7.0 Dissolved Oxygen

7.1 Summary

The Abiquiu Creek watershed is approximately 45 square miles. The main stem of Abiquiu Creek, from the mouth on Rio Chama to its headwaters, is approximately 12.93 miles long and a major tributary, Vallecitos Creek, is 5.7 miles in length. During the 1999 SWQB sampling monitoring effort in the Lower Rio Chama watershed, dissolved oxygen (DO) data showed several violations of the New Mexico water quality standard in Abiquiu Creek (see Table 7.1 a). Data were also collected on July 24–25, 2002 using a data sonde (see Table 7.1 b for the statistical data summary and Appendix G for the complete data set). Abiquiu Creek is listed on the 2002-2004 CWA Integrated §303(d)/§305(b) list with dissolved oxygen as a pollutant of concern.

Table 7.1 (a). Results of Dissolved Oxygen Monitoring on Abiquiu Creek at Highway 84 from 1999 Grab Samples

Date	DO (mg/L)	Flow (cfs)
4/19/99	7.1	---
4/20/99	9.0	0.51
4/21/99	7.4	---
4/22/99	7.9	---
7/27/99	**5.0**	---
7/28/99	**3.8**	0.18
9/24/99	8.8	---
10/05/99	6.4	0.251
10/6/99	6.7	---

Bolded values violate the DO standard of 6.0 mg/L.

Table 7.1 (b). Summary Table Results of Dissolved Oxygen Monitoring on Abiquiu Creek from 2002 Data Sonde

```
                    ABIQUIU CREEK
                  -- Statistical Report --
============================================================
>From 07/24/02 17:00 to 07/25/02 05:15
Number of samples: 50
------------------------------------------------------------
Parameter                 Min       Max      Mean       Std
------------------------------------------------------------
Temp (C)                16.71     23.69     19.19      1.67
SpCond (mS/cm)          0.201     0.247     0.217     0.015
DO Conc (mg/L)           2.47      6.66      5.40      1.27
pH ()                    7.93      8.40      8.10      0.12
DO percent (percent)     26.5      78.6      58.5      14.2
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The initial step in selecting the appropriate analytical tool for this analysis was to perform an analysis to correlate the impairment to basic causes such as nonpoint contributions,

flow conditions, stream and watershed characteristics, seasonal temperature effects, and others. The analysis revealed that the impairment coincides with low flows, slow stream velocities, and shallow water depths.

The steady-state QUAL2E model was selected for the following reasons:

- The critical low flow condition can be reasonably assumed to be steady state.
- The model conforms to the standard practices for developing wasteload allocations.
- It can be developed with a limited data set.
- It can handle branching tributaries.
- It has an established history in modeling dissolved oxygen for TMDLs.

Model Framework

QUAL2E is a comprehensive water quality model developed under a cooperative agreement between Tufts University's Department of Civil Engineering and U.S. EPA's Center for Water Quality Modeling, Environmental Research Laboratory, Athens, Georgia, in the late 1970s. It has been used nationwide and is supported by USEPA. The mass transport processes are described by the one-dimensional finite difference advection-dispersion mass transport equation that includes the effects of advection, dispersion, dilution, constituent reactions and interactions, and sources and sinks.

The model is a steady-state daily average model that uses a modified Streeter-Phelps DO equation. The Streeter-Phelps equation ties together two mechanisms governing DO in a stream: decomposition of organic material and oxygen reaeration. The QUAL2E model simulates ultimate carbonaceous biochemical oxygen demand (CBODu) decay, nitrification, and reaeration. Although the model can simulate algal photosynthesis and respiration, they were omitted for this application because data on and knowledge of algal growth in Abiquiu Creek were not available. An algal assay, done as part of the nutrient assessment and completed on July 24, 2002, by SWQB staff, showed only moderate productivity and did not indicate a nutrient impairment in this reach. Reaction rates for the in-stream processes are input by the user and corrected for temperature by the model. The model output includes water quality conditions in each computational element for DO, CBODu, and ammonia nitrogen (NH_3-N) concentrations. Refer to the users manual document for a more detailed discussion of simulated processes and model parameters (Brown and Barnwell 1987).

