USEPA-APPROVED

TOTAL MAXIMUM DAILY LOAD (TMDL)

FOR THE

JEMEZ RIVER WATERSHED

(FROM SAN YSIDRO TO HEADWATERS EXCLUDING WATERS IN THE VALLES CALDERA NATIONAL PRESERVE*)

SEPTEMBER 15, 2009

* In 2006, SWQB prepared a separate TMDL bundle for surface waters in the Valles Caldera National Preserve (VCNP). Available online at: http://www.nmenv.state.nm.us/swqb/VallesCaldera/VallesCaldera.

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4Q3	4-Day, 3-year low-flow frequency
BLM	Bureau of Land Management
BMP	Best management practices
CFR	Code of Federal Regulations
cfs	Cubic feet per second
CGP	Construction general storm water permit
CWA	Clean Water Act
^{o}C	Degrees Celcius
^{o}F	Degrees Farenheit
GIS	Geographic Information Systems
GPS	Global Positioning System
HQCW	High quality cold water
HUC	Hydrologic unit code
$j/m^2/s$	Joules per square meter per second
LA	Load allocation
lb/day	Pounds per Day
mg/L	Milligrams per Liter
mi^2	Square miles
mL	Milliliters
MOS	Margin of safety
MOU	Memoranda of Understanding
MS4	Municipal Separate Storm Sewer System
MSGP	Multi Sector General Storm Water Permit
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NPDES	National Pollutant Discharge Elimination System
NTU	Nephelometric turbidity units
QAPP	Quality Assurance Project Plan
RFP	Request for proposal
SSTEMP	Stream Segment Temperature Model
STORET	USEPA's Storage and Retrieval Database
SWPPP	Storm Water Pollution Prevention Plan
SWQB	Surface Water Quality Bureau
TMDL	Total maximum daily load
TSS	Total suspended solids
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
WLA	Waste load allocation
WQCC	Water Quality Control Commission
WQS	Water quality standards (NMAC 20.6.4 as amended through October 11, 2002)
WRAS	Watershed Restoration Action Strategy
WWTP	Waste water treatment plant

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EXECUTIVE SUMMARY

Section 303(d) of the Federal Clean Water Act requires states to develop Total Maximum Daily Load (TMDL) management plans for water bodies determined to be water quality limited. A TMDL documents the amount of a pollutant a water body can assimilate without violating a state's water quality standards. It also allocates that load capacity to known point sources and nonpoint sources at a given flow. TMDLs are defined in 40 Code of Federal Regulations Part 130 as the sum of the individual Waste Load Allocations (WLAs) for point sources and Load Allocations (LAs) for nonpoint source and background conditions, and includes a Margin of Safety (MOS).

The Jemez River watershed, a tributary of the Rio Grande, is located in north central New Mexico. The Surface Water Quality Bureau (SWQB) conducted an intensive surface water quality survey of the Jemez River watershed in 2005. Water quality monitoring stations were located throughout the watershed during the survey to evaluate the impact of tributary streams and ambient water quality conditions. As a result of assessing data generated during this monitoring effort, SWQB staff documented 34 impairments of the New Mexico water quality standards (WQS). New impairment listings include: temperature and arsenic on East Fork Jemez (San Antonio Creek to Valles Caldera National Preserve [VCNP] boundary); arsenic and boron on Jemez River (Zia Pueblo boundary to Jemez Pueblo boundary); arsenic and boron on Jemez River (Jemez Pueblo boundary to Rio Guadalupe); arsenic, boron, temperature, and plant nutrients on Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs); arsenic on Jemez River (Soda Dam near Jemez Springs to East Fork Jemez); plant nutrients on Rio de las Vacas (Rio Cebolla to Clear Creek); temperature on Rio Guadalupe (Jemez River to confluence with Rio Cebolla); temperature and sedimentation/siltation on Rito de las Palomas (Rio de las Vacas to headwaters); plant nutrients on Rito Peñas Negras (Rio de las Vacas to headwaters); and arsenic on San Antonio Creek (East Fork Jemez to VCNP boundary). This TMDL document addresses the above noted impairments as summarized in the tables below. The data used to develop this TMDL were collected during the 2005 survey with follow-up collections in 2006 and 2008. In 2006, SWQB prepared a separate TMDL bundle for surface waters in the VCNP based on earlier separate studies of waters in the preserve (available at: http://www.nmenv.state.nm.us/swqb/VallesCaldera).

SWQB staff also documented continued impairments of the New Mexico WQS. "Old" impairment listings that already resulted in a TMDL but continue to be impaired based on the 2005 data and assessments include:

- TEMPERATURE on Rio de las Vacas (Rio Cebolla to Clear Creek), Rito Peñas Negras (Rio de las Vacas to headwaters), and San Antonio Creek (East Fork Jemez to VCNP boundary); and
- SEDIMENTATION/SILTATION on Rio Cebolla (Fenton Lake to headwaters).

Ten assessment units (AUs) in this watershed but outside of the VCNP boundary were found to be impaired due to dissolved aluminum, however according to a geology-based analysis of the Jemez Watershed (Appendix A), the volcanic bedrock has ample supply and opportunity to mobilize total and dissolved aluminum species.

The ten AUs outside of the VCNP that are listed in the *2008-2010 State of New Mexico CWA §303(d)/§305(b) Integrated Report* as impaired due to aluminum include: East Fork Jemez (San Antonio Creek to VCNP boundary), Jemez River (Jemez Pueblo boundary to Rio Guadalupe), Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs), Jemez River (Soda Dam near Jemez Springs to East Fork), Rio Cebolla (Fenton Lake to headwaters), Rio de las Vacas (Clear Creek to headwaters), Rio Guadalupe (Jemez River to confl with Rio Cebolla), San Antonio Creek (East Fork Jemez to VCNP bnd), Sulphur Creek (San Antonio Creek to Redondo Creek), and Vallecito Creek (perennial reaches from diversion above Ponderosa to headwaters). Natural conditions contribute to high aluminum concentrations throughout the Jemez Watershed and impacts to aquatic life are unclear; WQS criteria are under review to identify appropriate/attainable levels. Therefore, the aluminum listings will remain in the Integrated Report as Category 5B and aluminum TMDLs will not be written until a review of the WQS is conducted.

It should also be noted that as a result of assessing data generated during this monitoring effort, SWQB staff also documented improvements in water quality which resulted in several impairments being removed from the 2008-2010 CWA §303(d) List of Impaired Waterbodies. These “delisted” waters include:

- TEMPERATURE on the Rio Cebolla (Fenton Lake to headwaters) and Redondo Creek (Sulphur Creek to headwaters); and
- SEDIMENTATION/SILTATION on the Jemez River (Rio Guadalupe to Soda Dam nr Jemez Springs), Jemez River (Soda Dam nr Jemez Springs to East Fork), Calaveras Creek (Rio Cebolla to headwaters), Rio Cebolla (Rio de las Vacas to Fenton Lake), and Rio Guadalupe (Jemez River to confl with Rio Cebolla).

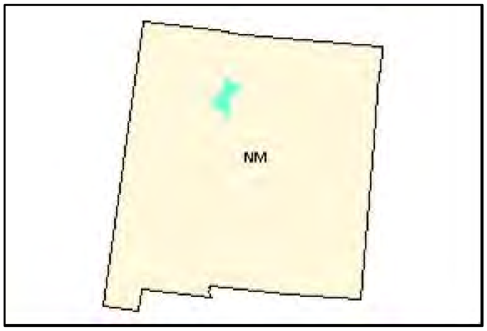
Waters removed from the 303(d) list do not require development of a TMDL.

The 2005 Jemez Watershed study identified other potential water quality impairments which are not addressed in this document. Additional data needs for verification of those impairments are being identified and data collection will follow. If these impairments are verified, subsequent TMDLs will be prepared in a separate TMDL document.

Additional water quality data will be collected by the SWQB during the standard rotational period for stream surveys. As a result, TMDL targets will be re-examined and potentially revised as this document is considered to be an evolving management plan. In the event that new data indicate that the targets used in this analysis are not appropriate and/or if new standards are adopted, the load capacity will be adjusted accordingly. When water quality standards have been achieved, the reach will be moved to the appropriate category in the Integrated Report.

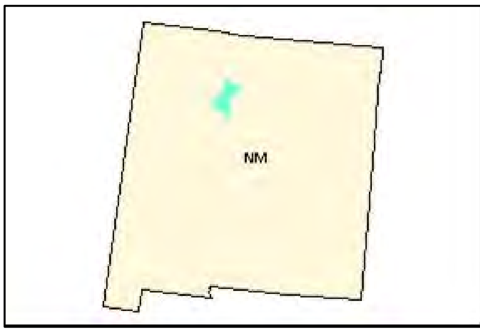
The SWQB’s Watershed Protection Section will continue to work with watershed groups to develop Watershed Restoration Action Strategies to develop and implement strategies to attempt to correct the water quality impairments detailed in this document. Implementation of items detailed in the Watershed Restoration Action Strategy will be done with participation of all interested and affected parties.

TOTAL MAXIMUM DAILY LOAD FOR
TEMPERATURE AND ARSENIC
EAST FORK JEMEZ RIVER (SAN ANTONIO CREEK TO VCNP BOUNDARY)



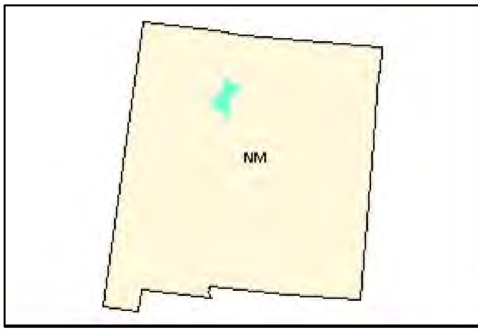
New Mexico Standards Segment	Jemez River Basin 20.6.4.108
Waterbody Identifier	East Fork Jemez River (San Antonio Creek to VCNP boundary) NM-2106.A_13 (formerly NM-MRG2-30000)
Segment Length	10.39 miles
Probable Causes of Impairment	Temperature; Arsenic
Uses Affected	High Quality Coldwater Aquatic Life
Geographic Location	Jemez USGS Hydrologic Unit Code 13020202
Scope/size of Watershed	67 mi^2
Omernik Ecoregion	Southern Rockies (21)
Land Use/Cover	63% Forest; 29% Grassland; 8% Shrubland; <1% Urban
Probable Sources of Impairment	Highway/road/bridge runoff, natural sources, other recreational pollution sources, rangeland grazing, silviculture harvesting, streambank modifications/destabilization.
Land Management	74% Valles Caldera National Preserve; 22% US Forest Service; 4% Private; <1% National Park Service
IR Category	5
Priority Ranking	High
TMDL for: Temperature Arsenic	 **WLA (0) + LA (90.4) + MOS (12.6) = 103 j/m^2/sec/day** **WLA (0) + LA (0.013) + MOS (0.0033) = 0.017 lbs/day**

TOTAL MAXIMUM DAILY LOAD FOR
ARSENIC AND BORON
JEMEZ RIVER (ZIA PUEBLO BND TO JEMEZ PUEBLO BND)



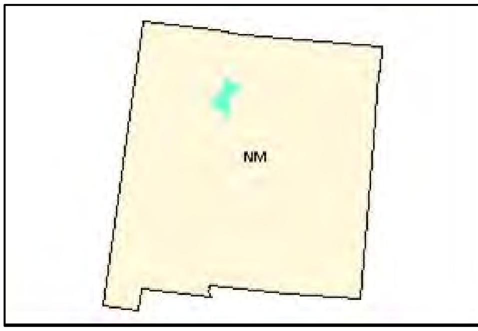
New Mexico Standards Segment	Jemez River Basin 20.6.4.106
Waterbody Identifier	Jemez River (Zia Pueblo bnd to Jemez Pueblo bnd) NM-2105_75
Segment Length	3.69 miles
Probable Causes of Impairment	Arsenic, Boron
Uses Affected	Marginal Warmwater Aquatic Life, Irrigation
Geographic Location	Jemez USGS Hydrologic Unit Code 13020202
Scope/size of Watershed	586 mi^2
Omernik Ecoregion	Arizona/New Mexico Plateau (22)
Land Use/Cover	75% Forest; 14% Grassland; 10% Shrubland; <1% Urban; <1% Agriculture
Probable Sources of Impairment	Natural sources, source unknown.
Land Management	65% US Forest Service; 23% Valles Caldera National Preserve; 8% Indian Land; 4% Private; <1% Bureau of Land Management
IR Category	5
Priority Ranking	High
TMDL for: Arsenic Boron	 **WLA (0) + LA (0.53) + MOS (0.13) = 0.67 lbs/day** **WLA (0) + LA (44.3) + MOS (11.1) = 55.4 lbs/day**

TOTAL MAXIMUM DAILY LOAD FOR
ARSENIC AND BORON
JEMEZ RIVER (JEMEZ PUEBLO BND TO RIO GUADALUPE)



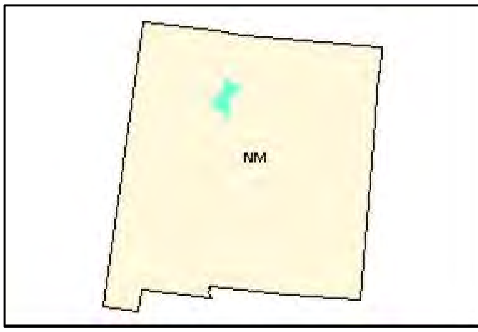
New Mexico Standards Segment	Jemez River Basin 20.6.4.107
Waterbody Identifier	Jemez River (Jemez Pueblo bnd to Rio Guadalupe) NM-2105_71 (formerly NM-MRG2-Jemez)
Segment Length	1.9 miles
Probable Causes of Impairment	Arsenic, Boron
Uses Affected	Coldwater Aquatic Life, Irrigation
Geographic Location	Jemez USGS Hydrologic Unit Code 13020202
Scope/size of Watershed	470 mi^2
Omernik Ecoregion	Southern Rockies (21) & Arizona/New Mexico Plateau (22)
Land Use/Cover	81% Forest; 13% Grassland; 5% Shrubland; <1% Urban; <1% Agriculture
Probable Sources of Impairment	Flow alterations from water diversions, highway/road/bridge runoff (non-construction related), inappropriate waste disposal, natural sources, other recreational pollution sources, rangeland grazing, source unknown.
Land Management	66% US Forest Service; 29% Valles Caldera National Preserve; 4% Private; <1% Indian Land; <1% State Parks
IR Category	5
Priority Ranking	High
TMDL for: Arsenic Boron	 **WLA (0.014) + LA (0.46) + MOS (0.12) = 0.59 lbs/day** **WLA (0.158) + LA (39.0) + MOS (9.78) = 48.9 lbs/day**

TOTAL MAXIMUM DAILY LOAD FOR
ARSENIC, BORON, PLANT NUTRIENTS, AND TEMPERATURE
JEMEZ RIVER (RIO GUADALUPE TO SODA DAM NR JEMEZ SPRINGS)



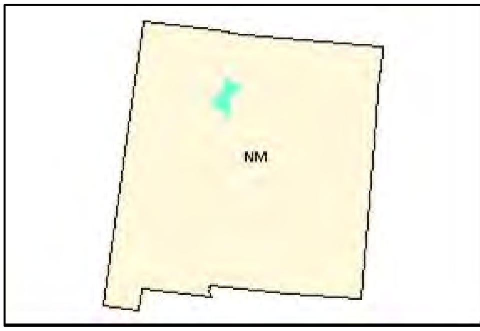
New Mexico Standards Segment	Jemez River Basin 20.6.4.107
Waterbody Identifier	Jemez River (Rio Guadalupe to Soda Dam nr Jemez Springs) NM-2105.5_10 (formerly NM-MRG2-20000)
Segment Length	9.67 miles
Probable Causes of Impairment	Arsenic, Boron, Plant Nutrients, Temperature
Uses Affected	Coldwater Aquatic Life, Irrigation
Geographic Location	Jemez USGS Hydrologic Unit Code 13020202
Scope/size of Watershed	200 mi^2
Omernik Ecoregion	Southern Rockies (21)
Land Use/Cover	70% Forest; 21% Grassland; 9% Shrubland; <1% Urban
Probable Sources of Impairment	On-site treatment systems (septic systems and similar decentralized systems, Highway/road/bridge runoff (non-construction related), loss of riparian habitat, natural sources, other recreational pollution sources, rangeland grazing, site clearance (Land Development and Redevelopment), streambank modification/destabilization.
Land Management	67% Valles Caldera National Preserve; 27% US Forest Service; 5% Private; <1% Indian Land; <1% National Park Service
IR Category	5/5A
Priority Ranking	High
TMDL for: Arsenic	**WLA (0.094) + LA (0.025) + MOS (0.031) = 0.150 lbs/day**
Boron	**WLA (1.34) + LA (8.90) + MOS (2.56) = 12.8 lbs/day**
Temperature	**WLA (0) + LA (181) + MOS (22.0) = 203 j/m^2/sec/day**
Plant Nutrients:	
Total Phosphorus	**WLA (0.626) + LA (0.170) + MOS (0.088) = 0.884 lbs/day**
Total Nitrogen	**WLA (2.97) + LA (1.01) + MOS (0.442) = 4.42 lbs/day**

TOTAL MAXIMUM DAILY LOAD FOR
ARSENIC
JEMEZ RIVER (SODA DAM NR JEMEZ SPRINGS TO EAST FORK)



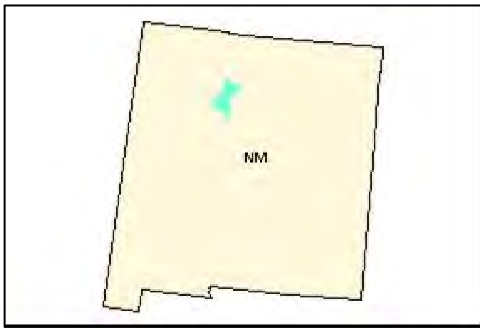
New Mexico Standards Segment	Jemez River Basin 20.6.4.108
Waterbody Identifier	Jemez River (Soda Dam nr Jemez Springs to East Fork) NM-2106.A_00 (formerly NM-MRG2-20000)
Segment Length	3.4 miles
Probable Causes of Impairment	Arsenic
Uses Affected	High Quality Coldwater Aquatic Life, Domestic Water Supply
Geographic Location	Jemez USGS Hydrologic Unit Code 13020202
Scope/size of Watershed	179 mi^2
Omernik Ecoregion	Southern Rockies (21)
Land Use/Cover	68% Forest; 24% Grassland; 8% Shrubland; <1% Urban
Probable Sources of Impairment	Highway/road/bridge runoff (non-construction related), loss of riparian habitat, natural sources, other recreational pollution sources, rangeland grazing, site clearance (Land Development and Redevelopment), streambank modification/destabilization
Land Management	74% Valles Caldera National Preserve; 22% US Forest Service; 4% Private; <1% Indian Land
IR Category	5/5B
Priority Ranking	High
TMDL for: Arsenic	 **WLA (0) + LA (0.033) + MOS (0.0083) = 0.042 lbs/day**

TOTAL MAXIMUM DAILY LOAD FOR
PLANT NUTRIENTS
RIO DE LAS VACAS (RIO CEBOLLA TO CLEAR CREEK)



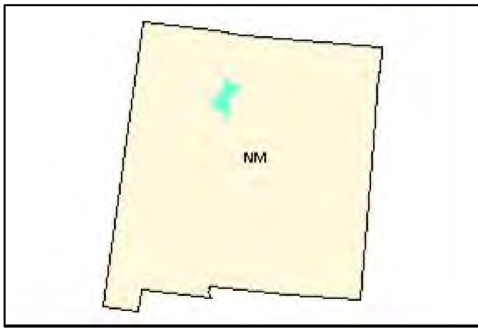
New Mexico Standards Segment	Jemez River Basin 20.6.4.108
Waterbody Identifier	Rio de las Vacas (Rio Cebolla to Clear Creek) NM-2106.A_40 (formerly MRG2-20200)
Segment Length	13.42 miles
Probable Causes of Impairment	Plant Nutrients
Uses Affected	High Quality Coldwater Aquatic Life
Geographic Location	Jemez USGS Hydrologic Unit Code 13020202
Scope/size of Watershed	121 mi^2
Omernik Ecoregion	Southern Rockies (21)
Land Use/Cover	91% Forest; 7% Grassland; 2% Shrubland
Probable Sources of Impairment	Loss of riparian habitat, rangeland grazing, streambank modifications/destabilization.
Land Management	96% US Forest Service; 4% Private; <1% Indian Land
IR Category	5
Priority Ranking	High
TMDL for: Plant Nutrients: Total Phosphorus Total Nitrogen	 **WLA (0) + LA (0.553) + MOS (0.061) = 0.614 lbs/day** **WLA (0) + LA (6.90) + MOS (0.767) = 7.67 lbs/day**

TOTAL MAXIMUM DAILY LOAD FOR
TEMPERATURE
RIO GUADALUPE (JEMEZ RIVER TO CONFL WITH RIO CEBOLLA)



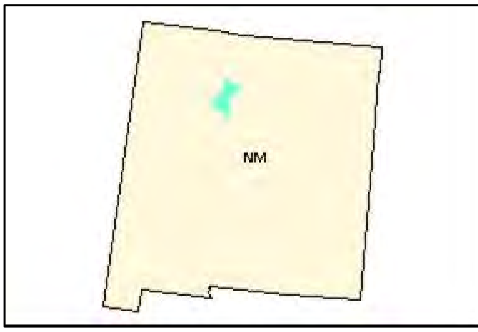
New Mexico Standards Segment	Jemez River Basin 20.6.4.108
Waterbody Identifier	Rio Guadalupe (Jemez River to confl with Rio Cebolla) NM-2106.A_30 (formerly NM-MRG2-20100)
Segment Length	12.65 miles
Probable Causes of Impairment	Temperature
Uses Affected	High Quality Coldwater Aquatic Life
Geographic Location	Jemez USGS Hydrologic Unit Code 13020202
Scope/size of Watershed	265 mi^2
Omernik Ecoregion	Southern Rockies (21)
Land Use/Cover	91% Forest; 7% Grassland; 2% Shrubland; <1% Agriculture
Probable Sources of Impairment	Loss of riparian habitat, off-road vehicles, natural sources, rangeland grazing.
Land Management	96% US Forest Service; 3% Private; <1% Valles Caldera National Preserve; <1% Indian Land
IR Category	5
Priority Ranking	High
TMDL for: Temperature	 **WLA (0) + LA (93.2) + MOS (11.8) = 105 j/m^2/sec/day**

TOTAL MAXIMUM DAILY LOAD FOR
TEMPERATURE AND SEDIMENTATION/SILTATION
RITO DE LAS PALOMAS (RIO DE LAS VACAS TO HEADWATERS)



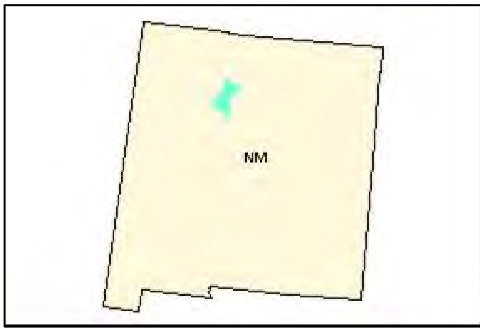
New Mexico Standards Segment	Jemez River Basin 20.6.4.108
Waterbody Identifier	Rito de las Palomas (Rio de las Vacas to headwaters) NM-2106.A_43
Segment Length	5.61 miles
Probable Causes of Impairment	Temperature, Sedimentation/Siltation
Uses Affected	High Quality Coldwater Aquatic Life
Geographic Location	Jemez USGS Hydrologic Unit Code 13020202
Scope/size of Watershed	12 mi^2
Omernik Ecoregion	Southern Rockies (21)
Land Use/Cover	89% Forest; 9% Grassland; 2% Shrubland
Probable Sources of Impairment	Highway/road/bridge runoff (non-construction related), loss of riparian habitat, rangeland grazing, streambank modifications/destabilization.
Land Management	99% US Forest Service; 1% Private
IR Category	5/5A
Priority Ranking	High
TMDL for: Temperature Sedimentation/Siltation (TSS Surrogate)	 **WLA (0) + LA (124) + MOS (15.0) = 139 j/m^2/sec/day** **WLA (0) + LA (1,236) + MOS (412) = 1,648 lbs/day (TSS)**

TOTAL MAXIMUM DAILY LOAD FOR
PLANT NUTRIENTS
RITO PEÑAS NEGRAS (RIO DE LAS VACAS TO HEADWATERS)



New Mexico Standards Segment	Jemez River Basin 20.6.4.108
Waterbody Identifier	Rito Peñas Negras (Rio de las Vacas to headwaters) NM-2106.A_42 (formerly NM-MRG2-20230)
Segment Length	11.78 miles
Probable Causes of Impairment	Plant Nutrients
Uses Affected	High Quality Coldwater Aquatic Life
Geographic Location	Jemez USGS Hydrologic Unit Code 13020202
Scope/size of Watershed	17 mi^2
Omernik Ecoregion	Southern Rockies (21)
Land Use/Cover	85% Forest; 11% Grassland; 4% Shrubland
Probable Sources of Impairment	Highway/road/bridge runoff (non-construction related), loss of riparian habitat, rangeland grazing, streambank modifications/destabilization.
Land Management	94% US Forest Service; 6% Private
IR Category	5/5A
Priority Ranking	High
TMDL for: Plant Nutrients: Total Phosphorus Total Nitrogen	 **WLA (0) + LA (0.108) + MOS (0.012) = 0.120 lbs/day** **WLA (0) + LA (1.36) + MOS (0.151) = 1.51 lbs/day**

TOTAL MAXIMUM DAILY LOAD FOR
ARSENIC
SAN ANTONIO CREEK (EAST FORK JEMEZ TO VCNP BND)



New Mexico Standards Segment	Jemez River Basin 20.6.4.108
Waterbody Identifier	San Antonio Creek (East Fork Jemez to VCNP bnd) NM-2106.A_20 (formerly NM-MRG2-40000)
Segment Length	11.28 miles
Probable Causes of Impairment	Arsenic
Uses Affected	High Quality Coldwater Aquatic Life, Domestic Water Supply
Geographic Location	Jemez USGS Hydrologic Unit Code 13020202
Scope/size of Watershed	104 mi^2
Omernik Ecoregion	Southern Rockies (21)
Land Use/Cover	69% Forest; 22% Grassland; 9% Shrubland; <1% Urban
Probable Sources of Impairment	Forest roads (road construction and use), loss of riparian habitat, natural sources, other recreational pollution sources, rangeland grazing, site clearance (land development and redevelopment), streambank modifications/destabilization.
Land Management	80% Valles Caldera National Preserve; 17% US Forest Service; 2% Private; <1% Indian Land
IR Category	5
Priority Ranking	High
TMDL for: Arsenic	 **WLA (0) + LA (0.027) + MOS (0.0067) = 0.034 lbs/day**

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1.0 INTRODUCTION

Under Section 303 of the Clean Water Act (CWA), states establish water quality standards, which are submitted and subject to the approval of the U.S. Environmental Protection Agency (USEPA). Under Section 303(d)(1) of the CWA, states are required to develop a list of waters within a state that are impaired and establish a total maximum daily load (TMDL) for each pollutant. A TMDL is defined as "*a written plan and analysis established to ensure that a waterbody will attain and maintain water quality standards including consideration of existing pollutant loads and reasonably foreseeable increases in pollutant loads*" (USEPA 1999). A TMDL documents the amount of a pollutant a waterbody can assimilate without violating a state's water quality standards. It also allocates that load capacity to known point sources and nonpoint sources at a given flow. TMDLs are defined in 40 Code of Federal Regulations (CFR) Part 130 as the sum of the individual Waste Load Allocations (WLAs) for point sources and Load Allocations (LAs) for nonpoint sources and natural background conditions, and includes a margin of safety (MOS). This document provides TMDLs for assessment units within the Jemez River watershed from the Jemez River crossing at NM Highway 4 upstream of San Ysidro to the headwaters that have been determined to be impaired based on an assessment of measured concentrations and conditions relative to water quality criteria and numeric translators for narrative standards. A separate TMDL document focuses on waters within the Valles Caldera National Preserve (VCNP) boundary (NMED/SWQB 2006). As a consequence, waters within the VCNP boundary are excluded from this document.

