3.0 TURBIDITY

3.1 Summary

During the SWQB 1998 intensive water quality survey in the Upper Rio Chama Watershed, several exceedences of the New Mexico water quality standard for turbidity were documented at the lower sampling station on Rito de Tierra Amarilla (SWQB Station 16). Consequently, the Rito de Tierra Amarilla from Rio Chama to State Highway 64 was listed on the 2000-2002 Clean Water Act §303(d) list for turbidity.

3.2 Endpoint Identification

Target Loading Capacity

Target values for this turbidity TMDL will be 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 turbidity are based on numeric criteria. This TMDL is also consistent with New Mexico's antidegradation policy.

According to the New Mexico Water Quality Standards (20.6.4 NMAC), the general narrative standard for turbidity reads:

> Turbidity attributable to other than natural causes shall not reduce light transmission to the point that the normal growth, function, or reproduction of aquatic life is impaired or that will cause substantial visible contrast with the natural appearance of the water.

The state's standard leading to an assessment of use impairment is the numeric criteria for turbidity of 25 NTU for this specific High Quality Coldwater Fishery (HQCWF).

The total suspended solids (TSS) analytical method is a commonly used measurement of suspended material in surface water. This method was originally developed for use on wastewater samples, but has widely been used as a measure of suspended materials in stream samples because it is acceptable for regulatory purposes and is an inexpensive laboratory procedure. Since there are no wastewater treatment plants discharging into Rito de Tierra Amarilla, it is assumed that TSS measurements in these ambient stream samples are representative of erosional activities and thus comprised primarily of suspended sediment vs. any potential biosolids from wastewater treatment plant effluent.

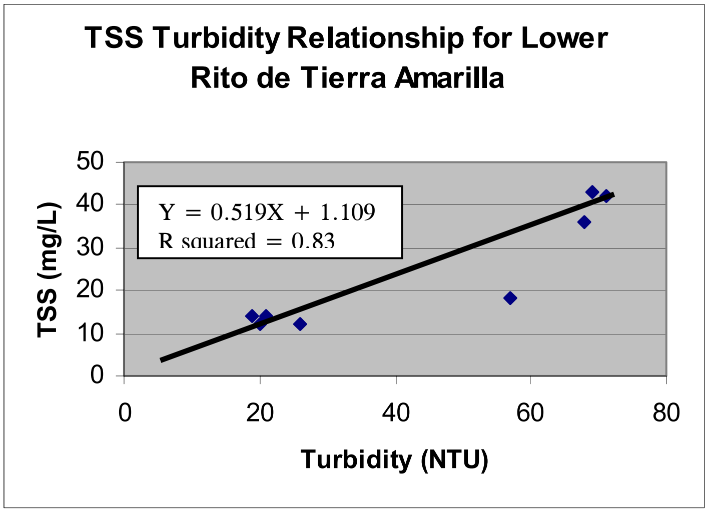
Turbidity levels can be inferred from studies that monitor suspended sediment concentrations. Extrapolation from these studies is possible when a site-specific relationship between concentrations of suspended sediments and turbidity is confirmed. Activities that generate varying amounts of suspended sediment will proportionally change or affect turbidity (USEPA 1991). The impacts of suspended sediment and turbidity are well documented in the literature. An increased sediment load is often the most important adverse effect of activities on streams, according to a monitoring guidelines report (USEPA 1991). This impact is largely a mechanical action that severely reduces the available habitat for macroinvertebrates and fish species that utilize the streambed in various life stages. An increase in suspended sediment concentration will reduce the penetration of light, decreases the ability of fish or fingerlings to capture prey, and reduce primary production (USEPA 1991). Specifically, increased turbidity by sediments can reduce stream primary production by reducing photosynthesis, physically abrading algae and other plants, and preventing attachment of autotrouphs to substrate surfaces (Van Nieuwenhuyse and LaPierre 1986, Brookes 1986).

At the lower sampling station on Rito de Tierra Amarilla, TSS and turbidity were measured during the 1998 survey (Table 3.1). The TSS target was derived using a regression equation developed using measured turbidity as the independent variable and measured TSS dependent variable. The equation and regression statistics are displayed below in Figure 3.1. A correlation (R^2=0.83) was found between TSS and turbidity for Rito de Tierra Amarilla.

