, namely the decay of oxygen consuming compounds and reaeration from the atmosphere. However, the level of detail necessary to develop a working water quality model is considerably greater. This is necessary because of the multitude of interactions between several constituents which influence the concentration of dissolved oxygen as shown in Figure 2-3. The water quality models typically employed for wasteload evaluations and other analyses are capable of tracking the concentrations of the many chemical parameters or constituents shown in Figure 2-3.

As indicated on Figure 2-3, each gram of organic carbon-containing material, usually denoted as biochemical oxygen demand (BOD), utilizes approximately 2.3 grams of dissolved oxygen. In the decay of organic nitrogen compounds (Organic N) a multi-step sequence occurs. In the presence of bacteria, this sequence of reactions converts ammonia (NH_3) to nitrite (NO_2) and, then, nitrite to nitrate (NO_3). These steps, respectively, consume approximately 1.1 and 3.2 grams of dissolved oxygen per gram of nitrogen. Another constituent which can be of importance for D.O. levels is Planktonic Algae, also called phytoplankton. Algae produce oxygen during photosynthesis in the presence of sunlight and consume oxygen during



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PRINCIPAL PATHWAYS OF DISSOLVED OXYGEN LOSS AND REPLENISHMENT DOWNSTREAM FROM A WASTELOAD INPUT

FIGURE 2-3

respiration. Algae are usually represented as the concentration of chlorophyll_a (ug/l) as opposed to the actual biomass of algae.[1]

Most water quality models use the finite-difference technique[2] wherein the stream under study is subdivided into a number of segments or elements as shown in Figure 2-4. For any given element *i* an equation based on the fundamental conservation of mass principle is solved for each constituent. The equation for any constituent *j* is,

$$\frac{\partial C_j}{\partial t} = \frac{1}{A_i}\frac{\partial}{\partial x}\left(EA_i\frac{\partial C_j}{\partial x}\right) - \frac{1}{A_i}\frac{\partial}{\partial x}\left(QC_j\right) + W_j - K_jC_j \qquad (2\text{-}1)$$

where,

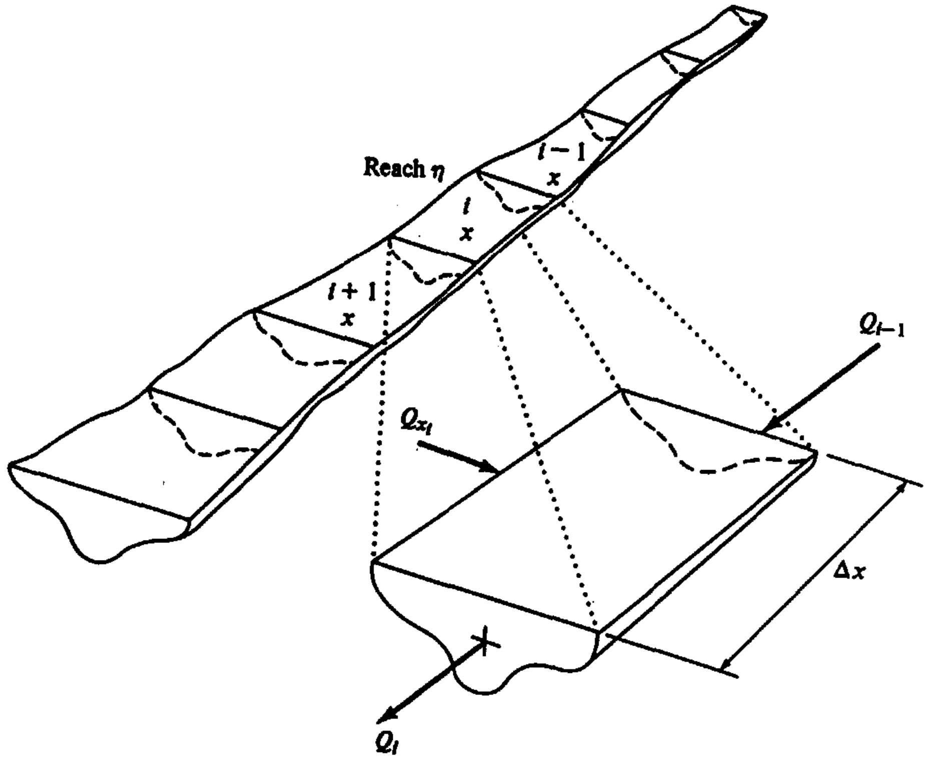
C_j = the concentration of constituent *j*,
x = distance along the stream channel,
A_i = cross sectional area of the stream element *i*,
E_i = dispersion coefficient for element *i*,
Q*i* = the streamflow at element *i*,
W_j = a wasteload source of constituent *j* entering element *i*,
K_j = the decay or transformation rate of constituent *j*.

For most applications of water quality models, the receiving stream and waste discharges are assumed to be at constant, or steady-state, conditions. Under this assumption, concentrations may vary spatially but do not vary through time allowing the left side of equation 2-1 to be set to zero. The derivation of Equation 2-1 is fully explained in standard reference texts such as Thomann and Mueller (1987)[3].

2.1.1 The QUAL-TX Model

One of the most widely used water quality models in the United States is the EPA-supported QUAL-2E model.[4] The TNRCC uses a specialized version of this model known as QUAL-TX. The predecessor to both of these models was the QUAL-I model developed under

[1] Thomann, R. V. and J. A. Mueller, "Principles of Surface Water Quality Modeling and Control." New York: Harper & Row. 1987.
[2] Smith, G D. "Numerical Solution of Partial Differential Equations." Oxford University Press: London, 1965.
[3] Thomann and Mueller, op cit.
[4] Brown, L. C. and Barnwell, T. O. "The Enhanced Stream Water Quality Models QUAL2E and QUAL2E-UNCAS: Documentation and User Manual" EPA Rep. 600/3-87/007. U. S. Environmental Protection Agency: Athens, GA. 1987.



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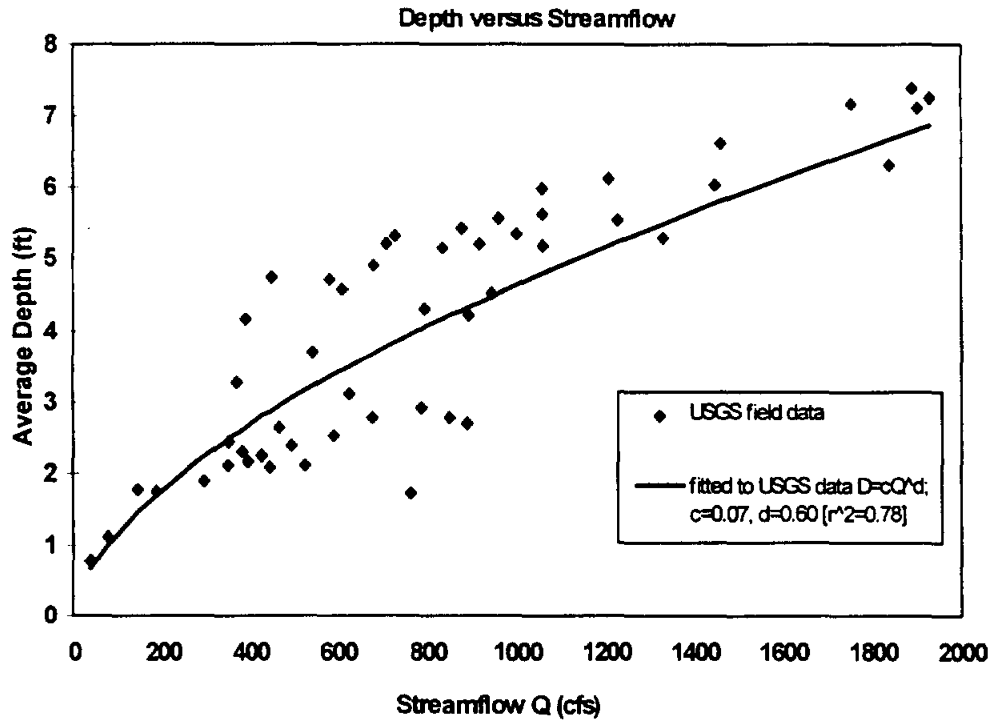
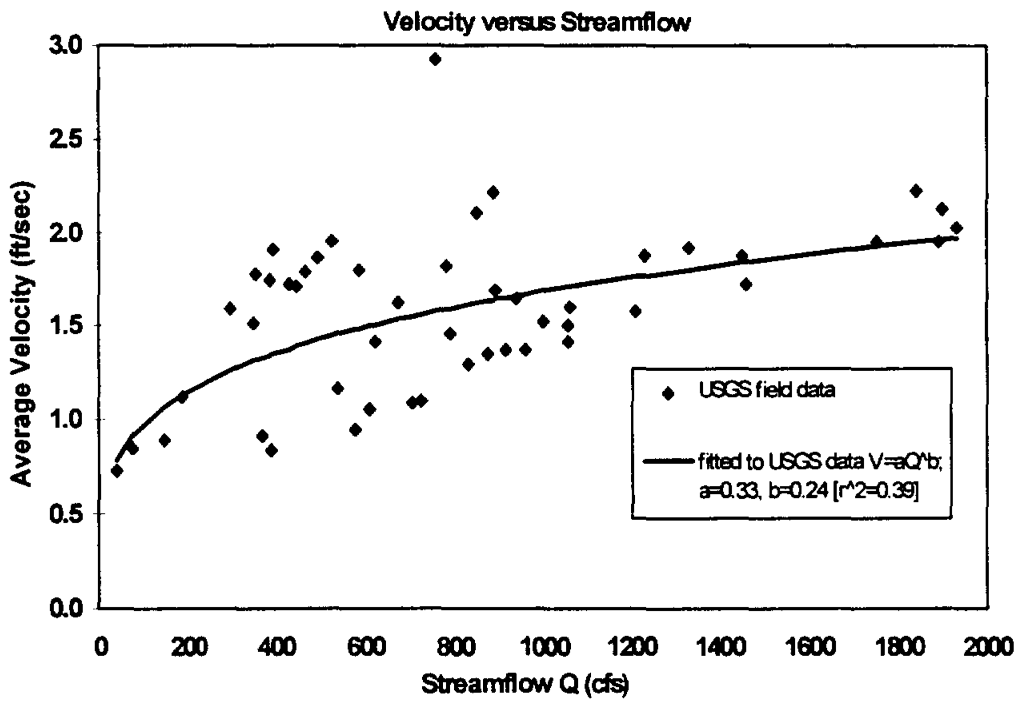
TYPICAL SEGMENTATION OF A STREAM IN A WATER QUALITY MODEL

FIGURE 2-4





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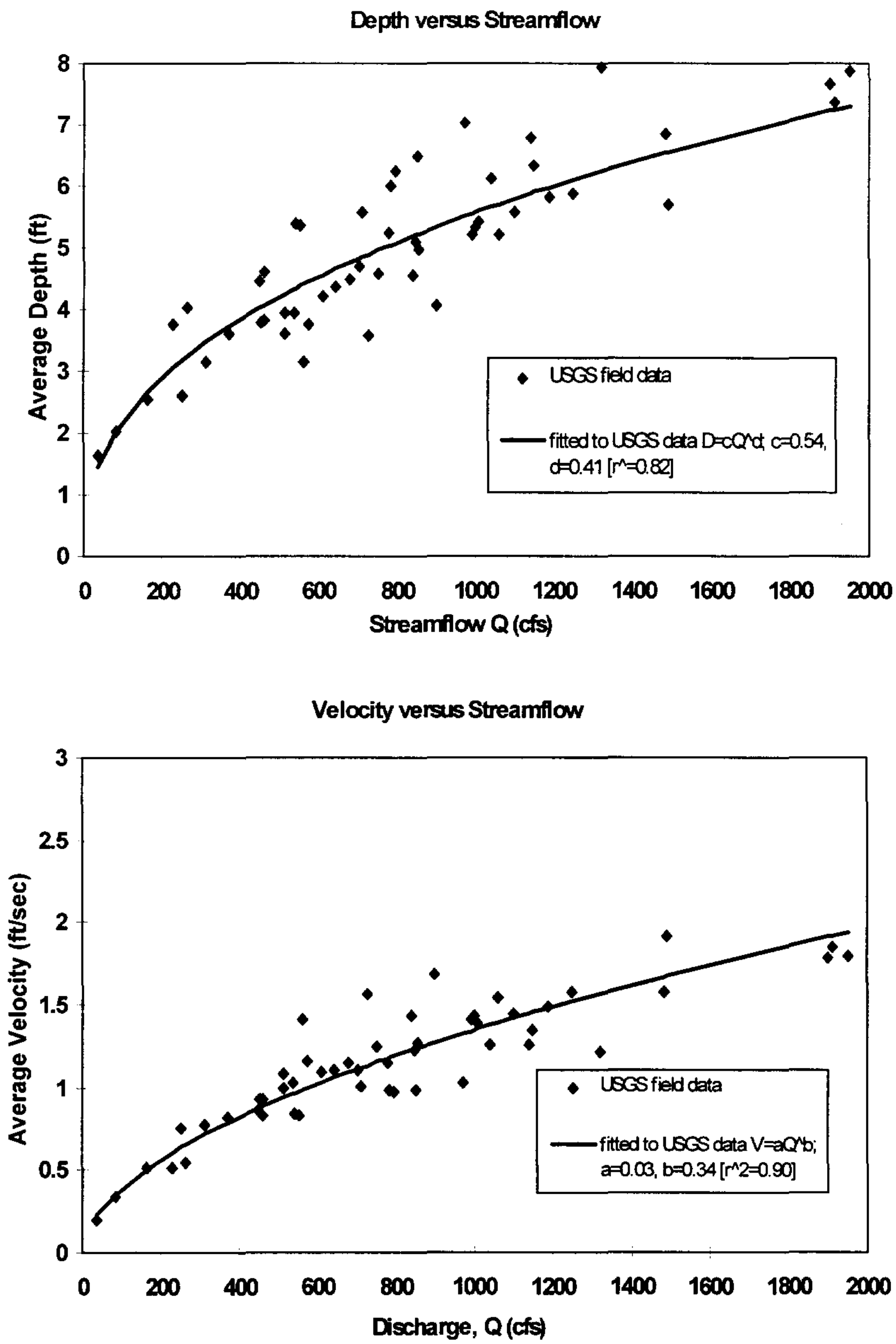
GUADALUPE RIVER CHANNEL HYDRAULIC CHARACTERIZATION AT CUERO (USGS #08175800)

FIGURE 2-8



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GUADALUPE RIVER CHANNEL HYDRAULIC CHARACTERIZATION AT VICTORIA (USGS #08176500)

FIGURE 2-9

contract to the Texas Water Development Board (TWDB) in the late 1960s. The QUAL-I model was able to track temperature, BOD and D.O. for steady-state solution (TWDB, 1970).[5]

Throughout the 1970s, the QUAL-I model underwent many changes to expand and upgrade its capabilities. In 1977, the QUAL-II version was released with the new capabilities to simulate the three component nitrogen series, phosphorus, phytoplankton, and coliform bacteria, in either a dynamic or steady-state manner (Roesner and others, 1977).[6]

The QUAL-II model continued to be modified with special capabilities for Texas conditions, culminating in 1985 with the release of a version named QUAL-TX. The changes represented not only refinements necessary to keep abreast of the burgeoning research concerning the natural processes occurring in receiving waters, but also increased the flexibility and applicability of the model. The internal mathematical solution algorithms for Equation 2-1 are the same for QUAL-TX and QUAL-II.[7] Among the changes made were to remove the dynamic capability of QUAL-II due to computational difficulties, modify several of the terms describing the loss of D.O. which was observed to be inhibited at low D.O. levels, provide for simulating water bodies influenced by tides, and update the simulation of phytoplankton.

Many water quality models provide for tracking the concentration of Planktonic Algae because of their influence of dissolved oxygen. Unfortunately, the simulation of algae growth is a very difficult process because it is a population dynamic process related to temperature, nutrient (NH_3 and NO_2/NO_3 and phosphorous) concentrations and sunlight availability. Because of this difficulty, the QUAL-TX model has the special capability of performing a pseudo-simulation of algae indicated by the dotted lines of Figure 2-3. Under this option the concentration of algae, as indicated by chlorophyll_a levels, in any reach is fixed. These fixed levels of algae produce dissolved oxygen and utilize ammonia and nitrite/nitrate.

The QUAL-TX model, with the latest version released in 1995, has now become the standard model in Texas for the evaluation of water quality and the wasteload permitting (wasteload allocation) process.

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[5] Texas Water Development Board. "Simulation of Water Quality in Streams and Canals: QUAL-I Program Documentation and User's Manual." Texas Water Development Board: Austin, TX. 1970.
[6] Roesner, L. A., J. R. Monser, and D. E. Evanson. "Computer Program Documentation for the Stream Quality Model QUAL-II." Water Resources Engineers: Walnut Creek, CA. 1977.
[7] Texas Natural Resource Conservation Commission. "QUAL-TX User's Manual, Version 3.4." Texas Natural Resource Conservation Commission: Austin, TX. 1995

2.1.2 Previous Use of the QUAL-TX Model in the Study Area

The QUAL-TX model has been used in several previous studies of creeks and rivers in the study area as shown on Figure 2-5. In all cases, QUAL-TX was used to support regulatory decisions on the acceptable wasteloads that could be discharged to the streams without violating D.O. standards.

The most extensive of these is the QUAL-TX model developed by the Texas Water Commission to model most of the major streams in the San Antonio River basin. Because of the geographic locations of the important wastewater discharges in the San Antonio River basin, the development of this model included separate tributary models for Leon and Medio creeks and the Medina River as well as the mainstem model of the San Antonio River.[8]

Another application of the QUAL-TX model in the study area was to Plum Creek[9] (see Figure 2-5) in order to recommend treatment levels for wastewater discharges through the year 2005. Finally, the QUAL-TX model was applied to a small portion of the San Marcos River during a wastewater discharge permit hearing.[10]

2.1.3 Model Layout and Calibration

Within the QUAL-TX model, the stream channel must be divided into reaches along its length. Each reach contains a number of elements, such as those shown in Figure 2-4. Each QUAL-TX model reach, and the elements within it, are characterized by constant properties. The subdivision of the stream into reaches is made primarily by choosing points which reflect any significant changes in stream properties. Many other coefficients related to the biologic processes of Figure 2-3 can only be varied on a reach-by-reach basis, thus serving as another criteria for the segmentation of the model.

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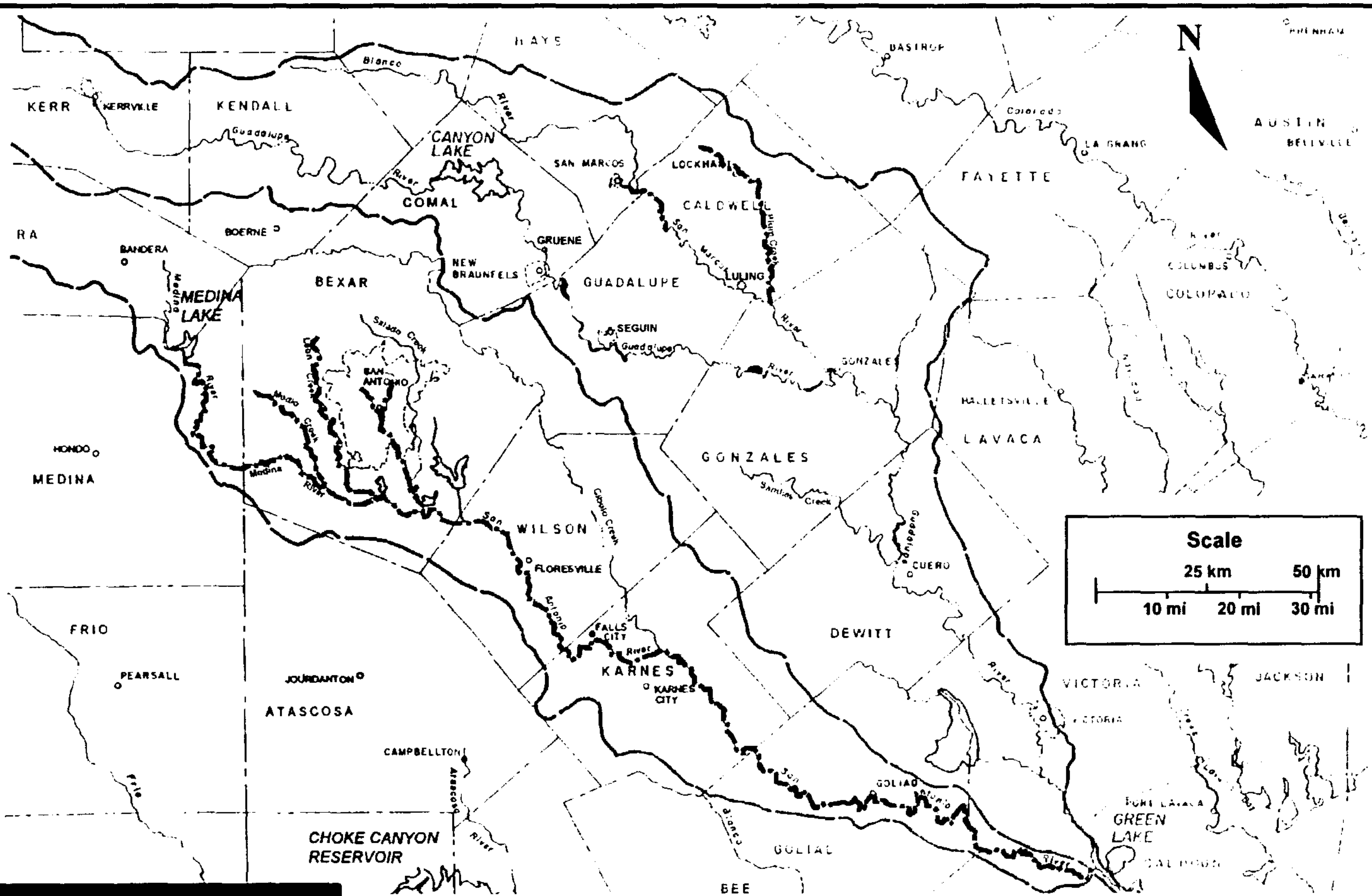
[8] Texas Water Commission. "Waste Load Evaluation for the San Antonio River System in the San Antonio River Basin." TWC Rep. WLE 89-01. Texas Water Commission: Austin, TX. 1989.

[9] Texas Water Commission. "Waste Load Evaluation for Plum Creek in the Guadalupe River Basin." TWC Rep. WLE 91-01. Texas Water Commission: Austin, TX. 1991.

[10] Black & Veatch, Inc. "City of San Marcos Wastewater Master Plan." San Marcos, TX. 1995.



Legend

- River Basin Boundary
- Previously Modeled
- Reservoir

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MAP OF STREAMS IN THE STUDY AREA WHERE THE QUAL-TX MODEL WAS PREVIOUSLY APPLIED

FIGURE 2-5

98-12

Within any given reach, the stream channel geometry is represented by two equations relating the average stream velocity and average depth at any point along a cross section to the streamflow. For stream velocity, the equation is:

$$V = aQ^b \tag{2-2}$$

where,

V = the average stream velocity,
Q = streamflow,
a & b = coefficients to be specified.

For stream depth the equation is:

$$D = cQ^d + e \tag{2-3}$$

where,

D = the average stream depth,
Q = streamflow,
c, d, and e = coefficients to be specified.

Thus, in order to accurately portray the hydrologic behavior of the stream channel, the model must be subdivided into reaches at each point where an appreciable change in depth and/or velocity occurs. The channel geometry coefficients *a, b, c, d,* and *e* must then be specified for each individual reach.

Achieving representative velocities and depths are important because of their influence on the simulation of transport and decay of the water quality constituents away from the discharge point. Specifically, a high-velocity channel will have a shallow D.O. sag curve as compared to a deeper or slower stream receiving the same wasteload. The actual derivation of these coefficients for each river section of this study is presented in following sections. The channel geometry coefficients are also of great importance because of their influence on the process of reaeration.

Within QUAL-TX there are a variety of functional forms for the reaeration process from which the modeler may choose. The most commonly used form is the so-called Texas

Reaeration Equation which was developed specifically with data collected by TNRCC and its predecessor agencies on Texas streams.[11] The equation is:

$$K_2 = 1.923 V^{0.273} / D^{0.894} \qquad (2\text{-}4)$$

where V and D are as defined above and K_2 is the reaeration rate (1/day). Because the average stream velocity and depth are of great importance in the reaeration equation, the channel geometry coefficients (*a, b, c, d* and *e*) on which they are based are critical.

One particular feature of the Texas Reaeration Equation of note is that for certain values of the channel geometry coefficients (*a, b, c, d* and *e*), the reaeration rate K_2 will increase with decreasing streamflow. Although this may be a true reflection of stream behavior, and is actually evident in the reaeration data from the San Antonio River[12] upon which the Texas Reaeration Equation is partially based, a more conservative approach was used in this study. In all evaluations of the effects of reducing streamflow below 7Q2, the reaeration rate was fixed at the baseline value corresponding to 7Q2 flow.

While the coefficients above are related to physical properties of the stream channel, there are many other coefficients affecting the simulation of biologic processes which must be specified. Each of the processes or transformations in Figure 2-3 is governed by a reaction rate coefficient, usually denoted by an uppercase K. The entries in Table 2-2 define each of the parameters of Figure 2-3. A thorough description of the theoretical basis for these constants and coefficients can be found in Bowie and others (1985).[13]

---

[11] Cleveland, K. D. "Predicting Reaeration Rates in Texas Streams." Journal of Environmental Engineering, V.115, No. 3. 1989.

[12] Ibid.

[13] Bowie, G. L., W. B. Mills, D. B. Porcella, C. L. Campbell, J. R. Pagenkopf, G. L. Rupp, K. M. Jonson, P. W. H. Chan, S. A. Gherini, and C. E. Chamberlin. "Rates, Constants, and Kinetic Formulations in Surface Water Quality Modeling (Second Edition)" EPA Rep. 600/3-85/040. U. S. Environmental Protection Agency: Athens, GA. 1985.

Table 2-2
Description of the Constants and Coefficients Used in the QUAL-TX Model of the Guadalupe and San Marcos Rivers

Constant or Coefficient Name	Description/Units
K1	aerobic decay rate of carbonaceous BOD (1/day)
K2	atmospheric reaeration rate constant (function of stream depth and velocity as in Equation. 2-4) (1/day)
KNorg	decay rate of organic nitrogen waste to ammonia (NH_3) (1/day)
KNH3	decay rate of ammonia to nitrite and nitrate (1/day)
KNO3	anaerobic loss rate of nitrite and nitrate to the atmosphere (1/day)
SOD	background sediment oxygen demand (gm/sq. meter -day)
VBstl	settling rate of BOD (converts to SOD) (m/day)
VNstl	settling rate of organic nitrogen (m/day)
Nup	nitrogen uptake rate constant for algae/ (mg Nitrogen/ug chlorophyll_a-day)
Npref	nitrogen source preference of algae (1 = total preference for NO_3, 0 = total preference for NH_3)
Oprd	production rate of dissolved oxygen by algae (mg D.O. / ug chlorophyll_a - day)
Ebod	effective interference of algae on BOD (mg BOD /ug chlorophyll_a)

The rate constants and coefficients in Table 2-2 vary depending on the characteristics of a given water body and the wasteload(s) entering it. As a water quality model for a stream is being developed, it is necessary to arrive at the unique set of these rate constants and coefficients such that the model can reasonably replicate actual stream concentrations. This process of tailoring the water quality model to the stream of interest via adjustment of the set of rate constants and coefficients is known as *calibration*. Calibration is typically performed by selecting a time when the stream is at low-flow and nearly steady-state conditions, that is, with constant streamflow and wastewater discharges. Model calibration, as well as model application, is also generally restricted to summer, high temperature periods because the reaction rates are at their highest and the D.O. curve is most severe.

The calibration effort is best supported by a rather rigorous set of data. Among the most important data requirements are: measurements of all entering river and tributary streamflows and constituent concentrations, measurements or estimates of the volumes and constituent concentrations of each wastewater discharge and, measurements of constituent concentrations along the length of the stream at a spatial resolution sufficient to capture the progress of the decay and transformation processes.

Once the model is fully calibrated to sufficiently represent the stream with the available data from one period, a verification is then performed. For verification, the calibrated set of constants and coefficients is used in conjunction with the streamflows and wastewater discharges of another period to see if the model can reasonably replicate the field-measured constituent concentrations again.

Figure 2-6 shows the simulated D.O. in the San Antonio River after the QUAL-TX model was calibrated with the in-stream data gathered in a previous study by the Texas Water Commission (now the TNRCC) specifically for that purpose.[14] The present study relied exclusively upon existing data for in-stream concentrations, streamflows, and wastewater discharges in the calibration process. The adequacy and shortcomings of these available data will be discussed in the following sections. A summary of the final calibration values for the rivers of interest in this study is also presented in a subsequent section.

2.1.4 Model Limitations

QUAL-TX is a fairly flexible water quality model allowing the user a great deal of latitude in the spatial layout of the system. This includes the capability to include tributaries, multiple waste loads in one segment, and other features added by the Texas Water Commission and/or Texas Department of Water Resources.[15]

Nonetheless, there are several limitations of the water quality modeling process which should be pointed out. At the most general level, the biggest limitation in water quality modeling is the assumption of steady-state conditions although most rivers are highly dynamic in streamflow behavior. Steady-state conditions are typically assumed because of the greatly increased data requirements necessary to calibrate a dynamic model. However, the steady-state assumption is generally considered reasonable since the critical low-flow periods of interest

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[14] Texas Water Commission. "Waste Load Evaluation for the San Antonio River System in the San Antonio River Basin." TWC Rep. WLE 89-01. Texas Water Commission: Austin, TX. 1989.

[15] Texas Natural Resource Conservation Commission. "QUAL-TX User's Manual, Version 3.4." Texas Natural Resource Conservation Commission: Austin, TX. 1995.

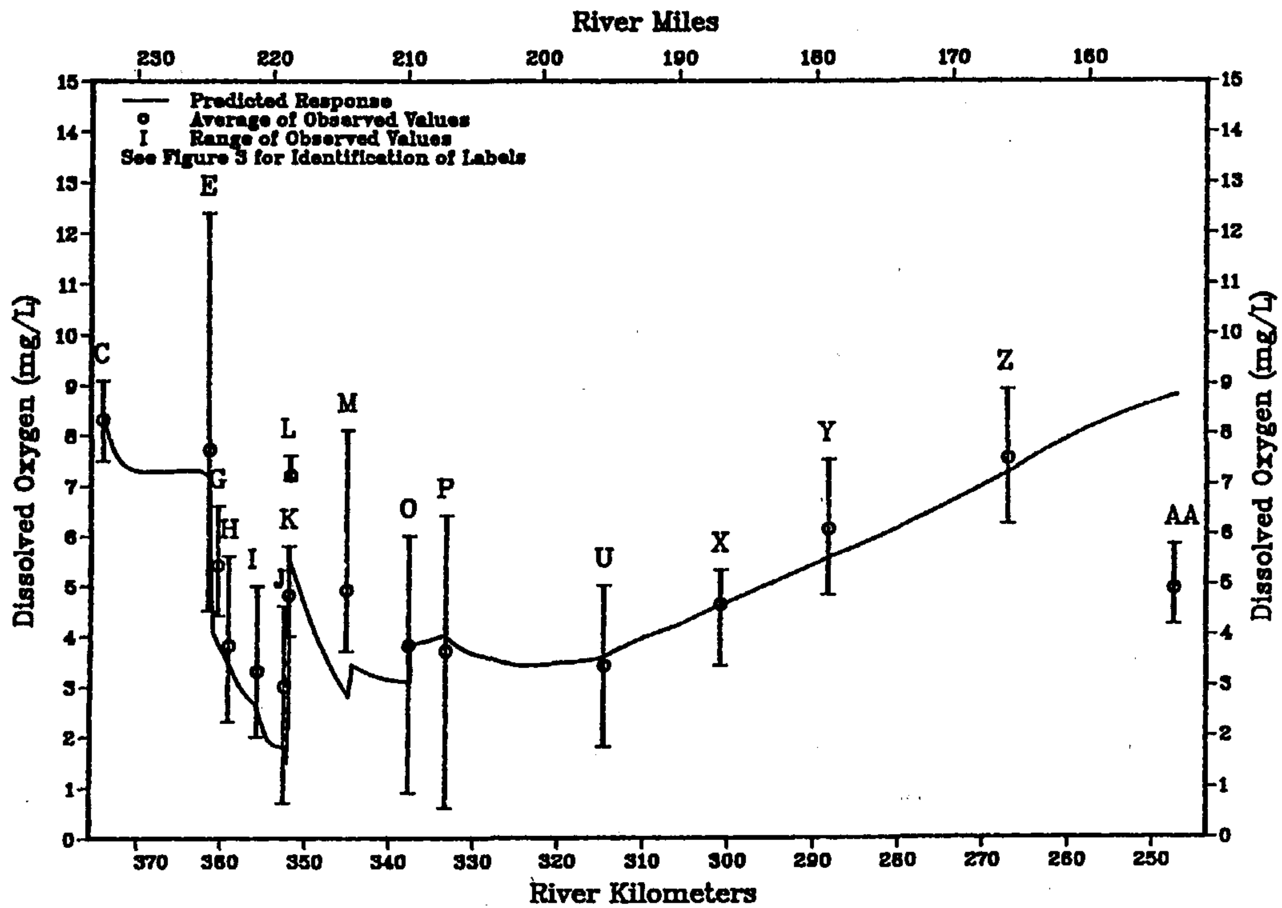


FIGURE 24

UPPER SAN ANTONIO RIVER CALIBRATION PLOT FOR DISSOLVED OXYGEN
July 23-August 1, 1984 Data

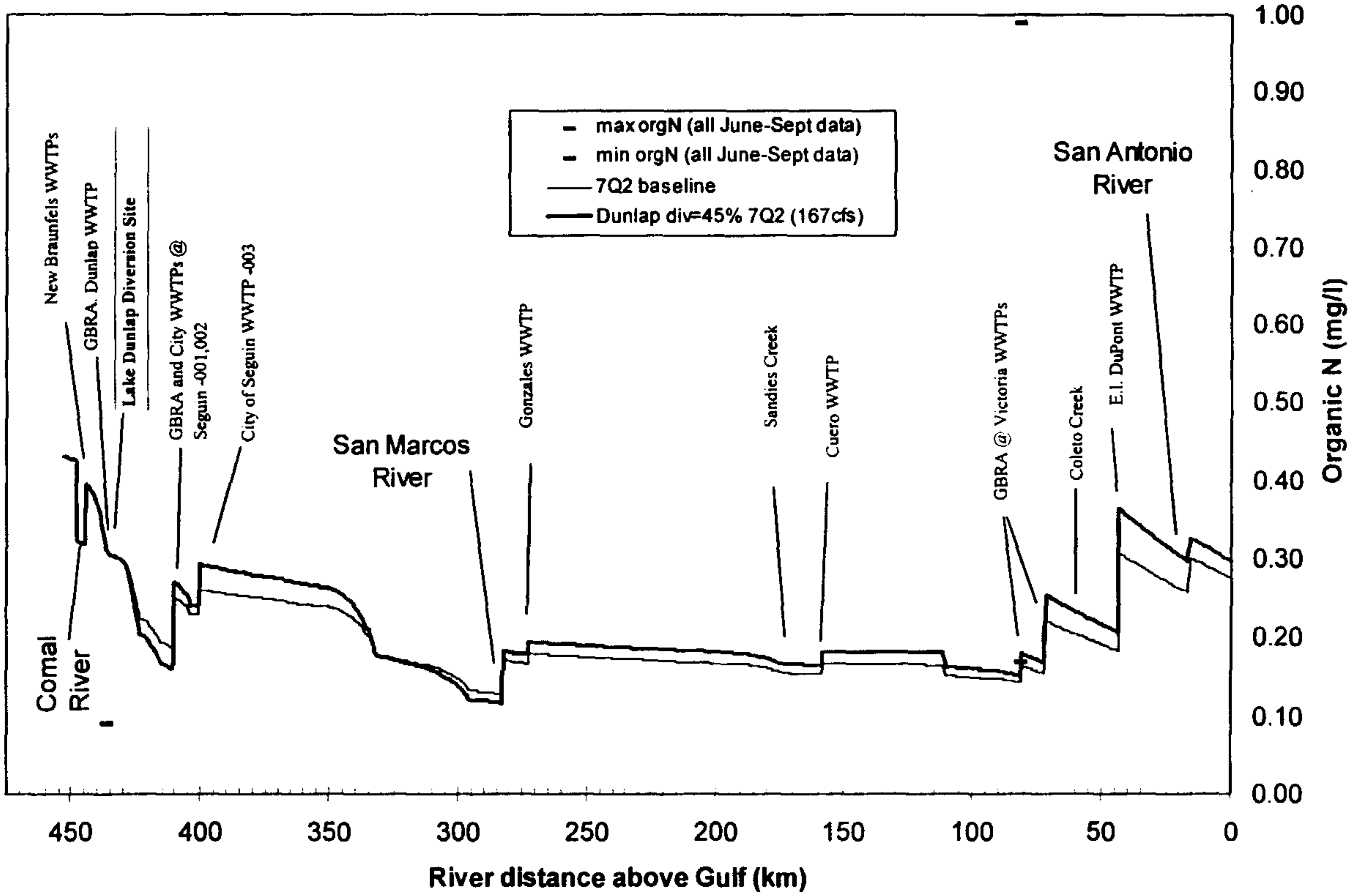
TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

HDR Engineering, Inc.

EXAMPLE OFMODEL CALIBRATION FOR THE SAN ANTONIO RIVER FROM A PREVIOUS STUDY

FIGURE 2-6

GUADALUPE - SAN ANTONIO RIVER BASIN ENVIRONMENTAL CRITERIA REFINEMENT



GUADALUPE - SAN ANTONIO RIVER BASIN
ENVIRONMENTAL CRITERIA REFINEMENT

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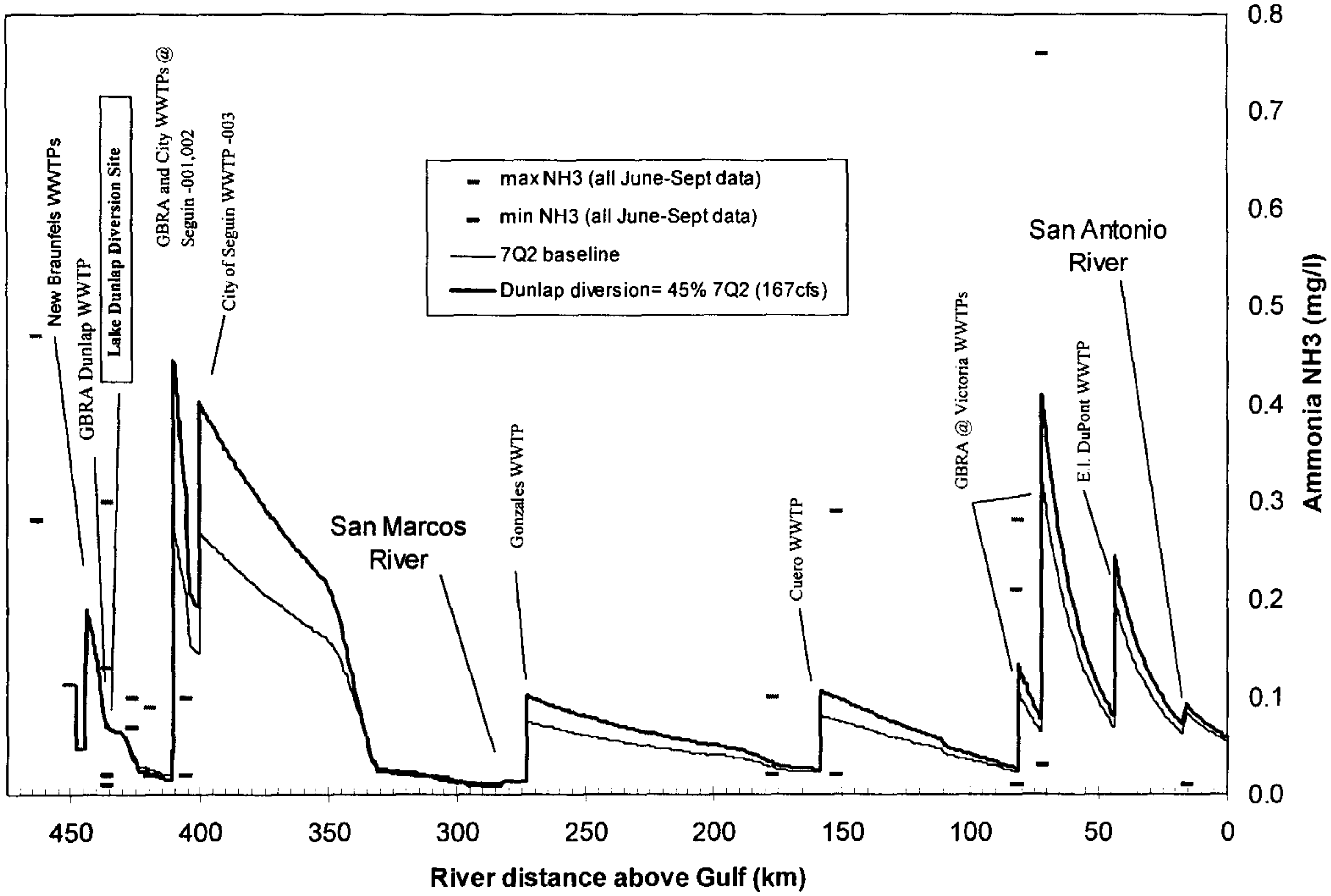
WEST CENTRAL STUDY AREA

CURRENT PERMIT SCENARIO-ORGANIC NITROGEN SIMULATION: DIVERSIONS FROM LAKE DUNLAP

FIGURE 2-24



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GUADALUPE - SAN ANTONIO RIVER BASIN ENVIRONMENTAL CRITERIA REFINEMENT

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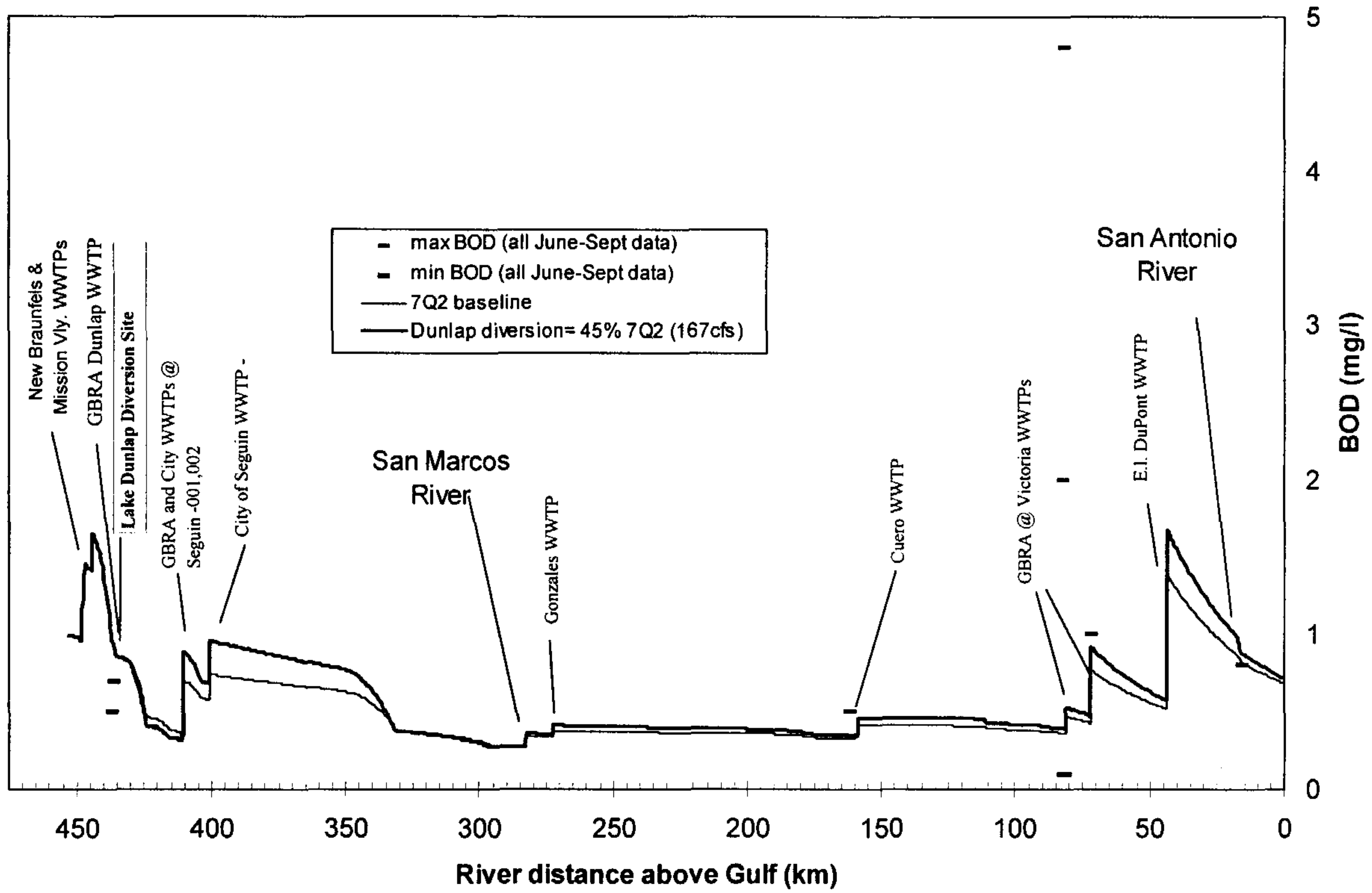
CURRENT PERMIT SCENARIO-AMMONIA SIMULATION: DIVERSIONS FROM LAKE DUNLAP

FIGURE 2-25



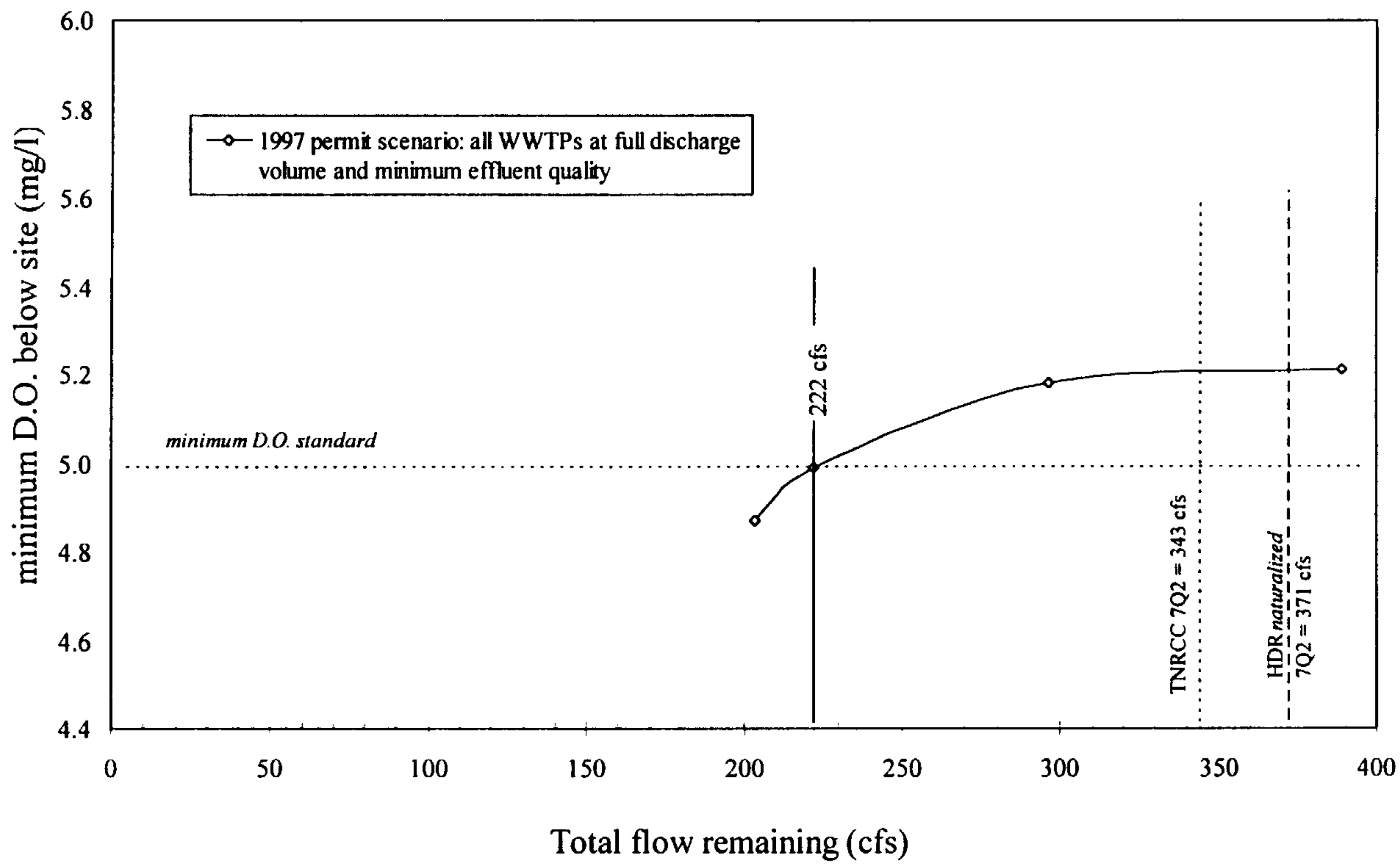
TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

CURRENT PERMIT SCENARIO-BOD SIMULATION: DIVERSION FROM LAKE DUNLAP

FIGURE 2-27

HDR Engineering, Inc.

GUADALUPE - SAN ANTONIO RIVER BASIN
ENVIRONMENTAL CRITERIA REFINEMENT



GUADALUPE - SAN ANTONIO RIVER BASIN
ENVIRONMENTAL CRITERIA REFINEMENT

HDR Engineering, Inc.

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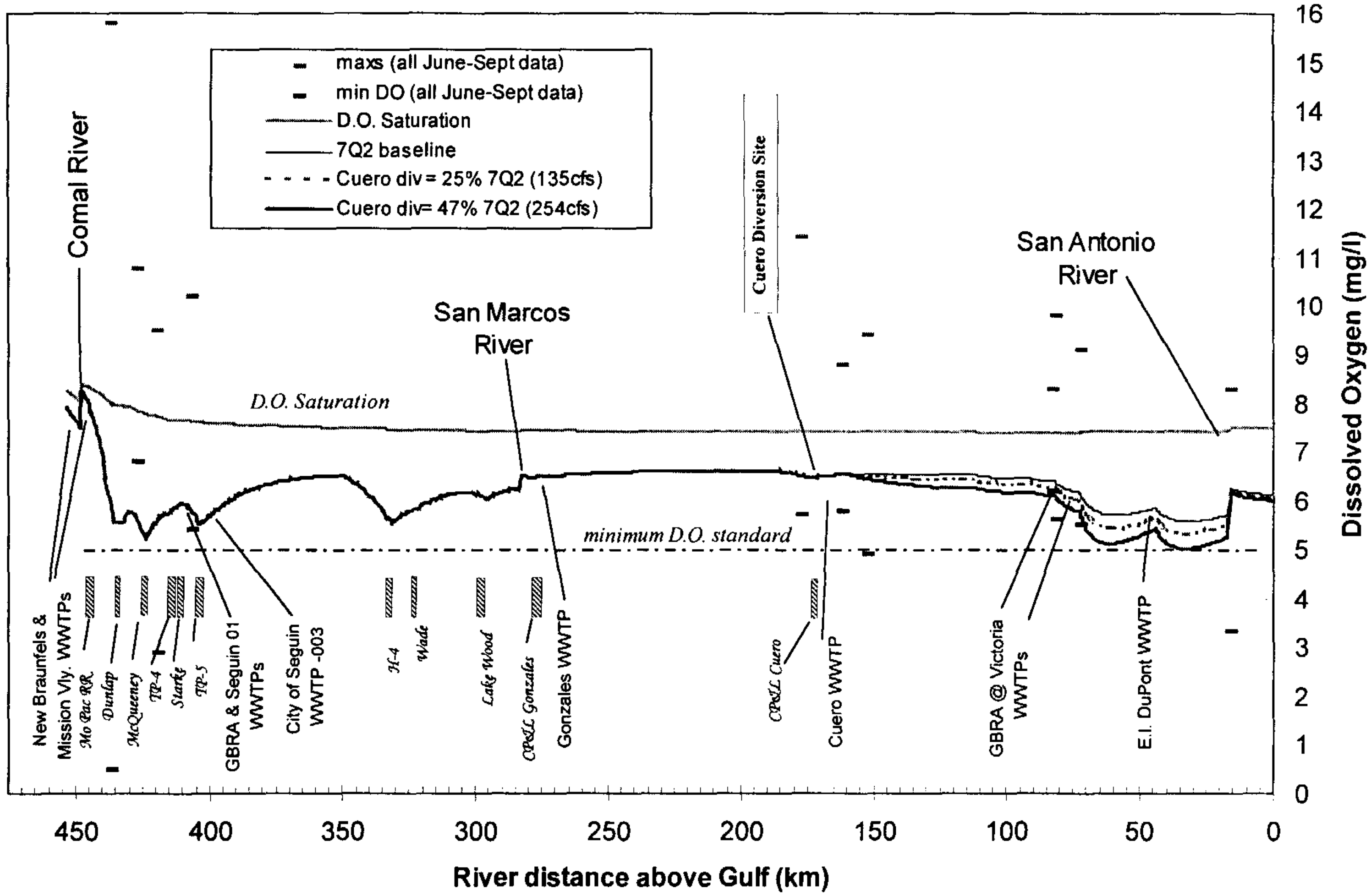
WEST CENTRAL STUDY AREA

CURRENT PERMIT SCENARIO-
FLOW VS. MINIMUM D.O. CURVE
FOR LAKE DUNLAP DIVERSION

FIGURE 2-28



GUADALUPE - SAN ANTONIO RIVER BASIN
ENVIRONMENTAL CRITERIA REFINEMENT

HDR Engineering, Inc.

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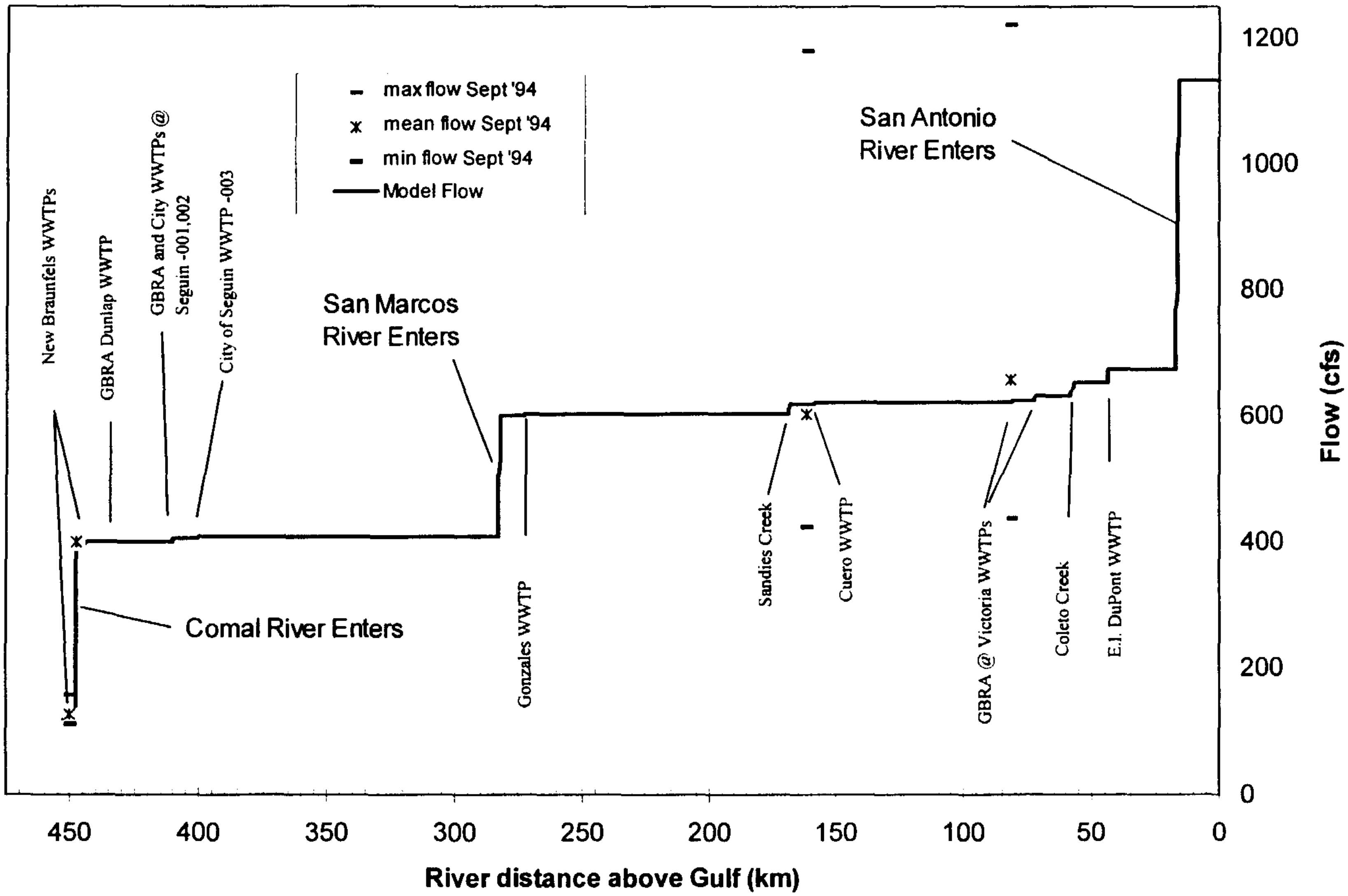
CURRENT PERMIT SCENARIO-D.O. SIMULATION: DIVERSION FROM CUERO

FIGURE 2-29



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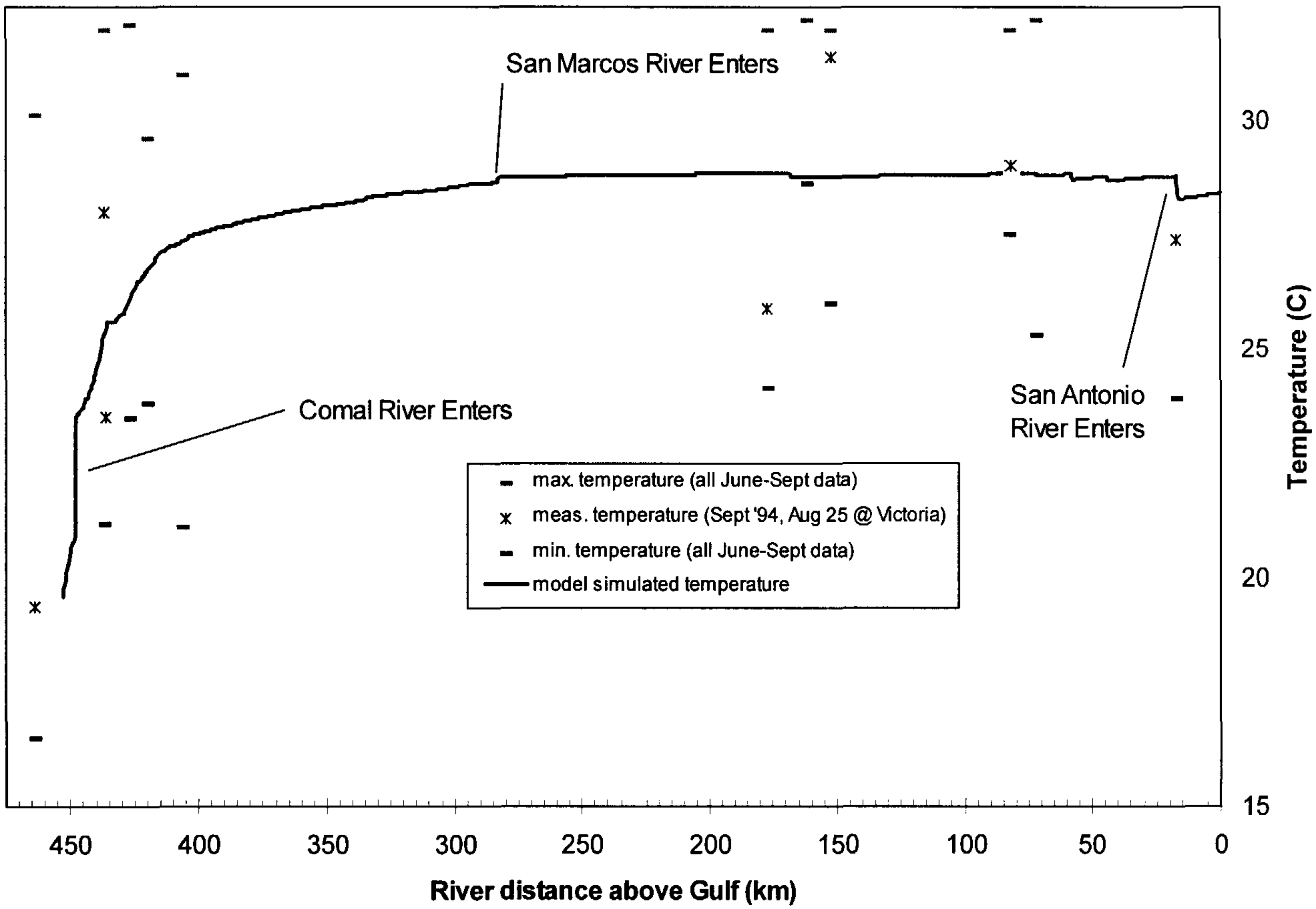
HDR Engineering, Inc.

FLOW CALIBRATION OF GUADALUPE/SAN MARCOS RIVER MODEL FOR SEPTEMBER 1994
FIGURE 2-13

GUADALUPE - SAN ANTONIO RIVER BASIN ENVIRONMENTAL CRITERIA REFINEMENT



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GUADALUPE - SAN ANTONIO RIVER BASIN
ENVIRONMENTAL CRITERIA REFINEMENT

HDR

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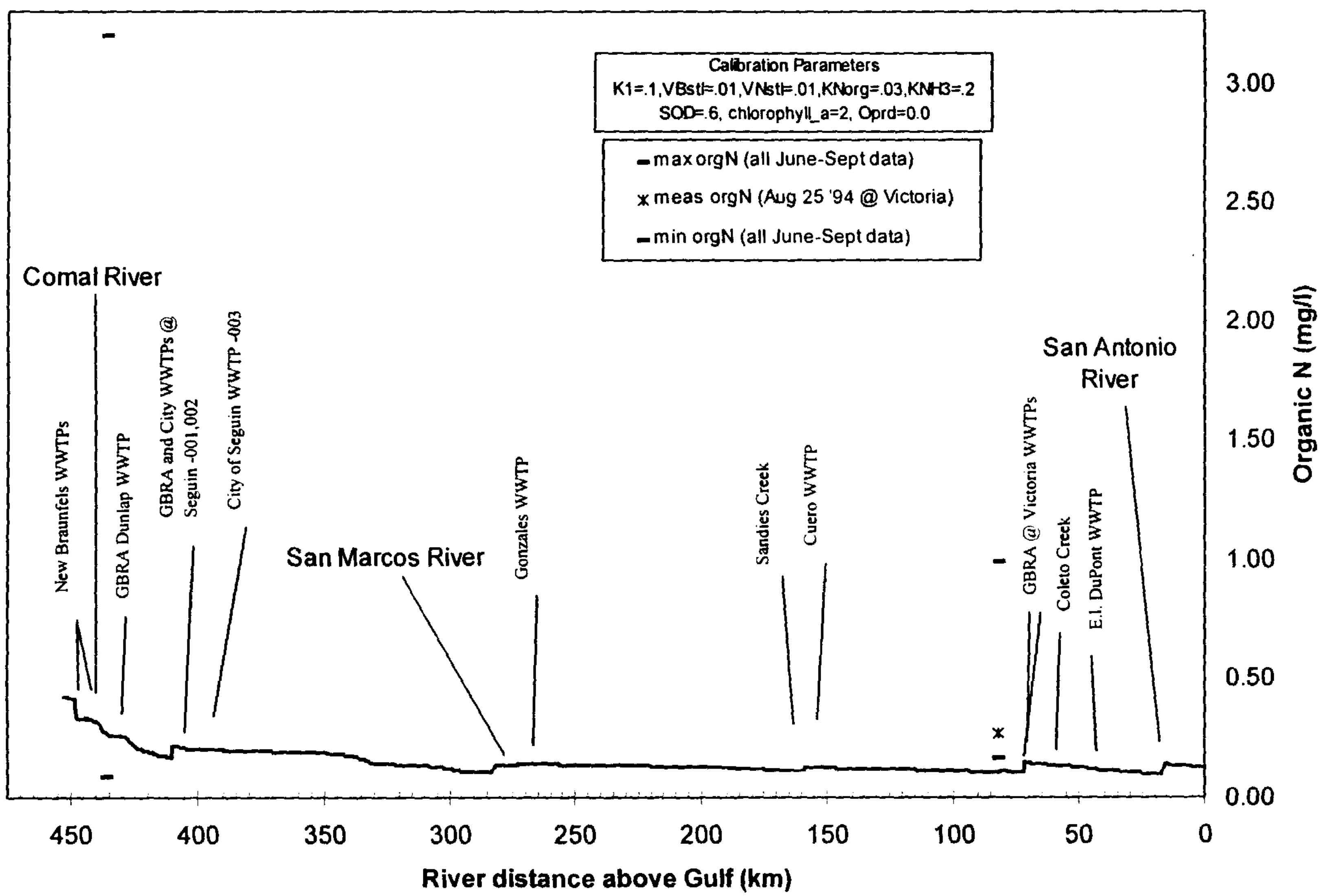
TEMPERATURE CALIBRATION OF GUADALUPE/SAN MARCOS RIVER MODEL FOR SEPTEMBER 1994

FIGURE 2-14



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ORGANIC NITROGEN CALIBRATION OF GUADALUPE/SAN MARCOS RIVER MODEL FOR SEPTEMBER 1994

FIGURE 2-15

GUADALUPE - SAN ANTONIO RIVER BASIN ENVIRONMENTAL CRITERIA REFINEMENT

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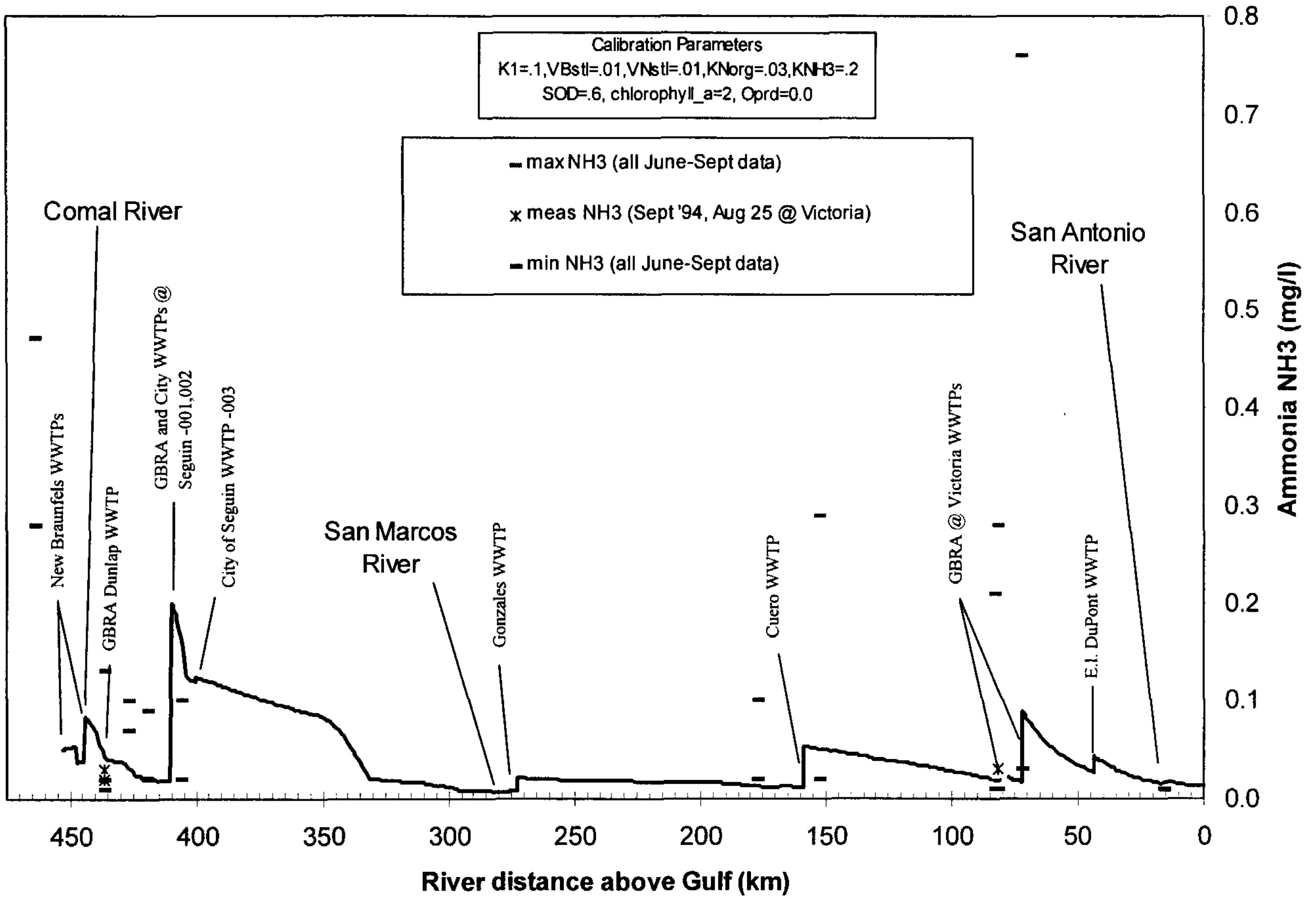

GUADALUPE - SAN ANTONIO RIVER BASIN
ENVIRONMENTAL CRITERIA REFINEMENT

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AMMONIA CALIBRATION OF GUADALUPE/SAN MARCOS RIVER MODEL FOR SEPTEMBER 1994

FIGURE 2-16

exhibit relatively stable streamflows. This may not be the case, however, for wastewater discharges which can exhibit variation during the course of a day. Often, the modeler is forced to use average data for streamflow and wastewater discharges to try and replicate the constituent concentrations measured in the stream or river which may have actually been influenced by short-term perturbations.

Another limitation of the QUAL-TX model, and other water quality models, is that similar constituents such as BOD, whether they originate in wasteloads or from natural runoff, are assumed to exhibit the same biochemical behavior once they enter the stream. For example, this means that background natural levels of BOD and BOD discharges from municipal or industrial sources are modeled with the same average decay rate K_1 although studies have shown differing decay characteristics.[16]

QUAL-TX is also limited by its treatment of planktonic algae and its effect on dissolved oxygen. It is known that algae and other plants can cause significant swings in dissolved oxygen over the course of the day because they produce D.O. in sunlight, but consume it through respiration at night. These daily variations cannot be captured in a steady-state model. Therefore, the modeled impact on nutrients (nitrogen) and dissolved oxygen represent somewhat of a 24-hour averaged effect.

As with any simulation model, those developed for this project are limited by the assumptions necessary to simulate the physical, chemical, spatial and temporal complexities of the reality they attempt to emulate. In spite of these limitations, a water quality model is essentially the only tool available for performing the work herein.

[16] Tchobanoglous, G. and F. L. Burton. "Wastewater Engineering: Treatment, Disposal, and Reuse, 3rd Ed." McGraw-Hill: New York. 1991.

2.2 The Guadalupe/San Marcos River Model

2.2.1 Model Layout and Hydraulics

In this study, the springflow-dominated portions of the Guadalupe River and its principal tributary the San Marcos River are the segments of interest. Therefore, as shown in Figure 2-7, the QUAL-TX model was applied to the Guadalupe River from a point just above New Braunfels, picking up Comal Springs at the Comal River confluence in New Braunfels, and continuing down to the Saltwater Barrier near Tivoli.

The San Marcos River model begins downstream of the City of San Marcos, below San Marcos Springs, and continues downstream to the junction with the Guadalupe River near Gonzales. Since the San Marcos River is a tributary to the Guadalupe River, the streamflow volume and constituent concentrations exiting the last element of the San Marcos QUAL-TX model were input to the main Guadalupe River model at the appropriate element representing the confluence of the rivers.

Other principal features of the Guadalupe/San Marcos model are also shown in Figure 2-7 including the 7Q2 streamflows and the principal wastewater discharges. These 7Q2 streamflows represent "naturalized" flows derived by using USGS and other gaged flows for the 1934-89 period and adjusting these for municipal and industrial return flows and diversions.[17,18] As is evident in Figure 2-7, the 7Q2 flow increases as one moves down the Guadalupe River Basin. At points between gages, 7Q2 streamflows were calculated by interpolation for the purposes of this study.

One of the most important aspects of the Guadalupe River which had to be considered in the application of the QUAL-TX model is the series of reservoirs along the mainstem between New Braunfels and Gonzales. These reservoirs are of great importance because of their effect on stream velocity and stream depths which in turn have a great influence on the reaeration rate K_2 (Section 2.1.2).

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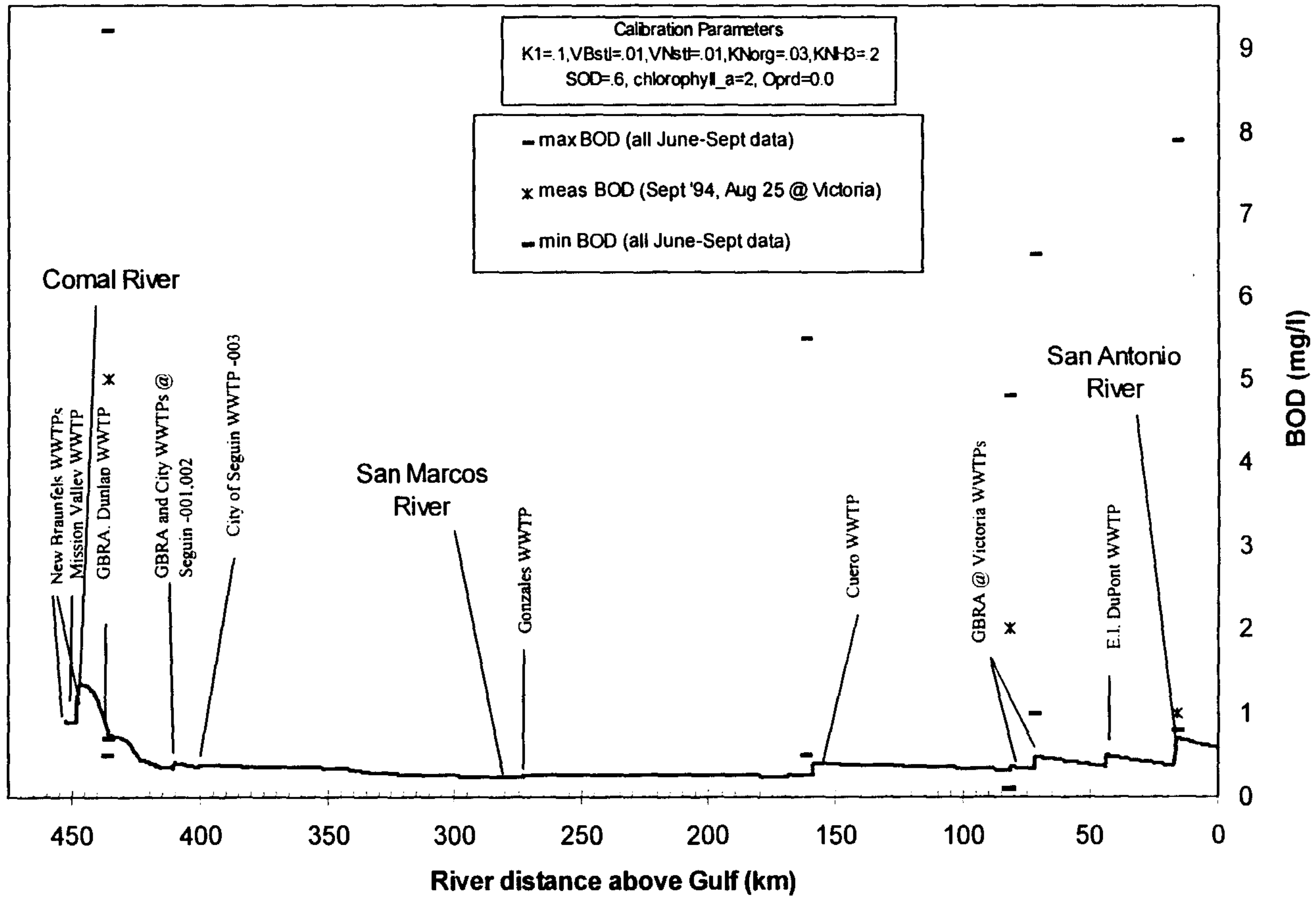
[17] HDR, "Guadalupe - San Antonio River Basin Recharge Enhancement Study," Edwards Underground Water District, September 1993..

[18] HDR, "Guadalupe - San Antonio River Basin Model Modifications and Enhancement," Technical Manual, Trans-Texas Water Program, West Central Study Area, San Antonio River Authority, et al. March 1998.