This document is divided into several sections. Section 2.0 provides background information on the location and history of the Jemez River basin, provides applicable water quality standards for the assessment units addressed in this document, and briefly discusses the intensive water quality survey that was conducted in the basin in 2005. Section 3.0 presents the TMDLs developed for arsenic, Section 4.0 provides boron TMDLs, Section 5.0 covers nutrient TMDLs, Section 6.0 discusses temperature TMDLs, and Section 7.0 addresses sedimentation/stilation TMDLs. Pursuant to Section 106(e)(1) of the Federal CWA, Section 8.0 provides a monitoring plan in which methods and procedures for data collection and analysis are discussed. Section 9.0 discusses implementation of TMDLs (phase two) and the relationship between TMDLs and Watershed Restoration Action Strategies (WRASs). Section 10.0 discusses assurance, section 11.0 describes public participation in the TMDL process, and Section 12.0 provides references.

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2.0 BACKGROUND

The Surface Water Quality Bureau conducted a water quality survey of the Jemez River watershed (Figure 2.1) between March and October, 2005. The survey extended from the Jemez River crossing at NM Highway 4 upstream of San Ysidro to the headwaters, excluding waters within the Valles Caldera National Preserve boundary (VCNP) boundary because these waters were previously surveyed during a special study. Tributaries sampled during the 2005 survey include San Antonio Creek, East Fork Jemez River, Clear Creek, Rio de las Vacas, Rito de las Palomas, Calaveras Creek, Rio Cebolla, Vallecitos Creek, and Rio Guadalupe. In addition, five of the region's geothermal springs were sampled once: San Antonio, Spence, Soda Dam, Jemez Springs Municipal Spring, and Giggling Springs Spa. Surface water quality monitoring stations were selected to characterize water quality of the stream reaches.

2.1 Location Description

The Jemez Watershed (US Geological Survey [USGS] Hydrologic Unit Code [HUC] 13020202) is a sub-basin of the Rio Grande Basin, located in northcentral New Mexico. Approximately sixty-eight percent of the watershed is managed by the Forest Service, twenty-five percent belongs to a Federal Trust, four percent is private land, two percent is Tribal land, and less than one percent is owned by the state (Figure 2.1). Land ownership in the upper Jemez basin is principally public, with approximately 94 percent of the SWQB survey area managed by the Santa Fe National Forest (SFNF). SFNF has restored over 50 dispersed camping areas and treated about 500 acres for watershed protection.

Land uses in watershed include rangeland, irrigated and dry-land agriculture, silviculture, mining and some urban development. Land use in the upper Jemez River watershed is primarily forested cattle range, with some logging and several pumice mines. Additionally, the area is heavily utilized by the public for fishing, hunting, camping, and off-road vehicle use. The lower watershed downstream of the Rio Guadalupe is primarily agricultural, with water diversions for agricultural use (Figure 2.2). Although the basin is in relatively good condition, the long-term grazing of cattle, sheep, and elk have impacted the streams within the Jemez watershed by reducing native bunchgrasses and increasing exotic species (Muldavin and Tonne 2003).

The Jemez Mountains possess a number of unique species and support a variety of ecosystems due to the great elevation range and the variety of soil types and climatic regimes. One may find local examples of riparian and wetland communities, juniper-grassland savannas, piñon-juniper woodlands, and forests composed of ponderosa pine, aspen, or mixed conifer species. In the warmer and drier areas, the forest communities consist of sparse piñon and juniper trees. At higher levels, the piñon-juniper is replaced by ponderosa pine, and above these communities, Douglas fir, blue spruce, limber pine, and white fir can be found. Virgin forests are located in the upper East Fork Jemez and San Antonio Creek watersheds (Muldavin and Tonne 2003).

Several species within this watershed are listed as either threatened or endangered by both State and federal agencies. Endangered species in this region include the Jemez Mountains salamander (*Plethodon neomexicanus*), Jumping meadow mouse (*Zapus hudsonis luteus*), Southwestern willow flycatcher (*Empidonax traillii extimus*), and Wrinkled marshsnail (*Stagnicola caperata*). Threatened species include the American marten (*Martes americana*), Baird's sparrow (*Ammodramus bairdii*), Bald eagle (*Heliaeetus leucocephalus*), Boreal owl (*Aegolius funereus*), Broad-billed hummingbird (*Cynanthus latirostris magicus*), Common black-hawk (*Buteogallus anthracinus anthracinus*), Costa's hummingbird (*Calypte costae*), Gray vireo (*Vireo vicinior*), Mexican spotted owl (*Strix occidentalis lucida*), Peregrine falcon (*Falco peregrinus*), and the Spotted bat (*Euderma maculatum*). Several examples of sensitive species and/or "former species of concern" found in the area include the Big free-tailed bat (*Nyctinomops macrotis*), Black swift (*Cypseloides niger*), Goat peak pika (*Ochotona princeps nigrescens*), Northern leopard frog (*Rana pipiens*), Northern goshawk (*Accipiter gentiles*), Rio Grande chub (*Gila pandora*), Rio Grande cutthroat trout (*Oncorhynchus clarki virginalis*), and the Rio Grande sucker (*Catostomus plebeius*).

2.2 Geology

The geology of the Jemez River basin consists of complex distribution of Paleozoic limestone, Quaternary alluvium, and significant Quaternary volcanic deposits (Figure 2.3). The dominant feature is the Jemez volcanic field, including the Jemez and Pajarito Plateaus, one of the most well studied volcanic complexes on earth. It is composed of extremely thick accumulations of extrusive volcanic rocks, ranging in composition from tuffaceous ash to rhyolite, andesite, and basalts. The Bandelier Tuff exists in three layers east and west of Jemez Springs; the thick layers of ash were deposited on an irregular surface full of valleys and ridges. Underlying the Bandelier Tuff is the red Abo Formation which, unlike most other Paleozoic formations in New Mexico, is continental rather than marine in origin (Chronic 1987).

Streams in the basin arise in two distinct geologic settings. In the western region of the basin, Clear Creek, Rio de las Vacas, and Rito Peñas Negras originate in Precambrian metamorphic and Permian sedimentary rocks. Streams in the central and eastern regions of the watershed, Calaveras Creek, Rio Cebolla, San Antonio Creek, Sulphur Creek, Redondo Creek, and the East Fork of the Jemez River, originate in volcanic rocks, principally basalts and tuffs associated with the Valles Caldera. At the confluence of San Antonio Creek and the East Fork, the Jemez River bed cuts through the volcanic rock and into a series of sedimentary strata that form the valley floor extending through the bottom of the study area. The Jemez Mountains contain a number of active hot springs resulting from groundwater flow above a subsurface body of partially molten igneous rock. The geothermal reservoir is recharged by rainwater that moves down through the aquifers to a depth of 6,500 feet at temperatures reaching 330ºC (USGS 2000). For further information, a geology-based analysis of the Jemez Watershed is presented in Appendix A.

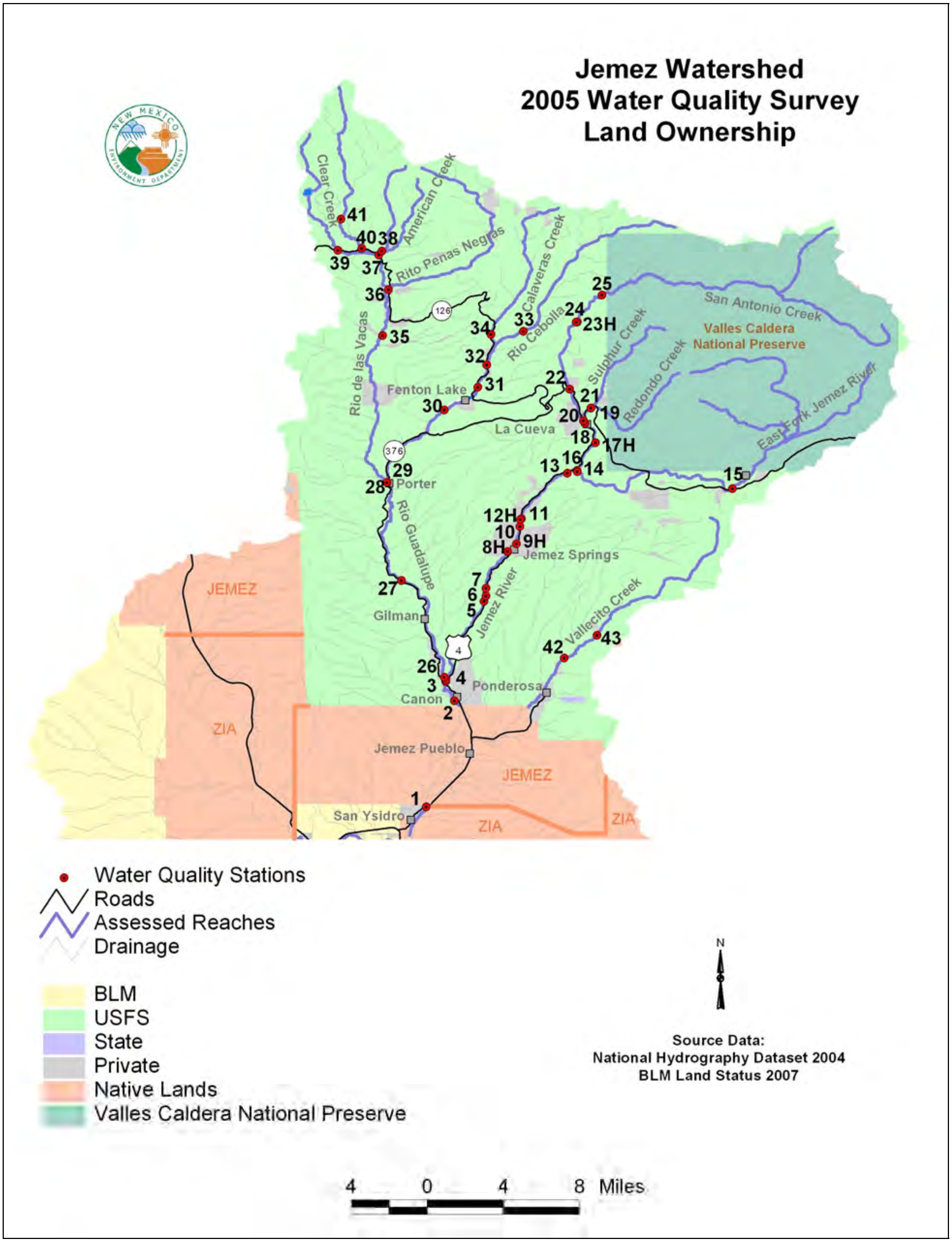


Figure 2.1 Jemez Watershed Land Ownership and 2005 Sampling Stations.

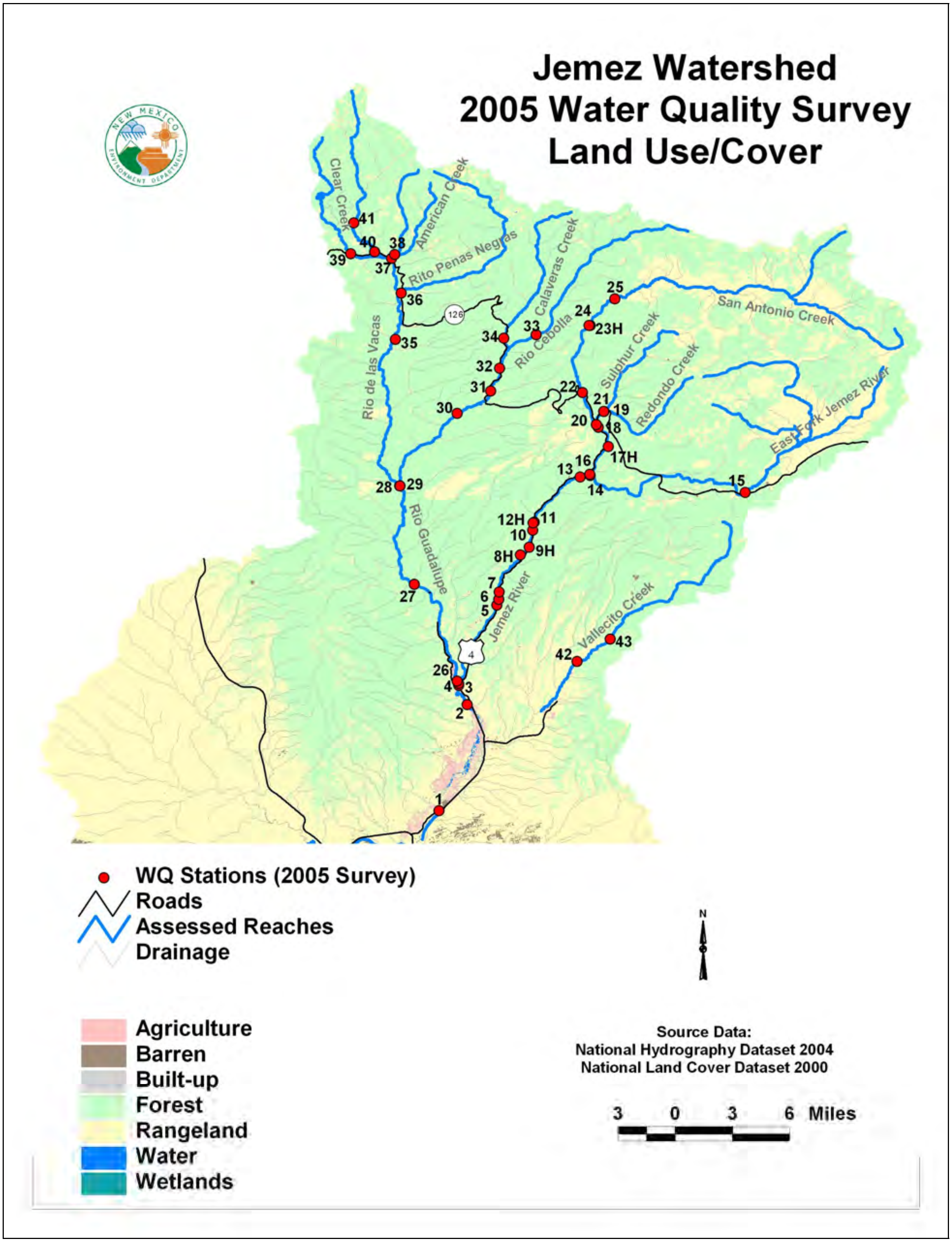


Figure 2.2 Jemez Watershed Land Use and 2005 Sampling Stations.

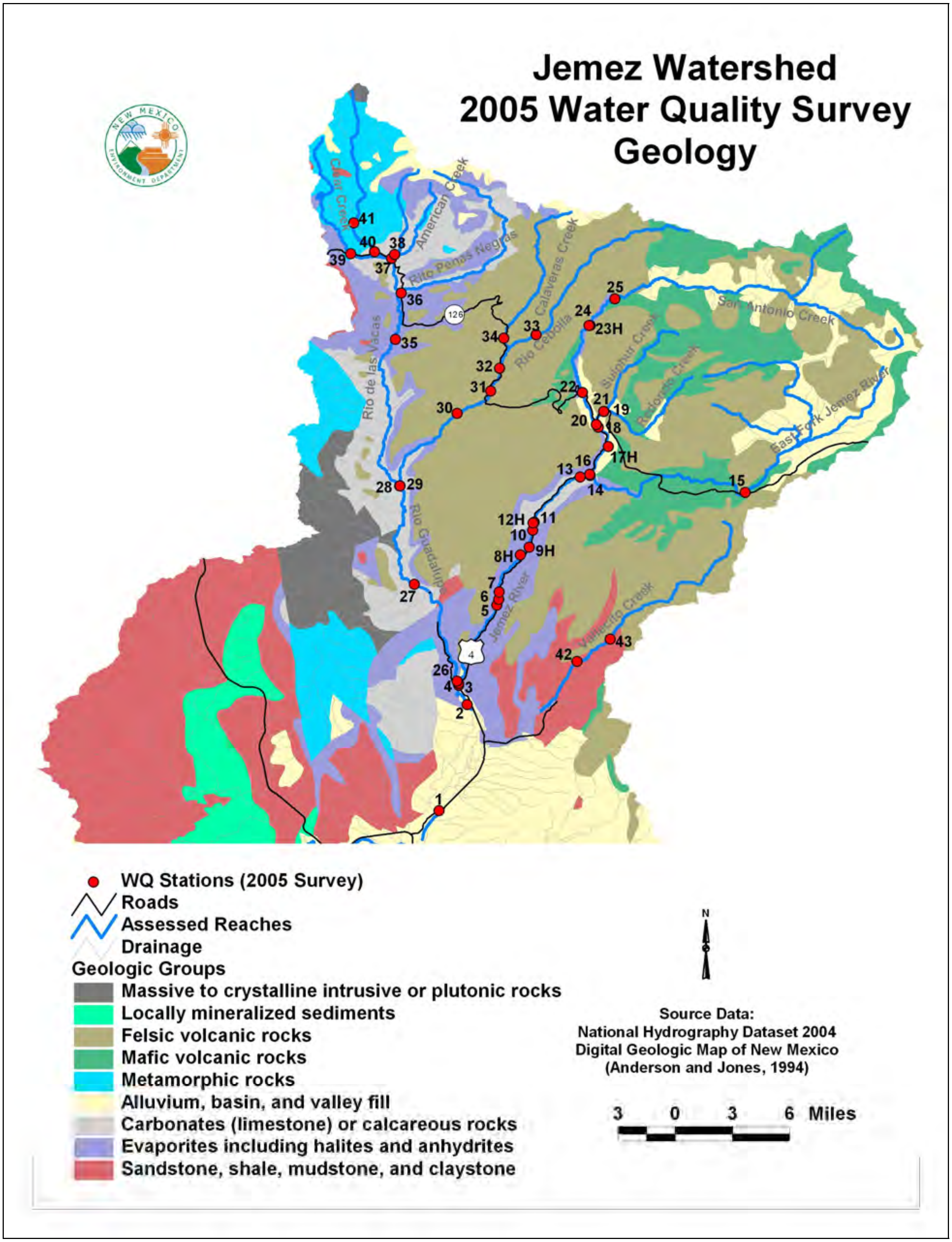


Figure 2.3 Jemez Watershed Geology

2.3 Water Quality Standards

State *and* tribal water quality standards constitute the baseline of water quality standards (WQS) in effect for Clean Water Act purposes. The Jemez River within the survey area flows through various jurisdictional boundaries including both state and pueblo lands (Figure 2.1), however Jemez Pueblo and Zia Pueblo do not have approved WQS at this time. Therefore the applicable WQS for all assessment units in this document are set forth in sections 20.6.4.107, 20.6.4.108, and 20.6.4.124 of the *NM Standards for Interstate and Intrastate Surface Waters* (NM Administrative Code [NMAC] 20.6.4) (NMAC 2007).

20.6.4.107 **RIO GRANDE BASIN -** The Jemez river from the Jemez pueblo boundary upstream to Soda dam near the town of Jemez Springs and perennial reaches of Vallecito creek.

A. **Designated Uses**: coldwater aquatic life, primary contact, irrigation, livestock watering and wildlife habitat.

B. **Criteria**:

(1) In any single sample: temperature 25°C (77°F) and pH within the range of 6.6 to 8.8. The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of E. coli bacteria 126 cfu/100 mL or less; single sample 410 cfu/100 mL or less (see Subsection B of 20.6.4.14 NMAC).

20.6.4.108 **RIO GRANDE BASIN -** Perennial reaches of the Jemez river and all its tributaries above Soda dam near the town of Jemez Springs, except Sulphur creek about its confluence with Redondo creek, and perennial reaches of the Guadalupe river and all its tributaries.

A. **Designated Uses:** domestic water supply, fish culture, high quality coldwater aquatic life, irrigation, livestock watering, wildlife habitat and secondary contact.

B. **Criteria:**

(1) In any single sample: specific conductance 400 μmhos/cm or less, pH within the range of 6.6 to 8.8 and temperature 20°C (68°F) or less. The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of E. coli bacteria 126/100 mL or less; single sample 235/100 mL or less (see Subsection B of 20.6.4.14 NMAC).

20.6.4.124 **RIO GRANDE BASIN -** Perennial reaches of Sulphur creek from its headwaters to its confluence with Redondo creek.

A. **Designated Uses:** limited aquatic life, wildlife habitat, livestock watering and secondary contact.

B. **Criteria:**

(1) In any single sample: pH within the range of 2.0 to 9.0 and temperature 30°C (86°F) or less. The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of E. coli bacteria 548/100 mL or less; single sample 2507/100 mL or less (see Subsection B of 20.6.4.14 NMAC).
(3) The chronic aquatic life criteria of Subsections I and J of 20.6.4.900 NMAC shall also apply.

NMAC 20.6.4.900 provides standards applicable to attainable or designated uses unless otherwise specified in 20.6.4.101 through 20.6.4.899. NMAC 20.6.4.13 lists general standards that apply to all surface waters of the state at all times, unless a specified standard is provided elsewhere in NMAC (2007).

2.4 Intensive Water Quality Sampling

The Jemez River basin was intensively sampled by the SWQB in 2005. A brief summary of the survey and the hydrologic conditions during the intensive sample period is provided in the following subsections.

2.4.1 Survey Design

Surface water quality samples were collected monthly from March through October 2005 for the SWQB study. Stations were located to evaluate the impact of tributary streams and to determine ambient water quality conditions (Figure 2.1). Monitoring these stations over three seasons enabled an assessment of the cumulative influence of the physical habitat, water sources, and land management activities upstream of the site. Data results from grab sampling are housed in the SWQB provisional water quality database and are scheduled to be uploaded to USEPA's Storage and Retrieval (STORET) database in 2009. In addition thermograph were deployed throughout the basin and are described in Section 6.0 (Table 6.1 and Figure 6.1). A water quality survey report has been prepared for this study (NMED/SWQB 2009).