Table 3.1 TSS and turbidity data from Rito de Tierra Amarilla at State Highway 112

Sample Date	TSS (mg/L)	Turbidity (NTU)
980601	14	19
980602	12	26*
980603	14	21
980604	12	20
980818	36	68*
980819	18	57*
981020	43	69*
981021	42	71*

* Exceedence of 25 NTU water quality criterion. Arithmetic mean of TSS values when measured turbidity exceeded the standard = 30.2 mg/L



SUMMARY OUTPUT	
Regression Statistics	
Multiple R	0.909114987
R Square	0.82649006
Adjusted R Square	0.797571736
Standard Error	6.254828273
Observations	8

Figure 3.1 Relationship between TSS and Turbidity at Rito de Tierra Amarilla

Flow

Sediment transport in a stream varies as a function of flow. As flow increases, the amount of sediment being transported increases. This TMDL is calculated for each reach at a specific flow. When available, US Geologic Survey gages are used to estimate flow. Where gages are absent, geomorphologic cross sectional information is taken at each site and the flows are modeled. Gaged streamflow data are not available for Rito de Tierra Amarilla. Cross sectional data was taken in order to estimate stream discharge using procedures from USGS Technical Paper 2193 (USGS 1982).

For perennial streams in areas with alpine regional-runoff characteristics and silt-clay or armored channel material characteristics, average annual discharge is calculated using the following regression equation (USGS 1982):

$Q_A = 64W_{ac}^{\ 1.88}$
Where Q_A = acre-feet/year and W_{ac} = width of the active channel (i.e., width at bankfull) in feet.

According to cross-section field data (see Appendix A), the width of Rito de Tierra at bankfull is 19.15 feet. Therefore,

RITO DE TIERRA AMARILLA --
$Q_A = 64W_{ac}^{\ 1.88} = 64\ (19.15\ \text{ft})^{1.88} = 16{,}468$ acre-feet/year
Q_A = 16,468 acre-feet/year (1 year/365 day) (1 day/86,400 sec) (43,560 ft3/acre-feet)
Q_A = 22.7 cfs

Q_A = 22.7 cfs (1 cfs/1.5473 mgd)
Q_A = 14.7 mgd

Average discharge is defined as that flow rate which would yield the observed annual volume of water if continued every day of the year. The average discharge usually fills a channel to approximately one-third of the channel depth and this flow rate is equaled or exceeded approximately 25% of the days in any given year (Leopold et al. 1964). Therefore, approximately 75% of the time, flows are less than then average discharge. The cross section of the channel and adjacent floodplain is key to predict velocity and water surface stage elevation during high and low flow events. 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 the target load will vary based on the changing flow. Management of the load should set a goal at water quality standards attainment versus meeting the calculated target load.

Calculations

Target loads for turbidity (expressed as TSS) are calculated based on a flow, the current water quality standards, and a conversion factor (8.34) that is a used to convert mg/L units to lbs/day (see Appendix B for Conversion Factor Derivation). The target loading capacity is calculated using Equation 1. The results are shown in Table 3.2.

Equation 1. critical flow (mgd) x standard (mg/L) x 8.34 (conversion factor) = target loading capacity

Table 3.2 Calculation of target loads for turbidity (expressed as TSS)

Location	Flow+ (mgd)	TSS* (mg/L)	Conversion Factor	Target Load Capacity (lbs/day)
Rito de Tierra Amarilla	14.7	14.1	8.34	1728.6

+ Since USGS gages were unavailable, flows are modeled using cross-sectional field data in order to estimate average stream discharge using USGS technical paper 2193 (USGS 1982).
*The TSS value was calculated using the relationship established between TSS and turbidity in Figure 3.1 (Y=0.519X + 1.109, R^2=0.83) using the turbidity standard of 25 NTU for the X variable.

The measured loads for turbidity (expressed as TSS) were similarly calculated. In order to achieve comparability between the target and measured loads, the flows used were the same for both calculations. The arithmetic mean of corresponding TSS values when turbidity exceeded the standard was substituted for the standard in Equation 1. The same conversion factor of 8.34 was used. Results are presented in Table 3.3.