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BOD CALIBRATION OF GUADALUPE/SAN MARCOS RIVER MODEL FOR SEPTEMBER 1994

FIGURE 2-18

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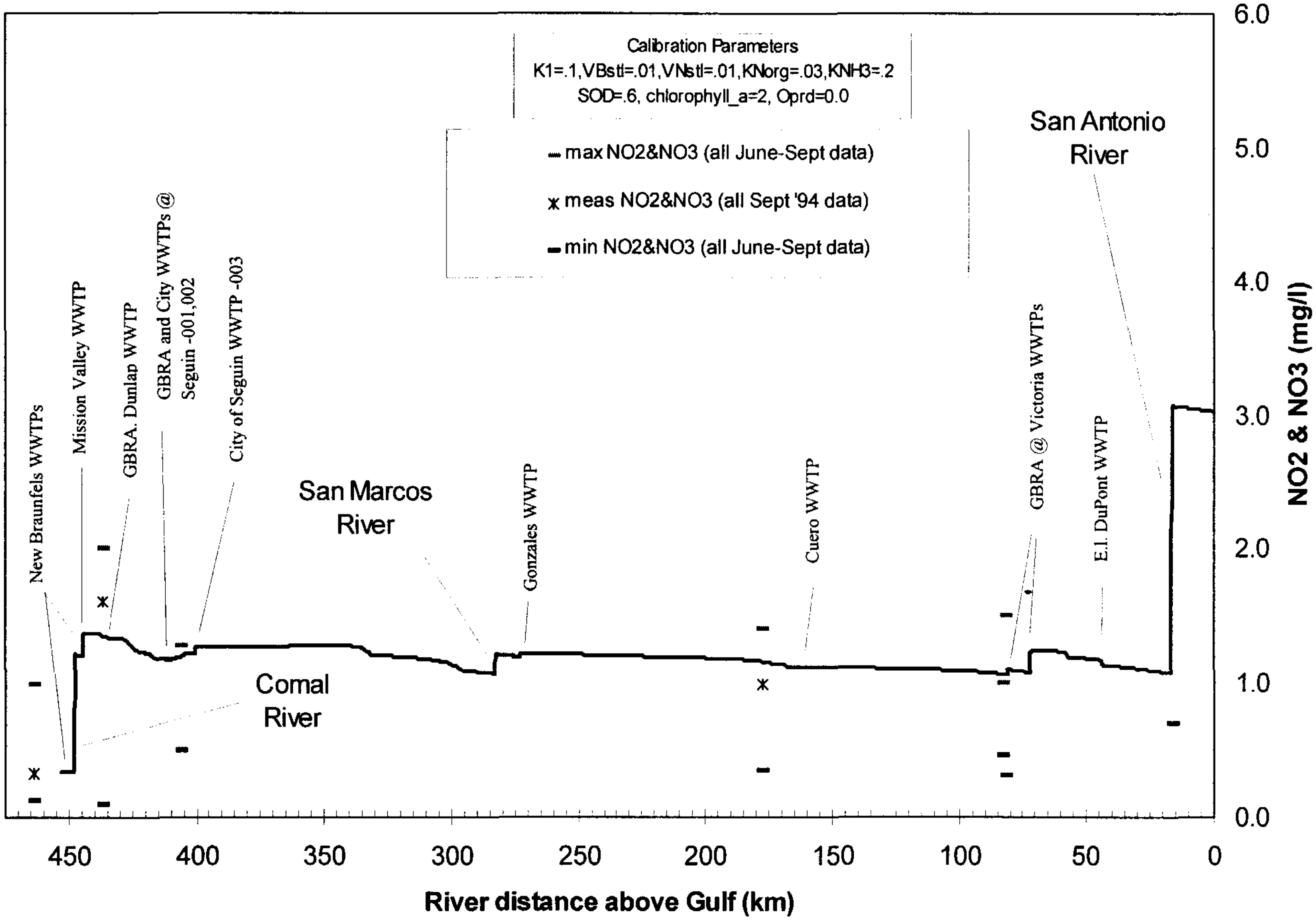
GUADALUPE - SAN ANTONIO RIVER BASIN
ENVIRONMENTAL CRITERIA REFINEMENT



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GUADALUPE - SAN ANTONIO RIVER BASIN
ENVIRONMENTAL CRITERIA REFINEMENT

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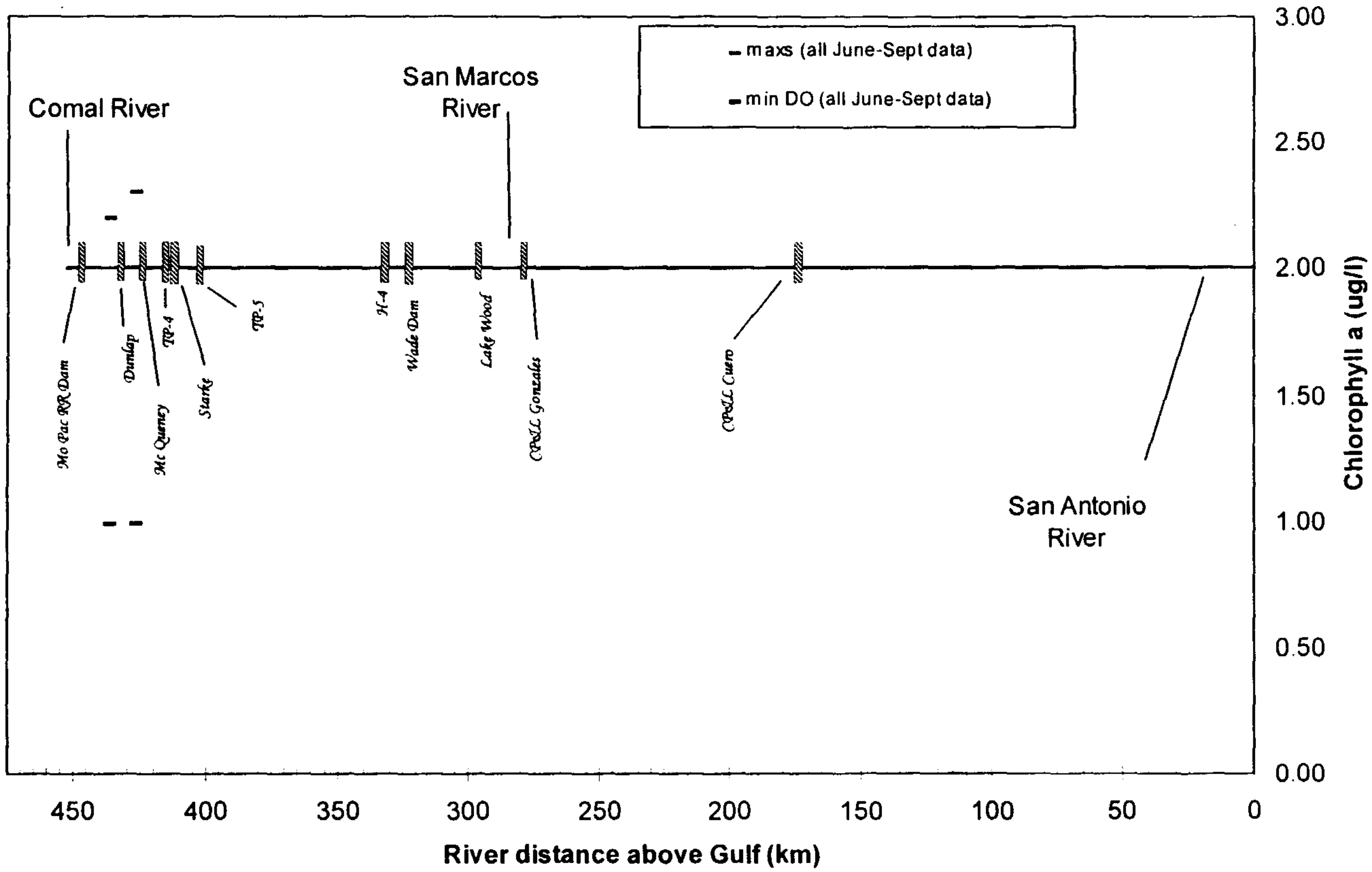
NITRITE AND NITRATE CALIBRATION OF GUADALUPE/SAN MARCOS RIVER MODEL FOR SEPTEMBER 1994

FIGURE 2-17



GUADALUPE - SAN ANTONIO RIVER BASIN
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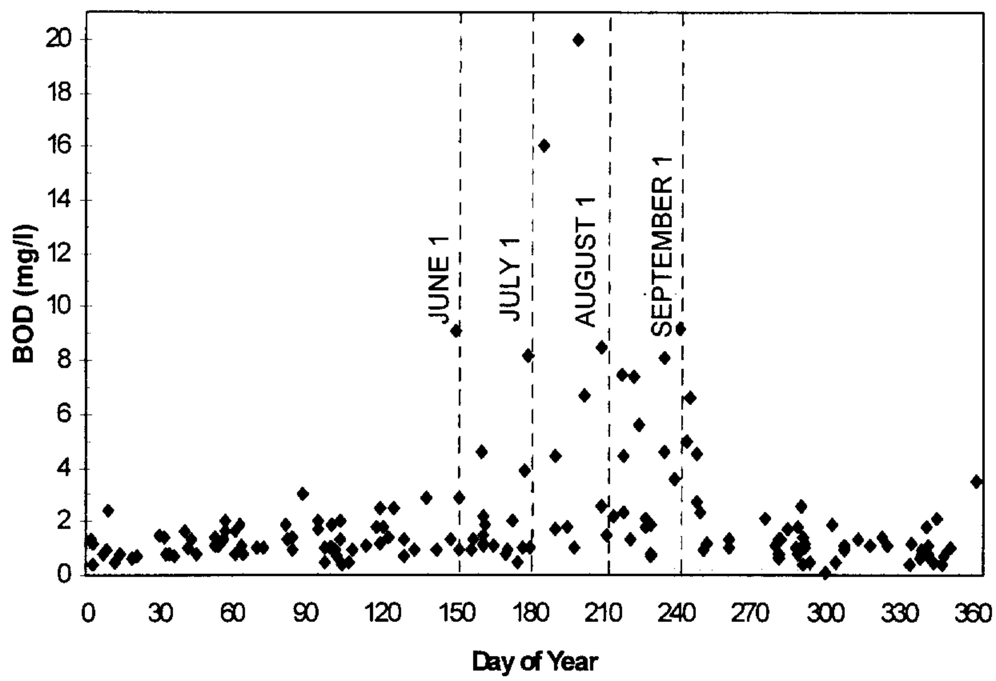
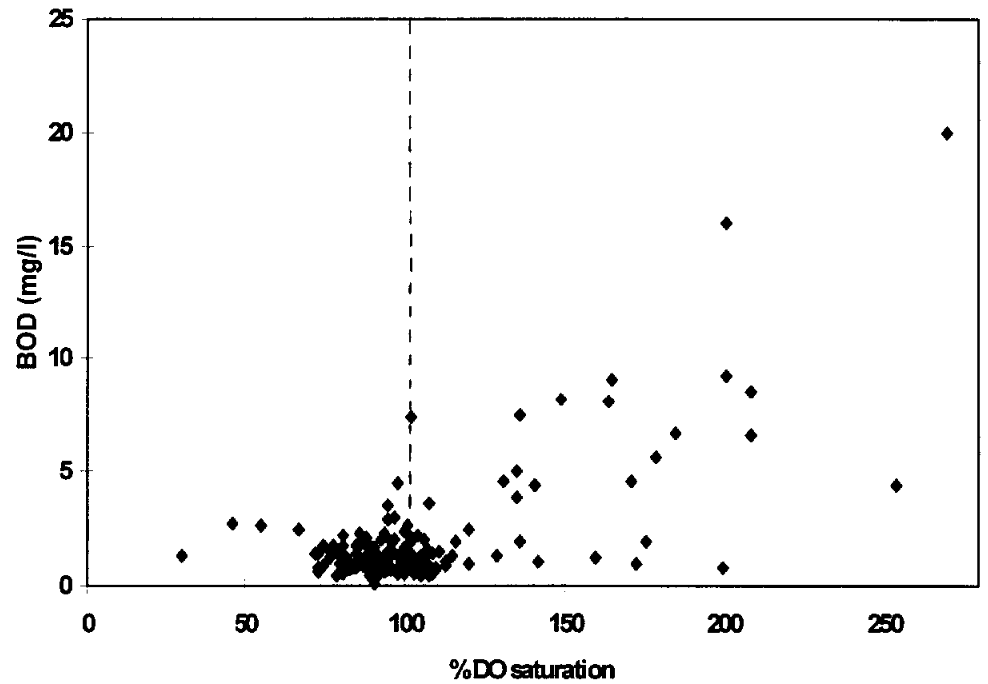
CHLOROPHYLL_A LEVELS IN THE GUADALUPE/SAN MARCOS RIVER MODEL FOR SEPTEMBER 1994

FIGURE 2-19





GUADALUPE - SAN ANTONIO RIVER BASIN
ENVIRONMENTAL CRITERIA REFINEMENT

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HDR Engineering, Inc.

LAKE DUNLAP
WATER QUALITY DATA
FOR THE 1968-96 PERIOD FROM
USGS STA. 08169580
FIGURE 2-20

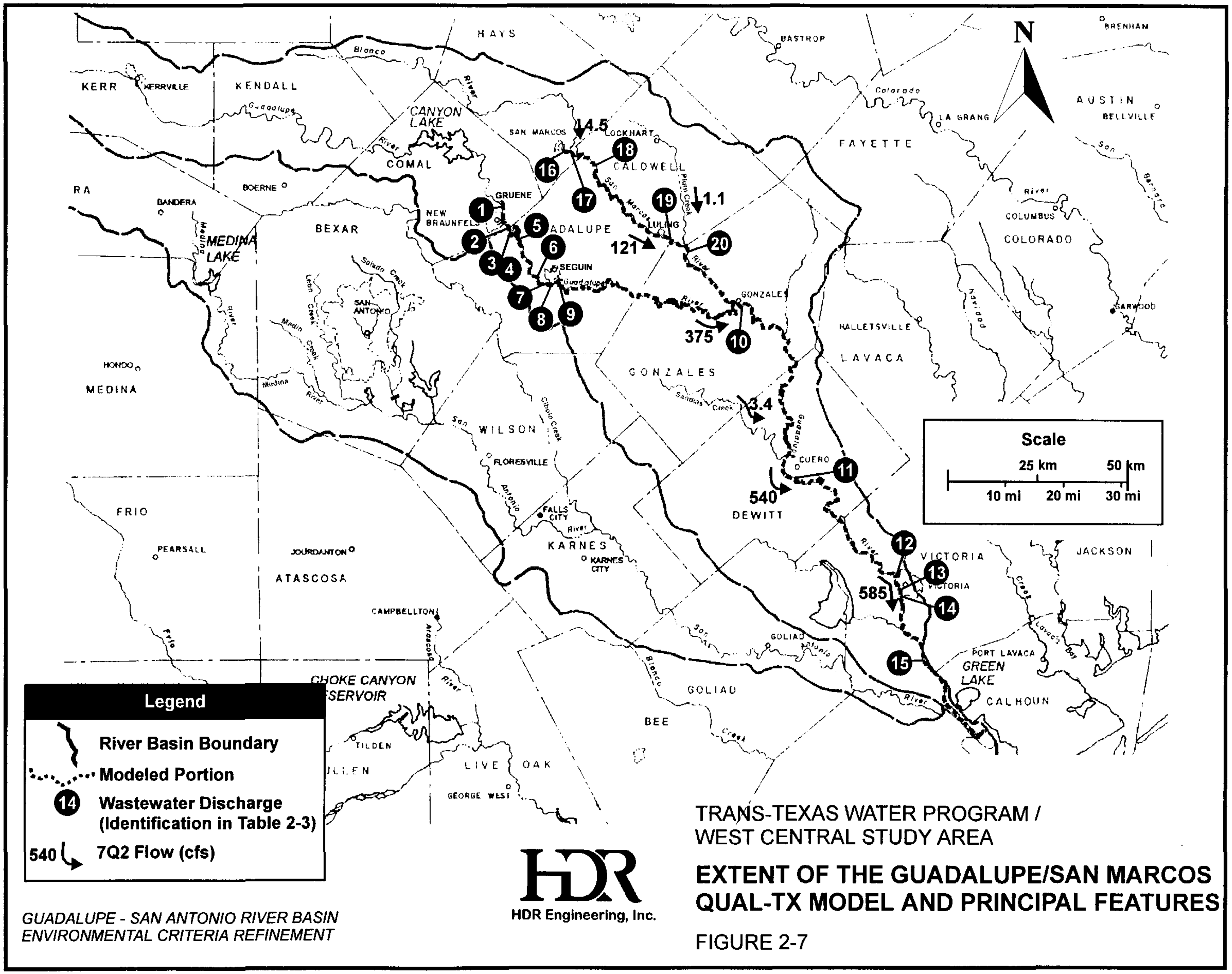
The coefficients of Equations 2-2 and 2-3 were derived for the portions of the Guadalupe River with and without reservoirs in differing manners. Generally, in Texas, for reaches of streams and rivers not influenced by the backwater effect of a dam, the coefficient *e* is set to zero, indicating that flow and depth diminish to zero simultaneously. For these regular channel sections without a reservoir, there were data for streamflow (Q), average velocity (V), and average depth available for the USGS streamflow gaging stations at Cuero and Victoria. These data were used to perform a least squares regression and derive the coefficients *a, b, c,* and *d* at each location. Figures 2-8 and 2-9 show the results for the gages at Cuero and Victoria, respectively. Often, in the absence of other data, the exponents for Equations 2-2 and 2-3 are assumed[19] to be $b= 0.5$ and $d= 0.4$. The derived values of the coefficient *b* at Cuero and Victoria were 0.24 and 0.34, respectively, while for *d* the values were 0.60 and 0.54, respectively. The derived values for coefficients *a* and *c* at Cuero and at Victoria are indicated in Figures 2-8 and 2-9. Values of the coefficient of determination (r^2) for the regression equations ranged from .39 to .90 indicating that between 39 percent and 90 percent of the observed variation in the USGS field data is explained by the regression equation.

In the portions of the Guadalupe River with reservoirs, small QUAL-TX reach lengths were used in order to capture the changing depths and widths of the stream channel along the length of the reservoir. Stream lengths were determined from USGS 7.5 minute topographic maps and a U.S. Army Corps of Engineers report.[20] Approximate average top stream widths for each reach were taken from 7.5 minute topographic maps. The depths within a given reservoir, at several points along its length, were taken from a U.S. Army Corps of Engineers Survey[21] by assuming the reservoir to be approximately level full at the 7Q2 streamflow. The depths and widths were used to calculate approximate cross-sectional areas and reach volumes (= area × length). These volumes were overestimated because they were calculated with the

[19] Texas Water Commission. "Waste Load Evaluation for the San Antonio River System in the San Antonio River Basin." TWC Rep. WLE 89-01. Texas Water Commission: Austin, TX. 1989

[20] U.S. Army Corps of Engineers. "Navigability Study: San Marcos River, Tributaries, and Lakes. San Marcos River Basin, Texas." U.S. Army Corps of Engineers: Ft. Worth. 1974.

[21] U.S. Army Corps of Engineers. "Report on Survey of Guadalupe and San Antonio Rivers and Tributaries, Texas for Flood Control and Allied Purposes." U.S. Army Corps of Engineers: Ft. Worth. 1950.



GUADALUPE - SAN ANTONIO RIVER BASIN
ENVIRONMENTAL CRITERIA REFINEMENT

TRANS-TEXAS WATER PROGRAM /
WEST CENTRAL STUDY AREA

EXTENT OF THE GUADALUPE/SAN MARCOS QUAL-TX MODEL AND PRINCIPAL FEATURES

FIGURE 2-7

stream top widths, whereas the average width across the stream would be lower. This discrepancy was corrected by summing the reach volumes within each reservoir and comparing the total to GBRA estimates of each reservoir storage capacity.[22] The cross sectional areas of each reservoir reach were then adjusted proportionally downward to correct the total reservoir volume.

The average depths and widths of each reach were then used to derive the channel geometry coefficients *a, b, c, d,* and *e*. The coefficients *b* and *d* were set at the common default values (b= 0.5 and d= 0.4). Flow velocity was calculated by dividing the 7Q2 flow by the adjusted cross-sectional area. With the velocity approximated for each reach at the 7Q2 flow it was then possible to derive a corresponding coefficient *a* by rearranging Equation 2-2.

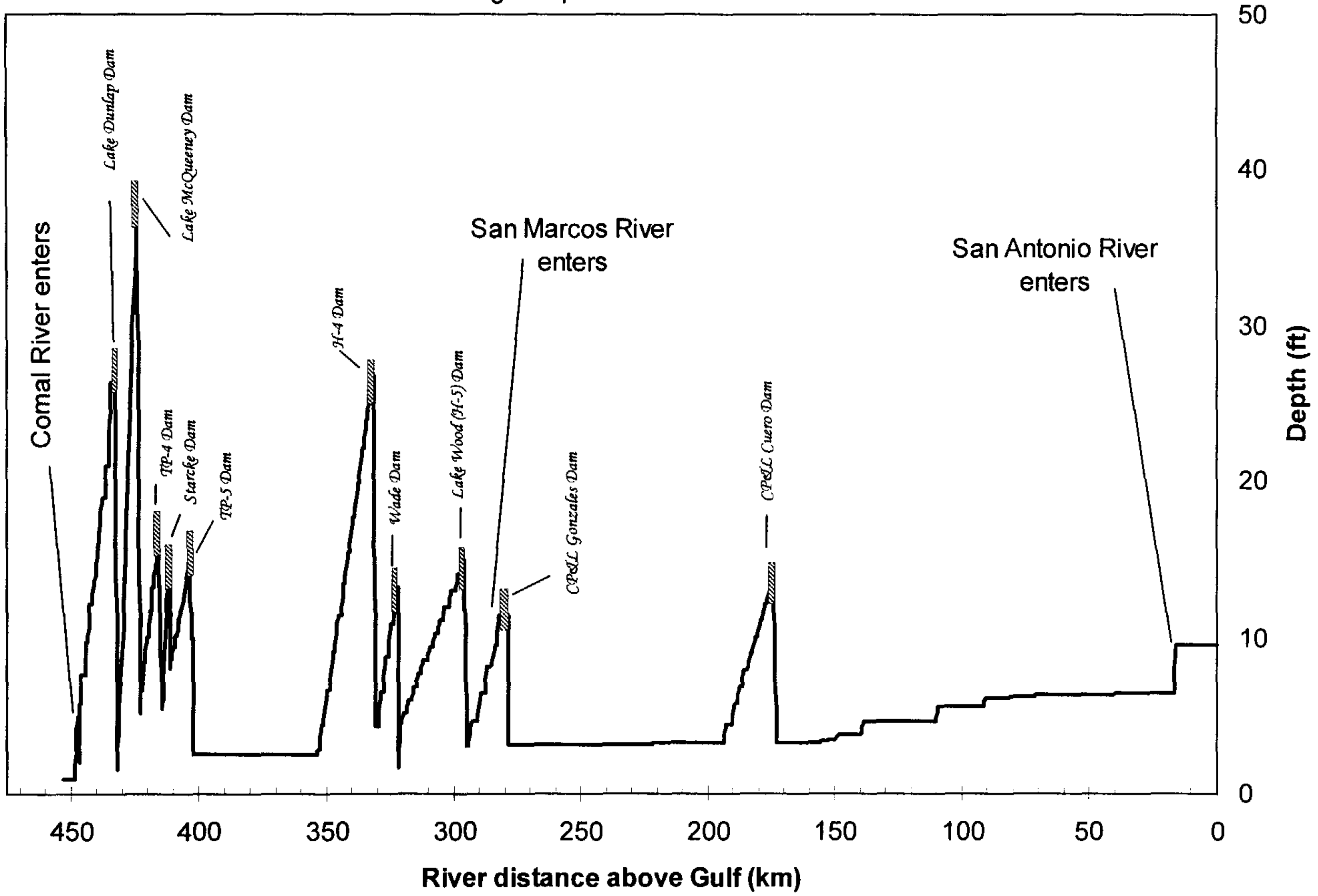
Unlike the regular river reaches, reaches in reservoirs do not approach zero depth as flow diminishes toward zero. Rather, zero-flow depths approach the level-pool reservoir depths near the dam and approach zero at the extreme upper end of the reservoir near the transition to a riverine channel. To reflect this, the coefficient *e* was set so that in the reach just above a dam, nearly all of the depth (99 percent) was due to the level-pool. In the reach representing the upstream end of the reservoir the coefficient *e* was set so that only 10 percent of the depth was accounted for by the backwater effect of the dam. For intermediate reaches along the length of the reservoir, the coefficient *e* was interpolated. For each reach, with a value for *e* determined, Equation 2-3 could be rearranged and solved by using the 7Q2 streamflow for Q.

Figures 2-10 and 2-11 show the great variation in depths and velocities along the length of the mainstem portion of the Guadalupe River model. To capture this great heterogeneity of the stream channel, the QUAL-TX model developed for this study utilized 202 reaches and 668 elements. A full description of these reaches and elements can be found in Appendix B.

For the San Marcos River tributary model, the channel geometry coefficients *a, b, c,* and *d* were determined in an earlier study for a portion of the river just below the City of San Marcos.[23] For the present study, these coefficients for the last reach of that earlier QUAL-TX model were

[22] Guadalupe Blanco River Authority "GBRA Operations Manual" photocopied pages, no date.
[23] Black & Veatch, Inc. "City of San Marcos Wastewater Master Plan." San Marcos, TX. 1995

Average Depth at 7Q2 Streamflow



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VARIATION OF DEPTH IN THE GUADALUPE/SAN MARCOS RIVER MODEL

FIGURE 2-10

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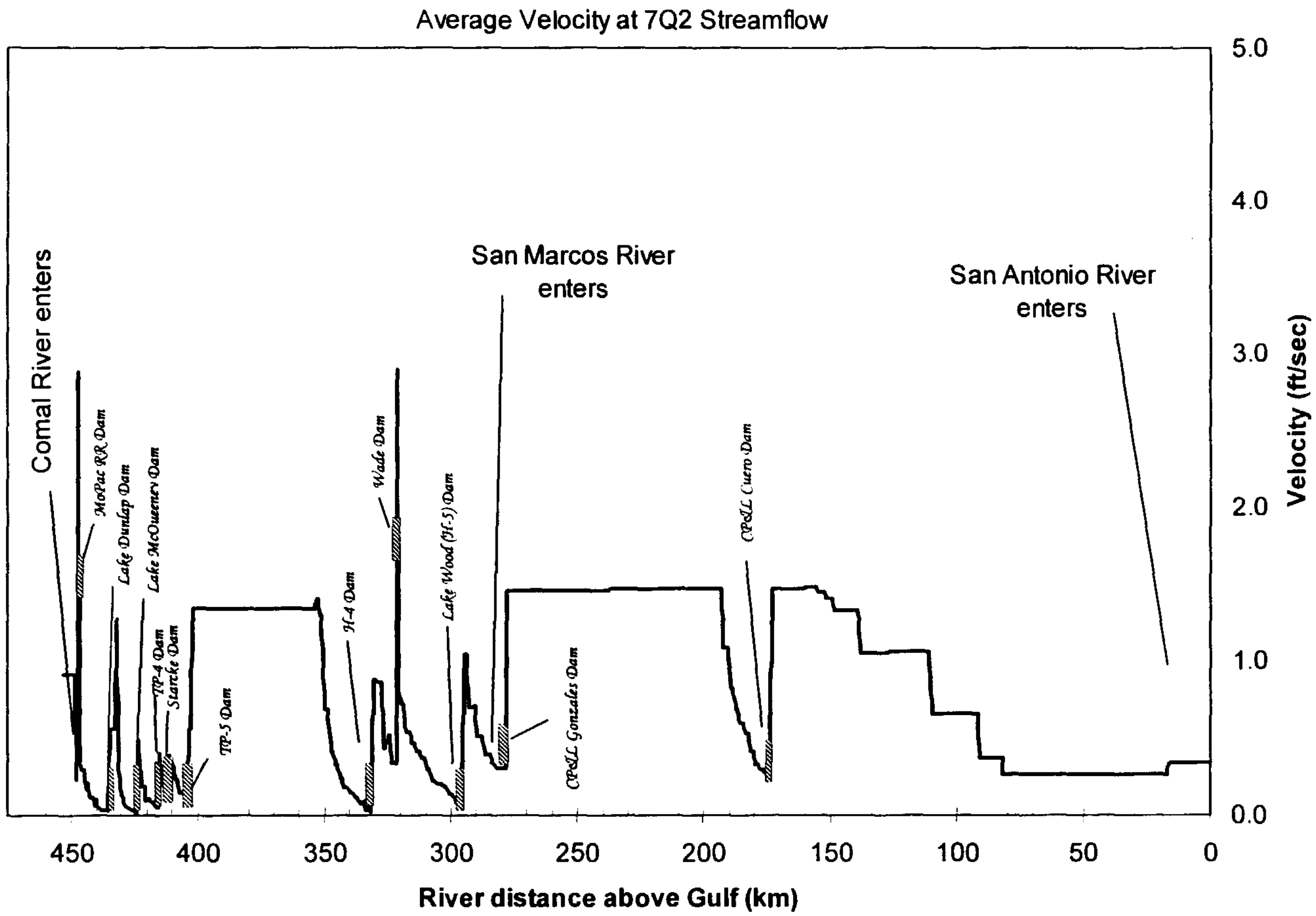
GUADALUPE - SAN ANTONIO RIVER BASIN ENVIRONMENTAL CRITERIA REFINEMENT



GUADALUPE - SAN ANTONIO RIVER BASIN
ENVIRONMENTAL CRITERIA REFINEMENT

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VARIATION OF VELOCITY IN THE GUADALUPE/SAN MARCOS RIVER MODEL

FIGURE 2-11

used to extend the coverage down to the junction with the Guadalupe River model. For the San Marcos tributary model, 41 reaches and 419 elements were utilized. Appendix B summarizes the channel segmentation used in the San Marcos tributary model.

2.2.2 Calibration

A critical portion of the data required to calibrate a water quality model is the set of concentrations of each modeled constituent. This study utilized only existing data available from the computerized databases of the TNRCC as well as printed and computer data from the USGS. Additional data was supplied by the Guadalupe - Blanco River Authority (GBRA). Figure 2-12 displays the mainstem Guadalupe River model and the San Marcos River model locations where water quality samples are collected. For this study, the water quality monitoring network offers a rather limited spatial resolution with great lengths of the rivers having no sampling stations. Also, not all of the modeled constituents (Figure 2-3) are sampled at each location.

Another consideration in the water quality model calibration process is the temporal resolution of the water quality data. Normally, all constituent concentration data are gathered in a relatively short time frame, at relatively steady-state conditions, in order to get an accurate depiction of the transport and decay processes occurring. If possible, each constituent is sampled multiple times to get a range of values, as in Figure 2-6 for the San Antonio River. Data for this fine-scale temporal resolution was not available for this study. It was necessary to utilize a month-long period since available wastewater discharge data is reported to the TNRCC as monthly averages. Also, the existing databases for water quality constituent concentrations have a somewhat limited frequency of sampling. For instance, the USGS database generally reports water quality concentrations about six times per year. The water quality data furnished by GBRA was based on approximately one sample per month.

The month of September 1994, which had relatively stable streamflow for the entire month, was chosen for calibration. This was also the period utilized in an earlier model of the upper San Marcos River.[24] For the purpose of calibration, all available water quality data taken at any time during September 1994 was utilized. Additional data from all warm-weather months

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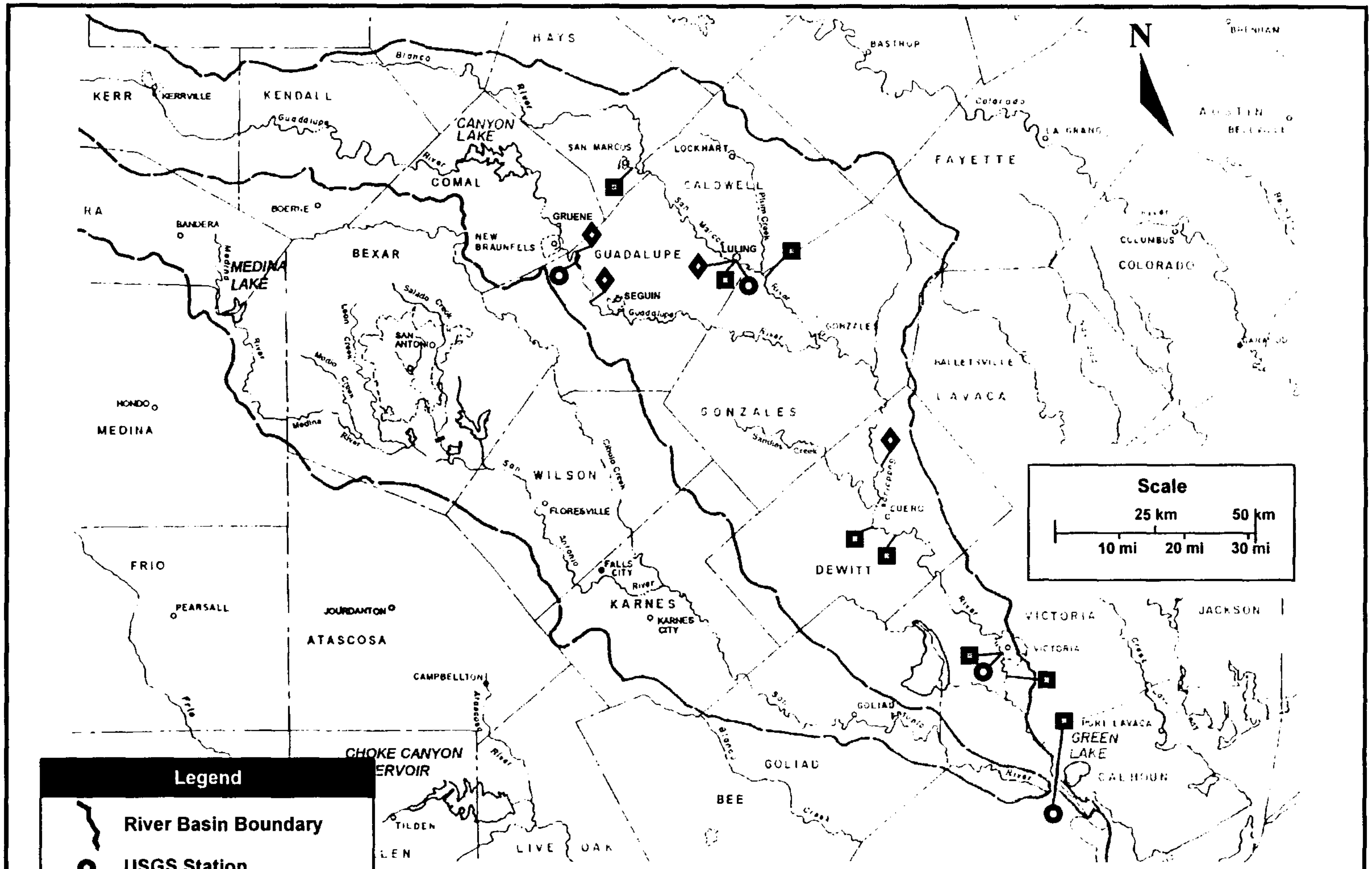
[24] Ibid.



Legend

- River Basin Boundary
- USGS Station
- GBRA Station
- TNRCC Station

GUADALUPE - SAN ANTONIO RIVER BASIN
ENVIRONMENTAL CRITERIA REFINEMENT

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WEST CENTRAL STUDY AREA

MAP OF WATER QUALITY FIELD DATA LOCATIONS FOR THE GUADALUPE/ SAN MARCOS MODEL

FIGURE 2-12

98-14

(June - September) was used to provide an approximate range of extreme values at some locations. However, no control for streamflow, temperature, precipitation, or runoff characteristics was exercised in the use of this data (other than September 1994 data), and it was, therefore, given little weight in the calibration process. The constituent concentration data used for the calibration of the mainstem Guadalupe River and San Marcos River models are presented in Appendix C.

All wastewater discharges to the Guadalupe and San Marcos rivers were set at their average values for the month of calibration by utilizing the TNRCC's "self-reporting" data. Table 2-3 summarizes the wastewater discharges for the September 1994 period. Most wastewater treatment plants were operating well below the permitted volume as indicated in the "percent capacity" column of Table 2-3.

It is important to note that, with the exception of BOD, wastewater discharge permits have no universal requirements with regard to which constituent concentrations are measured and reported. Because of the difficulty which this poses for a water quality study in which the discharge characteristics are needed, the TNRCC has developed a methodology to estimate the unknown constituent concentrations. This methodology, summarized in Table 2-4, is keyed to the percent flow capacity and BOD discharge concentration at which the plant is operating.

Other critical data requirements for a water quality model are the boundary conditions: the streamflows and constituent concentrations at the upstream beginning of the model and for major tributaries. Table 2-5 summarizes the boundary conditions used in the Guadalupe/San Marcos model for the September 1994 calibration. All other tributaries were set to zero flow.

To calibrate a multiple constituent model, it is necessary to make a large number of computer simulations. In each simulation, usually just one of the many constants and coefficients is varied to assess the performance of the model relative to the last simulation. The latest QUAL-TX manual has a recommended order of adjusting these many parameters[25] such that the process comes to closure with a minimum number of simulations. Nonetheless, calibration of a large model such as this is a lengthy process. As a beginning point in the calibration, all of the many constants and coefficients were set to levels within the range of values used in previous QUAL-TX models in the study area as presented in Figure 2-5.

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[25] Texas Natural Resource Conservation Commission. "QUAL-TX User's Manual, Version 3.4." Texas Natural Resource Conservation Commission: Austin, TX. 1995.

Table 2-3
Summary of Wastewater Discharges to the Guadalupe and San Marcos Rivers for September 1994

					Average Daily Wasteload Concentrations (mg/l)*				
					Maximums				Minimum
Map No.	Permit No.	Permittee	Discharge (MGD)	Percent Capacity (%)	BOD5	Organic Nitrogen	Ammonia	Nitrite +Nitrate	Dissolved Oxygen
	Guadalupe River								
1	10232-002	New Braunfels Utilities	0.16	15	2.65	1.00	0.54	18.50	6.00
2	00335-001	Mission Valley Textiles	2.59	86	5.59	0.10	0.10	0.10	5.00
3	10232-001	New Braunfels Utilities	1.29	31	2.54	1.00	2.00	17.00	6.45
4	10232-003	New Braunfels Utilities	1.88	61	3.93	1.00	5.00	14.00	4.40
5	11378-001	GBRA - Lake Dunlap	0.072	45	2.94	1.00	2.00	17.00	4.20
6	01712-001	Structural Metals, Inc.	0.084	70	2.30	0.10	0.10	0.10	5.00
7	11427-001	GBRA - Seguin	0.10	34	1.35	1.00	2.00	17.00	4.80
8	10277-001	City of Seguin	3.21	80	5.12	4.00	15.00	1.00	2.00
9	10277-003	City of Seguin - Geronimo Creek	0.70	33	4.79	1.00	2.00	17.00	2.37
10	10488-001	City of Gonzales	1.03	69	12.8	4.00	5.00	11.00	2.10
11	10403-002	City of Cuero	1.10	73	53.25	4.00	15.00	1.00	5.60
12	01165-002	Central Power and Light	0.38	32	0.0	0.00	0.00	0.00	6.50
13	10466-001	GBRA - Victoria	1.18	47	13.00	3.00	2.00	15.00	4.00
14	11078-001	GBRA - Victoria	5.86	73	11.00	3.00	5.00	12.00	5.00
15	00476-001	E.I. Du Pont De Nemours & Co.	13.17	82	4.34	0.00	0.57	0.00	5.00
	San Marcos River								
16	03381	TPWD - Texas Fish Hatchery	0.00	0	0.00	0.00	0.00	0.00	0.00
17	10273-001	City of San Marcos	3.95	63	6.00	1.00	5.00	14.00	7.40
18	12067-001	Gary's Job Corps	0.29	39	4.75	1.00	2.00	17.00	5.00
19	10582-001	City of Luling	0.63	126	2.20	3.00	15.0	2.00	5.00
20	10943-001	Texas Rehabilitation Hospital	0.02	50	6.00	1.00	5.00	14.00	5.00

* Wastewater volumes and constituent concentrations based on monthly self-reporting data submitted to TNRCC. Not all constituent concentrations are reported by each permittee. When not reported, the concentration is based on TNRCC's methodology for handling missing wasteload input data for constituent concentrations (Table 2-4).

Table 2-4
TNRCC's Methodology for Handling Missing Wasteload Input Data for Constituent Concentrations

Domestic wasteload:

Ammonia (NH_3):
- 15.0 mg/l if capacity* ≥ 80% or BOD_5 > 20 mg/l.
- 5.0 mg/l if capacity > 50% and < 80%.
- 2.0 mg/l if capacity ≤50%.

Organic Nitrogen (Org-N):
- 4.0 mg/l.
- 3.0 mg/l if BOD_5 < 11 mg/l or NH_3 < 7 mg/l.
- 2.0 mg/l if BOD_5 < 11 mg/l and NH_3 < 7 mg/l.
- 1.0 mg/l if BOD_5 < 7 mg/l and NH_3 <7 mg/l.

Nitrate (NO_3):
- 20 mg/l - (NH_3) - (Org-N).

Dissolved Oxygen:
- 2.0 mg/l.
- 4.0 mg/l if BOD_5 < 11 mg/l and NH_3 < 7 mg/l.
- 5.0 mg/l if BOD_5 < 7 mg/l.

Industrial Wasteload:

Ultimate BOD (BODu):
- 4.6 mg/l (BOD_5 = 2.3 x BODu)

Ammonia (NH_3):
- 0.1 mg/l

Organic Nitrogen (Org-N):
- 0.1 mg/l

Nitrate (NO_3):
- 0.1 mg/l

Dissolved Oxygen:
- 5.0 mg/l

*Capacity refers to percentage of permitted discharge volume, usually measured in million gallons/day (mgd).

Table 2-5
Boundary Conditions for the Guadalupe/San Marcos Model for September 1994

	Guadalupe Mainstem Model		San Marcos Tributary Model	
Parameter (Units)	Guadalupe River at Gruene	Comal River	San Marcos River near springs	Blanco River
streamflow (cfs)	118.8[a]	271.0[a]	124.0[a]	12.7[a]
temperature (C)	19.5[b]	24.5[c]	23.7[i]	28.2[i]
dissolved oxygen (mg/l)	9.0[d]	8.5[d]	9.1[i]	8.4[i]
BOD (mg/l)	0.9[e]	1.5[f]	0.5[i]	0.5[i]
Organic N (mg/l)	0.42[e]	0.30[g]	0.3[i]	0.2[i]
Ammonia-NH_3 (mg/l)	0.05[e]	0.03[h]	0.1[i]	0.1[i]
Nitrite & Nitrate -NO_2 & NO_3 (mg/l)	0.30[e]	1.60[h]	1.05[i]	0.1[i]

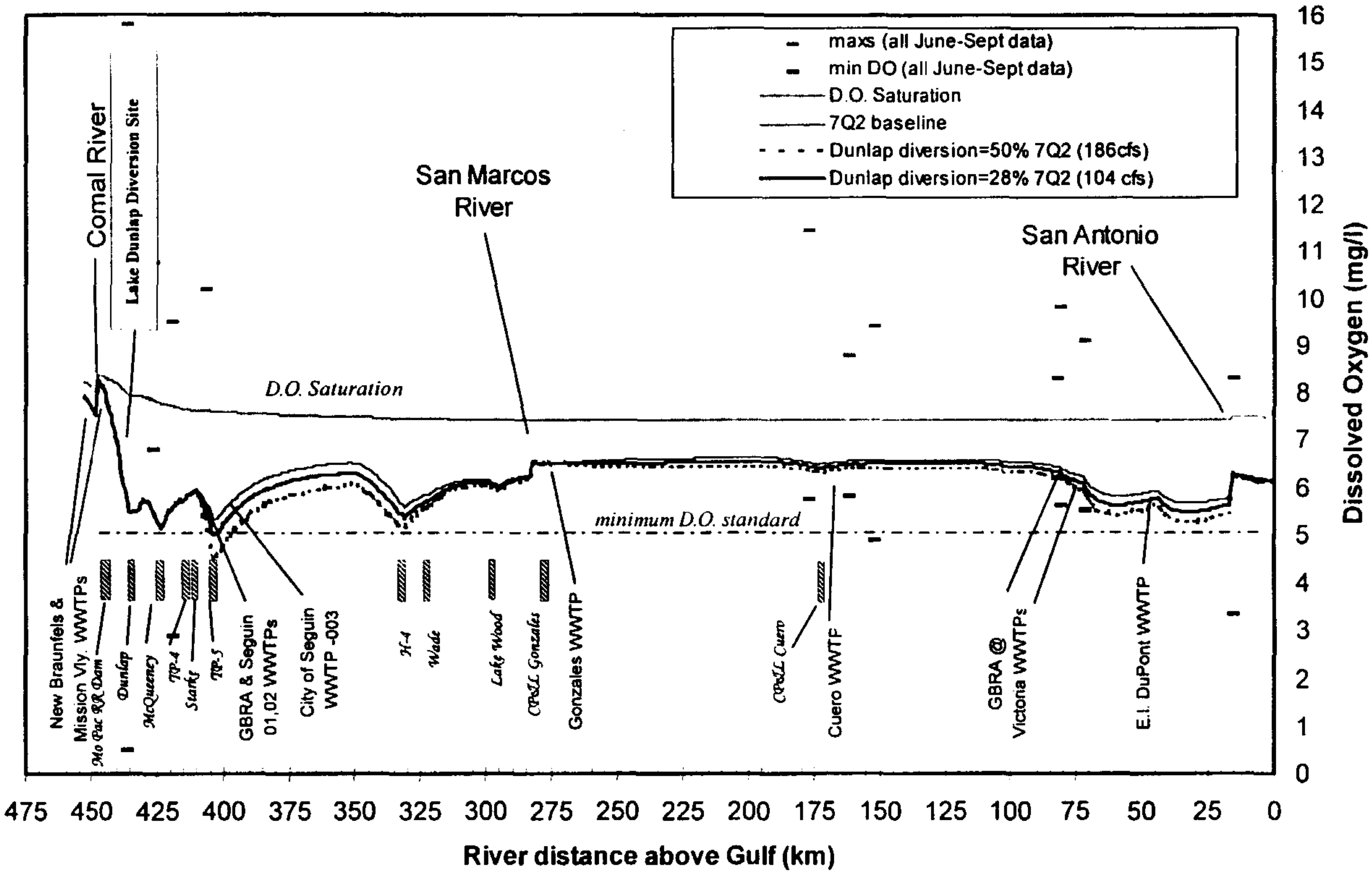
notes:
a- flows are monthly means from USGS published records.
b- estimated from GBRA measurement of 19.35 C taken Sept. 21 approximately 14 km above Gruene.
c- Estimated from GBRA measurements for Comal River at Hinman Island for August and September data 1995-97.
d- set to saturation values at indicated temperature.
e- these are mean values from the USGS water quality station at Sattler. Only August values, up to 8 entries, were available for the 1981-95.
f- average of 13 summertime values for the TNRCC Surface Water Quality Monitoring sta. 12653: Comal River below Clemons Dam in New Braunfels.
g- estimated from single measurement taken in March 1993 by USGS.
h- from August and September 1993 measurements for Landa Lake as found in McKenna D. C. and J. M. Sharp, Jr., "Springflow Augmentation of Comal Springs and San Marcos Springs, Texas: Phase 1 - Feasibility Study" Center for Research in Water Resources Rep. CRWR 247, University of Texas, Austin, TX. 1995.
i- from September 1994 as in Black and Veatch, Inc. "City of San Marcos Wastewater Master Plan."

Numerous simulations were performed in order to arrive at a representative set of model constants and coefficients. Only the final calibrated model results are presented here in Figures 2-13 through 2-19 and Figure 2-21. These figures present the simulated values of various water quality constituents for the mainstem portion of the Guadalupe/San Marcos River model. Figure 2-13 shows that the streamflows used in the QUAL-TX model calibration are approximately equal to the mean values for September 1994. Figure 2-14 shows the simulation for temperature. Figures 2-15 through 2-17 are respective plots of the model estimates for the three compartment nitrogen series (Organic N, NH_3, NO_2/NO_3). For each of the water quality constituent plots, the final set of calibrated constants and coefficients are indicated.

Figure 2-18 shows the model prediction for BOD. There is a notable large under prediction of BOD by the model in Lake Dunlap. The September 1994 field-measured values reported by the USGS and the GBRA were 5 mg/l. However, such a high value from the field data appears to be unrepresentative since the boundary conditions are much lower (Table 2-5) and the BOD of wastewater inputs upstream from this point are in the 3-6 mg/l range (first four discharges of Table 2-3). These discharges sum to 5.92 million gallons day (mgd), or 9.2 cfs, but this is only 2.3 percent of the total streamflow at this point.

The elevated BOD recorded in Lake Dunlap appears to be due to the interference of planktonic algae in the laboratory assessment for BOD. BOD is measured by incubating the sample for 5 days and taking the difference in dissolved oxygen before and after. High levels of algae can interfere with this determination by consuming oxygen during the incubation due to their respiration in the sample. Unfortunately, there were no field-measured values for chlorophyll_a for September 1994. A fixed algae level of 2 ug/l measured as chlorophyll_a seemed reasonable as shown in Figure 2-19.

Very high levels of "apparent" BOD have frequently been measured in Lake Dunlap during summer months as shown on the top half of Figure 2-20. The super-saturated D.O. conditions shown in the bottom half of Figure 2-20 are further evidence that these BOD levels are caused by algae interference. There is a very high correspondence between the elevated BOD levels and super-saturated D.O. conditions. A super-saturated D.O. condition is a typical characteristic of water bodies with high levels of algae and/or other plants producing oxygen during daylight hours when water quality sampling takes place. In other words, the elevated



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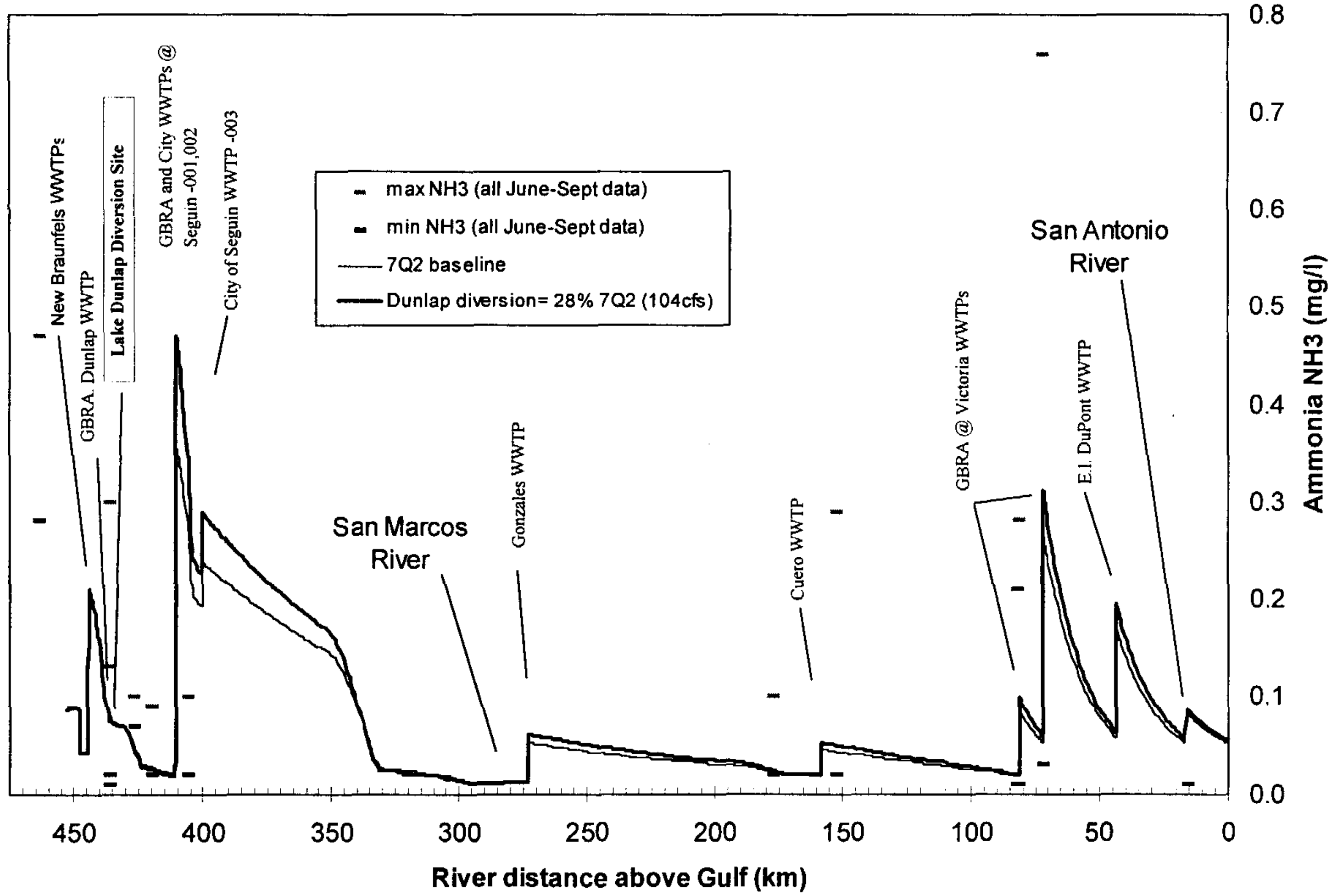
FUTURE SCENARIO "V"-
D.O. SIMULATION: DIVERSION
FROM LAKE DUNLAP

FIGURE 2-32



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FUTURE SCENARIO "V" - AMMONIA PREDICTION: DIVERSION FROM LAKE DUNLAP

FIGURE 2-33

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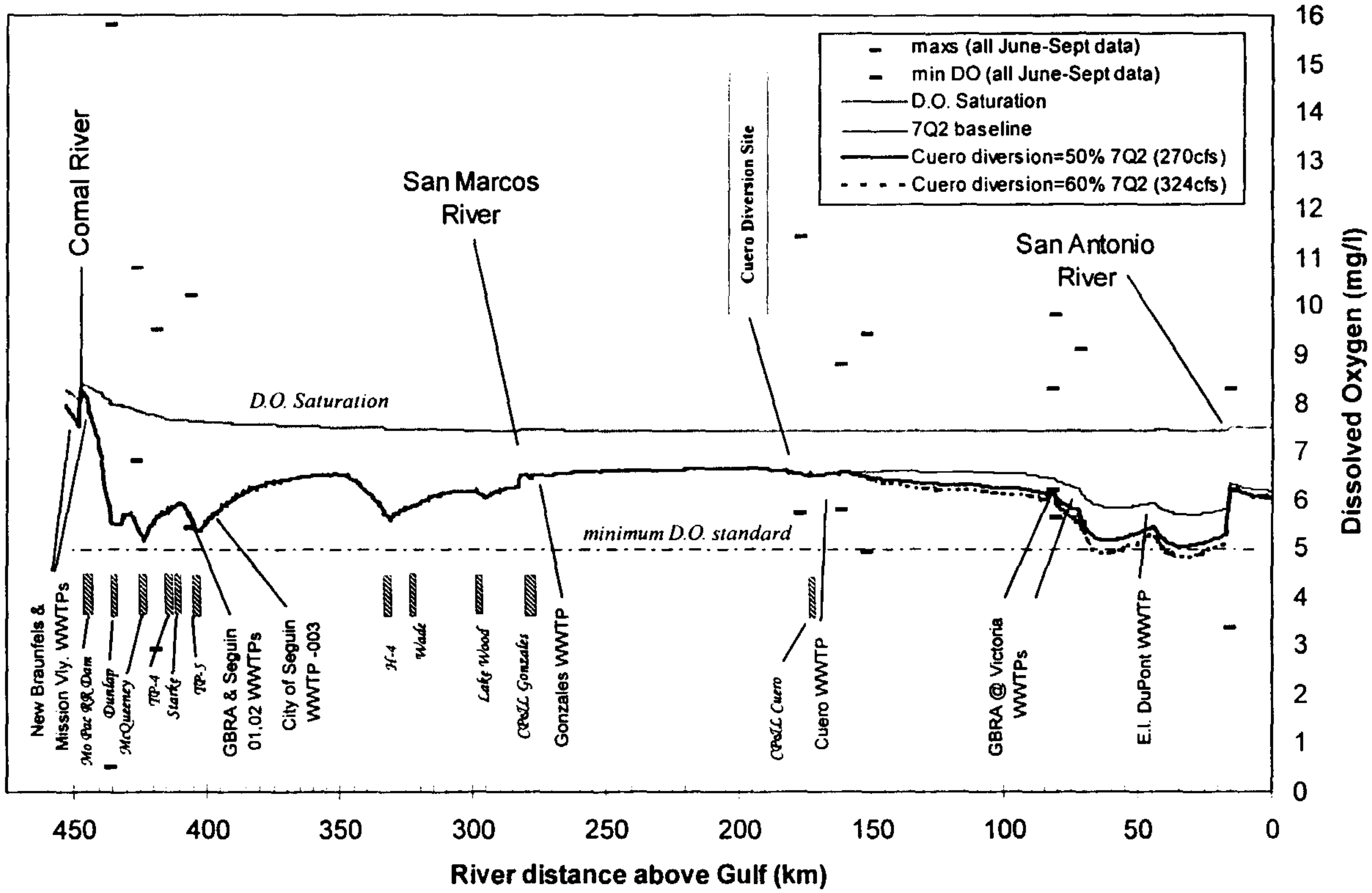

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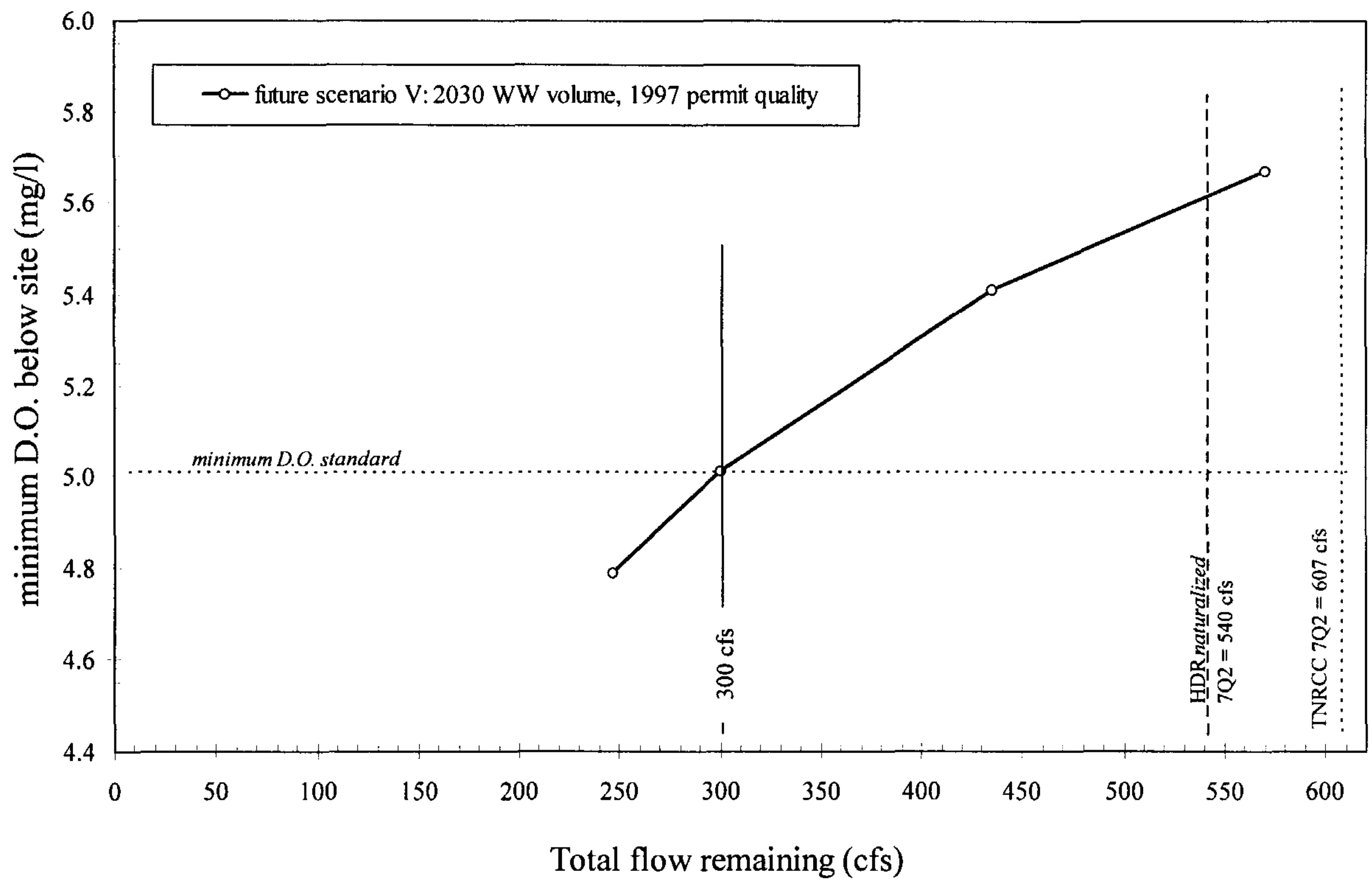
FUTURE SCENARIO "V" - D.O. SIMULATION: DIVERSION FROM CUERO

FIGURE 2-35



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FUTURE SCENARIO "V" - FLOW VS. MINIMUM D.O. CURVE FOR CUERO DIVERSION

FIGURE 2-36

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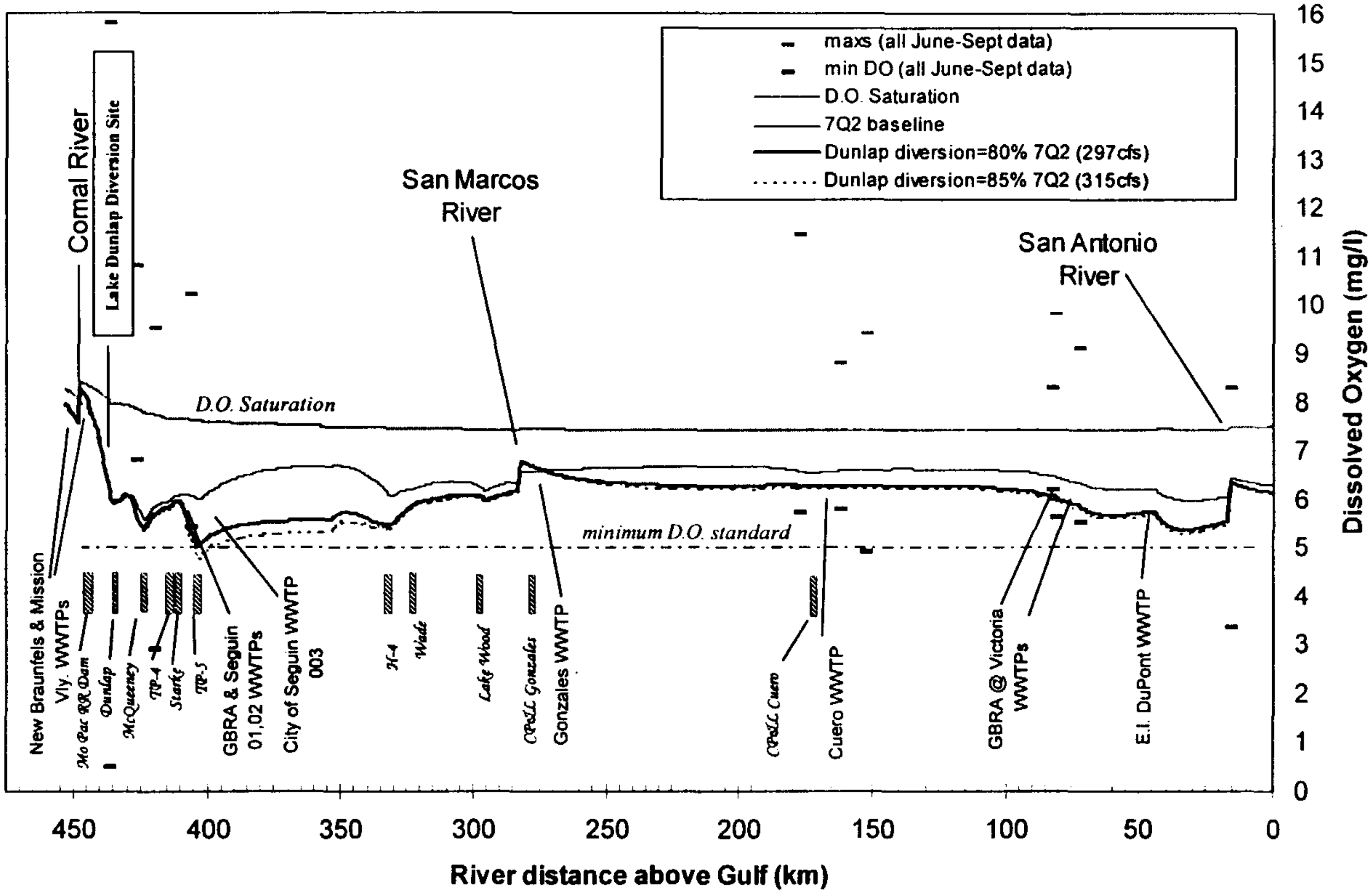

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FUTURE SCENARIO "VQ" - D.O. SIMULATION: DIVERSION FROM LAKE DUNLAP

FIGURE 2-37

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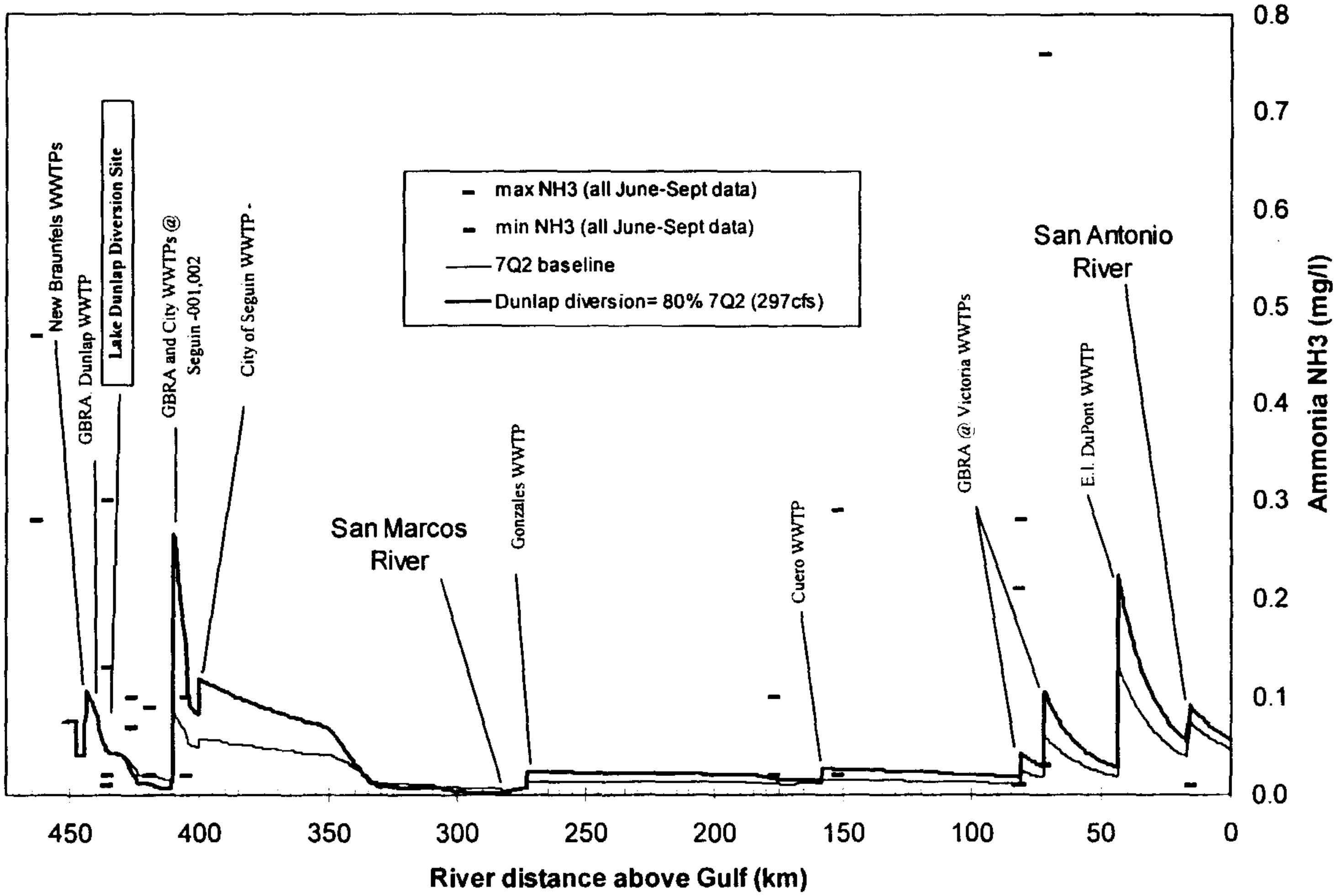
Table 2-8
Summary of Wastewater Discharges to the Guadalupe and San Marcos for Future Scenario "VQ".

Map No.	Permit No.	Permittee	Year 2030 Discharge (MGD)	Average Daily Wasteload Concentrations (mg/l)* Maximums BOD5	Organic Nitrogen	Ammonia	Nitrite +Nitrate	Minimum Dissolved Oxygen
	Guadalupe River							
1	10232-002	New Braunfels Utilities	0.64	5.00	1.00	2.00	17.00	5.00
2	00335-001	Mission Valley Textiles	2.30	5.00	0.10	0.10	0.10	5.00
3	10232-001	New Braunfels Utilities	2.82	5.00	1.00	2.00	17.00	5.00
4	10232-003	New Braunfels Utilities	5.80	5.00	1.00	2.00	17.00	5.00
5	11378-001	GBRA - Lake Dunlap	0.18	5.00	1.00	3.00	16.00	5.00
6	01712-001	Structural Metals, Inc.	0.11	5.00	0.10	0.10	0.10	5.00
7	11427-001	GBRA - Seguin	0.15	10.00	2.00	3.00	15.00	5.00
8	10277-001	City of Seguin	5.65	10.00	2.00	3.00	15.00	6.00
9	10277-003	City of Seguin - Geronimo Creek	0.80	10.00	2.00	3.00	15.00	5.00
10	10488-001	City of Gonzales	0.97	10.00	2.00	3.00	15.00	5.00
11	10403-002	City of Cuero	0.67	10.00	2.00	3.00	15.00	5.00
12	01165-002	Central Power and Light	0.38	0.00	0.00	0.00	0.00	6.00
13	10466-001	GBRA - Victoria	1.85	10.00	2.00	3.00	15.00	5.00
14	11078-001	GBRA - Victoria	6.11	10.00	2.00	3.00	15.00	5.00
15	00476-001	E.I. Du Pont De Nemours & Co.	16.96	10.00	2.00	3.00	15.00	5.00
	San Marcos River							
16	03381*	TPW - Texas Fish Hatchery	5.00	5.00	1.00	1.00	18.00	5.00
17	10273-001	City of San Marcos	6.38	5.00	1.00	2.00	17.00	6.00
18	12067-001	Gary's Job Corps	0.24	10.00	1.00	3.00	16.00	6.00
19	10582-001	City of Luling	0.59	10.00	1.00	3.00	16.00	5.00
20	10943-001	Texas Rehabilitation Hospital	0.027	10.00	1.00	3.00	16.00	5.00

* See notes in Table 2-3



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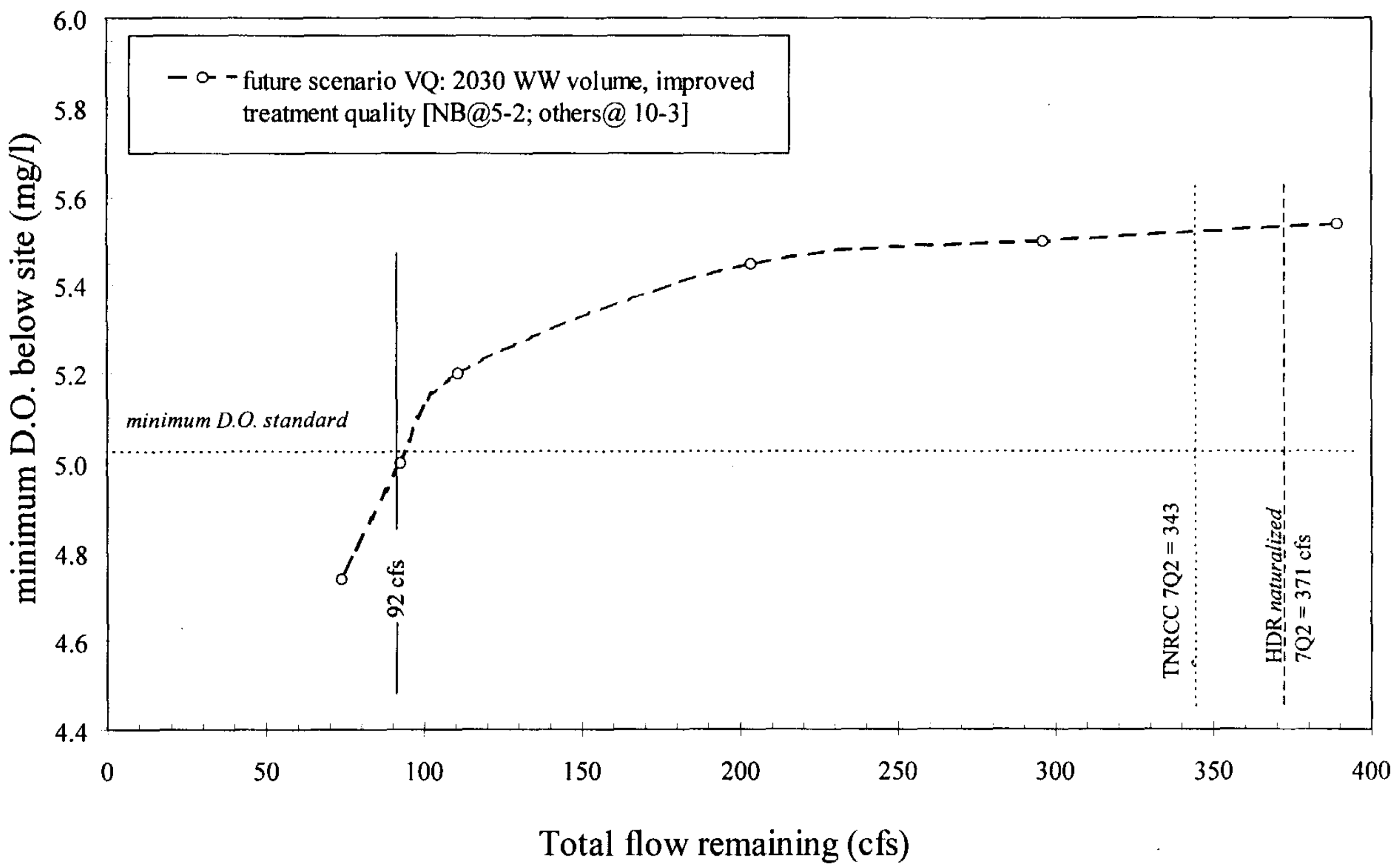
FUTURE SCENARIO "VQ" - AMMONIA SIMULATION: DIVERSION FROM LAKE DUNLAP

FIGURE 2-38



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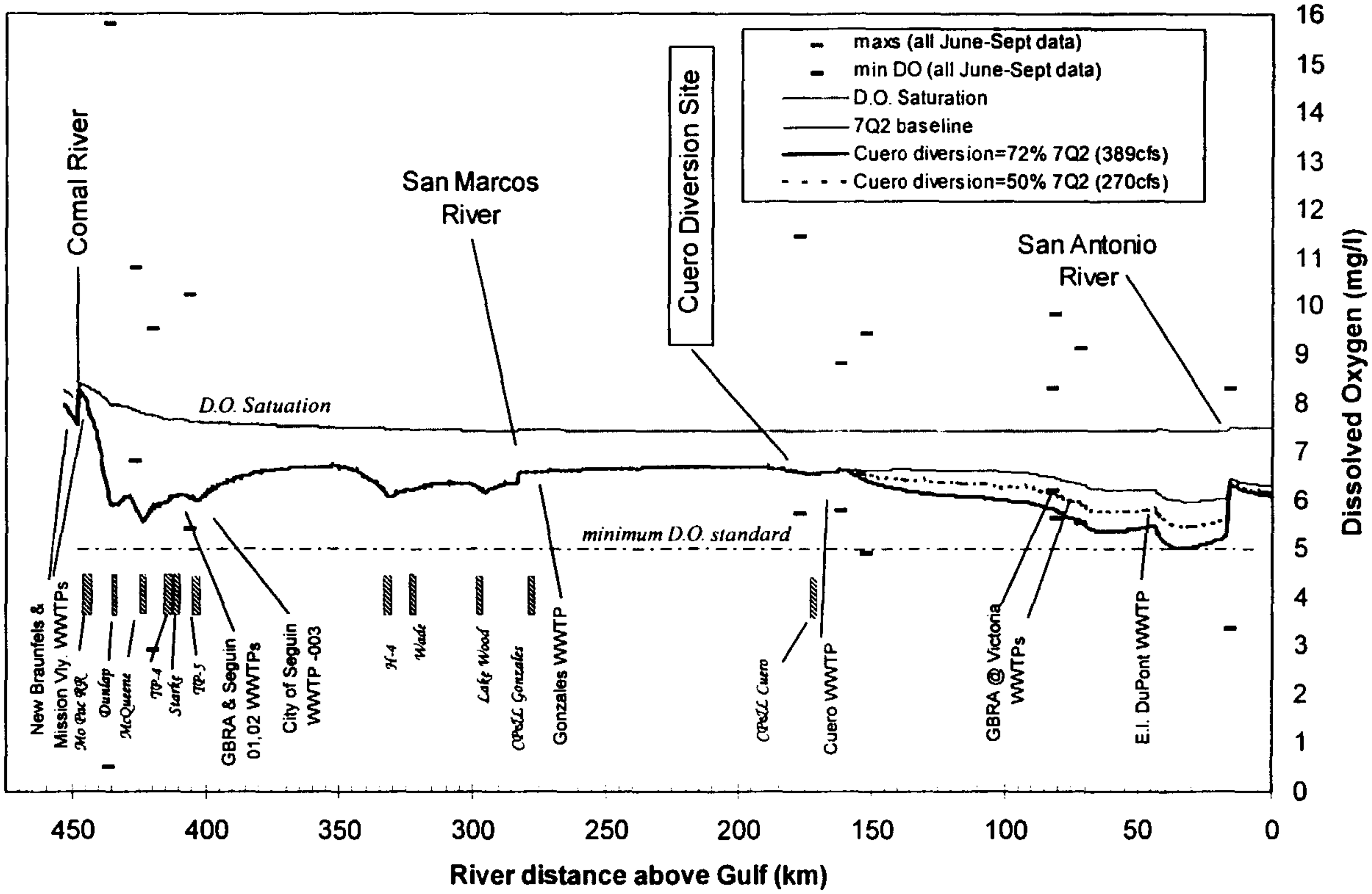
FUTURE SCENARIO "VQ" - FLOW VS. MINIMUM D.O. CURVE FOR LAKE DUNLAP DIVERSION

FIGURE 2-39



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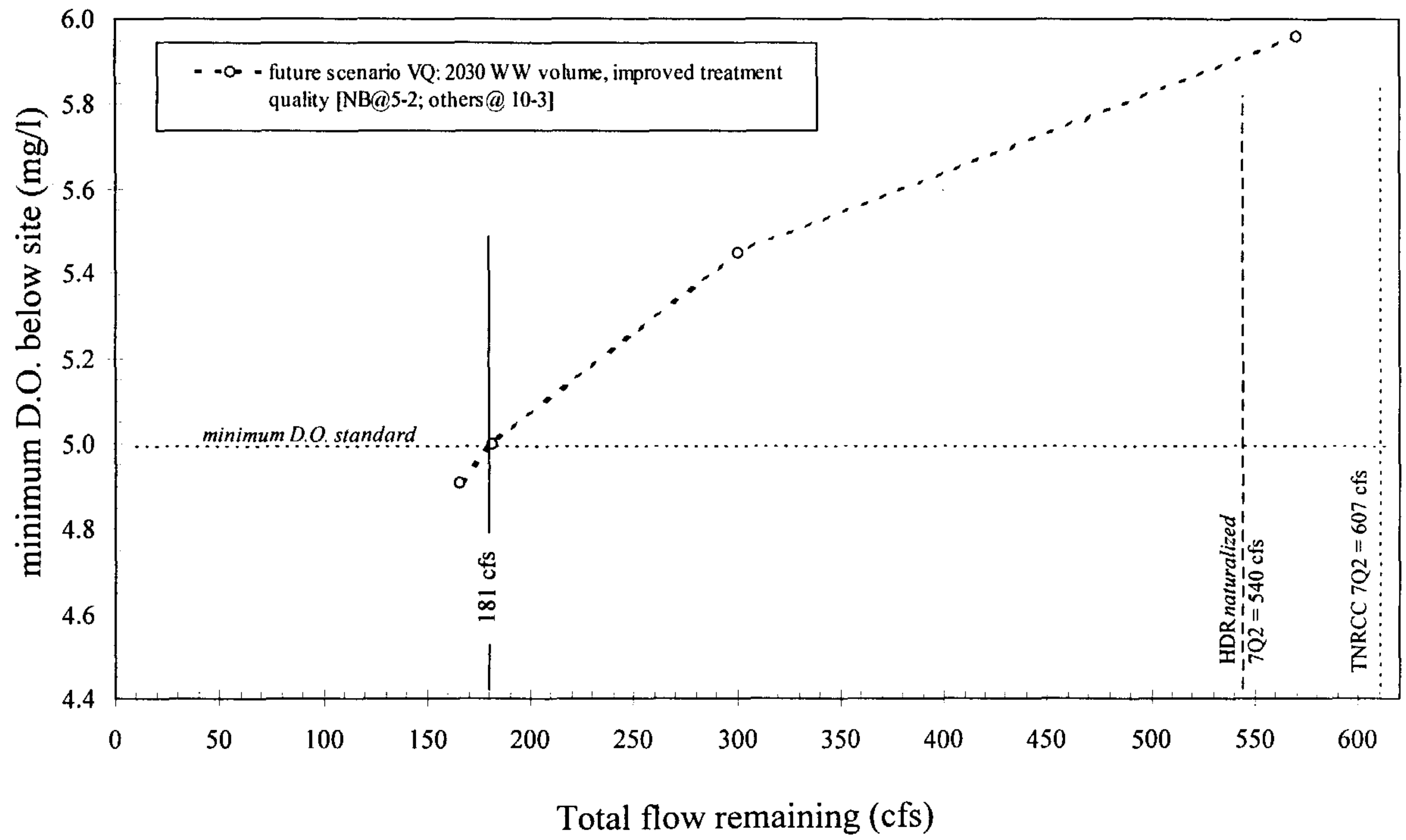
FUTURE SCENARIO "VQ" - D.O. SIMULATION: DIVERSION FROM CUERO

FIGURE 2-40



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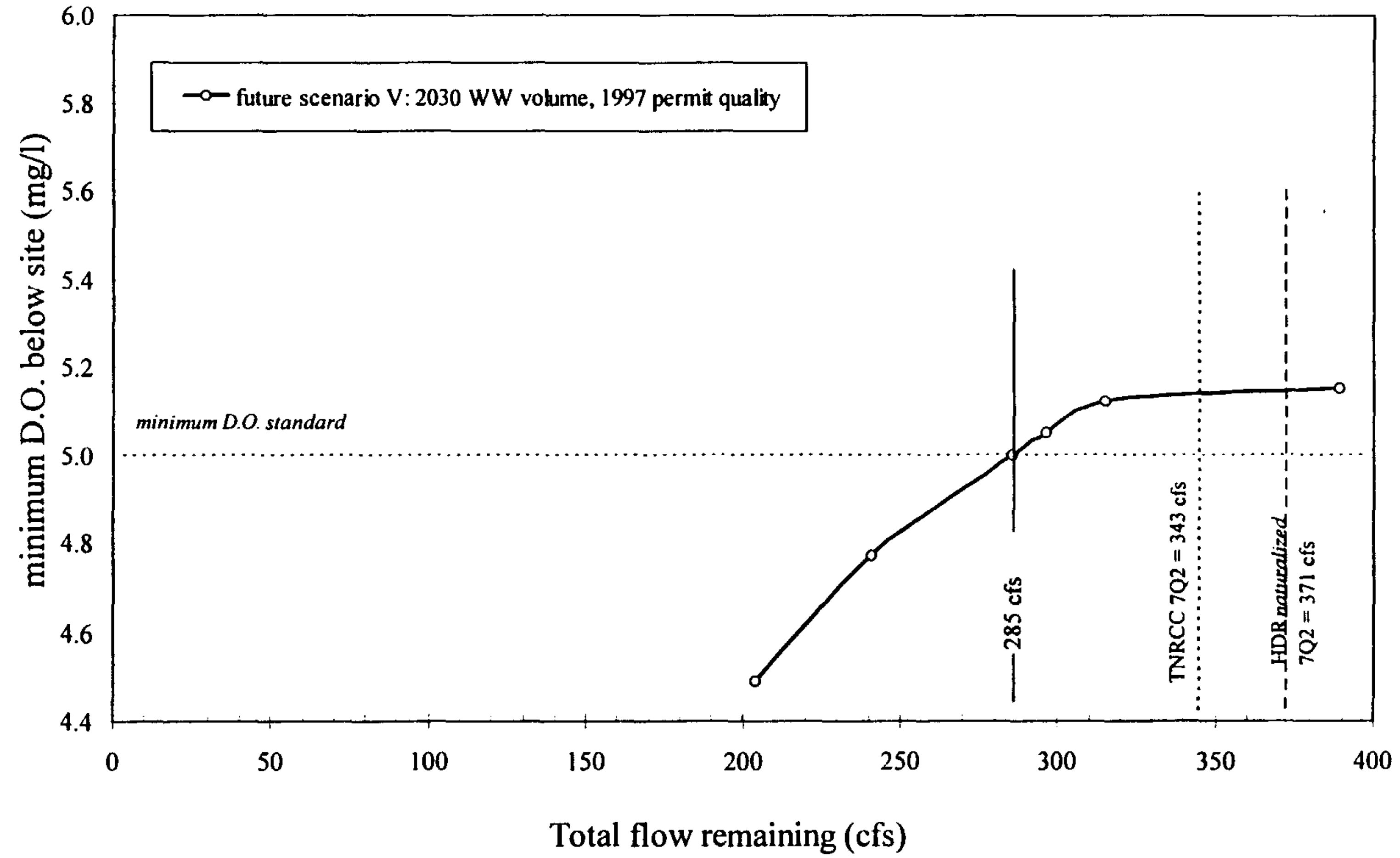
FUTURE SCENARIO "VQ" - FLOW VS. MINIMUM D.O. CURVE FOR CUERO DIVERSION

FIGURE 2-41



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FUTURE SCENARIO "V" - FLOW VS. MINIMUM D.O. CURVE FOR LAKE DUNLAP DIVERSION

GUADALUPE - SAN ANTONIO RIVER BASIN ENVIRONMENTAL CRITERIA REFINEMENT

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FIGURE 2-34

Figure 2-34 is the streamflow versus D.O. curve for the Lake Dunlap diversion under the Future Scenario "V". When the flow remaining after diversion, equal to remaining portion of the 7Q2 plus wastewater discharges, declines to 285 cfs, the minimum acceptable D.O. level is reached.