Table 2.1 SWQB 2005 Jemez Watershed Sampling Stations

Station #	STATION NAME	STORET NUMBER
1	Jemez River above San Ysidro at NM 4	31JemezR037.0
2	Jemez River near Canon, below Municipal School	31JemezR046.6
3	Jemez River below Rio Guadalupe	31JemezR048.7
4	Jemez River above Rio Guadalupe	31JemezR049.2
5	Jemez River below Jemez Springs WWTP	31JemezR057.4
6	Jemez Springs WWTP outfall	31JemezR057.9
7	Jemez River above Jemez Springs WWTP	31JemezR058.6
8^{H}	Giggling Springs hot spring	31JemezGigSpr
9^{H}	Jemez Springs Municipal hot spring	31JemezHotSpr
10	Jemez River at NM 4 Bridge by USFS Station	31JemezR064.2
11	Jemez River above Soda Dam	31JemezR064.9
12^{H}	Soda Dam hot spring	31SodaDamHtSp
13	Jemez River at USGS gage below Battleship Rock	31JemezR070.3
14	East Fork Jemez River above San Antonio Creek	31EFkJem000.1

Station #	STATION NAME	STORET NUMBER
15	East Fork Jemez River below Las Conchas day use area	31EFkJem015.2
16	San Antonio Creek above East Fork Jemez River	31SanAnt000.1
17[H]	Spence hot spring	31SpenceHotSp
18	San Antonio Creek below La Cueva	31SanAnt004.7
19	Redondo Creek above Sulphur Creek	31Redond000.1
20	Sulphur Creek above San Antonio Creek	31Sulphu000.1
21	Sulphur Creek above Redondo Creek	31Sulphu001.3
22	San Antonio Creek above NM 126	31SanAnt008.4
23[H]	San Antonio hot springs	31SanAntHotSp
24	San Antonio Creek above San Antonio hot springs	31SanAnt014.5
25	San Antonio Creek at VCNP boundary	31SanAnt018.0
26	Rio Guadalupe above Jemez River	31RGuada000.1
27	Rio Guadalupe at Deer Creek Landing	31RGuada010.0
28	Rio de Las Vacas above Rio Cebolla	31RVacas000.1
29	Rio Cebolla above Rio de las Vacas	31RCebol000.1
30	Rio Cebolla below Fenton Lake	31RCebol009.3
31	Rio Cebolla 0.5 mile above Fenton Lake	31RCebol011.4
32	Rio Cebolla at NM 126	31RCebol013.7
33	Rio Cebolla at campground abv Seven Springs hatchery	31RCebol017.9
34	Calaveras Creek on NM 126, above Rio Cebolla	31Calave001.1
35	Rio de las Vacas below inholdings at FR 20	31RVacas014.6
36	Rito Peñas Negras at NM 126	31RPNegr000.1
37	Rito de las Palomas at NM 126	31RPalom000.1
38	American Creek above Rito de las Palomas	31Americ000.1
39	Clear Creek at NM 126	31ClearC002.3
40	Rio de las Vacas at NM 126	31RVacas023.7
41	Rio de las Vacas above FR 70	31RVacas026.5
42	Vallecito Creek above Ponderosa diversion	31RValle012.2
43	Vallecito Creek at Paliza Campground	31RValle015.5

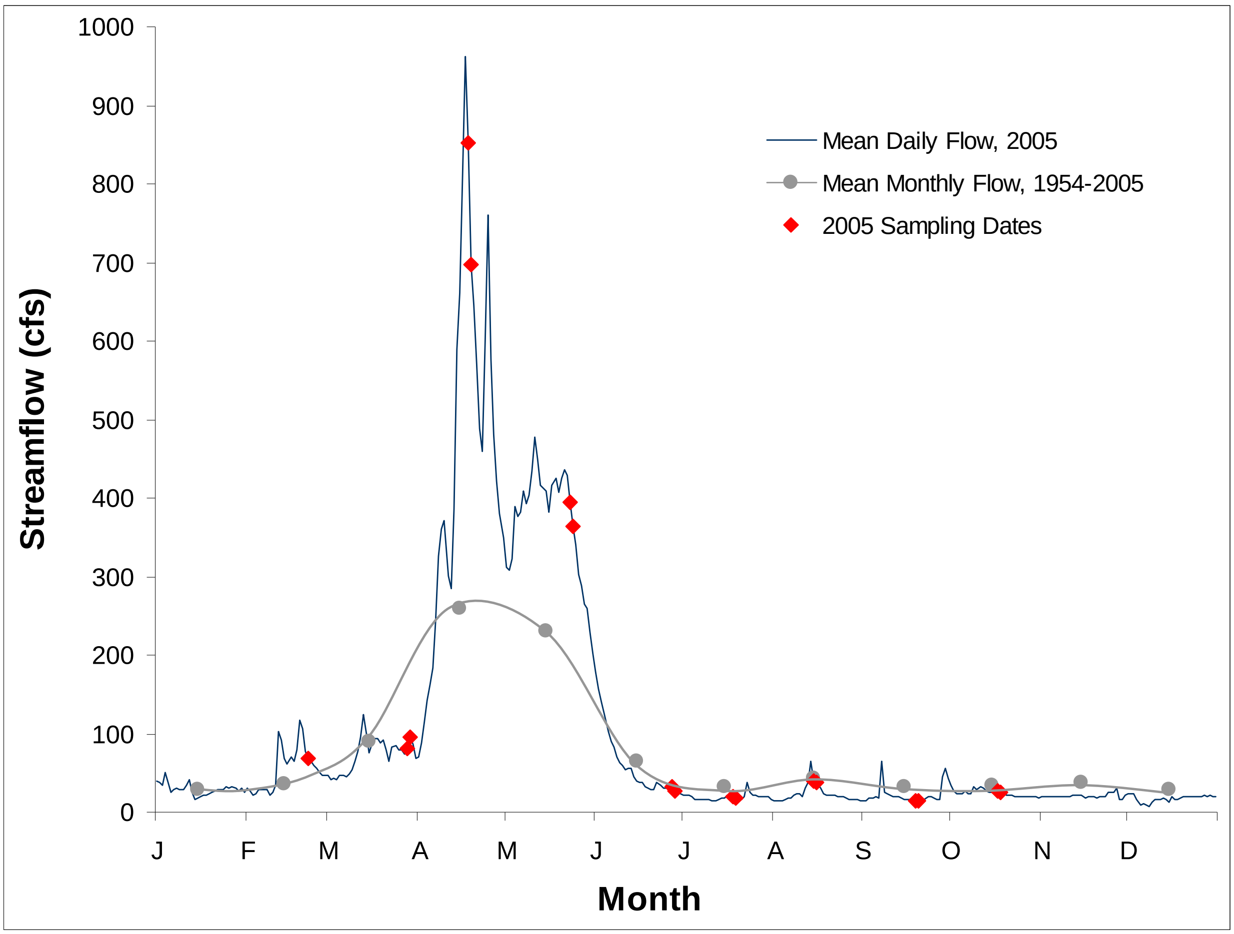
NOTES: [H] ***Geothermal Spring***
WWTP = Wastewater Treatment Plant
AU = Assessment Unit
USFS = U.S. Forest Service
USGS = U.S. Geological Survey
VCNP = Valles Caldera National Preserve
SFNF = Santa Fe National Forest

All temperature and chemical/physical sampling and assessment techniques are detailed in the *Quality Assurance Project Plan* (QAPP) (NMED/SWQB 2005), SWQB *Standard Operating Procedures for Data Collection* (NMED/SWQB 2004), the SWQB *Assessment Protocols* (NMED/SWQB 2008a), and the *Water Quality Survey Summary* (NMED/SWQB 2009). As a result of the 2005 monitoring effort and subsequent assessment of results, several surface water impairments were determined. Accordingly, these impairments were added to *New Mexico's 2008-2010 Integrated CWA §303(d)/305(b) Report* (NMED/SWQB 2008b).

2.4.2 Hydrologic Conditions

The nearest USGS gaging station, Jemez River near Jemez, NM (08324000), has a period of record from 1936-present and a daily mean streamflow of 75 cubic feet per second (cfs). Figure 2.4 displays the annual hydrograph of the Jemez River, with daily mean streamflows for 2005 compared to the 50-year monthly average. The river experienced high flow during the spring snow melt tapering off to low flow conditions throughout the summer months with several small spikes associated with summer monsoon flows.

Figure 2.4 Daily Mean Streamflow: USGS 08324000 Jemez River near Jemez, NM



As stated in the *Assessment Protocol* (NMED/SWQB 2008a), data collected during all flow conditions, including low flow conditions (i.e., flows below the 4-day, 3-year low-flow frequency [4Q3]), will be used to determine designated use attainment status during the assessment process. In terms of assessing designated use attainment in ambient surface waters, WQS apply at all times under all flow conditions.

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3.0 ARSENIC

Assessment of the data from the 2005 SWQB water quality survey in the Jemez River watershed identified exceedences of the New Mexico water quality standards for arsenic in East Fork Jemez (San Antonio Creek to Valles Caldera National Preserve [VCNP] boundary), Jemez River (Zia Pueblo boundary to Jemez Pueblo boundary), Jemez River (Jemez Pueblo boundary to Rio Guadalupe), Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs), Jemez River (Soda Dam near Jemez Springs to East Fork Jemez), and San Antonio Creek (East Fork Jemez to VCNP boundary). Consequently, these waterbodies were listed on the 2008-2010 Integrated CWA §303(d)/§305(b) list for arsenic (NMED/SWQB 2008b).

3.1 Target Loading Capacity

Target values for this arsenic TMDL will be determined based on 1) the presence of numeric criteria or appropriate numeric translator to a narrative standard, 2) the degree of experience in applying the indicator, and 3) the ability to easily monitor and produce quantifiable and reproducible results. This TMDL is also consistent with New Mexico's antidegradation policy.

According to the New Mexico water quality standards (20.6.4.900 NMAC), the dissolved arsenic criteria are 2.3 µg/L for domestic water supply, 9.0 µg/L for human health, and 100 µg/L for irrigation. Exceedences for each assessment unit are presented in Table 3.1.

Arsenic is a naturally occurring element widely distributed in the earth's crust. Arsenic occurs naturally in soil and minerals and may enter the air, water, and land from wind-blown dust and may get into water from runoff and leaching. Fish and shellfish can accumulate arsenic; most of this arsenic is in an organic form called arsenobetaine that is much less harmful.

Table 3.1 Dissolved arsenic exceedences

Assessment Unit	Designated Use Affected	Associated Criterion (µg/L)	Exceedence Ratio (# exceedences / total # samples)
East Fork Jemez (San Antonio Creek to VCNP bnd)	DWS	2.3	6/9
Jemez River (Zia Pueblo bnd to Jemez Pueblo bnd)	HH	9.0	3/3
Jemez River (Jemez Pueblo boundary to Rio Guadalupe)	HH	9.0	21/23
Jemez River (Rio Guadalupe to Soda Dam nr Jemez Springs)	HH	9.0	8/9
	IRR	100	2/9
Jemez River (Soda Dam nr Jemez Springs to E Fork Jemez)	DWS	2.3	7/8
	HH	9.0	3/8
San Antonio Creek (E Fork Jemez to VCNP bnd)	DWS	2.3	5/9

DWS = Domestic Water Supply.
HH = Human Health.
IRR = Irrigation
µg/L = micrograms per liter

3.2 Flow

Arsenic concentrations can vary as a function of flow, therefore TMDLs are calculated at a specific flow. The target flow value used to calculate the TMDL for this stream reach was obtained using a 4-day, 3-year low-flow frequency (4Q3) regression model. The 4Q3 is the annual lowest 4 consecutive day flow that occurs with a frequency of at least once every 3 years. When available, USGS gages are used to estimate flow.

The 4Q3 flow for the Jemez River (Jemez Pueblo boundary to Rio Guadalupe) is based on USGS gage data. Jemez River near Jemez, NM (USGS Gage 08324000) is located in the Jemez River (Jemez Pueblo bnd to Rio Guadalupe) assessment unit (AU). The 4Q3 was estimated using the USGS A193 calculation for Log Pearson Type III distribution through DFLOW software, Version 3.1b (USEPA 2006). DFLOW 3.1b is a Windows-based tool developed to estimate user selected design stream flows for low flow analysis. The calculated 4Q3 is as follows:

- Jemez River (Jemez Pueblo bnd to Rio Guadalupe) = 12.1 cfs

It is often necessary to calculate a critical flow for a portion of a watershed where there is no active flow gage as in the upper Jemez River, East Fork Jemez, and San Antonio Creek. This can be accomplished by applying one of several different formulas developed by the U.S. Geological Survey (USGS).

One formula is recommended when the ratio between the two watershed areas is between 0.5 and 1.5 (Thomas et al. 1997). The nearest gage to the points of interest in this watershed is USGS Gage 08324000 – Jemez River near Jemez, NM. The drainage area above this gage (A_g) is 470 mi^2. Using the guidelines recommended by the USGS, when the ratio between the ungaged and gaged watersheds is within the 0.5-1.5 range the following formula should be used to estimate flow:

$$Q_{T(u)} = Q_{T(g)} \left(A_u / A_g\right)^{0.566}$$

where,

$Q_{T(u)}$ = weighted flow frequency estimate at the ungaged site, in cubic feet per second (cfs)
$Q_{T(g)}$ = 4Q3 low-flow frequency estimate at the gaged site, in cfs
A_u = drainage area above the ungaged site, in square miles
A_g = drainage area above the gaged site, in square miles

The drainage area of the Jemez River above San Ysidro at NM Highway 4 is 586 mi^2. The watershed ratio between the gaged Jemez River (Jemez Pueblo boundary to Rio Guadalupe) and the ungaged Jemez River (Zia Pueblo boundary to Jemez Pueblo boundary) is 1.25. Therefore, the estimated 4Q3 is:

- Jemez River (Zia Pueblo bnd to Jemez Pueblo bnd) = 13.7 cfs

When the ratio between the gaged and ungaged watersheds is outside the 0.5-1.5 range analysis methods described by Waltemeyer (2002) are used to estimate flow. In this analysis, two regression equations for estimating 4Q3 were developed based on physiographic regions of NM (i.e., statewide and mountainous regions above 7,500 feet in elevation). The following regression equation for mountainous regions above 7,500 feet in elevation is based on data from 40 gaging stations with non-zero discharge (Waltemeyer 2002):

$$4Q3 \quad = \quad 7.3287 \times 10^{-5} \ DA^{0.70} \ P_w^{\ 3.58} \ S^{1.35} \qquad \text{(Eq. 1)}$$

where,

4Q3 = Four-day, three-year low-flow frequency (cfs)
DA = Drainage area (mi^2)
P_w = Average basin mean winter precipitation (inches)
S = Average basin slope (percent).

The average SEE and coefficient of determination are 94 and 66 percent, respectively, for this regression equation (Waltemeyer 2002). The 4Q3s for the upper Jemez River, East Fork Jemez, and San Antonio Creek were estimated using the regression equation for mountainous regions (Eq. 1) because the mean elevations for these assessment units were above 7,500 feet in elevation (Table 3.2).

Table 3.2 Calculation of 4Q3 Low-Flow Frequencies

Assessment Unit	Average elevation (ft.)	Drainage area (mi^2)	Mean winter precipitation (in.)	Average basin slope (percent)	4Q3 (cfs)
East Fork Jemez (San Antonio Creek to VCNP bnd)	8793	67	12.3	20.7%	1.33
Jemez River (Rio Guadalupe to Soda Dam nr Jemez Springs)	8750	200	11.9	24.2%	3.16
Jemez River (Soda Dam nr Jemez Springs to E Fork Jemez)	8829	179	12.6	23.2%	3.35
San Antonio Creek (E Fork Jemez to VCNP bnd)	8888	104	13.1	23.9%	2.72

The 4Q3 value for the East Fork Jemez was converted from cubic feet per second (cfs) to units of million gallons per day (mgd) as follows:

$$1.33\,\frac{ft^3}{\sec} \times 1{,}728\,\frac{in^3}{ft^3} \times 0.004329\,\frac{gal}{in^3} \times 86{,}400\,\frac{\sec}{day} \times 10^{-6} = 0.860\,mgd$$

The 4Q3 values for the other waterbodies were calculated in a similar manner.

It is important to remember that the TMDL itself is a value calculated at a defined critical condition, and is calculated as part of planning process designed to achieve water quality standards. Since flows vary throughout the year in these systems, the actual load at any given time will vary. Management of the load to improve stream water quality should be a goal to be attained.

3.3 Calculations

A target load for arsenic is calculated based on a flow, the current water quality criterion, and a conversion factor (0.00834) that is used to convert µg/L units to lbs/day (see Appendix B for conversion factor derivation). The target loading capacity is calculated using Equation 2. The results are shown in Table 3.3.

Critical flow (mgd) x Criterion (µg/L) x 0.00834 = Target Loading Capacity (Eq. 2)

Table 3.3 Calculation of target loads for dissolved arsenic

Assessment Unit	4Q3 Flow (mgd)	Dissolved Arsenic[1] (µg/L)	Conversion Factor	Target Load Capacity[2] (lbs/day)
East Fork Jemez (San Antonio Creek to VCNP bnd)	0.86	2.3	0.00834	0.017
Jemez River (Zia Pueblo bnd to Jemez Pueblo bnd)	8.86	9.0	0.00834	0.67
Jemez River (Jemez Pueblo bnd to Rio Guadalupe)	7.82	9.0	0.00834	0.59
Jemez River (Rio Guadalupe to Soda Dam nr Jemez Springs)	2.04	9.0	0.00834	0.15
Jemez River (Soda Dam nr Jemez Springs to E Fork Jemez)	2.17	2.3	0.00834	0.042
San Antonio Creek (E Fork Jemez to VCNP bnd)	1.76	2.3	0.00834	0.034

Notes: [1] target values are based on the most conservative criterion applicable to each assessment unit.
[2] values rounded to two significant figures

The measured loads for arsenic were similarly calculated. The arithmetic mean of the data used to determine the impairment was substituted for the criterion in Equation 2. The same conversion factor of 0.00834 was used. Results are presented in Table 3.4.

Table 3.4 Calculation of measured loads for dissolved arsenic

Assessment Unit	4Q3 Flow (mgd)	Dissolved Arsenic Arithmetic Mean[1] (µg/L)	Conversion Factor	Measured Load[2] (lbs/day)
East Fork Jemez (San Antonio Creek to VCNP bnd)	0.86	4.45	0.00834	0.032
Jemez River (Zia Pueblo bnd to Jemez Pueblo bnd)	8.86	46.7	0.00834	3.5
Jemez River (Jemez Pueblo bnd to Rio Guadalupe)	7.82	59.4	0.00834	3.9
Jemez River (Rio Guadalupe to Soda Dam nr Jemez Springs)	2.04	78.1	0.00834	1.3
Jemez River (Soda Dam nr Jemez Springs to E Fork Jemez)	2.17	13.0	0.00834	0.24
San Antonio Creek (E Fork Jemez to VCNP bnd)	1.76	4.50	0.00834	0.066

Notes: [1] dissolved arsenic concentration is the arithmetic mean of observed exceedences
[2] values rounded to two significant figures

3.4 Waste Load Allocations and Load Allocations

3.4.1 Waste Load Allocation

There are no facilities with an NPDES permit in the East Fork Jemez (San Antonio Creek to VCNP bnd), Jemez River (Zia Pueblo bnd to Jemez Pueblo bnd), Jemez River (Soda Dam near Jemez Springs to East Fork), or San Antonio Creek (East Fork Jemez to VCNP bnd). However, there are existing point source dischargers with NPDES permits in the other impaired reaches. The Jemez Valley Public Schools wastewater treatment plant (WWTP) (NM0028479) discharges directly into the Jemez River between the Jemez Pueblo boundary and Rio Guadalupe. The Village of Jemez Springs WWTP discharges directly into the Jemez River between Rio Guadalupe and Soda Dam. Each NPDES-permitted facility that discharges into an impaired reach has a wasteload allocation (WLA) included in this TMDL (Table 3.5). Currently, these treatment plants do not have arsenic effluent limits defined in their respective NPDES permits. A compliance schedule will be included in the NPDES permit for the facility to meet any new effluent requirements.

There are no individually permitted Municipal Separate Storm Sewer System (MS4) storm water permits in these assessment units. Because there are no individually permitted MS4 storm water permits in these assessment units, this TMDL does not include a specific WLA for storm water discharges for the East Fork Jemez, the mainstem of the Jemez River, or San Antonio Creek.

Excess metal levels may be a component of some (primarily construction) storm water discharges covered under General NPDES permits, so the load from these discharges should be addressed. In contrast to discharges from other industrial storm water and individual process wastewater permitted facilities, storm water discharges from construction activities are transient because they occur mainly during the construction itself, and then only during storm events. Coverage under the NPDES construction general storm water permit (CGP) requires preparation of a Storm Water Pollution Prevention Plan (SWPPP) that includes identification and control of all pollutants associated with the construction activities to minimize impacts to water quality. In addition, the current CGP also includes state specific requirements to implement best management practices (BMPs) that are designed to prevent to the maximum extent practicable, an increase in sediment, or a parameter that addresses sediment (e.g., total suspended solids, turbidity, siltation, stream bottom deposits, bacteria etc.) and water velocity during and after construction compared to pre-construction conditions. In this case, compliance with a SWPPP that meets the requirements of the CGP is generally assumed to be consistent with this TMDL.

Other industrial storm water facilities are generally covered under the current NPDES Multi-Sector General Storm Water Permit (MSGP). This permit also requires preparation of an SWPPP that includes identification and control of all pollutants associated with the industrial activities to minimize impacts to water quality. In addition, the current MSGP also includes specific requirements to further limit (or eliminate) pollutant loading to water quality impaired/water quality limited waters from facilities where there is a reasonable potential to contain pollutants for which the receiving water is impaired. In this case, compliance with a SWPPP that meets the requirements of the MSGP is generally assumed to be consistent with this TMDL. Individual WLAs for the General Permits were not possible to calculate at this time in this watershed using available tools. Loads that are in compliance with the General Permits from facilities covered are therefore currently calculated as part of the load allocation.

The WLAs for each NPDES-permitted facility were calculated based the design capacity of the WWTP, the average, measured in-stream concentration of arsenic, and a conversion factor (0.00834) that is used to convert µg/L units to lbs/day (see Appendix B for conversion factor derivation). Results are presented in Table 3.5.

Table 3.5 Calculation of wasteload allocations for dissolved arsenic

NPDES-Permitted Facility	Dilution Capacity [1]: Q^*	Design Capacity[2] (mgd)	Target Concentration (µg/L)	Conversion Factor	WLA[5] (lbs/day)
Jemez Valley Public Schools WWTP (NM0028479)	5%	0.030	57.6[3]	0.00834	0.014
Village of Jemez Springs WWTP (NM0028011)	13%	0.075	150[4]	0.00834	0.094

Notes: [1] Dilution capacity is the ability of the receiving stream to dilute and disperse effluent. When the dilution capacity is large (i.e. Q^* is small), the dilution factor is also large and vice versa.
[2] Based on the design capacity for the WWTP.
[3] Since no effluent data were available, target concentration is the average in-stream dissolved As concentration from the 2005 SWQB water quality survey (52.4 µg/L) + a 10% margin of error
[4] Target concentration is the average As concentration from the Jemez Springs WWTP during the 2005 SWQB water quality survey (150 µg/L)
[5] Values rounded to two significant figures

The amount of dilution available is an important factor to consider when allocating loads and determining allowable effluent concentrations. Receiving water quality primarily depends on the dilution capacity available and the effectiveness of the treatment technology. A discharge from a small facility into a large river may pose no threat to water quality, whereas a discharge from a larger facility into a smaller stream may cause significant water quality deterioration in the receiving water if the level of treatment is not adequate.

3.4.2 Load Allocation

In order to calculate the LA, the WLA and MOS were subtracted from the target capacity TMDL following Equation 3:

$$WLA + LA + MOS = TMDL \qquad \text{(Eq. 3)}$$

The MOS is estimated to be 20 percent of the target load calculated in Table 3.3. Results are presented in Table 3.6. Additional details on the MOS are presented in Section 3.7.

Table 3.6 TMDL for dissolved arsenic

Assessment Unit	WLA (lbs/day)	LA (lbs/day)	MOS (20%) (lbs/day)	TMDL* (lbs/day)
East Fork Jemez (San Antonio Creek to VCNP bnd)	0	0.013	0.0033	0.017
Jemez River (Zia Pueblo bnd to Jemez Pueblo bnd)	0	0.53	0.13	0.67
Jemez River (Jemez Pueblo bnd to Rio Guadalupe)	0.014	0.46	0.12	0.59
Jemez River (Rio Guadalupe to Soda Dam nr Jemez Springs)	0.094	0.025	0.031	0.15
Jemez River (Soda Dam nr Jemez Springs to E Fork Jemez)	0	0.033	0.0083	0.042
San Antonio Creek (E Fork Jemez to VCNP bnd)	0	0.027	0.0067	0.034

Notes: *values rounded to two significant figures

The extensive data collection and analyses necessary to determine background arsenic loads for the Jemez River watershed were beyond the resources available for this study. It is therefore assumed that a portion of the LA is made up of natural background loads.

The load reductions necessary to meet the target loads were calculated to be the difference between the calculated TMDL (Table 3.3) and the measured loads (Table 3.4), and are shown in Table 3.7. These load reduction tables are presented for informational purposes only. However, it is important to note that WLAs and LAs are estimates based on a specific flow condition (i.e., 4Q3 in this case). Under differing hydrologic conditions, the loads will change. For this reason the load allocations given here are less meaningful than are the relative percent reductions. Successful implementation of this TMDL will be determined based on achieving the current water quality standards.

Table 3.7 Calculation of load reduction for dissolved arsenic

Assessment Unit	Target Load (lbs/day) *(a)*	Measured Load (lbs/day)	Load Reduction (lbs/day)	Percent Reduction *(b)*
East Fork Jemez (San Antonio Creek to VCNP bnd)	0.013	0.032	0.019	59%
Jemez River (Zia Pueblo bnd to Jemez Pueblo bnd)	0.53	3.5	2.8	80%
Jemez River (Jemez Pueblo bnd to Rio Guadalupe)	0.47	3.9	3.4	88%
Jemez River (Rio Guadalupe to Soda Dam nr Jemez Springs)	0.12	1.3	1.2	91%
Jemez River (Soda Dam nr Jemez Springs to E Fork Jemez)	0.033	0.24	0.21	88%
San Antonio Creek (E Fork Jemez to VCNP bnd)	0.027	0.066	0.039	59%

Note: The MOS is not included in the load reduction calculations because it is a set aside value which accounts for any uncertainty or variability in TMDL calculations and therefore should not be subtracted from the measured load.
(a) Target Load = TMDL - MOS
(b) Percent reduction is the percent the existing measured load must be reduced to achieve the TMDL, and is calculated as follows: (Measured Load – Target Load) / Measured Load x 100

3.5 Identification and Description of Pollutant Source(s)

Probable sources that may be contributing to the observed load are displayed in Table 3.8. Probable sources of arsenic for these assessment units will be evaluated, refined, and changed as necessary through the Watershed Restoration Action Strategy (WRAS) process.