Table 3.3 Calculation of measured loads for turbidity (expressed as TSS)

Location	Flow+ (mgd)	TSS Arithmetic Mean * (mg/L)	Conversion Factor	Measured Load Capacity (lbs/day)
Rito de Tierra Amarilla	14.7	30.2	8.34	3702.5

+ Since USGS gages were unavailable, flows are modeled using cross-sectional field data in order to estimate average stream discharge using USGS technical paper 2193 (USGS 1982).
* Arithmetic mean of TSS values when measured turbidity exceeded the standard (see Table 3.1).

Waste Load Allocations and Load Allocations

•*Waste Load Allocation*
There are no point source contributions associated with this TMDL. The waste load allocation (WLA) is zero.

•Load Allocation

In order to calculate the Load Allocation (LA), the WLA and margin of safety (MOS) were subtracted from the target capacity (TMDL) following Equation 2.

Equation 2. $WLA + LA + MOS = TMDL$

The MOS is estimated to be 25% of the target load calculated in Table 3.2. Results are presented in Table 3.4. Additional details on the MOS chosen are presented in section 3.3 below.

Table 3.4 Calculation of TMDL for turbidity

Location	WLA (lbs/day)	LA (lbs/day)	MOS (25%) (lbs/day)	TMDL (lbs/day)
Rito de Tierra Amarilla	0	1296.4	432.2	1728.6

The extensive data collection and analyses necessary to determine background turbidity loads for the Rito de Tierra Amarilla watershed was beyond the resources available for this study. It is therefore assumed that a portion of the load allocation is made up of natural background loads.

The load reductions that would be necessary to meet the target loads were calculated to be the difference between the target load allocation (Table 3.2) and the measured load (Table 3.3), and are shown in Table 3.5.

Table 3.5 Calculation of load reduction for turbidity (expressed as TSS)

Location	Load Allocation (lbs/day)	Measured Load (lbs/day)	Load Reduction (lb/day)
Rito de Tierra Amarilla	1296.4	3702.5	2406.1

Identification and Description of pollutant source(s)

Pollutant sources that could contribute to each segment are listed in Table 3.6.

Table 3.6 Pollutant source summary for turbidity

Pollutant Sources	**Magnitude** (Load Allocation + MOS)	**Location**	**Potential Sources** (% from each)
Point: None	0	--------	0%
Nonpoint: Turbidity (expressed as TSS in lbs/day)		Rito de Tierra Amarilla	100% Range Grazing -- Riparian or Upland, Removal of Riparian Vegetation Road Maintenance and Runoff Flow Regulation/Modification Agriculture

Linkage of Water Quality and Pollutant Sources

Turbidity is an expression of the optical property in water that causes incident light to be scattered of absorbed rather than transmitted in straight lines. It is the condition resulting from suspended solids in the water, including silts, clays, and plankton. Such particles absorb heat in the sunlight, thus raising water temperature, which in turn lowers dissolved oxygen levels. It also prevents sunlight from reaching plants below the surface. This decreases the rate of photosynthesis, so less oxygen is produced by plants. Turbidity may harm fish and their larvae. Turbidity exceedences, historically, are generally attributable to soil erosion, excess nutrients, various wastes and pollutants, and the stirring of sediments up into the water column during high flow events. Turbidity increases, as observed in SWQB monitoring data, show turbidity values along this reach that exceed the State Standards for the protection of aquatic habitat, namely the high quality cold water fishery (HQCWF) designed use. Through monitoring, and pollutant source documentation, it has been observed that the most probable cause for these exceedences are due to the alteration of the stream's hydrograph and grazing impacts. Alterations can be historical or current in nature.

The components of a watershed continually change through natural ecological processes such as vegetation succession, erosion, and evolution of stream channels. Intrusive human activity often affects watershed function in ways that are inconsistent with the natural balance. These changes, often rapid and sometimes irreversible, occur when people:

- cut forests
- clear and cultivate land
- remove stream-side vegetation
- alter the drainage of the land
- channelize watercourses
- withdraw water for irrigation
- build towns and cities
- discharge pollutants into waterways.