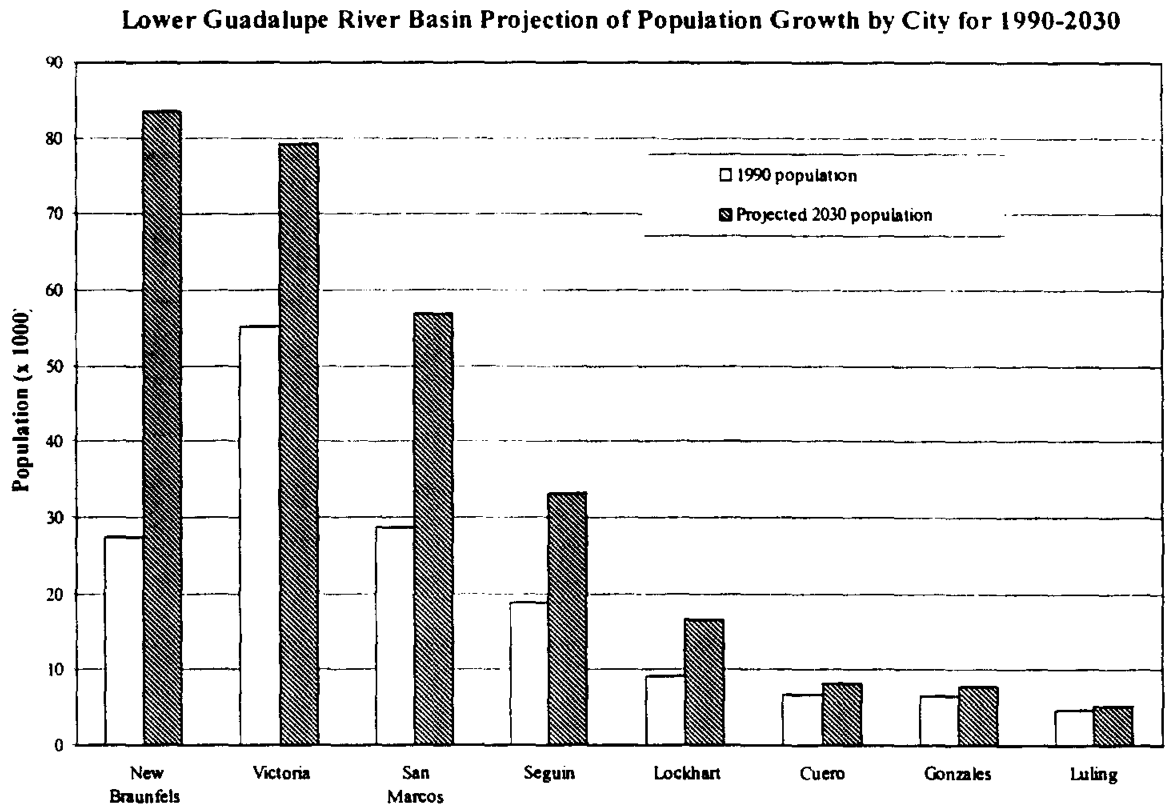
The results of model simulations for D.O. with diversions taking place at Cuero are shown in Figure 2-35. The maximum allowable diversion is 50 percent of 7Q2, or 270 cfs. Figure 2-36 is the streamflow versus D.O. curve for Cuero diversions under Future Scenario "V".

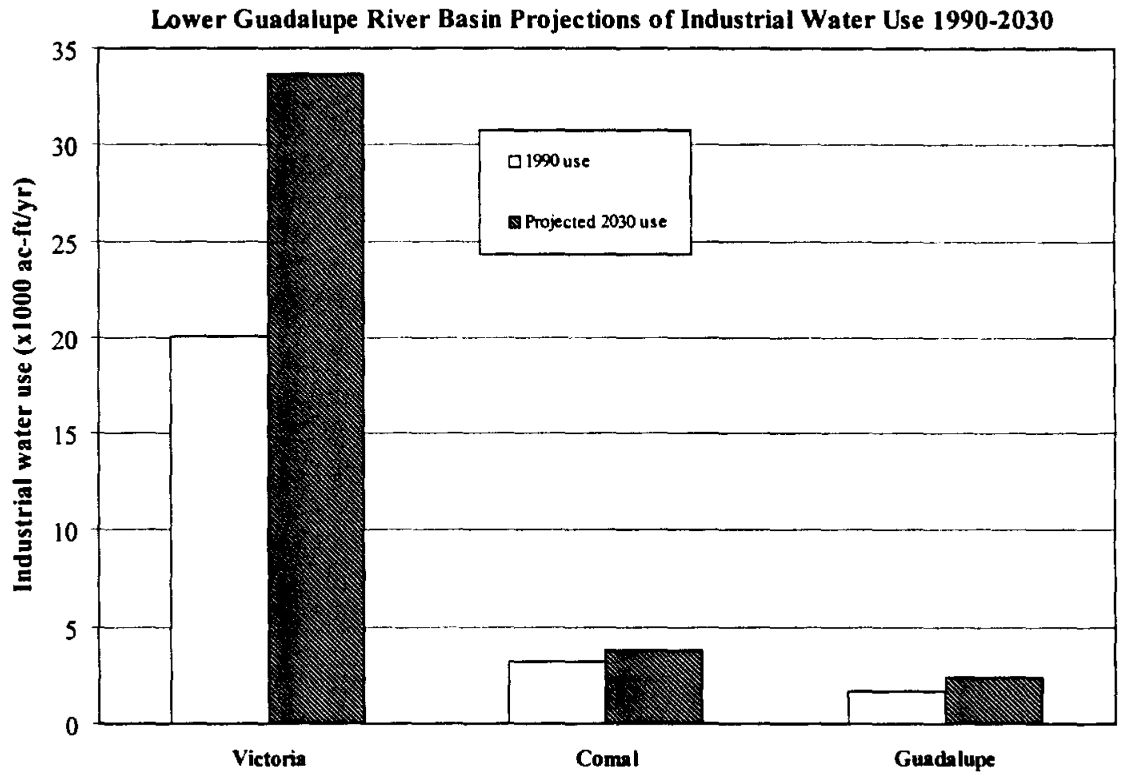
2.2.3.3 Future Scenario "VQ"

Under this scenario, the wastewater volumes were once again equal to the projected values for the year 2030. Wastewater effluent quality, however, was improved beyond the 1997 permit levels used in the previous two scenarios. Wastewater treatment plants currently holding permits allowing BOD discharges in the 15 mg/l and above range were set to a new limit of 10 mg/l. Plants with BOD permits limits in the 5-10 range were set to 5 mg/l. It was assumed that the WWTP for the City of New Braunfels would limit ammonia discharge concentrations to 2.0 mg/l. For other cities, this limit was assumed to be 3.0 mg/l. Table 2-8 summarizes the wastewater volumes and effluent concentrations used in this scenario.

Figure 2-37 portrays the results of the Guadalupe/San Marcos model simulations with a diversion taking place at Lake Dunlap. With the improvements in wastewater quality, the diversion could increase to 80 percent of 7Q2 (297 cfs) as compared to only 28 percent in the "V" scenario. Figure 2-38 shows the predicted levels of ammonia under the improved wastewater treatment assumption of this scenario. There are still peaks below major wastewater discharges, but they are approximately one-half of the levels in Future Scenario "V" (Figure 2-33). Figure 2-39 is the streamflow versus D.O. curve for the Lake Dunlap diversion.

The results of diverting water at the Cuero site are shown in Figure 2-40 for this scenario. The maximum diversion could equal 72 percent of 7Q2 (72% of 540 = 389 cfs) such that the minimum D.O. level of 5.0 mg/l is just maintained. Figure 2-41 is the streamflow versus D.O. curve for the Cuero diversion.





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PREDICTED GROWTH IN WATER USE FOR WWTP'S DISCHARGING TO THE GUADALUPE AND SAN MARCOS RIVERS

FIGURE 2-31

Table 2-7
Summary of Wastewater Discharges to the Guadalupe and San Marcos for Future Scenario "V"

				Average Daily Wasteload Concentrations (mg/l)*				
				Maximums				Minimum
Map No.	Permit No.	Permittee	Year 2030 Discharge (MGD)	BOD5	Organic Nitrogen	Ammonia	Nitrite +Nitrate	Dissolved Oxygen
	Guadalupe River							
1	10232-002	New Braunfels Utilities	0.64	5.0	1.0	3.0	16.0	4.0
2	00335-001	Mission Valley Textiles	2.30	8.0	0.1	0.1	0.1	5.0
3	10232-001	New Braunfels Utilities	2.82	10.0	3.0	5.0	2.0	4.0
4	10232-003	New Braunfels Utilities	5.80	10.0	3.0	5.0	2.0	4.0
5	11378-001	GBRA - Lake Dunlap	0.18	10.0	3.0	15.0	2.0	4.0
6	01712-001	Structural Metals, Inc.	0.11	20.0	0.1	0.1	0.1	5.0
7	11427-001	GBRA - Seguin	0.15	20.0	4.0	15.0	1.0	2.0
8	10277-001	City of Seguin	5.65	20.0	4.0	15.0	1.0	6.0
9	10277-003	City of Seguin - Geronimo Creek	0.80	20.0	4.0	15.0	1.0	2.0
10	10488-001	City of Gonzales	0.97	10.0	3.0	15.0	2.0	2.0
11	10403-002	City of Cuero	0.67	20.0	3.0	15.0	2.0	2.0
12	01165-002	Central Power and Light	0.38	0.0	0.0	0.0	0.0	6.5
13	10466-001	GBRA - Victoria	1.85	20.0	4.0	15.0	1.0	2.0
14	11078-001	GBRA - Victoria	6.11	20.0	4.0	15.0	1.0	2.0
15	00476-001	E.I. Du Pont De Nemours & Co.	16.96	20.0	3.0	3.0	14.0	5.0
	San Marcos River							
16	03381*	TPW - Texas Fish Hatchery	5.00	5.0	1.0	1.0	18.0	5.0
17	10273-001	City of San Marcos	6.38	5.0	1.0	2.0	17.0	6.0
18	12067-001	Gary's Job Corps	0.24	20.0	4.0	15.0	1.0	6.0
19	10582-001	City of Luling	0.59	20.0	4.0	15.0	1.0	2.0
20	10943-001	Texas Rehabilitation Hospital	0.027	20.0	4.0	15.0	1.0	2.0

* Wastewater constituent concentrations based on 1997 permit values. See additional notes in Table 2-3.

concentrations be set to 15.0 mg/l. This assumption is of critical importance because ammonia consumes a high amount of oxygen as it decays to nitrite/nitrate (see Figure 2-3). For many of the treatment plants on the Guadalupe River, this may be an appropriate approximation.

However, in the case of the WWTPs for the City of New Braunfels such a discharge appears to be an inordinately high. The WWTPs operated by the City of New Braunfels have fairly long residence times[26] which usually lead to high conversions of ammonia to nitrite/nitrate. Data provided by the City of New Braunfels indicate that the North Kuehler Road Plant (permit 10232-003) has an average ammonia discharge of 5.12 mg/l while operating at approximately 2/3 capacity.[27] The same data indicate that the adjacent South Kuehler Road Plant (permit 10232-001) has an average ammonia discharge of 3.47 mg/l while operating at approximately 50 percent capacity. For the Future Scenario "V" the ammonia discharges for these two plants were set to 5.0 mg/l. Table 2-6 summarizes the wastewater discharge volumes and constituent concentrations for all WWTPs in this scenario.

After the wastewater discharge characteristics were set, the Guadalupe/San Marcos model was used to evaluate the effects of streamflow on the D.O. sag curve. As a baseline, the first simulation was to set the streamflows, before wastewater discharges were added, to the naturalized 7Q2 levels shown in Figure 2-7. Figure 2-23 presents the results of this simulation. At the 7Q2 baseline flows, the model predicts a D.O. sag curve with several local minima: near the TP-5 Dam, near the H-4 Dam, and two superimposed sags due to discharges from the Victoria and E. I. Dupont WWTPs.

Next, a series of simulations were performed, each with a diversion of water from Lake Dunlap. The naturalized 7Q2 at this point is 371 cfs. The results of two simulations for D.O., with diversion rates of 25 percent and 45 percent of 7Q2 (93 cfs and 167 cfs) are also shown on Figure 2-23. The diversion of 167 cfs was just enough to cause the minimum D.O. near the TP-5 dam to decline to 5.0 mg/l. Hence, this is the largest diversion, or the lowest remaining amount of naturalized streamflow (371-167=204 cfs) that will maintain the water quality minimum of 5.0 mg/l of dissolved oxygen.

---

[26] Tommy Thompson, Engineer, City of New Braunfels Utilities ,personal communication, January 23, 1998.
[27] City of New Braunfels Utilities, unpublished data for the December 7, 1995 through December 31, 1997 period, photocopied.

Table 2-6
Summary of Permitted Wastewater Discharges to the Guadalupe and San Marcos Rivers as of August 1997

				Average Daily Wasteload Concentrations (mg/l)*				
				Maximums				Minimum
Map No.	Permit No.	Permittee	Permitted Discharge (MGD)	BOD5	Organic Nitrogen	Ammonia	Nitrite +Nitrate	Dissolved Oxygen
	Guadalupe River							
1	10232-002	New Braunfels Utilities	1.10	5.0	1.0	3.0	16.0	4.0
2	00335-001	Mission Valley Textiles	3.00	8.0	0.1	0.1	0.1	5.0
3	10232-001	New Braunfels Utilities	4.20	10.0	3.0	5.0	2.0	4.0
4	10232-003	New Braunfels Utilities	3.10	10.0	3.0	5.0	2.0	4.0
5	11378-001	GBRA - Lake Dunlap	0.16	10.0	3.0	15.0	2.0	4.0
6	01712-001	Structural Metals, Inc.	0.12	20.0	0.1	0.1	0.1	5.0
7	11427-001	GBRA - Seguin	0.30	20.0	4.0	15.0	1.0	2.0
8	10277-001	City of Seguin	4.00	20.0	4.0	15.0	1.0	6.0
9	10277-003	City of Seguin - Geronimo Creek	2.13	20.0	4.0	15.0	1.0	2.0
10	10488-001	City of Gonzales	1.50	10.0	3.0	15.0	2.0	2.0
11	10403-002	City of Cuero	1.50	20.0	3.0	15.0	2.0	2.0
12	01165-002	Central Power and Light	1.20	0.0	0.0	0.0	0.0	6.5
13	10466-001	GBRA - Victoria	2.50	20.0	4.0	15.0	1.0	2.0
14	11078-001	GBRA - Victoria	8.00	20.0	4.0	15.0	1.0	2.0
15	00476-001	E.I. Du Pont De Nemours & Co.	21.80	20.0	3.0	3.0	14.0	5.0
	San Marcos River							
16	03381**	TPWD - Texas Fish Hatchery	5.00	5.0	1.0	1.0	18.0	5.0
17	10273-001	City of San Marcos	9.00	5.0	1.0	2.0	17.0	6.0
18	12067-001	Gary's Job Corps	0.752	20.0	4.0	15.0	1.0	6.0
19	10582-001	City of Luling	0.50	20.0	4.0	15.0	1.0	2.0
20	10943-001	Texas Rehabilitation Hospital	0.04	20.0	4.0	15.0	1.0	2.0

* Wastewater volumes and constituent concentrations based on 1997 permits values. Not all constituent concentrations are specified in each permit. In such cases, the concentration is based on TNRCC's formulas of Table 2-4, unless other more specific data was obtained.
** Texas Parks and Wildlife Department is currently applying for a wastewater permit from TNRCC. Specifics of that application are based on data obtained from TNRCC.

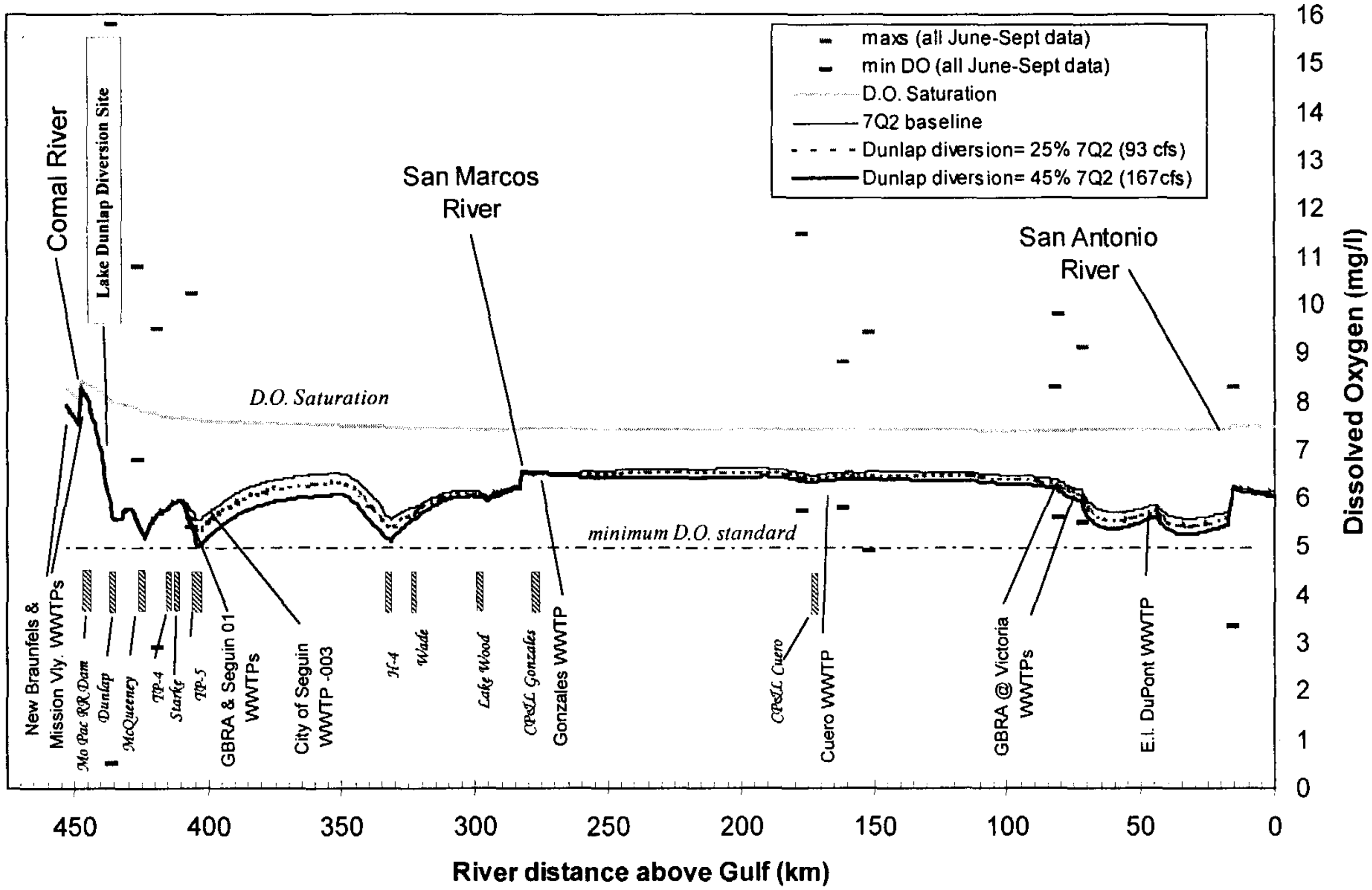
The simulations for organic nitrogen, ammonia, nitrite/nitrate, and BOD are presented in Figures 2-24 through 2-27. As water is diverted the concentrations of each water quality constituent are increased in the vicinity of discharge points. The elevated levels of ammonia in Figure 2-25 just downstream from WWTP discharge points are due to the assumed concentration of 15.0 mg/l from plants when they are operating at full capacity.

Figure 2-28 summarizes the multiple simulations under this scenario for the Lake Dunlap diversion in a different manner. The minimum D.O. resulting from each diversion is plotted in the vertical direction. The flow on the horizontal axis is the total flow remaining after the diversion. As indicated, the 5.0 mg/l limit is crossed when the total flow remaining after the diversion is 222 cfs. The minimum was reached when the diversion was 167 cfs and naturalized flow remaining was 204 cfs. The flow on Figure 2-28, 222 cfs, is the sum of the naturalized flow remaining, 204 cfs, and all of the wastewater discharge volumes above this point (11.6 mgd = 17.9 cfs). Similar plots, referred to as "flow versus minimum D.O. curves" will be presented for all scenario evaluations.

The next step in the Current Permit Scenario evaluation was to investigate streamflows necessary for D.O. maintenance with potential diversions from a site near Cuero. Figure 2-29 presents the results of several simulations with increasing diversion from the Cuero site. The naturalized 7Q2 at this point is 540 cfs. When the diversion rate was 47 percent of the 7Q2 at this point (254 cfs) the minimum of the D.O. sag curve declined to the minimum acceptable level of 5.0 mg/l. Figure 2-30 is the streamflow versus D.O. curve for the Cuero diversion site under the Current Permit Scenario. The value of flow remaining at which point the D.O. declines to 5.0 mg/l is 317 cfs. This value represents the naturalized flow remaining (540 - 254 = 286 cfs) plus the sum of all wastewater discharge volumes above this point (19.6 mgd = 30.3 cfs), with a small discrepancy due to rounding.

2.2.3.2 Future Scenario "V"

In Future Scenario "V," the wastewater discharge volumes were increased to reflect expected changes in municipal and industrial water use through the year 2030. For municipal wastewater, it was assumed that per capita discharge volumes would equal those in 1990. Under this scenario, the wastewater discharge volume for each city was calculated by multiplying the



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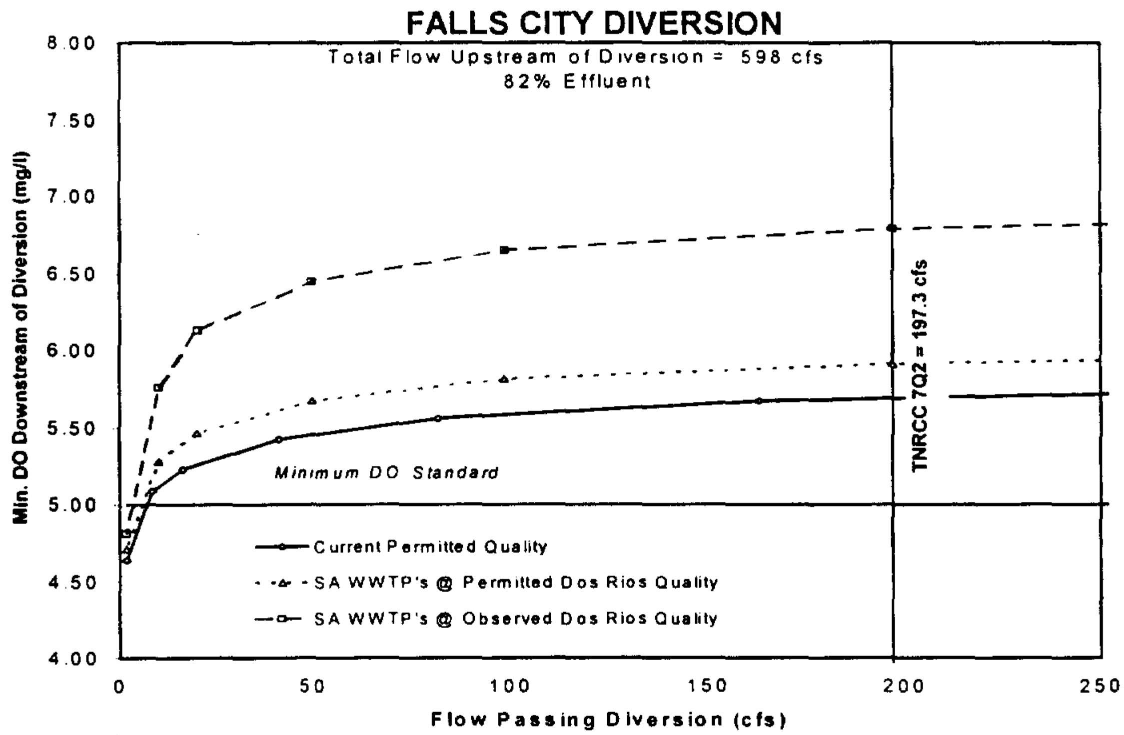
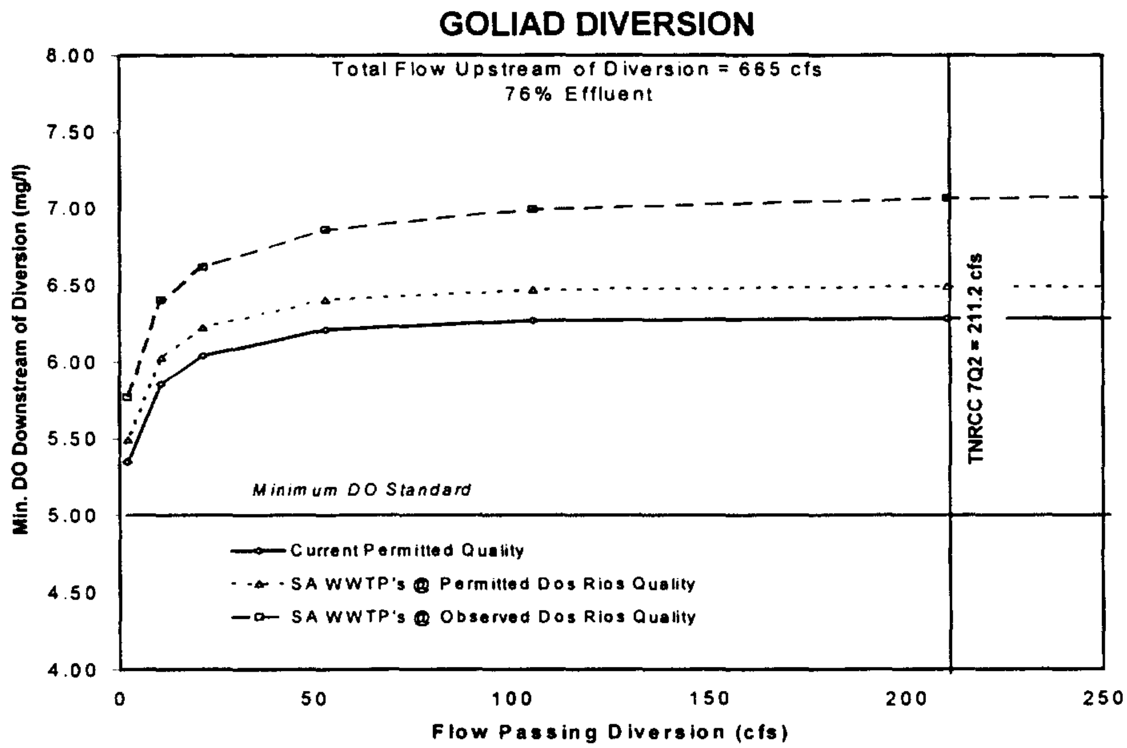
CURRENT PERMIT SCENARIO- D.O. SIMULATION: DIVERSIONS FROM LAKE DUNLAP

FIGURE 2-23





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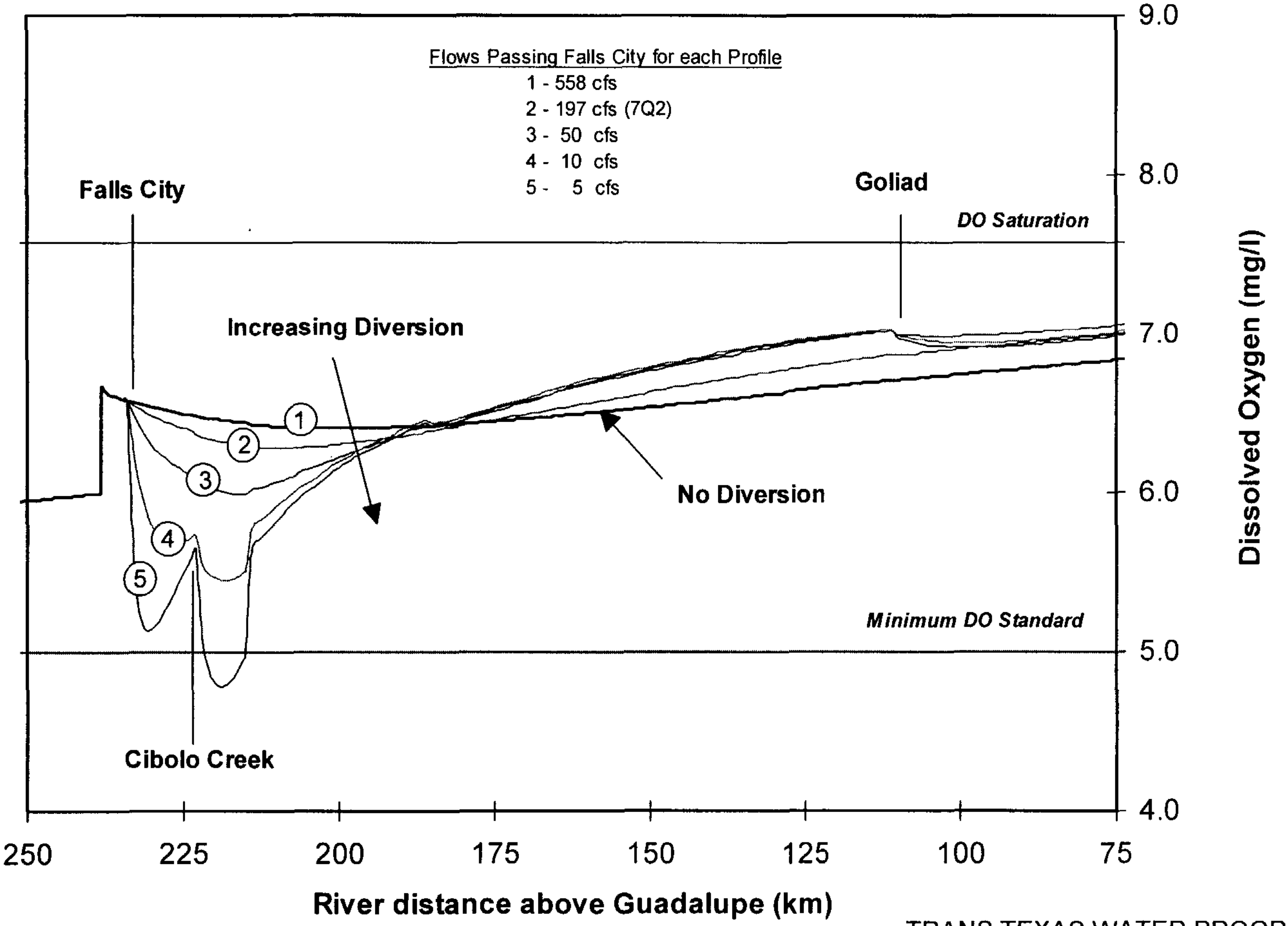
MINIMUM DISSOLVED OXYGEN VS. DISCHARGE - FUTURE CONDITIONS

FIGURE 2-49



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SAN ANTONIO RIVER DISSOLVED OXYGEN PROFILES WITH FALLS CITY DIVERSION

FIGURE 2-50

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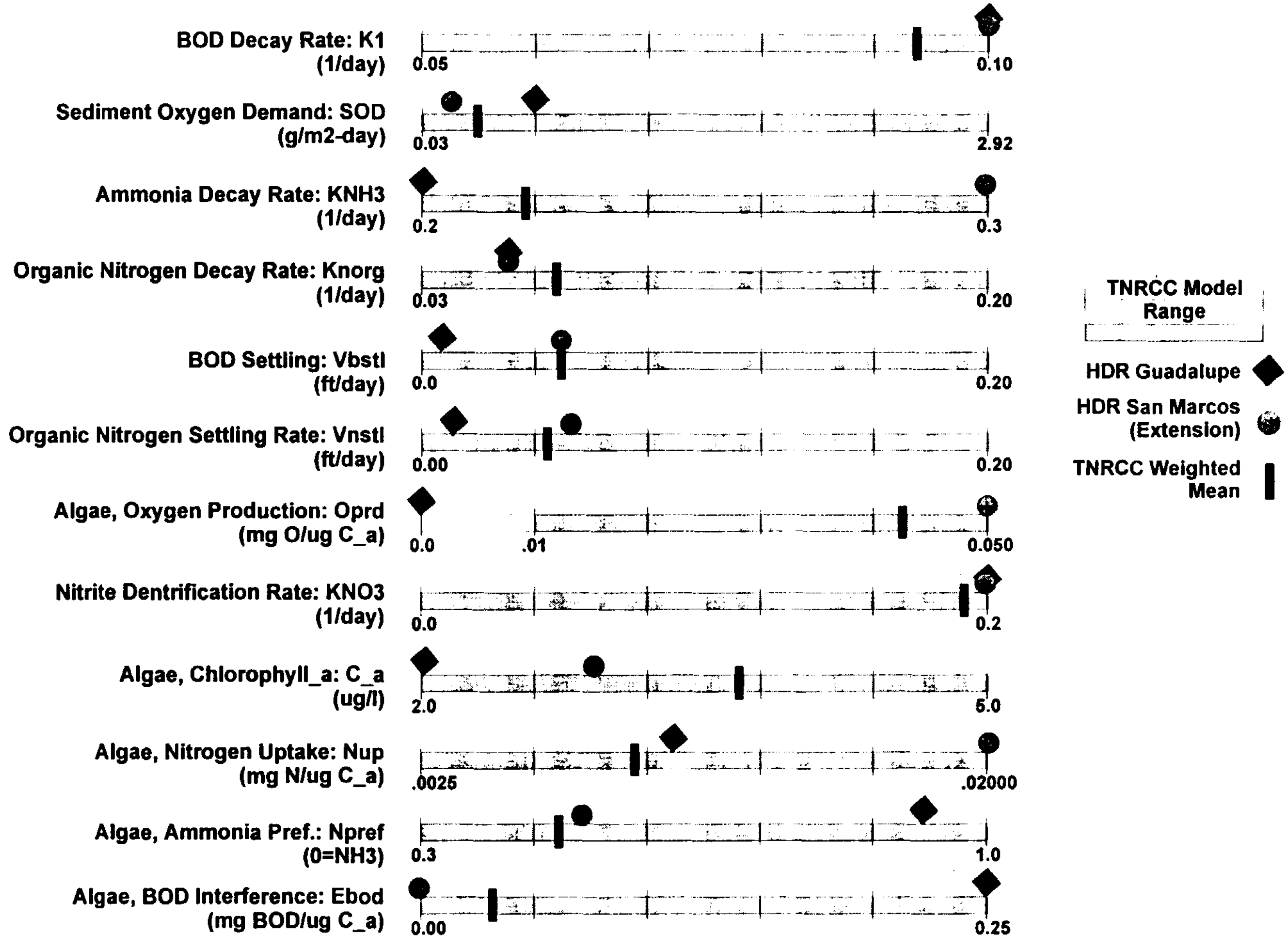

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FINAL CALIBRATION VALUES OF KINETIC COEFFICIENTS FOR HDR GUADALUPE - SAN MARCOS RIVER MODEL

FIGURE 2-22

98-17

2.2.3 Model Application

Once the Guadalupe/San Marcos model was fully calibrated, it was possible to apply it in the task of investigating the suitability of the 7Q2 low-flow criteria for Zone 3. In this application stage of modeling, three scenarios were evaluated in order to analyze the 7Q2 criteria. The scenarios evaluated were:

1) Current Permit Scenario - all wastewater discharges were set to the maximum allowable limits under the TNRCC permit as of August 1997. This means that discharge volume was set to the maximum and effluent constituent concentrations for BOD, organic nitrogen, ammonia, and nitrite/nitrate were set to maximum values. The D.O. of the wastewater was set to the permitted minimum.
2) Future Scenario "V" - all wastewater discharge volumes were increased to expected levels for the year 2030 while effluent quality was maintained at the levels of the Current Permit Scenario.
3) Future Scenario "VQ" - all wastewater discharge volumes were increased to expected levels for the year 2030 and effluent constituent concentrations were set to levels reflecting reasonable improvements in discharge quality.

In all three scenarios, the effects of reducing flow below the 7Q2 level were evaluated with the QUAL-TX model by simulating a diversion of water from a given model element. These diversions were increased until one of the local minima of the D.O. sag curve declined to the water quality criteria of 5.0 mg/l. Each of these simulations is referenced to a percentage of the naturalized 7Q2 at the point from which it is being diverted. Two such diversion sites were used in each scenario: a diversion from the Guadalupe River at Lake Dunlap below New Braunfels, and a diversion from the Guadalupe River near Cuero.

2.2.3.1 Current Permit Scenario

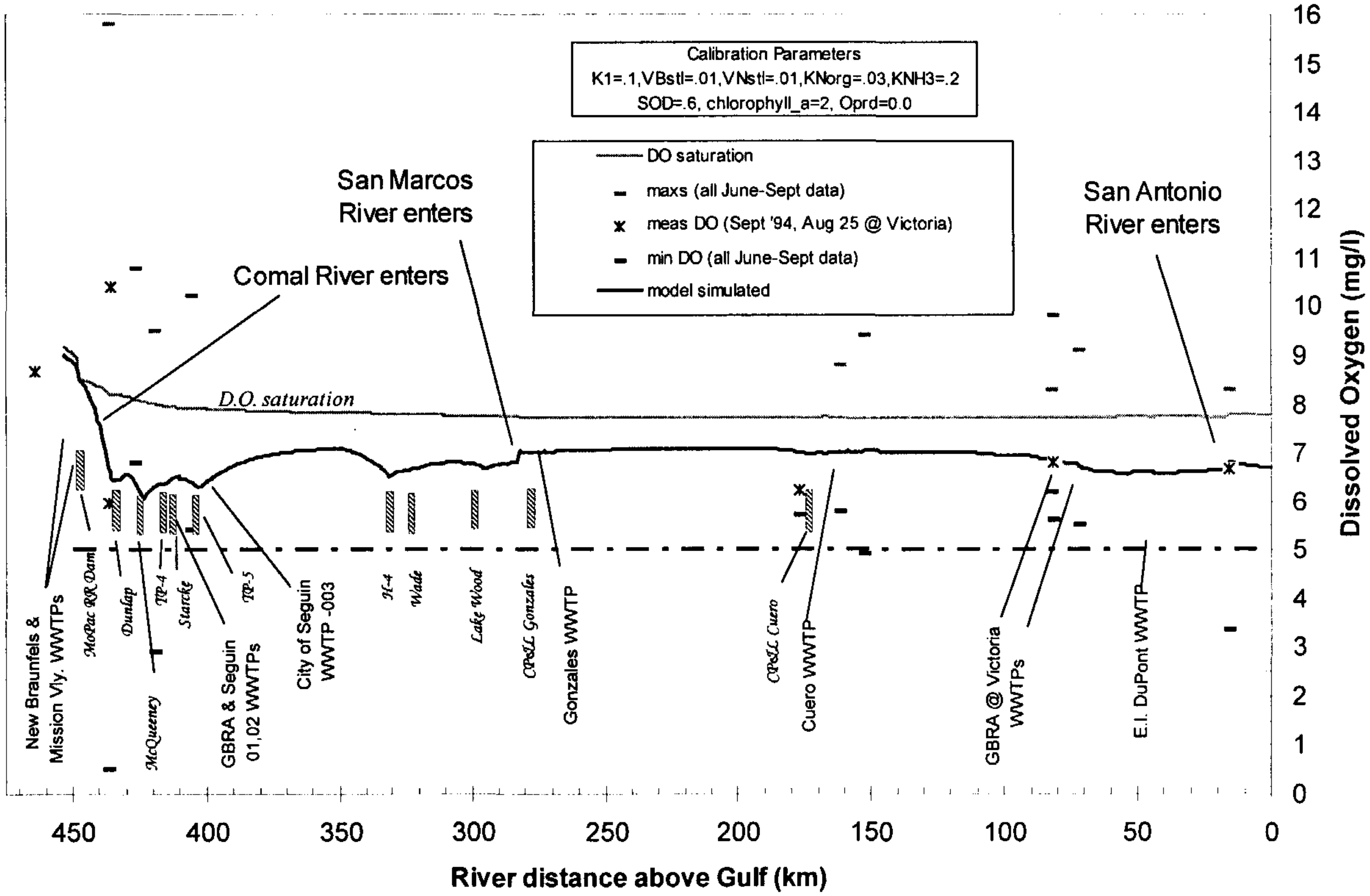
Under this scenario, all wastewater discharge volumes and constituent concentrations were set to the maximum allowable limits under the current (Aug. 1997) TNRCC permits. The total volume of wastewater discharge under this scenario is 54.6 million gallons per day (84.5 cfs). As was the case in the model calibration process, many current wastewater permits do not specify all of the constituent concentrations modeled. These were once again set to the levels indicated by the formulas of Table 2-4. Under this scenario all wastewater treatment plant capacities are at 100 percent, in which case the formulas of Table 2-4 dictate that ammonia

BOD values in Lake Dunlap correspond to times of high algae concentrations. In summary, the model-predicted value for BOD was assumed reasonable since the measured value for Lake Dunlap appears to be non-representative. There is a fair correspondence between model-prediction and available field data further downstream, although the data resolution is extremely coarse.

Figure 2-21 shows the model simulation of D.O. as compared to available field data. Again, there appears to be an algae interference in the Lake Dunlap area where two field-gathered data points are widely separated. The upper point (D.O. =10.4 mg/l) is far above dissolved oxygen saturation, very likely due to algae oxygen production. In the calibration, the lower dissolved oxygen value in Lake Dunlap was favored as a conservative approach. The shape of the D.O. sag curve shows the large influence that the dams along the mainstem of the Guadalupe River have. The low velocities and increased depths in these reservoirs cause reaeration rates to be extremely low and account for several local minima. The most pronounced are those near the Lake McQueeney Dam, near the TP-5 Dam, and near the H-4 Dam. Much further downstream, there are two superimposed sags due to discharges from the Victoria and E.I. Dupont wastewater treatment plants (WWTPs).

A conservative approach was maintained throughout the calibration effort. For example, lowering the decay rate of BOD (K_1) below the final calibration value of 0.10 (1/day) would improve the match between model-prediction of BOD and the downstream field data. However, this would shift the D.O. curve upwards. Similarly, lowering the decay rates of organic nitrogen and ammonia below the final calibration values would improve the match between model simulation of these constituents and the downstream field data, but again this would raise the D.O. curve. As a guiding principal, the final set of values for constants and coefficients was chosen to err on the conservative side and yet be within the range of values used in previous applications of the QUAL-TX model by the TNRCC in the study area. Figure 2-22 graphically portrays the calibration values for the Guadalupe/San Marcos model as compared to the other studies.

Once this final set of constants and coefficients was selected, the Guadalupe/San Marcos model was verified. This was accomplished by applying the model to the September 1995 period using streamflows; wastewater discharge flows and concentrations; and field data for constituent concentrations recorded for this period. The performance of the model was similar to that of the September 1994 calibration and was considered satisfactory.



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DISSOLVED OXYGEN CALIBRATION OF GUADALUPE/SAN MARCOS RIVER MODEL FOR SEPTEMBER 1994

FIGURE 2-21

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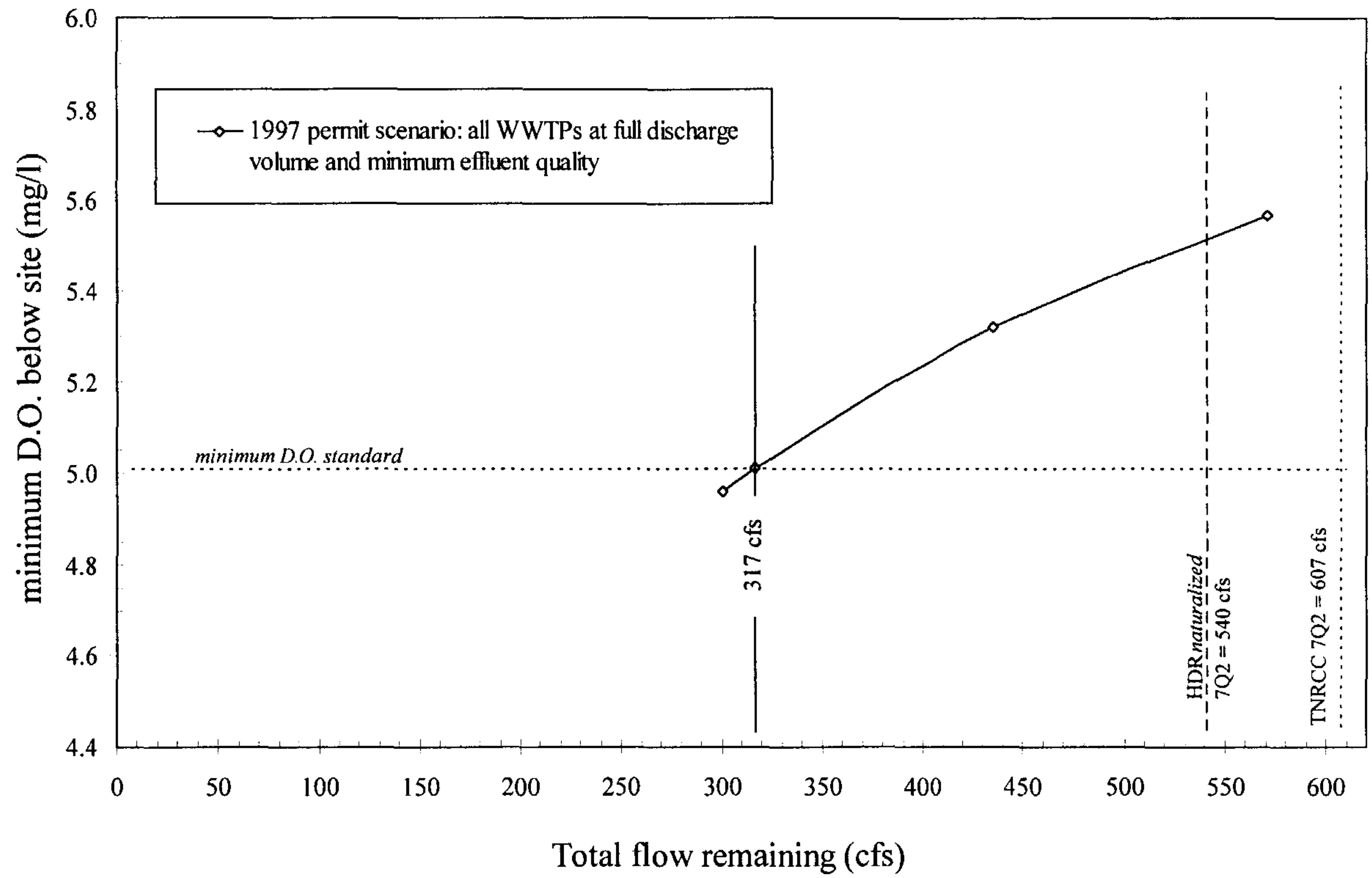
actual 1990 discharges by the ratio of the 2030 projected population to the 1990 population for each city. Similarly, industrial wastewater volumes were calculated based on projected increases in this type of water use for the year 2030 as compared to 1990. Wastewater effluent quality was maintained at the levels of the Current Permit Scenario (Table 2-6).

Population projections and forecast increases in the industrial water use[28] are shown graphically in Figure 2-31. Very large increases in population are anticipated for New Braunfels and San Marcos. Victoria is projected to increase by a lesser proportion, but would still be the second largest city discharging to the modeled portion of the Guadalupe River. The lower half of Figure 2-31 shows the projected increases in industrial water use for the three counties in the model which have industrial WWTP discharges; permit 00335-001 in Comal Co.; permit 01712-001 in Guadalupe Co.; and permit 00476-001 in Victoria Co. The discharge volume from the Texas Parks and Wildlife Department fish hatchery near San Marcos was assumed to remain at the 5.0 mgd level in the current permit application.

Table 2-7 shows the wastewater discharge volumes used in this scenario which total 59.8 mgd (92.5 cfs). It is important to point out that this is only a slight increase in total volume above the 54.6 mgd in the Current Permit Scenario. The reason for this small change is that the Current Permit Scenario is based on permitted amounts while this Future Scenario "V" is a projection scaled-up from actual discharges in 1990. Essentially, this indicates that there is some degree of "padding" in the current permits: discharges seldom reach the volume allowed in the permit. This was evident in the column labeled "percent capacity" in Table 2-3.

Figure 2-32 shows the results of several simulations of the Guadalupe/San Marcos model with diversions of water being taken at Lake Dunlap. At a diversion rate equal to 28 percent of 7Q2 (104 cfs), the minimum of the D.O. curve near the TP-5 dam reaches 5.0 mg/l. Figure 2-33 presents the predicted levels of ammonia under the simulations of this scenario. The elevated levels of ammonia are once again due to the assumed discharge concentration of 15.0 mg/l from WWTPs operating at full capacity. These levels were kept constant under the assumptions of this scenario.

[28] HDR Engineering. "Trans-Texas Water Program, West Central Study Area, Phase II, Population, Water Demand and Water Supply Projections" 1998.



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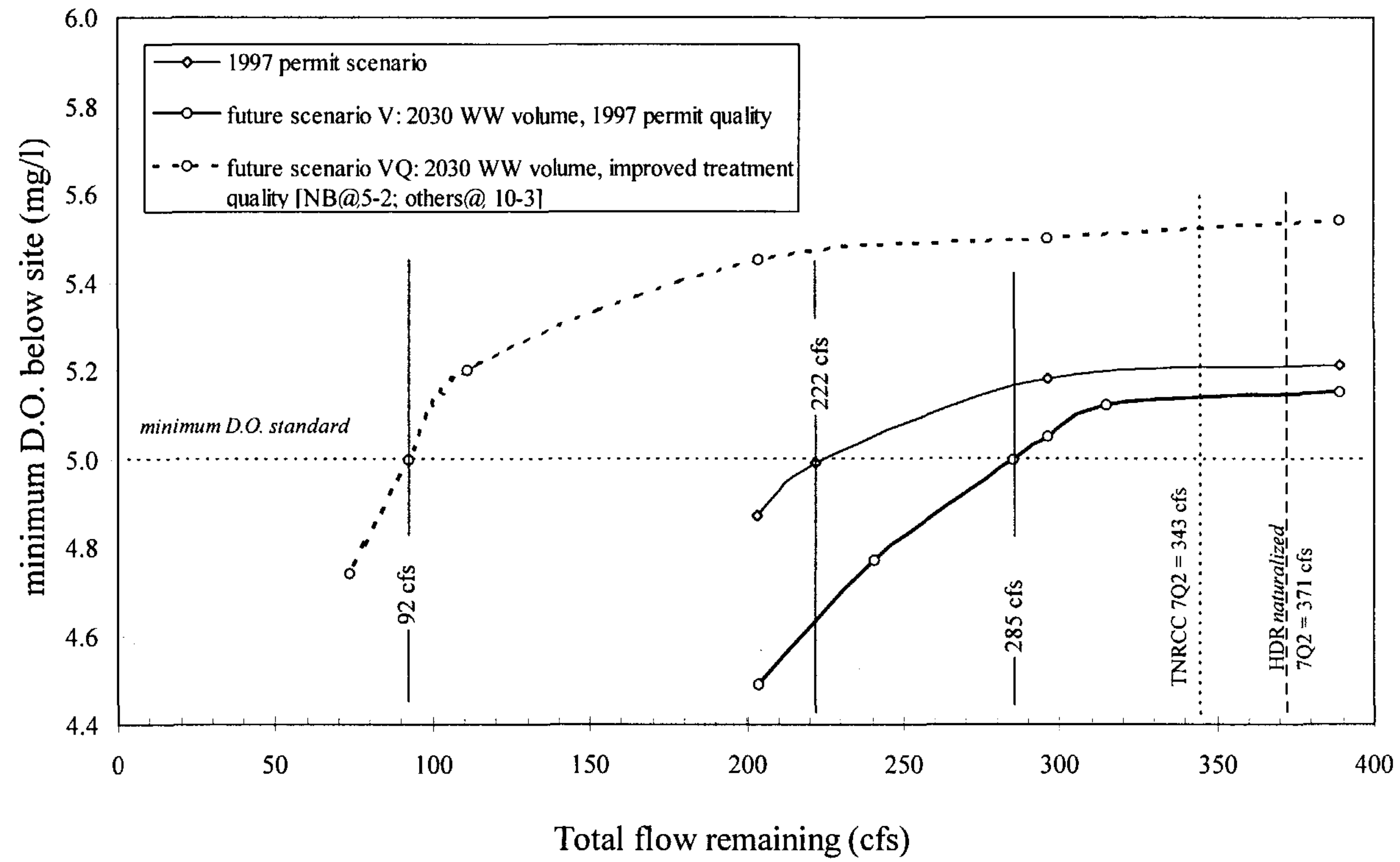
CURRENT PERMIT SCENARIO-FLOW VS. MINIMUM D.O. CURVE FOR CUERO DIVERSION

FIGURE 2-30

2.2.4 Comparisons of Scenarios

The results of all three scenarios can be compared by combining the streamflow versus D.O. curves for each diversion site. Figure 2-42 compares the minimum streamflows necessary to maintain the minimum dissolved oxygen level of 5.0 mg/l under each of the three scenarios simulated. Figure 2-43 is a similar comparison of the three scenarios for the Cuero diversion site.

On the basis of dissolved oxygen maintenance alone, minimum flows (7Q2) specified by TNRCC appear quite restrictive with respect to consideration of potential direct diversion projects under the Consensus Criteria.



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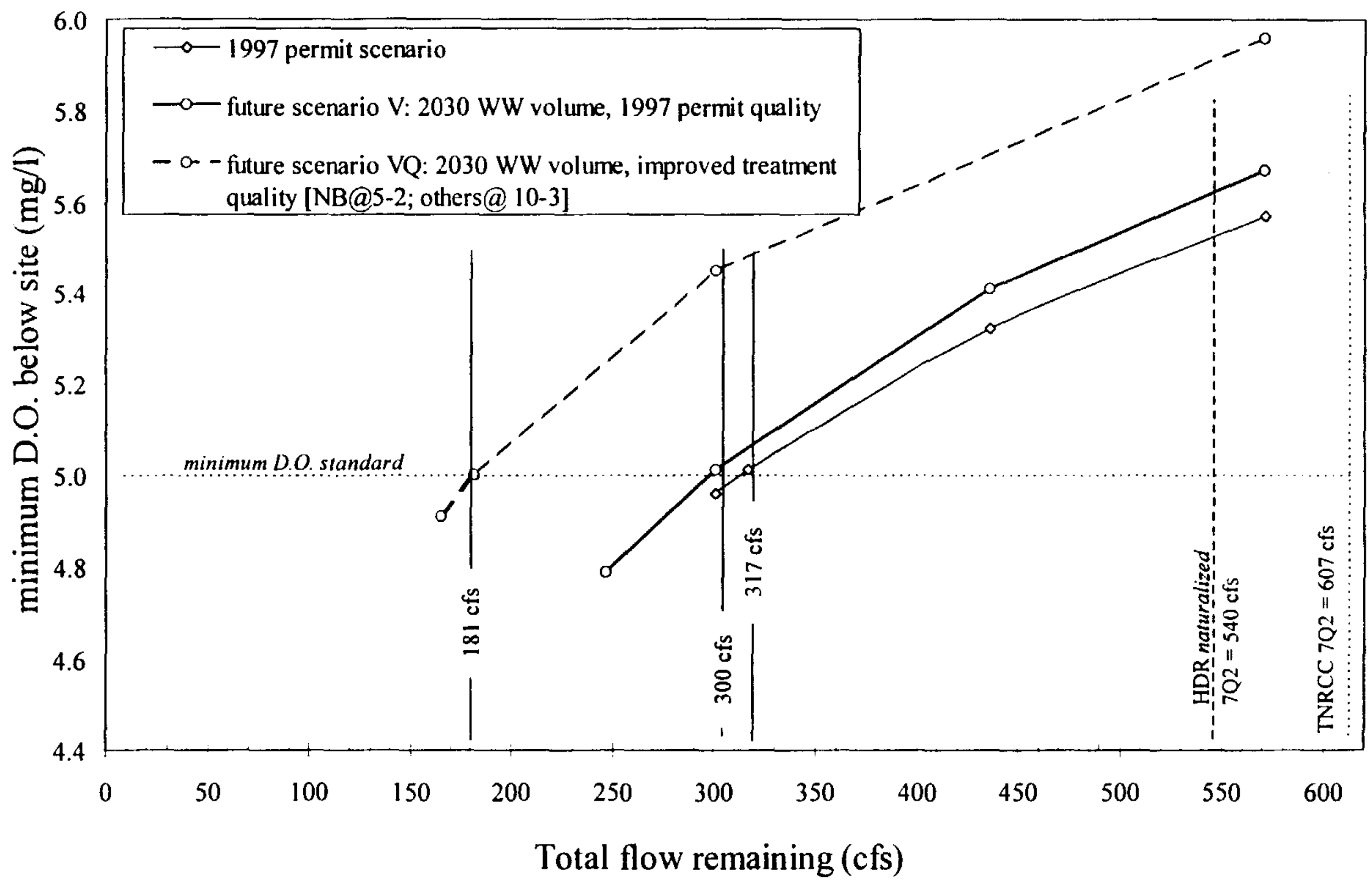
SUMMARY COMPARISON OF FLOW VS. MINIMUM D.O. CURVES FOR LAKE DUNLAP DIVERSION

FIGURE 2-42



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SUMMARY COMPARISON OF FLOW VS. MINIMUM D.O. CURVES FOR CUERO DIVERSION

FIGURE 2-43

2.3 The San Antonio River Model

2.3.1 Basin Overview

The San Antonio River Basin originates northwest of the City of San Antonio and extends across the south central portion of the state to the confluence with the Guadalupe River near San Antonio Bay. The total basin area is 4,180 square miles and encompasses portions of 13 counties.[29] Major cities and towns that discharge water in the basin include Castroville, Falls City, Floresville, Goliad, Karnes City, and the City of San Antonio.[30]

Historically, much of the flow in the San Antonio River emerged from springs supplied by the Edwards Aquifer, but as water demands in the San Antonio Area increased, the aquifer level often fell below the spring openings and natural their flow has decreased.[31] Industrial and municipal wastewater discharges augment the natural flows as the river system passes the City of San Antonio. With regard to dissolved oxygen, the interaction between these discharges and the natural flows dictate the quality in the downstream reaches.

In the recent past, water quality in the San Antonio River was relatively poor, particularly during periods of low-flow (less dilution). However, in recent years, advanced treatment has been instituted at the three major City of San Antonio wastewater treatment plants (Dos Rios, Leon Creek, and Salado Creek) and an older WWTP was retired (Rilling Road). As a result, dissolved oxygen levels in the San Antonio River have increased substantially.[32] The impact of treatment levels at the San Antonio WWTPs on dissolved oxygen is explored in greater detail herein. Since the wastewater discharges in the San Antonio metropolitan area are the primary influence on the dissolved oxygen levels in the river, the modeling effort starts with the reaches in and around the City of San Antonio and extends down to the confluence with the Guadalupe River.

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[29] Texas Natural Resource Conservation Commission, "The State of Texas Water Quality Inventory, 13th Edition (Vol. 3)." SFR-50. Austin, TX. 1996.
[30] The San Antonio River Authority, "Regional Assessment of Water Quality of the San Antonio River Basin." San Antonio, TX. 1996.
[31] Ibid.
[32] Ibid.

2.3.2 Model Description

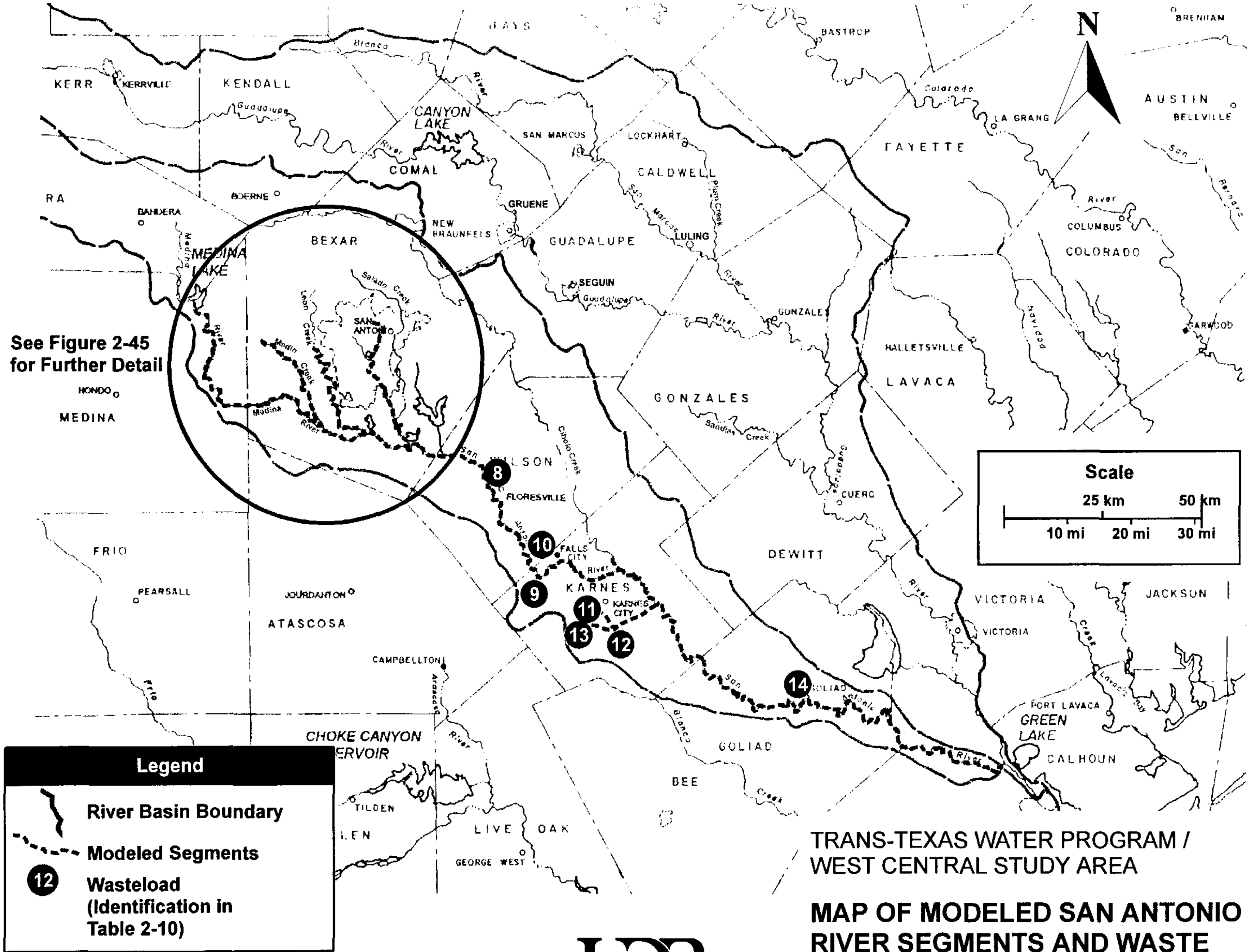
Unlike the Guadalupe River, the TNRCC and its predecessor agencies have already created QUAL-TX models for all the major river segments of the San Antonio River Basin being considered in this study. Due the high water quality of the Guadalupe River and most of its tributaries, the need for intensive field studies has never materialized, whereas the historically poor water quality of the San Antonio River has necessitated extensive analyses. The QUAL-TX model of the San Antonio River was created in response to the Federal Water Pollution Control Act Section 303(d)[33] for the purpose of evaluating and defining wastewater treatment levels and effluent limitations through the year 2000.

The San Antonio River model is actual comprised of five smaller submodels that include the Upper and Lower San Antonio Rivers (Segments 1911 and 1901), the Medina River (Segment 1903) from below Medina Lake to the San Antonio River, a portion of Leon Creek (Segment 1906) that runs from State Highway 16 to the confluence with the Medina River, and Medio Creek (Segment 1912). Figures 2-5 and 2-44 highlight the locations and limits of the modeled river segments. Although the five individual models can operate independently of each other, this analysis was performed with all the segments linked into one contiguous model. The input files for each of the models obtained from TNRCC are included in Appendix D.

Each of the models was calibrated and verified based on intensive surveys conducted between 1975 and 1986 by the Texas Department of Water Resources and the San Antonio River Authority.[34] The waste load evaluation for which the models were created was adopted by the Texas Water Commission on March 20, 1989 and approved by the Environmental Protection Agency on September 15, 1989.[35]

The intensive studies were generally performed during 7 to 10 day periods in a summer month under low-flow conditions. Major wastewater discharges, stream flow characteristics, and water quality constituents were all measured or sampled during the intensive survey. In most cases, the water quality samples were taken every 4 hours at designated

[33] Federal Water Pollution Control Act, as amended (United States Code Section 1244 et seq.). United States Government Printing Office, Washington, D.C.
[34] Texas Water Commission. "Waste Load Evaluation for the San Antonio River System in the San Antonio River Basin." TWC Rep. WLE 89-01. Austin, TX. 1989.
[35] Ibid.



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MAP OF MODELED SAN ANTONIO RIVER SEGMENTS AND WASTE OUTFALL LOCATIONS

FIGURE 2-44

98-15

stations along the river for a 24-hour period. The reports issued for each of the intensive surveys provide a more detailed discussion of the data used to calibrate and verify the models.[36,37,38,39,40]

It is important to mention that the intensive surveys were performed specifically for analyzing wasteload allocations under critical stream conditions (high temperatures and low-flows) and thus provided comprehensive data sets to calibrate and verify the water quality models. This contrasts with the intermittent data sets found in TNRCC's Surface Water Quality Monitoring database, the USGS water quality gage data, and the data collected for other initiatives such as the Clean Rivers Program. These periodic data sets provide the means for establishing long-term trends in water quality, but are less comprehensive than intensive survey data with regards to capturing behavior under critical flow scenarios such as 7Q2. This is the primary difference in the models developed for the San Antonio and Guadalupe Rivers.

The Texas Water Commission report "Waste Load Evaluation for the San Antonio River System in the San Antonio River Basin" elaborates on the application of the San Antonio River Basin QUAL-TX models.[41] The models account for the major sinks and sources of dissolved oxygen discussed in Section 2.0 including biochemical oxygen demand (BOD), nitrogenous oxygen demands, sediment oxygen demand (SOD), and the net effect of photosynthesis and respiration by phytoplanktonic algae. Temperature in this model is fixed in the initial model input based to field measured values. The water quality and hydraulic boundary conditions were derived from the intensive surveys and USGS gage data. The calibrated and verified parameters were then used to create the models for evaluating the impacts of wasteloads.

Application of the QUAL-TX model for the purpose of evaluating the effect of a wasteload is normally done at the 7Q2 streamflow. The TWC derived the naturalized 7Q2 flows

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[36] San Antonio River Authority. "Water Quality Modeling Data, Part 3." San Antonio, Texas. 1976.
[37] Twidwell, S.R.. "Intensive Survey of Medio Creek" Report IS 86-08. Texas Water Commission, Austin, Texas. 1986.
[38] Twidwell, S.R.. "Intensive Survey of Medio Creek." Report IS-51. Texas Department of Water Resources, Austin, Texas. 1983.
[39] Twidwell, S.R. "Intensive Survey of San Antonio River." Report IS-72. Texas Department of Water Resources, Austin, Texas. 1983.
[40] Twidwell, S.R. "Intensive Survey of San Antonio River." Report IS-59. Texas Department of Water Resources, Austin, Texas. 1984.
[41] Texas Water Commission. "Waste Load Evaluation for the San Antonio River System in the San Antonio River Basin." TWC Rep. WLE 89-01. Texas Water Commission: Austin, TX. 1989.

by performing frequency analyses of USGS streamflow gage records. The TWC used gages for the upper San Antonio River (USGS Station 08178000), the lower Medina River (USGS Station 08181500), lower Salado Creek (USGS Station 08178800) and lower Cibolo Creek (USGS Station 08186000) for the period from 1960 to 1984. These flows were then adjusted for any wastewater return flows and allocated as the baseflow throughout the watershed on a flow per unit area basis to establish the naturalized flow in the basin.[42]

Table 2-9 compares the 7Q2 baseflows used in the TNRCC's application of the model and the currently published 7Q2 flows. Note that the published 7Q2 values are based on total flows passing the stream gage and, therefore, include both natural flows and return flows from wastewater treatment plants. In comparing the published 7Q2 flows to the modeled 7Q2 flows, it is easy to see the influence that wastewater discharges have on the San Antonio River. By the time the river reaches USGS Station 08181800 near Elmendorf, its flow is approximately 42 percent treated effluent from WWTPs under these idealized 7Q2 conditions.

Table 2-9
Modeled Baseflows and Published 7Q2 Flows for the San Antonio River

Seg. No.	Segment Name	USGS Gauge	Published 7Q2[1] (cfs)	Modeled 7Q2 Baseflow[2] (cfs)
1901	Lower San Antonio River	8188500	211.2	162.9
1903	Medina River Below Medina Diversion Lake	8181500	65.8	42.9
1911	Upper San Antonio River	8183500	197.3	98.5
1911	Upper San Antonio River	8181800	163.3	94.2

[1] Texas Natural Resource Conservation Commission. Texas Surface Water Quality Standards Sections 307.1-307.10 Effective: July 13, 1995. Based on period from 1960 to 1984.
[2] Modeled flows are taken at gage's approximate location in the QUAL-TX model.

TNRCC staff continues to update the model for changes in the permitted return flows. The model includes 32 wasteloads of varying qualities and quantities. Figures 2-44 and 2-45

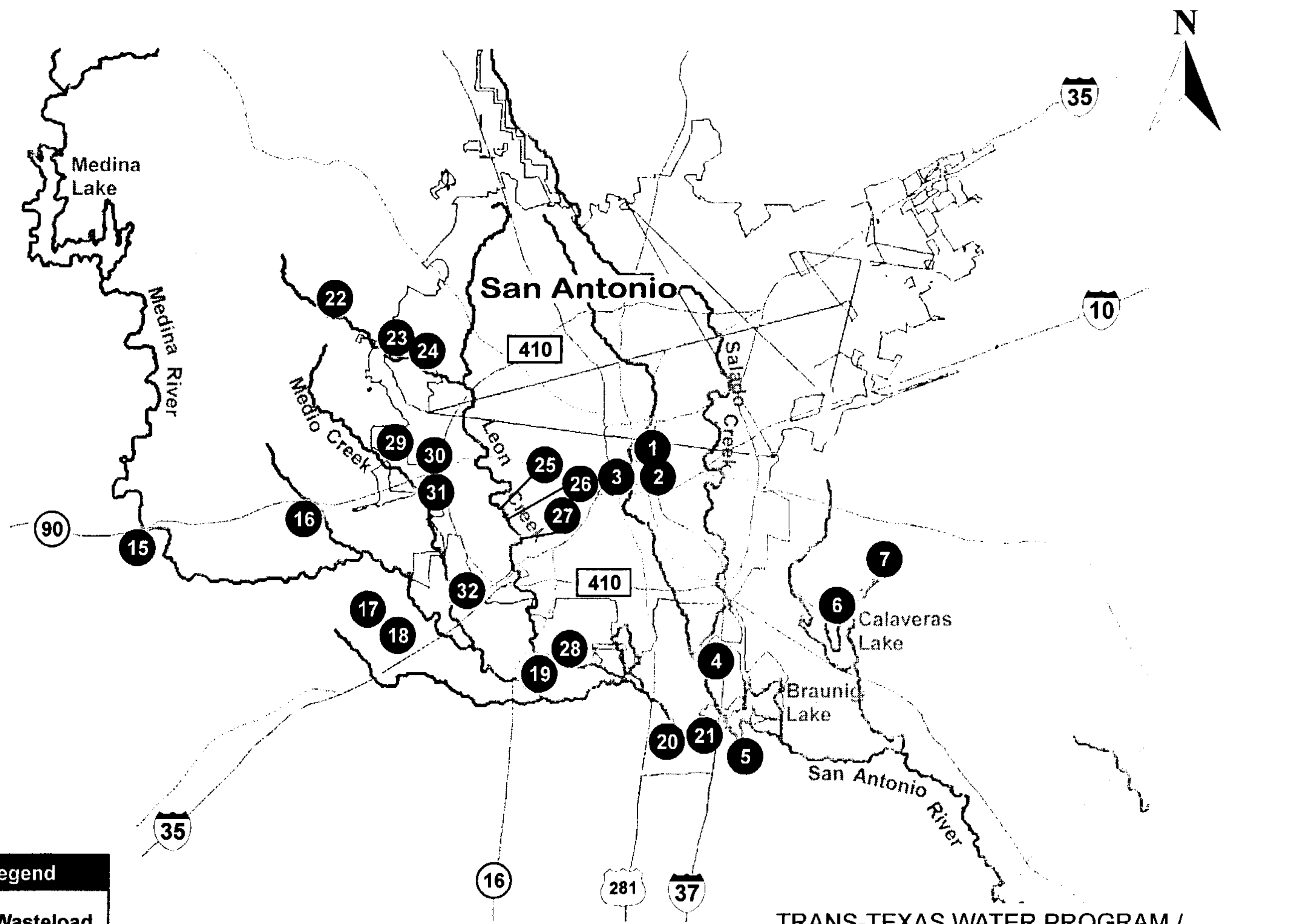
[42] Ibid.

show the location of the major discharges along the modeled river segments. Not all the permitted discharges are included in the model. Small intermittent discharges and permitted stormwater outfalls have been neglected by assuming that the model is simulating critical periods of low-flow with negligible rainfall. This assumption also precludes modeling any non-point source pollution associated with runoff events in the basin.

Table 2-10 shows the wastewater discharge quantities and effluent qualities for the wastewater treatment plant outfalls included in the model. The wasteload information is based on permitted values when available. If permitted concentrations were not available, they were established based on available data or assumed based on the procedures outlined in Table 2-4. Of the 307 mgd in permitted discharges, 75 percent is from municipal treatment plants, 24 percent is from private or industrial outfalls, and 1 percent of the volume is from permits granted to the federal government to operate the U.S. Air Force bases located throughout the San Antonio area.

The most significant changes to the permitted municipal wasteloads were the recent retirement of the Rilling Road WWTP and the institution of advanced treatment at the three other major San Antonio WWTPs (Dos Rios, Leon Creek, and Salado Creek).[43] The retirement of the Rilling Road WTTP and the opening of the Dos Rios WWTP with a more advanced treatment processes had a tremendous positive impact on effluent quality. Table 2-11 shows a snapshot comparison of the effluent quality in terms of BOD for the two plants during two comparable periods of low flow. Although other oxygen demanding materials, such as ammonia, were not reported, it is safe to assume that the Dos Rios WWTP effluent has significantly less oxygen consumptive power than the effluent that was being discharged from Rilling Road WWTP.

[43] Texas Natural Resource Conservation Commission, "The State of Texas Water Quality Inventory, 13th Edition, Vol. 3." SFR-50. Austin, TX. 1996



Legend

18 **Wasteload (Identification in Table 2-10)**

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WASTE OUTFALL LOCATIONS AROUND THE CITY OF SAN ANTONIO

FIGURE 2-45

98-16

Table 2-10
Permitted Discharges in the San Antonio River Basin QUAL-TX Model

Map ID	Permit No.	Permittee	Permitted Discharge (MGD)	Average Daily Wasteload Concentrations (mg/L)[1] Maximum: BOD5	Maximum: Organic Nitrogen	Maximum: Ammonia	Maximum: Nitrite +Nitrate	Minimum: Dissolved Oxygen
Upper San Antonio River								
1	01513-001	City Public Service of San Antonio	0.50	0.0	0.0	0.0	0.5	5.0
2	02933-001	Pioneer Concrete of Texas	0.0009	0.0	0.0	0.0	0.5	5.0
3	00968-000	Union Stock Yards	0.68	22.6	0.0	0.0	0.5	5.0
4	10137-008	SAWS - Salado Creek WWTP	46.00	10.0	2.0	5.0	16.0	4.0
5	13162-001	Koppe Corporation	0.113	10.0	3.0	15.0	2.0	4.0
6	01514-010	City Public Service of San Antonio	0.02	20.0	0.0	0.0	0.5	5.0
7	103701-001	East Central ISD	0.06	20.0	4.0	15.0	1.0	4.0
8	10085-001	City of Floresville	0.71	20.0	4.0	15.0	1.0	2.0
Lower San Antonio River								
9	03940-001	Aquatic Bioenhancements	15.00	20.0	4.0	12.0	4.0	2.0
10	10398-001	Falls City	0.07	30.0	11.0	8.0	1.0	4.0
11	10352-001	Karnes City	0.41	30.0	11.0	8.0	1.0	4.0
12	10746-001	City of Kenedy	0.83	20.0	4.0	12.0	4.0	5.0
13	10352-002	Karnes City	0.09	30.0	11.0	8.0	1.0	4.0
14	10458-001	City of Goliad	0.30	20.0	4.0	15.0	1.0	2.0
Medina River								
15	10952-001	Castroville	0.40	10.0	4.0	12.0	4.0	4.0
16	10137-038	Air Force Village	0.12	10.0	4.0	12.0	4.0	4.0
17	03025-002	San Antonio Industrial WWTP	0.47	0.0	0.1	25.2	0.5	5.0
18		Catfish Farm[2]	55.0	6.0	0.5	1.0	0.5	5.0
19	11822-001	City of Somerset	0.18	20.0	4.0	12.0	4.0	3.0
20	10137-039	SAWS- Southside ISD	0.06	20.0	4.0	12.0	4.0	2.0
21	103701-033	SAWS - Dos Rios WWTP	125.0	5.0	1.0	2.0	17.0	6.0
Leon Creek								
22	11647-001	San Antonio MUD #1	1.0	10.0	3.0	2.0	15.0	4.0
23	10137-042	SAWS - Culebra Creek	1.0	10.0	3.0	2.0	15.0	4.0
24	10137-036	SAWS - Northside ISD	0.064	20.0	4.0	15.0	1.0	2.0
25	02356-008	USAF - Kelly	1.0	0.0	0.0	0.0	0.5	5.0

Table 2-10
Permitted Discharges in the San Antonio River Basin QUAL-TX Model (Concluded)

				Average Daily Wasteload Concentrations (mg/L)[1]				
				Maximum				Minimum
Map ID	Permit No.	Permittee	Permitted Discharge (MGD)	BOD5	Organic Nitrogen	Ammonia	Nitrite +Nitrate	Dissolved Oxygen
26	02356-001	USAF - Kelly	2.0	10.0	0.0	2.1	0.5	5.0
27	01517-001	City Public Service of San Antonio	1.0	0.0	0.0	0.0	0.5	5.0
28	10137-003	SAWS - Leon Creek WWTP	46.0	7.0	2.0	2.0	16.0	5.0
Medio Creek								
29	10137-041	SAWS - Bear Creek WCID	0.50	20.0	2.0	3.0	15.0	4.0
30	10137-040	SAWS - Medio Creek WWTP	6.5	10.0	2.0	3.0	15.0	4.0
31	12033-001	USAF - Lackland	0.3	23.0	2.0	3.0	15.0	4.0
32	02635-001	San Antonio Southwest Industrial	0.15	23.0	0.0	15.0	0.5	5.0

[1] Wasteloads based on 1997 permit values when available and assumed based on TNRCC formulas if not included in permits.