Table 3.8 Pollutant source summary for Arsenic

Assessment Unit	Pollutant Sources	Magnitude[(a)] (lbs/day)	Probable Sources[(b)] (% from each)
East Fork Jemez (San Antonio Creek to VCNP bnd)	Point:	0	0%
	Nonpoint:	0.014	100% Highway/road/bridge runoff, natural sources, other recreational pollution sources, rangeland grazing, silviculture harvesting, streambank modifications/destabilization
Jemez River (Zia Pueblo bnd to Jemez Pueblo bnd)	Point:	0	0%
	Nonpoint:	3.5	100% Natural Sources; Source Unknown
Jemez River (Jemez Pueblo bnd to R Guadalupe)	Point: NM0028479	0.078	2% Municipal Wastewater Treatment Plant
	Nonpoint:	3.822	98% Flow alterations from water diversions, highway/road/bridge runoff (non-construction related), inappropriate waste disposal, natural sources, other recreational pollution sources, rangeland grazing, source unknown
Jemez River (R Guadalupe to Soda Dam nr Jemez Springs)	Point: NM0028011	0.094	7% Municipal Wastewater Treatment Plant
	Nonpoint:	1.24	93% On-site treatment systems (septic systems and similar decentralized systems, highway/road/ bridge runoff (non-construction related), loss of riparian habitat, natural sources, other recreational pollution sources, rangeland grazing, site clearance (Land Development and Redevelopment), streambank modification/ destabilization
Jemez River (Soda Dam nr Jemez Springs to E Fork Jemez)	Point:	0	0%
	Nonpoint:	0.20	100% Highway/road/bridge runoff (non-construction related), loss of riparian habitat, natural sources, other recreational pollution sources, rangeland grazing, site clearance (Land Development and Redevelopment), streambank modifications/ destabilization
San Antonio Creek (E Fork Jemez to VCNP bnd)	Point:	0	0%
	Nonpoint:	0.037	100% Forest roads (road construction and use), loss of riparian habitat, natural sources, other recreational pollution sources, rangeland grazing, site clearance (land development and redevelopment), streambank modifications/ destabilization

Notes:
(a) Measured Loads in pounds per day.
(b) From the 2008-2010 Integrated CWA 303(d)/305(b) list (NMED/SWQB 2008b). This list of probable sources is based on staff observation and known land use activities in the watershed. These sources are not confirmed nor quantified at this time.

3.6 Linkage of Water Quality and Pollutant Sources

SWQB fieldwork includes an assessment of the probable sources of impairment (NMED/SWQB 1999). The sample Probable Sources field sheet in Appendix C provides an approach for a visual analysis of a pollutant source along an impaired reach. Although this procedure is subjective, SWQB feels that it provides the best available information for the identification of probable sources of impairment in this watershed. Table 3.8 displays probable sources of impairments along the reach as determined by field reconnaissance and assessment. Appendix C provides relevant excerpts from the 2008-20010 Integrated CWA 303(d)/305(b) List which includes the probable sources associated with each Assessment Unit in the Jemez River watershed.

The geology of the Jemez River Basin consists of a unique and complex distribution of Paleozoic limestone, Quaternary alluvium, and significant Quaternary volcanic deposits (Table 2.1, Figure 2.3). Streams in the basin arise in two distinct geologic settings. In the western region of the basin, Clear Creek, Rio de las Vacas, and Rito Peñas Negras originate in Precambrian metamorphic and Permian sedimentary rocks. Streams in the central and eastern regions of the watershed, Calaveras Creek, Rio Cebolla, San Antonio Creek, Sulphur Creek, Redondo Creek, and the East Fork of the Jemez River, originate in volcanic rocks, principally basalts and tuffs associated with the Valles Caldera. At the confluence of the Rio San Antonio and the East Fork, the Jemez River bed cuts through the volcanic rock and into a series of sedimentary strata that form the valley floor extending through the bottom of the study area.

Arsenic occurs naturally in groundwater of the Jemez River watershed. Data from the 2005 SWQB survey confirm that hot spring waters contain substantial concentrations of arsenic (Table 3.9). Springs occur when groundwater travels to the surface, often through cracks in bedrock caused by faulting. As water moves through cracks in the various rock types, it erodes the rock and becomes enriched with different constituents. Because heated water can hold more dissolved solids, warm and especially hot springs also often have a very high mineral content. Each assessment unit in the Jemez watershed that is impaired for arsenic also has at least one known warm or hot spring discharging into its waters; McCaughly Warm Spring discharges into the East Fork Jemez; Soda Dam Hot Spring, Jemez Springs Municipal Hot Spring, and Giggling Springs Hot Spring all discharge into the mainstem of the Jemez River; and San Antonio Hot Spring and Spence Hot Spring discharge into San Antonio Creek. The fact that each impaired AU has at least one associated spring, combined with the elevated arsenic concentrations of these spring waters, strongly suggests that warm/hot springs are substantial sources of arsenic in the Jemez watershed.

Table 3.9 Hot spring data from the Jemez River watershed

HOT SPRING	Collection Date/Time	Temperature	Analyte	Result
Giggling Springs Hot Spring - 31JemezGigSpr	10/18/2005 12:00	51.73°C	Arsenic	520 µg/L
Jemez Hot Spring - 31JemezHotSpr	10/18/2005 11:45	71.51°C	Arsenic	730 µg/L
Soda Dam Hot Spring - 31SodaDamHtSp	10/18/2005 10:15	37.33°C	Arsenic	930 µg/L
Spence Hot Spring - 31SpenceHotSp	10/18/2005 9:30	40.01°C	Arsenic	46 µg/L
San Antonio Hot Spring - 31SanAntHotSp	10/17/2005 20:00	40.31°C	Arsenic	6 µg/L

3.7 Margin of Safety

TMDLs should reflect a MOS based on the uncertainty or variability in the data, the point and nonpoint source load estimates, and the modeling analysis. The MOS can be expressed either implicitly or explicitly. An implicit MOS is incorporated by making conservative assumptions in the TMDL analysis, such as allocating a conservative load to background sources. An explicit MOS is applied by reserving a portion of the TMDL and not allocating it to any other sources.

For these arsenic TMDLs, the margin of safety was developed using a combination of conservative assumptions and explicit recognition of potential errors. Therefore, this margin of safety is the sum of the following two elements:

- *Conservative Assumptions*

  Using the 4Q3 critical low flow "worst case scenario" to calculate the allowable loads.

  Using the design capacity for calculating the point source loading knowing that both the Jemez Valley Public Schools WWTP and the Village of Jemez Springs WWTP are batch dischargers and do not discharge continuously. Additionally, under most conditions, these treatment plants are not operating at full capacity.

- *Explicit recognition of potential errors*

  A level of uncertainty exists in water quality sampling. Techniques used for measuring arsenic concentrations in stream water can lead to inaccuracies in the data. A conservative MOS for this element is **10 percent.**

  There is also inherent error in all flow calculations. A conservative MOS for this element is **10 percent.**

  Therefore, based on the potential errors described above, a conservative, explicit MOS of 20% was assigned to the arsenic TMDLs.

3.8 Consideration of Seasonal Variation

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs take into consideration seasonal variation in watershed conditions and pollutant loading. During the 2005 water quality survey, arsenic exceedences occurred across most sampling events. Higher flows may flush more nonpoint source runoff containing sediment and metals. It is possible the criterion may be exceeded under a low flow condition when there is insufficient dilution. Evaluation of seasonal variability for potential nonpoint sources is difficult due to limited available data. Data used in the calculation of this TMDL were collected during the spring, summer, and fall of 2005 in order to ensure coverage of any potential seasonal variation in the system.

3.9 Future Growth

Growth estimates by county are available from the New Mexico Bureau of Business and Economic Research. These estimates project growth to the year 2035. Growth estimates for Sandoval County project a 51% growth rate through 2035. However, Sandoval County includes major cities such as Bernalillo, Corrales, and Rio Rancho. As of 2009, Jemez Springs' population (the largest incorporated town in the study area) is 1,367 people. Since 2000, Jemez Springs has had a population growth of 9.37 percent, but is not expected to have much growth in the future because it is confined by valley walls and surrounded by National Forest.

According to the data, the overwhelming source of arsenic loading is from hot springs and other diffuse nonpoint sources. Estimates of future growth are not anticipated to lead to a significant increase in metals concentrations that cannot be controlled with best management practice (BMP) implementation in this watershed. However, it is imperative that BMPs continue to be utilized and improved upon in this watershed while continuing to improve road conditions and grazing allotments and adhering to SWPPP requirements related to construction and industrial activities covered under the general permit.

4.0 BORON

Assessment of the data from the 2005 SWQB water quality survey in the Jemez River watershed identified exceedences of the New Mexico water quality standards for boron in the mainstem of the Jemez River, specifically Jemez River (Zia Pueblo boundary to Jemez Pueblo boundary), Jemez River (Jemez Pueblo boundary to Rio Guadalupe), and Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs). Consequently, these waterbodies were listed on the 2008-2010 Integrated CWA §303(d)/§305(b) list for boron (NMED/SWQB 2008b).

4.1 Target Loading Capacity

Target values for these boron TMDLs will be determined based on 1) the presence of numeric criteria or appropriate numeric translator to a narrative standard, 2) the degree of experience in applying the indicator, and 3) the ability to easily monitor and produce quantifiable and reproducible results. This TMDL is also consistent with New Mexico's antidegradation policy.

According to the New Mexico water quality standards (20.6.4.900 NMAC), the dissolved boron criteria are 750 µg/L for irrigation and 5,000 µg/L for livestock watering. Exceedences for each assessment unit are presented in Table 4.1.

Boron is a naturally occurring element widely distributed in the earth's crust, soils, and minerals. In water boron is usually found as boric acid. High concentrations of boron are common for some volcanic spring waters and boron may also enter the air, water, and land from wind-blown dust or runoff and leaching. Boron is an essential plant nutrient, although high soil concentrations of boron may also be toxic to plants. Additionally, sodium perborate serves as a source of active oxygen in many detergents, laundry detergents, cleaning products, laundry bleaches, and some tooth bleaching formulas.

Table 4.1 Dissolved boron exceedences

Assessment Unit	Designated Use Affected	Associated Criterion (µg/L)	Exceedence Ratio (# exceedences / total # samples)
Jemez River (Zia Pueblo bnd to Jemez Pueblo bnd)	IRR	750	2/3
Jemez River (Jemez Pueblo boundary to Rio Guadalupe)	IRR	750	6/24
Jemez River (Rio Guadalupe to Soda Dam nr Jemez Springs)	IRR	750	4/9

IRR = Irrigation
µg/L = micrograms per liter

4.2 Flow

Boron concentrations can vary as a function of flow; therefore TMDLs are calculated at a specific flow. The target flow value used to calculate the TMDL for this stream reach was obtained using a 4-day, 3-year low-flow frequency (4Q3) regression model. The 4Q3 is the annual lowest 4 consecutive day flow that occurs with a frequency of at least once every 3 years. When available, USGS gages are used to estimate flow.

The 4Q3 flow for the Jemez River (Jemez Pueblo boundary to Rio Guadalupe) is based on USGS gage data. Jemez River near Jemez, NM (USGS Gage 08324000) is located in the Jemez River (Jemez Pueblo bnd to Rio Guadalupe) assessment unit (AU). The 4Q3 was estimated using the USGS A193 calculation for Log Pearson Type III distribution through DFLOW software, Version 3.1b (USEPA 2006). DFLOW 3.1b is a Windows-based tool developed to estimate user selected design stream flows for low flow analysis. The calculated 4Q3 is as follows:

- Jemez River (Jemez Pueblo bnd to Rio Guadalupe) = 12.1 cfs

It is often necessary to calculate a critical flow for a portion of a watershed where there is no active flow gage as in the upper Jemez River. This can be accomplished by applying one of several different formulas developed by the U.S. Geological Survey (USGS).

One formula is recommended when the ratio between the two watershed areas is between 0.5 and 1.5 (Thomas et al. 1997). The nearest gage to the points of interest is the Jemez River near Jemez, NM (USGS Gage 08324000). The drainage area above this gage (A_g) is 470 mi^2. Using the guidelines recommended by the USGS, when the ratio between the ungaged and gaged watersheds is within the 0.5-1.5 range the following formula should be used to estimate flow:

$$Q_{T(u)} = Q_{T(g)} (A_u / A_g)^{0.566}$$

where,

$Q_{T(u)}$ = weighted flow frequency estimate at the ungaged site, in cubic feet per second (cfs)
$Q_{T(g)}$ = 4Q3 low-flow frequency estimate at the gaged site, in cfs
A_u = drainage area above the ungaged site, in square miles
A_g = drainage area above the gaged site, in square miles

The drainage area of the Jemez River above San Ysidro at NM Highway 4 is 586 mi^2. The watershed ratio between the gaged Jemez River (Jemez Pueblo boundary to Rio Guadalupe) and the ungaged Jemez River (Zia Pueblo boundary to Jemez Pueblo boundary) is 1.25. Therefore, the estimated 4Q3 is:

- Jemez River (Zia Pueblo bnd to Jemez Pueblo bnd) = 13.7 cfs

When the ratio between the gaged and ungaged watersheds is outside the 0.5-1.5 range analysis methods described by Waltemeyer (2002) are used to estimate flow. In this analysis, two regression equations for estimating 4Q3 were developed based on physiographic regions of NM (i.e., statewide and mountainous regions above 7,500 feet in elevation). The following regression equation for mountainous regions above 7,500 feet in elevation is based on data from 40 gaging stations with non-zero discharge (Waltemeyer 2002):

$$4Q3 = 7.3287 \times 10^{-5}\ DA^{0.70}\ P_w^{\ 3.58}\ S^{1.35} \qquad \text{(Eq. 1)}$$

where,

4Q3 = Four-day, three-year low-flow frequency (cfs)
DA = Drainage area (mi^2)
P_w = Average basin mean winter precipitation (inches)
S = Average basin slope (percent).

The average SEE and coefficient of determination are 94 and 66 percent, respectively, for this regression equation (Waltemeyer 2002). The 4Q3s for the upper Jemez River was estimated using the regression equation for mountainous regions (Eq. 1) because the mean elevation for this assessment unit was above 7,500 feet in elevation (Table 4.2).

Table 4.2 Calculation of 4Q3 Low-Flow Frequency

Assessment Unit	Average elevation (ft.)	Drainage area (mi^2)	Mean winter precipitation (in.)	Average basin slope (percent)	4Q3 (cfs)
Jemez River (Rio Guadalupe to Soda Dam nr Jemez Springs)	8750	200	11.9	24.2%	3.16

The 4Q3 value for the upper Jemez River was converted from cubic feet per second (cfs) to units of million gallons per day (mgd) as follows:

$$3.16\,\frac{ft^3}{\sec} \times 1{,}728\,\frac{in^3}{ft^3} \times 0.004329\,\frac{gal}{in^3} \times 86{,}400\,\frac{\sec}{day} \times 10^{-6} = 2.04 mgd$$

It is important to remember that the TMDL itself is a value calculated at a defined critical condition, and is calculated as part of planning process designed to achieve water quality standards. Since flows vary throughout the year in these systems, the actual load at any given time will vary based on the changing flow. Management of the load to improve stream water quality should be a goal to be attained.

4.3 Calculations

A target load for boron is calculated based on a flow, the current water quality criterion, and a conversion factor (0.00834) that is used to convert µg/L units to lbs/day (see Appendix B for conversion factor derivation). The target loading capacity is calculated using Equation 2. The results are shown in Table 4.3.

Critical flow (mgd) x Criterion (µg/L) x 0.00834 = Target Loading Capacity (Eq. 2)

Table 4.3 Calculation of target loads for dissolved boron

Assessment Unit	4Q3 Flow (mgd)	Dissolved Boron[1] (µg/L)	Conversion Factor	Target Load Capacity[2] (lbs/day)
Jemez River (Zia Pueblo bnd to Jemez Pueblo bnd)	8.86	750	0.00834	55.4
Jemez River (Jemez Pueblo bnd to Rio Guadalupe)	7.82	750	0.00834	48.9
Jemez River (Rio Guadalupe to Soda Dam nr Jemez Springs)	2.04	750	0.00834	12.8

Notes: [1] target values are based on the most conservative criterion applicable to each assessment unit.
[2] values rounded to three significant figures

The measured loads for boron were similarly calculated. The arithmetic mean of the data used to determine the impairment was substituted for the criterion in Equation 2. The same conversion factor of 0.00834 was used. Results are presented in Table 4.4.

Table 4.4 Calculation of measured loads for dissolved boron

Assessment Unit	4Q3 Flow (mgd)	Dissolved Boron Arithmetic Mean[1] (µg/L)	Conversion Factor	Measured Load[2] (lbs/day)
Jemez River (Zia Pueblo bnd to Jemez Pueblo bnd)	8.86	1,350	0.00834	99.8
Jemez River (Jemez Pueblo bnd to Rio Guadalupe)	7.82	952	0.00834	62.1
Jemez River (Rio Guadalupe to Soda Dam nr Jemez Springs)	2.04	1,125	0.00834	19.1

Notes: [1] dissolved boron concentration is the arithmetic mean of the observed exceedences
[2] values rounded to three significant figures

4.4 Waste Load Allocations and Load Allocations

4.4.1 Waste Load Allocation

There are no facilities with an NPDES permit in the Jemez River (Zia Pueblo boundary to Jemez Pueblo boundary). However, there are existing point source dischargers with NPDES permits in the other impaired reaches. The Jemez Valley Public Schools wastewater treatment plant (WWTP) (NM0028479) discharges directly into the Jemez River between the Jemez Pueblo boundary and Rio Guadalupe. The Village of Jemez Springs WWTP discharges directly into the Jemez River between Rio Guadalupe and Soda Dam. Each NPDES-permitted facility that discharges into an impaired reach has a wasteload allocation (WLA) included in this TMDL (Table 4.5). Currently, these treatment plants do not have boron effluent limits defined in their respective NPDES permits. A compliance schedule will be included in the NPDES permit for the facility to meet any new effluent requirements.

There are no individually permitted Municipal Separate Storm Sewer System (MS4) storm water permits in these assessment units. Because there are no individually permitted MS4 storm water permits in these assessment units, this TMDL does not include a specific WLA for storm water discharges for the mainstem of the Jemez River.

Excess boron levels may be a component of some (primarily construction) storm water discharges covered under General NPDES permits, so the load from these discharges should be addressed. In contrast to discharges from other industrial storm water and individual process wastewater permitted facilities, storm water discharges from construction activities are transient because they occur mainly during the construction itself, and then only during storm events. Coverage under the NPDES construction general storm water permit (CGP) requires preparation of a Storm Water Pollution Prevention Plan (SWPPP) that includes identification and control of all pollutants associated with the construction activities to minimize impacts to water quality. In addition, the current CGP also includes state specific requirements to implement best management practices (BMPs) that are designed to prevent to the maximum extent practicable, an increase in sediment, or a parameter that addresses sediment (e.g., total suspended solids, turbidity, siltation, stream bottom deposits, bacteria etc.) and water velocity during and after construction compared to pre-construction conditions. In this case, compliance with a SWPPP that meets the requirements of the CGP is generally assumed to be consistent with this TMDL.

Other industrial storm water facilities are generally covered under the current NPDES Multi-Sector General Storm Water Permit (MSGP). This permit also requires preparation of an SWPPP that includes identification and control of all pollutants associated with the industrial activities to minimize impacts to water quality. In addition, the current MSGP also includes specific requirements to further limit (or eliminate) pollutant loading to water quality impaired/water quality limited waters from facilities where there is a reasonable potential to contain pollutants for which the receiving water is impaired. In this case, compliance with a SWPPP that meets the requirements of the MSGP is generally assumed to be consistent with this TMDL. Individual WLAs for the General Permits were not possible to calculate at this time in this watershed using available tools. Loads that are in compliance with the General Permits from facilities covered are therefore currently calculated as part of the load allocation.

The WLAs for each NPDES-permitted facility were calculated based the design capacity of the WWTP, the average, measured in-stream concentration of boron, and a conversion factor (0.00834) that is used to convert μg/L units to lbs/day (see Appendix B for conversion factor derivation). Results are presented in Table 4.5.

Table 4.5 Calculation of wasteload allocations for dissolved boron

NPDES-Permitted Facility	Dilution Capacity [1]: Q^*	Design Capacity[2] (mgd)	Target Concentration (μg/L)	Conversion Factor	WLA[5] (lbs/day)
Jemez Valley Public Schools WWTP (NM0028479)	5%	0.030	632[3]	0.00834	0.158
Village of Jemez Springs WWTP (NM0028011)	13%	0.075	2,150[4]	0.00834	1.34

Notes: [1] Dilution capacity is the ability of the receiving stream to dilute and disperse effluent. When the dilution capacity is large (i.e. Q^* is small), the dilution factor is also large and vice versa.
[2] Based on the design capacity for the WWTP.
[3] Since no effluent data were available, target concentration is the average in-stream dissolved boron concentration from the 2005 SWQB water quality survey (575 μg/L) + a 10% margin of error
[4] Target concentration is the average boron concentration from the Jemez Springs WWTP during the 2005 SWQB water quality survey (2,150 μg/L)
[5] Values rounded to two significant figures

The amount of dilution available is an important factor to consider when allocating loads and determining allowable effluent concentrations. Receiving water quality primarily depends on the dilution capacity available and the effectiveness of the treatment technology. A discharge from a small facility into a large river may pose no threat to water quality, whereas a discharge from a larger facility into a smaller stream may cause significant water quality deterioration in the receiving water if the level of treatment is not adequate.

4.4.2 Load Allocation

In order to calculate the LA, the WLA and MOS were subtracted from the target capacity TMDL following **Equation 3**:

$$WLA + LA + MOS = TMDL \qquad \text{(Eq. 3)}$$

The MOS is estimated to be 20 percent of the target load calculated in Table 4.3. Results are presented in Table 4.6. Additional details on the MOS are presented in Section 4.7.

Table 4.6 TMDL for dissolved boron

Assessment Unit	WLA (lbs/day)	LA (lbs/day)	MOS (20%) (lbs/day)	TMDL* (lbs/day)
Jemez River (Zia Pueblo bnd to Jemez Pueblo bnd)	0	44.3	11.1	55.4
Jemez River (Jemez Pueblo bnd to Rio Guadalupe)	0.158	39.0	9.78	48.9
Jemez River (Rio Guadalupe to Soda Dam nr Jemez Springs)	1.34	8.90	2.56	12.8

Notes: *values rounded to three significant figures

The extensive data collection and analyses necessary to determine background boron loads for the Jemez River watershed were beyond the resources available for this study. It is therefore assumed that a portion of the LA is made up of natural background loads.

The load reductions necessary to meet the target loads were calculated to be the difference between the calculated TMDL (Table 4.3) and the measured loads (Table 4.4), and are shown in Table 4.7. These load reduction tables are presented for informational purposes only. However, it is important to note that WLAs and LAs are estimates based on a specific flow condition (i.e., 4Q3 in this case). Under differing hydrologic conditions, the loads will change. For this reason the load allocations given here are less meaningful than are the relative percent reductions. Successful implementation of this TMDL will be determined based on achieving the current water quality standards.

Table 4.7 Calculation of load reduction for dissolved boron

Assessment Unit	Target Load[(a)] (lbs/day)	Measured Load (lbs/day)	Load Reduction (lbs/day)	Percent Reduction[(b)]
Jemez River (Zia Pueblo bnd to Jemez Pueblo bnd)	44.3	99.8	55.5	56%
Jemez River (Jemez Pueblo bnd to Rio Guadalupe)	39.1	62.1	23.0	37%
Jemez River (Rio Guadalupe to Soda Dam nr Jemez Springs)	10.2	19.1	8.9	47%

Note: The MOS is not included in the load reduction calculations because it is a set aside value which accounts for any uncertainty or variability in TMDL calculations and therefore should not be subtracted from the measured load.
(a) Target Load = TMDL – MOS
(b) Percent reduction is the percent the existing measured load must be reduced to achieve the TMDL, and is calculated as follows: (Measured Load – Target Load) / Measured Load x 100

4.5 Identification and Description of Pollutant Source(s)

Probable sources of boron for these assessment units will be evaluated, refined, and changed as necessary through the Watershed Restoration Action Strategy (WRAS) process. Probable sources that may be contributing to the observed load are displayed in Table 4.8:

Table 4.8 Pollutant source summary for Boron

Assessment Unit	Pollutant Sources	Magnitude[(a)] (lbs/day)	Probable Sources[(B)] (% from each)
Jemez River (Zia Pueblo bnd to Jemez Pueblo bnd)	Point:	0	0%
	Nonpoint:	99.8	100% Natural Sources; Source Unknown
Jemez River (Jemez Pueblo bnd to R Guadalupe)	Point: NM0028479	0.621	1% Municipal Wastewater Treatment Plant
	Nonpoint:	61.5	99% Flow alterations from water diversions, highway/road/bridge runoff (non-construction related), inappropriate waste disposal, natural sources, other recreational pollution sources, rangeland grazing, source unknown
Jemez River (R Guadalupe to Soda Dam nr Jemez Springs)	Point: NM0028011	1.34	7% Municipal Wastewater Treatment Plant
	Nonpoint:	17.8	93% On-site treatment systems (septic systems and similar decentralized systems, highway/road/ bridge runoff (non-construction related), loss of riparian habitat, natural sources, other recreational pollution sources, rangeland grazing, site clearance (Land Development and Redevelopment), streambank modification/ destabilization

Notes:
(a) Measured Load.
(b) From the 2008-2010 Integrated CWA 303(d)/305(b) list (NMED/SWQB 2008b). This list of probable sources is based on staff observation and known land use activities in the watershed. These sources are not confirmed nor quantified at this time.