Possible effects of these practices on aquatic ecosystems include:

1. Increased amount of sediment carried into water by soil erosion which may

    - increase turbidity of the water
    - reduce transmission of sunlight needed for photosynthesis
    - interfere with animal behaviors dependent on sight (foraging, mating, and escape from predators)
    - impede respiration (e.g., by gill abrasion in fish) and digestion
    - reduce oxygen in the water

- cover bottom gravel and degrade spawning habitat cover eggs, which may suffocate or develop abnormally; fry may be unable to emerge from the buried gravel bed

2. Clearing of trees and shrubs from shorelines which may

    - destabilize banks and promote erosion
    - increase sedimentation and turbidity
    - reduce shade and increase water temperature which could disrupt fish metabolism
    - cause channels to widen and become more shallow

3. Land clearing, constructing drainage ditches, straightening natural water channels which may

    - create an obstacle to upstream movement of fish and suspend more sediment in the water due to increased flow
    - strand fish upstream and dry out recently spawned eggs due to subsequent low flows
    - reduce baseflows

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

SWQB fieldwork includes an assessment of the potential sources of impairment (SWQB/NMED 1999c). The completed Pollutant Source(s) Documentation Protocol forms 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 3.6 (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 privately held, but also to consider upland and upstream areas in a more holistic watershed approach to implementing this TMDL.

The primary sources of impairment for this reach identified in the state 303(d) list are range grazing, removal of riparian vegetation, road maintenance, flow regulation/modification, and agriculture. There were no turbidity exceedences observed at the upper Rito de Tierra Amarilla sampling station (SWQB station 15) during the 1998 survey. Increased turbidity at the lower station (SWQB station 16) likely results from a number of potential factors. There is a change in soil type and geology from the upper station to the lower station in the valley. The main sources of impairment along this lower reach appear to be from livestock grazing and removal of riparian vegetation in the floodplain upstream of the lower sampling stations. Agricultural practices such as grazing appear to have contributed to the removal of riparian vegetation and streambank destabilization. Field staff observed several horses, colts, and cattle while taking measurements at the lower sampling station. There are several small animal confinement pens, irrigation return flow, and poorly designed culverts at road crossings (SWQB/NMED 2001a). The reach flows through Tierra Amarilla in which all the above factors are concentrated (Photo 06). When the area was first settled, creating narrow strips from the road all the way to the stream so each family's livestock would have access to a water source broke up land. In many instances, these plots have been completely cleared of vegetation that would have filtered out sediments before reaching the stream. Direct access of livestock to the stream banks has caused streambank destabilization in many areas.

The channel appears to have an increased width-to-depth ratio throughout this lower portion of the Rito de Tierra Amarilla as a result of the above-mentioned landuse practices. Given the low valley slope at the lower station (0.0036), the channel should be narrower and deeper which would transport sediment more efficiently (Rosgen 1996).

Photo 06. Rito de Tierra Amarilla immediately upstream of HWY 84, 10/02/02.

3.3 Margin of Safety (MOS)

TMDLs should reflect a margin of safety based on the uncertainty or variability in the data, the point and nonpoint source load estimates, and the modeling analysis. For this TMDL, there will be no margin of safety for point sources since there are none in Rito de Tierra Amarilla. However, for the nonpoint sources the margin of safety is estimated to be an addition of **25%** of the TMDL. This margin of safety incorporates several factors:

•*Errors in calculating NPS loads*

A level of uncertainty does exist in the relationship between TSS and turbidity. In this case, the TSS measure does not include bedload and therefore does not account for a complete measure of sediment load. This does not influence the MOS because we need only be concerned with the turbidity portion of the sediment load, which is the basis for the standard. However, there is a potential to have errors in measurements of nonpoint source loads due to equipment accuracy, time of sampling, etc. Accordingly, a conservative margin of safety increases the TMDL by **15%**.

•*Errors in calculating flow*

Flow estimates were based on estimated mean average annual discharge using cross-section field data (Appendix A) and USGS Technical Paper 2193 (USGS 1982). To be conservative, an additional MOS of **10%** will be included to account for accuracy of flow computations.

3.4 Consideration of Seasonal Variation

Data used in the calculation of this TMDL were collected during spring, summer, and fall in order to ensure coverage of any potential seasonal variation in the system. Since the critical condition is set to estimate average stream discharge, all data collected throughout the seasons were used in determining the target capacities. Therefore, it is assumed that if critical conditions are met, coverage of any potential seasonal variation will also be met.

3.5 Future Growth

Estimations of future growth are not anticipated to lead to a significant increase for turbidity that cannot be controlled with best management practice implementation in this watershed.