Model Configuration

Model configuration involved setting up the model computational grid and setting initial conditions, boundary conditions, and hydraulic and kinetic parameters for the hydrodynamic and water quality simulation. This section describes the configuration and key components of the model.

Computational Grid Setup

The model of Abiquiu Creek includes the CWA Integrated §303(d)/§305(b) listed portion (mainstem) from its headwaters to the Rio Chama, and Vallecitos Creek. Vallecitos Creek is not listed for DO impairment, but it carries flow from a large portion of the watershed, approximately 28.5 square miles, and merges with the mainstem at 3.3 miles from the mouth. The creek was divided into sections called reaches to provide hydrologic ordering of the stream. These reaches begin or end where changes occur in the hydrology of the waterbody in order to maintain hydrologic connectivity. River miles were assigned to the waterbody, beginning with zero at the mouth. Within each reach, the modeled segments were divided into computational elements of 0.3 mile. The hydrologic and water quality characteristics were calculated by the model for each computational element. Figure 7.1 is a representation of the model domain.

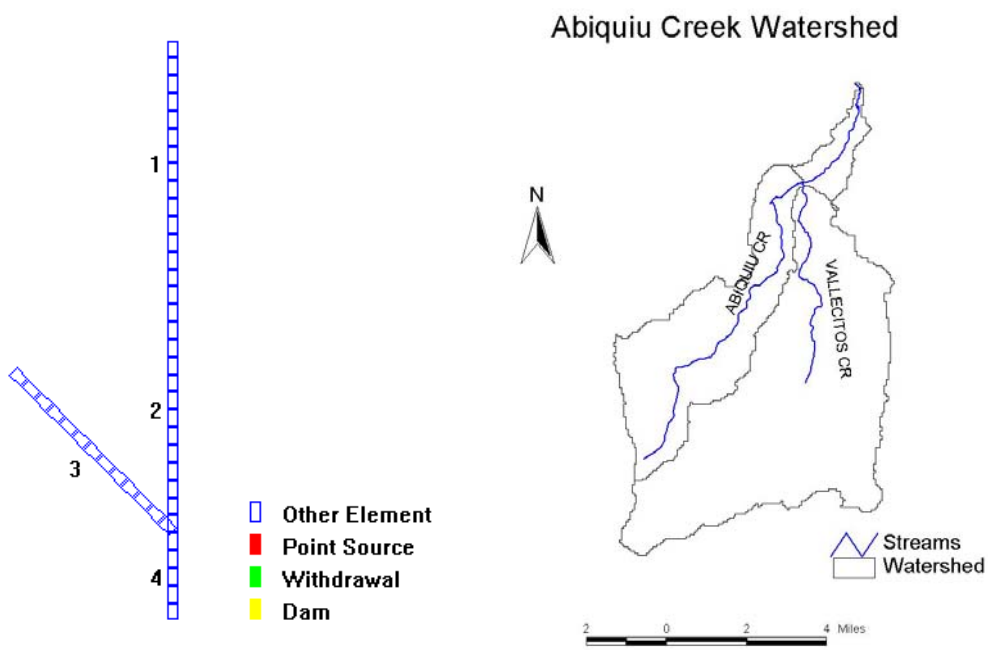

Figure 7.1. Computational Grid and Location Map of Abiquiu Creek and Tributary

7.2 Endpoint Identification

Target Loading Capacity

The target values for dissolved oxygen TMDLs are determined based on (1) the presence of numeric criteria, (2) the degree of experience in applying the indicator and (3) the ability to easily monitor and produce quantifiable and reproducible results. For this TMDL document, target values for dissolved oxygen are based on numeric criteria.

Dissolved Oxygen

Abiquiu Creek falls into the standard segment defined in 20.6.4.116 NMAC (formerly 2113), which reads:

> The Rio Chama from its mouth on the Rio Grande upstream to Abiquiu reservoir, the Rio Tusas, the Rio Ojo Caliente, Abiquiu Creek, and El Rito Creek below the town of El Rito.