[2] Catfish Farm is currently applying for a wastewater permit from TNRCC. Wasteload information based on data obtained from TNRCC.

Table 2-11 Comparison of Dos Rios and Rilling Road Effluent Qualities		
Parameter	**Rilling Road**[1]	**Dos Rios**[2]
Permitted Discharge (MGD)	94.0	83.0
Reported Discharge (MGD)	76.5	60.5
Percent Capacity	81.4%	72.9%
BOD_5 (mg/l)	60.0	2.0

[1] Data based on monthly self-reporting data reported to the Texas Department of Water Resources for June, 1983 operations.

[2] Data based on monthly self-reporting data reported to the Texas Natural Resources Conservation Commission for June, 1994 operations.

2.3.3 Model Application

The San Antonio River model was applied to study the potential impacts of direct diversions at Falls City or Goliad on dissolved oxygen levels. Five wasteload scenarios were considered to find the flow requirements necessary to maintain dissolved oxygen levels above the standard of 5.0 mg/l (see Table 2-1). The first two wasteload scenarios consider existing permitted conditions, and the other three analyze projected wasteload scenarios for the year 2030. In each scenario, wasteloads were discharged into the idealized 7Q2 baseflow conditions described herein. Then water was diverted from either Falls City or Goliad until the dissolved oxygen levels downstream of the diversion point fell below the stream standard.

As discussed in Section 2.1.2, reaeration rates in all the scenario evaluations were fixed at the baseline rate. This conservative approach was used although the Texas Reaeration Equation can exhibit increasing reaeration with decreasing discharge.[44] The results of the analyses are discharge versus dissolved oxygen curves for each wasteload scenario at each diversion location. Under the scenarios evaluated in this study, the magnitude of WWTP discharges is such that the total flow is well above the published 7Q2 values shown in Table 2-9. The published 7Q2 values are based on actual gaged flows which include treated effluent. The wastewater discharges in this modeling effort were added to the naturalized or "modeled" 7Q2 flows of Table 2-9. Thus, they represent the largest potential contributions that wasteloads could have to the total flow.

Figure 2-46 displays the flow composition at two diversion points in terms of natural flows and maximum allowable flows which are possible under current (August 1997) permits.

Figure 2-46 displays the flow composition at two diversion points in terms of natural flows and maximum allowable flows which are possible under current (August 1997) permits. Also displayed for comparison are the average return flows reported by the major municipal dischargers in 1990 stacked on the modeled baseflow. As shown, the total permitted flows at each location are almost three times greater than the published 7Q2 values and result in flows that are 81 percent and 74 percent effluent at Falls City and Goliad, respectively. By comparison, the 1990 return flows would result in flows that are only 75 percent and 66 percent effluent at the two respective locations.

2.3.3.1 Existing Conditions

Two wasteload scenarios were considered under the existing permitted condition. The first scenario uses wasteloads fixed at the their maximum permitted volumes and at their allowable concentrations. Without any diversion, the results of this scenario are basically those of the model obtained from TNRCC wasteload evaluation[45] and it is considered the baseline scenario.

The second scenario explores the impact that effluent quality has on the flow versus dissolved oxygen relationships by modeling Dos Rios WWTP at recently observed effluent qualities. The recently observed effluent qualities at the Dos Rios WWTP were derived from the monthly self-reporting data submitted by the San Antonio Water System to TNRCC since the permit was upgraded from 83 mgd to 125 mgd in August of 1995. This monthly data can be found in Appendix E. Table 2-12 compares the permitted wasteload concentrations to those recently observed at the plant. Differences in effluent quality at Dos Rios WWTP include a 13 percent increase in dissolved oxygen and a 70 percent reduction in oxygen consuming material (assuming that all wastes are completely assimilated to their final inorganic forms).

[45] Texas Water Commission. "Waste Load Evaluation for the San Antonio River System in the San Antonio River Basin." TWC Rep. WLE 89-01. Texas Water Commission: Austin, TX. 1989.

Table 2-12
Observed Versus Permitted Effluent Concentrations at Dos Rios WWTP

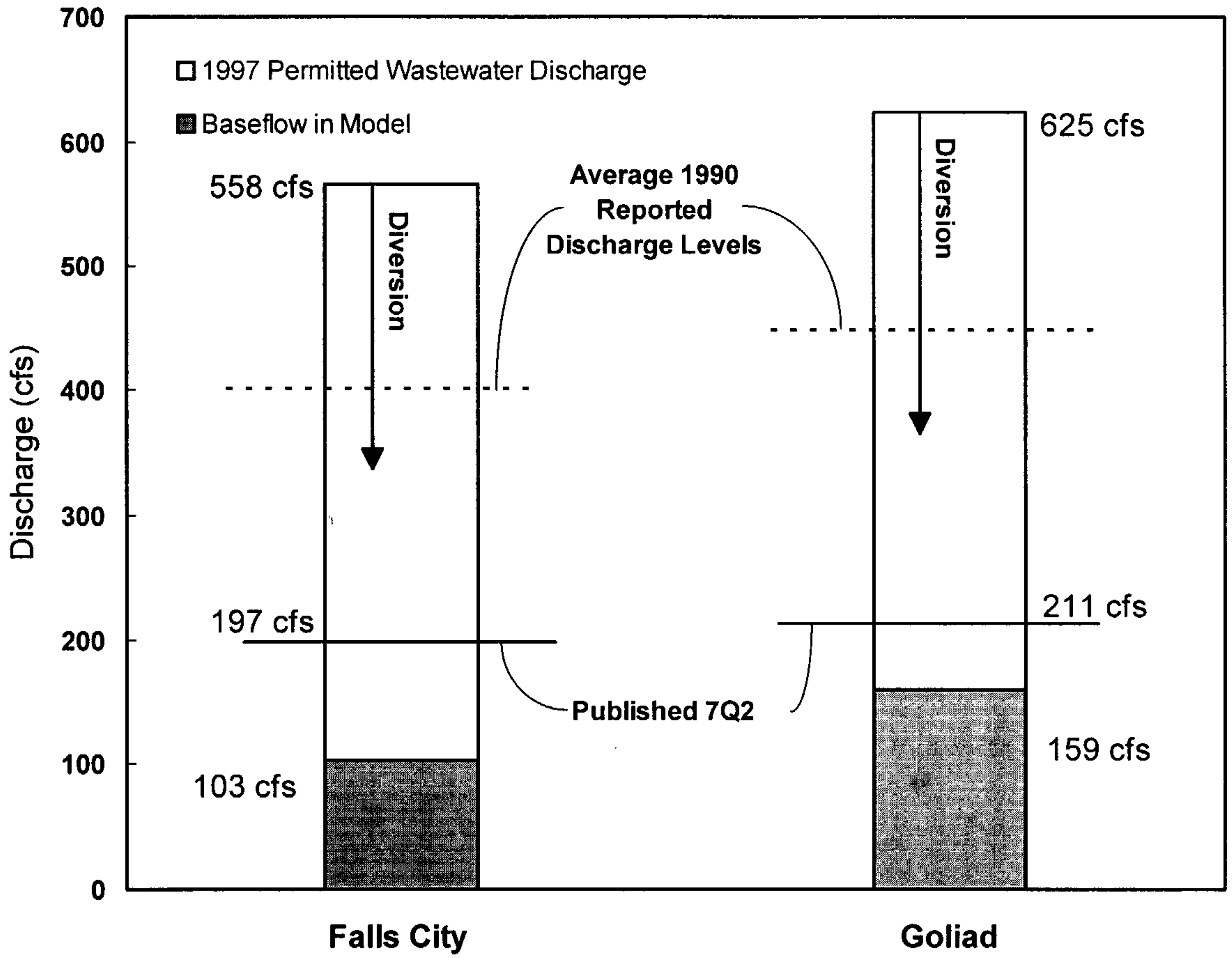
	Wasteload Concentrations (mg/l)			
	Dissolved Oxygen	**BOD**	**Organic Nitrogen[1]**	**Ammonia**
Permitted Quality	6.00	5.00	2.00	2.00
Observed Quality[2]	6.80	2.00	0.50	0.19
% Increase (Reduction)	13%	(60%)	(75%)	(91%)

[1]Organic nitrogen concentration is not included in the permit or self-reporting data. Values are assumed based on the level of treatment required and observed discharge for Ammonia.

[2] Observed data based on monthly self-reporting data reported to the TNRCC for operations between Aug. 1995 to Aug. 1997.

Figure 2-47 displays the dissolved oxygen profiles generated by the QUAL-TX model for the wasteload scenarios without any diversions. The two profiles for the existing conditions are identical in the upper portions of the San Antonio River. From the headwaters, the dissolved oxygen trends away from saturation until it undergoes a sharp decrease due to the Salado Creek WWTP outfall and then rebounds immediately after being reaerated by the fall over Otillo Dam. Below the dam, the sag continues downward to the confluence with the Medina River. At this point the profiles start to reflect the differences in quality at the Dos Rios WWTP.

As shown in Figure 2-45, the Dos Rios WWTP is located on the Medina River just upstream of the confluence with the San Antonio River. The D.O. profile representing the fully permitted volumes and qualities starts to stabilize and increases due the reaeration impacts of Braunig Diversion Dam and then steadily falls until it reaches a minimum of 4.89 mg/l near Floresville. After Floresville, the sag begins slow recovery until it increases sharply due to the reaeration caused by Mills Falls just upstream of Falls City. After this, the D.O. level steadily approaches saturation until it discharges into the Guadalupe River. The profile with the Dos Rios WWTP at observed qualities exhibits the same basic characteristics as the baseline profile except that the magnitude of the sag is not nearly as pronounced and only reaches a minimum of 5.84 mg/l. The profiles clearly indicate the significance that treatment levels have on the assimilative response of the river to wasteloads.



TRANS TEXAS WATER PROGRAM /
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FLOW COMPOSITION AT DIVERSION SITES ON THE SAN ANTONIO RIVER

FIGURE 2-46

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ENVIRONMENTAL CRITERIA REFINEMENT

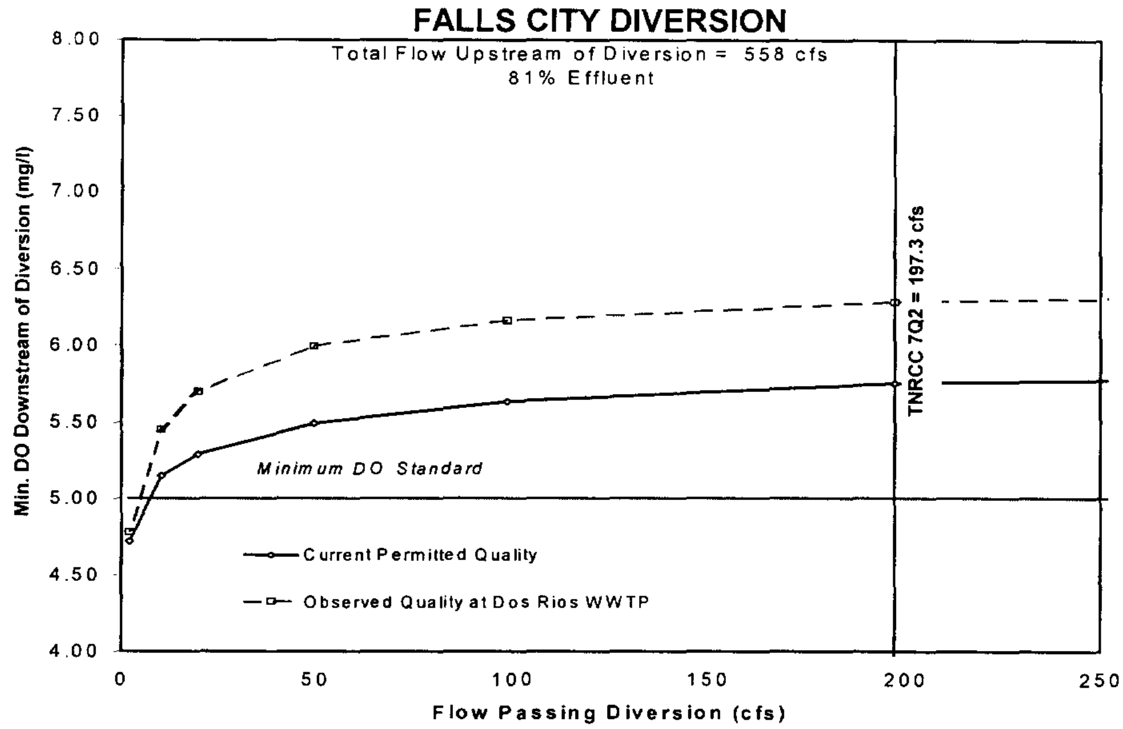
values of their existing permits. This resulted in a 10 percent increase in oxygen consuming wasteloads at the four WWTP's as compared to the baseline 1997 conditions. The second scenario changed the effluent standards at all four San Antonio WWTPs to the existing permitted effluent quality at the Dos Rios WWTP. This results in a 10 percent reduction in the oxygen consuming material at the WWTPs. The third scenario significantly improved the wasteload quality by setting all four of the San Antonio wastewater treatment plant discharges to the levels of quality recently observed at the Dos Rios Plant. This reduced the material available to consume oxygen at the WWTPs by 72 percent compared to the 1997 baseline conditions.

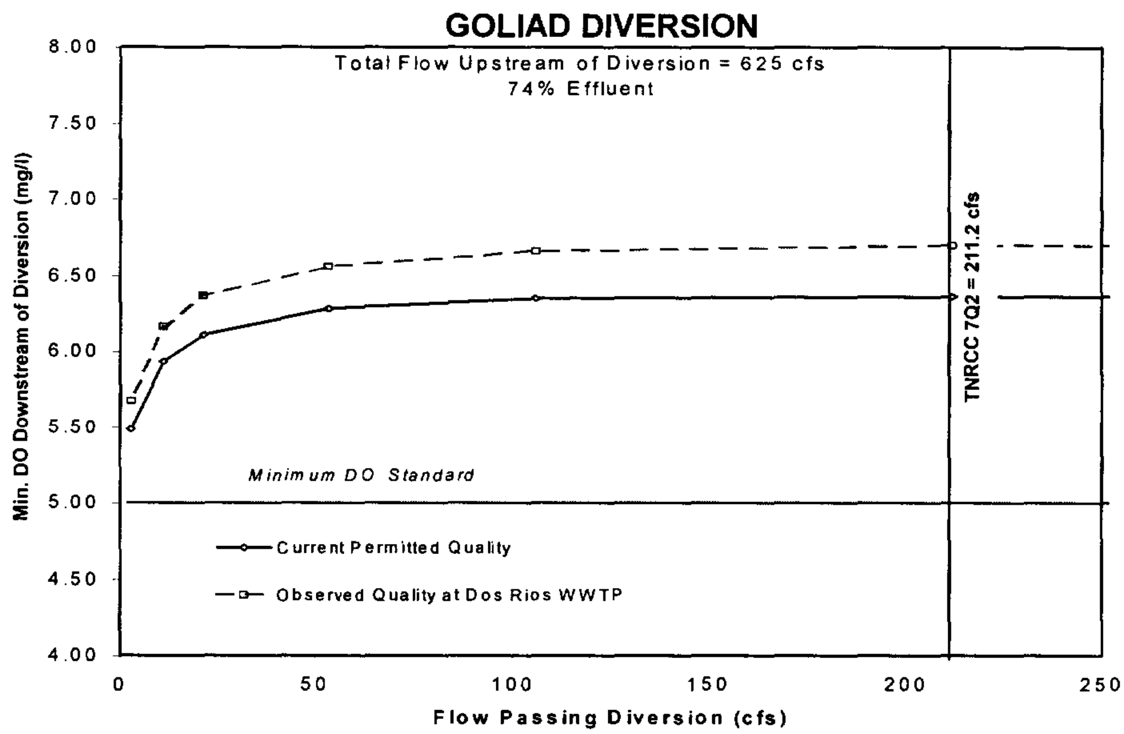
Figure 2-47 displays the dissolved oxygen profiles generated by the QUAL-TX San Antonio River model for the three 2030 scenarios without any diversions. At the future discharge volumes, the existing permitted quality and the Dos Rios permitted quality profiles reach respective minimums of 4.82 mg/l and 5.10 mg/l at Floresville. This is the same general behavior as the profiles for the existing conditions. The third profile, based on recently observed effluent quality at Dos Rios WWTP, shows a considerably different response. After the minimum just before Otillo Dam, the D.O. sag curve reaches a minimum of 6.70 mg/l just upstream of the confluence with the Medina River and continues to improve towards D.O. saturation all the way down to the Guadalupe River.

2.3.4 Summary of San Antonio River Results

Figures 2-48 and 2-49 present streamflow versus D.O. curves for potential diversion points at Falls City and Goliad for existing and future loading conditions. As expected, the scenarios with higher treatment levels have correspondingly higher dissolved oxygen minima. For the scenarios with a diversion at Falls City, the dissolved oxygen concentrations remain above the 5.0 mg/l criterion until remaining instream flow falls below 10 cfs. The flat shape of the curves above 50 cfs indicates a lack of sensitivity to streamflows well below the published 7Q2 value. Between 50 cfs and 25 cfs, the gaps between the curves narrow as the curves begin a sharp descent towards the D.O. criteria.

Figure 2-50 displays the impact that diversions at Falls City have on the dissolved oxygen profiles predicted by the San Antonio River model. As flows decrease, the D.O. profile separates into three separate sags. The first sag is just downstream of the diversion itself. The second sag





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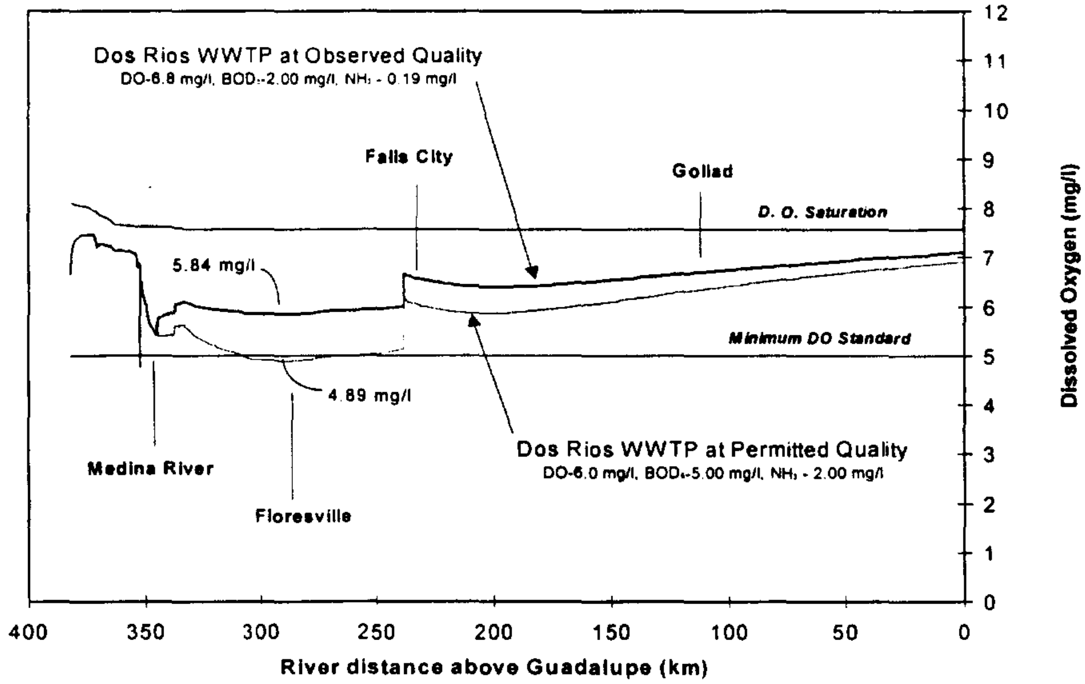
WEST CENTRAL STUDY AREA

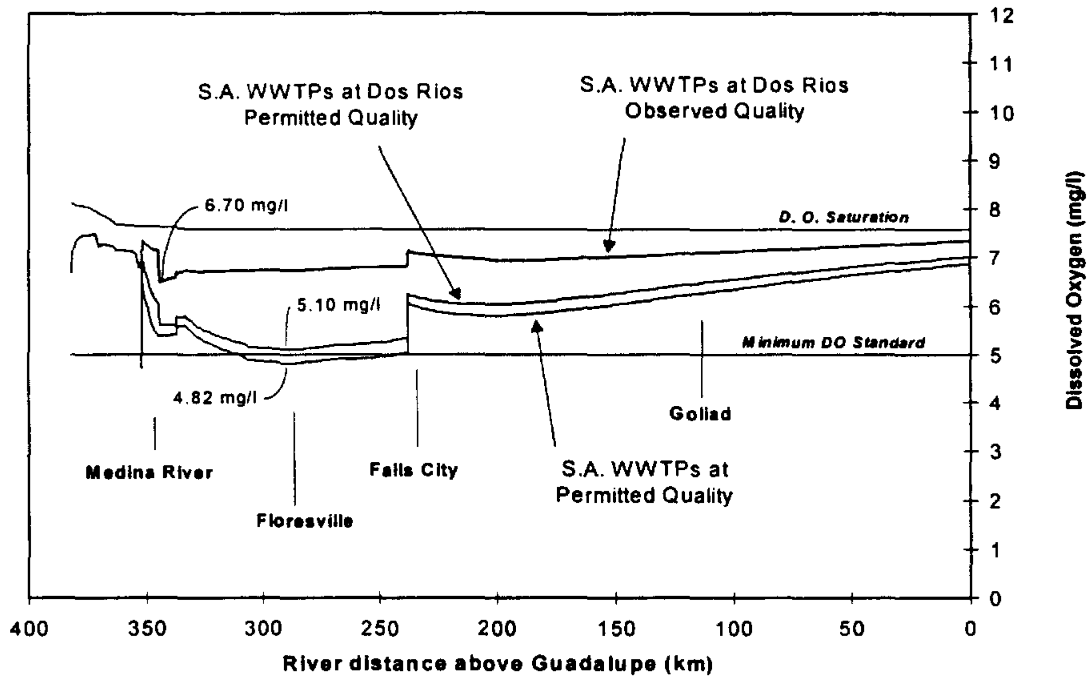
MINIMUM DISSOLVED OXYGEN VS. DISCHARGE - EXISTING CONDITIONS

FIGURE 2-48

1997 CONDITIONS



2030 CONDITIONS



GUADALUPE - SAN ANTONIO RIVER BASIN
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SAN ANTONIO RIVER DISSOLVED OXYGEN PROFILES NO DIVERSIONS

FIGURE 2-47

2.3.3.2 Future Conditions

The future wasteload scenarios considered three different treatment levels at the four major San Antonio WWTPs (Dos Rios, Leon Creek, Salado Creek, and Medio Creek) and wastewater volumes projected to the year 2030. All other permitted wastewater discharges were held at their existing permitted volumes. Treated effluent volumes were derived by multiplying current per capita discharge volume by the projected 2030 population. A per capita volume of 103 gallons/person/day was calculated based on 1990 return flows and 1990 census information for the San Antonio metropolitan area, and the projected 2030 population increased return flows from 120 mgd (1990) to 253 mgd (2030) at the four WWTPs.[46,47] To account for future conservation and consumptive reuse initiatives expected in and around the City of San Antonio, Leon Creek and Salado Creek WWTPs projected discharge volumes were reduced by a total of 41,000 acft/yr.[48]

Table 2-13 compares the 1997 permitted wasteload volumes to those projected for the year 2030 at the four major San Antonio WWTPs.

Table 2-13
San Antonio WWTPs Existing and Projected Effluent Volumes

WWTP	1997 Permitted Volume[1] (MGD)	2030 Projected Volume (MGD)
Dos Rios	125.0	141.8
Leon Creek	46.0	50.3[2]
Salado Creek	46.0	50.3[2]
Medio Creek	6.5	7.4
Total	223.5	249.8

[1]Wastewater permits filed with TNRCC.
[2]Based on a 41,000 acft/yr reduction in flow at Leon Creek and Salado Creek WWTPs due to projected conservation and reuse initiatives.

For the projected volumes shown in Table 2-13, three different treatment levels at the WTTPs were evaluated. The first scenario set all discharge effluent concentrations at the maximum

[46] Self-Reporting data submitted to Texas Water Commission (1990).
[47] HDR Engineering, Inc. (1998) "Population, Water Demand, and Water Supply Projections." Trans-Texas Water Program, West Central Study Area - Phase 2.
[48] Reuse volume (41,000 acft/yr) supplied by San Antonio Water System.

starts to appear at low San Antonio River flows, such that the flow and background wasteload from Cibolo Creek starts to dominate. The third sag develops due to the decreasing flow available to assimilate the wasteload from the City of Goliad's WWTP.

These three sags are directly related to the increasing diversion because this reduces streamflow velocity. Lower streamflow velocities provide more residence time for the wasteload to decay in the reaches immediately downstream of WWTP outfalls or the diversion site, hence a larger reduction in dissolved oxygen. The profiles also show that D.O. becomes much more sensitive to streamflow at the lower flow regimes by displaying multiple sags and large fluctuations.

The streamflow versus D.O. curves for scenarios with a diversion at Goliad are also shown in Figures 2-48 and 2-49. They exhibit the same general characteristics as the Falls City diversion except that the minimum dissolved oxygen concentrations never fall below the criterion for the diversions considered. Diversion were made until only 1 percent of the published 7Q2 remained instream.

Table 2-14 summarizes the results of each scenario with diversions at Falls City and Goliad. Although the flows can be reduced to below 10 cfs at Falls City and to less than one percent of the published 7Q2 at Goliad, it is unrealistic to expect streamflows to ever reach these levels due either to diversion or natural weather patterns. Although simulated dissolved oxygen levels exceed the standard under extremely low flows, the overall health of the aquatic community could still be impaired at such low flows due to other biological constraints.

Table 2-14
Streamflow At Minimum Allowable Dissolved Oxygen In San Antonio River For Diversion Scenarios

Scenario	Streamflow (cfs) Falls City	Streamflow (cfs) Goliad[3]
1997 Conditions[1]		
Permitted Quality	7.33	2.11
Dos Rios at Observed Quality	4.71	2.11
2030 Conditions[2]		
Permitted Quality	8.30	2.11
S.A. WWTPs at Permitted Dos Rios Quality	5.93	2.11
S.A. WWTPs at Observed Dos Rios Quality	3.43	2.11

[1] All permitted discharge at full permitted volumes
[2] San Antonio WWTPs a projected volumes.
[3] Dissolved Oxygen levels did not fall below criteria. Minimum flow considered to be 1% of 7Q2 (211.2 cfs) at Goliad.

2.4 Synthesis of the Zone 3 Refinement Process

For the Guadalupe River, the results of the constructed QUAL-TX model show that flows far below the naturalized 7Q2 would be sufficient to assimilate wasteloads under either currently permitted conditions or future conditions. Table 2-15 summarizes the results of the analyses on the Guadalupe River. For example, under current permitted conditions for all wastewater discharges, a streamflow of 222 cfs (55% of the naturalized 7Q2, 371 cfs, plus 18 cfs of upstream wastewater discharges) would be sufficient to keep D.O. levels at or above the 5.0 mg/l standard downstream of Lake Dunlap. For the reaches below Cuero, a streamflow of 317 cfs (53% of the naturalized 7Q2, 540 cfs, plus 30 cfs of wastewater) would be similarly sufficient for D.O. maintenance.

Table 2-15
Summary of Minimum Flows Necessary to Maintain D.O. above 5.0 mg/l for Two Locations on the Guadalupe River

	Lake Dunlap flows (cfs) [7Q2 – 371]				Cuero flows (cfs) [7Q2 = 540]			
Scenario	Waste-water flow	total flow	min. for D.O. maint'c. downst.	Δ	Waste-water flow	total flow	min. for D.O. maint'c. downst.	Δ
Current (1997) Permit	17.9	388.9	222	185	30.3	570.7	317	284
Future V: 2030 WW volume, 1997 quality	18.2	389.2	285	122	30.1	570.5	300	300
Future VQ: 2030 WW volume improved quality	18.2	389.2	92	315	30.1	570.5	181	419

In the San Antonio River analysis, the amount of reduction in the baseflow (naturalized 7Q2), is of limited significance because of the small contribution baseflow makes to the total flow when all permitted wastewater discharges are at their fully permitted volumes. Therefore, the results for the San Antonio River are not presented in terms of reduction in naturalized 7Q2 as done in the analysis of the baseflow-dominated Guadalupe River.

The results of the San Antonio River analysis show that large volumes of water can be diverted at Falls City and Goliad while maintaining dissolved oxygen levels above the TNRCC's standard. It is important to note that the magnitude of these possible diversions are the result of the diversion site's location relative to the point of minimum dissolved oxygen in the river and relative to the major dischargers in the basin. These large potential diversions do not indicate that TNRCC has been too restrictive in reviewing and approving wastewater permits on the San Antonio River. As in the original model obtained from TNRCC, the sag curve for the conditions modeled in this study reaches a minimum near 5.0 mg/l in the vicinity of Floresville under fully permitted flows and critical flow conditions. This indicates that TNRCC has properly approved wastewater permits so that the river's D.O. levels reach their allowable minimums under the maximum allowable waste loads and at the prescribed critical low-flows, 7Q2. Since potential diversion sites at Falls City and Goliad are well downstream of the minimum point, and there are not major discharges downstream of Floresville, the river has assimilated a majority of the oxygen-consuming material supplied by the outfalls in and near the City of San Antonio by the time it reaches these locations. As a result, larger reductions in flow at these sites are possible than would be if the diversions were closer to the major sources of waste. In other words, a diversion site closer to Floresville would require more water to maintain the stream standard than that needed at Falls City and Goliad. A diversion site upstream of Floresville would yield no water under current permit conditions since it is already at the dissolved oxygen standard. Therefore, in the San Antonio analysis, the selection of the diversion sites for this study was based on the results of the wasteload allocation performed by TNRCC in their permit approval process.

Another key element of the San Antonio River analysis is the impact that the effluent quality at the major municipal treatment plants in the City of San Antonio area have on the downstream dissolved oxygen profile. Improved quality at the WWTPs translates to increased D.O. levels and an environment more resistant to changes in instream flows and waste volumes.

3.0 BIOLOGICAL STUDIES

As part of the State water planning process, an interagency (Texas Water Development Board, Texas Parks and Wildlife Department, Texas Natural Resource Conservation Commission) team of scientists specializing in aquatic biology and instream flow issues have developed a set of water resource project planning guidelines. These guidelines include criteria that were intended to provide environmental streamflow requirements which would be protective of lotic biological resources. The guidelines were to be used when evaluating the cost and water yield of potential water supply projects within the Trans-Texas Water Program. However, as alternative water supply projects for the South Central and West Central Study Areas began to be analyzed, it became plain that the original instream flow criteria (Lyons method), based on a 1978 Texas Parks and Wildlife Department publication, severely limited the firm yield (the water available during the most severe drought on record) of direct diversion projects, including those with substantial off-channel storage.[1] Simply stated, water supply alternatives are evaluated on the basis of unit production costs (including land, construction, operation, energy and environmental costs) of firm yield, and the regulatory constraints on direct diversion, coupled with the practical limits on pumping rates, resulted in direct diversion projects with unit firm yield costs that are high relative to similarly sized reservoir projects.

Partially in response to the evident favoring of water supply alternatives that included construction of mainstem storage reservoirs, the "consensus" planning methods and guidelines were developed and approved as planning criteria by State of Texas water and environmental resource agencies, although the Texas Natural Resource Conservation Commission has initiated a process of accepting Consensus Criteria as permitting defaults only recently, and only for small projects. The Consensus Criteria were developed to incorporate seven basic ideas: mimic natural hydrology, mimic historical daily flux of streamflows, ramp diversion rates, maintain channels, maintain water quality standards, involve drought contingency, and account for regionalization.[2]

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[1] Lyons, B.W. "Existing reservoir and stream management recommendations, statewide minimum streamflow recommendations." Federal Aid Project F-30-R-4. Texas Parks and Wildlife Department, Austin, Texas. 1979.
[2] Texas Water Development Board. "Water for Texas Today and Tomorrow: a consensus-based update to the State Water Plan. Volume II, Technical Planning Appendix." Texas Water Development Board, Austin, Texas. 1997.

The instream flow guidelines embodied in the Consensus Criteria, the Lyons Method, and its forebearer, Tennant's Method, were designed as responses to the effects of mainstem reservoirs on downstream water quality and biological communities.[3,4] Although expressed in terms of streamflow and providing some drought yield when combined with appropriately sized off-channel storage, the Consensus Criteria for new direct diversion projects also come from this viewpoint, as exemplified by at least the first five of the seven basic ideas listed above.[5]

Stream impoundment is widely recognized to result in key environmental changes within the impounded stream valley (reduced mixing energy, increased depth) that interact to produce a cascade of effects within and downstream of any newly constructed reservoir. Mainstem (on-channel) reservoirs typically result in more frequent and longer periods of low flow, reductions in the frequency and intensity of flood events necessary for channel maintenance and "resetting" of the biological community because of increased valley storage, interference with the movements of migratory species, and altered temperature, dissolved oxygen, nutrient, and seasonal flow regimes in downstream reaches as a result of the physical consequences of obstructing the stream valley and impounding water. Direct diversion projects, because of the absence of an on-channel storage impoundment and a limited rate of storage, generally result in an annual hydrograph nearly indistinguishable from the natural (or without project) streamflow regimes except when the diversion becomes large relative to ambient discharge in the lowest flow ranges. Such direct diversion projects typically leave the characteristic short term fluctuations in streamflows unchanged, cannot cause the large, abrupt changes in streamflow typical of the spills and releases from large storage reservoirs, and do not involve impoundment-driven alterations of water quality.

The water storage capacity offered by a large reservoir project causes many of the problems that make instream flow requirements necessary, but it also makes compliance with those requirements possible while still providing a firm yield. In a reservoir, water capture and storage are essentially free and instantaneous, while a direct diversion is limited by the constraints of its pumping and transport system.

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[3]Tennant, D.L. "Instream flow regimens for fish, wildlife, recreation and related environmental resources." Fisheries 1(4):6-10. 1976.
[4]Lyons, B.W. 1979. Op Cit.
[5]Texas Water Development Board. 1997. Op Cit.

Because off-channel storage available to direct diversion projects may be limited, the ability to continue diversion over a wider range of hydrologic conditions, even if those diversions are restricted to amounts less than the maximum rate, may be very important to the feasibility of a diversion project.

The following sections examine the streamflow requirements of the Consensus Criteria as they would be applied to the lower San Antonio and Guadalupe Rivers with respect to the level of environmental protection they appear to afford the affected reach(es). The evaluation is accomplished using recently collected regional data and information obtained in warm-water streams across the southern US to characterize the stream biota at risk, and delineate the types, abundance and distribution of aquatic habitats as a function of streamflow. This analysis is then used to examine possible modifications to the Consensus Criteria that could enhance yields of diversion projects in the lower Guadalupe or San Antonio Rivers while still providing sufficient water to maintain downstream aquatic communities.

3.1 Lotic Environments of the Lower San Antonio and Guadalupe Basins

The Guadalupe River Basin was chosen as the focus of this effort because of our greater familiarity with that river, the availability of hydrologic, physiographic and biological data sets for analysis, and the observed similarity of macrohabitat and hydrologic characteristics in the lower Guadalupe River at Victoria and in the lower San Marcos River. The recently completed hydrodynamic modeling and biological study on the San Marcos River offers the opportunity to compare the Consensus Criteria to actual flow-habitat relationships observed in a stream in the basin, and to extend those results to other reaches on the basis of the macrohabitat and biological similarities. Other reaches of the Guadalupe River, and much of the San Antonio River have not been surveyed by the author, so assessments of macrohabitats and their hydrologic relationships are based on limited available information.

3.1.1 Regional Setting

The San Antonio River originally arose from an Edwards Aquifer spring complex located in the vicinity of what is now Brackenridge Park in the City of San Antonio, but now originates primarily in well pumpage, with only remnant spring flows. Both the hydrology and water quality of the San Antonio River are profoundly influenced by wastewater flows from the City of San Antonio.

The San Antonio River flows in a southeasterly direction, meandering through the ecotone between the more mesic Blackland Prairie and East Central Texas Plains (Post Oak Savanna) to the north and the relatively arid Southern Texas Plains to the south before entering the Gulf Prairies and Marshes Ecoregion where it joins the Guadalupe River near its mouth on San Antonio Bay. Below its confluence with the Medina River in southern Bexar County, the San Antonio River consists predominantly of slow run macrohabitat, with occasional pool and riffle habitats generally present in association with log jams and accumulations of woody debris. Substrates are reported to consist primarily of muds and sands. True (rocky) riffles and associated pool habitats are present in the vicinity of Falls City and downstream, where the river crosses narrow outcrops of resistant rock, but most of the pools are separated by shallow, sandy runs.[6] Whiteside et al reported channel morphology to be relatively uniform in a 54 kilometer (33.6 mile) reach in Goliad County (the proposed Goliad Reservoir site), where stream widths ranged from 24.0 to 30.0 meters (79 to 98 feet), and water depths of 1.5 to 2.0 meters (4.9 to 6.6 feet) were observed at seven sample locations.[7] Macrohabitats at all locations consisted of runs and pools floored by sandy or muddy substrates with large amounts of woody debris occurring as log jams and marginal snags. These observations were made during the period November 1992 through April 1993 at various streamflow levels.

Sampling in Cibolo Creek showed that habitats with cobble and bedrock slab substrate areas occur in that stream, particularly in the reach from the vicinity of Falls City to its confluence with the San Antonio River. While the sample reaches consisted primarily of runs and pools, riffle areas were commonly present. Both Cibolo Creek and the San Antonio River cross the Whitsett formation in this area, resulting in local increases in bed slope and substrate particle size where the more resistant sandstone strata of this formation are encountered.

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[6]Kuehne, R.A. "Stream Surveys of the Guadalupe and San Antonio Rivers." Texas Game and Fish Commission, Austin, Texas. 1955.

[7]Whiteside, B.G., T.L. Arsuffi, L Larralde, D. Solanik, and J. Peterson. "An aquatic inventory of the proposed Cobolo and Goliad reservoir sites, fishes and benthic macroinvertebrates." Final Report to Texas Parks and Wildlife Department, Austin. Contract Number (92-93) 1071. 1993.

The Guadalupe River originates in springs in southwestern Kerr County. It flows in a southeasterly direction 421 river miles through the Edwards Plateau, Blackland Prairie, East Central Texas Plains (Post Oak Savanna), and Gulf Prairies and Marshes Ecoregions to its mouth in the Guadalupe Estuary. The Guadalupe River and its major tributaries, the San Marcos River (of which The Blanco River and Plum Creek are tributaries), Peach, Coleto, and Sandies Creeks, and the San Antonio River. The Guadalupe and San Antonio Rivers join just above the Saltwater Barrier and the Guadalupe Estuary, draining a total of approximately 10,130 miles.[8,9]

The Guadalupe River is extensively impounded in the Blackland Prairie reach, and little lotic habitat exists between New Braunfels and Seguin, a reach that would correspond to the high gradient, riffle-pool reach of the San Marcos between Cummings and Staples Dams. East of Seguin, where the river enters the Post Oak Savanna, macrohabitats consist predominantly of long pools separated by short, gravel riffles. This reach corresponds to the intermediate reach of the San Marcos River extending from the vicinity of Staples Dam to Luling.[10] Rocky riffles and/or ledge-controlled pools may be present at locations where more resistant bedrock outcrops are crossed, but these areas are rare throughout the lower river.[11]

The San Marcos River joins the Guadalupe River at Gonzales in the Post Oak Savanna, about 120 river miles above its mouth in San Antonio Bay. The gradients of both rivers are low (<2 feet/mile, 0.38 m/km) at that point, and that of the Guadalupe continues to be low throughout its traverse of the coastal plain to its estuary. The San Marcos River below Luling (Caldwell County), and the reach of the Guadalupe River below Gonzales, are slightly entrenched into the sands and gravels of their respective floodplains. Both reaches are dominated by run and pool macrohabitats, steep, erodable banks, and silty sand substrates containing variable amounts of gravel and cobble. The lack of rocky substrate and low gradients limit riffle habitat to gravel bar margins and concentrations of woody debris (snags and log jams). At flows as high as the

[8] Texas Department of Water Resources. "Guadalupe Estuary: A study of the influence of freshwater inflows." Texas Department of Water Resources, LP-107. Austin, Texas. 1980.
[9] Paul Price Associates, Inc. "Environmental Assessment The City of Victoria Water Rights Application." Paul Price Associates, Inc., Austin, Texas 1994.
[10] Paul Price Associates, Inc. "Instream Flow Study of the San Marcos River." Paul Price Associates, Inc., Austin, Texas. 1998
[11] Kuehne, R.A. "Stream Surveys of the Guadalupe and San Antonio Rivers." Texas Game and Fish Commission, Austin, Texas. 1955

median average daily discharge (202 cfs on the San Marcos River and 985 cfs at Victoria on the Guadalupe River), shallow riffle habitat is reduced relative to lower flows as emergent bars have been inundated. Highest current velocities at flows below the medians tend to occur at channel bends and in chutes where the larger gravel bars or log jams have narrowed the channel. It is assumed that similar habitats predominate in the lower reaches of the San Antonio River based on literature descriptions and limited personal experience on that river.

The Academy of Natural Sciences of Philadelphia collected water quality data from 1949 to 1989 on the lower Guadalupe River.[12] The group I parameters (alkalinity, dissolved oxygen, nitrate, total hardness, sulfate, calcium) increased from 1949 to 1987, showing positive flow dependence. The dependence was confirmed with USGS flow/chemistry data. The parameters are assumed to be washing into the drainage basin during rain events. In contrast, group II parameters (turbidity, chloride and conductance) decreased through the study period and fluctuated inversely to flow. The data indicate these parameters are either conservative or the result of point source discharges. Their source is consistent in the drainage basin, they dilute during rain events and they increase during low flow conditions. In summary, over the course of the study the general water quality of the Guadalupe River improved as shown by the increased dissolved oxygen and decreased turbidity. however, nitrates also increased implying more room for improvement.

3.1.2 Aquatic Biota

The fish species reported to be present in the Guadalupe and San Antonio River drainages are listed in Table 3-1. The fish assemblage reported for the San Antonio River is similar, although less speciose, to that of the lower Guadalupe River. Excluding marine and brackish species, endemic species restricted to the Comal and uppermost San Marcos Rivers, and those species that are primarily inhabitants of the Edwards Plateau region of the basins, 39 species comprise the freshwater fish community of the lower Guadalupe River, while that of the San Antonio River includes only 29 species.[13]

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[12] Academy of Natural Sciences of Philadelphia. "A Review of Chemical and Biological Studies on the Guadalupe River, Texas , 1949-1989." Report No. 91-9. Division of Environmental Research, Academy of Natural Sciences of Philadelphia, Philadelphia, Pennsylvania. 1991.
[13] Ibid.

Table 3-1
Freshwater Fish Species Reported From the Guadalupe and San Antonio River Basins

Family	Scientific Name	FS, HG Lentic	Plateau Species	Guadalupe River Lower[1,2]	Guadalupe River Upper[1,3,4]	Guadalupe River San Marcos[1,5,6]	San Antonio River Lower[1,7]	San Antonio River Cibolo Creek[1,7]
Lepisosteidae	Lepisosteus oculatus	HG-L		A	X	X	X	X
	Lepisosteus osseus	HG-L		A	X	X	X	
	Lepisosteus spatula	HG-L		X			X	
Anguillidae	Anguilla rostrata	HG-L		X		X	X	X
Clupeidae	Dorosoma cepedianum	HG-L		A	X	X	X	X
	Dorosoma petenense	HG-L		A			X	
Engraulidae	Anchoa mitchilli			X				
Cyprinidae	Campostoma anomalum	FS	plateau		X	X		X
	Campostoma ornatum	FS	plateau					X
	Carassius auratus	HG-L	exotic		X	X		
	Cyprinella lepida		plateau		X			
	Cyprinella lutrensis	HG-L		A	X	A	X	X
	Cyprinella venusta	HG-L		X	X	A	X	
	Cyprinis carpio	HG-L	exotic	X		X	X	X
	Dionda episcopa	HG-L	plateau		X	X		
	Dionda episcopa serena	HG-L	plateau					X
	Hybognathus placitus	HG-L	plateau		X			
	Macrhybopsis aestivalis	FS		X	X	A	X	X
	Notemigonus crysoleucas	HG-L		X	X	X	X	X
	Notropis amabilis	FS		X	X	X	X	
	Notropis amnis	HG-L	plateau		X			X
	Notropis atrocaudalis	HG	plateau		X			X
	Notropis blennius	HG		X			X	
	Notropis buchanani	HG-L		X	X		X	
	Notropis chalybaeus	HG-L		X		X		
	Notropis stramineus	HG-L	plateau		X			X
	Notropis texanus	HG-L	plateau		X			X
	Notropis volucellus	FS		X	X	A	X	X
	Opsopoeodus emiliae	HG-L		X			X	
	Pimephales promelas	HG-L	plateau		X		X	X
	Pimephales vigilax	HG-L		A	X	A	X	X
	Tinca tinca	L	exotic		X			
Catastomidae	Carpiodes carpio	HG-L		X	X	X	X	
	Erimyzon oblongatus	HG	plateau		X			
	Erimyzon sucetta	HG-L		X			X	
	Ictiobus bubalus	HG-L		X		X	X	X
	Ictiobus niger	FS				X	X	
	Minytrema melanops	HG-L		X				
	Moxostoma congestum	FS		X	X	X	X	X
Characidae	Astyanax mexicanus	HG-L	exotic	X	X	X	X	
Ictaluridae	Ameiurus melas	HG-L			X	X		X
	Ameiurus natalis	HG-L		X	X	X	X	

Table 3-1
Freshwater Fish Species Reported From the Guadalupe and San Antonio River Basins
(Continued)

				Guadalupe River			San Antonio River	
Family	**Scientific Name**	**FS, HG Lentic**	**Plateau Species**	**Lower[1,2]**	**Upper[1,3,4]**	**San Marcos[1,5,6]**	**Lower[1,7]**	**Cibolo Creek[1,7]**
	Ameiurus nebulosus	HG-L						
	Ictalurus furcatus	HG-L		X		X	X	
Ictaluridae	Ictalurus lupus	HG	plateau		X			X
	Ictalurus punctatus	HG-L		A	X	A	X	X
	Noturus gyrinus	HG-L		X		X	X	X
	Pylodictis olivaris	HG-L		X	X		X	X
Loricariidae	Hypostomus plecostomus	HG-L	exotic				X	
Cyprinidontidae	Cyprinodon variegatus	HG-L		X				
	Fundulus chrysotus	HG-L		X				
	Fundulus notatus	HG-L		X	X	X	X	
Poeciliidae	Gambusia affinis	HG-L		A	X	A	X	X
	Gambusia geiseri	FS	springs			X		
	Poecilia formosa	HG-L				X		X
	Poecilia lattipinna	HG-L		X	X	X	X	
Atherinidae	Menedia beryllina	HG-L		X				
Percichthyidae	Morone chrysops	HG-L		X			X	
Centrarchidae	Ambloplites rupestris	HG-L		X	X	X		
	Centrarchus macropterus	HG-L					X	
	Elassoma zonatum	HG-L					X	
	Lepomis auritus	HG-L			X	X		X
	Lepomis cyanellus	HG-L		X	X	X	X	X
	Lepomis gulosus	HG-L		X	X	X	X	X
	Lepomis humilis	HG-L		X				X
	Lepomis macrochirus	HG-L		A	X	X	X	X
	Lepomis megalotis	HG-L		A	X	X	X	X
	Lepomis microlophus	HG-L		X	X	X	X	X
	Lepomis punctatus	HG-L			X	X		X
	Micropterus dolomieu	HG-L	exotic		X	X		
	Micropterus punctulatus	HG-L		X		X	X	X
	Micropterus salmoides	HG-L		X	X	X	X	X
	Micropterus treculi	HG-L		X	X	X	X	
	Pomoxis annularis	HG-L		X	X	X	X	X
	Pomoxis nigromaculatus	HG-L		X	X		X	
Percidae	Etheostoma chlorosomum	HG-L		X			X	
	Etheostoma fonticola	L	endangered		X	X		
	Etheostoma gracile	HG-L			X			X
	Etheostoma lepidum	FS	plateau		X			X
	Etheostoma spectabile	FS			X	X		X
	Percina caprodes	HG-L		X	X		X	
	Percina carbonaria	HG-L		X	X	X	X	
	Percina macrolepida	HG-L		X	X	X		
	Percina sciera	FS			X	A		
	Percina shumardi	FS		X				X

Table 3-1
Freshwater Fish Species Reported From the Guadalupe and San Antonio River Basins (Concluded)

Family	Scientific Name	FS, HG Lentic	Plateau Species	Guadalupe River Lower [i,ii]	Guadalupe River Upper [i,iii,iv]	Guadalupe River San Marcos [i,v,vi]	San Antonio River Lower [i,vii]	San Antonio River Cibolo Creek [i,vii]
Cichlidae	Cichlasoma cyanoguttatum	L	exotic	X	X	A	X	X
	Cichlasoma nigrofasciatum	L	exotic			X		X
	Tilapia aurea	L	exotic					X
	Tilapia mossambica	L	exotic		X			X
	Tilapia zilli	L	exotic					X
	Number of species			54	58	51	50	46

A - most abundant species found either in the survey by the Academy of Natural Sciences of Philadelphia or the survey by Paul Price Associates, Inc.

[1] Hubbs, C., J.D. McEachran, and C.R. Smith. 1994. Freshwater and marine fishes of Texas and the northwestern Gulf of Mexico. Texas System of Natural Laboratories Index Series No. FTX/NWGM-94, Austin, Texas.
[2] Academy of Natural Sciences of Philadelphia. 1991. A review of chemical and biological studies on the Guadalupe River, Texas, 1949-1989. Report No. 91-9. Division of Environmental Research, Academy of Natural Sciences of Philadelphia, Philadelphia, Pennsylvania.
[3] Hubbs, C. 1953. The fishes of the upper Guadalupe River, Texas. Texas Journal of Science 5(2):216-244.
[4] Espey, Huston and Associates, Inc. 1991. Assessment of impacts to fisheries, riparian habitat and recreational resources from low-flow conditions on the upper Guadalupe River near Kerrville, Texas. prepared for CH2M Hill and the Upper Guadalupe River Authority by Espey, Huston and Associates, Inc., Austin, Texas.
[5] Paul Price Associates, Inc. 1998. Instream flow study of the San Marcos River. prepared for the City of San Marcos, Texas by Paul Price Associates, Inc., Austin, Texas.
[6] Texas Parks and Wildlife Department. 1994. The San Marcos River: A Case Study. Cooperative Agreement No. X-006603-01-0. Texas Parks and Wildlife Department, Austin, Texas.
[7] Texas Parks and Wildlife Department, Texas Water Development Board, and Southwest Texas State University. 1993. Report of Studies Concerning the Proposed Cibilo and Goliad Reservoir Sites. Texas Parks and Wildlife Department, Austin, Texas.

The majority of this assemblage consists of habitat generalists, species that typically use a variety of lotic habitats, and which may display a variable selectivity with respect to physical habitat.[14] For example, at least 16 (41 percent) of the 39 species in the lower Guadalupe River and 24 (83 percent) of the 29 species in the San Antonio River, are known to maintain populations in lentic habitats, and would be tolerant of prolonged periods of low to zero flows. Other species, particularly those with wide geographic distributions, may be restricted to stream environments, but use a variety of lotic habitats in response to changing environmental conditions, and may also be tolerant of broader ranges of current velocity, temperature, and

[14] Travnichek, V.H., M.B. Bain, and M.J. Maceina. "Recovery of a warm-water fish assemblage after the initiation of a minimum-flow release downstream from a hydroelectric dam." Transactions of the American Fisheries Society 124(6):836-844. 1995

dissolved oxygen concentrations than fluvial specialists.[15,16] These characteristics tend to make habitat generalists poor indicators of critical flow conditions, particularly since it is likely that a substantial proportion of them represent a life history strategy that avoids physical habitat limitation in dynamic stream environments, at least as defined in terms of a strong dependence on a particular set of current velocities, depths, and substrates.[17,18,19]

The Academy of Natural Sciences of Philadelphia has studied fish communities in the lower Guadalupe River periodically since 1949 at seven sites: one mile south of Seguin, downriver from the confluence of Blue Bayou, one half mile upstream of the DuPont outfall, one mile downstream of the DuPont outfall, the DuPont effluent channel and Guadalupe River at the effluent channel confluence, 2.6 miles downstream of the DuPont effluent outfall, and 4.2 miles downstream of the DuPont effluent outfall.[20,21] The trend of improving water quality, noted previously, was accompanied by increased abundances of several fish species, including threadfin shad (*Dorosoma petenense*), green sunfish (*Lepomis cyanellus*), longear sunfish (*L. megalotis*), and warmouth (*L. gulosus*). Some introduced species have also increased in number and abundance: Mexican tetra (*Astyanax mexicanus*), orangespotted sunfish (*L. humilis*), sailfin molly (*Poecilia latipinna*), white crappie (*Pomoxis annularis*), black crappie (*P. nigromaculatus*) and white bass (*Morone chrysops*). The common carp (*Cyprinis carpio*), introduced from Europe prior to 1900, is one of the most abundant fish in the lower Guadalupe River. The increase in number and abundance of several introduced species was more dramatic at lower river stations than at the upstream station (south of Seguin), coinciding with improvements in water quality in the lower river. Introduced species also tended to occur in greater abundance in high flow years than in low flow years.

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[15] Ibid.

[16] Matthews, W.J. "Physicochemical tolerance and selectivity of stream fishes as related to their geographic ranges and local distributions." (in) Community and Evolutionary Ecology of North American Stream Fishes, Matthews, W.J. and D.C. Heins (eds). University of Oklahoma Press, Norman and London. 1987

[17] Travnichek, V.H., M.B. Bain, and M.J. Maceina. 1995. Op Cit.

[18] Freeman, M.C., Z.H. Bowen, and J.C. Crance. "Transferability of habitat suitability criteria for fishes in warm-water streams." North American Journal of Fisheries Management 17:20-31. 1997

[19] Walters, J.P. and J.R. Wilson.. "Intraspecific habitat segregation by smallmouth bass in the Buffalo River, Arkansas." Transactions of the American Fisheries Society 125(2):284-290. 1996

[20] Academy of Natural Sciences of Philadelphia. 1991. Op Cit.

[21] Academy of Natural Sciences of Philadelphia. "Chemical and Biological Investigations of the Guadalupe River for the E.I. du Pont de Nemours and Company." Report No. 88-23. Academy of Natural Sciences of Philadelphia, Philadelphia, Pennsylvania. 1987.

Marine and brackish fish species were collected primarily in the surveys conducted during low flow years (1952, 1962, and 1989) and are generally absent from the collections made during the higher flow years of 1949, 1950, 1966, 1973 and 1987. For example, the freshwater goby (*Gobionellus boleosoma*) was recorded only in 1962, the sheepshead minnow (*Cyprinodon variegatus*) and striped mullet (*Mugil cephalus*) were recorded only in 1952, 1962 and 1989.

Studies of macroinvertebrates have also been conducted by the Academy of Natural Sciences of Philadelphia in the Guadalupe River on an irregular basis, with collections made during surveys in 1949, 1950, 1952, 1962, 1966, 1973 and 1987. Samples collected in Victoria County upstream and downstream of the DuPont effluent outfall yielded the following dominant species of mollusks and crustaceans: *Corbicula fluminea* (Asiatic clam), *Quadrula aurea* (golden orb), *Toxolasma texasensis* (Texas lilliput); *Palaemontes* spp. (grass shrimp), *Procambarus clarkii* (crayfish) and *Callinectes sapidus* (blue crab). Blue crabs are known to penetrate into fresh waters and their presence in the lower Guadalupe River is not unusual.[22] The study authors concluded that mollusks and crustacean assemblages have remained relatively constant over the years, in terms of both species richness and abundance.

Macroinvertebrate collections from shallow (<45 cm) riffle areas adjacent to City Park in Victoria in July, 1994 are summarized in Table 3-2.[23] The river flows experienced during our field survey (561-599 cfs) were quite low, being exceeded 90 percent of the time at the Victoria gage. While this sampling was restricted to shallow water (<18 inches), most (98 percent) of the aquatic habitat at this flow regime consisted of runs, and almost no shallow riffle habitat is present here at higher flows. However, riffles are not the only habitat for benthic invertebrates.

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[22] Williams, A.B. "Shrimps, lobsters and crabs of the Atlantic coast of the eastern United States, Maine to Florida." Smithsonian Institution Press. 1984.

[23] Paul Price Associates, Inc. "Aquatic habitat survey of the Guadalupe River at Victoria, Texas, July, 1994." Prepared for The City of Victoria, Texas in support of Water Rights Permit Application 5466. 1994.

Table 3-2
Density (Number/m²) of Macroinvertebrates Collected from the Guadalupe River at City Park, Victoria, Texas, 27 July 1994

Sample	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00
Depth (inches)	12.00	16.00	7.50	6.50	11.00	18.00	18.00	18.00
Substrate[1]	Sa/LG	SG	G/C	G/C	G/C	C/Sa	C/Sa	C/Sa
Trichoptera								
Glossosomatidae	14	55		795	41	343	480	425
Glossosoma sp.					110			
Protopila sp.								96
Culoptila sp.			658		137			
Hydroptilidae				1644	110	781	1356	754
Limnephilidae					27			
Leptoceridae			69	206			110	
Helicopsyche sp.			137		55			
Hydropsyche sp.	164	69	1014	849	123	14	192	164
Leucotrichia sp.								55
Hydroptila sp.	14		2178		1110			69
Cheumatopsyche sp.			14					
Ochrotrichia sp.	55							
Agraylea sp.	55							178
Oecetis sp.	27			96		69		123
Coleoptera								
Stenelmis sp.	178	137	754	534	137	96	219	69
Heterelmis sp.		123						
Neoelmis sp.					301			
Hemiptera								
Ambrysus sp.			69	41			27	14
Diptera								
Empididae	14		27	82	14	27	27	41
Stratiomyidae pupae			14					
Ceratopgonidae					14		14	
Thienemannimyia sp.			82			27		137
Larsia sp.					14			
Pseudochironomus sp.					27			
Cryptochironomus sp.	41	14	55		356			69
Polypedilum sp.	14		110		137	41		123
Micropsectra sp.			14					
Glyptotendipes sp.			96					
Dicrotendipes sp.			14			41		123
Paratanytarsus sp.			14			27		55
Tanytarsus sp.								14
Cricotopus sp.			123		27	41		274

Table 3-2
Density (Number/m^2) of Macroinvertebrates Collected from the Guadalupe River at City Park, Victoria, Texas, 27 July 1994 (Concluded)

Sample	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00
Rheotanytarsus sp.			14					
Simulium sp.			14					
Ephemeroptera								
Caenis sp.								14
Tricorythodes sp.	41	14	206	562	41	411	356	534
Leptohyphes sp.	41		795	288	55	27		96
Thraulodes sp.	548	247	1329	712	96	260	438	397
Traverella sp.	644	96	2439	3055	55	14	110	110
Camelobaetidius sp.	137	41	1151	726	233	123	206	192
Baetis sp.	82	41	110	96			14	
Plecoptera								
Pteronarcys sp.	137	110	466	548	27	96	123	151
Anacroneuria sp.					14			
Lepidoptera								
Petrophila sp.			137	192	41	27	27	55
Megaloptera								
Corydalus sp.	55	14	370	288				
Pelecypoda								
Corbicula fluminea	41	41	82	27	69	14	27	
Oligochaeta								
Tubificidae	27	315	260	192	14		55	41
Branchiura sp.		110						
Total Number/m^2	2329	1425	12810	10933	3384	2480	3781	4370
Biomass (wet g/m^2)	3.91	2.21	28.95	27.28*	15.21**	2.09	6.77	4.10
Taxa Richness	20.00	15.00	31.00	19.00	27.00	19.00	17.00	27.00
Species Diversity (H')	3.33	3.41	3.75	3.47	3.67	3.19	3.09	4.12
Equitability (H'/Log_2 S)	0.76	0.85	0.76	0.80	0.77	0.74	0.74	0.86

[1] Substrate refers to dominant surface particle size. Wentworth Scale. Gordon et al. 1992
Sa/LG = Sand-Large Gravel (<64 mm)
SG = Small Gravel (<32mm)
G/C = Gravel-Small Cobble (<128 mm)
C/Sa = Scattered cobble (and gravel) in sand matrix

* 23.30 g/m^2 excluding a single, large *Corydalus* sp.

** 4.23 g/m^2 excluding a single, large *C. fluminea*

Abundant populations are also found in sand/gravel/cobble substrates, snags and woody debris in areas of high current velocities, habitats which provide the physical complexity, refuge from predation, and physiological enrichment necessary to support an abundant and diverse invertebrate community.[24]

One river species which is listed as a candidate for protection by the USFWS, Cagle's Map Turtle (*Graptemys kaglei*), is found in the Guadalupe River drainage basin and feeds on aquatic insects.[25] Cagle's Map Turtle, although endemic to the Guadalupe-San Antonio River system, is known from Victoria County only from a single observation in March 1989 at Riverside Park in Victoria.[26] Haynes and McKown describe its preferred habitat as sluggish pools containing partially submerged logs used as basking sites.[27] As current velocities in this reach of the Guadalupe tend to be high, relatively little pool habitat is present, although partially submerged logs are abundant.

3.1.3 Aquatic Habitats

To add to the qualitative habitat descriptions presented in Section 3.1.1, the following sections discuss the results of studies conducted at Victoria on the Guadalupe River, and over an extended reach of the San Marcos River. These stream reaches consist predominantly of pool and run complexes with occasional gravel riffles and, rarely, outcrops of resistant rock that may or may not result in rocky run or riffle habitat. For example, critical habitat for the endangered blue sucker (*Cycleptus elongatus*), consisting of deep, swift runs over scoured bedrock, occurs in the "Bastrop reach" where the Colorado River encounters resistant sandstone members of the Carrizo and Reklaw formations.[28] Where the San Marcos River crosses these formations upstream of Ottine in Caldwell County, a local increase in bedslope is evident, while sandstone bluffs and occasional rocky outcrops in the river were observed at a streamflow approximate to

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[24] Brown, Arthur V. and Peter P. Brussock. "Comparisons of benthic invertebrates between riffles and pools." Hydrobiologia 220: 99-108. 1991.
[25] Haynes, David and Ronald R. McKown. "A new species of map turtle (Genus Graptemys) from the Guadalupe River System in Texas." Tulane Studies in Zoology and Botany, Vol. 18, Num. 4. pp. 143-152. 1974.
[26] Killebrew, Flavius C. and Dan A. Porter. "Testudines, Graptemys caglei." Herp Review: 22(1), p. 24. 1991.
[27] Haynes, David and Ronald R. McKown. "A new species of map turtle (Genus Graptemys) from the Guadalupe River System in Texas." Tulane Studies in Zoology and Botany, Vol. 18, Num. 4. pp. 143-152. 1974.
[28] Mosier, D.T. and R.T. Ray. "Instream Flows for the Lower Colorado River: Reconciling Traditional Beneficial Uses with Ecological Requirements of the Native Aquatic Community." Lower Colorado River Authority, Austin, Texas. 1992.

the median August discharge. Riffles were restricted to the immediate vicinity of the bridge crossing at Ottine and immediately below the channel dam at Palmetto State Park. No deep, fast run habitat was observed. The Guadalupe River encounters these formations east of Seguin in the vicinity of the Capote Hills, and the San Antonio River crosses the Carrizo and Reklaw formations in a reach of about 10 river miles flanking the Bexar-Wilson County line.

Available information indicates that the macrohabitats observed in detail in the lower portion of the San Marcos River are similar to those of the lower Guadalupe and San Antonio Rivers, given the differences in hydrologic scale of the three streams. The freshwater fish faunae of these stream reaches are very similar, representing segments of a common assemblage occupying physically similar portions of their respective streams. These assemblages exclude many of the species typical of the Edwards Plateau, and the brackish and marine species present in the lowermost reaches of the Guadalupe and San Antonio Rivers during extreme drought periods (Table 3-1).

An approximately three mile reach of the Guadalupe River adjacent to the City of Victoria was examined to inventory the types and distribution of aquatic macrohabitats present. Macroinvertebrate samples from a major riffle were collected for later analysis and stream cross sections were measured at two major riffles. During the survey, daily average streamflow ranged from 561 to 599 cfs over 25-27 July 1994, although instantaneous flows exhibited a wider range as water levels were observed to vary by over six inches over a 24-hour period.[29]

In this flow range, the reach from the upstream boundary of City Park in Victoria to the Highway 59 crossing consisted of run habitat: 98 percent, pool habitat: Trace, riffle habitat: <2 percent. Snag habitat was not assessed quantitatively, but is believed to be more abundant than riffle habitat in this reach. The runs were 100-130 feet in width, averaging 123 feet, depth was generally 4-6 feet, with deeper water extending to 8 feet at channel bends and below riffles. Current velocities were approximately 1 foot per second over much of the cross section of the runs.

Riffles (areas exhibiting a distinct slope in water surface elevation and surface turbulence) comprised only 0.4 percent (8373 ft^2) of the study reach. Substrates in the study reach were

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[29] Paul Price Associates, Inc. "Aquatic habitat survey of the Guadalupe River at Victoria, Texas, July, 1994." 1994.

limited to sand and gravel with occasional cobbles, and substantial amounts of woody debris, for the most part submerged along the banks of the runs, but a log jam was visible in the river upstream of the park.

Cross sections of the Guadalupe River in the vicinity of the Central Power & Light Company (CP&L) Victoria Power Station showing width, depths and current velocities at flows of 790, 1250 and 1720 cfs (1 August 1974 and 10 and 30 September 1975) are shown in Appendix F.[30] The dimensions and current velocities observed at Station 1 in August 1974 at a discharge of 790 cfs (Figure F-1) were similar to the deeper sections of run we observed in 1994 at a discharge of about 600 cfs. The cross sections measured at discharges of 1720 and 1250 cfs (Figures F-2, and F-3 respectively) are not noticeably larger than at the lower flows, but current velocities are increased substantially.

The stage-discharge relationship at the CP&L Victoria Power Station, located at the downstream end of the PPA study reach showed that in the low flow range from about 200-900 cfs (approximately up to the annual median flow) depth changes on the order of 4.4 inches occur with each 100 cfs of flow change. Depth increases more rapidly as flows increase above the annual median, until the flood plain is inundated.[31] Personal communications with USGS staff in the fall of 1994 indicated that the low flow portion of the stage-discharge curve for that location on the Guadalupe River was still 4.4 inches/100 cfs of change.

During the Habitat Survey, fluctuations in water depth of over 6 inches in a few hours were observed, implying cyclic changes in discharge of about 150 cfs while daily average discharge was 560-600 cfs (see Section 3.1.4, Hydrology). Inspection of records made available from the CP&L power plant at Victoria confirmed that the observed daily changes in water level were an ordinary occurrence in this reach of the Guadalupe, a result of hydroelectric operations above Gonzales. Shallow riffle habitat, a critical spawning, nursery and foraging area which tends to have a particularly abundant invertebrate fauna, was not observed to decrease in area, but to move slightly down the bed slope as river stage decreased.

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[30] Espey, Huston & Associates, Inc. "Thermal plume studies Victoria Power Station." Prepared for Central Power & Light Co., Corpus Christi, Texas. Espey, Huston & Associates, Inc. Doc. No. 7547, Austin, Texas. 1975.
[31] Espey, Huston & Associates, Inc. "Thermal plume studies Victoria Power Station." Prepared for Central Power & Light Co., Corpus Christi, Texas. Espey, Huston & Associates, Inc. Doc. No. 7547, Austin, Texas. 1975.

On the other hand, shallow riffle habitat in the Guadalupe River appears to be a low flow phenomenon. For example, a bar and riffle that was present adjacent to City Park in Victoria on 27 July 1994 at an estimated discharge of 599 cfs was not evident during a previous survey conducted 13 August 1993 when Guadalupe River discharge was 983 cfs.[32] The other riffles surveyed were also associated with low-lying bars within the steep banks confining the channel that would be inundated by moderate rises, resulting in an increase in deep, fast runs and chutes and a decrease in shallow riffle area. It is likely that species that use shallow riffle habitat for spawning, foraging, or as a refuge from predation by juveniles, use the tributaries for these purposes during wet climatic conditions, as little of this habitat will be present in the Guadalupe River above annual median flows.

3.1.4 Hydrology

Table 3-3 presents naturalized average daily discharge statistics for the USGS stream gages at selected locations on the Guadalupe and San Antonio Rivers. The discussion of Guadalupe River hydrology is based on records from the USGS gage at Victoria, as observations of physical habitat and biota are available at that location which can be used to examine habitat discharge relationships. The reach from Lake Dunlap to Sequin consists of an almost continuous series of impoundments with highly regulated intervening flows and no undisturbed lotic habitat. Hydroelectric operations in that reach and at other locations downstream to the San Marcos River confluence presently result in brief periods of near-zero flow, a condition which can severely impact populations of fish that reside in lotic habitats, particularly those species generally reported to occur in streams and rivers, and which are typically described as requiring flowing water throughout life (fluvial specialists).[33] Channel morphology and hydrology at the gage at Cuero appear sufficiently similar to conditions at Victoria, that conclusions reached at the latter location can be extrapolated upstream. Extending that extrapolation to the vicinity of Gonzales

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[32] Paul Price Associates, Inc. "Environmental Assessment The City of Victoria Water Rights Application." Paul Price Associates, Inc., Austin, Texas. 1994.

[33] Travnichek, V.H., M.B. Bain, and M.J. Maceina. "Recovery of a warm-water fish assemblage after the initiation of a minimum-flow release downstream from a hydroelectric dam." Transactions of the American Fisheries Society 124(6):836-844. 1995.

Table 3-3
Naturalized Daily Streamflow Statistics (cfs)[1]

	Guadalupe River Basin			San Antonio River Basin	
	Cuero	**Victoria**	**Saltwater Barrier**	**Falls City**	**Goliad**
			Median		
JAN	983.4	1045.4	1476.9	229.2	294.2
FEB	1050.9	1122.8	1670.4	231.6	306.6
MAR	1046.1	1145.7	1483.2	231.0	306.8
APR	1078.7	1147.2	1513.0	217.1	305.8
MAY	1295.4	1371.7	1962.7	258.2	371.0
JUN	1170.0	1238.0	1814.6	236.3	346.3
JUL	865.0	916.9	1278.8	164.4	241.9
AUG	676.5	721.8	1022.4	137.0	199.4
SEP	749.0	806.0	1223.5	165.0	239.9
OCT	837.2	899.4	1360.9	174.0	258.0
NOV	866.5	917.2	1364.8	191.2	283.1
DEC	897.9	952.5	1355.7	208.8	288.9
			25th Percentile		
JAN	603.6	652.7	899.5	124.2	183.3
FEB	661.5	732.4	998.7	137.6	197.4
MAR	637.0	696.4	927.4	126.3	176.1
APR	625.9	688.7	913.6	114.6	157.0
MAY	694.8	747.9	1038.0	115.4	175.4
JUN	624.0	667.6	962.1	82.3	145.9
JUL	490.9	537.3	648.2	43.6	89.9
AUG	381.2	399.5	606.4	42.0	77.3
SEP	432.3	469.6	726.0	65.5	103.4
OCT	496.0	543.7	745.8	85.7	134.0
NOV	552.4	594.2	861.3	90.6	140.3
DEC	581.8	608.6	836.7	108.6	150.8
			7Q2		
	540.0	584.6	742.0	51.1	77.0
TNRCC 7Q2[2]	606.6	641.9	n/a	197.3	211.2

[1]Statics computed by HDR Engineering, Inc. based on natural streamflow for the 1934-89 historical period.
[2]Values computed by TNRCC based on gaged streamflows for the 1969-89 historical period.

or Lake Dunlap involves the additional factors cited above, but seems a reasonable approach considering the difficulties of attempting to evaluate habitat-discharge relationships in such a hydrologically disturbed environment.

As shown in Table 3-3 the lowest flows at Victoria for the Guadalupe River tend to occur in the month of August, during which natural median daily flows are about 722 cfs, while May is the wettest month with median daily flows of 1372 cfs. Naturalized flow frequency curves for the wettest (May) and driest (August) months are presented in Figure 3-1 for the Guadalupe River at Victoria, San Marcos River at Luling, and San Antonio River at Falls City. As in the Guadalupe River, May and August (respectively) are the months exhibiting the highest and lowest median daily flows both in the San Marcos River (290 and 167 cfs, respectively) and in the San Antonio River (Table 3-3)

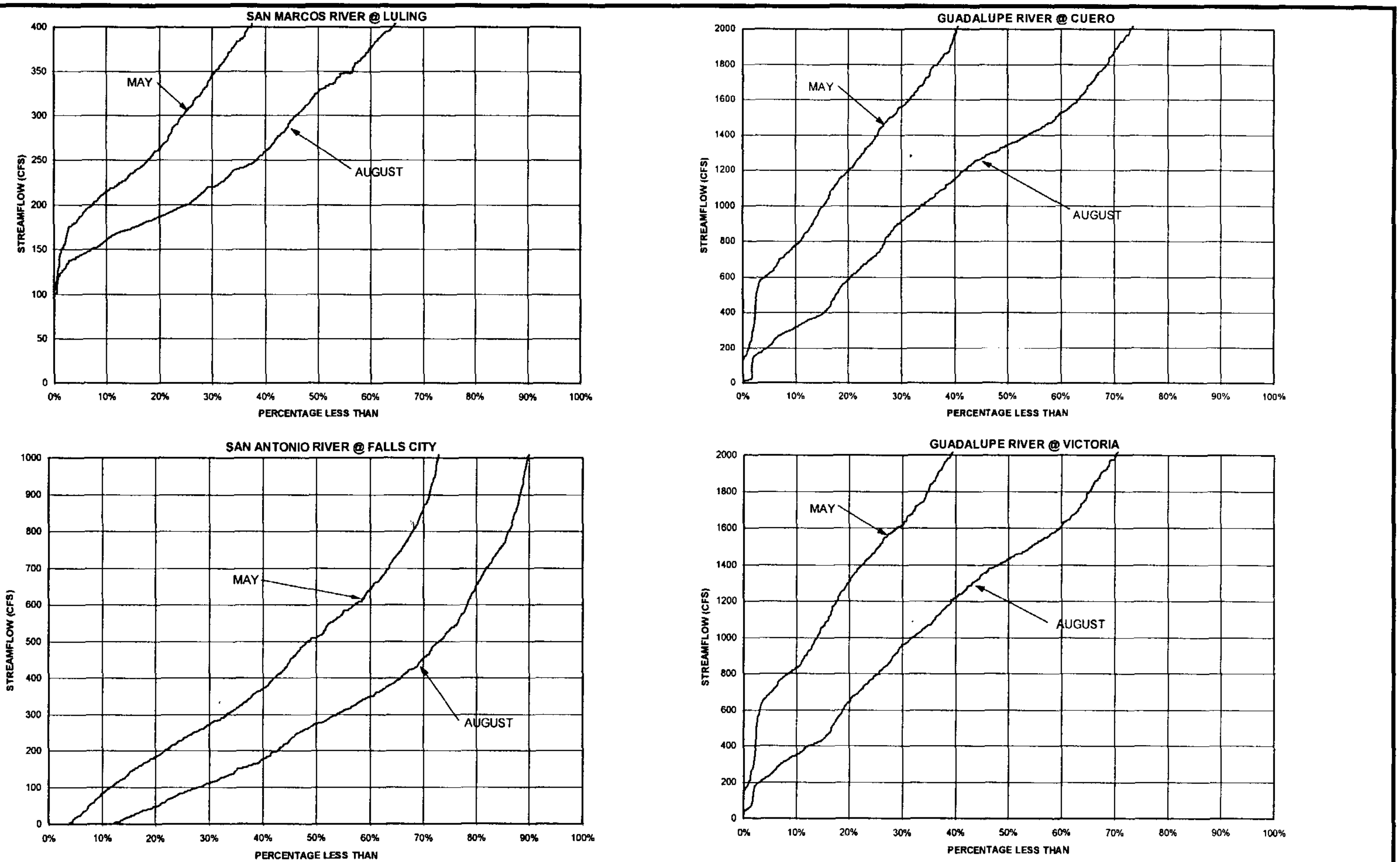
3.1.5 Habitat-Discharge Relationships in the San Marcos River

In any stream, the fish assemblage occupies a variety of physical habitats that can vary in area and distribution as a function of streamflow. Conversely, the fish populations can be characterized with respect to the habitat utilized in particular river reaches, and the degree to which a particular species may require, or be benefited by, particular sets of habitat parameters (e.g., particular ranges of depth, velocity, and substrate). A recent instream flow study for the San Marcos River[34] which includes examination of fish habitat streamflow relationships is described in the following paragraphs.

The study concentrated on obligate riverine species, or fluvial specialists, species having relatively distinct lotic habitat requirements, since it was assumed that the remaining habitat generalists would be relatively unaffected by reductions in streamflow as long as flows were sufficient to maintain water quality, and did not decline below historical minima. Fish were sampled from riffle habitats and the depth, current velocity and substrate where each fish was found was recorded. The data were analyzed using cluster analysis to define groups of fish species/life stages that were collected from habitats with similar depth-velocity-substrate characteristics (Habitat Types). Table 3-4 identifies five habitat types and the fish species collected from each.

Habitat type 1 (deep, fast) was defined by only four *Campostoma anomalum* individuals, all collected together in the same sample cell. The depths and velocities measured in this cell were used to define a deep, fast habitat but it is not believed that these characteristics necessarily reflect the preferences of *C. anomalum*. Deep, fast habitat was characterized by a velocity range of 2.34 to 3.66 f/s (0.71 to 1.12 m/s) and a depth greater than 1.5 feet (0.46 m).

[34] Paul Price Associates, Inc. "Instream Flow Study of the San Marcos River," City of San Marcos, 1998.



TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

GUADALUPE - SAN ANTONIO RIVER BASIN
ENVIRONMENTAL CRITERIA REFINEMENT

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STREAMFLOW FREQUENCY CURVES GUADALUPE - SAN ANTONIO RIVER BASIN

FIGURE 3-1

Table 3-4
Habitat Types Derived from Cluster Analysis

Representative Species	Size Range (cm)	N	Mean Velocity (fps)	Mean Depth (ft)	Primary Substrate	Froude Number
Habitat Type 1 (deep, fast)						
Campostoma anomalum	5-10 cm	4	3.14	1.7	5	0.0011
		4[1]	**3.14**[2]	**1.7**[2]	**5**[3]	**0.0011**[3]
Habitat Type 2 (slow, shallow riffles)						
Cichlasoma cyanoguttatum	0-10 cm	15	0.96	1.02	3.33	0.0009
Cyprinella lutrensis	0-3 cm	9	1.21	0.58	3	0.0035
Cyprinella lutrensis	3-5 cm	45	1.28	0.98	3.38	0.0013
Cyprinella venusta	0-5 cm	47	1.18	1.08	3.38	0.0010
Etheostoma spectabile	3-5 cm	5	1.38	1.02	3.6	0.0013
Etheostoma spectabile	5 + cm	6	1.61	0.98	3.33	0.0016
Gambusia affinis	0-3 cm	37	0.84	0.78	3.27	0.0013
Gambusia affinis	3-5 cm	48	0.85	0.68	3.67	0.0018
Gambusia affinis	5+ cm	6	0.93	0.61	3.17	0.0024
Ictalurus punctatus	0-5 cm	23	1.5	0.91	3.7	0.0018
Ictalurus punctatus	5-15 cm	11	1.32	0.73	3.45	0.0024
Lepomis auritus	5-10 cm	4	1.31	0.69	3.5	0.0027
Notropis volucellus	5-10 cm	30	1.14	1.25	3.47	0.0007
Percina sciera	10+ cm	5	1.05	0.94	4	0.0012
Percina sciera	5-10 cm	55	1.47	0.98	3.73	0.0015
Poecilia latipinna	3-5 cm	14	0.56	0.49	3.21	0.0023
		360[1]	**(0.5-1.8)**[2]	**(0.5-1.3)**[2]	**3.5**[3]	**0.0015**[3]
Habitat Type 3 (deep, fast riffles)						
Cyprinella lutrensis	5+ cm	35	2.12	1.73	3.74	0.0007
Cyprinella venusta	5+ cm	126	1.9	1.67	3.96	0.0007
Macrhybopsis aestivalis	5-10 cm	15	1.43	1.73	3.13	0.0005
Pimephales vigilax	0-5 cm	14	1.48	1.41	3.21	0.0007
		190[1]	**(1.4-2.4)**[2]	**(1.3-2.0)**[2]	**3.8**[3]	**0.0006**[3]
Habitat Type 4 (intermediate depth and velocity adjacent to large structure)						
Notropis amabilis	3-5 cm	4	1.71	1.58	4.75	0.0007
Notropis amabilis	5-10 cm	10	1.22	1.31	4.3	0.0007
		14[1]	**(0.7-2.0)**[2]	**(1.0-1.7)**[2]	**4.4**[3]	**0.0007**[3]
Habitat Type 5 (deep, slow riffles)						
Notropis volucellus	0-3 cm	49	0.73	1.39	3.63	0.0004
Notropis volucellus	3-5 cm	94	1.17	1.54	3.7	0.0005
Percina sciera	0-5 cm	6	0.87	1.58	3.83	0.0003
Pimephales vigilax	5+ cm	14	1.29	1.76	3.79	0.0004
		163[1]	**(0.3-1.7)**[2]	**(1.0-2.0)**[2]	**3.7**[3]	**0.0004**[3]

[1] Total number
[2] 50 percent Confidence Interval
[3] Average

Habitat Type 2 (slow, shallow riffle) was utilized by a large assemblage of diverse species: catfish, darters, sunfish, mosquitofish and small minnows preferring slower, shallower riffles. Some are typical of quiescent backwaters (*Gambusia affinis*, *Gambusia geiseri*, *Poecilia latipinna* and *Cichlasoma cyanoguttatum*) while others are juveniles (*Cyprinella lutrensis*, *C. venusta* and *Ictalurus punctatus*) not yet large enough to handle stronger flows and exposure to predation. Large darters (*Etheostoma spectabile* and *Percina sciera*) were included in this group as they were utilizing the riffles for spawning during the sampling period. This habitat type is typical of gently shoaling, shallow marginal areas, and broad, shallow riffles.

Habitat Type 3, consisted of the deeper, faster flowing riffles, especially near the riffle/run boundary. Deep riffle habitat was defined by the larger adults of the most common riffle-loving minnows (*Cyprinella lutrensis*, *Cyprinella venusta* and *Pimephales vigilax*) and speckled chub (*Macrhybopsis aestivalis*). *C. lutrensis* and *C. venusta* preferred the fastest waters with mean velocities of 2.12 f/s (0.65 m/s) and 1.9 f/s, respectively. Smaller and younger individuals of *Cyprinella lutrensis* and *C. venusta* were found in Habitat Type 2.

Habitat Type 4 was defined solely by *Notropis amabilis,* which were collected only in the Broken Bone study reach where it was found in riffle and run areas of intermediate depth and velocity. It was often collected adjacent to large structure (undercut banks, exposed, massive cypress roots, rock outcrop), frequently shaded by large cypress trees whose roots stabilized the bank on the outside of the sharp bend at Broken Bone (Figure 3.2-4). This habitat type did not appear to be present at Leisure Camp. Although areas within the depth and velocity boundaries, the larger substrate sizes and cover associated with this habitat type were not present.

Habitat Type 5 (deep, slow) consisted of riffle areas with current velocities similar to Type 2 and depth boundaries encompassing those of Types 3 and 4. Habitat Type 5 was defined by smaller *Notropis volucellus* and *Percina sciera* individuals, and the largest *Pimephales vigilax* individuals. Larger *N. volucellus* and *P. sciera* clustered in Group 2 habitat, presumably because they were engaged in spawning activities.

In general, the larger, stronger minnows that could maintain their position in faster water, utilized the faster, deeper riffles, riffle/run boundaries and runs. The smaller minnows preferred the slower shallower riffles, while the juvenile catfish and spawning darters preferred shallow areas of any velocity.

A two-dimensional model of the study reaches was used to calculate and display areas and distributions of habitat types at selected streamflows between the highest monthly median average daily discharge (flow) and the historical low flow of about 50 cfs (54 cfs naturalized flow at Cummings Dam based on monthly data, 43 cfs gaged at Luling). The results from one San Marcos River study reach are shown in Figure 3-2.

The downstream San Marcos River study reach (Leisure Camp) was selected to be representative of the gravel riffles of the lower San Marcos River. These areas are not extensive and the dominant macrohabitats are deep runs and pools over substrates of sand, gravel and silt with little shallow habitat present at median flows (202 cfs). The types and proportions of macrohabitats in the lower San Marcos River are similar to those observed in the lower Guadalupe River in the vicinity of Victoria. The model of the Leisure Camp study reach showed total wetted area does not dramatically decline between median flows and historic low flows. Riffle habitats with low to moderate current velocities (Habitat Types 2, 4, and 5 which are used by many fish species for spawning, foraging and as refugia for juveniles) were found to increase in area as streamflow declines from the vicinity of the median to about 60 cfs. This is a very low frequency flow for the San Marcos River, exceeded 98 percent of the time in all months. As streamflow diminishes, these habitats move down the bedslope toward the center of the channel, a behavior observed at riffles in the Guadalupe River at Victoria.

Deeper, higher velocity riffles (Habitat Type 3), however, become rarer with lower flows, with substantial reductions as flow declines from the median to the 25th percentile flow. Of the fish species collected that defined Habitat Type 3 in the San Marcos River, only one (*Macrhybopsis aestivalis*) is considered a fluvial specialist. Mosier and Ray assigned *M. aestivalis* to a guild/habitat type with a similar current velocity range but a shallower depth range.[35] Mathews reported it to be concentrated in habitats with lower current velocity ranges, but in deeper water in Sandies Creek than in the San Marcos or Colorado Rivers.[36] These differences may be due to shifts in habitat use as a result of differences in habitat availability

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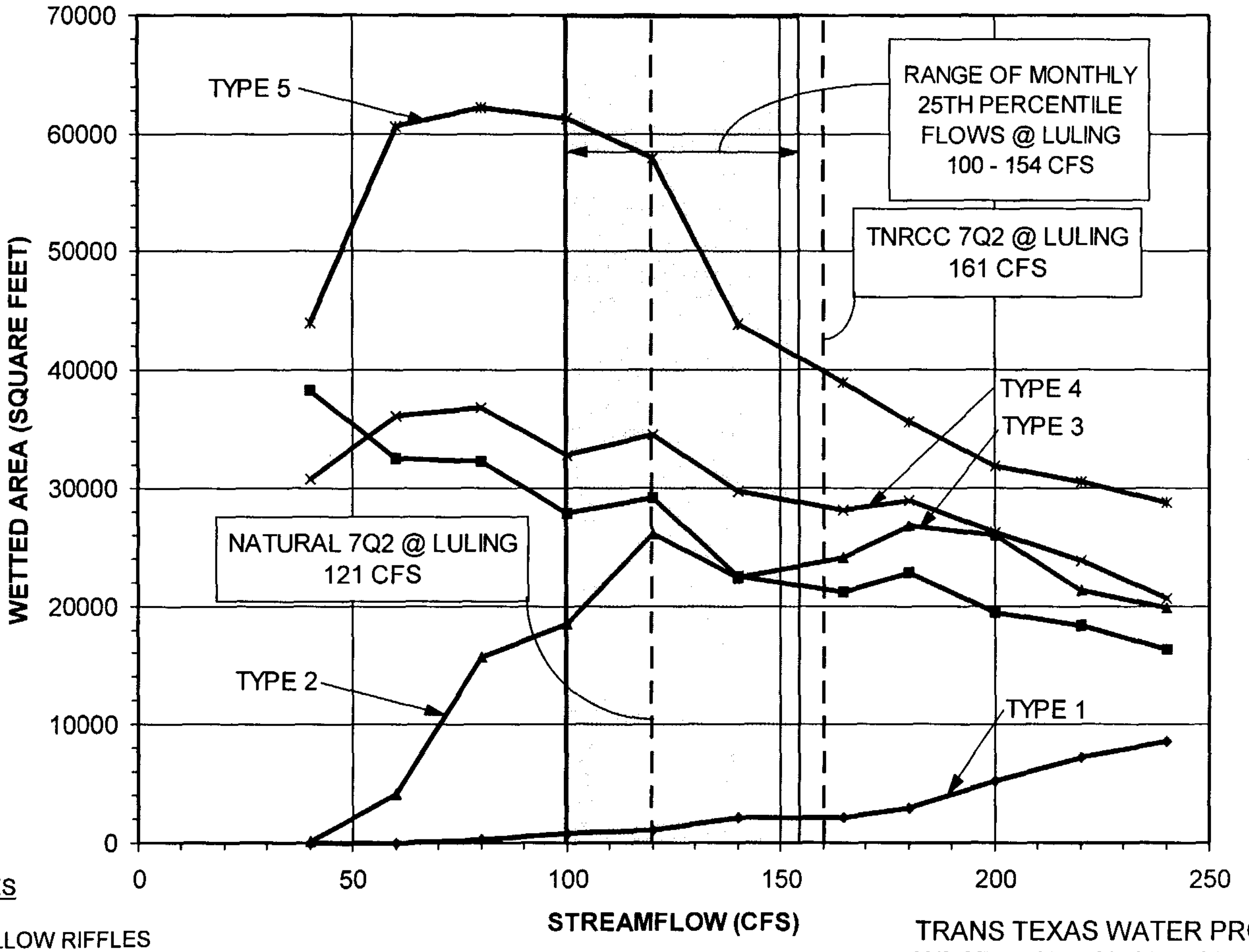
[35] Mosier, D.T. and R.T. Ray. "Instream Flows for the Lower Colorado River: Reconciling Traditional Beneficial Uses with Ecological Requirements of the Native Aquatic Community." Lower Colorado River Authority, Austin, Texas. 1992.

[36] Mathews, R.C. and J.R. Tallent. "Application of an instream habitat assessment technique to Sandies Creek, Texas." Paper presented to the Instream & Environmental Flows Symposium, 17th International Symposium of the North American Lake Management Society, Houston, Texas. 1997.



HABITAT TYPES
1 DEEP, FAST
2 SLOW, SHALLOW RIFFLES
3 DEEP, FAST RIFFLES
4 INTERMEDIATE DEPTH AND VELOCITY
5 DEEP, SLOW RIFFLES

GUADALUPE - SAN ANTONIO RIVER BASIN
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AREAS OF FISH HABITAT TYPE
SAN MARCOS RIVER AT
LEISURE CAMP

FIGURE 3-2

among the three streams. For example, the slower, deeper water of Sandies Creek where *M. aestivalis* was found offered the highest current velocities available in that stream as shallower habitats there exhibited lower current velocities. In the Colorado River, deeper habitat with comparable current velocities was available, but only in areas where rubble and larger sized substrates were dominant. These observations would be consistent with the hypothesis that *M. aestivalis* was selecting the highest current velocities available, that depth was secondary in importance to velocity, but that habitat use in the Colorado River was constrained by large substrate particle sizes..

At the Leisure Camp study reach, the area occupied by Habitat Type 3 is approximately constant at flows from 240 cfs down to 120 cfs, below which the area decreased in a roughly linear fashion until none was predicted to be present at 40 cfs, slightly below historical low flow. Between 120 cfs and 100 cfs, deep, fast riffle area declined from about 25,000 ft^2 to about 18,000 ft^2 (roughly 17 percent to 12 percent of wetted area, respectively). A discharge of 100 cfs corresponds to an August 25th percentile flow (flows of 100 cfs or less occurred on one fourth of the August days in the period of record), and a May 8th percentile flow (see Figure 3-1). The deeper, higher velocity habitats are constrained in the San Marcos River by velocity rather than by depth or substrate. Large areas of deep water continue to be available at the lowest flows, but areas of high current velocity are sharply reduced, very likely adversely affecting the abundance of species preferring this habitat.

Only a small amount of Habitat Type 1, representing chutes and deep runs, was available for sampling in the San Marcos River, and no species considered characteristic of that habitat was collected in the instream flow study. Like the deep, fast riffle discussed above, the deeper, higher velocity habitats (depth >1.5 feet, current velocity > 2.4 feet per second) are also constrained by velocity rather than depth or substrate. In the lower portion of the San Marcos River, areas of high current velocity may persist at sharp channel bends, or adjacent to gravel bars and log jams that constrict the channel. The areas are very small, however, accounting for only 4 percent of wetted area at Leisure Camp at 240 cfs, a flow somewhat less than the May median (41st percentile) and substantially more than the August median (Figure 3-1). Only small areas (<100 ft^2) of chute or run habitat were noted at three riffles on the Guadalupe River at Victoria when discharge was about 600 cfs, a flow equivalent to the May 80th percentile flow and the August 45th percentile flow (Figure 3-1) at that location. The pool and run cross-sections measured in 1974-75 at flows above the median show no areas of high (>2.4 feet per second) current velocity.

3.2 The Consensus Criteria

The Environmental Water Needs Criteria of the Consensus Planning Process (Consensus Criteria, Appendix A) for new direct diversions define three operating zones, or streamflow ranges, at which diversions are regulated. Zone 1 is defined as the hydrologic regime in which streamflows are greater than the median daily average flow, calculated for each month individually, using naturalized daily streamflow estimates. When the source streamflow is within Zone 1, the Consensus Criteria require that flows at least equivalent to the appropriate monthly median be allowed to pass downstream. Zone 2 is the range of streamflows between the monthly median (50th percentile) and the 25th percentile flow. In Zone 2, the Consensus Criteria require that at least the 25th percentile streamflow must be passed downstream. In Zone 3, the range of streamflows less than the 25th percentile flow, the Consensus Criteria allow diversions only to the extent that the flow necessary to maintain segment water quality standards is passed downstream. This "water quality standard" is published for many streams and generally coincides with the 7Q2 flow (the lowest flow occurring for 7 consecutive days with a 2-year return period or a 50 percent chance of occurrence in any given year) for that stream, however site specific conditions may dictate a different value.[37] Information presented in the following sections focuses on biological and water quality considerations pertinent to Zones 1, 2, and 3 as defined in the Consensus Criteria.

3.2.1 Zone 1 — Wet Conditions

The similarity in bed materials and hydrologic pattern (periods of relatively stable discharge punctuated by brief flood events) among the San Marcos, Guadalupe and San Antonio Rivers is expected to result in similar channel morphologies so that the relative abundances and distributions of particular combinations of depth, current velocity and substrate will also be

[37] Texas Water Development Board. "Water for Texas Today and Tomorrow: a consensus-based update to the State Water Plan. Volume II, Technical Planning Appendix." Texas Water Development Board, Austin, Texas. 1997.

similar when comparisons are scaled to their respective flow distributions.[38,39] Fish habitats present in significant amounts at Leisure Camp on the San Marcos River within the range of the monthly medians (shallow and deep slow to moderate velocity riffles, slow runs and pools) appear to be adequately protected by the minimum monthly median flow, that of August, 168 cfs (Figure 3-1). If these results are applied to the lower Guadalupe River at Victoria, and the San Antonio River at Falls City, shallow spawning and foraging habitat would be similarly protected at flows of 722 and 137 cfs, respectively, and would be enhanced during the wetter months when spawning and fry development of most of the sensitive species occurs as their median flows are reduced.

The similarity in macrohabitats and fish communities suggests that the lower reaches of the San Marcos, Guadalupe and San Antonio Rivers may be lacking in deep, fast habitat at flows below their respective medians. Certainly, the observations made in the river reach adjacent to the City of Victoria support this supposition, and the paucity, or lack, of species dependent on those habitats in the lower Guadalupe and San Antonio Rivers is consistent with the reduced availability or absence of deep, fast habitat (Habitat Types 1 and 3) at lower flows.

The physical habitats occupied by fish species resident in the lower Guadalupe River, which also occur in lentic environments, and those species which require or utilize lower current velocity riffles appear to experience reduced habitat at flows in Zone 1. Those species able to effectively utilize deeper habitats and higher current velocities could be expected to benefit from setting the Zone 1 passage requirement to the current values, but based on the San Marcos River model studies and observations made at Victoria, deep, fast habitat is expected to be present, if at all, in only small amounts at flows below even the highest monthly median. Among the lower Guadalupe River assemblage able to utilize deeper, faster areas, these appear to include speckled chub, *Macrhybopsis aestivalis*; dusky darter, *Percina sciera*; river darter, *P. shumardi*; grey redhorse sucker, *Moxostoma congestum*; smallmouth bass, *Micropterus dolomieui*; Guadalupe bass, *M. treculi*; juvenile channel catfish, *Ictalurus punctatus*; flathead catfish, *Pylodictus*

[38]Tennant, D.L. "Instream flow regimens for fish, wildlife, recreation and related environmental resources." Fisheries 1(4):6-10. 1976.
[39]Gordon, N.D., T.A. McMahon, B.L. Finlayson, and R.J. Nathan. "Stream hydrology." John Wiley & Sons, Chichester. 526 pages. 1992.

olivarus; and logperch, *Percina carbonaria*.[40,41,42] The first species listed are fluvial specialists that appear to be dependent on the maintenance of suitable lotic habitat conditions, while all these species appear to be present in the lower Guadalupe River, none are present in the lower San Antonio River (Table 3-1). The others listed are the more widely distributed habitat generalists, which may benefit to some extent from higher streamflows, but are not dependent on them. The smallmouth bass is a widely distributed species introduced into the Guadalupe River by Texas Parks and Wildlife Department as a gamefish. However, it has also been recognized as a threat, through competition and hybridization, to Guadalupe bass (*M. treculi*) populations.[43] The river darter is a widely distributed, silt tolerant darter typically found associated with higher velocity habitats in large rivers and the lower portions of moderate sized rivers. Although we did not find records of this fish in the lower portions of either river, described habitat preferences indicate that it might occur there (Table3-1).

With regard to *M. aestivalis*, the Zone 1 passage requirement of monthly medians appears to be overly protective. Applying the results obtained from the San Marcos River, this habitat is not expected to be reduced in area by flows as low as the monthly 25th percentiles, including August. Of the other species that might utilize the chute and run habitats (dusky darter, river darter, grey redhorse sucker, smallmouth bass, Guadalupe bass, juvenile channel and flathead catfish and logperch), the river darter might be dependent on this habitat type, while the others will use it opportunistically when it is present, but are evidently not dependent on the constant presence of high velocity habitat. All of these species (with the exception of smallmouth bass, which have been stocked into the river) survived the drought of record, through prolonged low flows and a minimum gaged flow of 14 cfs for the Guadalupe River at Victoria in August, 1956.

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[40] Paul Price Associates, Inc. "Instream Flow Study of the San Marcos River." Prepared for the City of San Marcos, Texas. Paul Price Associates, Inc., Austin, Texas. 1998.

[41] Minnesota Department of Natural Resources. "Microhabitat preferences of selected stream fishes and a community-oriented approach to instream flow assessments." Division of Fish and Wildlife, Minnesota Department of Natural Resources, St. Paul, Minnesota. 1991.

[42] Mosier, D.T. and R.T. Ray. "Instream Flows for the Lower Colorado River: Reconciling Traditional Beneficial Uses with Ecological Requirements of the Native Aquatic Community." Lower Colorado River Authority, Austin, Texas. 1992.

[43] Garrett, Gary P. "Guidelines for the Management of Guadalupe Bass." Inland Fisheries Branch, Texas Parks and Wildlife Department, Austin, Texas. PWD-RP-N3200-367-11/91. 1991.

The San Marcos River results indicate that one of the primary reasons for requiring instream flow requirements to vary by month, the need to provide spawning and juvenile foraging habitat during the spring, does not apply to that river, and may not apply to the Lower Guadalupe and San Antonio Rivers. The other widely cited reason for monthly variation in minimum flows is a postulated need to mimic seasonal variability and to allow periodic flushing or scouring of the system to reset the community to an earlier successional state. Channel maintenance flows are widely recognized to correspond to the bankfull flood stage, a flow having a return interval of about 1.5 years and corresponding to about 9,500 cfs in the Guadalupe River at Victoria. Even a very large direct diversion at that location would have an insignificant effect on the frequency of flows of this magnitude, particularly since the diversion would probably not be operating during a period of high turbidity and generally lower water quality (a flood event). In addition, the level at which required passage flows are set within the range of monthly medians would have no effect on the frequency of bankfull flood events. Finally, there is a daily variation in discharge on the lower Guadalupe River in excess of 150 cfs.

3.2.2 Zone 2 — Dry Conditions

Zone 2 of the Consensus Criteria applies when streamflows occur in the range below the monthly median (50th percentile) and above the 25th percentile flow. Direct diversions operating within Zone 2 would be required to pass downstream at least the monthly 25th percentile streamflow. At Leisure Camp on the San Marcos River, monthly natural 25th percentile flows range from 100 cfs in August to 154 cfs during May. Deep, fast (Type 1) habitat is not present in significant amounts in the lower San Marcos River at these flows, and applying those results to the other rivers, significant amounts of this habitat are not expected to be present in the lower Guadalupe and San Antonio Rivers within the range of natural monthly 25th percentile flows (Table 3-3, Figure 3-1).

The area of fast riffle (Type 3) habitat at Leisure Camp peaks broadly across the flow range 120-240 cfs, so that some decrease in this habitat occurs at 25th percentile flows in the drier months (August, July, and September), and corresponding decreases in this habitat could be expected to occur in the Lower Guadalupe and San Antonio Rivers. While a single fish species (speckled chub) that might be strongly affected by changes in this habitat type is certainly present in the lower Guadalupe River (three others might be present, but, are primarily characteristic of the Edwards Plateau), it does not appear to be present in the Lower San Antonio River. Speckled chub populations would appear to be adequately protected by requiring passage flow substantially lower than the 25th percentile flows of the wetter months. Other species would appear to be adequately protected year round at flows approximating the 25th percentile for the driest month.

In the naturalized period of record used for the Guadalupe and San Marcos Rivers in this analysis, several of the drier months exhibit 25th percentile flows that are lower than the naturalized 7Q2 flows for the corresponding reach (Table 3-3), and substantially lower than the published 7Q2 flows.[44] Under the Consensus Criteria, direct diversions are to be limited by the published 7Q2 flow for the affected river reach in Zone 3, but in the case of the lower Guadalupe and San Antonio Rivers, the appropriate 7Q2 flows exceed the 25th percentile flows for the 6-month period July through December at Victoria (published 7Q2 641.9 cfs) and for all months at Falls City on the San Antonio River (published 7Q2 197.3 cfs). In the latter case the published 7Q2 exceeds the naturalized median monthly flows for all 5 months from July through December at that location. Absent adverse effects on water quality (see following sections), this restriction is not based on demonstrated biological need or habitat-discharge relationship. The most sensitive habitat present at this flow range is not expected to experience any decline in area at flows above the 25th percentile for all months. As indicated in Figure 3-2, habitat areas of all types appear to be adequately preserved at flows approaching the 25th percentile in the driest month.

3.2.3 Zone 3 — Drought Conditions

Diversion operations in Zone 3 are limited by the required passage of at least the 7Q2 flow, unless site specific studies can show that water quality and aquatic life uses would be protected at lower flows. At Victoria, the published 7Q2 flow is 641.9 cfs (based on the 1968-89 historical period) while the natural 7Q2 is about 585 cfs (based on the 1934-89 historical period). Under Consensus Criteria, diversions would be suspended at the 7Q2, which is within Zone 2 during the drier months. Dissolved oxygen modeling to assess the extent that Segment dissolved

[44]Texas Administrative Code 307.10 B Low Flow Criteria.

oxygen standards would be protected at flows below the 7Q2 is being performed as part of this project by HDR Engineering, Inc. A less sophisticated modeling effort in support of the City of Victoria's water rights application resulted in the definition of monthly "low" flows ranging from 150 cfs up to 300 cfs that are "needed to protect water quality in the river, and to a limited extent on a short-term basis, provide dissolved oxygen levels for maintaining fish and wildlife species".[45]

In addition to dissolved oxygen, TNRCC staff has suggested that other appropriate variables be considered in evaluating minimum streamflows at the drought level. Suggested variables included all segment standards (i.e., pH, dissolved solids, sodium, etc.), standards for toxic materials, toxicity as shown by whole effluent biomonitoring results, and aquatic life uses. Based on substantial preliminary work by the TNRCC Water Quality Standards and Assessment group, an outline of procedures to address these issues is presented below.

Permit files are first compiled for all discharges below the proposed diversion to provide the data base from which to work. Non-point sources may or may not be a problem depending on the magnitude of the sources, dry weather transport (groundwater, animal movements), and the nature of the pollutants.

Permit files would be screened for conventional and toxic based permit limits, and thermal (temperature) limits. Where discharge locations are in tributaries, limits may have been set to protect the tributary stream.

Dissolved Oxygen modeling would be conducted to determine segment assimilative capacity (in terms of the minimum flows needed to maintain Segment DO standards), assuming existing water quality conditions and effluent sets, but using future discharge volumes predicted for the planning horizon. The assimilative capacity of a segment could be increased by increasing the level of wastewater treatment, or by reduction of non-point sources of oxygen demand.

Thermal discharges below the proposed diversion would be modeled individually to assure that permit criteria were met. These are generally in the form of upper temperature limits, and proportion of river channel affected. Central Power and Light Company (CP&L) has conducted

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[45]Water Rights Permit No. 5466, City of Victoria, Texas, January 29, 1996.

New waste load allocations would be calculated where projected wastewater volumes, existing toxic material concentrations, and the amount of reduction proposed for the low flow limit indicate that a change in permit status (i.e., monitoring or toxic limits required, toxic criteria violated) is a probable outcome of implementing a diversion. Background concentrations of some toxic materials may be a consideration in calculating waste load allocations at some locations. This will be reflected in the permit files, and can be included in the calculation of WLAs.

Whole effluent toxicity limits are determined by biomonitoring, and apply at and above 7Q2 streamflows. Examination of biomonitoring results together with recalculation of instream dilution expected with the new low flow limit may provide sufficient data to examine the potential effects. However, it may also be necessary to conduct additional biomonitoring studies at dilutions more appropriate to the proposed alteration of streamflows to resolve this question.

Aquatic Life Uses are determined from physical measurements and biological samples which are preferably collected during summer low flow conditions. Those conditions encompass the 7Q2 flow, and arguably any flow shown by the preceding analyses to protect water quality, and they coincide with the preferred sampling condition for evaluating Aquatic Life Uses and the biological integrity of fish and invertebrate assemblages. Use of one of these flows should not adversely impact those communities as pool, run and slow to moderate riffle and backwater habitats will still be relatively unaffected, while the faster riffle and run habitat is already nearly non-existent in this range under a natural flow regime. The speckled chub and the river darter are the species most likely to experience direct, adverse effects resulting from diversions from the lower Guadalupe River. Changes in population abundances of any of the resident species may occur, either evidently or obscurely, as a result of diminished flows, but the record compiled by the Philadelphia Academy of Natural Sciences and summarized in preceding sections is one of constantly fluctuating population sizes and changing assemblages of organisms having adaptations to similar ranges of environmental variables.

3.2.4 Operation at Zone Transitions

The transition through boundaries between zones under Consensus Criteria results in diminishing diversions as ambient streamflow approaches the zone minimum flow. This transition can affect project yield. More importantly, if written into permits, it could make day-to-day operations difficult by placing unnecessary restrictions on diversions at times when there is "plenty" of water in the river. There is no apparent biological rationale favoring this type of transition over one allowing for diversions to "ramp through" the Zone 1 and 2 minimum flows.

4.0 SENSITIVITY ANALYSES

As the sponsors of the Trans-Texas Water Program for the West Central Study Area continue with the development of feasible, long-range water supply plans, it is imperative that the environmental water needs criteria used to evaluate potential projects comprising these plans adequately reflect the unique characteristics of the Guadalupe - San Antonio River Basin. Furthermore, the environmental water needs criteria should, to the extent possible, facilitate the selection and implementation of the most economically and environmentally feasible projects. In this section, preliminary findings drawn from the water quality modeling results (Section 2) and consideration of biological studies (Section 3) are used in the performance of sensitivity analyses intended to illustrate the effects of instream flow criteria selection on water available for diversion, firm yield with off-channel storage, unit cost of water supply, streamflows below a new diversion location, and freshwater inflows to the Guadalupe Estuary.

All sensitivity analyses presented in this Technical Memorandum are based on potential direct diversions from the Guadalupe River near Cuero to a nearby off-channel storage reservoir. In order to portray the potential yields, costs, and environmental effects associated with a relatively large scale project, the maximum diversion rate from the Guadalupe River was set at almost 800 cfs which approximates the transmission capacity of two, 10-foot diameter pipelines. It is important to note that observations or conclusions drawn from sensitivity analyses based on this theoretical project configuration are not necessarily applicable for other potential projects in the Guadalupe - San Antonio River Basin. The sensitivity analysis procedure employed does, however, provide an example format for consideration of other potential projects at other locations.

4.1 Scenario Description

A spectrum of potential direct diversion criteria scenarios based upon the three-zoned structure used in the Environmental Water Needs Criteria of the Consensus Planning Process (Consensus Criteria) was considered in the performance of sensitivity analyses. This spectrum ranges from direct application of the Consensus Criteria as presently defined (Scenario 1) to the neglect of instream flow needs in deference to simply honoring senior water rights (Scenario 6). The six direct diversion criteria scenarios considered for a theoretical diversion from the

Guadalupe River near Cuero are summarized in Figure 4-1 and described (with focus on Zones 2 and 3) in Table 4-1. In Figure 4-1, it is important to note the degree to which Zone 3 is limited under Scenario 1 by the elevated 7Q2 (7 day low flow having a 2-year return period or 50 percent chance of occurrence in any given year) associated with a springflow dominated stream such as the Guadalupe River.

4.2 Water Availability

The Guadalupe - San Antonio River Basin Model (GSA Model)[1] was used to quantify monthly estimates of water available for a new direct diversion from the Guadalupe River near Cuero subject to each of the six direct diversion criteria scenarios identified in Table 4-1. Other assumptions pertinent to computation of these example water availability estimates included:

- Springflows resulting from a fixed Edwards Aquifer pumpage rate of 400,000 acft/yr
- Utilization of all consumptive water rights and water supply contracts
- Full subordination of hydropower rights to Canyon Reservoir
- Treated effluent discharge in amounts reported for 1989
- Maximum diversion rate of approximately 800 cfs

Long-term (1934-89) and drought (1947-56) average estimates of water available for diversion under each direct diversion criteria scenario are presented in Figure 4-2.

As indicated in Figure 4-2, average water availability at this location ranges from about 160,000 acft/yr to 390,000 acft/yr over the long-term and from about 40,000 acft/yr to 180,000 acft/yr during drought, depending on direct diversion criteria scenario. Comparing the extremes in terms of the direct diversion criteria scenarios presented in Figure 4-2, it is apparent that a long-term average of almost 60 percent [(390,000-160,000)/390,000] of the water potentially available for diversion subject to senior water rights and maximum diversion rate (Scenario 6) is committed to environmental water needs under the Consensus Criteria as presently defined (Scenario 1). This percentage increases to about 78 percent [(180,000-40,000)/180,000] during drought when environmental and other water needs become most critical. Potential modification of the water quality standard from the TNRCC 7Q2 to a value based on compliance with the

[1] HDR, "Guadalupe - San Antonio River Basin Recharge Enhancement Study," Edwards Underground Water District, September, 1993.

studies of the thermal effects of their cooling water discharge, located at Victoria, on the Guadalupe River. The information in this report may be sufficient to evaluate the interaction of the thermal discharge and streamflow level.

Numerical criteria for toxic material to protect aquatic life apply at and above 7Q2 flows, while those intended to protect human health apply at levels at and above harmonic-mean flows. Human health criteria include Total Dissolved Solids (TDS), chloride (Cl^-) and sulfate ($SO4^=$), which also apply at levels at and above harmonic-mean flows. Effluent screening for toxic materials is required for discharges larger than 1 million gallons per day (MGD), or if a pre-treatment system is in place. Examination of permit files will provide toxic screening information, calculated waste load allocations, and (where necessary) effluent concentration limits.

Permit limits for toxic materials are required where screening indicates that the material in the effluent is within 85 percent of the critical concentration (the effluent concentration that would result in a violation of a toxic standard at 7Q2 or harmonic mean streamflow, as applicable), and monitoring is required where a toxic material in an effluent is within 70 percent of the critical concentration. Discharge permits containing limits or monitoring requirements on toxic materials are therefore a "red flag" for diversions that would affect streamflows below the 7Q2 or harmonic-mean thresholds.

Toxic permit limits are calculated so that average and maximum effluent concentrations will not result in receiving water concentrations that exceed the appropriate acute or chronic criteria after complete mixing with the receiving water. Waste load allocations (WLA) are calculated to express toxic concentrations at the edge of the appropriate mixing zone (ZID or MZ) in units of the applicable toxic criterion (i.e., percent of criterion) as follows:

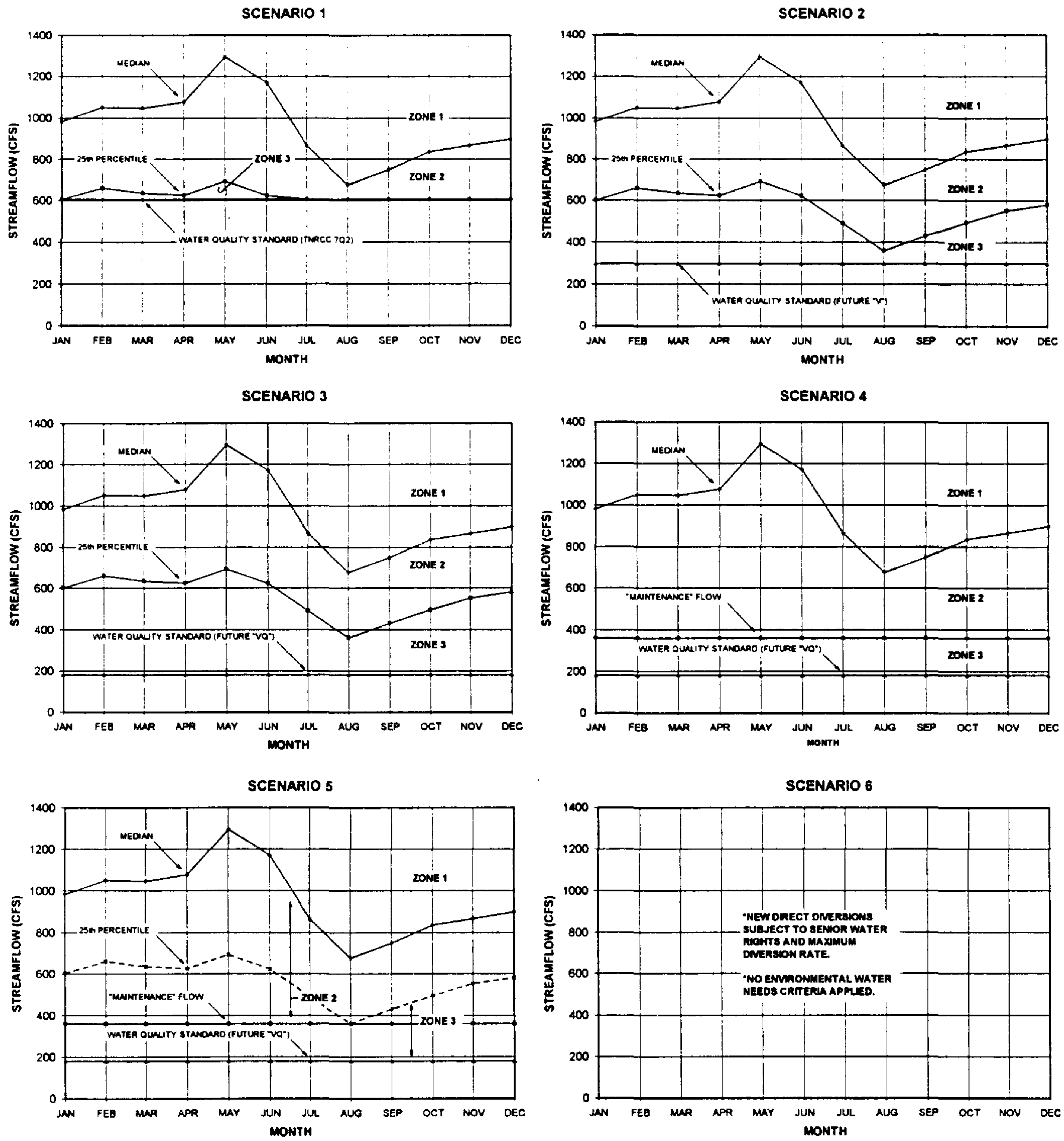
$$WLA = \text{Criterion} / \left[\left(Q_E / Q_S \cdot Q_E \right) * F \right]$$

Criterion = Maximum allowable concentration in the stream (acute, chronic, human health standard, etc.)

QS = low flow limit (25 percent7Q2, 7Q2, harmonic mean)

QE = effluent flow (permitted daily average, maximum monthly average, etc.)

F = fraction available (=1.0 except for some metals where only dissolved form is regulated)



NOTES:
1) EXAMPLE SCENARIOS FOR NEW DIRECT DIVERSION FROM GUADALUPE RIVER AT CUERO.
2) NEW DIRECT DIVERSION SUBJECT TO SENIOR WATER RIGHTS.

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SCENARIO SUMMARY
DIRECT DIVERSION CRITERIA
SENSITIVITY ANALYSES

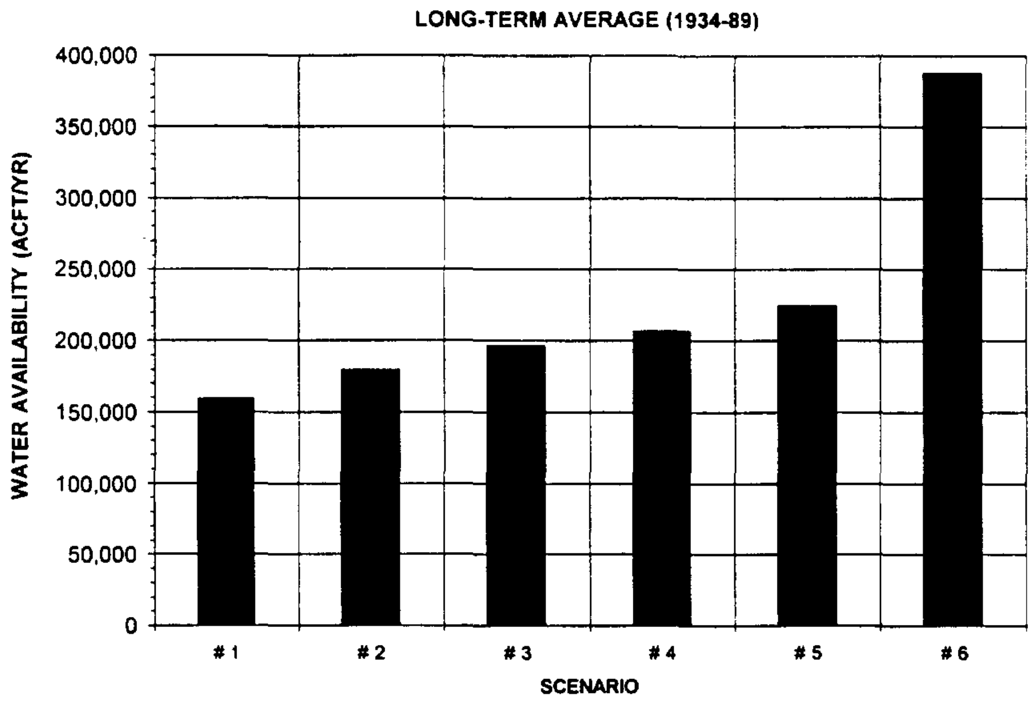
FIGURE 4-1

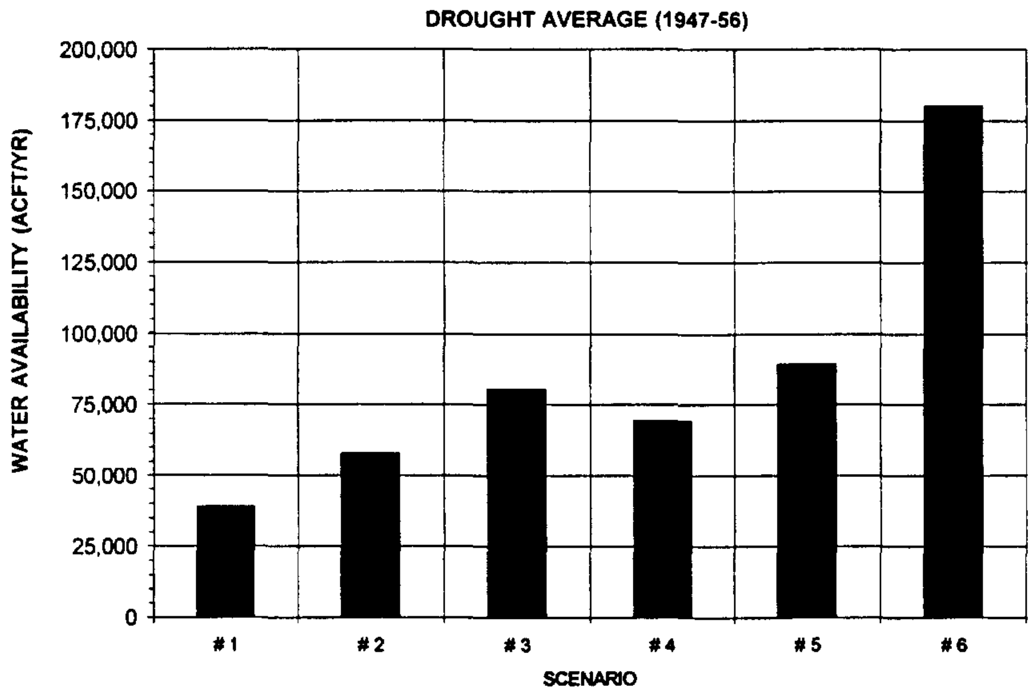
Scenario 5 Modified Consensus Criteria with Water Quality Standard Revised for Volume and Treatment and Replacement of Zone 2 Minimum with "Maintenance" Flow

- Zone 2 minimum = 361.2 cfs (minimum monthly 25th percentile flow) or "maintenance" flow per interpretation of data collected on San Marcos River and extrapolation to the Guadalupe River near Cuero (Section 3.2.2)
- Zone 3 minimum = 181 cfs per water quality modeling results for compliance with dissolved oxygen standard subject to future effluent volumes discharged at future treatment standards (Scenario "VQ," Section 2.2.5.3)

Scenario 6 No Environmental Water Needs Criteria Applied

- New direct diversions subject to senior water rights and maximum diversion rate





NOTES:
1) EXAMPLE SCENARIOS FOR NEW DIRECT DIVERSION FROM GUADALUPE RIVER @ CUERO
2) MAXIMUM DIVERSION RATE LIMITED TO ABOUT 800 CFS BASED ON 2-10' DIAMETER DIVERSION PIPELINES

GUADALUPE - SAN ANTONIO RIVER BASIN ENVIRONMENTAL CRITERIA REFINEMENT

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WATER AVAILABILITY SUMMARY WITHOUT OFF-CHANNEL STORAGE

FIGURE 4-2

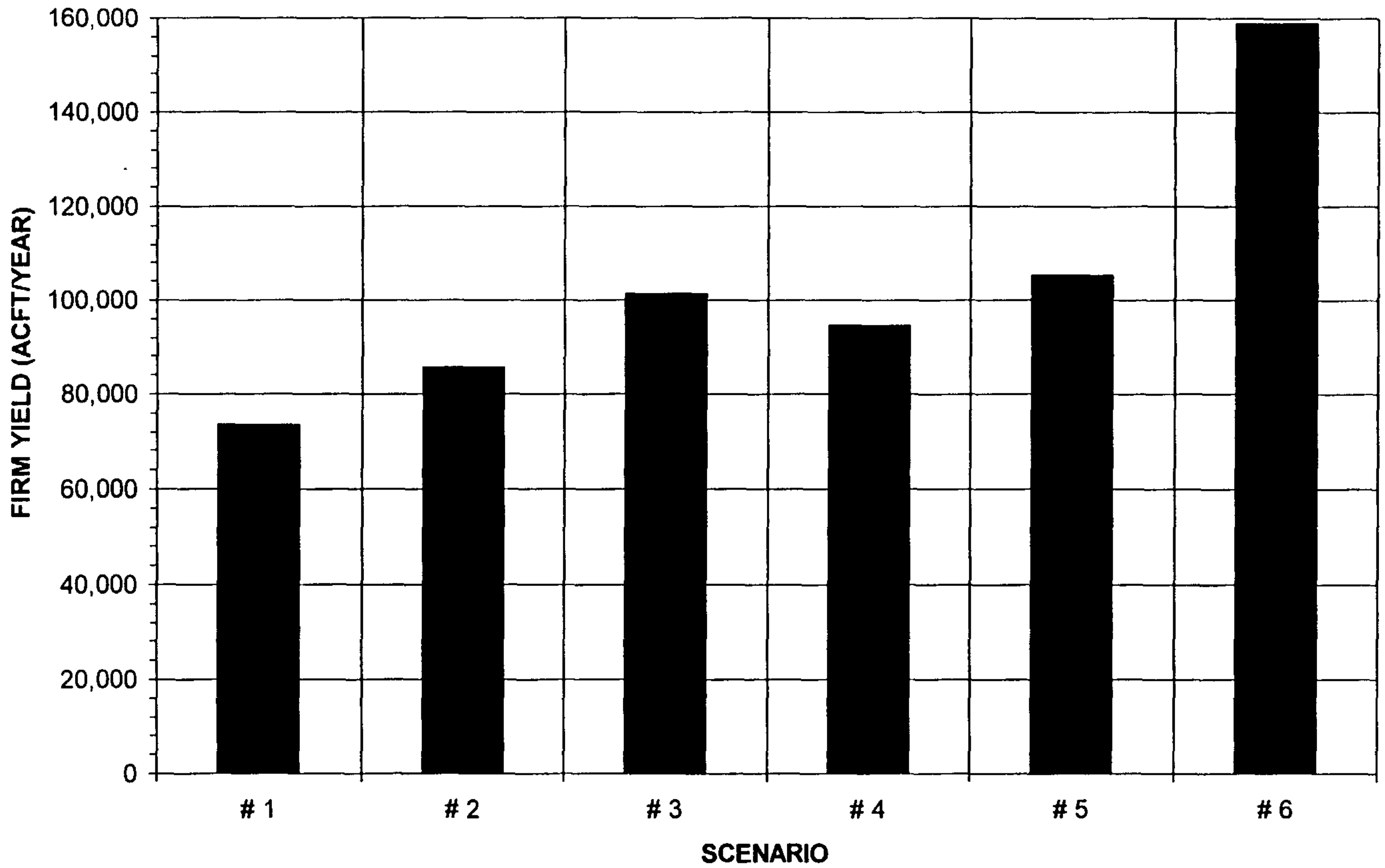
dissolved oxygen standard subject to future effluent volumes and treatment standards (Scenario 3) could more than double drought average availability relative to Scenario 1. Modification of the Zone 2 minimum flow to an assumed "maintenance" flow, however, results in relatively small incremental increases (Scenario 5) or decreases (Scenario 4) in drought average availability depending upon the Zone 3 trigger streamflow.

4.3 Firm Yield and Off-Channel Storage

Water availability may be highly variable from month to month necessitating the development of off-channel storage facilities to ensure a dependable, uninterrupted water supply or firm yield. Firm yield is defined to be the maximum amount of water which can be supplied from a reservoir without shortage through the most severe drought on record. Figure 4-3 summarizes the computed firm yield of a 606,000 acft off-channel reservoir with natural inflows supplemented by diversions from the Guadalupe River subject to each of the six direct diversion criteria scenarios identified in Table 4-1. Operations of the off-channel reservoir were governed by the Consensus Criteria for New Reservoirs and simulated using the SIMDLY computer model created by the Texas Water Development Board.

As indicated in Figure 4-3, firm yield ranges from 74,000 acft/yr to 159,000 acft/yr, depending on direct diversion criteria scenario. Potential modification of the water quality standard governing river diversions from the TNRCC 7Q2 to a value based on compliance with the dissolved oxygen standard subject to future effluent volumes and treatment standards (Scenario 3) could increase firm yield by about 38 percent relative to Scenario 1. Modification of the Zone 2 minimum flow to an assumed "maintenance" flow, however, results in relatively small incremental increases (Scenario 5) or decreases (Scenario 4) in firm yield depending upon the Zone 3 trigger streamflow. Hence, firm yield is substantially more sensitive to the water quality standard (Zone 3 minimum flow) than to the Zone 2 minimum flow.

The 606,000 acft off-channel reservoir assumed for computation of the firm yield estimates presented in Figure 4-3 is quite large and might or might not ultimately prove feasible as almost 30,000 acres (46 square miles) would be perennially inundated. Should decreasing the size of the off-channel reservoir be desirable, Figure 4-4 portrays the relationships between firm yield and off-channel storage capacity or area inundated by the reservoir for four direct diversion



NOTES:
1) EXAMPLE SCENARIOS FOR NEW DIRECT DIVERSION FROM GUADALUPE RIVER @ CUERO
2) MAXIMUM DIVERSION RATE LIMITED TO ABOUT 800 CFS BASED ON 2-10' DIAMETER DIVERSION PIPELINES
3) OFF-CHANNEL RESERVOIR STORAGE CAPACITY = 606,000 ACFT

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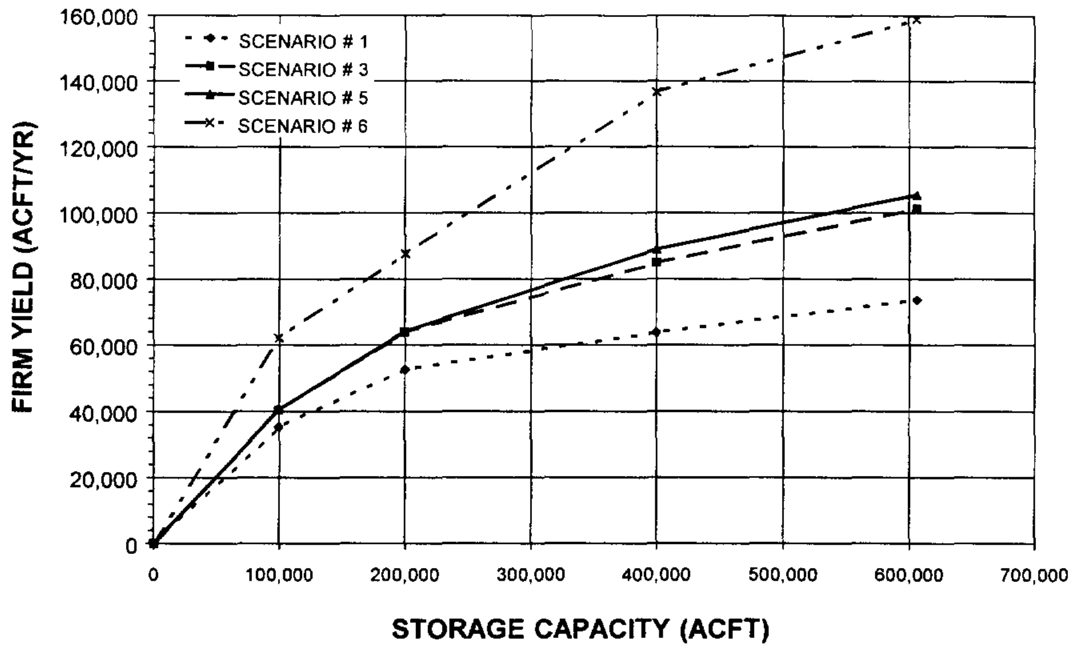
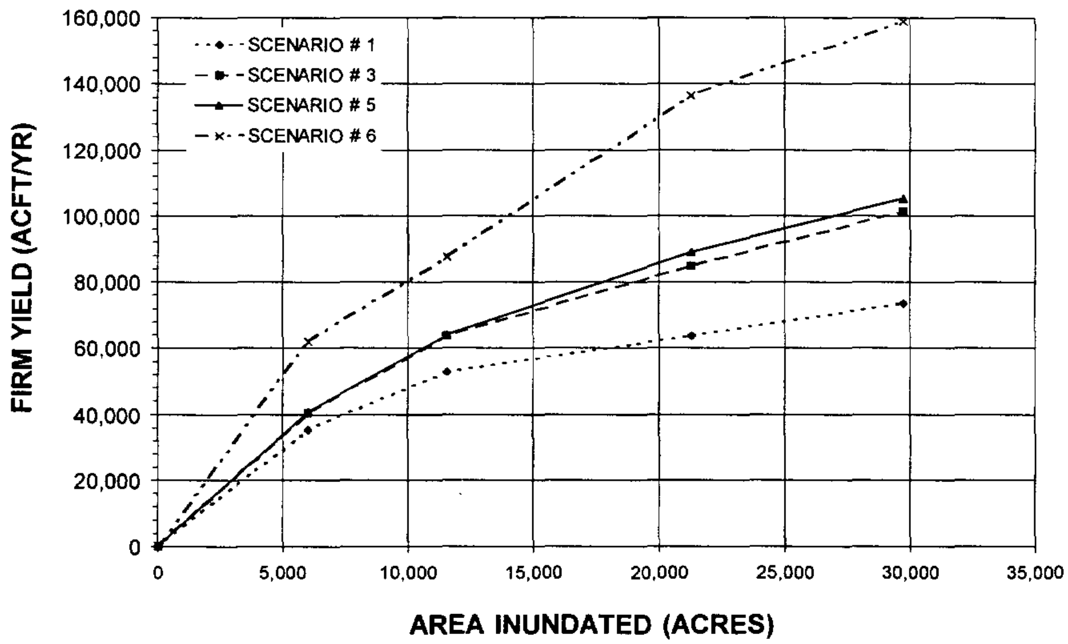
FIRM YIELD SUMMARY WITH OFF-CHANNEL STORAGE OF ASSUMED CAPACITY

FIGURE 4-3





NOTES:
1) EXAMPLE SCENARIOS FOR NEW DIRECT DIVERSION FROM GUADALUPE RIVER AT CUERO.
2) MAXIMUM DIVERSION RATE LIMITED TO ABOUT 800 CFS BASED ON 2-10' DIAMETER DIVERSION PIPELINES.

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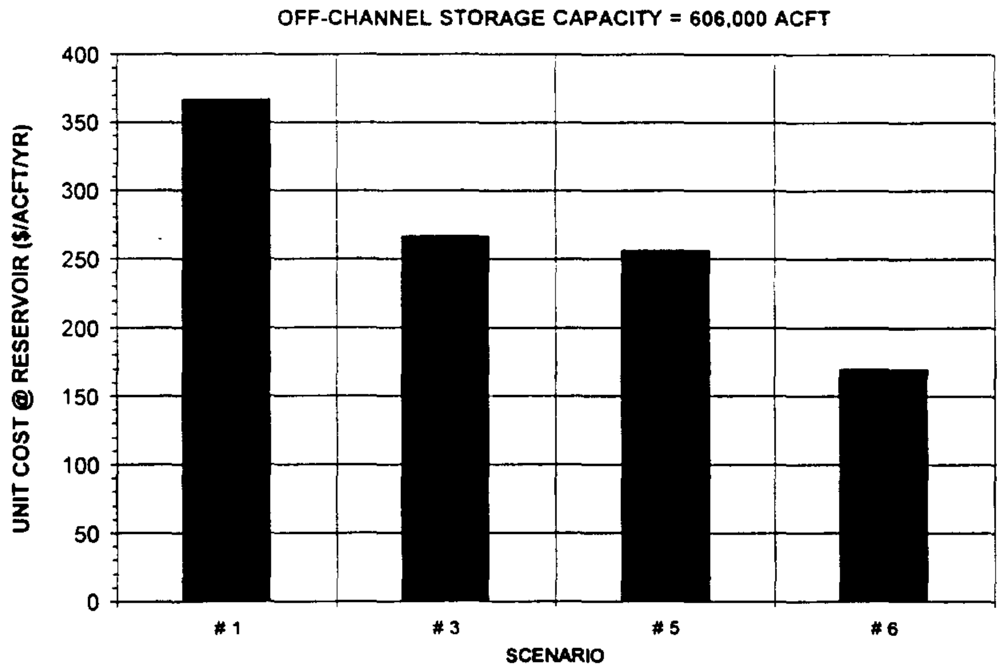
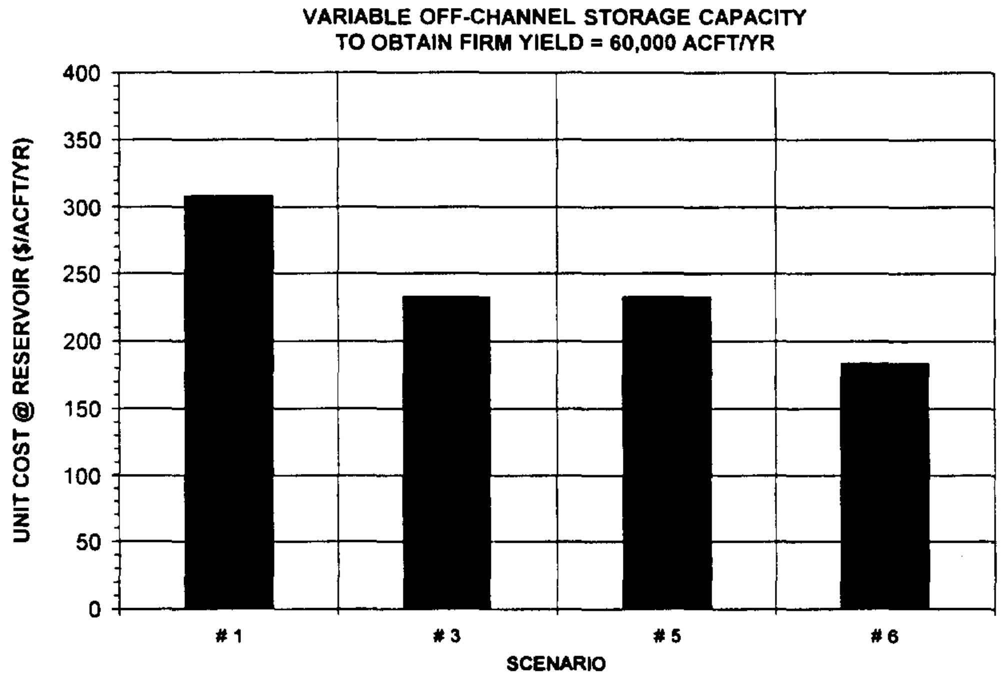
FIRM YIELD SUMMARY WITH OFF-CHANNEL STORAGE OF VARIABLE CAPACITY

FIGURE 4-4





NOTES:
1) EXAMPLE SCENARIOS FOR NEW DIRECT DIVERSION FROM GUADALUPE RIVER AT CUERO.
2) MAXIMUM DIVERSION RATE LIMITED TO ABOUT 800 CFS BASED ON 2-10' DIAMETER DIVERSION PIPELINES.
3) UNIT COSTS FOR FIRM YIELD AT OFF-CHANNEL RESERVOIR (COSTS DO NOT INCLUDE TRANSMISSION, TREATMENT, AND DISTRIBUTION)
4) UNIT COSTS DO NOT INCLUDE INCREMENTAL WASTEWATER TREATMENT PLANT UPGRADES TO OBTAIN ASSUMED EFFLUENT QUALITY.

GUADALUPE - SAN ANTONIO RIVER BASIN
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UNIT COST SUMMARY FOR FIRM YIELD WITH OFF-CHANNEL STORAGE

FIGURE 4-5

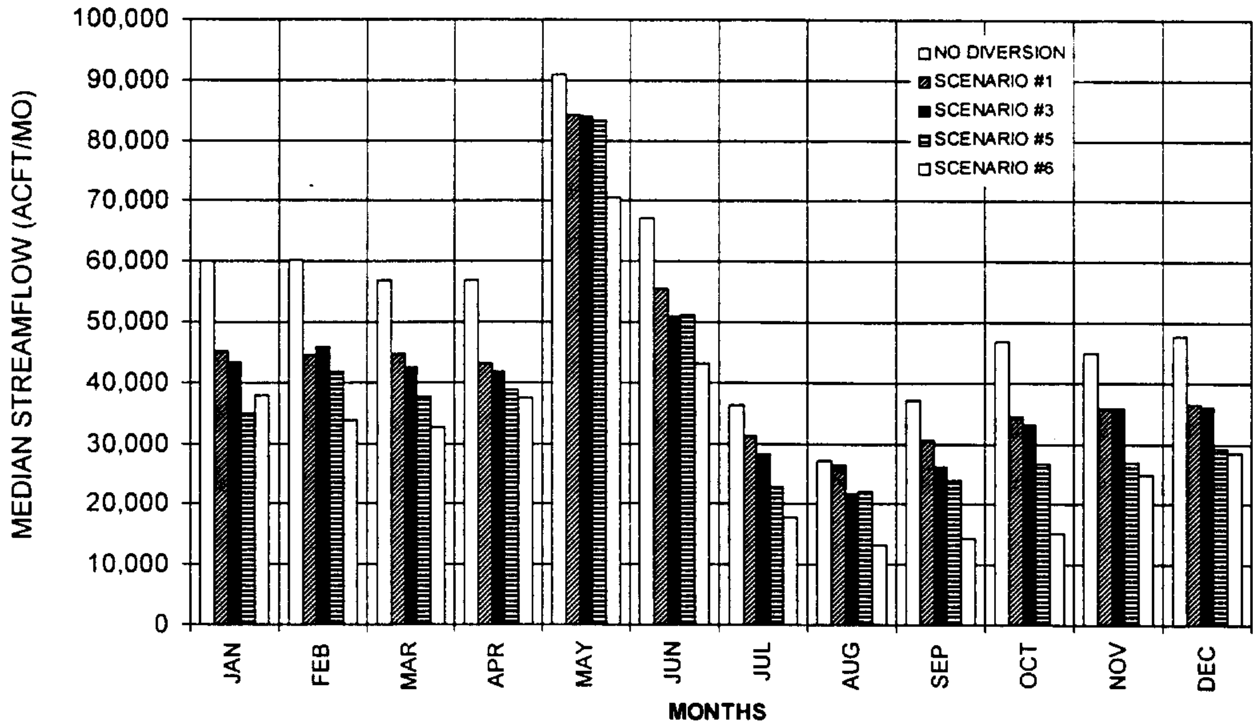
criteria scenarios. Figure 4-4 illustrates the potential effects of instream flow criteria (intended in part to protect estuarine and riverine habitats) on terrestrial habitat.

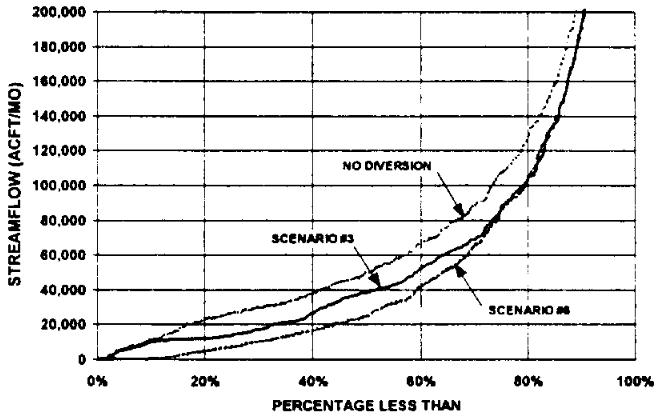
For example, if development of a direct diversion project providing a 60,000 acft/yr firm yield were the objective, Figure 4-4 indicates that between 330,000 acft (Scenario 1) and 95,000 acft (Scenario 6) of off-channel storage capacity would be required. Corresponding area inundated would range from about 18,000 acres (Scenario 1) down to only 6,000 acres (Scenario 6). Potential modification of the water quality standard governing river diversions from the TNRCC 7Q2 to a value based on compliance with the dissolved oxygen standard subject to future effluent volumes and treatment standards (Scenario 3) could reduce area inundated to about 11,000 acres which represents a 17 square mile (39 percent) reduction in inundated area necessary to obtain a 60,000 acft/yr firm yield as compared to Scenario 1. In the development of dependable water supply through direct diversions and off-channel storage, balancing the benefits of committing water to instream flow needs and the environmental costs of committing land to perennial inundation is clearly a very important consideration.

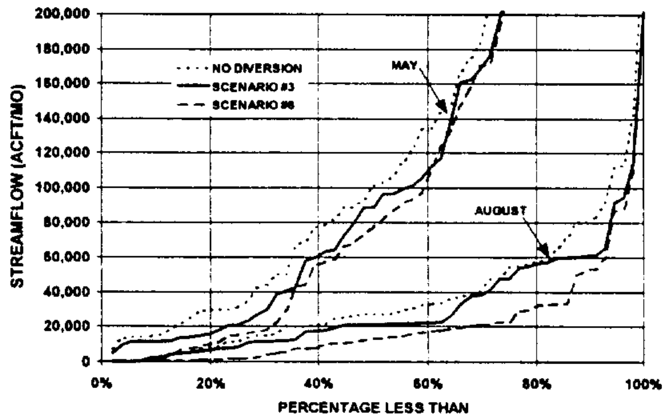
4.4 Unit Cost Considerations

The total annual cost of developing and maintaining a direct diversion water supply project may include specific capital or annual costs associated with diversion and transmission facilities, a dam and off-channel storage reservoir, land acquisition, environmental studies and mitigation, engineering and legal, debt service, operations and maintenance, and power for pumping facilities. The unit cost of a project is often presented in $/acft/yr and computed by dividing the total annual cost by the firm annual yield provided by the project. Furthermore, the unit cost water is a very useful figure for determining the appropriate size of a given project and for comparison of a given project to other potential alternatives.

Figure 4-5 provides a summary of the estimated unit cost of water at the off-channel reservoir (excluding other costs associated with water transmission, treatment, and distribution) subject to four of the direct diversion criteria scenarios. Unit costs are presented in Figure 4-5 for a single large off-channel storage capacity and for variable storage capacity as necessary to obtain a firm yield of 60,000 acft/yr. Note that these unit costs do not reflect costs associated







NOTES:
1) EXAMPLE SCENARIOS FOR NEW DIRECT DIVERSION FROM GUADALUPE RIVER AT CUERO.
2) MAXIMUM DIVERSION RATE LIMITED TO ABOUT 800 CFS BASED ON 2-10' DIAMETER DIVERSION PIPELINES.
3) OFF-CHANNEL RESERVOIR STORAGE CAPACITY = 606,000 ACFT.

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MODIFIED STREAMFLOW SUMMARY WITH NEW DIRECT DIVERSION GUADALUPE RIVER AT CUERO

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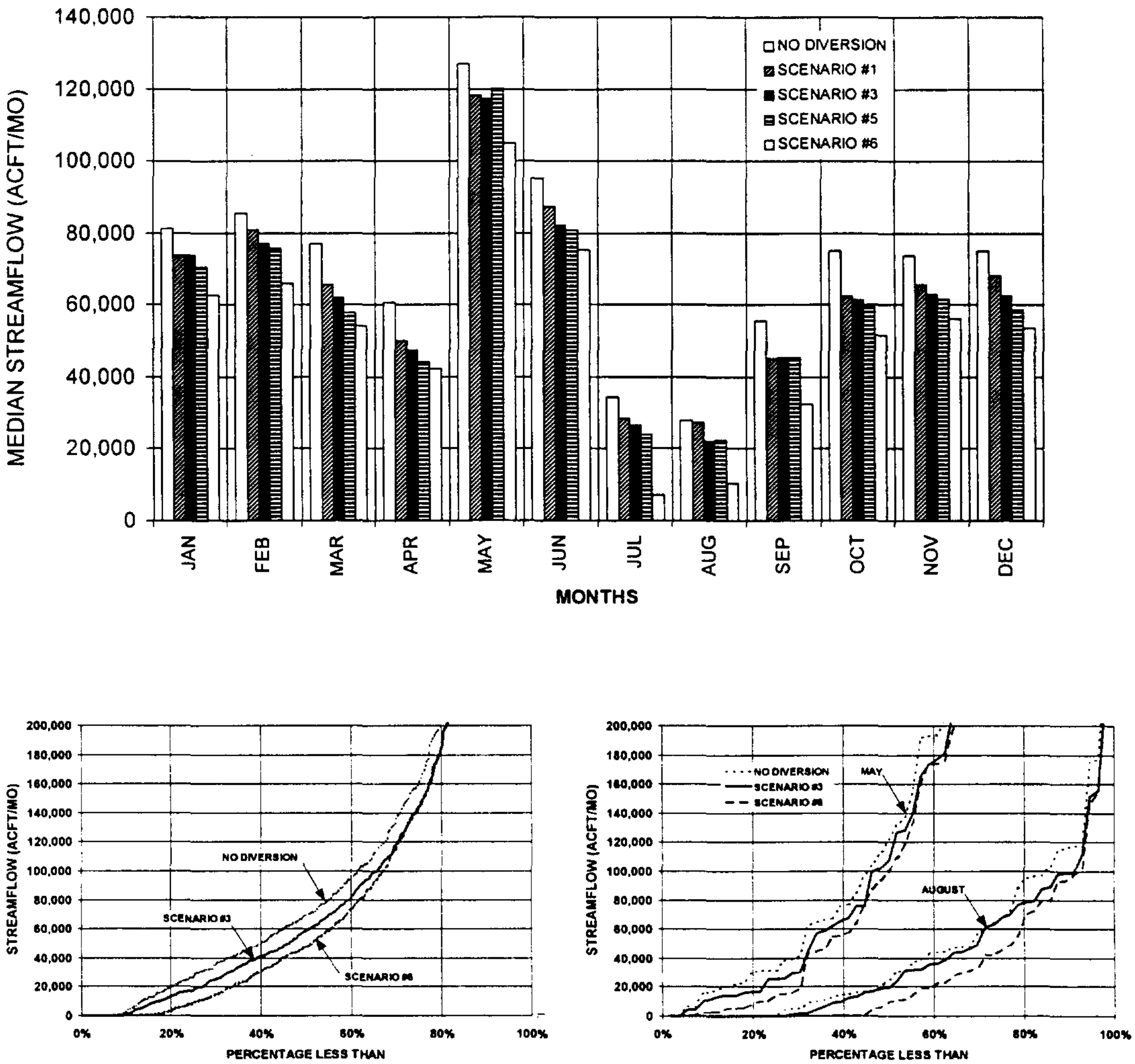
FIGURE 4-6

with wastewater treatment plant upgrades potentially necessary to allow modification of the water quality standard (Zone 3 minimum flow) under some direct diversion scenarios. For the large off-channel reservoir, unit costs at the reservoir range from $170/acft/yr (Scenario 6) up to $370/acft/yr (Scenario 1). Allowing off-channel storage capacity to vary as necessary to obtain a firm yield of 60,000 acft/yr, unit costs range from $180/acft/yr (Scenario 6) up to $310/acft/yr (Scenario 1). Potential modification of the water quality standard from the TNRCC 7Q2 to a value based on compliance with the dissolved oxygen standard subject to future effluent volumes and treatment standards (Scenario 3) could reduce unit cost by $80/acft/yr up to $100/acft/yr relative to Scenario 1. Modification of the Zone 2 minimum flow to an assumed "maintenance" flow, however, results in relatively small incremental decreases (Scenario 5) in unit cost.

4.5 Downstream Considerations

A relatively large scale direct diversion project with a large off-channel storage reservoir was selected for use in the performance of these sensitivity analyses in order to illustrate something approaching the maximum effect of a single project on downstream flows and freshwater inflows to the Guadalupe Estuary. For this series of illustrative examples, the mainstem location at which the greatest percentage changes in streamflow regime would occur is immediately below the Guadalupe River diversion point near Cuero. Figure 4-6 presents monthly median streamflows and streamflow frequency curves for the highest (May) and lowest (August) months and for all months subject to a range of direct diversion criteria scenarios. Note that this figure also includes "baseline" monthly medians and streamflow frequency curves which reflect no diversions in addition to those made under existing water rights.

Upon review of Figure 4-6, it is clear that implementation of a direct diversion project of this size would have substantial impacts on streamflows near Cuero. Comparing streamflow medians without additional diversions to those with diversions limited only by senior water rights and maximum river diversion rate (Scenario 6), reductions would average about 44 percent for all months and range from a minimum of 22 percent in May to a maximum of 67 percent in October. Diversion under Scenario 6 would reduce streamflows to essentially zero in more than 10 percent of the months simulated. Similarly, comparing streamflow medians without additional diversions to those with modification of the water quality standard (Scenario 3),



NOTES:
1) EXAMPLE SCENARIOS FOR NEW DIRECT DIVERSION FROM GUADALUPE RIVER AT CUERO.
2) MAXIMUM DIVERSION RATE LIMITED TO ABOUT 800 CFS BASED ON 2-10' DIAMETER DIVERSION PIPELINES.
3) OFF-CHANNEL RESERVOIR STORAGE CAPACITY = 606,000 ACFT.

GUADALUPE - SAN ANTONIO RIVER BASIN
ENVIRONMENTAL CRITERIA REFINEMENT

TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

HDR Engineering, Inc.

MODIFIED STREAMFLOW SUMMARY WITH NEW DIRECT DIVERSION GUADALUPE RIVER AT SALTWATER BARRIER
FIGURE 4-7

reductions would average about 23 percent for all months and range from a minimum of 8 percent in May to a maximum of 29 percent in September. Note, however, that modified streamflows subject to Scenario 3 approximate those without additional diversions during the most severe drought periods because additional diversions are precluded by the need to protect water quality. Under Consensus Criteria as presently defined (Scenario 1), reductions in monthly median streamflows as compared to those without additional diversions would average about 19 percent for all months.

Potential changes in streamflow for the Guadalupe River at the Saltwater Barrier near Tivoli resulting from the implementation of this example large scale direct diversion project are summarized in Figure 4-7. Due to the intervening contribution of the San Antonio River, impacts associated with diversions subject to several direct diversion criteria scenarios are somewhat less severe than those presented for the Guadalupe River near Cuero. Comparing streamflow medians without additional diversions to those with diversions limited only by senior water rights and maximum river diversion rate (Scenario 6), reductions would average about 34 percent for all months and range from a minimum of 18 percent in May to a maximum of 63 percent in August. Similarly, comparing streamflow medians without additional diversions to those with modification of the water quality standard (Scenario 3), reductions would average about 16 percent for all months and range from a minimum of 8 percent in May to a maximum of 23 percent in July. Under Consensus Criteria as presently defined (Scenario 1), reductions in monthly median streamflows as compared to those without additional diversions would average about 11 percent for all months.

In addition to summaries of changes in streamflows, estimates of Guadalupe Estuary fisheries harvest were computed from simulated freshwater inflows using a program[2] developed by HDR based on equations developed by the Texas Water Development Board and the Texas Parks & Wildlife Department.[3] Unfortunately, the results from application of these equations are inconclusive as general reductions in freshwater inflow decrease the number of years for which a valid harvest estimate can be obtained within the historical bounds of the seasonal freshwater

[2] HDR, "Guadalupe - San Antonio River Basin Model Modifications & Enhancements," Technical Memorandum, Trans-Texas Water Program, West Central Study Area, Phase II, San Antonio River Authority, et al., March, 1998.
[3] TWDB & TPWD, "Freshwater Inflows to Texas Bays and Estuaries: Ecological Relationships and Methods for Determination of Needs," Joint Estuaries Research Study, 1994.

inflow averages from which the equations were derived. Hence, fisheries harvest estimates resulting from simulated diversions subject to the direct diversion criteria scenarios are not presented herein. It is recommended that these equations be updated using available data from recent drought periods including 1988-89 and 1994-96 so that more reasonable fisheries harvest estimates may be computed when freshwater inflows are limited.

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5.0 CONCLUSIONS AND RECOMMENDATIONS

This Technical Memorandum presents studies pertinent to refinement of the Environmental Water Needs Criteria of the Consensus Planning Process ("Consensus Criteria") for application in the consideration of water supply alternatives involving new direct diversion projects in the Guadalupe - San Antonio River Basin. These studies focused on:

- Development and application of water quality models for simulation of dissolved oxygen concentrations under various effluent loadings and streamflow regimes;
- Summary and interpretation of biological studies providing information pertinent to the selection of minimum instream flows; and
- Performance of sensitivity analyses for illustration of the effects of variation of streamflow zone minima and triggers under the Consensus Criteria on water available for diversion, firm yield with off-channel storage, water supply project cost, instream flows, and freshwater inflows to the Guadalupe Estuary.

Significant preliminary conclusions and recommendations drawn from the performance of these technical studies are summarized as follows:

- Water quality modeling, focused on the simulation of dissolved oxygen concentrations, indicates that current TNRCC water quality standards based on 7Q2 values for the lower Guadalupe and San Antonio Rivers may be overly restrictive with respect to potential diversions under Consensus Criteria. This preliminary conclusion is supported at both present and future effluent loadings. Additional studies may be required to address potential concerns with other water quality constituents, toxins, and/or aquatic life uses. Improved calibration of the water quality models could be achieved with more frequent measurements of key constituent concentrations at a greater number of locations in the Guadalupe - San Antonio River Basin.
- Limited specific information relating streamflow, aquatic habitat, species populations, and habitat preferences in the San Marcos and Guadalupe Rivers tends to support the conclusion that using the 7Q2 as the water quality standard below which no new direct diversions would be allowed is overly restrictive. This limited information further suggests that a "maintenance" flow somewhat less than the natural 25th percentile streamflow in some months may be adequate to protect most, but not all, species utilizing aquatic habitats in the lower San Marcos and Guadalupe Rivers. In order to ensure adequate environmental protection, comprehensive, site-specific studies will

almost certainly be required prior to permitting or implementation of a new direct diversion project on the scale simulated in the sensitivity analyses presented herein.

- Sensitivity analyses indicate that both the magnitude and cost of a firm, dependable water supply from a new direct diversion project with off-channel storage in the Guadalupe - San Antonio River Basin near Cuero may be significantly affected by the selection of instream flow minima under the Consensus Criteria. Due in large part to springflow and/or treated effluent providing strong baseflow, the sensitivity analyses further suggest that the unit cost of firm water supply is affected to a substantially greater degree by the selection of the Zone 3 minimum or "water quality standard" than by the selection of a Zone 2 minimum or "maintenance" streamflow.

APPENDIX A
ENVIRONMENTAL WATER NEEDS CRITERIA OF THE CONSENSUS PLANNING PROCESS

APPENDIX A
ENVIRONMENTAL WATER NEEDS CRITERIA OF THE CONSENSUS PLANNING PROCESS

ENVIRONMENTAL WATER NEEDS CRITERIA OF THE CONSENSUS PLANNING PROCESS

In pursuit of the goals of reducing conflict among competing water interests, providing consistent State water policy, and increasing planning and regulatory clarity to State water managers, the draft consensus planning methods reached among the three State water agencies for providing water needs involve trade-offs where neither human nor environmental needs unacceptably "prevail" over the other. The proposed methodology is based on the concept of retaining target flows for environmental purposes and allowing human use of flows greater than the target flows. Each of the new project environmental criteria described below provides for the priority of human needs during dry conditions, but also provides for some sharing of the adverse impact of drought by humans and the environment.

Specific data or project features identified in the final design and permitting process of water supply projects may require consideration of detailed criteria, based on site-specific field studies, which were not applied during the longer-range planning process. The environmental provisions specified below are representative of the basic approach to apportion surface water subject to regulatory actions in the entire water development process (i.e., planning through permitting), but only approximating what may be required for environmental needs in the final permit decision. In addition to passage of environmental flows, adequate flows will be passed through for protection of downstream water rights. In lieu of site-specific studies in the permitting process, the criteria will have the rebuttable presumption of validity. When the results of intensive freshwater inflow or instream flow studies are available and criteria have been established, those criteria will be used in the Water Plan rather than any generic rule.