4.6 Linkage of Water Quality and Pollutant Sources

SWQB fieldwork includes an assessment of the probable sources of impairment (NMED/SWQB 1999). The Probable Sources field sheet sample in Appendix C provides an approach for a visual analysis of a pollutant source along an impaired reach. Although this procedure is subjective, SWQB feels that it provides the best available information for the identification of probable sources of impairment in this watershed. Table 4.7 displays probable sources of impairments along the reach as determined by field reconnaissance and assessment. Appendix C provides relevant excerpts from the 2008-20010 Integrated CWA 303(d)/305(b) List which includes the probable sources associated with each Assessment Unit in the Jemez River watershed.

The geology of the Jemez River basin consists of a unique and complex distribution of Paleozoic limestone, Quaternary alluvium, and significant Quaternary volcanic deposits (Table 2.1, Figure 2.3). Streams in the basin arise in two distinct geologic settings. In the western region of the basin, Clear Creek, Rio de las Vacas, and Rito Peñas Negras originate in Precambrian metamorphic and Permian sedimentary rocks. Streams in the central and eastern regions of the watershed, Calaveras Creek, Rio Cebolla, San Antonio Creek, Sulphur Creek, Redondo Creek, and the East Fork of the Jemez River, originate in volcanic rocks, principally basalts and tuffs associated with the Valles Caldera. At the confluence of the Rio San Antonio and the East Fork, the Jemez River bed cuts through the volcanic rock and into a series of sedimentary strata that form the valley floor extending through the bottom of the study area.

Boron occurs naturally in groundwater in the Jemez River watershed. Data from the 2005 SWQB survey confirm that hot spring waters contain substantial concentrations of boron (Table 4.9). Springs occur when groundwater travels to the surface, often through cracks in bedrock caused by faulting. As water moves through cracks in the various rock types, it erodes the rock and becomes enriched with different constituents. Because heated water can hold more dissolved solids, warm and especially hot springs also often have a very high mineral content. Each assessment unit in the Jemez watershed that is impaired for boron also has hot spring discharge mixing with its waters; Soda Dam Hot Spring, Jemez Springs Municipal Hot Spring, and Giggling Springs Hot Spring all discharge into the mainstem of the Jemez River. The fact that each impaired AU has at least one associated spring, combined with the elevated boron concentrations measured in these spring waters, strongly suggests that warm/hot springs are substantial sources of boron in the Jemez watershed.

Table 4.9 Hot spring data from the Jemez River watershed

HOT SPRING	Collection Date/Time	Temperature	Analyte	Result
Giggling Springs Hot Spring - 31JemezGigSpr	10/18/2005 12:00	51.73°C	Boron	7,000 µg/L
Jemez Hot Spring - 31JemezHotSpr	10/18/2005 11:45	71.51°C	Boron	8,100 µg/L
Soda Dam Hot Spring - 31SodaDamHtSp	10/18/2005 10:15	37.33°C	Boron	11,000 µg/L
Spence Hot Spring - 31SpenceHotSp	10/18/2005 9:30	40.01°C	Boron	200 µg/L
San Antonio Hot Spring - 31SanAntHotSp	10/17/2005 20:00	40.31°C	Boron	100 µg/L

4.7 Margin of Safety

TMDLs should reflect a MOS based on the uncertainty or variability in the data, the point and nonpoint source load estimates, and the modeling analysis. The MOS can be expressed either implicitly or explicitly. An implicit MOS is incorporated by making conservative assumptions in the TMDL analysis, such as allocating a conservative load to background sources. An explicit MOS is applied by reserving a portion of the TMDL and not allocating it to any other sources.

For these boron TMDLs, the margin of safety was developed using a combination of conservative assumptions and explicit recognition of potential errors. Therefore, this margin of safety is the sum of the following two elements:

- *Conservative Assumptions*

  Using the 4Q3 critical low flow "worst case scenario" to calculate the allowable loads.

  Using the design capacity for calculating the point source loading knowing that both the Jemez Valley Public Schools WWTP and the Village of Jemez Springs WWTP are batch dischargers and do not discharge continuously. Additionally, under most conditions, these treatment plants are not operating at full capacity.

- *Explicit recognition of potential errors*

  A level of uncertainty exists in water quality sampling. Techniques used for measuring boron concentrations in stream water can lead to inaccuracies in the data. A conservative MOS for this element is **10 percent.**

  There is inherent error in all flow calculations. A conservative MOS for this element is **10 percent.**

  Therefore, based on the potential errors described above, a conservative, explicit MOS of 20% was assigned to the boron TMDLs.

4.8 Consideration of Seasonal Variation

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs take into consideration seasonal variation in watershed conditions and pollutant loading. During the 2005 water quality survey, boron exceedences occurred across most sampling events. Higher flows may flush more nonpoint source runoff containing sediment and metals. It is possible the criterion may be exceeded under a low flow condition when there is insufficient dilution. Evaluation of seasonal variability for potential nonpoint sources is difficult due to limited available data. Data used in the calculation of this TMDL were collected during the spring, summer, and fall of 2005 in order to ensure coverage of any potential seasonal variation in the system.

4.9 Future Growth

Growth estimates by county are available from the New Mexico Bureau of Business and Economic Research. These estimates project growth to the year 2035. Growth estimates for Sandoval County project a 51% growth rate through 2035. However, Sandoval County includes major cities such as Bernalillo, Corrales, and Rio Rancho. As of 2009, Jemez Springs' population (the largest incorporated town in the study area) is 1,367 people. Since 2000, Jemez Springs has had a population growth of 9.37 percent, but is not expected to have much growth in the future because it is confined by valley walls and surrounded by National Forest.

According to the data, the overwhelming source of boron loading is from hot springs and other diffuse nonpoint sources. Estimates of future growth are not anticipated to lead to a significant increase in metals concentrations that cannot be controlled with best management practices (BMPs) in this watershed. However, it is imperative that BMPs continue to be utilized and improved upon in this watershed while continuing to improve road conditions and grazing allotments and adhering to SWPPP requirements related to construction and industrial activities covered under the general permit.

5.0 PLANT NUTRIENTS

The potential for excessive nutrients in the Jemez River, Rio de las Vacas, and Rito Peñas Negras was noted through visual observation during the 2005 SWQB watershed survey. Assessment of various water quality parameters indicated nutrient impairment in Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs), Rio de las Vacas (Rio Cebolla to Clear Creek), and Rito Peñas Negras (Rio de las Vacas to headwaters).

5.1 Target Loading Capacity

The target values for nutrient loads are determined based on 1) the presence of numeric or narrative 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 the target value for plant nutrients is based on both narrative and numeric translators.

The New Mexico WQCC has adopted narrative water quality standards criterion for plant nutrients to sustain and protect existing or attainable uses of the surface waters of the state. This general criterion applies to surface waters of the state at all times unless a specific criterion is provided elsewhere. The narrative criterion for plant nutrients leading to an assessment of use impairment is as follows (Subsection E of 20.6.4.13 NMAC):

> ***Plant Nutrients:*** *Plant nutrients from other than natural causes shall not be present in concentrations which will produce undesirable aquatic life or result in the dominance of nuisance species in surface waters of the state.*

There are two potential contributors to nutrient enrichment in a given stream: excessive nitrogen and/or phosphorus. The reason for controlling plant growth is to preserve aesthetic and ecologic characteristics along the waterway. The intent of numeric criteria for phosphorus and nitrogen is to control the excessive growth of attached algae and higher aquatic plants that can result from the introduction of these plant nutrients into streams. Numeric criteria or translators also are necessary to establish targets for total maximum daily loads (TMDLs), to develop water quality-based permit limits and source control plans, and to support designated uses within the watershed.

Phosphorous is found in water primarily as ortho-phosphate. In contrast nitrogen may be found as several dissolved species all of which must be considered in loading. Total Nitrogen is defined as the sum of Nitrate+Nitrite (N+N), and Total Kjeldahl Nitrogen (TKN). At the present time, there is no USEPA-approved method to test for Total Nitrogen, however a combination of USEPA method 351.2 (TKN) and USEPA method 353.2 (Nitrate + Nitrite) may be appropriate for estimating Total Nitrogen.

Nutrient criteria development in the State of New Mexico has taken place in three steps, thus far. First, the EPA compiled nutrient data from the national nutrient dataset, divided it by waterbody type, grouped it into nutrient ecoregions, and calculated the 25th percentiles for each aggregate and Level III ecoregion. EPA published these recommended water quality criteria to help states and tribes reduce problems associated with excess nutrients in waterbodies in specific areas of the country (USEPA 2000). Next a U.S. Geological Survey (USGS) employee, Evan Hornig, who assisted EPA Region 6 with nutrient criteria development, refined the recommended ecoregional nutrient criteria. Hornig used regional nutrient data from EPA's Storage and Retrieval System (STORET), the USGS, and the SWQB to create a regional dataset for New Mexico. Threshold values were calculated based on EPA procedures and the median for each Level III ecoregion.

The third round of analysis was conducted by SWQB to produce nutrient threshold values for streams based on ecoregion and designated aquatic life use. For this analysis, total phosphorus (TP), total Kjeldahl nitrogen (TKN), and nitrate plus nitrite (N+N) data from the National Nutrient Dataset (1990-1997) was combined with Archival STORET data from 1998, and 1999-2006 data from the SWQB in-house database. The data were then divided by waterbody type, removing all rivers, reservoirs, lakes, wastewater treatment effluent, and playas. For all of the stream data, Level III and IV Omernik ecoregions (Omernik 2006) as well as the designated aquatic life use were assigned to all stream data using GIS coverages and the station's latitude and longitude. Medians were calculated for each ecoregion/aquatic life use group using Excel. For comparison purposes, values below the detection limit were estimated in two ways; using the substitution method (one half the detection limit) in Excel and using the nonparametric Kaplan-Meier method in Minitab. The threshold values from the SWQB Stream Nutrient Assessment Protocol are shown in Table 5.1. They were generated with the complete dataset using the substitution method given that the substitution and Kaplan-Meier methods produced similar results.

Table 5.1 SWQB's Recommended Nutrient Targets for streams (in mg/L)

	ECOREGION									
Parameter	21-Southern Rockies		23-AZ/NM Mountains		22-AZ/NM Plateau		24-Chihuahuan Desert	26-SW Tablelands		
TP	0.02		0.02		0.05		0.04	0.03		
TN	0.25		0.25		0.35		0.53	0.38		
ALU	CW (volcanic)	T/WW (volcanic)	CW	T/WW	CW	T/WW	T/WW	CW	T	WW
TP	0.02 (0.05)	0.02 (0.05)	0.02	0.05	0.04	0.09	0.04	0.02	0.03	0.03
TN	0.25	0.25	0.25	0.29	0.28	0.48	0.53	0.25	0.38	0.45

NOTES:
TN = Total Nitrogen
TP = Total Phosphorus
ALU = Designated Aquatic Life Use
CW = Coldwater (those water quality segments having only coldwater uses)
T = Transitional (those water quality segments with marginal coldwater or both cold and warmwater uses)
WW = Warmwater (those water quality segments having only warmwater uses)

Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs) is located in Ecoregion 21 (Southern Rockies). In addition, this assessment unit is designated as coldwater aquatic life (20.6.4.107 NMAC). According to Table 5.1, Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs) should have numeric nutrient targets of 0.02 mg/L for total phosphorus and 0.25 mg/L for total nitrogen. While this AU does not fall in a volcanic ecoregion, the headwaters that supply most of the water to this reach do, so the ecoregion 21 (volcanic) TP threshold was used.

Rio de las Vacas (Rio Cebolla to Clear Creek) and Rito Peñas Negras (Rio de las Vacas to headwaters) are located in Ecoregion 21 (Southern Rockies). In addition, these assessment units have a designated use of high quality coldwater aquatic life (20.6.4.108 NMAC). According to Table 5.1, these waters should have numeric nutrient targets of 0.02 mg/L for total phosphorus and 0.25 mg/L for total nitrogen.

Table 5.2 Nutrient TMDL Target Concentrations

Assessment Unit	Total Phosphorus	Total Nitrogen
Jemez River (R Guadalupe to Soda Dam nr Jemez Springs)	0.05 mg/L	0.25 mg/L
Rio de las Vacas (Rio Cebolla to Clear Creek)	0.02 mg/L	0.25 mg/L
Rito Peñas Negras (Rio de las Vacas to headwaters)	0.02 mg/L	0.25 mg/L

5.2 Flow

The presence of plant nutrients in a stream can vary as a function of flow. Higher nutrient concentrations typically occur during low-flow conditions because there is reduced stream capacity to assimilate point source discharges due to less streamflow available for dilution. In other words, as flow decreases, the stream cannot effectively dilute its constituents causing the concentration of plant nutrients to increase. Thus, a TMDL is calculated for each assessment unit at a specific flow.

The *critical condition* can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence. The critical flow is used in calculation of point source (National Pollutant Discharge Elimination System [NPDES]) permit WLA and in the development of TMDLs.

The critical flow condition for these TMDLs occurs when the ratio of effluent to stream flow is the greatest and was obtained using a 4Q3 regression model. The 4Q3 is the minimum average four consecutive day flow that occurs with a frequency of at least once every 3 years. Low flow was chosen as the critical flow because of the negative effect low flows have on nutrient concentrations and algal growth.

It is often necessary to calculate a critical flow for a portion of a watershed where there is no active flow gage. The 4Q3 derivations for the Jemez River, Rio de las Vacas, and Rito Peñas Negras were based on analysis methods described by Waltemeyer (2002). In this analysis, two regression equations for estimating 4Q3 were developed based on physiographic regions of NM (i.e., statewide and mountainous regions above 7,500 feet in elevation). The following regression equation for mountainous regions above 7,500 feet in elevation is based on data from 40 gaging stations with non-zero discharge (Waltemeyer 2002):

$$4Q3 = 7.3287 \times 10^{-5}\ DA^{0.70}\ P_w^{\ 3.58}\ S^{1.35} \qquad \text{(Eq. 1)}$$

where,

4Q3 = Four-day, three-year low-flow frequency (cfs)
DA = Drainage area (mi^2)
P_w = Average basin mean winter precipitation (inches)
S = Average basin slope (percent).

The average SEE and coefficient of determination are 94 and 66 percent, respectively, for this regression equation (Waltemeyer 2002). The 4Q3s were estimated using the regression equation for mountainous regions (Eq. 1) because the mean elevation for all assessment units was above 7,500 feet in elevation (Table 5.3).

Table 5.3 Calculation of 4Q3 Low-Flow Frequencies

Assessment Unit	Average Elevation (ft.)	Drainage Area (mi^2)	mean winter precipitation (in.)	Average basin slope (percent)	4Q3 (cfs)
Jemez River (R Guad to Soda Dam nr Jemez Springs)	8750	200	11.9	24.2%	3.16
Rio de las Vacas (Rio Cebolla to Clear Creek)	8694	121	16.5	20.6%	5.69
Rito Peñas Negras (Rio de las Vacas to headwaters)	8881	17.1	15.7	19.5%	1.12

The 4Q3 value for the Jemez River was converted from cubic feet per second (cfs) to units of million gallons per day (mgd) as follows:

$$3.16\,\frac{ft^3}{\sec} \times 1{,}728\,\frac{in^3}{ft^3} \times 0.004329\,\frac{gal}{in^3} \times 86{,}400\,\frac{\sec}{day} \times 10^{-6} = 2.04 mgd$$

The 4Q3 values for the other waterbodies were calculated in a similar manner.

It is important to remember that the TMDL itself is a value calculated at a defined critical condition, and is calculated as part of planning process designed to achieve water quality standards. Since flows vary throughout the year in these systems, the actual load at any given time will vary based on the changing flow. Management of the load to improve stream water quality should be a goal to be attained.

5.3 Calculations

This section describes the relationship between the numeric target and the allowable pollutant-level by determining the waterbody's total assimilative capacity, or loading capacity, for the pollutant. The loading capacity is the maximum amount of pollutant loading that a waterbody can receive while meeting its water quality objectives.

As a river flows downstream it has a specific carrying capacity for nutrients. This carrying capacity, or TMDL, is defined as the mass of pollutant that can be carried under critical low-flow conditions without violating the target concentration for that constituent. These TMDLs were developed based on simple dilution calculations using 4Q3 flow, the numeric target, and a conversion factor. The specific carrying capacity of a receiving water for a given pollutant, may be estimated using Eq. 2.

4Q3 (in mgd) x Numeric Target (in mg/L) x 8.34 = TMDL (pounds per day [lbs/day]) (Eq. 2)

The annual target loads for TP and TN are summarized in Table 5.4.

Table 5.4 Annual Target Loads for TP & TN

Assessment Unit	Parameter	4Q3 Flow (mgd)	Numeric Target (mg/L)	Conversion Factor	Target Load (lbs/day)
Jemez River (R Guadalupe to Soda Dam near Jemez Springs)	Total Phosphorus	2.12+	0.05	8.34	0.884
	Total Nitrogen	2.12+	0.25	8.34	4.42
Rio de las Vacas (Rio Cebolla to Clear Creek)	Total Phosphorus	3.68	0.02	8.34	0.614
	Total Nitrogen	3.68	0.25	8.34	7.67
Rito Peñas Negras (Rio de las Vacas to headwaters)	Total Phosphorus	0.722	0.02	8.34	0.120
	Total Nitrogen	0.722	0.25	8.34	1.51

Notes:
\+ *Combined Flow = 4Q3 low-flow (2.04 mgd) + WWTP design capacity (0.075 mgd)*

The measured loads for TP and TN were similarly calculated. In order to achieve comparability between the target and measured loads, the same flow value was used for both calculations. The arithmetic mean of the collected data was substituted for the target in Equation 2. The same conversion factor of 8.34 was used. The results are presented in Table 5.5.

Table 5.5 Annual Measured Loads for TP and TN

Assessment Unit	Parameter	Flow (mgd)	Arithmetic Mean Conc.* (mg/L)	Conversion Factor	Measured Load (lbs/day)
Jemez River (R Guadalupe to Soda Dam near Jemez Springs)	Total Phosphorus	2.12+	0.0885	8.34	1.56
	Total Nitrogen	2.12+	0.573	8.34	10.1
Rio de las Vacas (Rio Cebolla to Clear Creek)	Total Phosphorus	3.68	0.0179	8.34	0.549
	Total Nitrogen	3.68	0.379	8.34	11.6
Rito Peñas Negras (Rio de las Vacas to headwaters)	Total Phosphorus	0.722	0.0301	8.34	0.182
	Total Nitrogen	0.722	0.500	8.34	3.01

Notes:
+ *Combined Flow = 4Q3 low-flow (2.04 mgd) + WWTP design capacity (0.075 mgd)*
* *Arithmetic mean of TP and TN concentration; values rounded to three significant figures.*

5.4 Waste Load Allocations and Load Allocations

5.4.1 Waste Load Allocation

There are no facilities with an NPDES permit in the Rio de las Vacas or Rio Peñas Negras assessment units. However, there is an existing point source with an individual NPDES permit in the Jemez River assessment unit; the Jemez Springs wastewater treatment plant (WWTP) (NM0028011). The WWTP discharges directly into the Jemez River between the Rio Guadalupe and Soda Dam near Jemez Springs. Each NPDES-permitted facility that discharges into an impaired reach has a wasteload allocation (WLA) included in this TMDL (Table 5.6). The Jemez Springs WWTP is currently not designed to treat effluent for total nitrogen and total phosphorus. The facility will need to develop and implement treatment to meet the new effluent requirements that will result from this TMDL. A compliance schedule will be included in the NPDES permit for the facility to meet the new effluent requirements.

There are no individually permitted Municipal Separate Storm Sewer System (MS4) storm water permits in these assessment units. Excess nutrient levels may be a component of some (primarily construction) storm water discharges so these discharges should be addressed. In contrast to discharges from other industrial storm water and individual process wastewater permitted facilities, storm water discharges from construction activities are transient because they occur mainly during the construction itself, and then only during storm events. Coverage under the NPDES construction general storm water permit (CGP) requires preparation of a Storm Water Pollution Prevention Plan (SWPPP) that includes identification and control of all pollutants associated with the construction activities to minimize impacts to water quality. In addition, the current CGP also includes state specific requirements to implement BMPs that are designed to prevent to the maximum extent practicable, an increase in sediment, or a parameter that addresses sediment (e.g., total suspended solids, turbidity, siltation, stream bottom deposits, etc.)

and flow velocity during and after construction compared to preconstruction conditions. In this case, compliance with a SWPPP that meets the requirements of the CGP is generally assumed to be consistent with this TMDL.

Other industrial storm water facilities are generally covered under the current NPDES Multi-Sector General Storm Water Permit (MSGP). This permit also requires preparation of an SWPPP that includes identification and control of all pollutants associated with the industrial activities to minimize impacts to water quality. In addition, the current MSGP also includes specific requirements to further limit (or eliminate) pollutant loading to water quality impaired/water quality limited waters from facilities where there is a reasonable potential to contain pollutants for which the receiving water is impaired. In this case, compliance with a SWPPP that meets the requirements of the MSGP is generally assumed to be consistent with this TMDL.

Because there are no individually permitted MS4 storm water permits in these assessment units, this TMDL does not include a specific WLA for storm water discharges for the Jemez River, Rio de las Vacas, or Rito Peñas Negras. However, because there is a facility with an NPDES permit that discharges into the Jemez River between the Rio Guadalupe and Soda Dam near Jemez Springs, a WLA for the WWTP is included in this TMDL (Tables 5.6 and 5.7).

Table 5.6 TP Waste Load Allocation for the Jemez River

Assessment Unit	Facility	Dilution Capacity[(a)]: Q^*	Flow[(b)] (mgd)	TP Target[(c)] (mg/L)	Conversion Factor	Waste Load Allocation[(d)] (lbs/day)
Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs)	**NM0028011** Jemez Springs Wastewater Treatment Plant	13%	0.075	1.0	8.34	0.626

Table 5.7 TN Waste Load Allocation for the Jemez River

Assessment Unit	Facility	Dilution Capacity[(a)]: Q^*	Flow[(b)] (mgd)	TN Target[(c)] (mg/L)	Conversion Factor	Waste Load Allocation[(d)] (lbs/day)
Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs)	**NM0028011** Jemez Springs Wastewater Treatment Plant	13%	0.075	4.75	8.34	2.97

Notes:
(a) Dilution capacity is the ability of the receiving stream to dilute and disperse effluent. When the dilution capacity is large (i.e. Q^* is small), the dilution factor is also large and vice versa.
(b) Based on the design capacity for the WWTP.
(c) Target concentration is a water quality-based target as discussed in Section 9.1.
(d) WLA = (flow) x (target concentration) x (conversion factor)

The amount of dilution available is an important factor to consider when allocating loads and determining allowable effluent concentrations. Receiving water quality primarily depends on the dilution capacity available and the effectiveness of the treatment technology. A discharge from a small facility into a large river may pose no threat to water quality, whereas a discharge from a larger facility into a smaller stream may cause significant water quality deterioration in the receiving water if the level of treatment is not adequate.

5.4.2 Load Allocation

In order to calculate the LAs for phosphorus and nitrogen, the WLAs and MOSs were subtracted from the target capacity (TMDL) using the following equation:

$$WLA + LA + MOS = TMDL \qquad \text{(Eq.3)}$$

The MOS was developed using a combination of conservative assumptions and explicit recognition of potential errors in flow calculations. Results using an explicit MOS of 10% (see Section 5.7 for details) are presented in Table 5.8.

Table 5.8 Calculation of Annual TMDL for TP and TN

Assessment Unit	Parameter	WLA (lbs/day)	LA (lbs/day)	MOS (10%) (lbs/day)	TMDL (lbs/day)
Jemez River (R Guadalupe to Soda Dam near Jemez Springs)	TP	0.626	0.170	0.088	0.884
	TN	2.97	1.01	0.442	4.42
Rio de las Vacas (Rio Cebolla to Clear Creek)	TP	0	0.553	0.061	0.614
	TN	0	6.90	0.767	7.67
Rito Peñas Negras (Rio de las Vacas to headwaters)	TP	0	0.108	0.012	0.120
	TN	0	1.36	0.151	1.51

The load reductions that would be necessary to meet the target loads were calculated to be the difference between the calculated annual target load (Table 5.4) and the measured load (Table 5.5), and are shown in Table 5.9.

Table 5.9 Calculation of Load Reduction for TP and TN

Assessment Unit	Parameter	Target Load[(a)] (lbs/day)	Measured Load (lbs/day)	Load Reduction (lbs/day)	Percent Reduction[(b)]
Jemez River (R Guadalupe to Soda Dam near Jemez Springs)	TP	0.796	1.56	0.764	49%
	TN	3.98	10.1	6.12	61%
Rio de las Vacas (Rio Cebolla to Clear Creek)	TP	0.553	0.549	-	0%
	TN	6.90	11.6	4.70	41%
Rito Peñas Negras (Rio de las Vacas to headwaters)	TP	0.108	0.182	0.074	41%
	TN	1.36	3.01	1.65	55%

Note: The MOS is not included in the load reduction calculations because it is a set aside value which accounts for any uncertainty or variability in TMDL calculations and therefore should not be subtracted from the measured load.
(a) Target Load = TMDL – MOS (refer to Table 5.8)
(b) Percent reduction is the percent the existing measured load must be reduced to achieve the target load, and is calculated as follows: (Measured Load – Target Load) / Measured Load x 100.