According to the State's standard, this creek has the designated uses of irrigation, livestock watering, wildlife habitat, coldwater fishery, warmwater fishery, and secondary contact (20.6.4.116 NMAC). The numeric criteria for DO to meet the designated use of a coldwater fishery is that "DO shall not be less than 6.0 mg/L" (20.6.4.900 NMAC).

Many factors influence DO concentrations, including

- Input and oxidation of carbonaceous material (CBODu)
- Input and oxidation of nitrogenous material (NBODu)
- Input and oxygen demand of sediments in the waterbody (SOD)
- Reaeration

The pollutant of concern is biochemical oxygen demand, both carbonaceous (CBODu) and nitrogenous (NBODu), which is expressed in terms of total ultimate biochemical oxygen demand (TBODu). The equation below shows this relationship. The TMDL will be expressed in terms of TBODu, based on the waterbody's assimilative capacity for oxygen-demanding substances.

$$\text{TBODu} = \text{CBODu} + \text{NBODu}$$

Where:

$$\text{5-day CBOD} * 2.54 = \text{CBODu}$$
$$\text{Total Kjedahl Nitrogen} * 4.57 = \text{NBODu}$$

Over the time scale of years, stream bottom sediments act as sinks for oxygen, with carbon and nitrogen removed from the water column (Chapra 1997, Thomann and Mueller 1987). Oxygen is consumed by the oxidation of organic carbon (CBODu) and by the nitrification of ammonia (NBODu) in the bottom sediment. This process is known as sediment oxygen demand (SOD). The role of sediments in the system-wide nutrient budget is especially important during the summer when seasonal low flows diminish tributary nutrient loads. During the summer, warm temperatures enhance biological processes in the sediments (USEPA 1993).

Oxygen-consuming constituents from nonpoint source pollution are delivered to the stream during storm events. Sources can include runoff from fields and leaf litter or plant material from riparian zones. These constituents settle out of the stormwater and become a part of the stream bottom. In slow flowing streams with a high bed-to-channel-volume

ratio, large portions of the organic material will settle to the sediment surface and thus increase the SOD. Washoff of settable material (CBODu and NBODu) accumulates and exerts an additional SOD attributable to land-disturbing activities. A stream impacted by heavy loads of oxygen-consuming pollutants, either natural or man-made, will exhibit low DO concentrations during warm low flow periods (Wood 2001; Thomann et al. 1994, Thomann and Mueller 1987, Congalton 1998, and Chapra 1997).

There have been numerous studies for establishing a SOD/TBODu relationship. According to the Streeter-Phelps SOD model, SOD is approximately 130 percent of the downward flux of TBODu (Chapra, 1997) and the TMDL will employ the following relationship to link TBODu and SOD.

SOD = 1.3 * TBODu

Model Parameters

The DO impairment was identified and listed based on the field data collected in 1999. The data were collected at a downstream location (at US 84 highway bridge), 0.3 mile from the river mouth. Among the observed three seasons, spring, summer, and fall, the DO impairment was observed only in the summer under a low flow condition. Since a stream is affected by heavy loads of oxygen-consuming pollutants, either natural or man-made, it will exhibit low DO concentrations during warm low flow periods due to high SOD, the critical condition for this TMDL was selected a summer low flow condition. During thermograph deployment on June 10, 2002, no measurable flow was recorded in Abiquiu Creek. There is no long-term data to represent the critical condition for Abiquiu Creek. In the absence of this data, the observed low flow condition on 07/28/99 was therefore assumed to be representative of critical conditions in the creek during the summer low-flow period. Best professional judgments were made to set the initial conditions for 5-day CBOD and groundwater DO concentration, in which no observed data are available.

<u>Initial conditions based on observations from Abiquiu Creek</u>

- Model temperature was set to 21.7 ºC as observed on 07/28/99.