NEW PROJECT ON-CHANNEL RESERVOIRS

The conservation storage of new, on-channel water supply reservoirs would be divided into three zones with provisions for varying levels of instream flows downstream of on-channel reservoir projects. Zone 1 occurs when reservoir water levels are greater than 80% of storage capacity, and inflows will be passed up to the monthly medians, calculated with naturalized daily stream flow estimates. Also, inflows will be passed to provide one channel flushing flow per season to provide for channel and habitat maintenance. Zone 2 occurs as dry conditions drop reservoir levels to between 50 and 80% of storage capacity. In this zone, inflows would be passed only up to the monthly 25th percentile flow values, calculated with naturalized daily stream flow estimates. In Zone 3, drought conditions worsen, dropping reservoir levels below 50% storage capacity. Inflows would be passed up to the established water quality standard (or 7Q2 value published by the TNRCC) for the downstream segment.

In all zones, instream flow pass-throughs would be targeted to reach the associated estuary system. Flows necessary for the protection of downstream water rights will be added to the appropriate instream flow value determined by the above method. In all cases, no releases will be made from water supply storage to provide environmental flows.

NEW DIRECT DIVERSIONS

Criteria governing direct diversions from a river or stream recommended in the State Water Plan would be based on stream flow conditions just upstream of the diversion point after providing for downstream water rights, and would also be divided into three zones based on hydrologic conditions. Zone 1 occurs when flow is greater than monthly medians; minimum flows passed will be the monthly medians, calculated with naturalized daily stream flow estimates. Zone 2 occurs when flows are greater than the monthly 25th percentile and less than or equal to medians. Minimum flows passed will be the monthly 25th percentile, calculated with naturalized daily stream flow estimates. Zone 3 occurs when stream flow is less than or equal to monthly 25th percentile values. Minimum flows passed will be the larger of: (1) the value necessary to maintain downstream water quality, or (2) a continuous flow threshold to be determined by consensus planning staff (e.g., 15th percentile), that would not allow the diversion by itself to dry up the stream.

NEW DIRECT DIVERSION PROJECTS INTO OFF-CHANNEL STORAGE

In those cases where a recommended water supply project would divert its water from a river or stream into off-channel storage, a combination of the direct diversion and reservoir criteria would apply. The direct diversion criteria will govern the ability to divert water into the off-channel reservoir. The reservoir criteria will address the ability of the project to capture water, as well as define the reservoir's operations to pass environmental flows from its own watershed.

BAY AND ESTUARY CONSIDERATIONS

For most planning purposes, the Zone 1 environmental flow requirements previously described will also provide the target inflows to bays and estuaries (B&E). However, where inflow values that are adequate to meet the beneficial inflow needs as described in Texas Water Code §11.147 have been established, those inflow volumes will be used as the basis for calculating the contributing portions of required water during Zone 1 conditions in new reservoirs or direct diversions for projects located within 200 river miles of the coast, to commence at the mouth of the river. No other special B&E provisions would be made in Zone 2 or Zone 3. These inflow values may be determined by TPWD until that agency and the TNRCC jointly make the determination in accordance with Texas Water Code §11.1491.

AMENDMENTS TO EXISTING PERMITS

Once water supply projects are specifically designed and submitted for permit consideration, a more detailed environmental assessment of its features may be performed. The scope of environmental review and permit consideration of an amendment to an existing water right is limited by law. Because of the many varied conditions around the State, the TNRCC can only provide general guidance as to how the Commission would evaluate applications for water rights and amendments to existing permits. In general, evaluation of impacts to instream or estuarine ecosystems will occur when there is a *significant* change in the point of diversion from downstream to upstream, to an adjoining tributary, to endangered species habitat, or if there is a change of purpose of use from non-consumptive to consumptive. Other changes in place or type of use may have limited or no further environmental review. For further details, refer to A Regulatory Guidance Document for Applications to Divert, Store or Use State Water (June, 1995), published by the TNRCC.

For planning purposes, proposed amendments, such as conversion from non-consumptive to consumptive use (having the effect of a new appropriation) would have the appropriate environmental considerations described for new projects. For other types of amendments where only the intervening river or stream would be affected, the appropriate reservoir or direct diversion instream flow criteria would be applied. Where applicable, environmental flow criteria would only affect that portion of the existing water right subject to change.

ENVIRONMENTAL WATER NEEDS CRITERIA OF THE CONSENSUS PLANNING PROCESS

OVERVIEW

In pursuit of the goals of reducing conflict among competing water interests, providing consistent State water policy, and increasing planning and regulatory clarity to State water managers, the draft consensus proposals reached among the Texas Water Development Board, the Texas Natural Resource Conservation Commission, and the Texas Parks and Wildlife Department on planning methods for providing water needs necessarily involve trade-offs where neither human nor environmental needs unacceptably "prevail" over the other. The challenge facing the technical and policy staff of the three agencies was to craft methods that seek to optimize the provision of environmental flows while minimizing impact on water supply capability.

A guiding desire was to develop a procedure for the Water Plan process that would improve the current method of providing instream flows for environmental purposes with one that will ensure the long-term maintenance of the water-based environment that is so important to Texans, realizing that dry conditions are a natural part of Texas. This process leaves water in the rivers up to an environmental target flow amount and allows human use of flows larger than the target rate. The agencies sought the advice of national experts on how to quantify instream environmental flow targets in a planning process. Their recommendation was that site specific studies should be required, but the instream environment that developed over time should be maintained if river flow rates are normal. The procedure developed uses median flows calculated from naturalized daily streamflow estimates. These estimates are calculated by removing human impacts on the measured flows to represent normal flows, with different operating procedures as river flow conditions change from normal to dry and finally to drought to balance human and environmental uses.

Inter-agency staff have modeled and evaluated well over 100 different scenarios with a variety of alternative management options and in diverse locations and site conditions around the State. We feel the draft proposals listed below produce an acceptable balance between human and environmental needs, and employing straightforward policy considerations and planning methods that are intuitive, consistent, and equitable in their approach. Each of the new project criteria described below provides for the priority of human needs during dry and drought conditions, but at the same time provides for some sharing of the adverse impact of drought by humans and the environment.

It should be emphasized that specific features that are identified in the final project design may require application of detailed criteria during the permitting process which were not applied during the long-range planning process. The environmental provisions specified below are representative of the basic approach to apportion surface water subject to regulatory action in the water planning process, and only approximating what may be required for environmental needs in the ultimate regulatory decision. In lieu of site-specific studies in the permitting process, the criteria will have the rebuttable presumption of validity.

For planning purposes, the environmental pass-through requirements for all zones will be added to flows that provide for downstream water rights. The protection of downstream water rights will be presented by using the full recorded amount of the existing water right and the higher of current reported use or future projected consumptive use (never larger than the full recorded amount of the right) for each downstream right. This range of available water will be noted so that sponsors of surface water development projects will be aware that certain actions on their part may be needed to produce the projected water supply. This approach will ensure that the full permitted rights are recognized during the planning process while identifying areas where significant amounts of appropriated water are presently not being used and potentially available to meet future water needs through marketing, subordination agreements, or other regulatory means.

NEW PROJECT ON-CHANNEL RESERVOIRS

As illustrated in Figure 1, the conservation storage of new-project, on-channel water supply reservoirs would be divided into three zones for environmental instream flow provision as follows:

Zone 1

In Zone 1 of the reservoir, when the reservoir water level is greater than 80% of storage capacity, inflows will be passed up to the monthly medians that are calculated with naturalized daily streamflow estimates.*

Also when the reservoir level is within Zone 1, inflows will be passed to provide one channel flushing flow event per three-month calendar season to provide for channel and habitat maintenance. The default planning criteria allow for a flushing flow event with a 72-hour duration and a peak discharge equal to the site's daily maximum flow with a 1.5-year recurrence interval calculated using an annual historical series of naturalized daily streamflow estimates. During these events, the reservoir will pass-through the higher of: (a) peak flow values, or (b) the sum of environmental pass-throughs, plus flows for protection of downstream water rights. Thus, the flushing flow is not to be stacked on other flow requirements. These environmental criteria should not and are not intended to provide any increase in flooding or cause over-banking below a new reservoir.

* Naturalized streamflow is the estimated amount of water that would have been present in a watercourse with no direct man-made impacts in the watershed. It is calculated by taking values of historically measured streamflow, adding amounts of estimated man-made losses from the upstream watershed caused by diversion and lake evaporation, then subtracting amounts of estimated man-made gains to the upstream watershed caused by return flows.

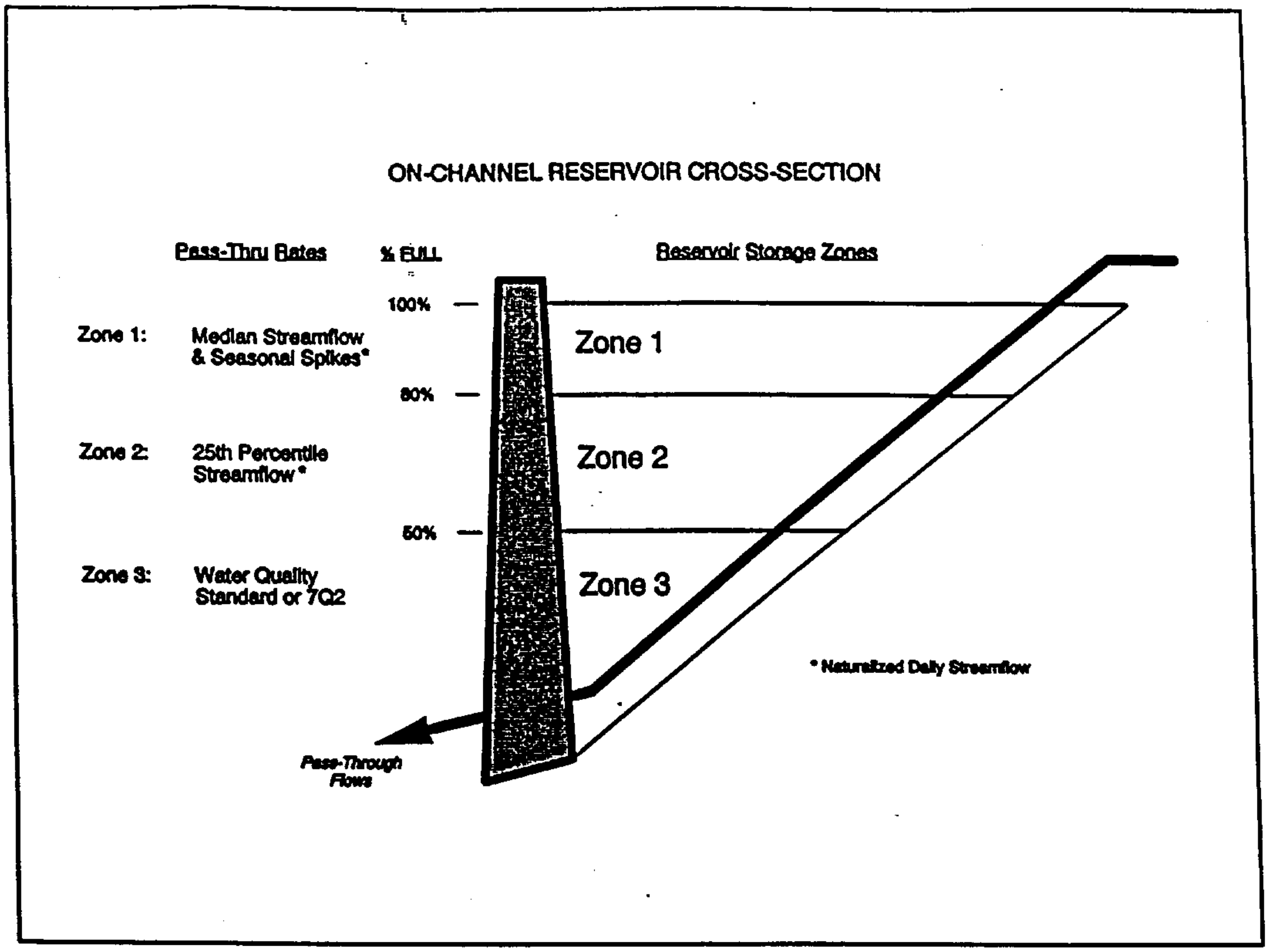

FIGURE 1
NEW PROJECT, ON-CHANNEL RESERVOIR CRITERIA
FOR PASSING ENVIRONMENTAL FLOWS

Zone 2

As dry conditions develop and the reservoir water level declines into Zone 2 between 50 and 80% storage capacity, inflows passed would be reduced and provided only up to the monthly 25th percentile flow values that are calculated with naturalized daily streamflow estimates.

Zone 3

As more severe drought conditions develop and the reservoir level declines into Zone 3 below 50% storage capacity, environmental pass-throughs would be reduced, and flows would be passed up to a target of the established water quality standard for the downstream segment. In lieu of any established water quality standard, the 7Q2 low flow value, as published in the TNRCC's Water Quality Standards, would be used as the default criterion for Zone 3 pass-throughs. If in Zones 1 and 2, the value necessary to maintain downstream water quality is higher than the medians or 25th percentiles then the value necessary to maintain downstream water quality will be used instead of the other target flow values.

All Reservoir Zones

In all zones, it is the intent of these planning criteria that flows passed for instream purposes would also reflect the needs of the associated bay and estuary system. In addition to passage of environmental flows, adequate flows will be passed through for protection of downstream water rights. In all zones, water that can be captured by reservoirs in excess of the environmental provisions is available for water supply storage, and no water will be released from storage to meet environmental targets when inflows are below these limits. However, most future reservoir projects and direct diversions are anticipated to be designed solely for water supply rather than flood control, meaning that most floods can't be captured by the reservoir, but will spill downstream. These spills increase the amount of water available for instream flow maintenance and estuarine needs than would be provided by the environmental criteria alone.

NEW PROJECT DIRECT DIVERSIONS

As illustrated in Figure 2, the criteria for direct diversions from a river or stream that are recommended in the Water Plan, would be based on streamflow conditions just upstream of the diversion point, and would also be divided into three zones as follows:

Zone 1

Zone 1 occurs when actual streamflow is greater than monthly medians calculated with naturalized daily streamflow estimates. When streamflow is within Zone 1, minimum flows passed will be the monthly medians that are calculated with naturalized daily streamflow estimates.

Zone 2

Zone 2 occurs when actual streamflow is less than or equal to medians, but greater than monthly 25th percentile values. When streamflow is within Zone 2, minimum flows passed will be the monthly 25th percentile values that are calculated with naturalized daily streamflow estimates.

Zone 3

Zone 3 occurs when actual streamflow is less than or equal to monthly 25th percentile values. When streamflow is within Zone 3, minimum flows passed will be the larger of: (1) the value necessary to maintain downstream water quality or (2) a continuous flow threshold to be determined by consensus planning staff (e.g., 15th percentile flow) that will not allow the diversion by itself, to dry up the stream.

For perennial river/stream segments where a water quality standard has been established for a stream segment, that value will be used as the pass-by target. Where such a standard has not yet been established, the default planning criterion is the 7Q2 value as published in the TNRCC's Water Quality Standards. For Zones 1 and 2, if the value necessary to maintain downstream water quality is higher than the medians or 25th percentiles, this value necessary to maintain downstream water quality will be used instead of the other values.

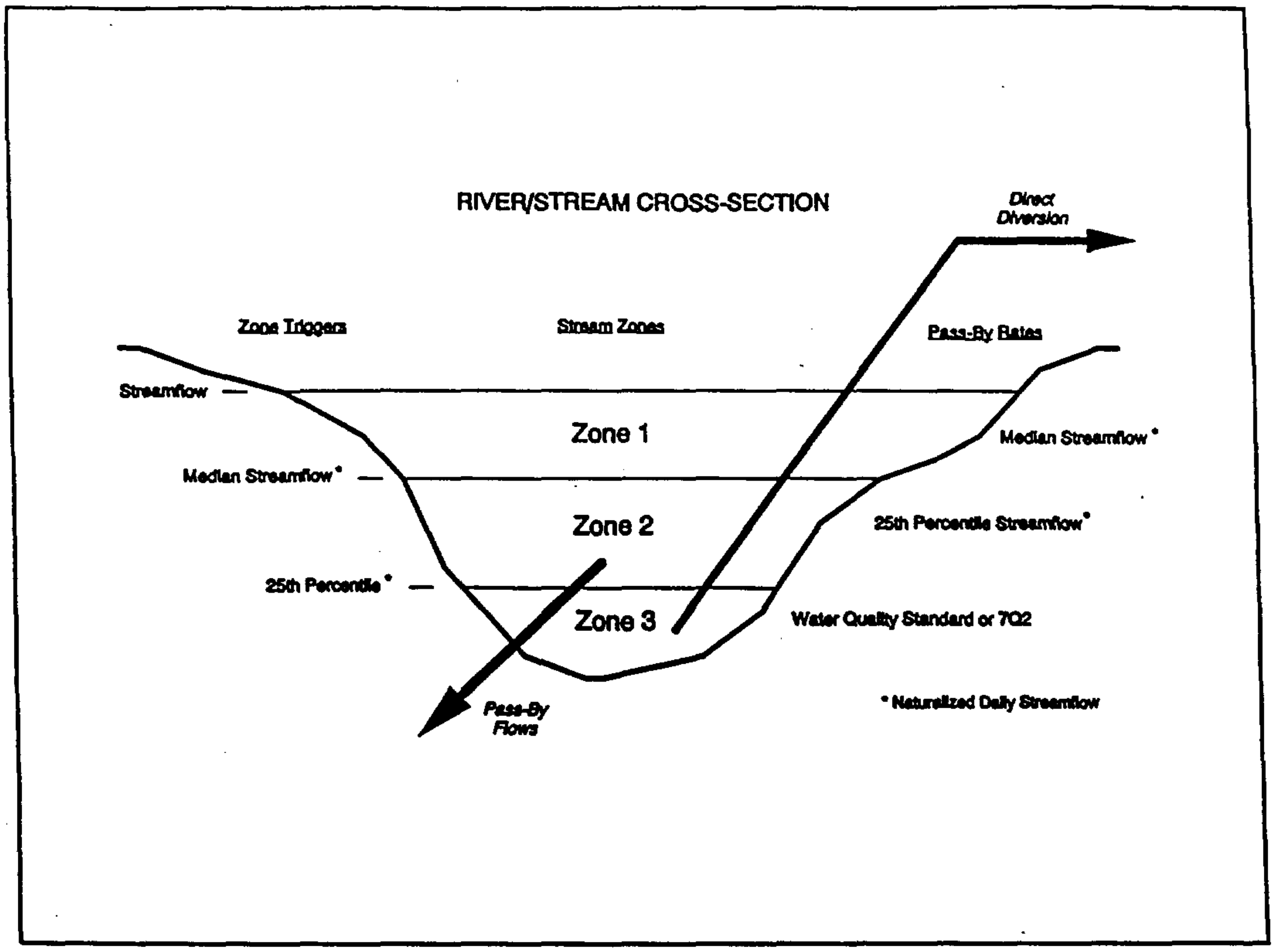

FIGURE 2
NEW PROJECT, DIRECT DIVERSION CRITERIA
FOR PASSING ENVIRONMENTAL FLOWS

All Zones

The trigger values above are calculated with naturalized daily streamflow estimates. In addition to passage of environmental flows, adequate flows will be passed through for protection of downstream water rights. The above procedure, because it provides a specific quantity of flow for environmental use for each zone, does not have smooth transitions between zones for diversion restrictions, and the agencies agree that the procedure should be investigated to see if it is possible to make smoother transitions.

NEW DIRECT DIVERSIONS INTO LARGE OFF-CHANNEL STORAGE

As illustrated in Figure 3, in those cases where a large water supply project would divert its water from a river or stream into off-channel storage, a combination of the direct diversion and reservoir criteria would apply.

The direct diversion criteria will govern the ability to divert water into the off-channel project. The reservoir criteria will address the ability of the reservoir to capture water from its own watershed, as well as define the reservoir's multi-stage operations to pass-through environmental flows, as well as flows for protection of downstream water rights.

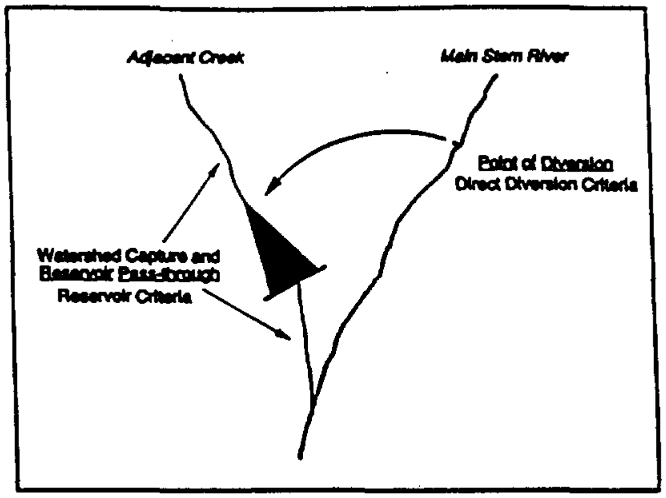

FIGURE 3
COMBINED CRITERIA FOR DIVERSION INTO OFF-CHANNEL RESERVOIR

BAY AND ESTUARY CONSIDERATIONS

As a planning place-holder value, the Zone 1 reservoir pass-throughs or direct diversion pass-bys described previously will also provide freshwater inflow to the bays and estuaries. However where inflow values adequate to meet the beneficial inflow needs as described in Texas Water Code §11.147 have been established, those inflow volumes will be used for projects within 200 river miles of the coast, commencing from the mouth of the river, as the basis for calculating the relative contributions of fresh water from the associated rivers and coastal basins during times of Zone 1 conditions. No other special provisions would be made for B&E purposes in Zone 2 or 3 conditions for either new reservoirs or large direct diversions. These inflow values may be determined by TPWD until that agency and the TNRCC jointly make the determination in accordance with Texas Water Code §11.1491.

The target flows in Zone 1 of the reservoir operating procedure should be established to provide the beneficial flows as defined in §11.147(a) of the Texas Water Code, i.e. the "salinity, nutrient, and sediment loading regime adequate to maintain an ecologically sound environment in the receiving bay and estuary system that is necessary for the maintenance of productivity of economically important and ecologically characteristic sport or commercial fish and shellfish species and estuarine life upon which such fish and shellfish are dependent."

In practical terms, that means it is not necessarily MinQ or MaxQ produced by the optimization model, but a point along that curve between these values that provides some margin of safety (comfort) in providing sufficient flows in Zone 1 to maintain average historic productivity on the fisheries. The fresh water inflow target is one that has been validated by comparing the seasonal distribution of salinity regimes with the density distribution of selected estuarine flora and fauna.

B&E pass-through requirements for a new water development project will be based on a pro-rata share of that location's contribution of flow to the estuary in question. Once the target amount of water reaches an estuary during a month, no additional flows need to be provided for bay and estuary purposes during that month. For the remainder of the month, environmental flows revert to the instream criteria.

RESULTS OF INFLOW AND INSTREAM STUDIES - USE OF STATE DETERMINATIONS

When the results of intensive fresh water inflow or instream flow studies are available and criteria have been established in the regulatory process, those criteria will be used in the Water Plan rather than any generic rule. The instream flow requirements for the Colorado River have been approved by TNRCC through the regulatory process. When established criteria are available and agreed to by TPWD and TNRCC, bay and estuary inflow requirements would be apportioned to each new project identified in the plan according to its proportional share (based on contribution hydrology), and as provided for by TNRCC's A Regulatory Guidance Document for Applications to Divert, Store or Use State Water (June, 1995). Where possible, this process seeks to restore seasonal flow patterns and minimize cumulative impacts from water development projects.

In order to facilitate the timely completion of the (joint) determination of the inflow conditions necessary for the (remaining) bays and estuaries, TPWD and TNRCC, per §11.1491 of the Texas Water Code, will each designate an employee to share equally in the oversight of the program to review the studies prepared by the TWDB and TPWD under Section 16.058 (bay and estuary inflow studies) to determine inflow conditions necessary for the bays and estuaries. The three agencies will continue to work together as they have in development of the Guadalupe Estuary (San Antonio Bay system) target flows to meet the bay and estuary studies completion deadlines, and that provides a salinity, nutrient, and sediment loading regime at or above the identified needs.

AMENDMENTS TO EXISTING PERMITS

Once projects are specifically designed and submitted for permit consideration, a more straightforward and factual environmental assessment of its features may then be performed. The scope of environmental review and corresponding permit considerations relating to an amendment of an existing water right is limited by law, and is set forth in more detail in the TNRCC's A Regulatory Guidance Document for Application to Divert, Store or Use State Water (June, 1995).

An environmental assessment and any corresponding permit conditions relating to an application for an amendment are limited to addressing any new or additional environmental impacts which may result from granting the amendment, and where such impacts would be beyond that which are possible under the full, legal operation of the existing water right prior to its amendment. Because of the many varied conditions around the State, the TNRCC Regulatory Guidance Document can only provide general procedures in many instances as to how the Commission would evaluate applications for water rights permits and amendments to existing permits. A summarization and categorization of the TNRCC's general guidance for determining potential adverse impact to the environment is as follows for types of possible water right amendments likely to be considered in the consensus planning process:

Type of Amendment	Scope of Environmental Review	Basis for Environmental Reservation
Interbasin Transfer with no change in *permitted* purpose of use, appropriative amount, point of diversion, and rate of diversion.	No additional environmental impacts considered with respect to the originating basin. Consideration of potential changes in water quality and/or migration of nuisance species, and excessive freshwater inflows to maintain proper salinity levels for B&E's may be made for receiving basin. A social, economic, and environmental impact statement may be required to be submitted.	Not applicable for originating basin.
Significant change in point of diversion from downstream to upstream, to adjoining tributary, or to endangered species habitat	Evaluation of impacts to intervening instream or site-affected environmental resources.	Case-by-case basis where level of significance evaluated as per Regulatory Guidance Document.
Change of purpose of use from non-consumptive to consumptive use	Evaluation of impacts to instream and B&E environmental resources.	Three-zone planning criteria described previously.
Change in purpose of use where there is no increase in the consumption of water from that legally authorized in the existing water right.	No environmental review.	not applicable.

For consensus planning purposes, possible water rights amendments, such as conversion from non-consumptive to consumptive use (having the effect of a new appropriation) would have the appropriate *instream and B&E* considerations described above for new projects applied in our planning assessment. For other types of amendments where only the intervening river or stream segment would be affected, the appropriate reservoir or direct diversion *instream* criteria would then be applied, in lieu of a detailed, site-specific study.

Where applicable, the "environmental planning criteria" would only affect that portion of the existing water right subject to change. Also, where regional or local planning efforts may specify higher environmental goals than that provided for by existing minimum legal or regulatory requirements, such alternate goals can be requested by the applicant and can be ultimately provided for in the permit language.

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Type of Amendment	Scope of Environmental Review	Basis for Environmental Reservation
Interbasin Transfer with no change in *permitted* purpose of use, appropriative amount, point of diversion, and rate of diversion.	No additional environmental impacts considered with respect to the originating basin. Consideration of potential changes in water quality and/or migration of nuisance species, and excessive freshwater inflows to maintain proper salinity levels for B&E's may be made for receiving basin. A social, economic, and environmental impact statement may be required to be submitted.	Not applicable for originating basin.
Significant change in point of diversion from downstream to upstream, to adjoining tributary, or to endangered species habitat	Evaluation of impacts to intervening instream or site-affected environmental resources.	Case-by-case basis where level of significance evaluated as per Regulatory Guidance Document.
Change of purpose of use from non-consumptive to consumptive use	Evaluation of impacts to instream and B&E environmental resources.	Three-zone planning criteria described previously.
Change in purpose of use where there is no increase in the consumption of water from that legally authorized in the existing water right.	No environmental review.	not applicable.

For consensus planning purposes, possible water rights amendments, such as conversion from non-consumptive to consumptive use (having the effect of a new appropriation) would have the appropriate *instream and B&E* considerations described above for new projects applied in our planning assessment. For other types of amendments where only the intervening river or stream segment would be affected, the appropriate reservoir or direct diversion *instream* criteria would then be applied, in lieu of a detailed, site-specific study.

Where applicable, the "environmental planning criteria" would only affect that portion of the existing water right subject to change. Also, where regional or local planning efforts may specify higher environmental goals than that provided for by existing minimum legal or regulatory requirements, such alternate goals can be requested by the applicant and can be ultimately provided for in the permit language.

APPENDIX B
SEGMENTATION FOR THE
GUADALUPE/SAN MARCOS RIVER MODEL

APPENDIX B
SEGMENTATION FOR THE
GUADALUPE/SAN MARCOS RIVER MODEL

Appendix B - Segmentation of the Guadalupe/San Marcos River model - Mainstem portion

reach no.	description	up-stream end (km)	down-stream end (km)	reach length (km)	elements used D (km)	no.	first	last	channel geometry coefficients *a*	*b*	*c*	*d*	*e*
1	Gruene bridge - falls&NB 002 WWTP	453.17	452.77	0.40	0.20	2	1	2	0.2310	0.2400	0.1900	0.6000	0.0000
2	falls - Hwy46	452.77	451.29	1.48	0.37	4	3	6	0.2310	0.2400	0.1900	0.6000	0.0000
3	Hwy 46 - Cypress Bend Park	451.29	448.69	2.60	0.65	4	7	10	0.2310	0.2400	0.1900	0.6000	0.0000
4	Cypress Bend Park - Comal River	448.69	448.04	0.65	0.65	1	11	11	0.0515	0.5000	0.3498	0.4000	0.4778
5	Comal River	0.10	0.00	0.10	0.10	1	12	12	0.0830	0.5000	0.1241	0.4000	0.8688
6	Comal R. - dam d/s MoPac	448.04	446.88	1.16	0.58	2	13	14	0.0533	0.5000	0.0297	0.4000	1.4443
7	dam d/s MoPac bridge	446.88	446.87	0.01	0.01	1	15	15	0.5000	0.2400	0.1500	0.6000	0.0000
8	dam d/s MoPac bridge-IH 35	446.87	446.27	0.60	0.30	2	16	17	0.0361	0.5000	0.6304	0.4000	0.1794
9	I.H. 35 - Un.Trib: WW outfall	446.27	444.35	1.92	0.48	4	18	21	0.0277	0.5000	0.7251	0.4000	0.4797
10	Un. Tributary, New Br. WWTP	0.10	0.00	0.10	0.10	1	22	22	0.1840	0.5000	1.2682	0.4000	0.0000
11	Un.Trib: WW outfall - county line	444.35	443.35	1.00	0.20	5	23	27	0.0156	0.5000	0.7790	0.4000	0.9706
12	county line - pipeline crossing	443.35	442.95	0.40	0.40	1	28	28	0.0198	0.5000	0.7837	0.4000	1.2604
13	pipeline crossing - u/s island/s	442.95	441.27	1.68	0.42	4	29	32	0.0109	0.5000	0.7651	0.4000	1.7561
14	island/s reach	441.27	440.93	0.34	0.34	1	33	33	0.0062	0.5000	0.7180	0.4000	2.3119
15	d/s island/s - narrows 1	440.93	440.51	0.42	0.42	1	34	34	0.0075	0.5000	0.6929	0.4000	2.5401
16	narrows 1 reach	440.51	440.21	0.30	0.30	1	35	35	0.0104	0.5000	0.6653	0.4000	2.7658
17	narrows 1 - narrows 2	440.21	439.81	0.40	0.40	1	36	36	0.0058	0.5000	0.6350	0.4000	2.9943
18	narrows 2 - d/s un. trib.	439.81	439.03	0.78	0.78	1	37	37	0.0042	0.5000	0.5762	0.4000	3.3993
19	d/s un. trib. - stack @ Cl Sprgs	439.03	438.03	1.00	1.00	1	38	38	0.0035	0.5000	0.4689	0.4000	4.0576
20	Cl Sprgs - USGS 816158 WQ	438.03	436.65	1.38	0.69	2	39	40	0.0028	0.5000	0.2907	0.4000	5.0269
21	USGS 816158 WQ - Dunlap canal	436.65	435.18	1.47	0.49	3	41	43	0.0034	0.5000	0.0249	0.4000	6.3218
22	Dunlap canal - Dunlap pwr. hse.	435.18	432.48	2.70	0.90	3	44	46	0.0532	0.5000	1.1897	0.4000	5.0000
23	0- .8 km d/s Dunlap pwr. hse.	432.48	431.68	0.80	0.80	1	47	47	0.1203	0.5000	0.2103	0.4000	0.0599
24	.8 - 1.6 km d/s Dunlap pwr. hse.	431.68	430.88	0.80	0.80	1	48	48	0.0396	0.5000	0.5398	0.4000	0.3223
25	1.6 d/s DPower.-Long Crk.	430.88	430.18	0.70	0.70	1	49	49	0.0223	0.5000	0.7788	0.4000	0.7471
26	Long Creek	0.10	0.00	0.10	0.10	1	50	50	0.1840	0.5000	1.2682	0.4000	0.0000
27	Long Crk. - .7 d/s Long Crk.	430.18	429.48	0.70	0.70	1	51	51	0.0146	0.5000	0.9409	0.4000	1.2998
28	.7- 1.4 d/s Long Crk.	429.48	428.78	0.70	0.70	1	52	52	0.0107	0.5000	1.0442	0.4000	2.0033
29	1.4 - 2.1 d/s Long Crk.	428.78	428.08	0.70	0.70	1	53	53	0.0060	0.5000	1.0887	0.4000	2.8575
30	2.1 - 2.8 d/s Long Crk	428.08	427.38	0.70	0.70	1	54	54	0.0049	0.5000	1.0742	0.4000	3.8626
31	2.8 - 3.5 d/s Long Crk	427.38	426.68	0.70	0.70	1	55	55	0.0037	0.5000	1.0010	0.4000	5.0184
32	3.5 - 4.2 d/s Long Crk	426.68	425.98	0.70	0.70	1	56	56	0.0033	0.5000	0.8688	0.4000	6.3250

Appendix B - Segmentation of the Guadalupe/San Marcos River model - Mainstem portion

reach no.	description	up-stream end (km)	down-stream end (km)	reach length (km)	elements used D (km)	no.	first	last	channel geometry coefficients *a*	*b*	*c*	*d*	*e*
33	4.2 d/s Long Crk.-Tr. Is. Cut-off	425.98	425.28	0.70	0.70	1	57	57	0.0028	0.5000	0.6779	0.4000	7.7823
34	Treasure Island Cut-off	425.28	424.38	0.90	0.90	1	58	58	0.0020	0.5000	0.3875	0.4000	9.6325
35	final bend - McQueeney Dam	424.38	423.78	0.60	0.60	1	59	59	0.0016	0.5000	0.0455	0.4000	11.5459
36	McQueeney Dam - Hwy 78	423.78	423.08	0.70	0.70	1	60	60	0.0448	0.5000	0.5651	0.4000	0.1609
37	Hwy 78 - Young's Crk.	423.08	421.88	1.20	0.60	2	61	62	0.0265	0.5000	0.6258	0.4000	0.4352
38	Young's Creek	0.10	0.00	0.10	0.10	1	63	63	0.1840	0.5000	1.2682	0.4000	0.0000
39	Yng Crk - island/s @ St. Metal.	421.88	420.72	1.16	0.29	4	64	67	0.0175	0.5000	0.6481	0.4000	0.9117
40	island/s @ St. Metal - I10	420.72	419.64	1.08	0.36	3	68	70	0.0088	0.5000	0.6150	0.4000	1.5032
41	I10 - Little Mill Creek	419.64	418.54	1.10	0.55	2	71	72	0.0095	0.5000	0.5319	0.4000	2.2091
42	Little Mill Creek	0.10	0.00	0.10	0.10	1	73	73	0.1840	0.5000	1.2682	0.4000	0.0000
43	.0 - .92 d/s Little Mill Crk	418.54	417.62	0.92	0.46	2	74	75	0.0080	0.5000	0.4102	0.4000	2.9778
44	.92 d/s L'l Mill -Deadman Creek	417.62	416.48	1.14	0.57	2	76	77	0.0072	0.5000	0.2418	0.4000	3.8753
45	Deadman Creek	0.10	0.00	0.10	0.10	1	78	78	0.1840	0.5000	1.2682	0.4000	0.0000
46	Deadman Creek - Dam TP- 4	416.48	415.48	1.00	1.00	1	79	79	0.0045	0.5000	0.0194	0.4000	4.9290
47	0.0- .8 km d/s TP-4	415.48	414.68	0.80	0.80	1	80	80	0.0372	0.5000	0.6125	0.4000	0.1743
48	.8 - 1.6 d/s TP-4	414.68	413.88	0.80	0.80	1	81	81	0.0248	0.5000	0.6274	0.4000	0.7651
49	1.6 - 2.4 d/s TP-4	413.88	413.08	0.80	0.80	1	82	82	0.0180	0.5000	0.5331	0.4000	1.6358
50	2.4 d/s TP4 - .8 u/s Starcke Dam	413.08	412.28	0.80	0.80	1	83	83	0.0149	0.5000	0.3295	0.4000	2.7864
51	.8 -.0 u/s Max Starcke Dam	412.28	411.48	0.80	0.80	1	84	84	0.0127	0.5000	0.0166	0.4000	4.2170
52	Max Starcke Dam - Hwy 513	411.48	411.38	0.10	0.10	1	85	85	0.0266	0.5000	0.8556	0.4000	0.2436
53	Hwy 513 - GBRA11427 outfall	411.38	411.08	0.30	0.30	1	86	86	0.0372	0.5000	0.8522	0.4000	0.3071
54	GBRA11427 outfall element	411.08	410.98	0.10	0.10	1	87	87	0.0283	0.5000	0.8478	0.4000	0.3732
55	GBRA11427 outfall - Walnut Brch.	410.98	410.23	0.75	0.25	3	88	90	0.0304	0.5000	0.8351	0.4000	0.5221
56	Walnut Br., Sequin STP	0.10	0.00	0.10	0.10	1	91	91	0.1840	0.5000	1.2682	0.4000	0.0000
57	Walnut Branch - .8 d/s	410.23	409.43	0.80	0.10	8	92	99	0.0322	0.5000	0.8004	0.4000	0.8234
58	.8 - 1.6 d/s Walnut Branch	409.43	408.63	0.80	0.40	2	100	101	0.0299	0.5000	0.7488	0.4000	1.1747
59	1.6 - 2.4 d/s Walnut Branch	408.63	407.83	0.80	0.40	2	102	103	0.0217	0.5000	0.6813	0.4000	1.5668
60	2.4 - 3.2 d/s Walnut Branch	407.83	407.03	0.80	0.80	1	104	104	0.0153	0.5000	0.5979	0.4000	1.9998
61	3.2 d/s Walnut Branch- Hwy 123	407.03	406.25	0.78	0.78	1	105	105	0.0144	0.5000	0.4998	0.4000	2.4676
62	Hwy 123 - .8 d/s	406.25	405.45	0.80	0.80	1	106	106	0.0136	0.5000	0.3862	0.4000	2.9751
63	.8 d/s Hwy 123-South turn neck	405.45	404.65	0.80	0.80	1	107	107	0.0103	0.5000	0.2552	0.4000	3.5298
64	South turn neck - East turn neck	404.65	403.87	0.78	0.78	1	108	108	0.0059	0.5000	0.1103	0.4000	4.1176

Appendix B - Segmentation of the Guadalupe/San Marcos River model - Mainstem portion

reach no.	description	up-stream end (km)	down-stream end (km)	reach length (km)	elements used D (km)	no.	first	last	channel geometry coefficients *a*	*b*	*c*	*d*	*e*
65	East turn neck - bypass entrance	403.87	403.72	0.15	0.15	1	109	109	0.0119	0.5000	0.0177	0.4000	4.4823
66	Bypass - Meadow Lk. TP-5 dam	403.72	402.42	1.30	0.65	2	110	111	0.0532	0.5000	0.5949	0.4000	1.5240
67	Meadow Lk TP-5 - FM466	402.42	402.02	0.40	0.40	1	112	112	0.2310	0.2400	0.1900	0.6000	0.0000
68	FM466 - Geronimo Creek	402.02	400.52	1.50	0.75	2	113	114	0.2310	0.2400	0.1900	0.6000	0.0000
69	Geronimo Creek	0.10	0.00	0.10	0.10	1	115	115	0.2310	0.2400	0.1900	0.6000	0.0000
70	Ger. Crk, Seguin -003 outfall	400.52	400.42	0.10	0.10	1	116	116	0.2310	0.2400	0.1900	0.6000	0.0000
71	0 - .8 km d/s Seguin -003 outfall	400.42	399.62	0.80	0.10	8	117	124	0.2310	0.2400	0.1900	0.6000	0.0000
72	.8-1.6 km d/s Seguin -003 outfall	399.62	398.82	0.80	0.40	2	125	126	0.2310	0.2400	0.1900	0.6000	0.0000
73	1.6 d/s Seguin003 - Cantau Crk.	398.82	395.82	3.00	0.50	6	127	132	0.2310	0.2400	0.1900	0.6000	0.0000
74	Cantau Creek.	0.10	0.00	0.10	0.10	1	133	133	0.2310	0.2400	0.1900	0.6000	0.0000
75	Cantau Crk. - Bridge near 1177	395.82	395.12	0.70	0.70	1	134	134	0.2310	0.2400	0.1900	0.6000	0.0000
76	Bridge near 1177 - Saul Crk.	395.12	390.62	4.50	0.90	5	135	139	0.2310	0.2400	0.1900	0.6000	0.0000
77	Saul Creek	0.10	0.00	0.10	0.10	1	140	140	0.2310	0.2400	0.1900	0.6000	0.0000
78	Saul Creek - Cordell Creek	390.62	389.52	1.10	0.55	2	141	142	0.2310	0.2400	0.1900	0.6000	0.0000
79	Cordell Creek	0.10	0.00	0.10	0.10	1	143	143	0.2310	0.2400	0.1900	0.6000	0.0000
80	Cordell Creek - Polecat Creek	389.52	389.01	0.51	0.51	1	144	144	0.2310	0.2400	0.1900	0.6000	0.0000
81	Polecat Creek	0.10	0.00	0.10	0.10	1	145	145	0.2310	0.2400	0.1900	0.6000	0.0000
82	Polecat Creek - Salt Creek	389.01	386.13	2.88	0.96	3	146	148	0.2310	0.2400	0.1900	0.6000	0.0000
83	Salt Creek	0.10	0.00	0.10	0.10	1	149	149	0.2310	0.2400	0.1900	0.6000	0.0000
84	Salt Creek - Mill Creek	386.13	382.63	3.50	0.70	5	150	154	0.2310	0.2400	0.1900	0.6000	0.0000
85	Mill Creek	0.10	0.00	0.10	0.10	1	155	155	0.2310	0.2400	0.1900	0.6000	0.0000
86	Mill Creek - Sawlog Creek	382.63	373.63	9.00	1.00	9	156	164	0.2310	0.2400	0.1900	0.6000	0.0000
87	Sawlog Creek	0.10	0.00	0.10	0.10	1	165	165	0.2310	0.2400	0.1900	0.6000	0.0000
88	Sawlog Creek - Darst Creek	373.63	372.13	1.50	0.75	2	166	167	0.2310	0.2400	0.1900	0.6000	0.0000
89	Darst Creek	0.10	0.00	0.10	0.10	1	168	168	0.2310	0.2400	0.1900	0.6000	0.0000
90	Darst Creek - Guad/Gonz Co line	372.13	364.21	7.92	0.99	8	169	176	0.2310	0.2400	0.1900	0.6000	0.0000
91	Guad/Gonz Co line - Nash Creek	364.21	358.61	5.60	0.80	7	177	183	0.2310	0.2400	0.1900	0.6000	0.0000
92	Nash Creek	0.10	0.00	0.10	0.10	1	184	184	0.2310	0.2400	0.1900	0.6000	0.0000
93	Nash Creek - top Lk Gonzales	358.61	353.81	4.80	0.96	5	185	189	0.2310	0.2400	0.1900	0.6000	0.0000
94	top Lk Gonzales - 1.4 km us Hwy 80	353.81	352.41	1.40	0.70	2	190	191	0.1884	0.5000	0.3023	0.4000	0.0862
95	1.4 km us Hwy 80 - Hwy 80	352.41	351.01	1.40	0.70	2	192	193	0.1212	0.5000	0.4393	0.4000	0.2125
96	Hwy 80 - Burroughs Crk.	351.01	348.46	2.55	0.85	3	194	196	0.0645	0.5000	0.5956	0.4000	0.4857

Appendix B - Segmentation of the Guadalupe/San Marcos River model - Mainstem portion

reach		up-stream end	down-stream end	reach length	elements used				channel geometry coefficients				
no.	description	(km)	(km)	(km)	D (km)	no.	first	last	*a*	*b*	*c*	*d*	*e*
97	Burroughs Creek	0.10	0.00	0.10	0.10	1	197	197	0.1840	0.5000	1.2682	0.4000	0.0000
98	0 - 2 km d/s Burroughs Creek	348.46	346.46	2.00	1.00	2	198	199	0.0388	0.5000	0.7218	0.4000	0.9385
99	2 - 4 km d/s Burroughs Creek	346.46	344.46	2.00	1.00	2	200	201	0.0312	0.5000	0.7852	0.4000	1.4586
100	4 km d/s Burr. Crk - Foster Branch	344.46	342.86	1.60	0.80	2	202	203	0.0227	0.5000	0.8042	0.4000	2.0242
101	Foster Branch	0.10	0.00	0.10	0.10	1	204	204	0.1840	0.5000	1.2682	0.4000	0.0000
102	0 - 2 km d/s Foster Branch	342.86	340.86	2.00	1.00	2	205	206	0.0173	0.5000	0.7872	0.4000	2.6824
103	2 - 4 km d/s Foster Branch	340.86	338.86	2.00	1.00	2	207	208	0.0134	0.5000	0.7261	0.4000	3.5222
104	4 - 6 km d/s Foster Branch	338.86	336.86	2.00	1.00	2	209	210	0.0107	0.5000	0.6205	0.4000	4.4762
105	6 - 8 km d/s Foster Branch	336.86	334.86	2.00	1.00	2	211	212	0.0074	0.5000	0.4705	0.4000	5.5443
106	8 km d/s Foster - 1st chnl split	334.86	334.32	0.54	0.54	1	213	213	0.0090	0.5000	0.3521	0.4000	6.2819
107	1st - 2nd chnl split	334.32	333.62	0.70	0.70	1	214	214	0.0035	0.5000	0.2878	0.4000	6.6587
108	2nd split - L. Gonzales main	333.62	332.12	1.50	0.75	2	215	216	0.0056	0.5000	0.1632	0.4000	7.3542
109	L. Gonzales main - H-4 Dam	332.12	331.52	0.60	0.60	1	217	217	0.0023	0.5000	0.0317	0.4000	8.0503
110	H-4 Dam - 2km d/s	331.52	329.52	2.00	1.00	2	218	219	0.0828	0.5000	0.4584	0.4000	0.1308
111	2 - 4 km d/s H-4 Dam	329.52	327.52	2.00	1.00	2	220	221	0.0810	0.5000	0.5256	0.4000	0.6566
112	4 km d/s H-4 Dam-Clemens Crk	327.52	325.72	1.80	0.90	2	222	223	0.0406	0.5000	0.4748	0.4000	1.4503
113	Clemens Creek	0.10	0.00	0.10	0.10	1	224	224	0.3187	0.5000	0.8172	0.4000	0.0000
114	0 - 2 km d/s Clemens Creek	325.72	323.74	1.98	0.99	2	225	226	0.0488	0.5000	0.3137	0.4000	2.5240
115	2 d/s Clem. Cr.-Wade Dam	323.74	321.64	2.10	0.70	3	227	229	0.0322	0.5000	0.0157	0.4000	4.0012
116	Wade Dam	321.64	321.63	0.01	0.01	1	230	230	0.5000	0.2400	0.1500	0.6000	0.0000
117	Wade Dam - Co. rd. bridge	321.63	320.53	1.10	0.55	2	231	232	0.0775	0.5000	0.4901	0.4000	0.1398
118	0 - 2 km d/s Co. rd. bridge	320.53	318.53	2.00	1.00	2	233	234	0.0681	0.5000	0.5241	0.4000	0.2460
119	2 - 4 km d/s Co. rd. bridge	318.53	316.53	2.00	1.00	2	235	236	0.0504	0.5000	0.5559	0.4000	0.4142
120	4 - 6.1 km d/s Co. rd. bridge	316.53	314.43	2.10	0.70	3	237	239	0.0443	0.5000	0.5742	0.4000	0.6230
121	6.1 - 8.2 km d/s Co. rd. bridge	314.43	312.33	2.10	0.70	3	240	242	0.0394	0.5000	0.5780	0.4000	0.8752
122	8.2 km d/s Co. rd. -Answorth Br.	312.33	310.23	2.10	0.70	3	243	245	0.0354	0.5000	0.5668	0.4000	1.1662
123	Answorth Branch	0.10	0.00	0.10	0.10	1	246	246	0.1840	0.5000	1.2682	0.4000	0.0000
124	0 - 2 km d/s Answorth Branch	310.23	308.23	2.00	1.00	2	247	248	0.0282	0.5000	0.5412	0.4000	1.4876
125	2 - 4 km d/s Answorth Branch	308.23	306.23	2.00	1.00	2	249	250	0.0208	0.5000	0.5025	0.4000	1.8367
126	4 km d/s Answ. Br. - Stevens Crk.	306.23	304.23	2.00	1.00	2	251	252	0.0193	0.5000	0.4500	0.4000	2.2210
127	Stevens Creek	0.10	0.00	0.10	0.10	1	253	253	0.1840	0.5000	1.2682	0.4000	0.0000
128	0 - 2.5 km d/s Stevens Creek	304.23	301.71	2.52	0.84	3	254	256	0.0178	0.5000	0.3743	0.4000	2.6975

Appendix B - Segmentation of the Guadalupe/San Marcos River model - Mainstem portion

reach		up-stream end	down-stream end	reach length	elements used				channel geometry coefficients				
no.	description	(km)	(km)	(km)	D (km)	no.	first	last	*a*	*b*	*c*	*d*	*e*
129	2.5 - 5 km d/s Stevens Creek	301.71	299.19	2.52	0.84	3	257	259	0.0126	0.5000	0.2692	0.4000	3.2817
130	5km d/s Stevens - Keifer Slough	299.19	296.67	2.52	0.84	3	260	262	0.0076	0.5000	0.1425	0.4000	3.9217
131	Keifer Slough	0.10	0.00	0.10	0.10	1	263	263	0.0016	0.5000	1.1414	0.4000	2.7737
132	Keifer Slough - 1st bay	296.67	296.39	0.28	0.28	1	264	264	0.0091	0.5000	0.0626	0.4000	4.3014
133	1st Bay - main Wood Lake	296.39	295.99	0.40	0.40	1	265	265	0.0048	0.5000	0.0422	0.4000	4.3962
134	main body - H5 Dam	295.99	295.59	0.40	0.40	1	266	266	0.0036	0.5000	0.0177	0.4000	4.5090
135	H5 - 10.5 km us San Marcos	295.59	293.59	2.00	1.00	2	267	268	0.0976	0.5000	0.3334	0.4000	0.0951
136	10.5 - 7.5 km us San Marcos River	293.59	290.59	3.00	1.00	3	269	271	0.0660	0.5000	0.4055	0.4000	0.3657
137	7.5 - 4.5 km us San Marcos River	290.59	287.59	3.00	1.00	3	272	274	0.0475	0.5000	0.4171	0.4000	0.8829
138	4.5 - 1.5 km us San Marcos River	287.59	284.59	3.00	1.00	3	275	277	0.0371	0.5000	0.3469	0.4000	1.6100
139	1.5- .0 km us San Marcos River	284.59	283.13	1.46	0.73	2	278	279	0.0319	0.5000	0.2417	0.4000	2.2866
140	San Marcos Confluence	0.10	0.00	0.10	0.10	1	280	280	0.0288	0.5000	0.5744	0.4000	1.2940
141	SM Confluence- "Union Lake" Dam	283.13	278.23	4.90	0.98	5	281	285	0.0242	0.5000	0.0120	0.4000	3.4520
142	"Union Lake" Dam @ Gonzales	278.23	278.13	0.10	0.10	1	286	286	0.2310	0.2400	0.1900	0.6000	0.0000
143	Dam - Tnsly. Cr.&Gonz-1 outfall	278.13	272.85	5.28	0.88	6	287	292	0.2310	0.2400	0.1900	0.6000	0.0000
144	Tinsley Cr.&Gonz001 WW	0.10	0.00	0.10	0.10	1	293	293	0.2310	0.2400	0.1900	0.6000	0.0000
145	0-1 km d/s Tinsley Creek	272.85	271.85	1.00	0.10	10	294	303	0.2310	0.2400	0.1900	0.6000	0.0000
146	1-5.5 km d/s Tinsley Creek	271.85	267.35	4.50	0.50	9	304	312	0.2310	0.2400	0.1900	0.6000	0.0000
147	5.5km d/s Tinsley - Cottle Crk.	267.35	258.35	9.00	1.00	9	313	321	0.2310	0.2400	0.1900	0.6000	0.0000
148	Cottle Creek	0.10	0.00	0.10	0.10	1	322	322	0.2310	0.2400	0.1900	0.6000	0.0000
149	Cottle Creek - Peach Creek	258.35	235.85	22.50	0.90	25	323	347	0.2310	0.2400	0.1900	0.6000	0.0000
150	Peach Creek	0.10	0.00	0.10	0.10	1	348	348	0.2310	0.2400	0.1900	0.6000	0.0000
151	Peach CRr. - 1km d/s Hwy183	235.85	214.85	21.00	1.00	21	349	369	0.2310	0.2400	0.1900	0.6000	0.0000
152	1 km d/s Hwy 183 - Denton Creek	214.85	210.35	4.50	0.90	5	370	374	0.2310	0.2400	0.1900	0.6000	0.0000
153	Denton Creek	0.10	0.00	0.10	0.10	1	375	375	0.2310	0.2400	0.1900	0.6000	0.0000
154	0 - .6 km d/s Denton Creek	210.35	209.75	0.60	0.60	1	376	376	0.2310	0.2400	0.1900	0.6000	0.0000
155	.6 km d/s Denton Cr.-Fulcher Cr.	209.75	199.75	10.00	1.00	10	377	386	0.2310	0.2400	0.1900	0.6000	0.0000
156	Fulcher Creek	0.10	0.00	0.10	0.10	1	387	387	0.2310	0.2400	0.1900	0.6000	0.0000
157	Ful. Cr. - top CP&L Cuero Lake	199.75	193.35	6.40	0.80	8	388	395	0.2310	0.2400	0.1900	0.6000	0.0000
158	top Cuero Lake - McCoy Cr.	193.35	190.35	3.00	0.75	4	396	399	0.0838	0.5000	0.4013	0.4000	0.1308
159	McCoy Creek	0.10	0.00	0.10	0.10	1	400	400	0.1840	0.5000	1.2682	0.4000	0.0000
160	0 - 2 km d/s McCoy Creek	190.35	188.35	2.00	1.00	2	401	402	0.0638	0.5000	0.4544	0.4000	0.3870

Appendix B - Segmentation of the Guadalupe/San Marcos River model - Mainstem portion

reach		up-stream end	down-stream end	reach length	elements used				channel geometry coefficients				
no.	description	(km)	(km)	(km)	D (km)	no.	first	last	*a*	*b*	*c*	*d*	*e*
161	2 - 4 km d/s McCoy Creek	188.35	186.35	2.00	1.00	2	403	404	0.0535	0.5000	0.4716	0.4000	0.6661
162	4 - 6 km d/s McCoy Creek	186.35	184.35	2.00	1.00	2	405	406	0.0461	0.5000	0.4663	0.4000	1.0111
163	6 - 8 km d/s McCoy Creek	184.35	182.35	2.00	1.00	2	407	408	0.0405	0.5000	0.4386	0.4000	1.4221
164	8 - 10 km d/s McCoy Creek	182.35	180.35	2.00	1.00	2	409	410	0.0316	0.5000	0.3883	0.4000	1.8990
165	10 km d/s McCoy - Cuero Creek	180.35	178.35	2.00	1.00	2	411	412	0.0253	0.5000	0.3156	0.4000	2.4419
166	Cuero Cr.	0.10	0.00	0.10	0.10	1	413	413	0.1840	0.5000	1.2682	0.4000	0.0000
167	0 - 2 km d/s Cuero Creek	178.35	176.35	2.00	1.00	2	414	415	0.0231	0.5000	0.2204	0.4000	3.0506
168	2 - 4 km d/s Cuero Creek	176.35	174.35	2.00	1.00	2	416	417	0.0212	0.5000	0.1027	0.4000	3.7253
169	4 d/s Cuero Crk- Cuero Lk. Dam	174.35	173.76	0.59	0.59	1	418	418	0.0201	0.5000	0.0145	0.4000	4.1974
170	Cuero Lk. Dam-Sandies Creek	173.76	168.66	5.10	0.85	6	419	424	0.2310	0.2400	0.1900	0.6000	0.0000
171	Sandies Creek	0.10	0.00	0.10	0.10	1	425	425	0.2310	0.2400	0.1900	0.6000	0.0000
172	Sandies Cr.-USGS 8175800	168.66	161.94	6.72	0.84	8	426	433	0.2310	0.2400	0.1900	0.6000	0.0000
173	USGS 8175800 - Cuero WWTP	161.94	158.59	3.35	0.67	5	434	438	0.2310	0.2400	0.1900	0.6000	0.0000
174	0-1km d/s Cuero WWTP	158.59	157.59	1.00	0.10	10	439	448	0.2310	0.2400	0.1900	0.6000	0.0000
175	1-3 km d/s Cuero WWTP	157.59	155.59	2.00	0.50	4	449	452	0.2310	0.2400	0.1900	0.6000	0.0000
176	3 km d/s Cuero WWTP - FM 236	155.59	152.51	3.08	0.77	4	453	456	0.2242	0.2430	0.1973	0.5980	0.0000
177	0 - 3.2 km d/s FM 236	152.51	149.31	3.20	0.80	4	457	460	0.2159	0.2470	0.2064	0.5960	0.0000
178	3.2 km d/s FM 236 - Irish Cr.	149.31	139.31	10.00	1.00	10	461	470	0.1983	0.2560	0.2255	0.5910	0.0000
179	Irish Creek	0.10	0.00	0.10	0.10	1	471	471	0.2310	0.2400	0.1900	0.6000	0.0000
180	Irish Cr. - Rayburn Substation	139.31	110.51	28.80	0.96	30	472	501	0.1466	0.2810	0.2816	0.5760	0.0000
181	Rayburn Substation - Spring Cr.	110.51	91.61	18.90	0.90	21	502	522	0.0831	0.3110	0.3505	0.5590	0.0000
182	Spring Creek	0.10	0.00	0.10	0.10	1	523	523	0.2310	0.2400	0.1900	0.6000	0.0000
183	Spring Cr. - USGS No. 8176500	91.61	81.61	10.00	1.00	10	524	533	0.0446	0.3290	0.3923	0.5480	0.0000
184	USGS - CP&L 01165 d/schg.	81.61	81.43	0.18	0.18	1	534	534	0.0310	0.3360	0.4070	0.5440	0.0000
185	CP&L - GBRA10466 WWTP	81.43	81.13	0.30	0.10	3	535	537	0.0310	0.3360	0.4070	0.5440	0.0000
186	0-1 km d/s GBRA10466 WWTP	81.13	80.13	1.00	0.10	10	538	547	0.0310	0.3360	0.4070	0.5440	0.0000
187	1-4 km d/s GBRA10466 WWTP	80.13	77.13	3.00	0.50	6	548	553	0.0310	0.3360	0.4070	0.5440	0.0000
188	4 d/s GBRA10466 -GBRA11078	77.13	72.03	5.10	0.51	10	554	563	0.0310	0.3360	0.4070	0.5440	0.0000
189	0-1 km d/s GBRA11078	72.03	71.03	1.00	0.10	10	564	573	0.0310	0.3360	0.4070	0.5440	0.0000
190	1-4 km d/s GBRA11078	71.03	68.03	3.00	0.50	6	574	579	0.0310	0.3360	0.4070	0.5440	0.0000
191	4 d/s GBRA11078-Coleto Crk.	68.03	58.23	9.80	0.98	10	580	589	0.0310	0.3360	0.4070	0.5440	0.0000
192	Coleto Creek	0.10	0.00	0.10	0.10	1	590	590	0.0310	0.3360	0.4070	0.5440	0.0000

Appendix B - Segmentation of the Guadalupe/San Marcos River model - Mainstem portion

reach no.	description	up-stream end (km)	down-stream end (km)	reach length (km)	elements used D (km)	elements used no.	elements used first	elements used last	channel geometry coefficients *a*	*b*	*c*	*d*	*e*
193	Coleto Cr.- Du Pont (00476-001)	58.23	43.83	14.40	0.90	16	591	606	0.0310	0.3360	0.4070	0.5440	0.0000
194	0-1.3 km d/s Du Pont Discharge	43.83	42.53	1.30	0.10	13	607	619	0.0310	0.3360	0.4070	0.5440	0.0000
195	1.3-3.3 km d/s Du Pont Discharge	42.53	40.53	2.00	0.50	4	620	623	0.0310	0.3360	0.4070	0.5440	0.0000
196	3-14 km d/s Du Pont - un. trib.	40.53	26.53	14.00	1.00	14	624	637	0.0310	0.3360	0.4070	0.5440	0.0000
197	Unknown Trib.	0.10	0.00	0.10	0.10	1	638	638	0.0310	0.3360	0.4070	0.5440	0.0000
198	Unk. Trib - Elm Bayou	26.53	17.33	9.20	0.92	10	639	648	0.0310	0.3360	0.4070	0.5440	0.0000
199	Elm Bayou	0.10	0.00	0.10	0.10	1	649	649	0.0310	0.3360	0.4070	0.5440	0.0000
200	Elm Bayou - San Antonio R.	17.33	17.06	0.27	0.27	1	650	650	0.0310	0.3360	0.4070	0.5440	0.0000
201	San Antonio Riv.	0.10	0.00	0.10	0.10	1	651	651	0.0310	0.3360	0.4070	0.5440	0.0000
202	San Antonio Riv. - Guadalupe mouth	17.06	0.06	17.00	1.00	17	652	668	0.0310	0.3360	0.4070	0.5440	0.0000

Appendix B - Segmentation of the Guadalupe/San Marcos River model - San Marcos portion

reach		up-stream end	down-stream end	reach length	elements used				channel geometry coefficients				
no.	description	(km)	(km)	(km)	D (km)	no.	first	last	*a*	*b*	*c*	*d*	*e*
1	USGS GAGE - SAN MARCOS WWTP	122.84	121.94	0.90	0.100	9	1	9	0.1474	0.5000	0.5539	0.4000	0.0000
2	SAN MARCOS WWTP - STATION 3	121.94	120.84	1.10	0.100	11	10	20	0.0658	0.5000	1.1172	0.4000	0.0000
3	STATION 3 - W/M SITE	120.84	119.94	0.90	0.100	9	21	29	0.0212	1.0000	0.0000	0.0000	3.0900
4	W/M SITE - BLANCO CONFLUENCE	119.94	119.34	0.60	0.100	6	30	35	0.0212	1.0000	0.0000	0.0000	3.0900
5	BLANCO RIVER	0.1	0	0.10	0.100	1	36	36	0.1474	0.5000	0.5539	0.4000	0.0000
6	BLANCO CONFLUENCE - CUMMINS DM	119.34	118.34	1.00	0.100	10	37	46	0.0098	1.0000	0.0000	0.0000	2.6700
7	CUMMINS DAM SPILLWAY	118.34	118.24	0.10	0.100	1	47	47	0.1474	0.5000	0.5539	0.4000	0.0000
8	CUMMINS DAM - STA 7	118.24	116.34	1.90	0.100	19	48	66	0.1474	0.5000	0.5539	0.4000	0.0000
9	STA 7 - TX ED. FOUNDATION TRIB	116.34	112.24	4.10	0.100	41	67	107	0.1474	0.5000	0.5539	0.4000	0.0000
10	TX ED. TRIB - STA 10	112.24	111.34	0.90	0.100	9	108	116	0.1474	0.5000	0.5539	0.4000	0.0000
11	STA 10 - STA 9	111.34	109.54	1.80	0.100	18	117	134	0.1474	0.5000	0.5539	0.4000	0.0000
12	MARTINDALE DAM SPILLWAY	109.54	109.44	0.10	0.100	1	135	135	0.1474	0.5000	0.5539	0.4000	0.0000
13	STA 9 - FM1979	109.44	108.54	0.90	0.100	9	136	144	0.1474	0.5000	0.5539	0.4000	0.0000
14	FM 1979 TO MORRISON CR.	108.54	102.48	6.06	0.505	12	145	156	0.1474	0.5000	0.5539	0.4000	0.0000
15	MORRISON CR.	0.1	0	0.10	0.100	1	157	157	0.1474	0.5000	0.5539	0.4000	0.0000
16	MORRISON CR. TO STAPLES DAM	102.48	100.05	2.43	0.810	3	158	160	0.1474	0.5000	0.5539	0.4000	0.0000
17	STAPLES SPILLWAY	100.05	99.95	0.10	0.100	1	161	161	0.1474	0.5000	0.5539	0.4000	0.0000
18	STAPLES TO DICKERSON CR.	99.95	86.63	13.32	0.555	24	162	185	0.1474	0.5000	0.5539	0.4000	0.0000
19	DICKERSON CR.	0.1	0	0.10	0.100	1	186	186	0.1474	0.5000	0.5539	0.4000	0.0000
20	DICKERSON CR. TO YORK CR.	86.63	76.63	10.00	0.500	20	187	206	0.1474	0.5000	0.5539	0.4000	0.0000
21	YORK CR.	0.5	0	0.50	0.500	1	207	207	0.1474	0.5000	0.5539	0.4000	0.0000
22	YORK CR. TO HWY 90	76.63	64.42	12.21	0.814	15	208	222	0.1374	0.5000	0.5539	0.4000	0.0000
23	HWY 90 TO SEALS CR.	64.42	57.67	6.75	0.450	15	223	237	0.0800	0.5000	0.0000	0.0000	1.5000
24	SEALS CR	0.1	0	0.10	0.100	1	238	238	0.1474	0.5000	0.5539	0.4000	0.0000
25	SEALS CR. TO ZEYDLER DAM-LULING	57.67	55.17	2.50	0.500	5	239	243	0.0200	1.0000	0.0000	0.0000	2.0000
26	ZEYDLER DAM SPILLWAY - LULING	55.17	55.07	0.10	0.100	1	244	244	0.1474	0.5000	0.5539	0.4000	0.0000
27	ZEYDLER DAM TO SEWAGE PLANT	55.07	54.21	0.86	0.430	2	245	246	0.1474	0.5000	0.5539	0.4000	0.0000
28	SEWAGE PLANT TO TRIB.	54.21	50.91	3.30	0.100	33	247	279	0.1474	0.5000	0.5539	0.4000	0.0000
29	TRIB TO PLUM CREEK CONFLUENCE	50.91	41.31	9.60	0.480	20	280	299	0.1474	0.5000	0.5539	0.4000	0.0000
30	PLUM CREEK	1	0	1.00	0.500	2	300	301	0.1474	0.5000	0.5539	0.4000	0.0000
31	PLUM CREEK TO B. ZEYDLER DAM	41.31	35.99	5.32	0.532	10	302	311	0.1474	0.5000	0.5539	0.4000	0.0000
32	B. ZEYDLER SPILLWAY	35.99	35.89	0.10	0.100	1	312	312	0.1474	0.5000	0.5539	0.4000	0.0000

Appendix B - Segmentation of the Guadalupe/San Marcos River model - San Marcos portion

reach no.	description	up-stream end (km)	down-stream end (km)	reach length (km)	elements used D (km)	elements used no.	elements used first	elements used last	channel geometry coefficients *a*	*b*	*c*	*d*	*e*
33	B. ZEYDLER DAM TO HOSPITAL DIS.	35.89	32.61	3.28	0.410	8	313	320	0.1474	0.5000	0.5539	0.4000	0.0000
34	HOSPITAL DIS TO MULE CR.	32.61	29.31	3.30	0.100	33	321	353	0.1474	0.5000	0.5539	0.4000	0.0000
35	MULE CR.	0.1	0	0.10	0.100	1	354	354	0.1474	0.5000	0.5539	0.4000	0.0000
36	MULE CR. TO CANOE CR.	29.31	19.11	10.20	0.408	25	355	379	0.1474	0.5000	0.5539	0.4000	0.0000
37	CANOE CR.	0.1	0	0.10	0.100	1	380	380	0.1474	0.5000	0.5539	0.4000	0.0000
38	CANOE CR TO TRIB.	19.11	12.53	6.58	0.470	14	381	394	0.1474	0.5000	0.5539	0.4000	0.0000
39	TRIB TO TRIB	12.53	8.2	4.33	0.433	10	395	404	0.1474	0.5000	0.5539	0.4000	0.0000
40	TRIB TO BRIDGE NEAR GONZALES	8.2	3.33	4.87	0.487	10	405	414	0.1474	0.5000	0.5539	0.4000	0.0000
41	BRIDGE TO GUADALUPE	3.33	0	3.33	0.666	5	415	419	0.1474	0.5000	0.5539	0.4000	0.0000

Appendix B - Segmentation of the Guadalupe/San Marcos River model - San Marcos portion

reach no.	description	up-stream end (km)	down-stream end (km)	reach length (km)	elements used D (km)	no.	first	last	channel geometry coefficients *a*	*b*	*c*	*d*	*e*
33	B. ZEYDLER DAM TO HOSPITAL DIS.	35.89	32.61	3.28	0.410	8	313	320	0.1474	0.5000	0.5539	0.4000	0.0000
34	HOSPITAL DIS TO MULE CR.	32.61	29.31	3.30	0.100	33	321	353	0.1474	0.5000	0.5539	0.4000	0.0000
35	MULE CR.	0.1	0	0.10	0.100	1	354	354	0.1474	0.5000	0.5539	0.4000	0.0000
36	MULE CR. TO CANOE CR.	29.31	19.11	10.20	0.408	25	355	379	0.1474	0.5000	0.5539	0.4000	0.0000
37	CANOE CR.	0.1	0	0.10	0.100	1	380	380	0.1474	0.5000	0.5539	0.4000	0.0000
38	CANOE CR TO TRIB.	19.11	12.53	6.58	0.470	14	381	394	0.1474	0.5000	0.5539	0.4000	0.0000
39	TRIB TO TRIB	12.53	8.2	4.33	0.433	10	395	404	0.1474	0.5000	0.5539	0.4000	0.0000
40	TRIB TO BRIDGE NEAR GONZALES	8.2	3.33	4.87	0.487	10	405	414	0.1474	0.5000	0.5539	0.4000	0.0000
41	BRIDGE TO GUADALUPE	3.33	0	3.33	0.666	5	415	419	0.1474	0.5000	0.5539	0.4000	0.0000

APPENDIX C
CONSTITUENT CONCENTRATION FIELD DATA USED FOR GUADALUPE/SAN MARCOS MODEL CALIBRATION

APPENDIX C
CONSTITUENT CONCENTRATION FIELD DATA USED FOR GUADALUPE/SAN MARCOS MODEL CALIBRATION

Appendix C - Field concentrations.

Model Elem.	model position (km)	Physical Description	Flow Min (Sept '94)	Flow Mean (Sept '94)	Flow Max (Sept '94)	Dissolved Oxygen Min.*	Dissolved Oxygen Meas. (Sept '94)	Dissolved Oxygen Max.**	BOD Min.*	BOD Meas. (Sept '94)	BOD Max.**
Guadalupe River											
	484.5	USGS, Sattler 8167800	97	110	148	4.9		10	0.7		1.1
	463.75	GBRA below Canyon					8.65				
1	452.97	New Braunfels -10232-002									
8	449.99	USGS 8168500 above Comal	112	128	159						
40	436.65	Lake Dunlap - 12596				0.5	5.94	15.8	0.5	5	9.2
41	436.16	USGS16958					10.4		0.7	5	20
55	426.68	GBRA McQueeney wq stn.				6.8		10.78			
70	419.64	IH 10 West of Seguin - 12595				2.9		9.5			
105	406.25	SE of Seguin - 12594				5.4		10.2			
414	177.35	FM 766 Crossing - 12592				5.73	6.24	11.45			
433	161.94	Hwy 183 Cuero,12593	424	604	1180	5.8		8.8	0.5		5.5
434	161.27	USGS 8175800									
456	152.51	FM 236 Crossing - 12591				4.9		9.4			
532	82.61	Vict. Hwy 59,12585				6.2		8.3	0.1		2
533	81.61	Victoria USGS8176500	437	658	1220	5.6	6.8	9.8	0.1	2	4.8
538	81.03	1/4 mile b.Willow St. Vict. - 12583									
563	72.03	Hwy 175 South of Victoria - 12581				5.5		9.1	1		6.5
648	17.33	U/S Elm Bayou - 12579									
652	16.06	Salt Water Barrier - 12578				3.34	6.65	8.3	0.8	1	7.9

notes: * minimum of all reported June - September data for this location. ** maximum of all reported June - September data for this location. No control for flow, precipitation, runoff, etc. for the minimum and

Appendix C - Field concentrations.											
			Flow			Dissolved Oxygen			BOD		
Model Elem.	model position (km)	Physical Description	Min (Sept '94)	Mean (Sept '94)	Max (Sept '94)	Min.*	Meas. (Sept '94)	Max.**	Min.*	Meas. (Sept '94)	Max.**
San Marcos River											
1	122.74	Old USGS Gauge - BV 1	123	124	124	8.5	9.1	9.5		0.72	
12	121.64	D/S of San Marcos WWTP - BV 2				8.2	8.6	9.2		0.23	
37	119.24	Blanco River Conflunece - BV 4				6.9	7.5	8.7		0.11	
45	118.44	U/S of Cummins Dam BV 5				7.3	7.8	8.8		0.1	
47	118.24	D/S of Cummins Dam BV 6				8.5	8.9	9.1		0.1	
66	116.34	Pecan Park - BV 7				7.7	8.6	9.3		0.1	
116	111.34	D/S Gary's Job Corps - BV 9				8.5	9.4	10.2			
135	109.44	Martinsdale road bridge - BV 10				7.9	8.5	8.9		0.1	
246	54.00	Hwy 80 - Luling - 12626	105	131	219	6.0	7.87	10.5	0.5	1.63	4.5
319	33.02	Palmetto Bend State Park - 12624				7.0	9.4	9.4			

notes: * minimum of all reported June - September data for this location. ** maximum of all reported June - September data for this location. No control for flow, precipitation, runoff, etc. for the minimum and

Appendix C - Field concentrations.											
			Org-N			NH3			N02+NO3		
Model Elem.	model position (km)	Physical Description	Min.*	Meas. (Sept '94)	Max.**	Min.*	Meas. (Sept '94)	Max.**	Min.*	Meas. (Sept '94)	Max.**
Guadalupe River											
	484.5	USGS, Sattler 8167800	0.28		0.6	0.04		0.05	0.1		0.41
	463.75	GBRA below Canyon				0.28		0.47	0.12	0.33	0.99
1	452.97	New Braunfels -10232-002									
8	449.99	USGS 8168500 above Comal									
40	436.65	Lake Dunlap - 12596				0.01	0.03	0.3	0.1	1.6	2
41	436.16	USGS16958	0.09		3.2	0.02	0.02	0.13			
55	426.68	GBRA McQueeney wq stn.				0.07		0.1			
70	419.64	IH 10 West of Seguin - 12595				0.02		0.09			
105	406.25	SE of Seguin - 12594				0.02		0.1	0.5		1.28
414	177.35	FM 766 Crossing - 12592				0.02		0.1	0.35	0.99	1.4
433	161.94	Hwy 183 Cuero,12593									
434	161.27	USGS 8175800									
456	152.51	FM 236 Crossing - 12591				0.02		0.29			
532	82.61	Vict. Hwy 59,12585				0.01		0.21	0.46		1
533	81.61	Victoria USGS8176500	0.17	0.27	0.99	0.01	0.03	0.28	0.31		1.5
538	81.03	1/4 mile b.Willow St. Vict. - 12583									
563	72.03	Hwy 175 South of Victoria - 12581				0.03		0.76			
648	17.33	U/S Elm Bayou - 12579									
652	16.06	Salt Water Barrier - 12578				0.01		2.8	0.7		6.6

notes: * minimum of all reported June - September data for this location. ** maximum of all reported June - September data for this location. No control for flow, precipitation, runoff, etc. for the minimum and

Appendix C - Field concentrations.											
			Org-N			NH3			N02+NO3		
Model Elem.	model position (km)	Physical Description	Min.*	Meas. (Sept '94)	Max.**	Min.*	Meas. (Sept '94)	Max.**	Min.*	Meas. (Sept '94)	Max.**
San Marcos River											
1	122.74	Old USGS Gauge - BV 1		0.3		0.01	0.08	0.1		1.05	
12	121.64	D/S of San Marcos WWTP - BV 2		0.13			0.35			1.98	
37	119.24	Blanco River Conflunece - BV 4		0.29			0.21			1.68	
45	118.44	U/S of Cummins Dam BV 5		0.81			0.25				
47	118.24	D/S of Cummins Dam BV 6		0.14			0.19			1.77	
66	116.34	Pecan Park - BV 7		0.15			0.19			1.78	
116	111.34	D/S Gary's Job Corps - BV 9		0.31			0.1			1.87	
135	109.44	Martinsdale road bridge - BV 10									
246	54.00	Hwy 80 - Luling - 12626				0.02		0.1			
319	33.02	Palmetto Bend State Park - 12624				0.02	0.03	0.08	0.87		1.17

notes: * minimum of all reported June - September data for this location. ** maximum of all reported June - September data for this location. No control for flow, precipitation, runoff, etc. for the minimum and

Appendix C - Field concentrations.											
			NO3			Chlorophyll a			Temperature		
Model Elem.	model position (km)	Physical Description	Min.*	Meas. (Sept '94)	Max.**	Min.*	Meas. (Sept '94)	Max.**	Min.*	Meas. (Sept '94)	Max.**
Guadalupe River											
	484.5	USGS, Sattler 8167800							14.5		23.5
	463.75	GBRA below Canyon							16.5	19.35	30.1
1	452.97	New Braunfels -10232-002									
8	449.99	USGS 8168500 above Comal									
40	436.65	Lake Dunlap - 12596	0.08	1.6	2	0.99		2.2	21.15	28	32
41	436.16	USGS16958								23.5	
55	426.68	GBRA McQueeney wq stn.	0.02		0.67	0.99		2.3	23.46		32.11
70	419.64	IH 10 West of Seguin - 12595	0.01		0.72				23.8		29.6
105	406.25	SE of Seguin - 12594	0.5		1.28				21.1		31
414	177.35	FM 766 Crossing - 12592	0.35	0.99	1.4				24.14	25.91	32
433	161.94	Hwy 183 Cuero,12593	0.03		0.9				28.62		32.2
434	161.27	USGS 8175800									
456	152.51	FM 236 Crossing - 12591	0.15		1.09				26	31.4	32
532	82.61	Vict. Hwy 59,12585							27.5	29	32
533	81.61	Victoria USGS8176500								29	
538	81.03	1/4 mile b.Willow St. Vict. - 12583									
563	72.03	Hwy 175 South of Victoria - 12581	0.03		1.9				25.3		32.2
648	17.33	U/S Elm Bayou - 12579									
652	16.06	Salt Water Barrier - 12578	0.42		6.6						

notes: * minimum of all reported June - September data for this location. ** maximum of all reported June - September data for this location. No control for flow, precipitation, runoff, etc. for the minimum and

Appendix C - Field concentrations.