5.5 Identification and Description of Pollutant Sources

Probable sources of impairment for TP that could contribute to this assessment unit are listed in Table 5.10. Probable sources of impairment for TN are listed in Table 5.11.

Table 5.10 Pollutant Source Summary for Total Phosphorus

Assessment Unit	Pollutant Sources	Magnitude (lbs/day)	Probable Sources* (% from each)
Jemez River (R Guadalupe to Soda Dam near Jemez Springs)	Point: NM0028011	1.48[a]	95% Municipal Point Source Discharge
	Nonpoint:	0.08[b]	5% On-site Treatment Systems (Septic Systems and Similar Decentralized Systems), highway/road/bridge runoff (non-construction related), loss of riparian habitat, natural sources, other recreational pollution sources, rangeland grazing, site clearance (Land Development and Redevelopment), streambank modification/destabilization
Rio de las Vacas (Rio Cebolla to Clear Creek)	Point:	n/a	0%
	Nonpoint:	0.549	100% Loss of riparian habitat, rangeland grazing, streambank modifications/destabilization.
Rito Peñas Negras (Rio de las Vacas to headwaters)	Point:	n/a	0%
	Nonpoint:	0.182	100% Highway/road/bridge runoff (non-construction related), loss of riparian habitat, rangeland grazing, streambank modifications/ destabilization.

Notes:

[a] The magnitude for point sources was calculated by multiplying the arithmetic mean TP concentration (2.37 mg/L for the WWTP), the design flow of the facility (0.075 mgd), and the 8.34 conversion factor to get a result in lbs/day.

[b] The magnitude for nonpoint sources was calculated by subtracting the magnitude of the point sources from the measured load (Section 5.3, Table 5.5; 1.56 lbs/day).

* From the 2008-2010 Integrated CWA §303(d)/§305(b) List. This list of probable sources is based on staff observation and known land use activities in the watershed. These sources are not confirmed nor quantified at this time.

Table 5.11 Pollutant Source Summary for Total Nitrogen

Assessment Unit	Pollutant Sources	Magnitude (lbs/day)	Probable Sources* (% from each)
Jemez River (R Guadalupe to Soda Dam near Jemez Springs)	Point: NM0028011	2.70[a]	27% Municipal Point Source Discharge
	Nonpoint:	7.40[b]	73% On-site Treatment Systems (Septic Systems and Similar Decentralized Systems), highway/road/bridge runoff (non-construction related), loss of riparian habitat, natural sources, other recreational pollution sources, rangeland grazing, site clearance (Land Development and Redevelopment), streambank modification/destabilization.
Rio de las Vacas (Rio Cebolla to Clear Creek)	Point:	n/a	0%
	Nonpoint:	11.6	100% Loss of riparian habitat, rangeland grazing, streambank modifications/destabilization.
Rito Peñas Negras (Rio de las Vacas to headwaters)	Point:	n/a	0%
	Nonpoint:	3.01	100% Highway/road/bridge runoff (non-construction related), loss of riparian habitat, rangeland grazing, streambank modifications/ destabilization.

Notes:

[a] The magnitude for point sources was calculated by multiplying the arithmetic mean TN concentration (4.32 mg/L for the WWTP), the design flow of the facility (0.075 mgd), and the 8.34 conversion factor to get a result in lbs/day.

[b] The magnitude for nonpoint sources was calculated by subtracting the magnitude of the point sources from the measured load (Section 5.3, Table 5.5; 10.1 lbs/day).

* From the 2008-2010 Integrated CWA §303(d)/§305(b) List. This list of probable sources is based on staff observation and known land use activities in the watershed. These sources are not confirmed nor quantified at this time.

5.6 Linkage between Water Quality and Pollutant Sources

The source assessment phase of TMDL development identifies sources of nutrients that may contribute to both elevated nutrient concentrations and the stimulation of algal growth in a waterbody. Where data gaps exist or 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.

Phosphorus and nitrogen generally drive the productivity of algae and macrophytes in aquatic ecosystems, therefore they are regarded as the primary limiting nutrients in freshwaters. The main reservoirs of natural phosphorus are rocks and natural phosphate deposits. Weathering, leaching, and erosion are all processes that breakdown rock and mineral deposits allowing phosphorus to be transported to aquatic systems via water or wind. The breakdown of mineral phosphorus produces inorganic phosphate ions ($H_2PO_4^-$, HPO_4^{2-}, and PO_4^{3-}) that can be absorbed by plants from soil or water (USEPA 1999). Phosphorus primarily moves through the food web as organic phosphorus (after it has been incorporated into plant or algal tissue) where it may be released as phosphate in urine or other waste by heterotrophic consumers and reabsorbed by plants or algae to start another cycle (Nebel and Wright 2000).

The largest reservoir of nitrogen is the atmosphere. About 80 percent of the atmosphere by volume consists of nitrogen gas (N_2). Although nitrogen is plentiful in the environment, it is not readily available for biological uptake. Nitrogen gas must be converted to other forms, such as ammonia (NH_3 and NH_4^+), nitrate (NO_3^-), or nitrite (NO_2^-) before plants and animals can use it. Conversion of gaseous nitrogen into usable mineral forms occurs through three biologically mediated processes of the nitrogen cycle: nitrogen fixation, nitrification, and ammonification (USEPA 1999). Mineral forms of nitrogen can be taken up by plants and algae and incorporated into plant or algal tissue. Nitrogen follows the same pattern of food web incorporation as phosphorus and is released in waste primarily as ammonium compounds. The ammonium compounds are usually converted to nitrates by nitrifying bacteria, making it available again for uptake, starting the cycle anew (Nebel and Wright 2000).

Rain, overland runoff, groundwater, drainage networks, and industrial and residential waste effluents transport nutrients to receiving waterbodies. Once nutrients have been transported into a waterbody they can be taken up by algae, macrophytes, and microorganisms either in the water column or in the benthos; they can sorb to organic or inorganic particles in the water column and/or sediment; they can accumulate or be recycled in the sediment; or they can be transformed and released as a gas from the waterbody (Figure 5.1).

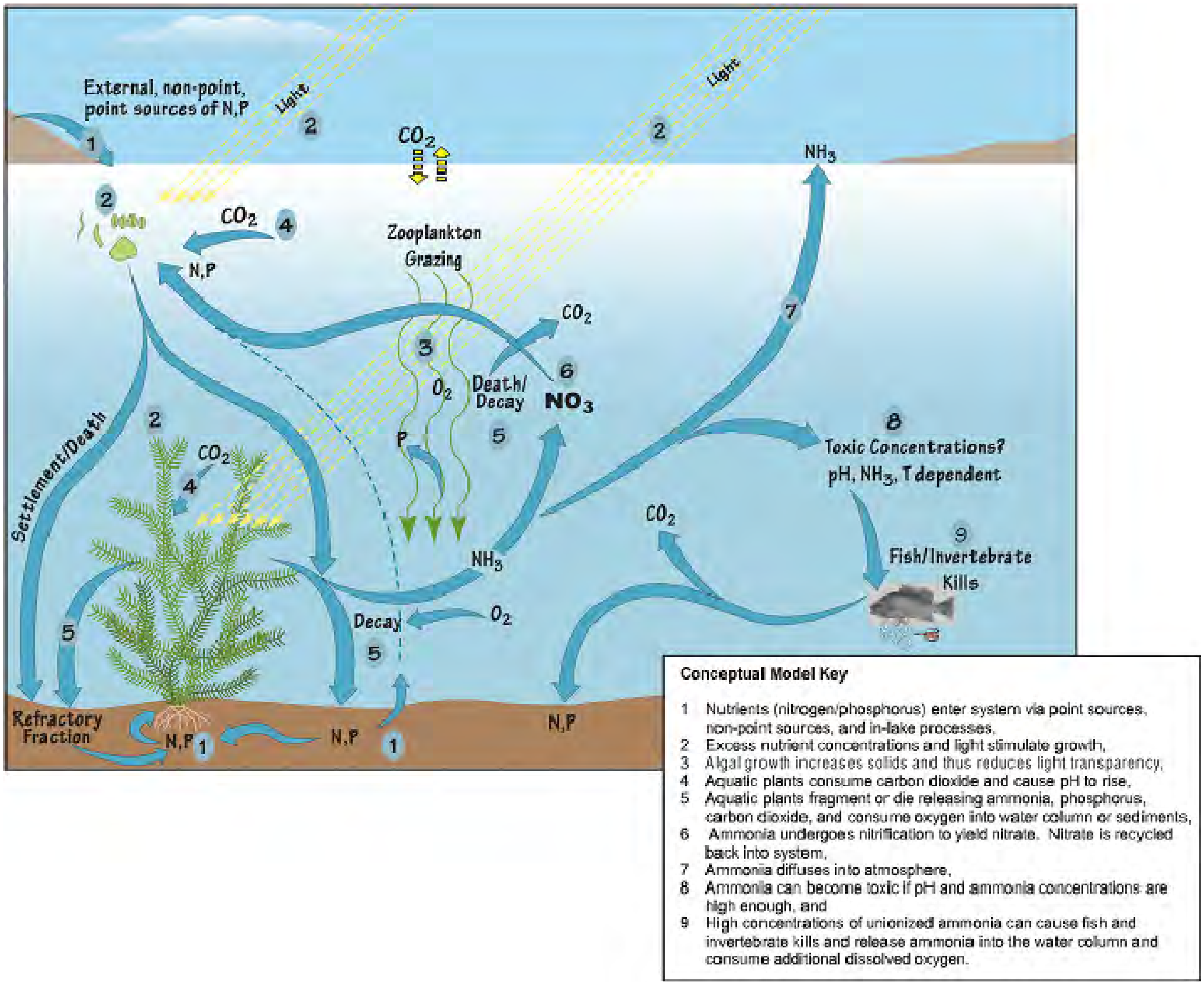

Figure 5.1 Nutrient Conceptual Model (USEPA 1999)

As noted above, phosphorus and nitrogen are essential for proper functioning of ecosystems. However, excess nutrients cause conditions unfavorable for the proper functioning of aquatic ecosystems. Nuisance levels of algae and other aquatic vegetation (macrophytes) can develop rapidly in response to nutrient enrichment when other factors (e.g., light, temperature, substrate, etc.) are not limiting (Figure 5.1). The relationship between nuisance algal growth and nutrient enrichment in stream systems has been well documented in the literature (Welch 1992; Van Nieuwenhuyse and Jones 1996; Dodds et al. 1997; Chetelat et al. 1999). Unfortunately, the magnitude of nutrient concentration that constitutes an “excess” is difficult to determine and varies by ecoregion.

As described in Section 5.2, the presence of plant nutrients in a stream can vary as a function of flow. As flow decreases through water diversions and/or drought-related stressors, the stream cannot effectively dilute its constituents, which causes the concentration of plant nutrients to increase. Nutrients generally reach a waterbody from land uses that are in close proximity to the stream because the hydrological pathways are shorter and have fewer obstacles than land uses located away from the riparian corridor. However, during the growing season (i.e. in agricultural return flow) and in storm water runoff, distant land uses can become hydrologically connected to the stream, thus transporting nutrients from the hillslopes to the stream during these time periods.

In addition to agriculture, there are several other human-related activities that influence nutrient concentrations in rivers and streams. Residential areas contribute nutrients from septic tanks, landscape maintenance, as well as backyard livestock (e.g. cattle, horses) and pet wastes. Urban development contributes nutrients by disturbing the land and consequently increasing soil erosion, by increasing the impervious area within the watershed, and by directly applying nutrients to the landscape. Recreational activities such as hiking and biking can also contribute nutrients to the stream by reducing plant cover and increasing soil erosion (e.g. trail network, streambank destabilization), direct application of human waste, campfires and/or wildfires, and dumping trash near the riparian corridor.

Undeveloped, or natural, landscapes also can deliver nutrients to a waterbody through decaying plant material, soil erosion, and wild animal waste. Another geographically occurring nutrient source is atmospheric deposition, which adds nutrients directly to the waterbody through dryfall and rainfall. Atmospheric phosphorus and nitrogen can be found in both organic and inorganic particles, such as pollen and dust. The contributions from these natural sources are generally considered to represent background levels.

Water pollution caused by on-site septic systems is a widespread problem in New Mexico (McQuillan 2004). Septic system effluents have contaminated more water supply wells, and more acre-feet of ground water, than all other sources in the state combined. Groundwater contaminated by septic system effluent can discharge into streams gaining from groundwater inflow. Nutrients such as phosphorous and nitrogen released into gaining streams from aquifers contaminated by septic systems can contribute to eutrophic conditions. The Village of Jemez Springs has several on-site municipal wells and the Jemez Valley has numerous septic systems, with sewerage services also being available for some residents.

SWQB fieldwork includes an assessment of the probable sources of impairment (NMED/SWQB 1999). The completed *Pollutant Source(s) Summary Table* in Appendix C provides 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 probable sources of impairment in this watershed. 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 TMDLs. These nutrient TMDLs were calculated using the best available methods that were known at the time of calculation and may be revised in the future.

5.7 Margin of Safety (MOS)

TMDLs should reflect a MOS based on the uncertainty or variability in the data, the point and nonpoint source load estimates, and the modeling analysis. The MOS can be expressed either implicitly or explicitly. An implicit MOS is incorporated by making conservative assumptions in the TMDL analysis, such as allocating a conservative load to background sources. An explicit MOS is applied by reserving a portion of the TMDL and not allocating it to any other sources.

For these nutrient TMDLs, the margin of safety was developed using a combination of conservative assumptions and explicit recognition of potential errors. Therefore, this margin of safety is the sum of the following two elements:

- *Conservative Assumptions*

  Treating phosphorus and nitrogen as conservative pollutants, that is a pollutant that does not readily degrade in the environment, was used as a conservative assumption in developing these loading limits.

  Using the 4Q3 critical low flow "worst case scenario" to calculate the allowable loads.

  Using the design capacity for calculating the point source loading knowing that the treatment plant is a batch discharger and does not discharge continuously and, under most conditions, the treatment plant is not operating at full capacity.

- *Explicit recognition of potential errors*

  A level of uncertainty exists in water quality sampling. Accordingly, a conservative MOS for this element is **10 percent** of the TMDL.

5.8 Consideration of Seasonal Variability

Section 303(d)(1) of the CWA requires TMDLs to be "established at a level necessary to implement the applicable WQS with 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. Exceedences were observed from March through October, during all seasons, which captured flow alterations related to snowmelt, the growing season, and summer monsoonal rains. The critical condition used for calculating the TMDL was low-flow. Calculations made at the critical low-flow (4Q3), in addition to using other conservative assumptions as described in the previous section on MOS, should be protective of the water quality standards designed to preserve aquatic life in the stream. It was assumed that if critical conditions were met during this time, coverage of any potential seasonal variation would also be met.

5.9 Future Growth

Growth estimates by county are available from the New Mexico Bureau of Business and Economic Research. These estimates project growth to the year 2035. Growth estimates for Sandoval County project a 51% growth rate through 2035. However, Sandoval County includes major cities such as Bernalillo, Corrales, and Rio Rancho. As of 2009, Jemez Springs' population (the largest incorporated town in the study area) is 1,367 people. Since 2000, Jemez Springs has had a population growth of 9.37 percent, but is not expected to have much growth in the future because it is confined by valley walls and surrounded by National Forest.

According to the data, nutrient loading is primarily due to diffuse nonpoint sources. Estimates of future growth are not anticipated to lead to a significant increase in nutrient concentrations that cannot be controlled with best management practices (BMPs) in this watershed. However, it is imperative that BMPs continue to be utilized and improved upon in this watershed while continuing to improve road conditions and grazing allotments and adhering to SWPPP requirements related to construction and industrial activities covered under the general permit.

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6.0 TEMPERATURE

Monitoring for temperature was conducted by SWQB in 2005. Based on available data, several exceedences of the New Mexico WQS for temperature were noted throughout the watershed (Figure 6.1). Thermographs were set to record once every hour for several months during the warmest time of the year (generally May through October). Thermograph data are assessed using Appendix C of the *State of New Mexico Procedures for Assessing Standards Attainment for the Integrated CWA §303(d)/§305(b) Water Quality Monitoring and Assessment Report [Assessment Protocol]* (NMED/SWQB 2008a). Based on 2005 data, temperature listings were added to the *2008-2010 State of NM §303(d) List for Impaired Waters* (NMED/SWQB 2008b) for East Fork Jemez (San Antonio Creek to Valles Caldera National Preserve [VCNP] boundary), Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs), Rio Guadalupe (Jemez River to confluence with Rio Cebolla), and Rito de las Palomas (Rio de las Vacas to headwaters). Temperature data from 2005 were used to develop these TMDLs.

6.1 Target Loading Capacity

Target values for these temperature TMDLs 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 temperature are based on the reduction in solar radiation necessary to achieve numeric criteria as predicted by a temperature model. This TMDL is also consistent with New Mexico's antidegradation policy.

The State of New Mexico has developed and adopted numeric water quality criteria for temperature to protect the designated use of high quality coldwater (HQCW) and coldwater (CW) aquatic life (20.6.4.900.C NMAC). These WQS have been set at a level to protect coldwater aquatic life such as trout. The HQCW and CW aquatic life use designations require that a stream reach must have water quality, streambed characteristics, and other attributes of habitat sufficient to protect and maintain a propagating coldwater fishery (i.e., a population of reproducing salmonids). The primary standard leading to an assessment of use impairment is the numeric criterion for temperature of 20°C (68°F). Table 6.1 and Figure 6.1 highlight the 2005 thermograph deployments. The following TMDL addresses four reaches where temperatures exceeded the criterion (**Appendix D** of this document provides a graphical representation of thermograph data):

East Fork Jemez (San Antonio Creek to VCNP boundary): Two thermographs were deployed on this reach in 2005 at East Fork Jemez above confluence with San Antonio Creek (site 6) and East Fork Jemez River below Las Conchas day use area (site 7). Recorded temperatures from June 15 through September 7 exceeded the HQCW aquatic life use criterion 536 of 3,857 times (14%) with a maximum temperature of 23.0°C on July 18.

Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs): One thermograph was deployed on this reach in 2005 at Jemez River above Rio Guadalupe (site 3). Recorded temperatures from June 15 through September 8 exceeded the CW aquatic life use criterion 267 of 2,033 times (13.1%) with a maximum temperature of 29.1°C on July 21.

Rio Guadalupe (Jemez River to confluence with Rio Cebolla): Two thermographs were deployed on this reach in 2005 at Rio Guadalupe above Jemez River (site 13) and Rio Guadalupe at Porter Landing (site 14). Recorded temperatures from June 15 through September 8 exceeded the HQCW aquatic life use criterion 887 of 3,900 times (23%) with a maximum temperature of 25.7°C on Aug 11.

Rito de las Palomas (Rio de las Vacas to headwaters): One thermograph was deployed on this reach in 2005 at Rito de las Palomas at NM Highway 126 (site 23). Recorded temperatures from June 15 through August 29 exceeded the HQCW aquatic life use criterion 349 of 1,802 times (19%) with a maximum temperature of 27.4°C on July 19.

Table 6.1 Jemez River watershed thermograph sites (2005)

Site Number	STORET ID	Site Name	Deployment Dates (2005)
1	31JemezR037.0	Jemez River above San Ysidro at NM Hwy 4	15 Jun - 6 Sep
2	31JemezR048.7	Jemez River below Rio Guadalupe	15 Jun - 8 Sep
3	31JemezR049.2	Jemez River above Rio Guadalupe	15 Jun - 8 Sep
4	31JemezR064.9	Jemez River above Soda Dam	15 Jun - 1 Sep
5	31JemezR070.3	Jemez River at USGS gage below Battleship Rock	15 Jun - 8 Sep
6	31EFkJem000.1	East Fork Jemez above confluence with San Antonio Creek	15 Jun - 7 Sep
7	31EFkJem015.2	East Fork Jemez below Las Conchas day use area	15 Jun - 31 Aug
8	31SanAnt000.1	San Antonio Creek above confluence with East Fork Jemez	15 Jun - 7 Sep
9	31Redond000.1	Redondo Creek above Sulphur Creek	15 Jun - 31 Aug
10	31Sulphu001.3	Sulphur Creek above Redondo Creek	15 Jun - 31 Aug
11	31SanAnt008.4	San Antonio Creek above NM Hwy 126	15 Jun - 31 Aug
12	31SanAnt014.5	San Antonio Creek above San Antonio Hot Spring	15 Jun - 7 Sep
13	31RGuada000.1	Rio Guadalupe above Jemez River	15 Jun - 8 Sep
14	31RGuada019.7	Rio Guadalupe at Porter Landing	15 Jun - 1 Sep
15	31RVacas000.1	Rio de Las Vacas above the Rio Cebolla	15 Jun - 30 Aug
16	31RVacas014.6	Rio de las Vacas below inholdings at FR 20	15 Jun - 29 Aug
17	31RCebol000.1	Rio Cebolla above the Rio de las Vacas	15 Jun - 1 Sep
18	31RCebol009.3	Rio Cebolla below Fenton Lake	15 Jun - 31 Aug
19	31RCebol011.4	Rio Cebolla ~0.5 mile above Fenton Lake	15 Jun - 30 Aug
20	31RCebol017.9	Rio Cebolla at campground above Seven Springs hatchery	28 Jun - 9 Aug
21	31Calave001.1	Calaveras Creek above Rio Cebolla on NM 126	15 Jun - 31 Aug
22	31RPNegr000.1	Rito Penas Negras at NM Hwy 126	15 Jun - 29 Aug
23	31RPalom000.1	Rito de las Palomas at NM Hwy 126	15 Jun - 29 Aug
24	31ClearC002.3	Clear Creek at NM Hwy 126	15 Jun - 29 Aug
25	31RVacas023.7	Rio de Las Vacas at NM Hwy 126	7 Jun - 29 Aug
26	31Vallec012.2	Vallecito Creek above Ponderosa diversion	15 Jun - 6 Sep
27	31Vallec015.5	Vallecito Creek at Paliza Campground	15 Jun - 6 Sep

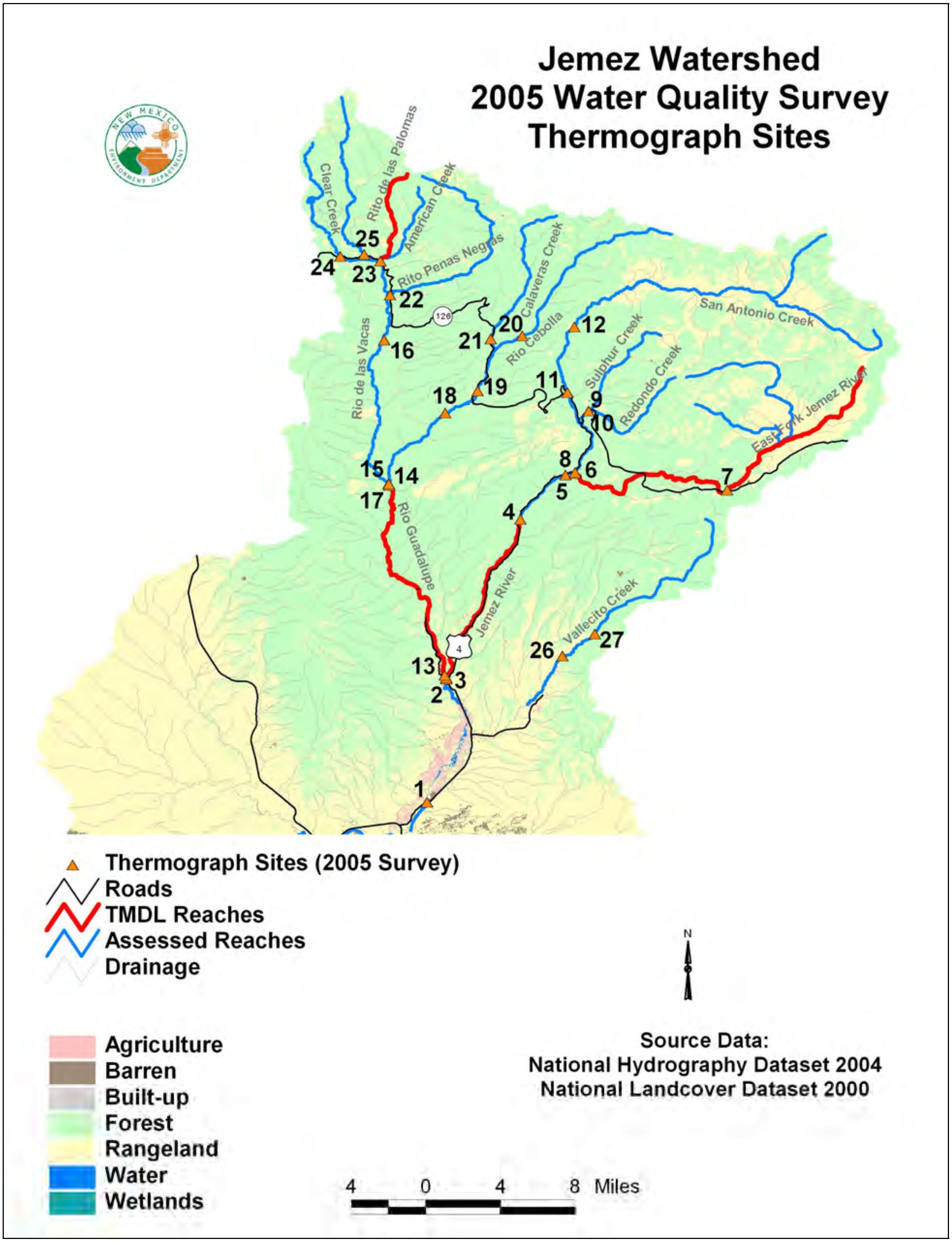

Figure 6.1 Jemez River watershed thermograph sites (2005)

6.2 Calculations

The Stream Segment Temperature (SSTEMP) Model, Version 2.0, developed by the USGS Biological Resource Division (Bartholow 2002) was used to predict stream temperatures based on watershed geometry, hydrology, and meteorology. The model predicts mean, minimum, and maximum daily water temperatures throughout a stream reach by estimating the heat gained or lost from a parcel of water as it passes through a stream segment (Bartholow 2002). The predicted temperature values are compared to actual thermograph readings measured in the field in order to calibrate the model. The SSTEMP model identifies current stream and/or watershed characteristics that control stream temperatures. The model also quantifies the maximum loading capacity of the stream to meet water quality criteria for temperature. This model is important for estimating the effect of changing controls, or constraints, (such as riparian grazing, stream channel alteration, and reduced streamflow) on stream temperature. The model can also be used to help identify possible implementation activities to improve stream temperature by targeting those factors causing impairment to the stream.