- Dissolved oxygen was set to 90 percent saturation (6.3 mg/L) for inflow based on the observed temperature and elevation of Abiquiu Creek.
- The observed low flow of 0.18 cfs on 07/28/99 was set as the critical stream flow. Based on the critical stream flow, 0.004 cfs/sq.mile (per area flow) was used to estimate the low flow in the reaches and tributary. The flow was distributed by area over the watershed.
- Instream Organic-N, NH_3-N, and NO_2-N were set to 0.2 mg/L, 0.1 mg/L, and 0.1 mg/L, respectively as observed on 07/28/99.

<u>Initial conditions based on best professional judgment</u>

- Ultimate Carbonaceous Oxygen Demand (CBODu) was assumed as 2.0 mg/L based on USGS observations of 5-day CBOD in Rio Chama on 6/3/1969 at 14:30 (USGS 8286500). Abiquiu Creek is a tributary of the Lower Rio Chama and the above-mentioned conditions were observed near the confluence of Abiquiu Creek with the

Rio Chama. The observations at Rio Chama (USGS 8286500) are at observed an altitude within 1000' of the main stem Abiquiu Creek. Lower Chama has no point sources. Therefore, the 5-day CBOD in Rio Chama reasonably represents the initial condition of Abiquiu Creek, where the primary source of impairment is non-point sources.

- Abiquiu Creek is a sandy stream (lots of fines), and the oxygen replenishment in the interstitial places is very limited. In general, the groundwater entering the stream at this condition has a low concentration of DO (EPA 1991). Therefore, one can assume that the Abiquiu Creek has low DO concentration. As a conservative assumption, the DO of groundwater was assumed to be 2.0 mg/L.

Saturation DO is sensitive to elevation or atmospheric pressure and temperature. The QUAL2E model estimates the saturation DO based on the atmospheric pressure. The average elevation of Abiquiu Creek is approximately 6,500 feet. By comparing the historical July atmospheric pressure of adjacent climate records from Albuquerque International Airport (5,300 feet and 24.8 in inches of mercury), Farmington Four Corners (5,500 feet and& 24.6 in inches of mercury), and Alamosa San Luis Valley (7,500 feet and 23 in inches of mercury), the model atmospheric pressure was set to 24 in inches of mercury.

Coefficients are needed to describe the water quality reaction rates within the stream. Initial estimates were obtained from QUAL2E default values, general literature values (USEPA 1985), and from the QUAL2E user's manual (Brown and Barnwell 1987). Water quality coefficients are presented in Table 7.2.

Table 7.2. Water Quality Calibration Rates and Coefficients

Parameter	Description	Units	Value
K1	Carbonaceous Biochemical Oxygen Deoxygenation Rate	1/day	0.1
CKNH2	Organic Nitrogen Hydrolysis	1/day	0.1
CKNH3	Ammonia Oxidation Rate	1/day	0.25
CKNO2	Nitrite Oxidation Rate	1/day	2.5

Channel hydraulics, reaeration rate, and SOD substantially influence the concentration of DO in the streams. Due to the lack of data for these parameters, the following assumptions were made:

- Based on field observation, the channel profile was assumed to be a parabolic.
- In sandy bottom streams, SOD values range from 0.2 to 1 g $m^{-2}d^{-1}$(Chapra 1997).)As Abiquiu creek is a sandy stream, the baseline (existing) SOD rate was set to 0.08 grams per square feet per day (0.86g $m^{-2}d^{-1}$).
- The reaeration rate is either set by the user or by formulas available in QUAL2E. As reported by USEPA (1985), many empirical formulas which estimate reaeration rate based on hydraulic parameters and/or flow work well within the depth range of 1 to 10 feet. The flow depth is less than 1 foot in Abiquiu Creek. Therefore, the reaeration coefficient was used as a calibration parameter of the Abiquiu DO model.

Assumptions

- No surface runoff driven nonpoint loadings are entering the stream during the low flow summer condition.
- The main cause of low DO during low flow is attributable to the SOD.
- A detailed assessment of channel geometry was not performed; therefore, stream velocities and channel depths were approximated.