Model Elem.	model position (km)	Physical Description	NO3 Min.*	NO3 Meas. (Sept '94)	NO3 Max.**	Chlorophyll a Min.*	Chlorophyll a Meas. (Sept '94)	Chlorophyll a Max.**	Temperature Min.*	Temperature Meas. (Sept '94)	Temperature Max.**
San Marcos River											
1	122.74	Old USGS Gauge - BV 1	0.78	0.92	1.5				22	23.5	26.1
12	121.64	D/S of San Marcos WWTP - BV 2									
37	119.24	Blanco River Conflunece - BV 4	0.75		1.44				22		22.7
45	118.44	U/S of Cummins Dam BV 5									
47	118.24	D/S of Cummins Dam BV 6								25.1	
66	116.34	Pecan Park - BV 7								25.4	
116	111.34	D/S Gary's Job Corps - BV 9								25.5	
135	109.44	Martinsdale road bridge - BV 10								25.9	
246	54.00	Hwy 80 - Luling - 12626	0.46	1.18	1.8				21.1	27	30.5
319	33.02	Palmetto Bend State Park - 12624	0.53	0.53	1.25				26.9	30.5	30.9

notes: * minimum of all reported June - September data for this location. ** maximum of all reported June - September data for this location. No control for flow, precipitation, runoff, etc. for the minimum and

APPENDIX D

INPUT DATA FILES FOR TNRCC
SAN ANTONIO RIVER QUAL-TX MODEL

APPENDIX D
INPUT DATA FILES FOR TNRCC
SAN ANTONIO RIVER QUAL-TX MODEL

Upper San Antonio River Input File

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CNTROL01     TNRCC'S QUAL-TX MODEL OF UPPER SAN ANTONIO RIVER (SG. 1911)
CNTROL02     SAN ANTONIO SPRINGS TO FALLS CITY GAUGE; MEDINA TRIBUTARY.
CNTROL03 YES ECHO DATA INPUT
CNTROL04  NO INTERMEDIATE SUMMARY
CNTROL05  NO FINAL REPORT
CNTROL5B YES SPECIAL REPORT
CNTROL06  NO LINE PRINTER PLOT
CNTROL07  NO GRAPHICS CAPABILITY
CNTROL08 YES METRIC UNITS
CNTROL09 YES OXYGEN DEPENDENT RATES
CNTROL10  NO SENSITIVITY ANALYSIS
CNTROL11  NO CAPSULE SUMMARY
ENDATA01
MODOPT01  NO TEMPERATURE
MODOPT02  NO SALINITY
MODOPT03 YES CONSERVATIVE MATERIAL  I = CONDUCTIVITY (UMHOS/CM)
MODOPT04 YES CONSERVATIVE MATERIAL II = CHLORIDES (MG/L)
MODOPT05 YES DISSOLVED OXYGEN
MODOPT06 YES BIOCHEMICAL OXYGEN DEMAND
MODOPT07 YES NITROGEN
MODOPT08  NO PHOSPHORUS
MODOPT09  NO CHLOROPHYLL A
MODOPT10  NO MACROPHYTES
MODOPT11  NO COLIFORM
MODOPT12  NO NONCONSERVATIVE MATERIAL =
ENDATA02
PROGRAM  PLOT CONTROL VALUE                 =  3.0
PROGRAM  BOD OXYGEN UPTAKE RATE             =  2.3
PROGRAM  N PREFERENCE                       = 0.50
PROGRAM  LOGICAL UNIT NUMBER FOR SEQUENCING =  18.
PROGRAM  SPECIAL REPORT TYPE                =  123.0
ENDATA03
ENDATA04
ENDATA05
ENDATA06
ENDATA07
REACH ID    1  SA SA SPRINGS - ALAMO STREET          382.5     374.0      0.5
REACH ID    2  SA ALAMO STREET - SAN PEDRO CK.       374.0     371.0      0.5
REACH ID    3  SP SAN PEDRO CREEK                      3.0       0.0      0.5
REACH ID    4  SA SAN PEDRO CK - DAM STRUCTURE       371.0     364.5      0.5
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REACH ID     5  SA DAM STRUCTURE - ASHLEY RD.            364.5     363.0      0.5
REACH ID     6  SA ASHLEY RD. - RILLING RD. STP          363.0     361.5      0.5
REACH ID     7  SA RILLING RD STP - IH 410               361.5     361.0      0.5
REACH ID     8  SA IH 410 - RIVER BEND PARK              361.0     359.0      0.5
REACH ID     9  SA RIVER BEND PARK - PIPE CROSSING       359.0     356.0      0.5
REACH ID    10  SA PIPE CROSSING - SALADO CREEK          356.0     354.0      0.5
REACH ID    11  SC SALADO CREEK                           0.01        0.     0.01
REACH ID    12  SA SALADO CREEK - U/S BLUE WING RD       354.0     353.0      0.5
REACH ID    13  SA U/S BLUE WING RD - BLUE WING RD       353.0     352.6      0.1
REACH ID    14  SA BLUE WING RD - SALADO CK STP          352.6     352.2      0.1
REACH ID    15  SA SALADO CK STP - OTILLO DAM            352.2     352.0      0.1
REACH ID    16  SA OTILLO DAM                           352.01     352.0     0.01
REACH ID    17  SA OTILLO DAM - MEDINA RIVER             352.0     345.0      0.5
REACH ID    18  MR MEDINA RIVER                           0.01        0.     0.01
REACH ID    19  SA MEDINA RIVER - IH 37                  345.0     344.5      0.5
REACH ID    20  SA IH 37 - BRAUNIG DIVERSION             344.5     337.5      0.5
REACH ID    21  SA BRAUNIG DIVERSION DAM                337.51     337.5     0.01
REACH ID    22  SA BRAUNIG DIVERSION - SH 1604           337.5     333.5      0.5
REACH ID    23  SA SH 1604 - MERCADO PROPERTY            333.5     328.5      0.5
REACH ID    24  SA MERCADO PROP. - SASPAMCO CO RD        328.5     324.5      0.5
REACH ID    25  SA SASPAMCO CO RD - GUTIERREZ PROP.      324.5     320.0      0.5
REACH ID    26  SA GUTIERREZ PROP - CALAVERAS CO RD      320.0     315.0      0.5
REACH ID    27  SA CALAVERAS CO RD - PUNDT PROP.         315.0     310.0      1.0
REACH ID    28  SA PUNDT PROP. - LABATT RD               310.0     306.0      1.0
REACH ID    29  SA LABATT RD - DIETZ RD                  306.0     301.0      1.0
REACH ID    30  SA DIETZ RD - SH 97                      301.0     288.0      1.0
REACH ID    31  SA SH 97 - FM 541                        288.0     267.0      1.0
REACH ID    32  SA FM 541 - FM 791                       267.0     247.0      1.0
ENDATA08
HYDR-1       1       0.203     0.5       0.184     0.4          0.   0.03
HYDR-1       2       0.203     0.5       0.184     0.4          0.   0.03
HYDR-1       3       0.203     0.5       0.184     0.4          0.   0.03
HYDR-1       4       0.203     0.5       0.184     0.4          0.   0.03
HYDR-1       5       0.203     0.5       0.184     0.4          0.   0.03
HYDR-1       6       0.203     0.5       0.184     0.4          0.   0.03
HYDR-1       7       0.321     0.5       0.165     0.4          0.   0.03
HYDR-1       8       0.204     0.5       0.185     0.4          0.   0.03
HYDR-1       9       0.151     0.5       0.212     0.4          0.   0.03
HYDR-1      10       0.090     0.5       0.305     0.4          0.   0.03
HYDR-1      11       0.090     0.5       0.305     0.4          0.   0.03
HYDR-1      12       0.090     0.5       0.305     0.4          0.   0.03
HYDR-1      13       0.090     0.5       0.305     0.4          0.   0.03
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HYDR-1	14	0.045	0.5	0.882	0.4	0.	0.03
HYDR-1	15	0.045	0.5	0.882	0.4	0.	0.03
HYDR-1	16	0.068	0.5	0.467	0.4	0.	0.03
HYDR-1	17	0.068	0.5	0.467	0.4	0.	0.03
HYDR-1	18	0.110	0.5	0.382	0.4	0.	0.03
HYDR-1	19	0.144	0.5	0.365	0.4	0.	0.03
HYDR-1	20	0.144	0.5	0.365	0.4	0.	0.03
HYDR-1	21	0.060	0.5	0.669	0.4	0.	0.03
HYDR-1	22	0.119	0.5	0.303	0.4	0.	0.03
HYDR-1	23	0.106	0.5	0.794	0.4	0.	0.03
HYDR-1	24	0.114	0.5	0.655	0.4	0.	0.03
HYDR-1	25	0.101	0.5	0.598	0.4	0.	0.03
HYDR-1	26	0.101	0.5	0.644	0.4	0.	0.03
HYDR-1	27	0.116	0.5	0.682	0.4	0.	0.03
HYDR-1	28	0.093	0.5	0.865	0.4	0.	0.03
HYDR-1	29	0.109	0.5	0.674	0.4	0.	0.03
HYDR-1	30	0.111	0.5	0.742	0.4	0.	0.03
HYDR-1	31	0.114	0.5	0.696	0.4	0.	0.03
HYDR-1	32	0.089	0.5	0.790	0.4	0.	0.03

ENDATA09
ENDATA10

INITIAL	1	26.0	0.	7.3	1.00	1.00	1.00	4.0	0.
INITIAL	2	26.7	0.	7.2	1.00	1.00	1.00	4.0	0.
INITIAL	3	29.4	0.	6.8	1.00	1.00	1.00	4.0	0.
INITIAL	4	27.3	0.	7.1	1.00	1.00	1.00	4.0	0.
INITIAL	5	28.6	0.	6.9	1.00	1.00	1.00	4.0	0.
INITIAL	6	29.2	0.	6.8	1.00	1.00	1.00	4.0	0.
INITIAL	7	29.2	0.	6.8	1.00	1.00	1.00	4.0	0.
INITIAL	8	29.2	0.	6.8	1.00	1.00	1.00	4.0	0.
INITIAL	9	29.3	0.	6.8	1.00	1.00	1.00	4.0	0.
INITIAL	10	29.3	0.	6.8	1.00	1.00	1.00	4.0	0.
INITIAL	11	29.4	0.	6.8	1.00	1.00	1.00	4.0	0.
INITIAL	12	29.4	0.	6.8	1.00	1.00	1.00	4.0	0.
INITIAL	13	29.4	0.	6.8	1.00	1.00	1.00	4.0	0.
INITIAL	14	29.4	0.	6.8	1.00	1.00	1.00	4.0	0.
INITIAL	15	29.4	0.	6.8	1.00	1.00	1.00	4.0	0.
INITIAL	16	29.4	0.	6.8	1.00	1.00	1.00	4.0	0.
INITIAL	17	29.4	0.	6.8	1.00	1.00	1.00	4.0	0.
INITIAL	18	29.4	0.	6.8	1.00	1.00	1.00	4.0	0.
INITIAL	19	29.4	0.	6.8	1.00	1.00	1.00	4.0	0.
INITIAL	20	29.5	0.	6.8	1.00	1.00	1.00	4.0	0.
INITIAL	21	29.6	0.	6.8	1.00	1.00	1.00	4.0	0.

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INITIAL    22       29.7      0.      6.8     1.00     1.00     1.00      4.0       0.
INITIAL    23       29.8      0.      6.8     1.00     1.00     1.00      4.0       0.
INITIAL    24       29.8      0.      6.8     1.00     1.00     1.00      4.0       0.
INITIAL    25       29.8      0.      6.8     1.00     1.00     1.00      4.0       0.
INITIAL    26       29.8      0.      6.8     1.00     1.00     1.00      4.0       0.
INITIAL    27       29.8      0.      6.8     1.00     1.00     1.00      4.0       0.
INITIAL    28       29.8      0.      6.8     1.00     1.00     1.00      4.0       0.
INITIAL    29       29.8      0.      6.8     1.00     1.00     1.00      4.0       0.
INITIAL    30       29.8      0.      6.8     1.00     1.00     1.00      4.0       0.
INITIAL    31       29.8      0.      6.8     1.00     1.00     1.00      4.0       0.
INITIAL    32       29.8      0.      6.8     1.00     1.00     1.00      4.0       0.
ENDATA11
COEF-1      1   11.                          0.2     0.1     .05 1.0     0.05
COEF-1      2   11.                          0.2     0.1     .05 1.0     0.05
COEF-1      3    1.     10.                  0.2     0.1     .05 1.0     0.05
COEF-1      4   11.                          0.2     0.1     .05 1.0     0.05
COEF-1      5   11.                          0.2     0.1     .05 1.0     0.05
COEF-1      6   11.                          0.2     0.1     .05 1.0     0.05
COEF-1      7   11.                          0.2     0.1     .05 1.0     0.05
COEF-1      8   11.                          0.2     0.1     .05 1.0     0.05
COEF-1      9   11.                          0.2     0.1     .05 1.0     0.05
COEF-1     10   11.                          0.2     0.1     .05 1.0     0.05
COEF-1     11   11.                          0.2     0.1     .05 1.0     0.05
COEF-1     12   11.                          0.2     0.1     .05 1.0     0.05
COEF-1     13   11.                          0.2     0.1     .05 1.0     0.05
COEF-1     14   11.                          0.2     0.1     .05 1.0     0.05
COEF-1     15   11.                          0.2     0.1     .01 1.0     0.05
COEF-1     16    1.   1500.                  0.2     0.1     .01 1.0     0.05
COEF-1     17   11.                          0.2     0.1     .01 1.0     0.05
COEF-1     18   11.                          0.2     0.1     .01 1.0     0.05
COEF-1     19   11.                          0.2     0.1     .01 1.0     0.05
COEF-1     20   11.                          0.2     0.1     .01 1.0     0.05
COEF-1     21    1.    150.                  0.2     0.1     .01 1.0     0.05
COEF-1     22   11.                          0.2     0.1     .01 1.0     0.05
COEF-1     23   11.                          0.2     0.1     .01 1.0     0.05
COEF-1     24   11.                          0.2     0.1     .01 1.0     0.05
COEF-1     25   11.                          0.2     0.1     .01 1.0     0.05
COEF-1     26   11.                          0.2     0.1     .01 1.0     0.05
COEF-1     27   11.                          0.2     0.1     .01 1.0     0.05
COEF-1     28   11.                          0.2     0.1     .01 1.0     0.05
COEF-1     29   11.                          0.2     0.1     .01 1.0     0.05
COEF-1     30   11.                          0.2     0.1     .01 1.0     0.05
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COEF-1      31   11.                          0.2     0.1     .01 1.0    0.05
COEF-1      32   11.                          0.2     0.1     .01 1.0    0.05
ENDATA12
COEF-2       1     0.05    .05    1.0    .30     0.      0.     0.2
COEF-2       2     0.05    .05    1.0    .30     0.      0.     0.2
COEF-2       3     0.05    .05    1.0    .30     0.      0.     0.2
COEF-2       4     0.05    .05    1.0    .30     0.      0.     0.2
COEF-2       5     0.05    .05    1.0    .30     0.      0.     0.2
COEF-2       6     0.05    .05    1.0    .30     0.      0.     0.2
COEF-2       7     0.05    .05    1.0    .30     0.      0.     0.2
COEF-2       8     0.05    .05    1.0    .30     0.      0.     0.2
COEF-2       9     0.05    .05    1.0    .30     0.      0.     0.2
COEF-2      10     0.05    .05    1.0    .30     0.      0.     0.2
COEF-2      11     0.05    .05    1.0    .30     0.      0.     0.2
COEF-2      12     0.05    .05    1.0    .30     0.      0.     0.2
COEF-2      13     0.05    .05    1.0    .30     0.      0.     0.2
COEF-2      14     0.05    .05    1.0    .30     0.      0.     0.2
COEF-2      15     0.05    .01    1.0    .30     0.      0.     0.2
COEF-2      16     0.05    .01    1.0    .30     0.      0.     0.2
COEF-2      17     0.05    .01    1.0    .20     0.      0.     0.2
COEF-2      18     0.05    .01    1.0    .20     0.      0.     0.2
COEF-2      19     0.05    .01    1.0    .20     0.      0.     0.2
COEF-2      20     0.05    .01    1.0    .20     0.      0.     0.2
COEF-2      21     0.05    .01    1.0    .20     0.      0.     0.2
COEF-2      22     0.05    .01    1.0    .20     0.      0.     0.2
COEF-2      23     0.05    .01    1.0    .20     0.      0.     0.2
COEF-2      24     0.05    .01    1.0    .20     0.      0.     0.2
COEF-2      25     0.05    .01    1.0    .20     0.      0.     0.2
COEF-2      26     0.05    .01    1.0    .20     0.      0.     0.2
COEF-2      27     0.05    .01    1.0    .20     0.      0.     0.2
COEF-2      28     0.05    .01    1.0    .20     0.      0.     0.2
COEF-2      29     0.05    .01    1.0    .20     0.      0.     0.2
COEF-2      30     0.05    .01    1.0    .20     0.      0.     0.2
COEF-2      31     0.05    .01    1.0    .20     0.      0.     0.2
COEF-2      32     0.05    .01    1.0    .20     0.      0.     0.2
ENDATA13
ENDATA14
ENDATA15
INCR-1       1               0.155     29.4      0.     792.      80.
INCR-1       2               0.005     29.4      0.     792.      80.
INCR-1       3               0.014     29.4      0.     792.      80.
INCR-1       4               0.027     29.4      0.     792.      80.
```

INCR-1	5		0.027	29.4	0.	792.	80.
INCR-1	6		0.007	29.4	0.	792.	80.
INCR-1	7		0.002	29.4	0.	792.	80.
INCR-1	8		0.005	29.4	0.	792.	80.
INCR-1	9		0.010	29.4	0.	792.	80.
INCR-1	10		0.007	29.4	0.	792.	80.
INCR-1	12		0.002	29.4	0.	792.	80.
INCR-1	13		0.008	29.4	0.	792.	80.
INCR-1	14		0.006	29.4	0.	792.	80.
INCR-1	15		0.002	29.4	0.	792.	80.
INCR-1	16		0.0	29.4	0.	792.	80.
INCR-1	17		0.025	29.4	0.	792.	80.
INCR-1	19		0.002	29.4	0.	792.	80.
INCR-1	20		0.013	29.4	0.	792.	80.
INCR-1	21		0.0	29.4	0.	792.	80.
INCR-1	22		0.004	29.4	0.	792.	80.
INCR-1	23		0.013	29.4	0.	792.	80.
INCR-1	24		0.009	29.4	0.	792.	80.
INCR-1	25		0.009	29.4	0.	792.	80.
INCR-1	26		0.067	29.4	0.	792.	80.
INCR-1	27		0.004	29.4	0.	792.	80.
INCR-1	28		0.049	29.4	0.	792.	80.
INCR-1	29		0.029	29.4	0.	792.	80.
INCR-1	30		0.204	29.4	0.	792.	80.
INCR-1	31		0.074	29.4	0.	792.	80.
INCR-1	32		0.117	29.4	0.	792.	80.
ENDATA16							
INCR-2	1	6.1	1.3	0.5	0.05	0.2	
INCR-2	2	6.1	1.3	0.5	0.05	0.2	
INCR-2	3	6.1	1.3	0.5	0.05	0.2	
INCR-2	4	6.1	1.3	0.5	0.05	0.2	
INCR-2	5	6.1	1.3	0.5	0.05	0.2	
INCR-2	6	6.1	1.3	0.5	0.05	0.2	
INCR-2	7	6.1	1.3	0.5	0.05	0.2	
INCR-2	8	6.1	1.3	0.5	0.05	0.2	
INCR-2	9	6.1	1.3	0.5	0.05	0.2	
INCR-2	10	6.1	1.3	0.5	0.05	0.2	
INCR-2	12	6.1	1.3	0.5	0.05	0.2	
INCR-2	13	6.1	1.3	0.5	0.05	0.2	
INCR-2	14	6.1	1.3	0.5	0.05	0.2	
INCR-2	15	6.1	1.3	0.5	0.05	0.2	
INCR-2	16	6.1	1.3	0.5	0.05	0.2	

```
INCR-2     17         6.1        1.3        0.5       0.05        0.2
INCR-2     19         6.1        1.3        0.5       0.05        0.2
INCR-2     20         6.1        1.3        0.5       0.05        0.2
INCR-2     21         6.1        1.3        0.5       0.05        0.2
INCR-2     22         6.1        1.3        0.5       0.05        0.2
INCR-2     23         6.1        1.3        0.5       0.05        0.2
INCR-2     24         6.1        1.3        0.5       0.05        0.2
INCR-2     25         6.1        1.3        0.5       0.05        0.2
INCR-2     26         6.1        1.3        0.5       0.05        0.2
INCR-2     27         6.1        1.3        0.5       0.05        0.2
INCR-2     28         6.1        1.3        0.5       0.05        0.2
INCR-2     29         6.1        1.3        0.5       0.05        0.2
INCR-2     30         6.1        1.3        0.5       0.05        0.2
INCR-2     31         6.1        1.3        0.5       0.05        0.2
INCR-2     32         6.1        1.3        0.5       0.05        0.2
ENDATA17
ENDATA18
ENDATA19
HDWTR-1     1  SAN ANTONIO RIVER            0.203     26.0       0.    792.0     80.
HDWTR-1    24  SAN PEDRO CREEK              0.021     29.4       0.    792.0     80.
HDWTR-1    64  SALADO CREEK                 0.301     29.8       0.    792.0     80.
HDWTR-1    92  MEDINA RIVER         17.
ENDATA20
HDWTR-2     1         6.2        1.3       0.5       0.05       0.2
HDWTR-2    24         6.1        1.3       0.5       0.05       0.2
HDWTR-2    64         6.1        1.3       0.5       0.05       0.2
HDWTR-2    92
ENDATA21
ENDATA22
JUNCTION   30    23   SAN PEDRO CREEK CONFLUENCE
JUNCTION   65    63   SALADO CREEK CONFLUENCE
JUNCTION   93    91   MEDINA RIVER CONFLUENCE
ENDATA23
WSTLD-1    22. SA-MISSION 01513.001   .02191                 .5      95.0      40.0
WSTLD-1    22. PIONEER    02933.001   .00004                 .5      95.0      40.0
WSTLD-1    25. UNION STOC 00968.001   .02980                 .5      95.0      40.0
WSTLD-1    75. SA-SALADO  10137.008  2.01572                 .5      95.0      40.0
WSTLD-1   109. KOPPE CORP 13162.001   .00495                 .5      95.0      40.0
WSTLD-1   153. SA-SOMMERS 01514.010   .00088                 .5      95.0      40.0
WSTLD-1   153. E CENT ISD 11961.001   .00263                 .5      95.0      40.0
WSTLD-1   176. FLORESVILL 10085.001   .03111                 .5      95.0      40.0
ENDATA24
```

```
WSTLD-2     22.       5.0        .0     .0      .0        .0     .0       .5
WSTLD-2     22.       5.0        .0     .0      .0        .0     .0       .5
WSTLD-2     25.       5.0      22.6     .0      .0        .0     .0       .5
WSTLD-2     75.       4.0      10.0    2.9     2.0       2.0    8.5     16.0
WSTLD-2    109.       4.0      10.0   24.2     3.0      15.0   56.5      2.0
WSTLD-2    153.       5.0      19.8   37.7      .0        .0   75.8       .5
WSTLD-2    153.       2.0      20.0   56.4     4.0      15.0   91.7      1.0
WSTLD-2    176.       3.4      43.6     .0     3.0       9.6    0.0      7.4
ENDATA25
ENDATA26
ENDATA27
ENDATA28
ENDATA29
NUMBER OF PLOTS = 1
NUMBER OF REACHES IN PLOT 1 =  29                          INCREMENT = 1.0
PLOT RCH  1  2  4  5  6  7  8  9 10 12 13 14 15 16 17 19 20 21 22 23 24 25 26 27
PLOT RCH 28 29 30 31 32
ENDATA30
ENDATA31
```

Lower San Antonio River Input File

```
CNTROL01      TNRCC'S QUAL-TX MODEL OF LOWER SAN ANTONIO RIVER (SG. 1901)
CNTROL02      FALLS CITY TO GUADALUPE CONFLUENCE.
CNTROL03 YES ECHO DATA INPUT
CNTROL04  NO INTERMEDIATE SUMMARY
CNTROL05  NO FINAL REPORT
CNTROL5B YES SPECIAL REPORT
CNTROL06  NO LINE PRINTER PLOT
CNTROL07  NO GRAPHICS CAPABILITY
CNTROL08 YES METRIC UNITS
CNTROL09 YES OXYGEN DEPENDENT RATES
CNTROL10  NO SENSITIVITY ANALYSIS
CNTROL11  NO CAPSULE SUMMARY
ENDATA01
MODOPT01  NO TEMPERATURE
MODOPT02  NO SALINITY
MODOPT03 YES CONSERVATIVE MATERIAL  I = CONDUCTIVITY (UMHOS/CM)
MODOPT04 YES CONSERVATIVE MATERIAL II = CHLORIDES (MG/L)
MODOPT05 YES DISSOLVED OXYGEN
MODOPT06 YES BIOCHEMICAL OXYGEN DEMAND
MODOPT07 YES NITROGEN
MODOPT08  NO PHOSPHORUS
MODOPT09  NO CHLOROPHYLL A
MODOPT10  NO MACROPHYTES
MODOPT11  NO COLIFORM
MODOPT12  NO NONCONSERVATIVE MATERIAL =
ENDATA02
PROGRAM  BOD OXYGEN UPTAKE RATE            =  2.3
PROGRAM  PLOT TYPE                         =  3.0
PROGRAM  N PREFERENCE                      = 0.50
PROGRAM  SPECIAL REPORT TYPE               =  123.0
ENDATA03
ENDATA04
ENDATA05
ENDATA06
ENDATA07
REACH ID    1  SA MAYS CROSSING-MILLS FALLS          247.0     238.0        1.0
REACH ID    2  SA MILLS FALLS                        238.01    238.0        .01
REACH ID    3  SA MILLS FALLS - CIBOLO CREEK         238.0     215.0        1.0
REACH ID    4  SA U/S CIBOLO CR. - CIBOLO CR.        215.01    215.0        .01
REACH ID    5  CC CIBOLO CREEK                         0.01      0.0        .01
```

```
REACH ID    6  SA CIBOLO CREEK - ESCONDIDO CR.        215.0      186.0          1.0
REACH ID    7  EC HEADWATER - DRY ESCONDIDO CR.        14.0        8.0          1.0
REACH ID    8  DE HEADWATER - IMPOUNDMENT              14.0       10.0          1.0
REACH ID    9  DE IMPOUNDMENT - DAM STRUCTURE          10.0        8.0          1.0
REACH ID   10  DE DAM STRUCTURE - CONFLUENCE            8.0        0.0          1.0
REACH ID   11  EC DRY ESCONDIDO - CONFLUENCE            8.0        0.0          1.0
REACH ID   12  SA ESCONDIDO CR. - OJO DE AGUA CR.     186.0      180.0          1.0
REACH ID   13  OA HEADWATER - CONFLUENCE                8.0        0.0          1.0
REACH ID   14  SA OJO DE AGUA CR. - SH 239            180.0      160.0          1.0
REACH ID   15  SA SH 239 - GOLIAD WWTP                160.0      111.0          1.0
REACH ID   16  SA GOLIAD WWTP - FM 2506               111.0       77.0          1.0
REACH ID   17  SA FM 2506 - US 77                      77.0       22.0          1.0
REACH ID   18  SA US 77 - GUADALUPE RIVER              22.0        0.0          1.0
ENDATA08
HYDR-1      1      0.085        0.5      0.7        0.4        0.   0.03
HYDR-1      2      0.050        0.5      0.7        0.4        0.   0.03
HYDR-1      3        0.1        0.5      0.7        0.4        0.   0.03
HYDR-1      4        0.1        0.5      0.7        0.4        0.   0.03
HYDR-1      5        0.1        0.5      0.7        0.4        0.   0.03
HYDR-1      6        0.1        0.5      0.7        0.4        0.   0.03
HYDR-1      7        0.1        0.5      0.7        0.4        0.   0.03
HYDR-1      8        0.1        0.5      0.7        0.4        0.   0.03
HYDR-1      9        0.1        0.5      0.7        0.4        0.   0.03
HYDR-1     10        0.1        0.5      0.7        0.4        0.   0.03
HYDR-1     11        0.1        0.5      0.7        0.4        0.   0.03
HYDR-1     12        0.1        0.5      0.7        0.4        0.   0.03
HYDR-1     13        0.1        0.5      0.7        0.4        0.   0.03
HYDR-1     14        0.1        0.5      0.7        0.4        0.   0.03
HYDR-1     15        0.1        0.5      0.7        0.4        0.   0.03
HYDR-1     16        0.1        0.5      0.7        0.4        0.   0.03
HYDR-1     17        0.1        0.5      0.7        0.4        0.   0.03
HYDR-1     18        0.1        0.5      0.7        0.4        0.   0.03
ENDATA09
ENDATA10
INITIAL     1      29.8      0.      6.1     1.0     1.0     1.0     4.0       0.
INITIAL     2      29.8      0.      6.1     1.0     1.0     1.0     4.0       0.
INITIAL     3      29.8      0.      6.1     1.0     1.0     1.0     4.0       0.
INITIAL     4      29.8      0.      6.1     1.0     1.0     1.0     4.0       0.
INITIAL     5      29.8      0.      6.1     1.0     1.0     1.0     4.0       0.
INITIAL     6      29.8      0.      6.1     1.0     1.0     1.0     4.0       0.
INITIAL     7      29.8      0.      6.1     1.0     1.0     1.0     4.0       0.
INITIAL     8      29.8      0.      6.1     1.0     1.0     1.0     4.0       0.
```

```
COE    INITIAL    9     29.8    0.    6.1    1.0    1.0    1.0    4.0    0.
COE    INITIAL   10     29.8    0.    6.1    1.0    1.0    1.0    4.0    0.
COE    INITIAL   11     29.8    0.    6.1    1.0    1.0    1.0    4.0    0.
COE    INITIAL   12     29.8    0.    6.1    1.0    1.0    1.0    4.0    0.
COE    INITIAL   13     29.8    0.    6.1    1.0    1.0    1.0    4.0    0.
COE    INITIAL   14     29.8    0.    6.1    1.0    1.0    1.0    4.0    0.
END    INITIAL   15     29.8    0.    6.1    1.0    1.0    1.0    4.0    0.
END    INITIAL   16     29.8    0.    6.1    1.0    1.0    1.0    4.0    0.
END    INITIAL   17     29.8    0.    6.1    1.0    1.0    1.0    4.0    0.
INC    INITIAL   18     29.8    0.    6.1    1.0    1.0    1.0    4.0    0.
INC    ENDATA11
INC    COEF-1     1   11.                     0.2    0.1    .05    1.0    0.05
INC    COEF-1     2    1.  1000.              0.2    0.1    .05    1.0    0.05
INC    COEF-1     3   11.                     0.2    0.1    .05    1.0    0.05
INC    COEF-1     4   11.                     0.2    0.1    .05    1.0    0.05
INC    COEF-1     5   11.                     0.2    0.1    .05    1.0    0.05
INC    COEF-1     6   11.                     0.2    0.1    .05    1.0    0.05
INC    COEF-1     7   11.                     0.2    0.1    .05    1.0    0.05
INC    COEF-1     8   11.                     0.2    0.1    .05    1.0    0.05
INC    COEF-1     9   11.                     0.2    0.1    .05    1.0    0.05
INC    COEF-1    10   11.                     0.2    0.1    .05    1.0    0.05
INC    COEF-1    11   11.                     0.2    0.1    .05    1.0    0.05
INC    COEF-1    12   11.                     0.2    0.1    .05    1.0    0.05
INC    COEF-1    13   11.                     0.2    0.1    .05    1.0    0.05
END    COEF-1    14   11.                     0.2    0.1    .05    1.0    0.05
INC    COEF-1    15   11.                     0.2    0.1    .05    1.0    0.05
INC    COEF-1    16   11.                     0.2    0.1    .05    1.0    0.05
INC    COEF-1    17   11.                     0.2    0.1    .05    1.0    0.05
INC    COEF-1    18   11.                     0.2    0.1    .05    1.0    0.05
INC    ENDATA12
INC    COEF-2     1     0.05    .05    1.0    0.2    0.     0.     0.2
INC    COEF-2     2     0.05    .05    1.0    0.2    0.     0.     0.2
INC    COEF-2     3     0.05    .05    1.0    0.2    0.     0.     0.2
INC    COEF-2     4     0.05    .05    1.0    0.2    0.     0.     0.2
INC    COEF-2     5     0.05    .05    1.0    0.2    0.     0.     0.2
INC    COEF-2     6     0.05    .05    1.0    0.2    0.     0.     0.2
INC    COEF-2     7     0.05    .05    1.0    0.2    0.     0.     0.2
INC    COEF-2     8     0.05    .05    1.0    0.2    0.     0.     0.2
INC    COEF-2     9     0.05    .05    1.0    0.2    0.     0.     0.2
INC    COEF-2    10     0.05    .05    1.0    0.2    0.     0.     0.2
END    COEF-2    11     0.05    .05    1.0    0.2    0.     0.     0.2
END    COEF-2    12     0.05    .05    1.0    0.2    0.     0.     0.2
```

```
ENDATA19
HDWTR-1     1  SAN ANTONIO RIVER     18.
HDWTR-1    35  CIBOLO CREEK                 0.332    29.8      0.     95.    40.
HDWTR-1    65  ESCONDIDO CREEK              0.003    29.8      0.     95.    40.
HDWTR-1    71  DRY ESCONDIDO                .0001    29.8      0.     95.    40.
HDWTR-1    99  OJO DE AGUA                  0.003    29.8      0.     95.    40.
ENDATA20
HDWTR-2     1
HDWTR-2    35        6.1      1.3      0.5     0.05      0.2
HDWTR-2    65        6.1      1.3      0.5     0.05      0.2
HDWTR-2    71        6.1      1.3      0.5     0.05      0.2
HDWTR-2    99        6.1      1.3      0.5     0.05      0.2
ENDATA21
ENDATA22
JUNCTION   36   34  CIBOLO CREEK CONFLUENCE
JUNCTION   85   70  DRY ESCONDIDO CREEK CONFLUENCE
JUNCTION   93   64  ESCONDIDO CREEK CONFLUENCE
JUNCTION  107   98  OJO DE AGUA CREEK CONFLUENCE
ENDATA23
WSTLD-1    11. AQUATIC BI 03940.000   .06573                 .5     95.0     40.0
WSTLD-1    13. FALLS CITY 10398.001   .00285                 .5     95.0     40.0
WSTLD-1    26. KARNES-MLM 10352.001   .01797                 .5     95.0     40.0
WSTLD-1    65. KENEDY     10746.001   .03615                 .5     95.0     40.0
WSTLD-1    71. KARNES-MN  10352.002   .00403                 .5     95.0     40.0
WSTLD-1   176. GOLIAD     10458.001   .01315                 .5     95.0     40.0
ENDATA24
WSTLD-2    11.       2.0      20.0    .0     4.0     12.0    .0     4.0
WSTLD-2    13.       4.0      30.0  16.9    11.0      8.0  30.9     1.0
WSTLD-2    26.       4.0      30.0  25.1    11.0      8.0  43.9     1.0
WSTLD-2    65.       5.0      20.0    .0     4.0     12.0    .0     4.0
WSTLD-2    71.       4.0      30.0    .0    11.0      8.0    .0     1.0
WSTLD-2   176.       2.0      20.0    .0     4.0     15.0    .0     1.0
ENDATA25
ENDATA26
ENDATA27
ENDATA28
ENDATA29
NUMBER OF PLOTS = 1
NUMBER OF REACHES IN PLOT 1 =  11                         INCREMENT = 1.0
PLOT RCH  1  2  3  4  6 12 14 15 16 17 18
ENDATA30
ENDATA31
```

Medina River Input File

```
CNTROL01     TNRCC QUAL-TX MODEL FOR MEDINA RIVER (SEG1903). TRIB OF SAN ANTONIO
CNTROL02     RIVER. ALL PARAMETERS AS ORIGINAL INCL. BOD INPUT AS ULTIMATE.
CNTROL03 YES ECHO DATA INPUT
CNTROL04  NO INTERMEDIATE SUMMARY
CNTROL05  NO FINAL REPORT
CNTROL5B YES SPECIAL REPORT
CNTROL06  NO LINE PRINTER PLOT
CNTROL07  NO GRAPHICS CAPABILITY
CNTROL08 YES METRIC UNITS
CNTROL09 YES OXYGEN DEPENDENT RATES
CNTROL10  NO SENSITIVITY ANALYSIS
CNTROL11 YES CAPSULE SUMMARY
ENDATA01
MODOPT01  NO TEMPERATURE
MODOPT02  NO SALINITY
MODOPT03 YES CONSERVATIVE MATERIAL  I = CONDUCTIVITY , UMHOS/CM
MODOPT04 YES CONSERVATIVE MATERIAL II = CHLORIDE , MG/L
MODOPT05 YES DISSOLVED OXYGEN
MODOPT06 YES BIOCHEMICAL OXYGEN DEMAND
MODOPT07 YES NITROGEN
MODOPT08  NO PHOSPHORUS
MODOPT09  NO CHLOROPHYLL A
MODOPT10  NO MACROPHYTES
MODOPT11  NO COLIFORM
MODOPT12  NO NONCONSERVATIVE MATERIAL =
ENDATA02
PROGRAM  LOGICAL UNIT NUMBER FOR SEQUENCING =  17.0
PROGRAM  PLOT CONTROL VALUE                 = 4.
PROGRAM  BOD OXYGEN UPTAKE RATE (MG O/MG)   = 2.3
PROGRAM  N ALGAL UPTAKE (MG N/UG CHLA/D)    = 0.01
PROGRAM  N PREFERENCE                       = 0.3
ENDATA03
ENDATA04
ENDATA05
ENDATA06
ENDATA07
REACH ID    1  MR DIVERSION DAM-RD @ KM119.8      121.0      106.0      1.0
REACH ID    2  MR RD @ KM119.8-RD @ KM90.5        106.0      91.0       1.0
REACH ID    3  MR RD @ KM90.5-CASTROVILLE STP     91.0       85.0       1.0
```

REACH ID	4	MR CASTROVILLE STP-RD @ KM79.4	85.0	79.0	1.0	
REACH ID	5	MR RD @ KM79.4-RD @ KM69.6	79.0	70.0	1.0	
REACH ID	6	MR RD @ KM69.6 - MONTGOMERY RD	70.0	63.0	1.0	
REACH ID	7	MR MONTGOMERY RD - POTRANCA CK	63.0	57.0	1.0	
REACH ID	8	PC POTRANCA CK	6.0	0.0	1.0	
REACH ID	9	MR POTRANCA CK - SH 1604	57.0	54.0	1.0	
REACH ID	10	MR SH 1604 - FM 2536	54.0	46.0	1.0	
REACH ID	11	MR FM 2536 - MOPAC RR BRIDGE	46.0	40.0	1.0	
REACH ID	12	MR MOPAC RR BRIDGE - MEDIO CK	40.0	37.0	1.0	
REACH ID	13	MC MEDIO CREEK	0.01	0.0	0.01	
REACH ID	14	MR MEDIO CK - SH 16	37.0	29.0	0.5	
REACH ID	15	MR SH 16 - APPLEWHITE RD	29.0	24.5	0.5	
REACH ID	16	MR APPLEWHITE RD - LEON CK	24.5	14.5	0.5	
REACH ID	17	LC LEON CREEK	0.01	0.0	0.01	
REACH ID	18	MR LEON CK - MITCHELL LAKE DITCH	14.5	11.5	0.5	
REACH ID	19	MR MITCHELL LAKE DITCH - US 281	11.5	10.5	0.5	
REACH ID	20	MR US 281 - LOZANO PROPERTY	10.5	8.0	0.5	
REACH ID	21	MR LOZANO PROPERTY - FM 1937	8.0	6.5	0.5	
REACH ID	22	MR FM 1937 - U/S SAR	6.5	1.0	0.5	
REACH ID	23	MR U/S SAR - SAN ANTONIO RIVER	1.0	0.0	0.5	
ENDATA08						
HYDR-1	1	0.116	0.5	1.060	0.4	0. 0.030
HYDR-1	2	0.116	0.5	1.060	0.4	0. 0.030
HYDR-1	3	0.116	0.5	1.060	0.4	0. 0.030
HYDR-1	4	0.116	0.5	1.060	0.4	0. 0.030
HYDR-1	5	0.116	0.5	1.060	0.4	0. 0.030
HYDR-1	6	0.116	0.5	1.060	0.4	0. 0.030
HYDR-1	7	0.116	0.5	1.060	0.4	0. 0.030
HYDR-1	8	0.116	0.5	1.060	0.4	0. 0.030
HYDR-1	9	0.116	0.5	1.060	0.4	0. 0.030
HYDR-1	10	0.116	0.5	1.060	0.4	0. 0.030
HYDR-1	11	0.155	0.5	0.720	0.4	0. 0.030
HYDR-1	12	0.155	0.5	0.720	0.4	0. 0.030
HYDR-1	13	0.055	0.5	1.555	0.4	0. 0.030
HYDR-1	14	0.115	0.5	1.090	0.4	0. 0.030
HYDR-1	15	0.115	0.5	1.090	0.4	0. 0.030
HYDR-1	16	0.115	0.5	1.090	0.4	0. 0.030
HYDR-1	17	0.401	0.5	0.266	0.4	0. 0.030
HYDR-1	18	0.183	0.5	0.381	0.4	0. 0.030
HYDR-1	19	0.183	0.5	0.381	0.4	0. 0.030
HYDR-1	20	0.083	0.5	0.391	0.4	0. 0.030
HYDR-1	21	0.156	0.5	0.303	0.4	0. 0.030

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HYDR-1     22       0.110       0.5     0.382       0.4        0.  0.030
HYDR-1     23       0.110       0.5     0.382       0.4        0.  0.030
ENDATA09
ENDATA10
INITIAL     1      29.4     0.     6.1     1.0     1.0     1.0     4.0      0.
INITIAL     2      29.4     0.     6.1     1.0     1.0     1.0     4.0      0.
INITIAL     3      29.4     0.     6.1     1.0     1.0     1.0     4.0      0.
INITIAL     4      29.4     0.     6.1     1.0     1.0     1.0     4.0      0.
INITIAL     5      29.4     0.     6.1     1.0     1.0     1.0     4.0      0.
INITIAL     6      29.4     0.     6.1     1.0     1.0     1.0     4.0      0.
INITIAL     7      29.4     0.     6.1     1.0     1.0     1.0     4.0      0.
INITIAL     8      29.4     0.     6.1     1.0     1.0     1.0     4.0      0.
INITIAL     9      29.4     0.     6.1     1.0     1.0     1.0     4.0      0.
INITIAL    10      29.4     0.     6.1     1.0     1.0     1.0     4.0      0.
INITIAL    11      29.4     0.     6.1     1.0     1.0     1.0     4.0      0.
INITIAL    12      29.4     0.     6.1     1.0     1.0     1.0     4.0      0.
INITIAL    13      29.4     0.     6.1     1.0     1.0     1.0     4.0      0.
INITIAL    14      29.4     0.     6.1     1.0     1.0     1.0     4.0      0.
INITIAL    15      29.4     0.     6.1     1.0     1.0     1.0     4.0      0.
INITIAL    16      29.4     0.     6.1     1.0     1.0     1.0     4.0      0.
INITIAL    17      29.4     0.     6.1     1.0     1.0     1.0     4.0      0.
INITIAL    18      29.4     0.     6.1     1.0     1.0     1.0     4.0      0.
INITIAL    19      29.4     0.     6.1     1.0     1.0     1.0     4.0      0.
INITIAL    20      29.4     0.     6.1     1.0     1.0     1.0     4.0      0.
INITIAL    21      29.4     0.     6.1     1.0     1.0     1.0     4.0      0.
INITIAL    22      29.4     0.     6.1     1.0     1.0     1.0     4.0      0.
INITIAL    23      29.4     0.     6.1     1.0     1.0     1.0     4.0      0.
ENDATA11
COEF-1      1  11.0                0.5     0.1     0.1     1.0    0.05
COEF-1      2  11.                 0.5     0.1     0.1     1.0    0.05
COEF-1      3  11.                 0.5     0.1     0.1     1.0    0.05
COEF-1      4  11.                 0.5     0.1     0.1     1.0    0.05
COEF-1      5  11.                 0.5     0.1     0.1     1.0    0.05
COEF-1      6  11.                 0.5     0.1     0.1     1.0    0.05
COEF-1      7  11.                 0.5     0.1     0.1     1.0    0.05
COEF-1      8  11.0                0.5     0.1     0.1     1.0    0.05
COEF-1      9  11.                 0.5     0.1     0.1     1.0    0.05
COEF-1     10  11.                 0.5     0.1     0.1     1.0    0.05
COEF-1     11  11.                 0.5     0.1     0.1     1.0    0.05
COEF-1     12  11.                 0.5     0.1     0.1     1.0    0.05
COEF-1     13  11.                 0.5     0.1     .05     1.0    0.05
COEF-1     14  11.                 0.5     0.1     .05     1.0    0.05
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COEF-2     13     0.05     .05     1.0     0.2     0.     0.     0.2
COEF-2     14     0.05     .05     1.0     0.2     0.     0.     0.2
COEF-2     15     0.05     .05     1.0     0.2     0.     0.     0.2
COEF-2     16     0.05     .05     1.0     0.2     0.     0.     0.2
COEF-2     17     0.05     .05     1.0     0.2     0.     0.     0.2
COEF-2     18     0.05     .05     1.0     0.2     0.     0.     0.2
ENDATA13
ENDATA14
ENDATA15
INCR-1      1              0.083     29.8      0.      95.      40.
INCR-1      3              0.235     29.8      0.      95.      40.
INCR-1      6              0.563     29.8      0.      95.      40.
INCR-1      7              0.161     29.8      0.      95.      40.
INCR-1      8              0.007     29.8      0.      95.      40.
INCR-1      9              0.010     29.8      0.      95.      40.
INCR-1     10              0.013     29.8      0.      95.      40.
INCR-1     11              0.019     29.8      0.      95.      40.
INCR-1     12              0.004     29.8      0.      95.      40.
INCR-1     13              0.025     29.8      0.      95.      40.
INCR-1     14              0.082     29.8      0.      95.      40.
INCR-1     15              0.389     29.8      0.      95.      40.
INCR-1     16              0.381     29.8      0.      95.      40.
INCR-1     17              0.148     29.8      0.      95.      40.
INCR-1     18              0.060     29.8      0.      95.      40.
ENDATA16
INCR-2      1       6.1       1.3      0.5     0.05      0.2
INCR-2      3       6.1       1.3      0.5     0.05      0.2
INCR-2      6       6.1       1.3      0.5     0.05      0.2
INCR-2      7       6.1       1.3      0.5     0.05      0.2
INCR-2      8       6.1       1.3      0.5     0.05      0.2
INCR-2      9       6.1       1.3      0.5     0.05      0.2
INCR-2     10       6.1       1.3      0.5     0.05      0.2
INCR-2     11       6.1       1.3      0.5     0.05      0.2
INCR-2     12       6.1       1.3      0.5     0.05      0.2
INCR-2     13       6.1       1.3      0.5     0.05      0.2
INCR-2     14       6.1       1.3      0.5     0.05      0.2
INCR-2     15       6.1       1.3      0.5     0.05      0.2
INCR-2     16       6.1       1.3      0.5     0.05      0.2
INCR-2     17       6.1       1.3      0.5     0.05      0.2
INCR-2     18       6.1       1.3      0.5     0.05      0.2
ENDATA17
ENDATA18
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COEF-1     15   11.                    0.5    0.1    .05    1.0   0.05
COEF-1     16   11.                    0.5    0.1    .05    1.0   0.05
COEF-1     17   11.                    0.5    0.1    .05    1.0   0.05
COEF-1     18   11.                    0.8    0.1    .05    1.0   0.05
COEF-1     19   11.                    0.8    0.1    .05    1.0   0.05
COEF-1     20   11.                    0.8    0.1    .05    1.0   0.05
COEF-1     21   11.                    0.8    0.1    .05    1.0   0.05
COEF-1     22   11.                    0.8    0.1    .05    1.0   0.05
COEF-1     23   11.                    0.8    0.1    .05    1.0   0.05
ENDATA12
COEF-2      1     0.05   0.1    1.0    0.2    0.     0.    0.2
COEF-2      2     0.05   0.1    1.0    0.2    0.     0.    0.2
COEF-2      3     0.05   0.1    1.0    0.2    0.     0.    0.2
COEF-2      4     0.05   0.1    1.0    0.2    0.     0.    0.2
COEF-2      5     0.05   0.1    1.0    0.2    0.     0.    0.2
COEF-2      6     0.05   0.1    1.0    0.2    0.     0.    0.2
COEF-2      7     0.05   0.1    1.0    0.2    0.     0.    0.2
COEF-2      8     0.05   0.1    1.0    0.2    0.     0.    0.2
COEF-2      9     0.05   0.1    1.0    0.2    0.     0.    0.2
COEF-2     10     0.05   0.1    1.0    0.2    0.     0.    0.2
COEF-2     11     0.05   0.1    1.0    0.2    0.     0.    0.2
COEF-2     12     0.05   0.1    1.0    0.2    0.     0.    0.2
COEF-2     13     0.05   .05    1.0    0.2    0.     0.    0.2
COEF-2     14     0.05   .05    1.0    0.2    0.     0.    0.2
COEF-2     15     0.05   .05    1.0    0.2    0.     0.    0.2
COEF-2     16     0.05   .05    1.0    0.2    0.     0.    0.2
COEF-2     17     0.05   .05    1.0    0.2    0.     0.    0.2
COEF-2     18     0.05   .05    1.0    0.3    0.     0.    0.2
COEF-2     19     0.05   .05    1.0    0.3    0.     0.    0.2
COEF-2     20     0.05   .05    1.0    0.3    0.     0.    0.2
COEF-2     21     0.05   .05    1.0    0.3    0.     0.    0.2
COEF-2     22     0.05   .05    1.0    0.3    0.     0.    0.2
COEF-2     23     0.05   .05    1.0    0.3    0.     0.    0.2
ENDATA13
ENDATA14
ENDATA15
INCR-1      1.           0.000    29.4      0.0     792.0     80.0
INCR-1      2.           0.000    29.4      0.0     792.0     80.0
INCR-1      3.           0.000    29.4      0.0     792.0     80.0
INCR-1      4.           0.000    29.4      0.0     792.0     80.0
INCR-1      5.           0.000    29.4      0.0     792.0     80.0
INCR-1      6.           0.000    29.4      0.0     792.0     80.0
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INCR-1      7.            0.000    29.4      0.0      792.0     80.0
INCR-1      8.            0.000    29.4      0.0      792.0     80.0
INCR-1      9.            0.000    29.4      0.0      792.0     80.0
INCR-1     10.            0.000    29.4      0.0      792.0     80.0
INCR-1     11.            0.000    29.4      0.0      792.0     80.0
INCR-1     12.            0.000    29.4      0.0      792.0     80.0
INCR-1     14.            0.000    29.4      0.0      792.0     80.0
INCR-1     15.            0.000    29.4      0.0      792.0     80.0
INCR-1     16.            0.000    29.4      0.0      792.0     80.0
INCR-1     18.            0.000    29.4      0.0      792.0     80.0
INCR-1     19.            0.000    29.4      0.0      792.0     80.0
INCR-1     20.            0.000    29.4      0.0      792.0     80.0
INCR-1     21.            0.000    29.4      0.0      792.0     80.0
INCR-1     22.            0.000    29.4      0.0      792.0     80.0
INCR-1     23.            0.000    29.4      0.0      792.0     80.0
ENDATA16
INCR-2      1.    6.1      1.3      0.5      0.05      0.2
INCR-2      2.    6.1      1.3      0.5      0.05      0.2
INCR-2      3.    6.1      1.3      0.5      0.05      0.2
INCR-2      4.    6.1      1.3      0.5      0.05      0.2
INCR-2      5.    6.1      1.3      0.5      0.05      0.2
INCR-2      6.    6.1      1.3      0.5      0.05      0.2
INCR-2      7.    6.1      1.3      0.5      0.05      0.2
INCR-2      8.    6.1      1.3      0.5      0.05      0.2
INCR-2      9.    6.1      1.3      0.5      0.05      0.2
INCR-2     10.    6.1      1.3      0.5      0.05      0.2
INCR-2     11.    6.1      1.3      0.5      0.05      0.2
INCR-2     12.    6.1      1.3      0.5      0.05      0.2
INCR-2     14.    6.1      1.3      0.5      0.05      0.2
INCR-2     15.    6.1      1.3      0.5      0.05      0.2
INCR-2     16.    6.1      1.3      0.5      0.05      0.2
INCR-2     18.    6.1      1.3      0.5      0.05      0.2
INCR-2     19.    6.1      1.3      0.5      0.05      0.2
INCR-2     20.    6.1      1.3      0.5      0.05      0.2
INCR-2     21.    6.1      1.3      0.5      0.05      0.2
INCR-2     22.    6.1      1.3      0.5      0.05      0.2
INCR-2     23.    6.1      1.3      0.5      0.05      0.2
ENDATA17
ENDATA18
ENDATA19
HDWTR-1     1  MEDINA RIVER            0.6920    29.4      0.    792.0    80.0
HDWTR-1    65  POTRANCA CREEK          0.0000    29.4      0.    792.0    80.0
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HDWTR-1    91  MEDIO CREEK          15.   0.6921    29.4      0.   342.0    64.4
HDWTR-1   137  LEON CREEK           16.   2.3945    29.4      0.   101.0    40.3
ENDATA20
HDWTR-2     1       6.10     1.30     0.50     0.05     0.20
HDWTR-2    65       6.10     1.30     0.50     0.05     0.20
HDWTR-2    91       5.94     2.07     0.36     0.28     6.43
HDWTR-2   137       5.42     5.98     1.68     1.68    14.93
ENDATA21
ENDATA22
JUNCTION   71   64  POTRANCA CREEK CONFLUENCE
JUNCTION   92   90  MEDIO CREEK CONFLUENCE
JUNCTION  138  136  LEON CREEK CONFLUENCE
ENDATA23
WSTLD-1    37. CASTROVILE 10952       .01753                .5     95.0     40.0
WSTLD-1    65. AIRFRC VLG 10137.038   .00526                .5     95.0     40.0
WSTLD-1    81. SA-IND WWT 03025.001   .00208                .5     95.0     40.0
WSTLD-1    82. CATFISH FARM          2.42325                .5     95.0     40.0
WSTLD-1   115. SOMERSET   11822.001   .00789                .5     95.0     40.0
WSTLD-1   151. SOSIDE ISD 10137.039   .00263                .5     95.0     40.0
WSTLD-1   165. SA-DOS RIO 10137.033  5.47750                .5     95.0     40.0
ENDATA24
WSTLD-2    37.      4.0     10.0    .0     4.0     12.0    .0     4.0
WSTLD-2    65.      4.0     10.0    .0     4.0     12.0    .0     4.0
WSTLD-2    81.      5.0       .0   8.8      .1     25.2  24.2      .5
WSTLD-2    82.      5.0      6.0    .0      .5      1.0    .0      .5
WSTLD-2   115.      3.0     20.0  32.7     4.0     12.0  69.6     4.0
WSTLD-2   151.      2.0     20.0   2.6     4.0     12.0   7.6     4.0
WSTLD-2   165.      6.0      5.0    .0     0.0      2.0    .0     0.0
ENDATA25
ENDATA26
ENDATA27
ENDATA28
ENDATA29
NUMBER OF PLOTS = 1
NUMBER OF REACHES IN PLOT 1 =  20                         INCREMENT = 1.0
PLOT RCH  1  2  3  4  5  6  7  9 10 11 12 14 15 16 18 19 20 21 22 23
ENDATA30
ENDATA31
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Medio Creek Input File

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CNTROL01      TNRCC QUAL-TX MODEL FOR MEDIO CREEK (SEG. 1903) TRIBUTARY OF MEDINA
CNTROL02      RIVER. ALL PARAMETERS AS ORIGINAL INCL. BOD INPUT AS ULTIMATE.
CNTROL03 YES ECHO DATA INPUT
CNTROL04  NO INTERMEDIATE SUMMARY
CNTROL05  NO FINAL REPORT
CNTROL06  NO LINE PRINTER PLOT
CNTROL07 YES GRAPHICS CAPABILITY
CNTROL08 YES METRIC UNITS
CNTROL09 YES OXYGEN DEPENDENT RATES
CNTROL10  NO SENSITIVITY ANALYSIS
CNTROL11  NO CAPSULE SUMMARY
CNTROL08 YES SPECIAL REPORT
ENDATA01
MODOPT01  NO TEMPERATURE
MODOPT02  NO SALINITY
MODOPT03 YES CONSERVATIVE MATERIAL  I = CONDUCTIVITY , UMHOS/CM
MODOPT04 YES CONSERVATIVE MATERIAL II = CHLORIDE , MG/L
MODOPT05 YES DISSOLVED OXYGEN
MODOPT06 YES BIOCHEMICAL OXYGEN DEMAND
MODOPT07 YES NITROGEN
MODOPT08  NO PHOSPHORUS
MODOPT09  NO CHLOROPHYLL A
MODOPT10  NO MACROPHYTES
MODOPT11  NO COLIFORM
MODOPT12  NO NONCONSERVATIVE MATERIAL =
ENDATA02
PROGRAM  LOGICAL UNIT NUMBER FOR SEQUENCING = 15.0
PROGRAM  PLOT TYPE                          =  3.0
PROGRAM  ALGAE OXYGEN PRODUCTION            =  0.01
PROGRAM  N PREFERENCE                       =  0.5
PROGRAM  N ALGAL UPTAKE                     =  0.02
PROGRAM  MAXIMUM ITERATION LIMIT            = 500.0
PROGRAM  WIND VELOCITY  (KM/HR)             =  15.1
ENDATA03
ENDATA04
ENDATA05
ENDATA06
ENDATA07
REACH ID    1  MC TALLEY RD - WESTCREEK STP       31.5      28.0      0.5
REACH ID    2  MC WESTCREEK STP - SH 1604         28.0      25.0      0.5
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REACH ID    3  MC SH 1604 - COMM. TREAT. STP      25.0       19.0       0.5
REACH ID    4  MC COMM. TREAT. STP - US 90        19.0       17.0       0.5
REACH ID    5  MC US 90 - UPSTREAM OF DAM         17.0       16.3       0.7
REACH ID    6  MC UPSTREAM OF DAM - PARK DAM      16.3       15.5       0.4
REACH ID    7  MC LACK. PARK DAM - MEDINA B. RD   15.5       14.5       0.5
REACH ID    8  MC MEDINA B. RD - LACKLAND STP     14.5       13.0       0.5
REACH ID    9  MC LACKLAND STP - COVEL RD         13.0       10.0       0.5
REACH ID   10  MC COVEL RD - LOW WTR XING         10.0       8.5        0.5
REACH ID   11  MC LOW WTR XING - PEARSALL RD      8.5        7.5        0.5
REACH ID   12  MC PEARSALL RD - RD @ KM 6.5       7.5        6.5        0.5
REACH ID   13  MC RD @ KM 6.5 - KM 4.0            6.5        4.0        0.5
REACH ID   14  MC KM 4.0 - RD @ KM 3.7            4.0        3.7        0.1
REACH ID   15  MC RD @ KM 3.7 - KM 3.6            3.7        3.6        0.1
REACH ID   16  MC KM 3.6 - KM 3.3                 3.6        3.3        0.1
REACH ID   17  MC KM 3.3 - IH 35                  3.3        2.8        0.1
REACH ID   18  MC IH 35 - KM 2.5                  2.8        2.5        0.1
REACH ID   19  MC KM 2.5 - KM 1.6                 2.5        1.6        0.1
REACH ID   20  MC KM 1.6 - KM 1.3                 1.6        1.3        0.1
REACH ID   21  MC KM 1.3 - KM 0.8                 1.3        0.8        0.1
REACH ID   22  MC KM 0.8 - KM 0.7                 0.8        0.7        0.1
REACH ID   23  MC KM 0.7 - KM 0.1                 0.7        0.1        0.1
REACH ID   24  MC KM 0.1 - MEDINA RIVER           0.1        0.0        0.1
ENDATA08
HYDR-1      1       0.227     0.500     0.705     0.400        0.  0.030
HYDR-1      2       0.227     0.500     0.705     0.400        0.  0.030
HYDR-1      3       0.227     0.500     0.705     0.400        0.  0.030
HYDR-1      4       0.227     0.500     0.705     0.400        0.  0.030
HYDR-1      5       0.076     0.500     1.528     0.400        0.  0.030
HYDR-1      6       0.095     0.500     0.874     0.400        0.  0.030
HYDR-1      7       0.150     0.500     0.822     0.400        0.  0.030
HYDR-1      8       0.125     0.500     0.796     0.400        0.  0.030
HYDR-1      9       0.140     0.500     0.735     0.400        0.  0.030
HYDR-1     10       0.119     0.500     0.687     0.400        0.  0.030
HYDR-1     11       0.080     0.500     1.432     0.400        0.  0.030
HYDR-1     12       0.115     0.500     1.087     0.400        0.  0.030
HYDR-1     13       0.007     1.000        0.        0.       1.5  0.030
HYDR-1     14       0.007     1.000        0.        0.       1.5  0.030
HYDR-1     15       0.200     0.500     0.695     0.400        0.  0.030
HYDR-1     16       0.200     0.500     0.695     0.400        0.  0.030
HYDR-1     17       0.200     0.500     0.695     0.400        0.  0.030
HYDR-1     18       0.266     0.500     0.849     0.400        0.  0.030
HYDR-1     19       0.266     0.500     0.849     0.400        0.  0.030
```

```
HYDR-1     20       0.266     0.500     0.849     0.400          0.  0.030
HYDR-1     21       0.055     0.500     1.555     0.400          0.  0.030
HYDR-1     22       0.055     0.500     1.555     0.400          0.  0.030
HYDR-1     23       0.055     0.500     1.555     0.400          0.  0.030
HYDR-1     24       0.055     0.500     1.555     0.400          0.  0.030
ENDATA09
ENDATA10
INITIAL     1      29.4      0.      6.1     1.00     1.00     1.00      4.0       0.
INITIAL     2      29.4      0.      6.1     1.00     1.00     1.00      4.0       0.
INITIAL     3      29.4      0.      6.1     1.00     1.00     1.00      4.0       0.
INITIAL     4      29.4      0.      6.1     1.00     1.00     1.00      4.0       0.
INITIAL     5      29.4      0.      6.1     1.00     1.00     1.00      4.0       0.
INITIAL     6      29.4      0.      6.1     1.00     1.00     1.00      4.0       0.
INITIAL     7      29.4      0.      6.1     1.00     1.00     1.00      4.0       0.
INITIAL     8      29.4      0.      6.1     1.00     1.00     1.00      4.0       0.
INITIAL     9      29.4      0.      6.1     1.00     1.00     1.00      4.0       0.
INITIAL    10      29.4      0.      6.1     1.00     1.00     1.00      4.0       0.
INITIAL    11      29.4      0.      6.1     1.00     1.00     1.00      4.0       0.
INITIAL    12      29.4      0.      6.1     1.00     1.00     1.00      4.0       0.
INITIAL    13      29.4      0.      6.1     1.00     1.00     1.00      4.0       0.
INITIAL    14      29.4      0.      6.1     1.00     1.00     1.00      4.0       0.
INITIAL    15      29.4      0.      6.1     1.00     1.00     1.00      4.0       0.
INITIAL    16      29.4      0.      6.1     1.00     1.00     1.00      4.0       0.
INITIAL    17      29.4      0.      6.1     1.00     1.00     1.00      4.0       0.
INITIAL    18      29.4      0.      6.1     1.00     1.00     1.00      4.0       0.
INITIAL    19      29.4      0.      6.1     1.00     1.00     1.00      4.0       0.
INITIAL    20      29.4      0.      6.1     1.00     1.00     1.00      4.0       0.
INITIAL    21      29.4      0.      6.1     1.00     1.00     1.00      4.0       0.
INITIAL    22      29.4      0.      6.1     1.00     1.00     1.00      4.0       0.
INITIAL    23      29.4      0.      6.1     1.00     1.00     1.00      4.0       0.
INITIAL    24      29.4      0.      6.1     1.00     1.00     1.00      4.0       0.
ENDATA11
COEF-1      1   11.                         0.1     0.1    0.05     1.0    0.05
COEF-1      2   11.                         0.1     0.1    0.05     1.0    0.05
COEF-1      3   11.                         0.1     0.1    0.05     1.0    0.05
COEF-1      4   11.                         0.5     0.1    0.10     1.0    0.05
COEF-1      5   11.                         0.5     0.1    0.10     1.0    0.05
COEF-1      6   11.                         0.3     0.1    0.10     1.0    0.05
COEF-1      7   11.                         0.3     0.1    0.10     1.0    0.05
COEF-1      8   11.                         0.3     0.1    0.10     1.0    0.05
COEF-1      9   11.                         0.1     0.1    0.10     1.0    0.05
COEF-1     10   11.                         0.1     0.1    0.10     1.0    0.05
```

```
COEF-1      11   11.                      0.1    0.1   0.10    1.0   0.05
COEF-1      12   11.                      0.1    0.1   0.10    1.0   0.05
COEF-1      13   12.                      0.1    0.1   0.10    1.0   0.05
COEF-1      14   12.                      0.1    0.1   0.10    1.0   0.05
COEF-1      15   11.                      0.1    0.1   0.10    1.0   0.05
COEF-1      16   11.                      0.1    0.1   0.10    1.0   0.05
COEF-1      17   11.                      0.1    0.1   0.10    1.0   0.05
COEF-1      18   11.                      0.1    0.1   0.10    1.0   0.05
COEF-1      19   11.                      0.1    0.1   0.10    1.0   0.05
COEF-1      20   11.                      0.1    0.1   0.10    1.0   0.05
COEF-1      21   11.                      0.1    0.1   0.10    1.0   0.05
COEF-1      22   11.                      0.1    0.1   0.10    1.0   0.05
COEF-1      23   11.                      0.1    0.1   0.10    1.0   0.05
COEF-1      24   11.                      0.1    0.1   0.10    1.0   0.05
ENDATA12
COEF-2       1     0.05   .05   1.0   0.2    0.    0.   0.2
COEF-2       2     0.05   .05   1.0   0.2    0.    0.   0.2
COEF-2       3     0.05   .05   1.0   0.2    0.    0.   0.2
COEF-2       4     0.05   .10   1.0   0.2    0.    0.   0.2
COEF-2       5     0.05   .10   1.0   0.2    0.    0.   0.2
COEF-2       6     0.05   .10   1.0   0.2    0.    0.   0.2
COEF-2       7     0.05   .10   1.0   0.2    0.    0.   0.2
COEF-2       8     0.05   .10   1.0   0.2    0.    0.   0.2
COEF-2       9     0.05   .10   1.0   0.2    0.    0.   0.2
COEF-2      10     0.05   .10   1.0   0.2    0.    0.   0.2
COEF-2      11     0.05   .10   1.0   0.2    0.    0.   0.2
COEF-2      12     0.05   .10   1.0   0.2    0.    0.   0.2
COEF-2      13     0.05   .10   1.0   0.2    0.    0.   0.2
COEF-2      14     0.05   .10   1.0   0.2    0.    0.   0.2
COEF-2      15     0.05   .10   1.0   0.2    0.    0.   0.2
COEF-2      16     0.05   .10   1.0   0.2    0.    0.   0.2
COEF-2      17     0.05   .10   1.0   0.2    0.    0.   0.2
COEF-2      18     0.05   .10   1.0   0.2    0.    0.   0.2
COEF-2      19     0.05   .10   1.0   0.2    0.    0.   0.2
COEF-2      20     0.05   .10   1.0   0.2    0.    0.   0.2
COEF-2      21     0.05   .10   1.0   0.2    0.    0.   0.2
COEF-2      22     0.05   .10   1.0   0.2    0.    0.   0.2
COEF-2      23     0.05   .10   1.0   0.2    0.    0.   0.2
COEF-2      24     0.05   .10   1.0   0.2    0.    0.   0.2
ENDATA13
ENDATA14
ENDATA15
```

```
ENDATA16
ENDATA17
ENDATA18
ENDATA19
HDWTR-1     1  MEDIO CREEK              0.0030    29.4      0.    792.    80.
ENDATA20
HDWTR-2     1        6.1      3.0    0.50      0.05      0.20
ENDATA21
ENDATA22
ENDATA23
WSTLD-1    25. BC WCID#16 10130.001   .02191                .5     95.0     40.0
WSTLD-1    26. COMMUN-MED 10827.003   .37247                .5     95.0     40.0
WSTLD-1    38. AIR FORCE  12033.001   .01315                .5     95.0     40.0
WSTLD-1    51. MITCHELL LAKE INFLOW   .71700                .5    492.0     80.0
WSTLD-1    58. MITCHELL LAKE WIDTH.  -.44200
WSTLD-1    64. SA-SOWST   02635.001   .00657                .5     95.0     40.0
ENDATA24
WSTLD-2    25.      4.0     23.0   3.8     2.0      3.0   7.4    15.0
WSTLD-2    26.      4.0     18.0    .0     2.0      2.0    .0    16.0
WSTLD-2    38.      4.0     23.0    .0     2.0      3.0    .0    15.0
WSTLD-2    51.      6.1      3.0    .0     0.5      .05    .0    0.20
WSTLD-2    58.
WSTLD-2    64.      5.0     23.0    .0      .1     15.0    .0      .5
ENDATA25
ENDATA26
ENDATA27
ENDATA28
ENDATA29
NUMBER OF PLOTS = 1
NUMBER OF REACHES IN PLOT 1 =  24                       INCREMENT = 0.25
PLOT RCH  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
ENDATA30
ENDATA31
```

Leon Creek Input File

```
CNTROL01      TNRCC QUAL-TX MODEL FOR LEON CREEK (SEG. 1906)
CNTROL02      ALL PARAMETERS AS PER ORIGINAL.
CNTROL03 YES ECHO DATA INPUT
CNTROL04  NO INTERMEDIATE SUMMARY
CNTROL05  NO FINAL REPORT
CNTROL06  NO LINE PRINTER PLOT
CNTROL07  NO GRAPHICS CAPABILITY
CNTROL08 YES METRIC UNITS
CNTROL09 YES OXYGEN DEPENDENT RATES
CNTROL10  NO SENSITIVITY ANALYSIS
CNTROL11 YES CAPSULE SUMMARY
ENDATA01
MODOPT01  NO TEMPERATURE
MODOPT02  NO SALINITY
MODOPT03 YES CONSERVATIVE MATERIAL  I = CONDUCTIVITY , UMHOS/CM
MODOPT04 YES CONSERVATIVE MATERIAL II = CHLORIDE , MG/L
MODOPT05 YES DISSOLVED OXYGEN
MODOPT06 YES BIOCHEMICAL OXYGEN DEMAND
MODOPT07 YES NITROGEN
MODOPT08  NO PHOSPHORUS
MODOPT09  NO CHLOROPHYLL A
MODOPT10  NO MACROPHYTES
MODOPT11  NO COLIFORM
MODOPT12  NO NONCONSERVATIVE MATERIAL =
ENDATA02
PROGRAM  LOGICAL UNIT NUMBER FOR SEQUENCING = 16.0
PROGRAM  BOD OXYGEN UPTAKE RATE (MG O/MG)   = 2.3
PROGRAM  N ALGAL UPTAKE (MG N/UG CHLA/D)    = 0.02
PROGRAM  N PREFERENCE                       = 0.5
ENDATA03
ENDATA04
ENDATA05
ENDATA06
ENDATA07
REACH ID    1  LC SH 16 - CULEBRA CREEK           51.0      45.5      0.5
REACH ID    2  CC CULEBRA CREEK                   13.5      0.        0.5
REACH ID    3  LC CULEBRA CREEK - INGRAM ROAD     45.5      44.5      0.5
REACH ID    4  LC INGRAM ROAD - HUEBNER CREEK     44.5      44.0      0.5
REACH ID    5  HC HEADWATER - CINNAMON CK CONF    7.51      7.5       0.01
REACH ID    6  CC CINNAMON CREEK                  3.5       0.0       0.5
```

REACH ID	7	HC CINNAMON CK CONF - CONFLUENCE	7.5	0.0	0.5
REACH ID	8	LC HUEBNER CREEK - W COMMERCE ST.	44.0	40.5	0.5
REACH ID	9	LC W COMMERCE ST - RODRIGUEZ PK	40.5	35.5	0.5
REACH ID	10	LC RODRIGUEZ PK - UNNAMED TRIB.	35.5	35.0	0.5
REACH ID	11	UT UNNAMED TRIBUTARY	5.0	0.	0.5
REACH ID	12	LC UNNAMED TRIB - US 90	35.0	34.5	0.5
REACH ID	13	LC US 90 - BILLY MITCHELL DR.	34.5	29.5	0.5
REACH ID	14	LC BILLY MITCHELL DR. - SH 13	29.5	26.0	0.5
REACH ID	15	LC SH 13 - KELLY AFB IWTP	26.0	25.0	0.5
REACH ID	16	LC KELLY AFB IWTP - PRIVATE RD.	25.0	24.0	0.5
REACH ID	17	LC PRIVATE RD. - IH 35	24.0	18.0	0.5
REACH ID	18	LC IH 35 - IH 410	18.0	16.0	0.5
REACH ID	19	LC IH 410 - INDIAN CREEK	16.0	10.5	0.5
REACH ID	20	IC INDIAN CREEK	16.0	0.	0.5
REACH ID	21	LC INDIAN CREEK - SH 16	10.5	9.5	0.5
REACH ID	22	LC SH 16 - COMANCHE CREEK	9.5	2.5	0.5
REACH ID	23	CC HEADWATER - LEON CREEK STP	6.0	0.5	0.5
REACH ID	24	CC LEON CREEK STP - CONFLUENCE	0.5	0.	0.5
REACH ID	25	LC COMANCHE CREEK - MEDINA RIVER	2.5	0.	0.5

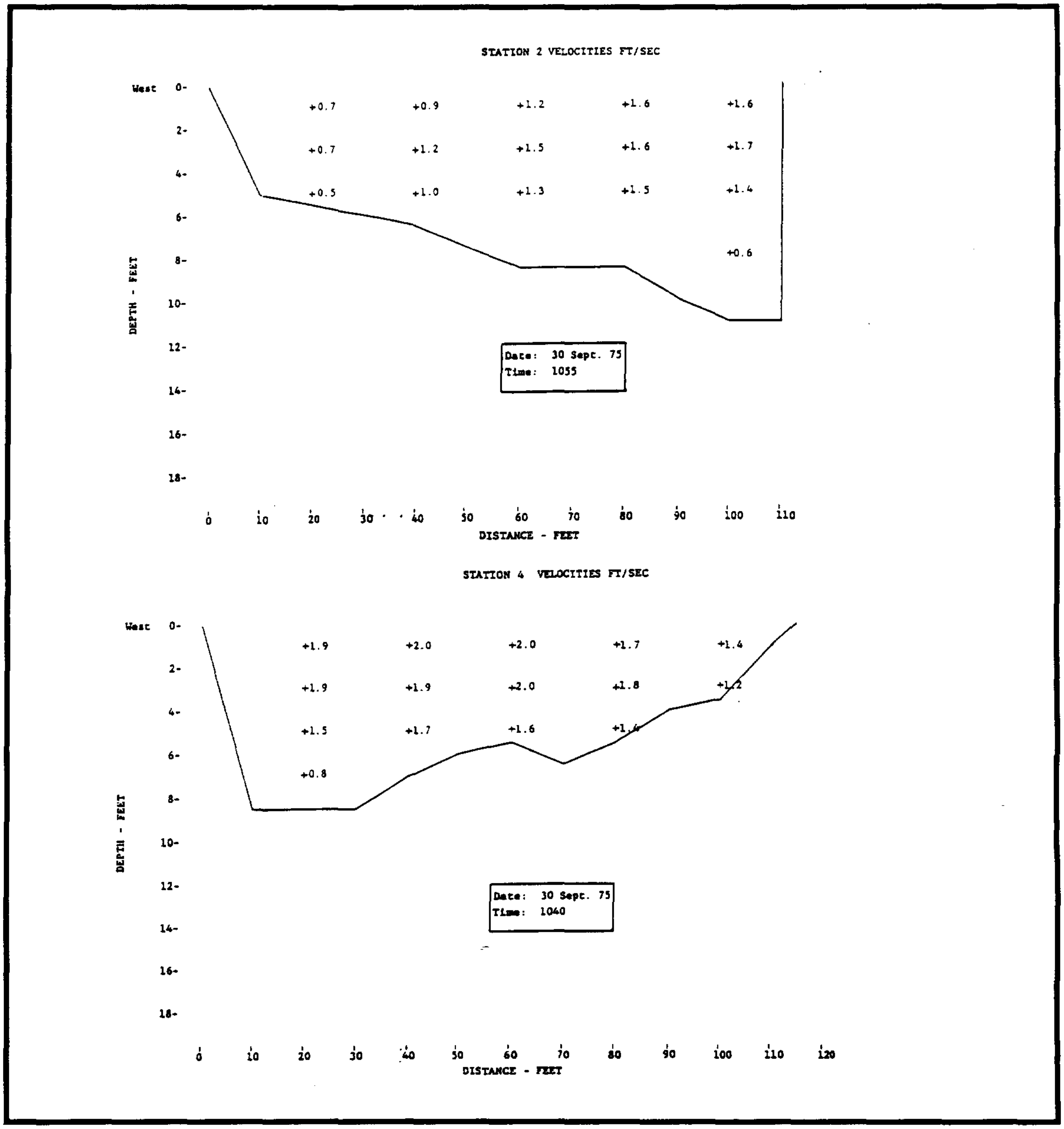
ENDATA08

HYDR-1	1	0.161	0.5	0.625	0.4	0.	0.03
HYDR-1	2	0.161	0.5	0.625	0.4	0.	0.03
HYDR-1	3	0.161	0.5	0.625	0.4	0.	0.03
HYDR-1	4	0.161	0.5	0.625	0.4	0.	0.03
HYDR-1	5	0.161	0.5	0.625	0.4	0.	0.03
HYDR-1	6	0.161	0.5	0.625	0.4	0.	0.03
HYDR-1	7	0.161	0.5	0.625	0.4	0.	0.03
HYDR-1	8	0.161	0.5	0.625	0.4	0.	0.03
HYDR-1	9	0.161	0.5	0.625	0.4	0.	0.03
HYDR-1	10	0.161	0.5	0.625	0.4	0.	0.03
HYDR-1	11	0.161	0.5	0.625	0.4	0.	0.03
HYDR-1	12	0.161	0.5	0.625	0.4	0.	0.03
HYDR-1	13	0.161	0.5	0.625	0.4	0.	0.03
HYDR-1	14	0.161	0.5	0.625	0.4	0.	0.03
HYDR-1	15	0.095	0.5	1.398	0.4	0.	0.03
HYDR-1	16	0.095	0.5	1.398	0.4	0.	0.03
HYDR-1	17	0.095	0.5	1.398	0.4	0.	0.03
HYDR-1	18	0.095	0.5	1.398	0.4	0.	0.03
HYDR-1	19	0.116	0.5	1.312	0.4	0.	0.03
HYDR-1	20	0.116	0.5	1.312	0.4	0.	0.03
HYDR-1	21	0.116	0.5	1.312	0.4	0.	0.03
HYDR-1	22	0.116	0.5	1.312	0.4	0.	0.03

```
COEF-1   12   11.                        0.2   0.1   0.05   1.0   0.05
COEF-1   13   11.                        0.2   0.1   0.05   1.0   0.05
COEF-1   14   11.                        0.2   0.1   0.05   1.0   0.05
COEF-1   15   11.                        0.2   0.1   0.05   1.0   0.05
COEF-1   16   11.                        0.2   0.1   0.05   1.0   0.05
COEF-1   17   11.                        0.2   0.1   0.05   1.0   0.05
COEF-1   18   11.                        0.2   0.1   0.05   1.0   0.05
COEF-1   19   11.                        0.2   0.1   0.05   1.0   0.05
COEF-1   20   11.                        0.2   0.1   0.05   1.0   0.05
COEF-1   21   11.                        0.2   0.1   0.05   1.0   0.05
COEF-1   22   11.                        0.2   0.1   0.05   1.0   0.05
COEF-1   23   11.                        0.2   0.1   0.05   1.0   0.05
COEF-1   24   11.                        0.2   0.1   0.05   1.0   0.05
COEF-1   25   11.                        0.2   0.1   0.05   1.0   0.05
ENDATA12
COEF-2    1     0.05   .05   1.0   0.2   0.    0.    0.2
COEF-2    2     0.05   .05   1.0   0.2   0.    0.    0.2
COEF-2    3     0.05   .05   1.0   0.2   0.    0.    0.2
COEF-2    4     0.05   .05   1.0   0.2   0.    0.    0.2
COEF-2    5     0.05   .05   1.0   0.2   0.    0.    0.2
COEF-2    6     0.05   .05   1.0   0.2   0.    0.    0.2
COEF-2    7     0.05   .05   1.0   0.2   0.    0.    0.2
COEF-2    8     0.05   .05   1.0   0.2   0.    0.    0.2
COEF-2    9     0.05   .05   1.0   0.2   0.    0.    0.2
COEF-2   10     0.05   .05   1.0   0.2   0.    0.    0.2
COEF-2   11     0.05   .05   1.0   0.2   0.    0.    0.2
COEF-2   12     0.05   .05   1.0   0.2   0.    0.    0.2
COEF-2   13     0.05   .05   1.0   0.2   0.    0.    0.2
COEF-2   14     0.05   .05   1.0   0.2   0.    0.    0.2
COEF-2   15     0.05   .05   1.0   0.2   0.    0.    0.2
COEF-2   16     0.05   .05   1.0   0.2   0.    0.    0.2
COEF-2   17     0.05   .05   1.0   0.2   0.    0.    0.2
COEF-2   18     0.05   .05   1.0   0.2   0.    0.    0.2
COEF-2   19     0.05   .05   1.0   0.2   0.    0.    0.2
COEF-2   20     0.05   .05   1.0   0.2   0.    0.    0.2
COEF-2   21     0.05   .05   1.0   0.2   0.    0.    0.2
COEF-2   22     0.05   .05   1.0   0.2   0.    0.    0.2
COEF-2   23     0.05   .05   1.0   0.2   0.    0.    0.2
COEF-2   24     0.05   .05   1.0   0.2   0.    0.    0.2
COEF-2   25     0.05   .05   1.0   0.2   0.    0.    0.2
ENDATA13
ENDATA14
```

```
ENDATA15
ENDATA16
ENDATA17
ENDATA18
ENDATA19
HDWTR-1     1  LEON CREEK (1906)          0.003    29.4      0.     792.     80.
HDWTR-1    12  CULEBRA CREEK              0.003    29.4      0.     792.     80.
HDWTR-1    42  HUEBNER CREEK              0.003    29.4      0.     792.     80.
HDWTR-1    43  CINNAMON CREEK             0.003    29.4      0.     792.     80.
HDWTR-1    83  UNNAMED TRIBUTARY          0.003    29.4      0.     792.     80.
HDWTR-1   142  INDIAN CREEK               0.003    29.4      0.     792.     80.
HDWTR-1   190  COMANCHE CREEK             0.003    29.4      0.     792.     80.
ENDATA20
HDWTR-2     1        6.1      1.3      0.5     0.05      0.2
HDWTR-2    12        6.1      1.3      0.5     0.05      0.2
HDWTR-2    42        6.1      1.3      0.5     0.05      0.2
HDWTR-2    43        6.1      1.3      0.5     0.05      0.2
HDWTR-2    83        6.1      1.3      0.5     0.05      0.2
HDWTR-2   142        6.1      1.3      0.5     0.05      0.2
HDWTR-2   190        6.1      1.3      0.5     0.05      0.2
ENDATA21
ENDATA22
JUNCTION   39   11  CULEBRA CREEK
JUNCTION   50   42  CINNAMON CREEK
JUNCTION   65   41  HUEBNER CREEK
JUNCTION   93   82  UNNAMED TRIBUTARY
JUNCTION  174  141  INDIAN CREEK
JUNCTION  202  189  COMANCHE CREEK
ENDATA23
WSTLD-1    12. SA MUD#1   11647.001   .04382                .5     95.0     40.0
WSTLD-1    21. SA-CUL     10137.042   .04382                .5     95.0     40.0
WSTLD-1    22. SA-NOSIDE  10137.036   .00280                .5     95.0     40.0
WSTLD-1   112. AIR FORCE  02356.008   .04820                .5     95.0     40.0
WSTLD-1   113. AIR FORCE  02356.001   .08764                .5     95.0     40.0
WSTLD-1   122. SA-LEON SE 01517.001   .04382                .5     95.0     40.0
WSTLD-1   201. SA-LEON CK 10137.003  2.01572                .5     95.0     40.0
ENDATA24
WSTLD-2    12.       4.0     10.0   8.5      2.0      3.0  23.5     15.0
WSTLD-2    21.       4.0     10.0    .0      2.0      3.0    .0     15.0
WSTLD-2    22.       2.0     20.0   4.8      4.0     15.0  13.8      1.0
WSTLD-2   112.       5.0       .0    .0       .0       .0    .0       .5
WSTLD-2   113.       5.0     10.0    .0       .1      2.1    .0       .5
```

```
WSTLD-2   122.      5.0       .0   4.8      .0       .0  13.8      .5
WSTLD-2   201.      5.0      7.0    .0     2.0      2.0    .0    16.0
ENDATA25
ENDATA26
ENDATA27
ENDATA28
ENDATA29
NUMBER OF PLOTS = 1
NUMBER OF REACHES IN PLOT 1 =  17                          INCREMENT = 0.5
PLOT RCH  1  3  4  8  9 10 12 13 14 15 16 17 18 19 21 22 25
ENDATA30
ENDATA31
```



adapted from: Espey, Huston & Associates, Inc. 1975. Thermal Plume Studies Victoria Power Station. prepared for Central Power & Light Co., Corpus Christi, Texas. Espey, Huston & Associates, Inc. Doc. No. 7547, Austin, Texas.