6.3 Waste Load Allocations and Load Allocations

6.3.1 Waste Load Allocation

With the exception of the Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs), there are no point source contributions associated with these TMDLs.

The Jemez Springs Wastewater Treatment Plant (WWTP) discharges into the Jemez River between Rio Guadalupe and Soda Dam. There is some debate regarding whether or not effluent from WWTPs has an impact on temperature. The Jemez Springs WWTP NPDES permit does not have limitations or monitoring requirements for temperature. WWTP effluent has never been noted to be a significant source contributor of temperature impairment. Data indicate that the Jemez Springs WWTP is not contributing to elevated temperature in the Jemez River. In fact, both mean (= 16.85 degrees C) and median (= 17.85 degrees C) of ambient temperature measurements taken at station “Jemez River above Jemez Springs WWTP” are very similar to, and slightly higher than, the mean (= 16.82 degrees C) and median (= 16.26 degrees C) of measurements taken at station “Jemez River below Jemez Springs WWTP.” Therefore, the WLA is zero.

6.3.2 Load Allocation

Water temperature can be expressed as heat energy per unit volume. SSTEMP provides an estimate of heat energy expressed in joules per square meter per second ($j/m^2/s$) and Langley’s per day. The following information relevant to the model runs used to determine temperature TMDLs is taken from the SSTEMP documentation (Bartholow 2002). Please refer to the SSTEMP User’s Manual for complete text. Various notes have been added below in brackets to clarify local sources of input data.

The program will predict the minimum, mean, and maximum daily water temperature for the set of variables you provide. The theoretical basis for the model is strongest for the mean daily temperature. The maximum is largely an estimate and likely to vary widely with the maximum daily air temperature. The minimum is computed by subtracting the difference between maximum and mean from the mean; but the minimum is always positive. (Bartholow 2002).

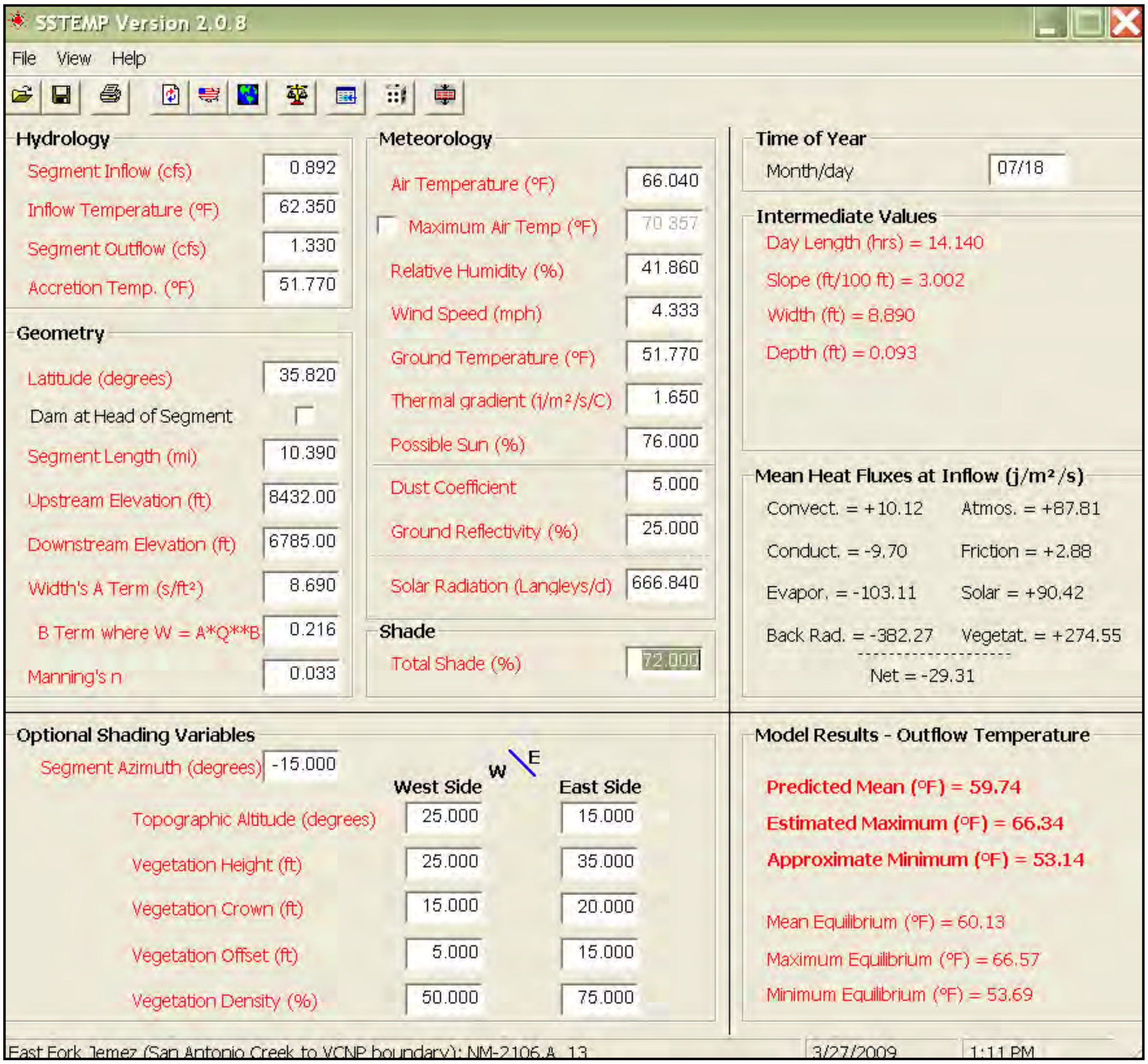

Figure 6.2 Example of SSTEMP input and output for East Fork Jemez

SSTEMP may be used to compute a one-at-a-time sensitivity of a set of input values. This simply increases and decreases most active input (i.e., non-grayed out values) by 10% and displays a screen for changes to mean and maximum temperatures. The schematic graph that accompanies the display gives an indication of which variables most strongly influence the results (Bartholow 2002). See Figure 6.3 for an example of a sensitivity analysis.

6.3.2.1 Temperature Allocations as Determined by % Total Shade and Width-to-Depth Ratios

Tables 6.2-6.5 detail model run outputs for segments on East Fork Jemez, Jemez River, Rio Guadalupe, and Rito de las Palomas. SSTEMP was first calibrated against thermograph data to determine the standard error of the model. Initial conditions were determined. As the percent total shade was increased and the Width's A term was decreased, the maximum 24-hour temperature decreased until the segment-specific standard of 20ºC was achieved. The calculated 24-hour solar radiation component is the maximum solar load that can occur in order to meet the WQS (i.e., the target capacity). In order to calculate the actual LA, the WLA and MOS were subtracted from the target capacity (TMDL) following **Equation 3**.

$$WLA + LA + MOS = TMDL \qquad \text{(Eq. 3)}$$

The allocations for each assessment unit requiring a temperature TMDL are provided in the following tables.

Temperature Load Allocation for East Fork Jemez (San Antonio Creek to VCNP boundary)
For East Fork Jemez (San Antonio Creek to VCNP boundary), the WQS for temperature is achieved when the percent total shade is increased to 68%. According to the SSTEMP model, the actual LA of 90.42 j/m^2/s is achieved when the shade is further increased to 72% (Table 6.2).

Table 6.2 SSTEMP Model Results for East Fork Jemez (San Antonio Creek to VCNP boundary)

<table>
<tr><th>Rosgen (1996) Channel Type</th><th>WQS (HQCW Aquatic Life)</th><th>Model Run Date</th><th>Segment Length (miles)</th><th>Solar Radiation Component per 24-Hours (+/-)</th><th>% Total Shade</th><th>Width's A Term</th><th>Modeled Temperature °C (24 hour)</th></tr>
<tr><td>---</td><td>20°C (68°F)</td><td>7/18/05</td><td>10.39</td><td>Current Field Condition
+113.02
j/m²/s</td><td>65</td><td>8.69</td><td>Minimum: 12.32
Mean: 16.39
Maximum: 20.46</td></tr>
<tr><td colspan="4" rowspan="3">TEMPERATURE ALLOCATIONS FOR
East Fork Jemez
(San Antonio Creek to VCNP boundary)

(a) 24-HOUR ACHIEVEMENT OF SURFACE WQS FOR TEMPERATURE

(b) 24-HOUR LOAD ALLOCATION (LA) NEEDED TO ACHIEVE SURFACE WQS WITH A 10% MARGIN OF SAFETY

Actual reduction in solar radiation necessary to meet surface WQS for temperature:

Current Condition – Load Allocation =

113.02 j/m²/s – 90.42 j/m²/s

= 22.60 j/m²/s</td><td>Run 1
+106.56
j/m²/s</td><td>67</td><td>8.69</td><td>Minimum: 12.24
Mean: 16.18
Maximum: 20.11</td></tr>
<tr><td>Run 2
+103.33 (a)
j/m²/s</td><td>68</td><td>8.69</td><td>Minimum: 12.20
Mean: 16.07
Maximum: 19.93</td></tr>
<tr><td>Actual LA

90.42 (b)
j/m²/s</td><td>72</td><td>8.69</td><td>Minimum: 12.07
Mean: 15.68
Maximum: 19.30</td></tr>
</table>

<u>Temperature Load Allocation for Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs)</u>
For Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs), the WQS for temperature is achieved when the percent total shade is increased to 25%. According to the SSTEMP model, the actual LA of 181.33 j/m^2/s is achieved when the shade is further increased to 33% (Table 6.3).

Table 6.3 SSTEMP Model Results for Jemez River (Rio Guadalupe to Soda Dam nr Jemez Springs)

<table>
<tr><th>Rosgen (1996) Channel Type</th><th>WQS (Coldwater Aquatic Life)</th><th>Model Run Date</th><th>Segment Length (miles)</th><th>Solar Radiation Component per 24-Hours (+/-)</th><th>% Total Shade</th><th>Width's A Term</th><th>Modeled Temperature °C (24 hour)</th></tr>
<tr><td>---</td><td>25°C (77°F)</td><td>7/21/05</td><td>9.67</td><td>Current Field Condition
+211.10 j/m^2/s</td><td>22</td><td>18.4</td><td>Minimum: 12.26
Mean: 18.30
Maximum: 24.35</td></tr>
<tr><td colspan="4" rowspan="3">TEMPERATURE ALLOCATIONS FOR Jemez River
(Rio Guadalupe to Soda Dam nr Jemez Springs)

(a) 24-HOUR ACHIEVEMENT OF SURFACE WQS FOR TEMPERATURE

(b) 24-HOUR LOAD ALLOCATION (LA) NEEDED TO ACHIEVE SURFACE WQS WITH A 10% MARGIN OF SAFETY

Actual reduction in solar radiation necessary to meet surface WQS for temperature:

Current Condition – Load Allocation =

211.10 j/m^2/s – 181.33 j/m^2/s

= 29.77 j/m^2/s</td><td>Run 1
+205.68 j/m^2/s</td><td>24</td><td>18.4</td><td>Minimum: 12.18
Mean: 18.14
Maximum: 24.10</td></tr>
<tr><td>Run 2
+202.98 (a)
j/m^2/s</td><td>25</td><td>18.4</td><td>Minimum: 12.15
Mean: 18.06
Maximum: 23.98</td></tr>
<tr><td>Actual LA
181.33 (b)
j/m^2/s</td><td>33</td><td>18.4</td><td>Minimum: 11.87
Mean: 17.42
Maximum: 22.96</td></tr>
</table>

NOTE: It is assumed that geothermal activity along this reach is affecting model results, as indicated by the maximum modeled temperature under current field conditions (24.35 °C). Actual maximum temperature, measured by SWQB's thermograph, was 29.1 °C. However this assumption could not be verified because there are no USGS well logs available for Jemez Springs or the Jemez watershed in general.

Temperature Load Allocation for Rio Guadalupe (Jemez River to confluence with Rio Cebolla)
For Rio Guadalupe (Jemez River to confluence with Rio Cebolla), the WQS for temperature is achieved when the percent total shade is increased to 48%. According to the SSTEMP model, the actual LA of 93.20 j/m^2/s is achieved when the shade is further increased to 54% (Table 6.4).

Table 6.4 SSTEMP Model Results for Rio Guadalupe (Jemez River to confluence with Rio Cebolla)

Rosgen (1996) Channel Type	WQS (HQCW Aquatic Life)	Model Run Date	Segment Length (miles)	Solar Radiation Component per 24-Hours (+/-)	% Total Shade	Width's A Term	Modeled Temperature °C (24 hour)
---	20°C (68°F)	8/11/05	12.65	**Current Field Condition** +131.70 j/m^2/s	35	13.5	Minimum: 12.14 Mean: 16.76 Maximum: 21.38
TEMPERATURE ALLOCATIONS FOR Rio Guadalupe (Jemez River to confluence with Rio Cebolla) [a] **24-HOUR ACHIEVEMENT OF SURFACE WQS FOR TEMPERATURE** [b] 24-HOUR LOAD ALLOCATION (LA) NEEDED TO ACHIEVE SURFACE WQS WITH A 10% MARGIN OF SAFETY				**Run 1** +121.57 j/m^2/s	40	13.5	Minimum: 12.06 Mean: 16.45 Maximum: 20.85
				Run 2 +105.36 [a] j/m^2/s	48	13.5	Minimum: 11.95 Mean: 15.95 Maximum: 19.96
Actual reduction in solar radiation necessary to meet surface WQS for temperature: Current Condition – Load Allocation = 131.70 j/m^2/s – 93.20 j/m^2/s **= 38.50 j/m^2/s**				**Actual LA** +93.20 [b] j/m^2/s	54	13.5	Minimum: 11.87 Mean: 15.57 Maximum: 19.28

Temperature Load Allocation for Rito de las Palomas (Rio de las Vacas to headwaters)
For Rito de las Palomas (Rio de las Vacas to headwaters), the WQS for temperature is achieved when the percent total shade is increased to 51%. According to the SSTEMP model, the actual LA of 124.38 j/m^2/s is achieved when the shade is further increased to 56% (Table 6.5).

Table 6.5 SSTEMP Model Results for Rito de las Palomas (Rio de las Vacas to headwaters)

Rosgen (1996) Channel Type	WQS (HQCW Aquatic Life)	Model Run Date	Segment Length (miles)	Solar Radiation Component per 24-Hours (+/-)	% Total Shade	Width's A Term	Modeled Temperature °C (24 hour)
---	20°C (68°F)	7/19/05	5.61	**Current Field Condition** +228.97 j/m^2/s	19	2.34	Minimum: 10.91 Mean: 17.70 Maximum: 24.49
TEMPERATURE ALLOCATIONS FOR Rito de las Palomas (Rio de las Vacas to headwaters) [a] **24-HOUR ACHIEVEMENT OF SURFACE WQS FOR TEMPERATURE** [b] 24-HOUR LOAD ALLOCATION (LA) NEEDED TO ACHIEVE SURFACE WQS WITH A 10% MARGIN OF SAFETY Actual reduction in solar radiation necessary to meet surface WQS for temperature: Current Condition – Load Allocation = 228.97 j/m^2/s – 124.38 j/m^2/s **=104.59 j/m^2/s**				**Run 1** +183.74 j/m^2/s	35	2.34	Minimum: 10.29 Mean: 16.31 Maximum: 22.34
				Run 2 +138.51 [a] j/m^2/s	51	2.34	Minimum: 9.73 Mean: 14.86 Maximum: 19.99
				Actual LA 124.38 [b] j/m^2/s	56	2.34	Minimum: 9.57 Mean: 14.39 Maximum: 19.22

According to the Sensitivity Analysis feature of the model runs (Figure 6.3), mean daily air temperature had the greatest influence on the predicted outflow temperatures and total shade values have the greatest influence on temperature reduction. Reducing Width's A term did not have a significant effect on the predicted mean or maximum temperatures.

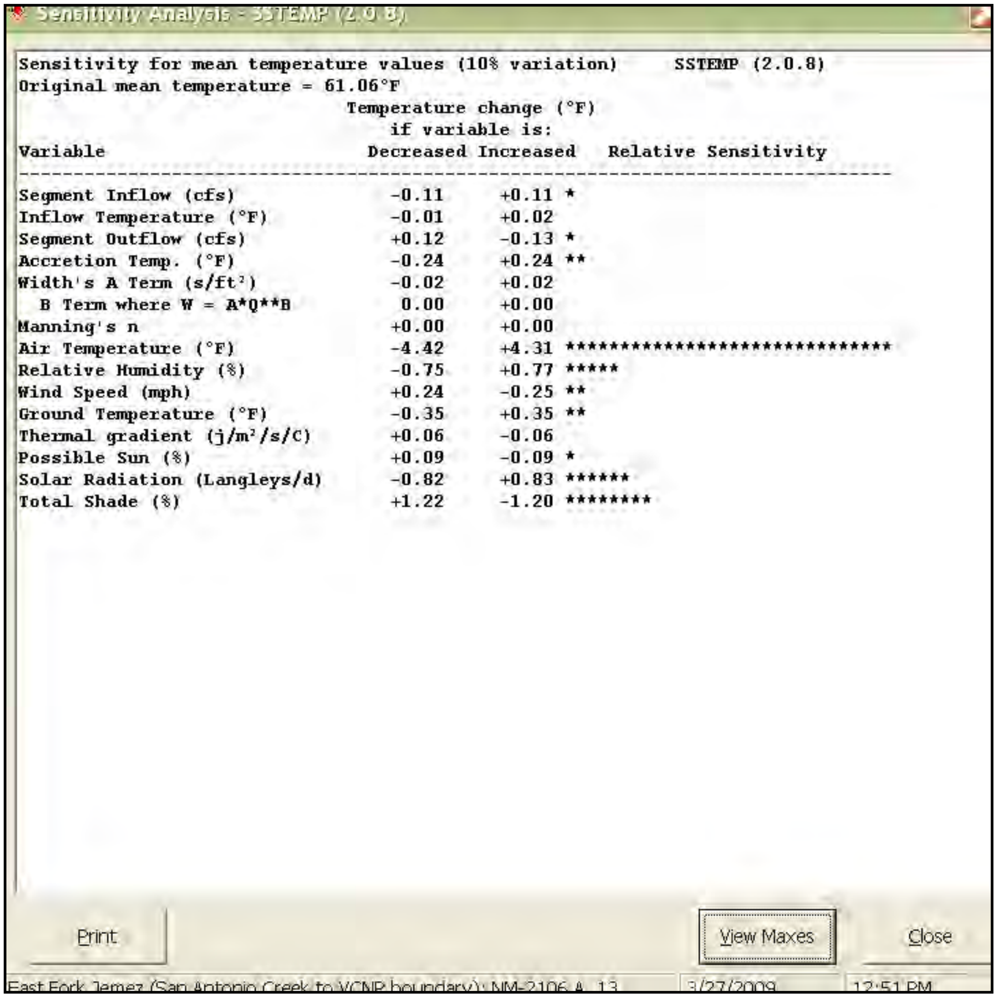

Figure 6.3 Example of SSTEMP sensitivity analysis for East Fork Jemez

The estimate of total shade used in the model calibration was based on densiometer readings (field notes) and examination of aerial photographs (see **Appendix E**). Target loads as determined by the modeling runs are summarized in Tables 6.2 – 6.5. The MOS is estimated to be 10% of the target load calculated by the modeling runs. Results are summarized in Table 6.6. Additional details on the MOS are presented in Section 6.7 below.

Table 6.6 Calculation of TMDLs for Temperature

Assessment Unit	WLA ($j/m^2/s$)	LA ($j/m^2/s$)	MOS (10%)[(a)] ($j/m^2/s$)	TMDL ($j/m^2/s$)
East Fork Jemez (San Antonio Creek to VCNP boundary)	0	90.4*	12.6*	103*
Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs)	0	181*	22.0*	203*
Rio Guadalupe (Jemez River to confluence with Rio Cebolla)	0	93.2*	11.8*	105*
Rito de las Palomas (Rio de las Vacas to headwaters)	0	124*	15.0*	139*

Notes:
[(a)] Actual MOS values may be slightly greater than 10% because the final MOS is back calculated after the Total Shade value is increased enough to reduce the modeled solar radiation component to a value less than the target load minus 10%.
* Values rounded to three significant figures.

The load reductions that would be necessary to meet the target loads were calculated to be the difference between the calculated target load and the measured load (i.e., current field condition in Tables 6.2 – 6.5), and are shown in Table 6.7.

Table 6.7 Calculation of Load Reduction for Temperature

Location	Target Load[(a)] ($j/m^2/s$)	Measured Load ($j/m^2/s$)	Load Reduction ($j/m^2/s$)	Percent Reduction[(b)]
East Fork Jemez (San Antonio Creek to VCNP boundary)	90.4*	113*	22.6*	20%
Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs)	181*	211*	29.8*	14%
Rio Guadalupe (Jemez River to confluence with Rio Cebolla)	93.2*	132*	38.5*	29%
Rito de las Palomas (Rio de las Vacas to headwaters)	124*	229*	105*	46%

Notes: The MOS is not included in the load reduction calculations because it is a set aside value which accounts for any uncertainty, or variability, in TMDL calculations and therefore should not be subtracted from the measured load.
(a) Target Load = LA + WLA
(b) Percent reduction is the percent the existing measured load must be reduced to achieve the target load, and is calculated as follows: (Measured Load – Target Load) / Measured Load x 100.
* Values rounded to three significant figures.

6.4 Identification and Description of pollutant source(s)

Pollutant sources that could contribute to each segment are listed in Table 6.8.

Table 6.8 Pollutant source summary for Temperature

Pollutant Sources	**Magnitude**[a]	**Location**	**Probable Sources**[b] (% from each)
Point:			
None	0	--------	0%
Nonpoint:			
	113.02	East Fork Jemez	100% Highway/road/bridge runoff (non-construction related), natural sources, other recreational pollution sources, rangeland grazing, silviculture harvesting, streambank modifications/destabilization.
	211.10	Jemez River	100% On-site treatment systems (septic systems and similar decentralized systems, highway/ road/bridge runoff (non-construction related), loss of riparian habitat, natural sources (hotsprings), other recreational pollution sources, rangeland grazing, site clearance (land development or redevelopment), streambank modifications/ destabilization.
	131.70	Rio Guadalupe	100% Loss of riparian habitat, off-road vehicles, natural sources, rangeland grazing.
	228.97	Rito de las Palomas	100% Highway/road/bridge runoff (non-construction related), loss of riparian habitat, rangeland grazing, streambank modifications/destabilization.

Notes:
(a) Measured Load as $j/m^2/s$. Expressed as solar radiation.
(b) From the 2008-2010 Integrated CWA §303(d)/305(b) list unless otherwise noted.

6.5 Linkage of Water Quality and Pollutant Sources

Water temperature influences the metabolism, behavior, and mortality of fish and other aquatic organisms. Natural temperatures of a waterbody fluctuate daily and seasonally. These natural fluctuations do not eliminate indigenous populations, but may affect existing community structure and geographical distribution of species. In fact, such temperature cycles are often necessary to induce reproductive cycles and may regulate other aspects of life history (Mount 1969). Behnke and Zarn (1976) in a discussion of temperature requirements for endangered western native trout recognized that populations cannot persist in waters where maximum temperatures consistently exceed 21-22°C, but they may survive brief daily periods of higher temperatures (25.5-26.7°C). Anthropogenic impacts can lead to modifications of these natural temperature cycles, often leading to deleterious impacts on the fishery. Such modifications may contribute to changes in geographical distribution of species and their ability to persist in the presence of introduced species. Of all the environmental factors affecting aquatic organisms in a waterbody, temperature is always a factor. Heat, which is a quantitative measure of energy of molecular motion that is dependent on the mass of an object or body of water is fundamentally different than temperature, which is a measure (unrelated to mass) of energy intensity. Organisms respond to temperature, not heat.

Temperature increases, as observed in SWQB thermograph data, show temperatures that exceed the State Standards for the protection of aquatic habitat, namely the HQCW and CW aquatic life designated uses. Through monitoring, and pollutant source documentation, it has been observed that the most probable cause for these temperature exceedences are due to the alteration of the stream's hydrograph, removal of riparian vegetation, livestock grazing, and natural causes such as geothermal inputs. Alterations can be historical or current in nature.