It is important to remember that the TMDL is a planning tool to be used to achieve water quality standards. Since flows vary throughout the year in these systems at water quality standards the target load will vary based on the changing flow. Management of the load should set a goal attainment, not meeting the calculated target load.

Waste Load Allocations and Load Allocations

• *Waste Load Allocation*

There are no point source contributions associated with this TMDL. The waste load allocation is therefore zero.

• *Load Allocation*

The load allocation was determined using the QUAL2E model.

Model Results

Calibration was an iterative process. The model reaeration rate was adjusted until the model predictions fit the DO observation. In-stream DO data were collected at the US Highway 84 bridge, which is approximately 0.3 mile from the mouth. Although the analysis focused on the entire 12.93 miles, the calibration was limited to observation at 0.3 mile. Figure 7.2 shows the longitudinal change in DO for the calibration low flow condition. The figure also shows the flow at each element. The changes in DO at river miles 7.5 and 3.3 are associated with the inflow from the drainage area reach number 2 and the tributary flow, respectively.

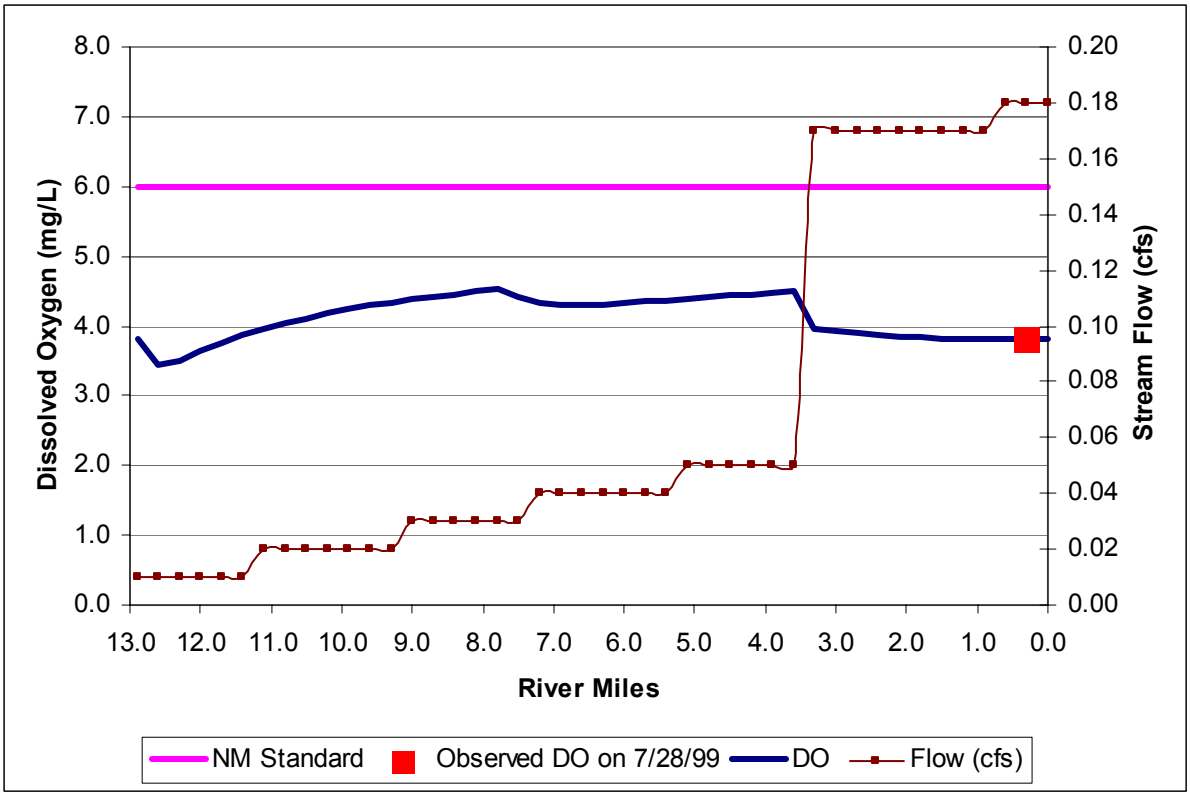

Figure 7.2. Model-predicted DO for Existing Critical Conditions of the Abiquiu Creek

The calibration or baseline model run reflects the summertime low flow condition of Abiquiu Creek. The baseline condition model was run adjusting the SOD (while keeping the rest of the calibrated parameters the same), to bring the in-stream average DO concentration up to or above 6.0 mg/L (representing the state standard). This involved an iterative process to determine the SOD rate that would not violate water quality standards for DO (Figure 7.3).