Figure F-3

Victoria Thermal Plume Study Results
Technical Memorandum: Environmental Water Needs Criteria for Major Rivers in the Trans-Texas West Central Study Area

APPENDIX E
DOS RIOS WWTP MONTHLY EFFLUENT DATA

APPENDIX E
DOS RIOS WWTP MONTHLY EFFLUENT DATA

Trans-Texas Water Program
West Central Study Area
Environmental Criteria Refinement

Meeting #1
Environmental Criteria Subcommittee (ECS)
October 10, 1997 @ 1:30 PM @ HDR Engineering, Inc.

Meeting Notes

Introduction

Following is a summary of discussions during Meeting #1 presented by Agenda item.

I. Evolution of Environmental Water Needs Criteria Used for Planning Purposes
Vaugh provided a brief review of the evolution of environmental water needs criteria governing run-of-the-river diversions used in the Trans-Texas Water Program for the West Central Study Area including the following:

A. Original "Trans-Texas" Criteria: Monthly timestep, Single zone (no drought contingency provisions)

B. "Alternative" Criteria: Monthly timestep, Two zones, Drought contingency provisions based on moving averages of streamflow

C. "Consensus" Criteria: Daily timestep, Three zones, Drought contingency provisions based on concurrent streamflow

II. Review/Discussion of Consensus Criteria

A. Definition (Zones, Assumptions, Application, etc.)

   1. Vaugh provided brief summary of the Environmental Water Needs Criteria of the Consensus Planning Process (Consensus Criteria) for New Project using excerpts from documentation prepared by the Texas Water Development Board (TWDB).

B. Outstanding Issues

   1. Powell and Moss identified some concerns about naturalized streamflows as referenced in the Consensus Criteria because of perceived lack of documentation. However, both feel that use of natural streamflows is appropriate based on agreement in principle between the TNRCC, TWDB, and TPWD. In addition, TNRCC has committed to use natural streamflows as the basis for new water availability models.

Trans-Texas Water Program
West Central Study Area
Environmental Criteria Refinement

Meeting #2
Environmental Criteria Subcommittee (ECS)
November 18, 1997 @ 1:30 PM @ San Antonio River Authority

Meeting Notes

Introduction

Following is a summary of discussions during Meeting #2 presented by Agenda item.

I. Distribution of Notes from Meeting #1
Vaugh provided draft copy of notes summarizing discussions during ECS Meeting #1 and requested that any corrections/clarifications be submitted within about 2 weeks.

II. Identification of Greatest Environmental Concerns at Potential Diversion Points

A. Lake Dunlap
   1. Quality of New Braunfels treated effluent.
   2. Hydrilla in Lake Dunlap (and McQueeny) which has required herbicide application and triploid carp introduction to control.
   3. Potential increases in the duration of near-zero flows (on an hourly scale) associated with hydropower operations.
   4. Relatively short pipeline to Bexar County and diversion from an existing impoundment were mentioned as advantages of potential Lake Dunlap diversions.

B. Guadalupe River @ Gonzales
   1. Potential impacts/effects related to operations of hydropower facilities.
   2. It was noted that instream flow minimums could be of less significance with respect to diversions from the Guadalupe River between New Braunfels and Gonzales as about 70 percent of this segment is in reservoir pools.

C. Guadalupe River @ Cuero
   1. This segment of the river has been identified as Cagle's map turtle habitat. Apparently, no specific studies have been performed to assess instream flow needs for this turtle.
   2. Mayes noted that riffles are very important features in this segment and that Cagle's map turtles use riffles for feeding.
   3. Mayes also noted that river darters and other species utilize runs in this segment.

III. General Discussion

A. Mayes questioned whether discussion of "ramping" included in the draft document prepared by Paul Price Associates should be included in the final Technical Memorandum. Raabe and Vaugh supported inclusion of a very brief discussion in the memorandum for the primary purpose of simply identifying this potential operational concern.

B. Moss asked whether recommendations for revision/refinement of Consensus Criteria for application in the Guadalupe - San Antonio River Basin would be included in the Technical Memorandum. Raabe advised that the memorandum will focus on presentation of findings rather than recommendations, thereby allowing the new regional planning group(s) created by SB1 to make interpretations and judgments.

IV. Deliverables

A. Vaugh advised that a draft of the Technical Memorandum would be distributed on or about March 6, 1998 with comments due on or before March 20, 1998.

Attendance:

TWDB - Ray Mathews, Jorge Arroyo
SAWS - Mike Brinkmann, Susan Butler
SARA - Steve Raabe, Mike Gonzales
TNRCC - Bruce Moulton
GBRA - Thomas Hill
PPA - Paul Price
HDR - Sam Vaugh
EAA - Rick Illgner
TPWD - Cindy Loeffler, Randy Moss, Kevin Mayes, David Bradsby

Trans-Texas Water Program
West Central Study Area
Environmental Criteria Refinement

Meeting #3
Environmental Criteria Subcommittee (ECS)
January 29, 1998 @ 1:30 PM @ HDR Engineering, Inc.

Draft Meeting Notes

Introduction

Following is a summary of discussions during Meeting #3 presented by Agenda item.

I. General Project Status
Vaugh provided very brief status report.

II. Water Quality Model for Guadalupe River

A. Calibration & Verification

1. Johns provided summary of water quality model development for the Guadalupe River including locations of key physical features, chemical and biological processes affecting dissolved oxygen concentration, standard reaeration equation for Texas streams, and the calibration process focusing on September, 1994 critical conditions.
2. Johns presented a summary of Final Calibration Values of Kinetic Coefficients as compared to the range of values typically assumed by TNRCC to illustrate "conservative" assumptions.
3. Johns noted that HDR did not model algae in order to avoid any over-prediction of dissolved oxygen.
4. Moss questioned appearance that simulated ammonia concentrations did not appear to split the range between the maximum and minimum observed values for June through September. Johns responded that calibration was specifically focused on August and September, 1994 measurements which the model was able to replicate fairly well. Maximum and minimum observed values represent a broad range of streamflows for months in addition to August and September.
5. Moss expressed in interest in overall range of streamflow magnitude for some of the reference bounds in the calibration.

B. Scenario Descriptions & Key Assumptions

1. Johns provided description of final calibration values of kinetic coefficients illustrating that each was selected based on best available data or near the conservative end of the range used by the TNRCC.

3. Hill advised that GBRA and Espey, Huston & Assoc. are conducting a nutrient study on Lake Dunlap.

IV. Water Quality Modeling Discussion

A. General Theoretical Background

Johns provided a general summary of important parameters and considerations in the development, calibration, and application of water quality models focusing on simulation of dissolved oxygen using QUAL-TX. Emphasizing that dissolved oxygen concentrations result from the interaction of hydrological and biological processes, Johns reviewed concepts including waste load, oxygen demand/consumption, reaeration, kinematic equations, and the sag curve.

B. Medina & San Antonio Rivers

Johns provided a summary of the TNRCC's development, calibration, and previous application of QUAL-TX models for the Medina and San Antonio Rivers in the performance of a waste load evaluation study. A dissolved oxygen profile was presented for a critical streamflow and current permitted loadings which showed a sag curve falling just slightly below the 5 mg/l standard near Floresville. Comments included:

1. Brinkmann observed that the wasteload concentration entering the treatment plants is noticeably reduced during some rainfall events due to infiltration in the collection system.
2. Illgner asked whether discharge from the "catfish farm" was included in the simulations and Johns responded that it was included.

C. San Marcos River

Goodman provided a summary of HDR's extension of an existing TNRCC QUAL-TX model (applicable only to the San Marcos River immediately below San Marcos) downstream to the confluence with the Guadalupe River near Gonzales. Goodman described the development and calibration process including the need to increase the sediment oxygen demand below Cummings Dam in order to better match measured dissolved oxygen levels. Dissolved oxygen profiles were presented for several assumed streamflows and loadings. Goodman observed that the San Marcos is a very "healthy" stream with respect to dissolved oxygen from Cummings Dam to the Guadalupe River confluence with the only concerns being above Cummings Dam where the dissolved oxygen standard is 6 mg/l.

D. Guadalupe River

Johns detailed the status of HDR's development and calibration of a QUAL-TX model for the Guadalupe River between New Braunfels and the Saltwater Barrier. At present, the model extends through Lake Dunlap. One concern with respect to calibration is the relative scarcity of BOD samples and measurements. Johns noted that strong diurnal fluctuations were evident in the dissolved oxygen measurements for Lake Dunlap during the summer of 1993.

E. General discussion included the following points:

1. Johns provided example of curves representing the relationships between streamflow and dissolved oxygen for various loading conditions affecting

Trans-Texas Water Program
West Central Study Area
Environmental Criteria Refinement

Meeting #4
Environmental Criteria Subcommittee (ECS)
February 20, 1998 @ 9:00 AM @ TPWD (San Marcos)

Draft Meeting Notes

Introduction

Following is a summary of discussions during Meeting #4 presented by Agenda item.

I. General Project Status

A. Vaugh provided draft copy of notes summarizing discussions during ECS Meeting #2 and requested that any corrections/clarifications be submitted with about 2 weeks.

B. Vaugh provided revised copies of three figures originally presented during Meeting #3.

II. Sensitivity Analyses

A. Vaugh described six scenarios potentially involving modification of minimum and trigger streamflows for Zones 2 and 3 under the Consensus Criteria which were used for performance of sensitivity analyses. These scenarios range from Consensus Criteria as presently defined (Scenario 1) to limitation of diversions only by the flows that must be passed for downstream water rights (Scenario 6). Other scenarios include modification of Zone 3 minimum flow based on dissolved oxygen (DO) modeling results (Scenarios 2 and 3) and incremental modification of Zone 2 minimum and/or Zone 3 trigger streamflows based on interpretation and extrapolation of studies conducted on the San Marcos River (Scenarios 4 and 5). Comments and discussion regarding the formulation and application of these scenarios included the following:

1. Moulton expressed concern about potential changes in the permitting process and procedures associated with modification of the water quality standard. Moss and Moulton advised that the Environmental Protection Agency (EPA) would likely be quite concerned with any loss of focus on the 7Q2 as the water quality standard.
2. Mathews asked about the possibility of TNRCC shifting focus to parameters other than 7Q2 for setting streamflow standards. Moss responded that Davenport (TNRCC) prepared a pertinent working document during the Consensus Planning Process (previously distributed

currently. Some have questioned whether a more lengthy period of record should be considered in the derivation of 7Q2.

   b. Raabe pointed out that the 7Q2 will continue to get bigger and bigger as cities grow and return flows increase if 7Q2 derivation is based on gaged streamflows.
   c. Powell and Moss both note that agencies may not be receptive to 7Q2 values based on naturalized streamflows. Powell notes that the Consensus Criteria references published water quality standards as preferred to 7Q2 estimates.
   d. Powell advised that some other states use 7Q2 values derived for each month rather than annual values as used in Texas.

5. Moss noted that the effects of daily river flow fluctuations associated with the operations of hydroelectric dams on the Guadalupe River may be difficult to assess with respect to biological and water availability issues. Hill advised that flows immediately below H-5 (Lake Wood) are typically 500 cfs, 1100 cfs, or 0 cfs.
6. Powell asked why HDR had decided to use QUAL-TX rather than QUAL-2E for the water quality modeling. Vaugh responded that decision was based primarily on consistency with TNRCC models previously developed and agreed to provide a brief memorandum clarifying the change for the record. HDR will provide a presentation on water quality modeling effort at Meeting #2.
7. Brinkmann asked what effluent loadings would be assumed for performance of sensitivity analyses. Group agreed that this item would be discussed during Meeting #2.
8. Vaugh advised that results of water quality sensitivity analyses will likely include curves relating flow, loading, and dissolved oxygen at several locations.

C. Refinement of Criteria for River Basins/Segments

1. Examples were provided illustrating the perceived need to refine the Consensus Criteria for regional planning in the Guadalupe - San Antonio River Basin. Key points included:
   a. Naturalized annual 7Q2 exceeds the 25th percentile flow in several months at many locations on the Guadalupe River (including Spring Branch, Lake Dunlap, and Cuero) and on the San Marcos River @ Luling. This is due to the strong baseflow and springflow influences.
   b. Naturalized annual 7Q2 exceeds the 25th percentile streamflow in only the driest summer months on the Medina River @ San Antonio and San Antonio River @ Falls City. This is most likely due to the comparison of an annual statistic (7Q2) to a monthly statistic (25th percentile streamflow).

2. Goodman discussed relationship between reaeration rate and streamflow used in the TNRCC model which results in improved reaeration as streamflows decrease. Johns notes that data from the San Antonio River was used in the development of such relationships generally applied in Texas streams (see paper by Karen Cleveland). HDR held reaeration rate constant in simulations to ensure "conservative" estimate of DO.
3. Goodman notes that the original San Antonio River water quality model was calibrated with the Rilling Road WWTP on line and that water quality has improved dramatically since the installation of Dos Rios WWTP and closure of Rilling Road WWTP.

B. Results of Application (Flow/DO Curves)
1. Goodman presented the results of water simulations in the form of streamflow / DO curves subject to the range of scenarios considered. Based on the relatively high quality discharge from the Dos Rios WWTP (permitted or observed), Goodman concluded that DO is not likely to be the limiting factor with respect to potential diversions from the San Antonio River.
2. In subsequent discussions, Davenport expressed concern about the essential absence of a minimum flow in some effluent-dominated streams (like the San Antonio River) and suggested that appropriate minimum streamflows in this situation should be set on the basis of biological data.

IV. Interpretive Assessment of Stream-Specific Studies

A. Studies on San Marcos and Guadalupe Rivers
1. Price provided discussion and summary of recently completed studies on the San Marcos River above Luling and less comprehensive studies on Guadalupe River near Victoria completed several years ago.
2. Price also provided a draft technical memorandum summarizing these studies and various conclusions or recommendations that might be drawn therefrom.

B. Preliminary Recommendations
1. Price presented some preliminary recommendations regarding appropriate streamflow minimums for various locations. These preliminary recommendations are based on the following assumptions:
   a. Macrohabitats in the Guadalupe River are similar to those in the San Marcos River above Luling; and
   b. Percentile streamflows adequate to protect habitat types on the San Marcos River are representative of streamflows adequate to protect habitat types on the Guadalupe River below Gonzales and, possibly, some locations on the San Antonio River where it is gravel bedded.
2. Observations and preliminary recommendations include the following:
   a. The lowest monthly median streamflow may be an appropriate minimum streamflow for Zone 1 in the lower Guadalupe River.

V. Identification of Pertinent Biological Studies (Zones 2 & 3)

>Discussed together.

VI. Identification of Pertinent Water Quality Studies (Zone 3)

A. Price presented preliminary list of potential references for pertinent information.

B. The following were also identified as potentially pertinent studies:

1. Hill noted the IFIM studies conducted for the FERC license for hydropower at Canyon Dam.
2. Hill noted the water quality modeling performed for the City of Victoria by Michael Sullivan & Assoc.
3. Powell advised that the TWDB has draft studies for the Guadalupe River at Dunlap and Gonzales, some partial data regarding habitat utilization for the San Antonio River at Goliad, and additional studies for Sandies and Cibolo Creeks.
4. Hill advised that GBRA is working with TNRCC and SWTSU collecting data for the Guadalupe River from New Braunfels down to H-5 (Lake Wood).

C. Raabe and Gonzales were not aware of any additional pertinent studies on the San Antonio River, but did advise that there will be more sampling in the lower portions of the river during 1998.

D. Hill suggested that the USGS NAWQA program might provide some useful information.

E. Powell noted that identification of limiting habitats is critical for these streams. Although two dimensional modeling can define physical habitat, there is still substantial judgment to be applied from that point. The North American Lake Management Society will be hosting a meeting focusing on instream flows in Houston on 12/2/97.

VII. Topics and Schedule for Future Meetings

A. Group agreed to hold 11/18/97 @ 1:30 PM @ SARA for Meeting #2 as several participants will likely be in San Antonio on other business during the morning of that date.

B. Group agreed that we should contact TNRCC regarding their absence from Meeting #1 and solicit their active participation in Meeting #2 as it will be somewhat focused on water quality modeling efforts.

Attendance:

TWDB - Gary Powell
SARA - Steve Raabe, Mike Gonzales
GBRA - Thomas Hill
PPA - Paul Price

TPWD - Cindy Loeffler, Randy Moss
SAWS - Mike Brinkmann
HDR - Sam Vaugh, Herb Grubb

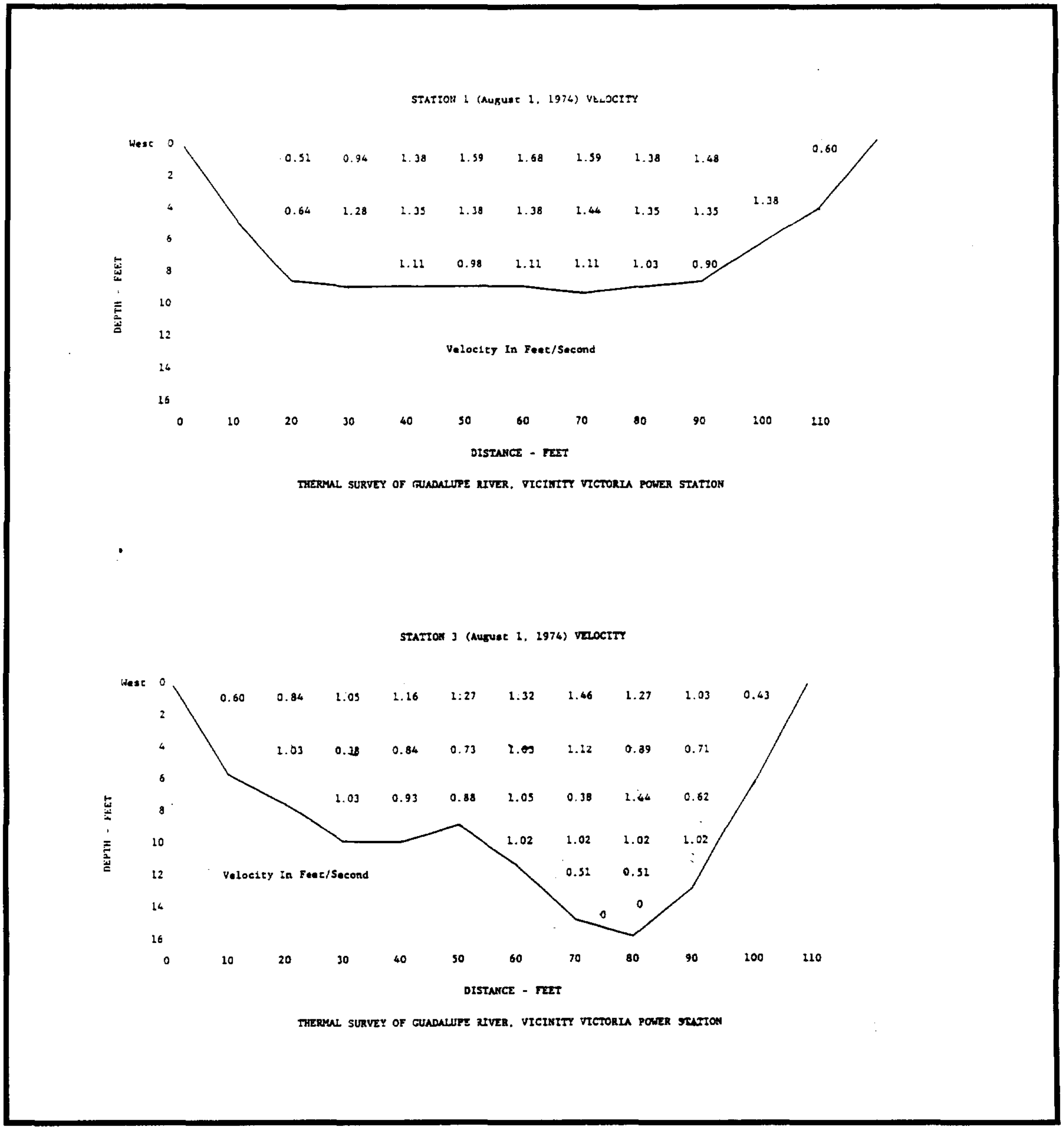
APPENDIX F
VICTORIA THERMAL PLUME
STUDY RESULTS

Observed Water Quality at Dos Rios WWTP in San Antonio

Year	Month	Max. Daily Average Discharge (MGD)	Max. Daily Average CBOD5 (mg/L)	Max. Daily Average NH3-N (mg/L)	Daily Max. Discharge (MGD)	Daily Max. CBOD5 (mg/L)	Daily Max. NH3-N (mg/L)	Daily Min. Dissolved Oxygen (mg/L)
Capacity of Plant Upgraded to 125 MGD from 83 MGD								
1995	8	60.490	2.0	0.13	68.400	2.0	0.34	7.1
1995	9	54.120	2.0	0.13	79.040	5.0	0.26	7.1
1995	10	55.210	2.0	0.13	59.430	4.0	0.32	7.1
1995	11	54.930	2.0	0.10	64.390	3.0	0.10	7.0
1995	12	53.760	2.0	0.10	56.270	2.0	0.14	7.0
1996	1	53.180	2.0	0.15	56.260	2.0	0.73	7.1
1996	2	54.680	2.0	0.18	59.500	2.0	0.44	7.4
1996	3	54.450	2.0	0.18	57.770	3.0	0.27	7.1
1996	4	54.370	2.0	0.16	58.190	3.0	0.23	6.7
1996	5	54.830	2.0	0.21	58.330	3.0	0.32	7.0
1996	6	55.470	2.0	0.18	61.100	4.0	0.62	6.9
1996	7	56.020	2.0	0.19	65.290	3.0	0.50	6.5
1996	8	54.950	2.0	0.25	60.000	6.0	0.56	6.5
1996	9	56.210	2.0	0.27	68.920	6.0	1.29	6.5
1996	10	54.050	2.0	0.20	65.000	3.0	0.28	6.8
1996	11	52.830	2.0	0.19	58.490	4.0	0.39	6.8
1996	12	53.080	2.0	0.17	57.940	3.0	0.25	7.1
1997	1	52.440	2.0	0.16	56.160	4.0	0.28	7.0
1997	2	53.630	2.0	0.16	66.690	2.0	0.22	7.0
1997	3	55.190	2.0	0.21	67.300	3.0	0.28	7.1
1997	4	60.060	2.0	0.19	93.920	2.0	0.28	7.0
1997	5	58.750	2.0	0.23	83.720	3.0	1.40	7.0
1997	6	66.650	2.0	0.14	121.800	3.0	0.25	7.1
1997	7	57.910	2.0	0.15	63.800	2.0	0.27	7.0
1997	8	56.240	2.0	0.17	59.0999	2.0	0.24	6.8
Annual Statistics								
Average		55.740	2.0	0.17	66.672	3.2	0.41	6.9
Max.		66.650	2.0	0.27	121.800	6.0	1.40	7.4
Min.		52.440	2.0	0.10	56.160	2.0	0.10	6.5
Summer Statistics								
Average		57.196	2.0	0.19	72.382	3.9	1.29	6.8
Max.		66.650	2.0	0.27	121.801	6.0	0.50	7.1
Min.		54.120	2.0	0.13	59.100	2.0	0.24	6.5

Source: monthly self-reporting data submitted by San Antonio Water System to TNRCC.

APPENDIX G
ENVIRONMENTAL CRITERIA SUBCOMMITTEE
MEETING NOTES



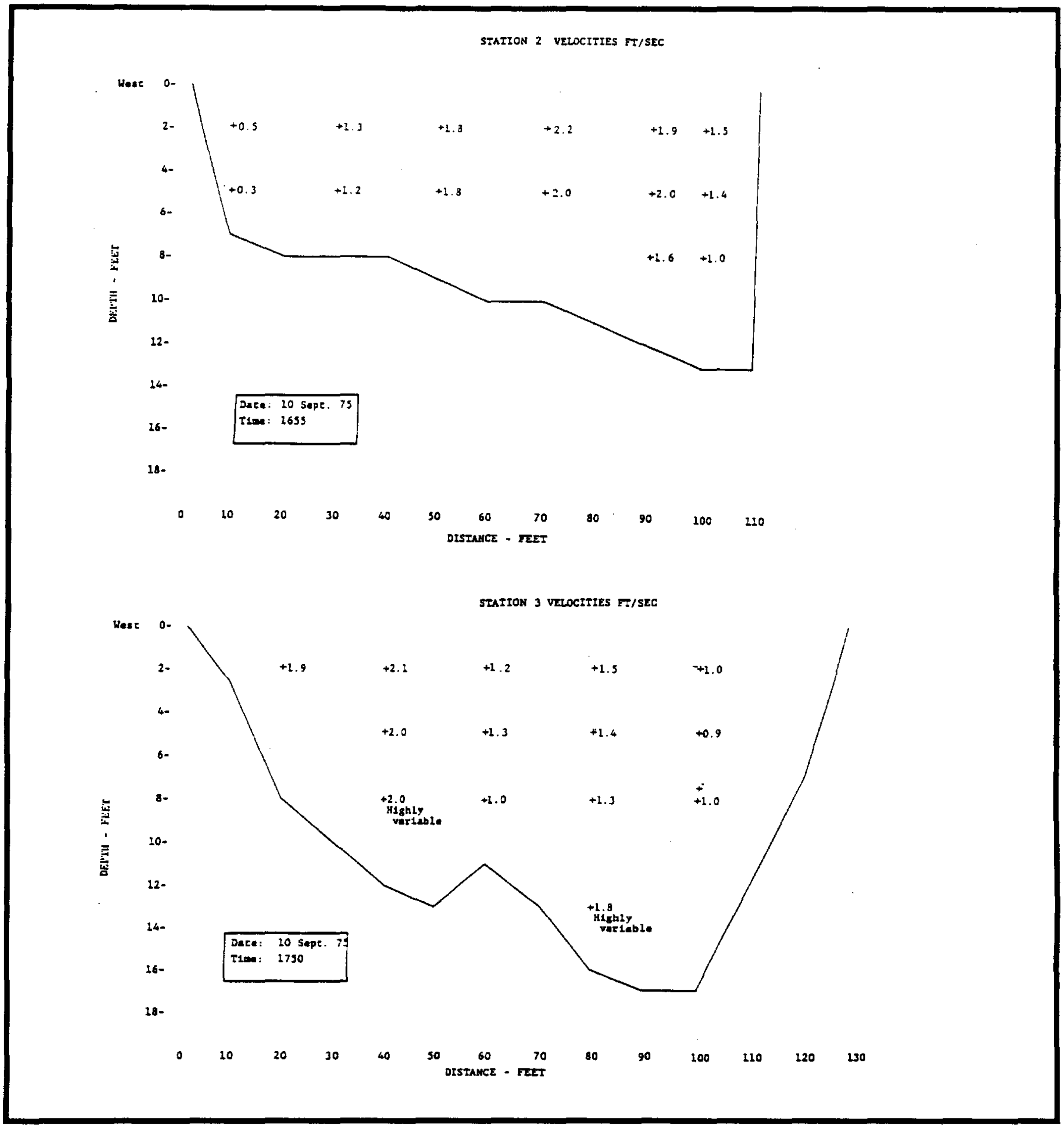
adapted from: Espey, Huston & Associates, Inc. 1975. Thermal Plume Studies Victoria Power Station. prepared for Central Power & Light Co., Corpus Christi, Texas. Espey, Huston & Associates, Inc. Doc. No. 7547, Austin, Texas.

Figure F-1

Victoria Thermal Plume Study Results
Technical Memorandum: Environmental Water Needs Criteria for Major Rivers in the Trans-Texas West Central Study Area

Paul Price Associates, Inc.

ECOLOGY, WATER QUALITY, CULTURAL RESOURCES, PLANNING



adapted from: Espey, Huston & Associates, Inc. 1975. Thermal Plume Studies Victoria Power Station. prepared for Central Power & Light Co., Corpus Christi, Texas. Espey, Huston & Associates, Inc. Doc. No. 7547, Austin, Texas.

Figure F-2

Victoria Thermal Plume Study Results
Technical Memorandum: Environmental Water Needs Criteria for Major Rivers in the Trans-Texas West Central Study Area

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ENDATA11
COEF-1      1   11.                        0.1    0.1   0.05     1.0   0.05
COEF-1      2   11.                        0.1    0.1   0.05     1.0   0.05
COEF-1      3   11.                        0.1    0.1   0.05     1.0   0.05
COEF-1      4   11.                        0.5    0.1   0.10     1.0   0.05
COEF-1      5   11.                        0.5    0.1   0.10     1.0   0.05
COEF-1      6   11.                        0.3    0.1   0.10     1.0   0.05
COEF-1      7   11.                        0.3    0.1   0.10     1.0   0.05
COEF-1      8   11.                        0.3    0.1   0.10     1.0   0.05
COEF-1      9   11.                        0.1    0.1   0.10     1.0   0.05
COEF-1     10   11.                        0.1    0.1   0.10     1.0   0.05
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COEF-1     11   11.                       0.1    0.1    0.10    1.0    0.05
COEF-1     12   11.                       0.1    0.1    0.10    1.0    0.05
COEF-1     13   12.                       0.1    0.1    0.10    1.0    0.05
COEF-1     14   12.                       0.1    0.1    0.10    1.0    0.05
COEF-1     15   11.                       0.1    0.1    0.10    1.0    0.05
COEF-1     16   11.                       0.1    0.1    0.10    1.0    0.05
COEF-1     17   11.                       0.1    0.1    0.10    1.0    0.05
COEF-1     18   11.                       0.1    0.1    0.10    1.0    0.05
COEF-1     19   11.                       0.1    0.1    0.10    1.0    0.05
COEF-1     20   11.                       0.1    0.1    0.10    1.0    0.05
COEF-1     21   11.                       0.1    0.1    0.10    1.0    0.05
COEF-1     22   11.                       0.1    0.1    0.10    1.0    0.05
COEF-1     23   11.                       0.1    0.1    0.10    1.0    0.05
COEF-1     24   11.                       0.1    0.1    0.10    1.0    0.05
ENDATA12
COEF-2      1     0.05    .05    1.0    0.2    0.     0.     0.2
COEF-2      2     0.05    .05    1.0    0.2    0.     0.     0.2
COEF-2      3     0.05    .05    1.0    0.2    0.     0.     0.2
COEF-2      4     0.05    .10    1.0    0.2    0.     0.     0.2
COEF-2      5     0.05    .10    1.0    0.2    0.     0.     0.2
COEF-2      6     0.05    .10    1.0    0.2    0.     0.     0.2
COEF-2      7     0.05    .10    1.0    0.2    0.     0.     0.2
COEF-2      8     0.05    .10    1.0    0.2    0.     0.     0.2
COEF-2      9     0.05    .10    1.0    0.2    0.     0.     0.2
COEF-2     10     0.05    .10    1.0    0.2    0.     0.     0.2
COEF-2     11     0.05    .10    1.0    0.2    0.     0.     0.2
COEF-2     12     0.05    .10    1.0    0.2    0.     0.     0.2
COEF-2     13     0.05    .10    1.0    0.2    0.     0.     0.2
COEF-2     14     0.05    .10    1.0    0.2    0.     0.     0.2
COEF-2     15     0.05    .10    1.0    0.2    0.     0.     0.2
COEF-2     16     0.05    .10    1.0    0.2    0.     0.     0.2
COEF-2     17     0.05    .10    1.0    0.2    0.     0.     0.2
COEF-2     18     0.05    .10    1.0    0.2    0.     0.     0.2
COEF-2     19     0.05    .10    1.0    0.2    0.     0.     0.2
COEF-2     20     0.05    .10    1.0    0.2    0.     0.     0.2
COEF-2     21     0.05    .10    1.0    0.2    0.     0.     0.2
COEF-2     22     0.05    .10    1.0    0.2    0.     0.     0.2
COEF-2     23     0.05    .10    1.0    0.2    0.     0.     0.2
COEF-2     24     0.05    .10    1.0    0.2    0.     0.     0.2
ENDATA13
ENDATA14
ENDATA15
```

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ENDATA16
ENDATA17
ENDATA18
ENDATA19
HDWTR-1     1  MEDIO CREEK               0.0030    29.4      0.    792.    80.
ENDATA20
HDWTR-2     1        6.1      3.0    0.50      0.05      0.20
ENDATA21
ENDATA22
ENDATA23
WSTLD-1    25. BC WCID#16 10130.001   .02191                 .5    95.0    40.0
WSTLD-1    26. COMMUN-MED 10827.003   .37247                 .5    95.0    40.0
WSTLD-1    38. AIR FORCE  12033.001   .01315                 .5    95.0    40.0
WSTLD-1    51. MITCHELL LAKE INFLOW   .71700                 .5   492.0    80.0
WSTLD-1    58. MITCHELL LAKE WIDTH.  -.44200
WSTLD-1    64. SA-SOWST   02635.001   .00657                 .5    95.0    40.0
ENDATA24
WSTLD-2    25.      4.0     23.0   3.8     2.0      3.0   7.4    15.0
WSTLD-2    26.      4.0     18.0    .0     2.0      2.0    .0    16.0
WSTLD-2    38.      4.0     23.0    .0     2.0      3.0    .0    15.0
WSTLD-2    51.      6.1      3.0    .0     0.5      .05    .0    0.20
WSTLD-2    58.
WSTLD-2    64.      5.0     23.0    .0      .1     15.0    .0      .5
ENDATA25
ENDATA26
ENDATA27
ENDATA28
ENDATA29
NUMBER OF PLOTS = 1
NUMBER OF REACHES IN PLOT 1 =  24                        INCREMENT = 0.25
PLOT RCH  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
ENDATA30
ENDATA31
```

Leon Creek Input File

```
CNTROL01     TNRCC QUAL-TX MODEL FOR LEON CREEK (SEG. 1906)
CNTROL02     ALL PARAMETERS AS PER ORIGINAL.
CNTROL03 YES ECHO DATA INPUT
CNTROL04  NO INTERMEDIATE SUMMARY
CNTROL05  NO FINAL REPORT
CNTROL06  NO LINE PRINTER PLOT
CNTROL07  NO GRAPHICS CAPABILITY
CNTROL08 YES METRIC UNITS
CNTROL09 YES OXYGEN DEPENDENT RATES
CNTROL10  NO SENSITIVITY ANALYSIS
CNTROL11 YES CAPSULE SUMMARY
ENDATA01
MODOPT01  NO TEMPERATURE
MODOPT02  NO SALINITY
MODOPT03 YES CONSERVATIVE MATERIAL  I = CONDUCTIVITY , UMHOS/CM
MODOPT04 YES CONSERVATIVE MATERIAL II = CHLORIDE , MG/L
MODOPT05 YES DISSOLVED OXYGEN
MODOPT06 YES BIOCHEMICAL OXYGEN DEMAND
MODOPT07 YES NITROGEN
MODOPT08  NO PHOSPHORUS
MODOPT09  NO CHLOROPHYLL A
MODOPT10  NO MACROPHYTES
MODOPT11  NO COLIFORM
MODOPT12  NO NONCONSERVATIVE MATERIAL =
ENDATA02
PROGRAM  LOGICAL UNIT NUMBER FOR SEQUENCING = 16.0
PROGRAM  BOD OXYGEN UPTAKE RATE (MG O/MG)   = 2.3
PROGRAM  N ALGAL UPTAKE (MG N/UG CHLA/D)    = 0.02
PROGRAM  N PREFERENCE                       = 0.5
ENDATA03
ENDATA04
ENDATA05
ENDATA06
ENDATA07
REACH ID    1  LC SH 16 - CULEBRA CREEK           51.0      45.5      0.5
REACH ID    2  CC CULEBRA CREEK                   13.5      0.        0.5
REACH ID    3  LC CULEBRA CREEK - INGRAM ROAD     45.5      44.5      0.5
REACH ID    4  LC INGRAM ROAD - HUEBNER CREEK     44.5      44.0      0.5
REACH ID    5  HC HEADWATER - CINNAMON CK CONF    7.51      7.5       0.01
REACH ID    6  CC CINNAMON CREEK                  3.5       0.0       0.5
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REACH ID    7  HC CINNAMON CK CONF - CONFLUENCE   7.5       0.0        0.5
REACH ID    8  LC HUEBNER CREEK - W COMMERCE ST.  44.0      40.5       0.5
REACH ID    9  LC W COMMERCE ST - RODRIGUEZ PK    40.5      35.5       0.5
REACH ID   10  LC RODRIGUEZ PK - UNNAMED TRIB.    35.5      35.0       0.5
REACH ID   11  UT UNNAMED TRIBUTARY               5.0       0.         0.5
REACH ID   12  LC UNNAMED TRIB - US 90            35.0      34.5       0.5
REACH ID   13  LC US 90 - BILLY MITCHELL DR.      34.5      29.5       0.5
REACH ID   14  LC BILLY MITCHELL DR. - SH 13      29.5      26.0       0.5
REACH ID   15  LC SH 13 - KELLY AFB IWTP          26.0      25.0       0.5
REACH ID   16  LC KELLY AFB IWTP - PRIVATE RD.    25.0      24.0       0.5
REACH ID   17  LC PRIVATE RD. - IH 35             24.0      18.0       0.5
REACH ID   18  LC IH 35 - IH 410                  18.0      16.0       0.5
REACH ID   19  LC IH 410 - INDIAN CREEK           16.0      10.5       0.5
REACH ID   20  IC INDIAN CREEK                    16.0      0.         0.5
REACH ID   21  LC INDIAN CREEK - SH 16            10.5      9.5        0.5
REACH ID   22  LC SH 16 - COMANCHE CREEK          9.5       2.5        0.5
REACH ID   23  CC HEADWATER - LEON CREEK STP      6.0       0.5        0.5
REACH ID   24  CC LEON CREEK STP - CONFLUENCE     0.5       0.         0.5
REACH ID   25  LC COMANCHE CREEK - MEDINA RIVER   2.5       0.         0.5
ENDATA08
HYDR-1      1       0.161       0.5      0.625       0.4        0.   0.03
HYDR-1      2       0.161       0.5      0.625       0.4        0.   0.03
HYDR-1      3       0.161       0.5      0.625       0.4        0.   0.03
HYDR-1      4       0.161       0.5      0.625       0.4        0.   0.03
HYDR-1      5       0.161       0.5      0.625       0.4        0.   0.03
HYDR-1      6       0.161       0.5      0.625       0.4        0.   0.03
HYDR-1      7       0.161       0.5      0.625       0.4        0.   0.03
HYDR-1      8       0.161       0.5      0.625       0.4        0.   0.03
HYDR-1      9       0.161       0.5      0.625       0.4        0.   0.03
HYDR-1     10       0.161       0.5      0.625       0.4        0.   0.03
HYDR-1     11       0.161       0.5      0.625       0.4        0.   0.03
HYDR-1     12       0.161       0.5      0.625       0.4        0.   0.03
HYDR-1     13       0.161       0.5      0.625       0.4        0.   0.03
HYDR-1     14       0.161       0.5      0.625       0.4        0.   0.03
HYDR-1     15       0.095       0.5      1.398       0.4        0.   0.03
HYDR-1     16       0.095       0.5      1.398       0.4        0.   0.03
HYDR-1     17       0.095       0.5      1.398       0.4        0.   0.03
HYDR-1     18       0.095       0.5      1.398       0.4        0.   0.03
HYDR-1     19       0.116       0.5      1.312       0.4        0.   0.03
HYDR-1     20       0.116       0.5      1.312       0.4        0.   0.03
HYDR-1     21       0.116       0.5      1.312       0.4        0.   0.03
HYDR-1     22       0.116       0.5      1.312       0.4        0.   0.03
```

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COEF-1     12    11.                          0.2    0.1   0.05    1.0   0.05
COEF-1     13    11.                          0.2    0.1   0.05    1.0   0.05
COEF-1     14    11.                          0.2    0.1   0.05    1.0   0.05
COEF-1     15    11.                          0.2    0.1   0.05    1.0   0.05
COEF-1     16    11.                          0.2    0.1   0.05    1.0   0.05
COEF-1     17    11.                          0.2    0.1   0.05    1.0   0.05
COEF-1     18    11.                          0.2    0.1   0.05    1.0   0.05
COEF-1     19    11.                          0.2    0.1   0.05    1.0   0.05
COEF-1     20    11.                          0.2    0.1   0.05    1.0   0.05
COEF-1     21    11.                          0.2    0.1   0.05    1.0   0.05
COEF-1     22    11.                          0.2    0.1   0.05    1.0   0.05
COEF-1     23    11.                          0.2    0.1   0.05    1.0   0.05
COEF-1     24    11.                          0.2    0.1   0.05    1.0   0.05
COEF-1     25    11.                          0.2    0.1   0.05    1.0   0.05
ENDATA12
COEF-2      1      0.05    .05    1.0    0.2    0.     0.    0.2
COEF-2      2      0.05    .05    1.0    0.2    0.     0.    0.2
COEF-2      3      0.05    .05    1.0    0.2    0.     0.    0.2
COEF-2      4      0.05    .05    1.0    0.2    0.     0.    0.2
COEF-2      5      0.05    .05    1.0    0.2    0.     0.    0.2
COEF-2      6      0.05    .05    1.0    0.2    0.     0.    0.2
COEF-2      7      0.05    .05    1.0    0.2    0.     0.    0.2
COEF-2      8      0.05    .05    1.0    0.2    0.     0.    0.2
COEF-2      9      0.05    .05    1.0    0.2    0.     0.    0.2
COEF-2     10      0.05    .05    1.0    0.2    0.     0.    0.2
COEF-2     11      0.05    .05    1.0    0.2    0.     0.    0.2
COEF-2     12      0.05    .05    1.0    0.2    0.     0.    0.2
COEF-2     13      0.05    .05    1.0    0.2    0.     0.    0.2
COEF-2     14      0.05    .05    1.0    0.2    0.     0.    0.2
COEF-2     15      0.05    .05    1.0    0.2    0.     0.    0.2
COEF-2     16      0.05    .05    1.0    0.2    0.     0.    0.2
COEF-2     17      0.05    .05    1.0    0.2    0.     0.    0.2
COEF-2     18      0.05    .05    1.0    0.2    0.     0.    0.2
COEF-2     19      0.05    .05    1.0    0.2    0.     0.    0.2
COEF-2     20      0.05    .05    1.0    0.2    0.     0.    0.2
COEF-2     21      0.05    .05    1.0    0.2    0.     0.    0.2
COEF-2     22      0.05    .05    1.0    0.2    0.     0.    0.2
COEF-2     23      0.05    .05    1.0    0.2    0.     0.    0.2
COEF-2     24      0.05    .05    1.0    0.2    0.     0.    0.2
COEF-2     25      0.05    .05    1.0    0.2    0.     0.    0.2
ENDATA13
ENDATA14
```

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ENDATA15
ENDATA16
ENDATA17
ENDATA18
ENDATA19
HDWTR-1     1  LEON CREEK (1906)           0.003    29.4      0.     792.     80.
HDWTR-1    12  CULEBRA CREEK               0.003    29.4      0.     792.     80.
HDWTR-1    42  HUEBNER CREEK               0.003    29.4      0.     792.     80.
HDWTR-1    43  CINNAMON CREEK              0.003    29.4      0.     792.     80.
HDWTR-1    83  UNNAMED TRIBUTARY           0.003    29.4      0.     792.     80.
HDWTR-1   142  INDIAN CREEK                0.003    29.4      0.     792.     80.
HDWTR-1   190  COMANCHE CREEK              0.003    29.4      0.     792.     80.
ENDATA20
HDWTR-2     1        6.1      1.3      0.5     0.05      0.2
HDWTR-2    12        6.1      1.3      0.5     0.05      0.2
HDWTR-2    42        6.1      1.3      0.5     0.05      0.2
HDWTR-2    43        6.1      1.3      0.5     0.05      0.2
HDWTR-2    83        6.1      1.3      0.5     0.05      0.2
HDWTR-2   142        6.1      1.3      0.5     0.05      0.2
HDWTR-2   190        6.1      1.3      0.5     0.05      0.2
ENDATA21
ENDATA22
JUNCTION   39    11  CULEBRA CREEK
JUNCTION   50    42  CINNAMON CREEK
JUNCTION   65    41  HUEBNER CREEK
JUNCTION   93    82  UNNAMED TRIBUTARY
JUNCTION  174   141  INDIAN CREEK
JUNCTION  202   189  COMANCHE CREEK
ENDATA23
WSTLD-1    12. SA MUD#1    11647.001   .04382                .5     95.0     40.0
WSTLD-1    21. SA-CUL      10137.042   .04382                .5     95.0     40.0
WSTLD-1    22. SA-NOSIDE   10137.036   .00280                .5     95.0     40.0
WSTLD-1   112. AIR FORCE   02356.008   .04820                .5     95.0     40.0
WSTLD-1   113. AIR FORCE   02356.001   .08764                .5     95.0     40.0
WSTLD-1   122. SA-LEON SE  01517.001   .04382                .5     95.0     40.0
WSTLD-1   201. SA-LEON CK  10137.003  2.01572                .5     95.0     40.0
ENDATA24
WSTLD-2    12.       4.0      10.0   8.5     2.0      3.0  23.5     15.0
WSTLD-2    21.       4.0      10.0    .0     2.0      3.0    .0     15.0
WSTLD-2    22.       2.0      20.0   4.8     4.0     15.0  13.8      1.0
WSTLD-2   112.       5.0        .0    .0      .0       .0    .0       .5
WSTLD-2   113.       5.0      10.0    .0      .1      2.1    .0       .5
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WSTLD-2   122.       5.0        .0   4.8       .0        .0  13.8      .5
WSTLD-2   201.       5.0       7.0    .0      2.0       2.0    .0    16.0
ENDATA25
ENDATA26
ENDATA27
ENDATA28
ENDATA29
NUMBER OF PLOTS = 1
NUMBER OF REACHES IN PLOT 1 =  17                           INCREMENT = 0.5
PLOT RCH  1  3  4  8  9 10 12 13 14 15 16 17 18 19 21 22 25
ENDATA30
ENDATA31
```
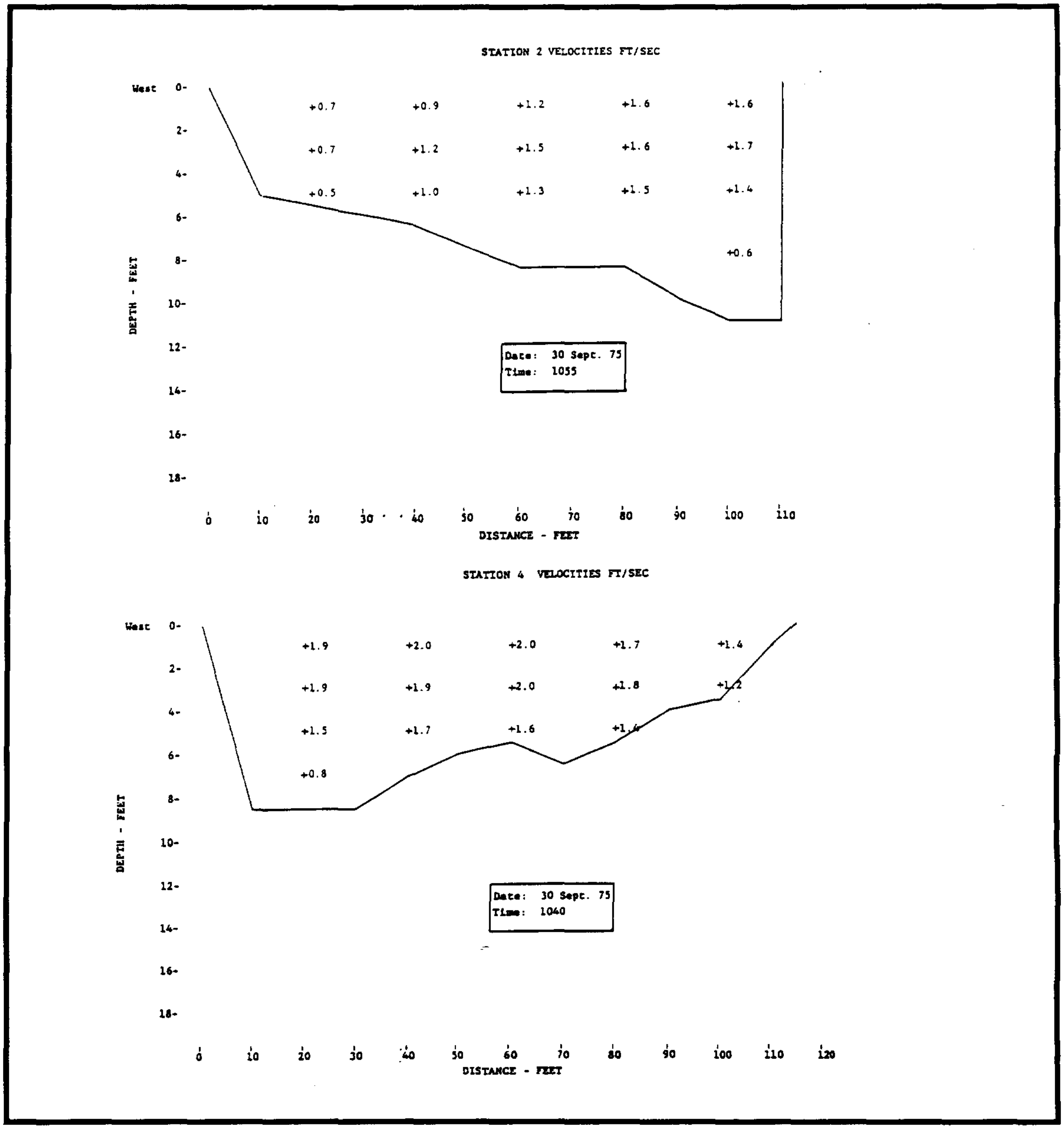

DELLJOBS\0239\FIG2.3-1.CDR\1-12-98



adapted from: Espey, Huston & Associates, Inc. 1975. Thermal Plume Studies Victoria Power Station. prepared for Central Power & Light Co., Corpus Christi, Texas. Espey, Huston & Associates, Inc. Doc. No. 7547, Austin, Texas.

Figure F-3

Victoria Thermal Plume Study Results
Technical Memorandum: Environmental Water Needs Criteria for Major Rivers in the Trans-Texas West Central Study Area

Paul Price Associates, Inc.

ECOLOGY, WATER QUALITY, CULTURAL RESOURCES, PLANNING

APPENDIX E
DOS RIOS WWTP MONTHLY EFFLUENT DATA

APPENDIX E
DOS RIOS WWTP MONTHLY EFFLUENT DATA

Trans-Texas Water Program
West Central Study Area
Environmental Criteria Refinement

Meeting #1
Environmental Criteria Subcommittee (ECS)
October 10, 1997 @ 1:30 PM @ HDR Engineering, Inc.

Meeting Notes

Introduction

Following is a summary of discussions during Meeting #1 presented by Agenda item.

I. Evolution of Environmental Water Needs Criteria Used for Planning Purposes
Vaugh provided a brief review of the evolution of environmental water needs criteria governing run-of-the-river diversions used in the Trans-Texas Water Program for the West Central Study Area including the following:

A. Original "Trans-Texas" Criteria: Monthly timestep, Single zone (no drought contingency provisions)
B. "Alternative" Criteria: Monthly timestep, Two zones, Drought contingency provisions based on moving averages of streamflow
C. "Consensus" Criteria: Daily timestep, Three zones, Drought contingency provisions based on concurrent streamflow

II. Review/Discussion of Consensus Criteria

A. Definition (Zones, Assumptions, Application, etc.)
   1. Vaugh provided brief summary of the Environmental Water Needs Criteria of the Consensus Planning Process (Consensus Criteria) for New Project using excerpts from documentation prepared by the Texas Water Development Board (TWDB).
B. Outstanding Issues
   1. Powell and Moss identified some concerns about naturalized streamflows as referenced in the Consensus Criteria because of perceived lack of documentation. However, both feel that use of natural streamflows is appropriate based on agreement in principle between the TNRCC, TWDB, and TPWD. In addition, TNRCC has committed to use natural streamflows as the basis for new water availability models.

Trans-Texas Water Program
West Central Study Area
Environmental Criteria Refinement

Meeting #2
Environmental Criteria Subcommittee (ECS)
November 18, 1997 @ 1:30 PM @ San Antonio River Authority

Meeting Notes

Introduction

Following is a summary of discussions during Meeting #2 presented by Agenda item.

I. Distribution of Notes from Meeting #1
Vaugh provided draft copy of notes summarizing discussions during ECS Meeting #1 and requested that any corrections/clarifications be submitted within about 2 weeks.

II. Identification of Greatest Environmental Concerns at Potential Diversion Points

A. Lake Dunlap
   1. Quality of New Braunfels treated effluent.
   2. Hydrilla in Lake Dunlap (and McQueeny) which has required herbicide application and triploid carp introduction to control.
   3. Potential increases in the duration of near-zero flows (on an hourly scale) associated with hydropower operations.
   4. Relatively short pipeline to Bexar County and diversion from an existing impoundment were mentioned as advantages of potential Lake Dunlap diversions.

B. Guadalupe River @ Gonzales
   1. Potential impacts/effects related to operations of hydropower facilities.
   2. It was noted that instream flow minimums could be of less significance with respect to diversions from the Guadalupe River between New Braunfels and Gonzales as about 70 percent of this segment is in reservoir pools.

C. Guadalupe River @ Cuero
   1. This segment of the river has been identified as Cagle's map turtle habitat. Apparently, no specific studies have been performed to assess instream flow needs for this turtle.
   2. Mayes noted that riffles are very important features in this segment and that Cagle's map turtles use riffles for feeding.
   3. Mayes also noted that river darters and other species utilize runs in this segment.

III. General Discussion

A. Mayes questioned whether discussion of "ramping" included in the draft document prepared by Paul Price Associates should be included in the final Technical Memorandum. Raabe and Vaugh supported inclusion of a very brief discussion in the memorandum for the primary purpose of simply identifying this potential operational concern.

B. Moss asked whether recommendations for revision/refinement of Consensus Criteria for application in the Guadalupe - San Antonio River Basin would be included in the Technical Memorandum. Raabe advised that the memorandum will focus on presentation of findings rather than recommendations, thereby allowing the new regional planning group(s) created by SB1 to make interpretations and judgments.

IV. Deliverables

A. Vaugh advised that a draft of the Technical Memorandum would be distributed on or about March 6, 1998 with comments due on or before March 20, 1998.

Attendance:

TWDB - Ray Mathews, Jorge Arroyo
SAWS - Mike Brinkmann, Susan Butler
SARA - Steve Raabe, Mike Gonzales
TNRCC - Bruce Moulton
GBRA - Thomas Hill
PPA - Paul Price
HDR - Sam Vaugh
EAA - Rick Illgner
TPWD - Cindy Loeffler, Randy Moss, Kevin Mayes, David Bradsby

Trans-Texas Water Program
West Central Study Area
Environmental Criteria Refinement

Meeting #3
Environmental Criteria Subcommittee (ECS)
January 29, 1998 @ 1:30 PM @ HDR Engineering, Inc.

Draft Meeting Notes

Introduction

Following is a summary of discussions during Meeting #3 presented by Agenda item.

I. General Project Status

Vaugh provided very brief status report.

II. Water Quality Model for Guadalupe River

A. Calibration & Verification

1. Johns provided summary of water quality model development for the Guadalupe River including locations of key physical features, chemical and biological processes affecting dissolved oxygen concentration, standard reaeration equation for Texas streams, and the calibration process focusing on September, 1994 critical conditions.
2. Johns presented a summary of Final Calibration Values of Kinetic Coefficients as compared to the range of values typically assumed by TNRCC to illustrate "conservative" assumptions.
3. Johns noted that HDR did not model algae in order to avoid any over-prediction of dissolved oxygen.
4. Moss questioned appearance that simulated ammonia concentrations did not appear to split the range between the maximum and minimum observed values for June through September. Johns responded that calibration was specifically focused on August and September, 1994 measurements which the model was able to replicate fairly well. Maximum and minimum observed values represent a broad range of streamflows for months in addition to August and September.
5. Moss expressed in interest in overall range of streamflow magnitude for some of the reference bounds in the calibration.

B. Scenario Descriptions & Key Assumptions

1. Johns provided description of final calibration values of kinetic coefficients illustrating that each was selected based on best available data or near the conservative end of the range used by the TNRCC.

3. Hill advised that GBRA and Espey, Huston & Assoc. are conducting a nutrient study on Lake Dunlap.

IV. Water Quality Modeling Discussion

A. General Theoretical Background

Johns provided a general summary of important parameters and considerations in the development, calibration, and application of water quality models focusing on simulation of dissolved oxygen using QUAL-TX. Emphasizing that dissolved oxygen concentrations result from the interaction of hydrological and biological processes, Johns reviewed concepts including waste load, oxygen demand/consumption, reaeration, kinematic equations, and the sag curve.

B. Medina & San Antonio Rivers

Johns provided a summary of the TNRCC's development, calibration, and previous application of QUAL-TX models for the Medina and San Antonio Rivers in the performance of a waste load evaluation study. A dissolved oxygen profile was presented for a critical streamflow and current permitted loadings which showed a sag curve falling just slightly below the 5 mg/l standard near Floresville. Comments included:

1. Brinkmann observed that the wasteload concentration entering the treatment plants is noticeably reduced during some rainfall events due to infiltration in the collection system.
2. Illgner asked whether discharge from the "catfish farm" was included in the simulations and Johns responded that it was included.

C. San Marcos River

Goodman provided a summary of HDR's extension of an existing TNRCC QUAL-TX model (applicable only to the San Marcos River immediately below San Marcos) downstream to the confluence with the Guadalupe River near Gonzales. Goodman described the development and calibration process including the need to increase the sediment oxygen demand below Cummings Dam in order to better match measured dissolved oxygen levels. Dissolved oxygen profiles were presented for several assumed streamflows and loadings. Goodman observed that the San Marcos is a very "healthy" stream with respect to dissolved oxygen from Cummings Dam to the Guadalupe River confluence with the only concerns being above Cummings Dam where the dissolved oxygen standard is 6 mg/l.

D. Guadalupe River

Johns detailed the status of HDR's development and calibration of a QUAL-TX model for the Guadalupe River between New Braunfels and the Saltwater Barrier. At present, the model extends through Lake Dunlap. One concern with respect to calibration is the relative scarcity of BOD samples and measurements. Johns noted that strong diurnal fluctuations were evident in the dissolved oxygen measurements for Lake Dunlap during the summer of 1993.

E. General discussion included the following points:

1. Johns provided example of curves representing the relationships between streamflow and dissolved oxygen for various loading conditions affecting

Trans-Texas Water Program
West Central Study Area
Environmental Criteria Refinement

Meeting #4
Environmental Criteria Subcommittee (ECS)
February 20, 1998 @ 9:00 AM @ TPWD (San Marcos)

Draft Meeting Notes

Introduction

Following is a summary of discussions during Meeting #4 presented by Agenda item.

I. General Project Status

A. Vaugh provided draft copy of notes summarizing discussions during ECS Meeting #2 and requested that any corrections/clarifications be submitted with about 2 weeks.

B. Vaugh provided revised copies of three figures originally presented during Meeting #3.

II. Sensitivity Analyses

A. Vaugh described six scenarios potentially involving modification of minimum and trigger streamflows for Zones 2 and 3 under the Consensus Criteria which were used for performance of sensitivity analyses. These scenarios range from Consensus Criteria as presently defined (Scenario 1) to limitation of diversions only by the flows that must be passed for downstream water rights (Scenario 6). Other scenarios include modification of Zone 3 minimum flow based on dissolved oxygen (DO) modeling results (Scenarios 2 and 3) and incremental modification of Zone 2 minimum and/or Zone 3 trigger streamflows based on interpretation and extrapolation of studies conducted on the San Marcos River (Scenarios 4 and 5). Comments and discussion regarding the formulation and application of these scenarios included the following:

   1. Moulton expressed concern about potential changes in the permitting process and procedures associated with modification of the water quality standard. Moss and Moulton advised that the Environmental Protection Agency (EPA) would likely be quite concerned with any loss of focus on the 7Q2 as the water quality standard.
   2. Mathews asked about the possibility of TNRCC shifting focus to parameters other than 7Q2 for setting streamflow standards. Moss responded that Davenport (TNRCC) prepared a pertinent working document during the Consensus Planning Process (previously distributed

currently. Some have questioned whether a more lengthy period of record should be considered in the derivation of 7Q2.

b. Raabe pointed out that the 7Q2 will continue to get bigger and bigger as cities grow and return flows increase if 7Q2 derivation is based on gaged streamflows.

c. Powell and Moss both note that agencies may not be receptive to 7Q2 values based on naturalized streamflows. Powell notes that the Consensus Criteria references published water quality standards as preferred to 7Q2 estimates.

d. Powell advised that some other states use 7Q2 values derived for each month rather than annual values as used in Texas.

5. Moss noted that the effects of daily river flow fluctuations associated with the operations of hydroelectric dams on the Guadalupe River may be difficult to assess with respect to biological and water availability issues. Hill advised that flows immediately below H-5 (Lake Wood) are typically 500 cfs, 1100 cfs, or 0 cfs.

6. Powell asked why HDR had decided to use QUAL-TX rather than QUAL-2E for the water quality modeling. Vaugh responded that decision was based primarily on consistency with TNRCC models previously developed and agreed to provide a brief memorandum clarifying the change for the record. HDR will provide a presentation on water quality modeling effort at Meeting #2.

7. Brinkmann asked what effluent loadings would be assumed for performance of sensitivity analyses. Group agreed that this item would be discussed during Meeting #2.

8. Vaugh advised that results of water quality sensitivity analyses will likely include curves relating flow, loading, and dissolved oxygen at several locations.

C. Refinement of Criteria for River Basins/Segments

1. Examples were provided illustrating the perceived need to refine the Consensus Criteria for regional planning in the Guadalupe - San Antonio River Basin. Key points included:

a. Naturalized annual 7Q2 exceeds the 25th percentile flow in several months at many locations on the Guadalupe River (including Spring Branch, Lake Dunlap, and Cuero) and on the San Marcos River @ Luling. This is due to the strong baseflow and springflow influences.

b. Naturalized annual 7Q2 exceeds the 25th percentile streamflow in only the driest summer months on the Medina River @ San Antonio and San Antonio River @ Falls City. This is most likely due to the comparison of an annual statistic (7Q2) to a monthly statistic (25th percentile streamflow).

2. Goodman discussed relationship between reaeration rate and streamflow used in the TNRCC model which results in improved reaeration as streamflows decrease. Johns notes that data from the San Antonio River was used in the development of such relationships generally applied in Texas streams (see paper by Karen Cleveland). HDR held reaeration rate constant in simulations to ensure "conservative" estimate of DO.
3. Goodman notes that the original San Antonio River water quality model was calibrated with the Rilling Road WWTP on line and that water quality has improved dramatically since the installation of Dos Rios WWTP and closure of Rilling Road WWTP.

B. Results of Application (Flow/DO Curves)
1. Goodman presented the results of water simulations in the form of streamflow / DO curves subject to the range of scenarios considered. Based on the relatively high quality discharge from the Dos Rios WWTP (permitted or observed), Goodman concluded that DO is not likely to be the limiting factor with respect to potential diversions from the San Antonio River.
2. In subsequent discussions, Davenport expressed concern about the essential absence of a minimum flow in some effluent-dominated streams (like the San Antonio River) and suggested that appropriate minimum streamflows in this situation should be set on the basis of biological data.

IV. Interpretive Assessment of Stream-Specific Studies

A. Studies on San Marcos and Guadalupe Rivers
1. Price provided discussion and summary of recently completed studies on the San Marcos River above Luling and less comprehensive studies on Guadalupe River near Victoria completed several years ago.
2. Price also provided a draft technical memorandum summarizing these studies and various conclusions or recommendations that might be drawn therefrom.

B. Preliminary Recommendations
1. Price presented some preliminary recommendations regarding appropriate streamflow minimums for various locations. These preliminary recommendations are based on the following assumptions:
   a. Macrohabitats in the Guadalupe River are similar to those in the San Marcos River above Luling; and
   b. Percentile streamflows adequate to protect habitat types on the San Marcos River are representative of streamflows adequate to protect habitat types on the Guadalupe River below Gonzales and, possibly, some locations on the San Antonio River where it is gravel bedded.
2. Observations and preliminary recommendations include the following:
   a. The lowest monthly median streamflow may be an appropriate minimum streamflow for Zone 1 in the lower Guadalupe River.

V. Identification of Pertinent Biological Studies (Zones 2 & 3)

>Discussed together.

VI. Identification of Pertinent Water Quality Studies (Zone 3)

A. Price presented preliminary list of potential references for pertinent information.

B. The following were also identified as potentially pertinent studies:
   1. Hill noted the IFIM studies conducted for the FERC license for hydropower at Canyon Dam.
   2. Hill noted the water quality modeling performed for the City of Victoria by Michael Sullivan & Assoc.
   3. Powell advised that the TWDB has draft studies for the Guadalupe River at Dunlap and Gonzales, some partial data regarding habitat utilization for the San Antonio River at Goliad, and additional studies for Sandies and Cibolo Creeks.
   4. Hill advised that GBRA is working with TNRCC and SWTSU collecting data for the Guadalupe River from New Braunfels down to H-5 (Lake Wood).

C. Raabe and Gonzales were not aware of any additional pertinent studies on the San Antonio River, but did advise that there will be more sampling in the lower portions of the river during 1998.

D. Hill suggested that the USGS NAWQA program might provide some useful information.

E. Powell noted that identification of limiting habitats is critical for these streams. Although two dimensional modeling can define physical habitat, there is still substantial judgment to be applied from that point. The North American Lake Management Society will be hosting a meeting focusing on instream flows in Houston on 12/2/97.

VII. Topics and Schedule for Future Meetings

A. Group agreed to hold 11/18/97 @ 1:30 PM @ SARA for Meeting #2 as several participants will likely be in San Antonio on other business during the morning of that date.

B. Group agreed that we should contact TNRCC regarding their absence from Meeting #1 and solicit their active participation in Meeting #2 as it will be somewhat focused on water quality modeling efforts.

Attendance:

TWDB - Gary Powell
SARA - Steve Raabe, Mike Gonzales
GBRA - Thomas Hill
PPA - Paul Price
TPWD - Cindy Loeffler, Randy Moss
SAWS - Mike Brinkmann
HDR - Sam Vaugh, Herb Grubb

APPENDIX F
VICTORIA THERMAL PLUME
STUDY RESULTS

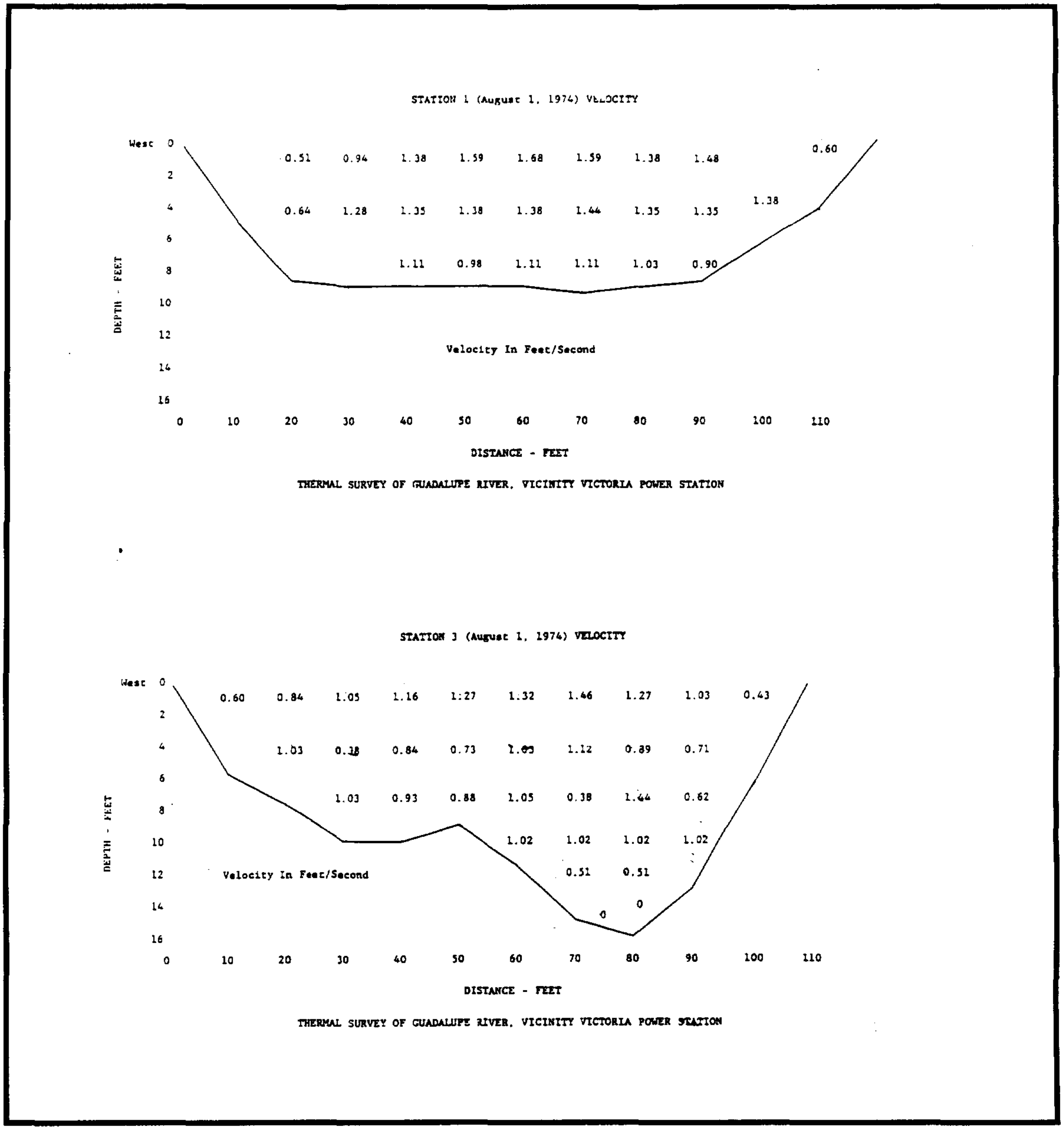
Observed Water Quality at Dos Rios WWTP in San Antonio

		Max. Daily Average			Daily Max.			Daily Min.
Year	Month	Discharge (MGD)	CBOD5 (mg/L)	NH3-N (mg/L)	Discharge (MGD)	CBOD5 (mg/L)	NH3-N (mg/L)	Dissolved Oxygen (mg/L)
Capacity of Plant Upgraded to 125 MGD from 83 MGD								
1995	8	60.490	2.0	0.13	68.400	2.0	0.34	7.1
1995	9	54.120	2.0	0.13	79.040	5.0	0.26	7.1
1995	10	55.210	2.0	0.13	59.430	4.0	0.32	7.1
1995	11	54.930	2.0	0.10	64.390	3.0	0.10	7.0
1995	12	53.760	2.0	0.10	56.270	2.0	0.14	7.0
1996	1	53.180	2.0	0.15	56.260	2.0	0.73	7.1
1996	2	54.680	2.0	0.18	59.500	2.0	0.44	7.4
1996	3	54.450	2.0	0.18	57.770	3.0	0.27	7.1
1996	4	54.370	2.0	0.16	58.190	3.0	0.23	6.7
1996	5	54.830	2.0	0.21	58.330	3.0	0.32	7.0
1996	6	55.470	2.0	0.18	61.100	4.0	0.62	6.9
1996	7	56.020	2.0	0.19	65.290	3.0	0.50	6.5
1996	8	54.950	2.0	0.25	60.000	6.0	0.56	6.5
1996	9	56.210	2.0	0.27	68.920	6.0	1.29	6.5
1996	10	54.050	2.0	0.20	65.000	3.0	0.28	6.8
1996	11	52.830	2.0	0.19	58.490	4.0	0.39	6.8
1996	12	53.080	2.0	0.17	57.940	3.0	0.25	7.1
1997	1	52.440	2.0	0.16	56.160	4.0	0.28	7.0
1997	2	53.630	2.0	0.16	66.690	2.0	0.22	7.0
1997	3	55.190	2.0	0.21	67.300	3.0	0.28	7.1
1997	4	60.060	2.0	0.19	93.920	2.0	0.28	7.0
1997	5	58.750	2.0	0.23	83.720	3.0	1.40	7.0
1997	6	66.650	2.0	0.14	121.800	3.0	0.25	7.1
1997	7	57.910	2.0	0.15	63.800	2.0	0.27	7.0
1997	8	56.240	2.0	0.17	59.0999	2.0	0.24	6.8
Annual Statistics								
Average		55.740	2.0	0.17	66.672	3.2	0.41	6.9
Max.		66.650	2.0	0.27	121.800	6.0	1.40	7.4
Min.		52.440	2.0	0.10	56.160	2.0	0.10	6.5
Summer Statistics								
Average		57.196	2.0	0.19	72.382	3.9	1.29	6.8
Max.		66.650	2.0	0.27	121.801	6.0	0.50	7.1
Min.		54.120	2.0	0.13	59.100	2.0	0.24	6.5

Source: monthly self-reporting data submitted by San Antonio Water System to TNRCC.

APPENDIX G
ENVIRONMENTAL CRITERIA SUBCOMMITTEE
MEETING NOTES

DELLJOBS\0239\FIG2.3-1.CDR\1-12-98



adapted from: Espey, Huston & Associates, Inc. 1975. Thermal Plume Studies Victoria Power Station. prepared for Central Power & Light Co., Corpus Christi, Texas. Espey, Huston & Associates, Inc. Doc. No. 7547. Austin, Texas.

Figure F-1

Victoria Thermal Plume Study Results
Technical Memorandum: Environmental Water Needs Criteria for Major Rivers in the Trans-Texas West Central Study Area

Paul Price Associates, Inc.

ECOLOGY, WATER QUALITY, CULTURAL RESOURCES, PLANNING

DELLJOBS\0239\FIG2.3-1.CDR\1-12-98

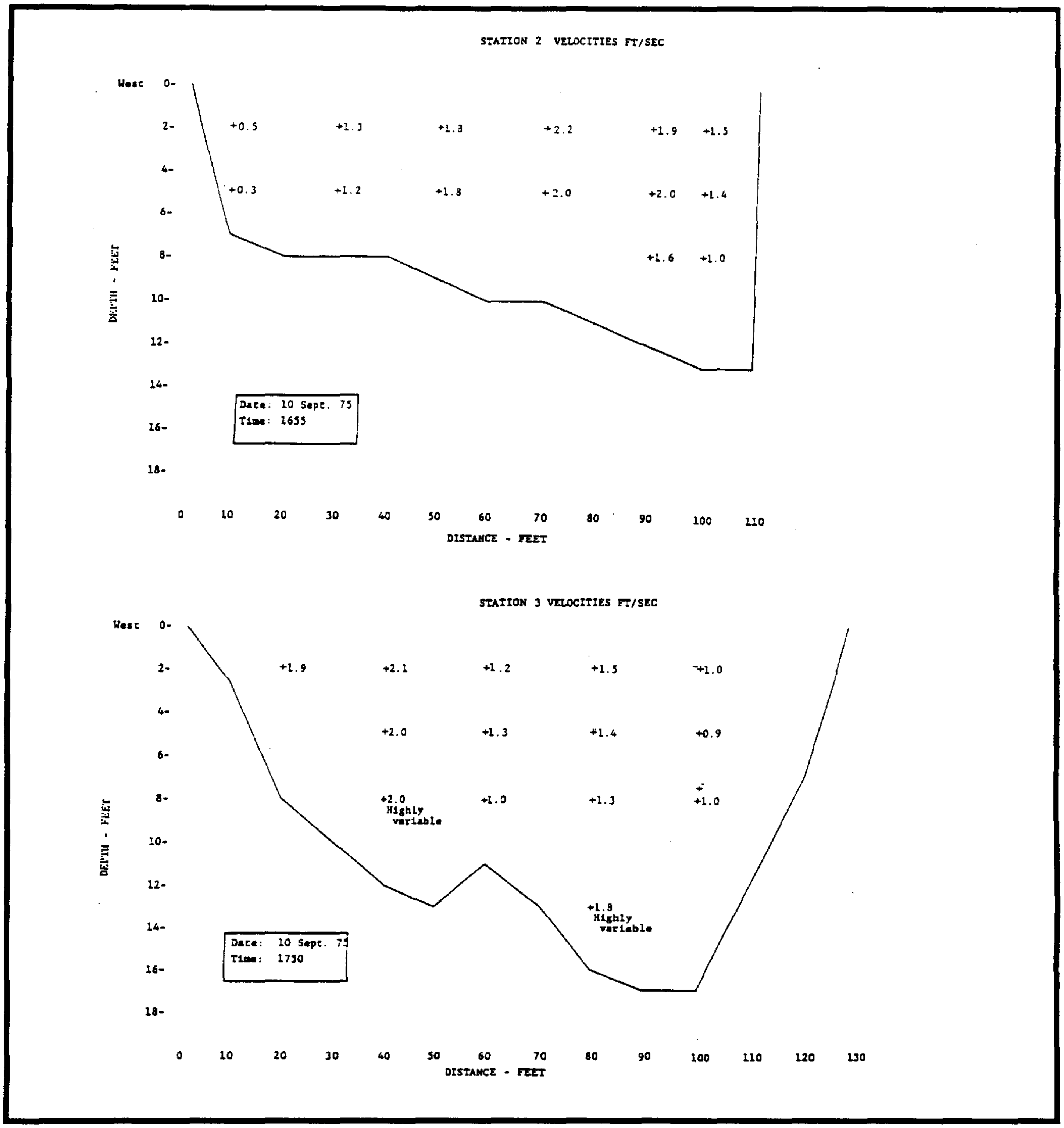


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Figure F-2

Victoria Thermal Plume Study Results
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