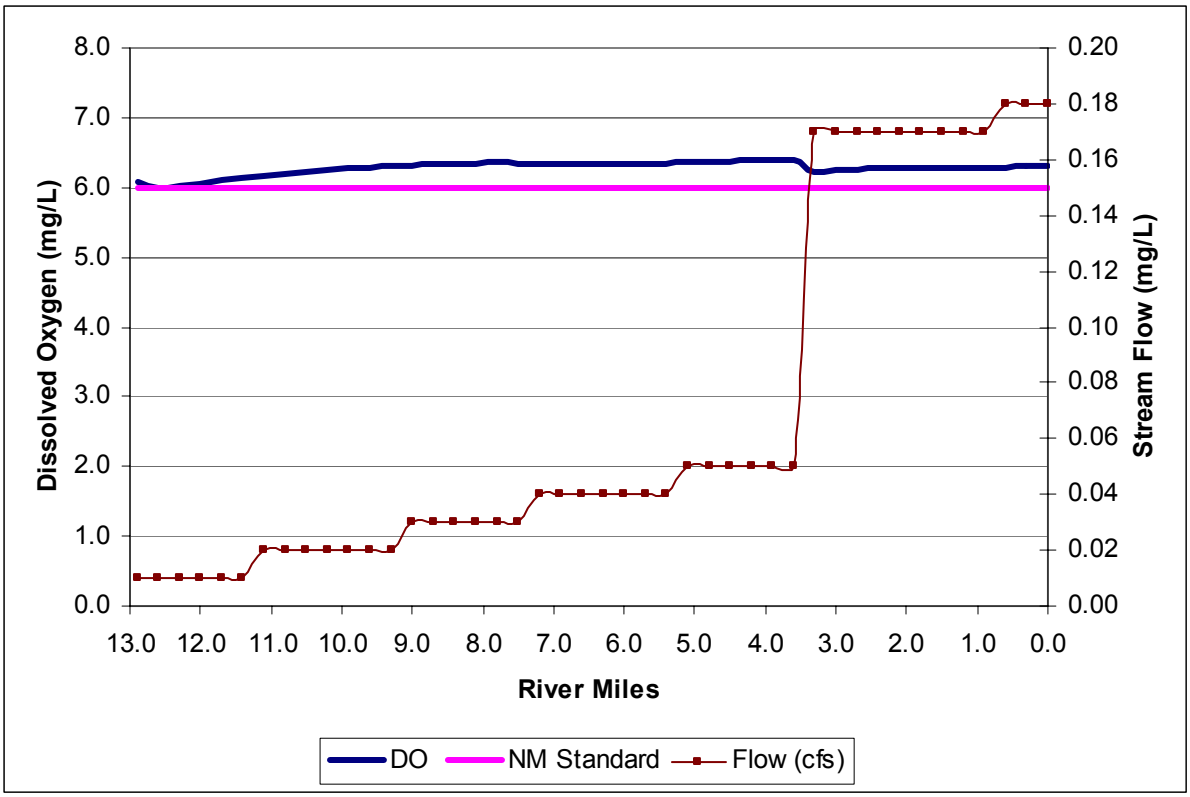

Figure 7.3 Model-predicted DO Concentrations in the Abiquiu Creek with for the TMDL scenario.

TMDL Scenario
SOD at which the DO will meet the standard is 0.015 g/ft^{2}day. It is equivalent to 0.012 g/ft^{2}day TBODu based on the Streeter-Phelps SOD model.

Identification and Description of pollutant source(s)

Potential pollutant sources are listed for the segment in Table 7.3.

Table 7.3. Pollutant Source Summary for Dissolved Oxygen

Pollutant Sources (percent from each)	**Magnitude** (Load Allocation + MOS)	**Location**	**Potential Sources**
Point: None (0 percent)	0		None
Nonpoint: (100 percent) Dissolved oxygen As SOD As TBODu	 0.015 g/ft^{2}day 0.012 g/ft^{2}day	Abiquiu Creek	Land Disposal, Rangeland, Hydromodification, Removal of Riparian Vegetation, Streambank Modification/Destabilization, and Road Maintenance or Runoff

Linkage Between Water Quality and Pollutant Sources

When available data are incomplete or the level of uncertainty in the characterization of sources is high, the recommended approach to TMDL assignments requires the development of allocations based on estimates using the best available information.

SWQB fieldwork includes an assessment of the potential sources of impairment (SWQB/NMED 1999). The Pollutant Source(s) Documentation Protocol form and Potential Sources Summary Table in Appendix C provide documentation of a visual analysis of probable sources along an impaired reach. Although this procedure is subjective, SWQB feels that it provides the best available information for the identification of potential sources of impairment in this watershed. Table 7.3 (Pollutant Source Summary) identifies and quantifies potential sources of nonpoint source impairments along each reach as determined by field reconnaissance and assessment. It is important to consider not only the land directly adjacent to the stream, which is predominantly State and privately managed land, but also the upland and upstream areas in a more holistic watershed approach to implementing this TMDL.

Abiquiu Creek

The primary sources of DO impairment in Abiquiu Creek are rangeland, land disposal (on-site wastewater systems), hydromodification (channelization), removal of riparian vegetation, streambank modification/destabilization, and road maintenance or runoff. Field notes indicate that this creek goes dry in places during the year. Upstream activities, such as grazing, confined feeding operations, natural springs, residential area runoff and wastewater systems, and the highway 84 bridge, may be contributing to the DO impairment. There is a healthy riparian area along the reach.

The above-mentioned watershed activities increase nutrient rich and organic enriched substances in the stream. It results in high SOD and low DO. Reduction/control in watershed activities associated to nutrient rich and organic enriched substances will result in lower SOD and higher DO.

7.3 Margin of Safety (MOS)

The MOS is one of the required elements of a TMDL. There are two basic methods for incorporating the MOS (USEPA, 1991):

- Implicitly incorporate the MOS using conservative model assumptions to develop allocations.
- Explicitly specify a portion of the total TMDL as the MOS; use the remainder for allocations.

The margin of safety for this TMDL was expressed implicitly through implicit conservative assumptions that provide a margin of safety. Specific conservative assumptions include:

For the TMDL analysis, the temperature was kept the same as for the existing condition (21.7 ^{o}C). TMDL implementation may include such activities as planting riparian vegetation that serves to increase shade and decrease in-stream temperature. These activities will result in increased DO saturation concentration due to an increased the ability to absorb more oxygen from the atmosphere. This approach results in SOD reduction being the primary factor to meet the DO standard in the TMDL scenario and thus potentially a large load reduction than it ultimately necessary. In sandy bottom streams, SOD values range from 0.2 to 1 g $m^{-2}d^{-1}$(Chapra 1997). For the current critical condition, the SOD rate was set to 0.86 g $m^{-2}d^{-1}$, close to the high end of the range.

7.4 Consideration of Seasonal Variation

Data used in the calculation of this TMDL were collected during the spring, summer, fall of 1999, and summer of 2002 in order to ensure coverage of any potential seasonal variation in the system. Critical conditions were set to low-flow for dissolved oxygen since data violations were measured during low summer flows. A flow measurement taken during the 1999 summer sampling run was used in the calculations.

7.5 Future Growth

Estimates of future growth do not indicate a significant decrease of DO that cannot be controlled with BMP implementation in this watershed.