A variety of factors impact stream temperature (Figure 6.4). Decreased effective shade levels result from reduction of riparian vegetation. When canopy densities are compromised, thermal loading increases in response to the increase in incident solar radiation. Likewise, it is well documented that many past hydromodification activities have lead to channel widening. Wider stream channels also increase the stream surface area exposed to sunlight and heat transfer. Riparian area and channel morphology disturbances are attributed to past and to some extent current rangeland grazing practices that have resulted in reduction of riparian vegetation and streambank destabilization. These nonpoint sources of pollution primarily affect the water temperature through increased solar loading by: (1) increasing stream surface solar radiation and (2) increasing stream surface area exposed to solar radiation.

Riparian vegetation, stream morphology, hydrology, climate, geographic location, and aspect influence stream temperature. Although climate, geographic location, and aspect are outside of human control, the condition of the riparian area, channel morphology and hydrology can be affected by land use activities. Specifically, the elevated summertime stream temperatures attributable to anthropogenic causes in the Jemez basin result from the following conditions:

1. Channel widening (i.e., increased width to depth ratios) that has increased the stream surface area exposed to incident solar radiation,

2. Riparian vegetation disturbance that has reduced stream surface shading, riparian vegetation height and density, and
3. Reduced summertime base flows that result from instream withdrawals and/or inadequate riparian vegetation. Base flows are maintained with a functioning riparian system so that loss of a functioning riparian system may lower and sometimes eliminate baseflows. Although removal of upland vegetation has been shown, in some cases, to increase water yield, studies show that removal of riparian vegetation along the stream channel subjects the water surface and adjacent soil surfaces to wind and solar radiation, partially offsetting the reduction in transpiration with evaporation. In losing stream reaches, increased temperatures can result in increased streambed infiltration, which can result in lower base flow (Constantz et al. 1994).

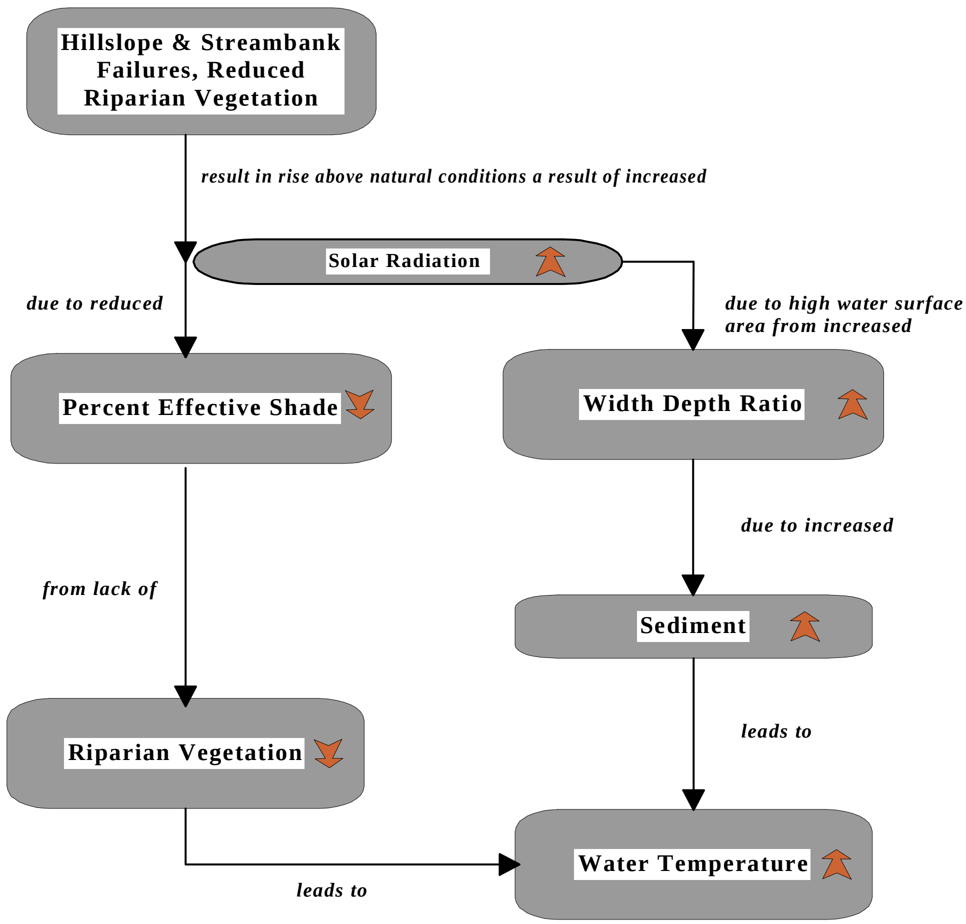

Figure 6.4 Factors That Impact Water Temperature

Analyses presented in these TMDLs demonstrate that defined loading capacities will ensure attainment of New Mexico WQS. Specifically, the relationship between shade, channel dimensions, solar radiation, and water quality attainment was demonstrated. Vegetation density increases will provide necessary shading, as well as encourage bank-building processes in severe hydrologic events.

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 a determination of the probable sources of impairment (NMED/SWQB 1999). 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 probable sources of impairment in this watershed. Table 6.6 identifies and quantifies probable 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, but also to consider upland and upstream areas in a more holistic watershed approach to implementing this TMDL.

6.6 Margin of Safety (MOS)

The Federal CWA requires that each TMDL be calculated with a MOS. This statutory requirement that TMDLs incorporate a MOS is intended to account for uncertainty in available data or in the actual effect controls will have on loading reductions and receiving water quality. A MOS may be expressed as unallocated assimilative capacity or conservative analytical assumptions used in establishing the TMDL (e.g., derivation of numeric targets, modeling assumptions or effectiveness of proposed management actions). The MOS may be implicit, utilizing conservative assumptions for calculation of the loading capacity, WLAs, and LAs. The MOS may also be explicitly stated as an added separate quantity in the TMDL calculation.

For this TMDL, there were no MOS adjustments for point sources since there are none.

In order to develop this temperature TMDL, the following conservative assumptions were used to parameterize the model:

- Data from the warmest time of the year were used in order to capture the seasonality of temperature exceedences.
- Critical upstream and downstream low flows were used because assimilative capacity of the stream to absorb and disperse solar heat is decreased during these flow conditions.
- Low flow was modeled using formulas developed by the USGS. One formula (Thomas et al. 1997) is recommended when the ratio between the gaged watershed area and the ungaged watershed area is between 0.5 and 1.5. When the ratio is outside of this range, a different regression formula is used (Waltemeyer 2002). See **Appendix E** for details.

As detailed in **Appendix E,** a variety of high quality hydrologic, geomorphologic, and meteorological data were used to parameterize the SSTEMP model. Because of the high quality of data and information that was put into this model and the continuous field monitoring data used to verify these model outputs, an explicit MOS of 10% is assigned to this TMDL.

6.7 Consideration of seasonal variation

Section 303(d)(1) of the CWA requires TMDLs to be "established at a level necessary to implement the applicable WQS with seasonal variation." Both stream temperature and flow vary seasonally and from year to year. Water temperatures are coolest in winter and early spring months.

Thermograph records show that temperatures exceed State of New Mexico WQS in summer and early fall. Warmest stream temperatures corresponded to prolonged solar radiation exposure, warmer air temperature, and low flow conditions. These conditions occur during late summer and early fall and promote the warmest seasonal instream temperatures. It is assumed that if critical conditions are met, coverage of any potential seasonal variation will also be met.

6.8 Future Growth

Growth estimates by county are available from the New Mexico Bureau of Business and Economic Research. These estimates project growth to the year 2035. Growth estimates for Sandoval County project a 51% growth rate through 2035. However, Sandoval County includes major cities such as Bernalillo, Corrales, and Rio Rancho. As of 2009, Jemez Springs' population (the largest incorporated town in the study area) is 1,367 people. Since 2000, Jemez Springs has had a population growth of 9.37 percent, but is not expected to have much growth in the future because it is confined by valley walls and surrounded by National Forest.

Estimations of future growth are not anticipated to lead to a significant increase for temperature that cannot be controlled with BMP implementation in this watershed.

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7.0 SEDIMENTATION/SILTATION (STREAM BOTTOM DEPOSITS)

During the 2005 SWQB water quality survey in the Jemez Watershed, impairment due to excessive sedimentation/siltation (previously listed as impairment due to Stream Bottom Deposits [SBD]) was confirmed for Rito de las Palomas [NM-2106.A_43] (Rio de las Vacas to headwaters).

7.1 Target Loading Capacity

Target values for this Sedimentation/Siltation TMDL are determined based on 1) the presence of numeric criteria or appropriate numeric translator to a narrative standard, 2) the degree of experience in applying the indicator, and 3) the ability to easily monitor and produce quantifiable and reproducible results. This TMDL is also consistent with New Mexico's antidegradation policy.

The state of New Mexico has developed and adopted a narrative criterion for "bottom deposits." The current general narrative criterion for the deposition of material on the bottom of a stream channel is specifically found in Paragraph (1) of Subsection A of 20.6.4.13 of the State of New Mexico Standards for Interstate and Intrastate Surface Waters (20.6.4 NMAC):

> ***A. Bottom Deposits and Suspended or Settleable Solids:***
> ***(1)*** *Surface waters of the state shall be free of water contaminants including fine sediment particles (less than two millimeters in diameter), precipitates or organic or inorganic solids from other than natural causes that have settled to form layers on or fill the interstices of the natural or dominant substrate in quantities that damage or impair the normal growth, function, or reproduction of aquatic life or significantly alter the physical or chemical properties of the bottom.*

The SWQB Sediment Workgroup evaluated a number of methods described in the literature that would provide information allowing a direct assessment of the impacts to the stream bottom substrate. In order to address the narrative criteria for bottom deposits, SWQB compiled techniques to measure the level of sedimentation of a stream bottom. These procedures are presented in Appendix C of the *State of New Mexico Procedures for Assessing Standards Attainment for the Integrated §303(d)/§305(b) Water Quality Monitoring and Assessment Report* *[Assessment Protocol]* (NMED/SWQB 2008a). The purpose of the protocol is to provide an assessment of the narrative criterion for stream bottom deposits. A final set of monitoring procedures was implemented at a wide variety of sites during the 2005 monitoring season. These procedures included conducting pebble counts (to determine percent (%) fines), stream bottom cobble embeddedness, geomorphologic measurements, and the collection and enumeration of benthic macroinvertebrates.

Target Setting

In setting a TMDL target for the Rito de las Palomas, the State uses a reference watershed approach when developing TMDLs for sediment. The reference waterbody for this TMDL is Rio de las Vacas above Forest Road 70. The reference site and study site have similar characteristics as shown in Table 7.1. Benthic macroinvertebrate samples and pebble counts were collected at both stations according to methods described by Barbour et al. (1999) and Wohlman (1954).

Collection of benthic macroinvertebrates involved the compositing of three individual kick net samples taken from a riffle at each sampling location. Each kick involved the disturbance of approximately one-third of a square meter of substrate for one minute into a 500-micron mesh net. The rapid bioassessment protocol (RBP) metrics were applied to a 300-organism subsample of the composite sample at each site (Barbour et al. 1999).

The macroinvertebrate community is generally the first to show a response to certain stressors such as the fine sediment that settles to the bottom of the channel. By collecting data on the macroinvertebrate communities that are present in a stream reach SWQB can identify changes that indicate stress on the community. Currently information is compiled on all identified species to create a stream condition index score (SCI) ranging from 0-100. This score expresses the amount of stress a macroinvertebrate community is encountering based on the diversity of species and the tolerance and feeding habitats of those taxa present in the stream reach. Selection of those metrics that are particularly suited to the delineation of sediment impacts highlights the degree of impairment. Table 7.2 displays the macroinvertebrate data metrics used to calculate the SCI score and the overall SCI score for each site.

Table 7.1 Comparison of Reference Site and Study Site

	Reference Site[(a)]	**Study Site[(b)]**
Latitude	36.01950	35.99247
Longitude	106.82320	106.79443
Watershed Area (mi^2)	13.4	12.2
Elevation (feet)	8989	8110
Ecoregion	21	21

Notes:
[(a)] Reference Site = Rio de las Vacas above FR 70
[(b)] Study Site = Rito de las Palomas at NM 126

Table 7.2 Macroinvertebrate Data Metrics and SCI Scores

	Taxonomic Composition			Taxonomic Richness		Tolerance		Habitat			Functional Feeding Group		
Stations **Bold indicates reference site**	Shannon Weiner	Evenness	Percent Plecoptera	Number of Ephemeroptera	Number of Plecoptera	Percent EPT	Percent Intolerance	Clinger Richness	Sprawler Richness	Swimmer Richness	Percent Scraper	Scraper Richness	Overall SCI Score
Rito de las Palomas at NM 126	3.07	0.41	1.67	4	1	14.4	7.78	4	8	4	22.2	3	51.64
Rio de Las Vacas above FR 70	**3.25**	**0.41**	**12.3**	**5**	**3**	**61.7**	**51.1**	**11**	**5**	**3**	**15.3**	**3**	**68.98**

In establishing a target for the Rito de las Palomas, NMED considered several factors. First, a District of Columbia Court of Appeals decision (*Friends of the Earth, Inc. v. EPA et al*), has now made it necessary for TMDLs to include "*daily load*" calculation. Currently the Clean Water Act Section 303(d)(1)(C) requires that TMDLs be established for pollutants which are, "suitable for calculation." In the case of stream bottom deposits it is impossible to calculate a "*daily load.*" Secondly, the Jemez watershed (Figure 7.1) has both natural processes and watershed disturbances (both anthropogenic and non-anthropogenic) that contribute to sediment deposition. By addressing sources of suspended sediment (i.e. watershed disturbances) that contribute to instream total suspended solids (TSS), there should be an improvement in biological community and reduction in the amount of embeddedness overtime, thus improving overall stream health. Therefore, this TMDL will focus on reducing TSS.

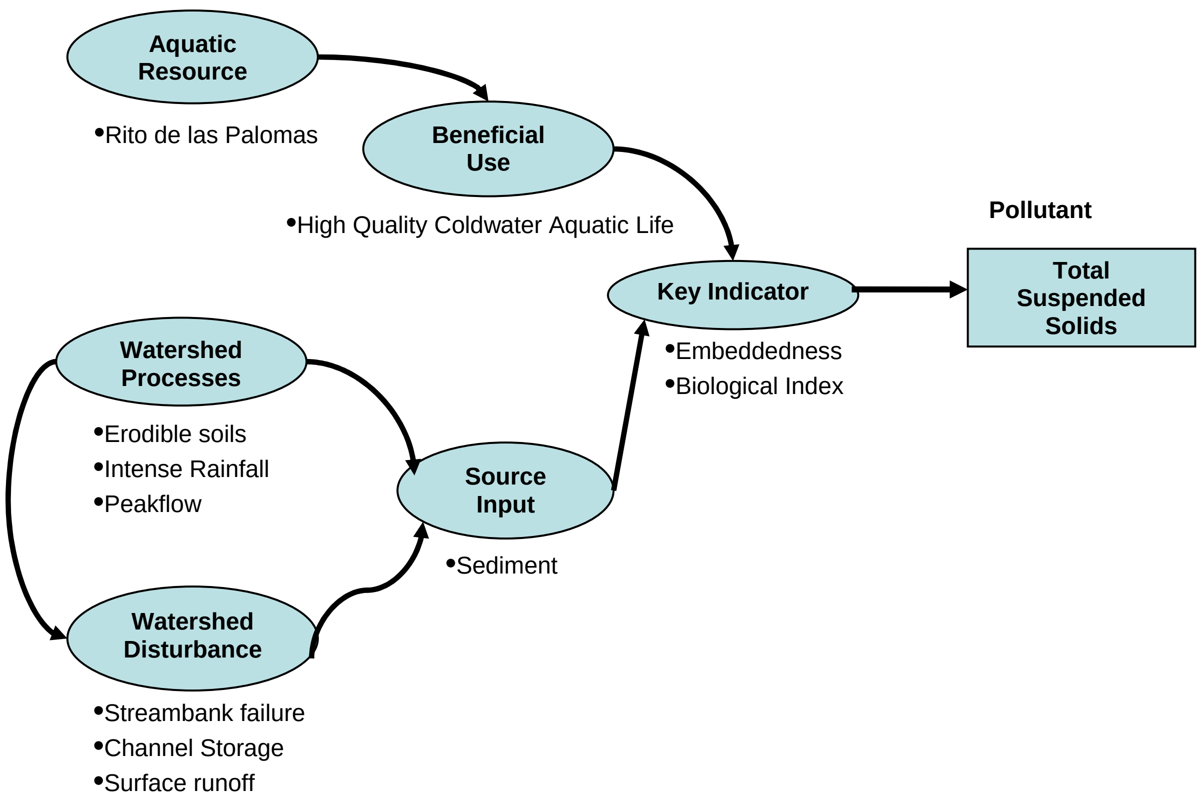

Figure 7.1 Sediment Issues and TMDL Target Setting

In examining the existing water quality data for the Rito de las Palomas, limited streamflow, TSS, and turbidity data were available (Table 7.3). Even though the data were limited, an analysis was performed on the Rito de las Palomas at NM 126 data which represent the entire segment, Rito de las Palomas (Rio de las Vacas to headwaters).

Table 7.3 Available Water Quality Data for the Rito de las Palomas

	Number of Samples		
Rito de las Palomas (Rio de las Vacas to headwaters)	TSS	Turbidity	Flow
Rito de las Palomas at NM 126	9	9	7

The segment-specific turbidity value from the 2002 State of New Mexico Surface Water Quality Standards was used as a target value for Rito de las Palomas. Based on the 2002 State standards, it was determined that a turbidity value of 25 NTU is the target that should be protective of the high quality coldwater aquatic use in the Rito de las Palomas. In order to calculate a TMDL in pounds per day (lbs/day), TSS is used as a surrogate for turbidity which in turn is used as a surrogate for stream bottom deposits. Figure 7.2 depicts the relationship between TSS and turbidity for the Rito de las Palomas (R^2 = 0.98).

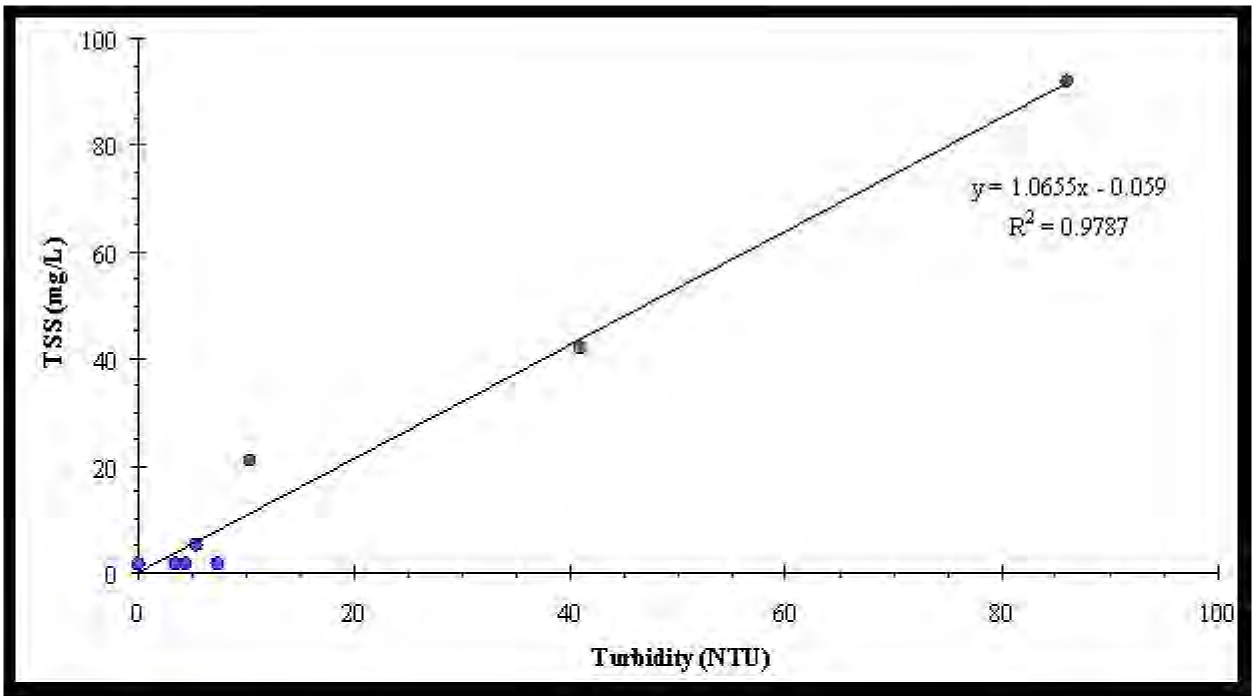

Figure 7.2 Rito de las Palomas TSS vs. Turbidity Relationship

The data show that 98% of the variability in turbidity is explained by TSS in the Rito de las Palomas. In addition, Pearson correlation coefficient was used to assess whether a statistically valid relationship existed between TSS and turbidity. Pearson correlation coefficient measures the strength and direction of a *linear* relationship between *X* and *Y* variables. Like other numerical measures, the population correlation coefficient is "ρ" (the Greek letter "rho") and the sample correlation coefficient is denoted by *r*.

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

When examining the Rito de las Palomas data set, the data show a positive association between TSS and turbidity (r = 0.99). The relationship between TSS and turbidity shows that TSS is the major control on turbidity.

Using the TSS/Turbidity relationship from Figure 7.2 and a turbidity target of 25 NTU, the TSS concentration required to achieve NM water quality standards are:

- Rito de las Palomas (Rio de las Vacas to headwaters)
  (1.0655 x 25 NTU) – 0.059 ≅ 26.6 mg/L of TSS

7.2 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 at specific flows, however it is often necessary to calculate a critical flow for a portion of a watershed where there is no active flow gage as in the Rito de las Palomas. For this reach, streamflow was measured by SWQB during the 2005 sampling season using standard procedures (NMED/SWQB 2004). Flows were measured in the Rito de las Palomas at State Highway 126 with flows ranging from 0.25 cfs to 40 cfs. Water quality standard exceedences ***only*** occurred during high flows. Therefore, the critical streamflow value for this TMDL is the lowest streamflow at which the turbidity standard is exceeded, or the expected flow at which the turbidity is equal to 25 NTU. Figure 7.3 depicts the relationship between turbidity and streamflow for the Rito de las Palomas (R^2 = 0.96).

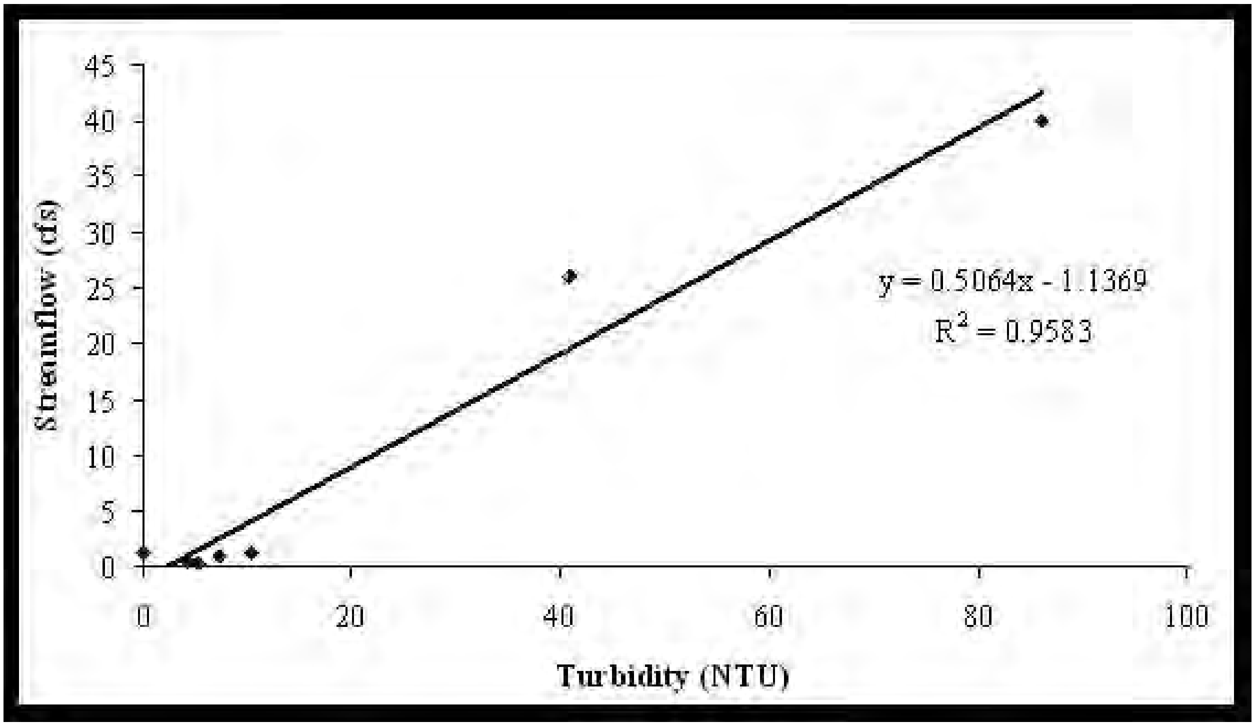

Figure 7.3 Rito de las Palomas Turbidity vs. Streamflow Relationship

The critical flow is based on SWQB data and was calculated using the relationship between turbidity and steramflow presented above. Using the Turbidity/Flow relationship and the turbidity standard of 25 NTU for the x-variable, the critical flow at which NM water quality standards are exceeded is:

$$(0.5064 \text{ x } 25 \text{ NTU}) - 1.1369 \cong 11.5 \text{ cubic feet per second}$$

The critical streamflow value was converted from cubic feet per second (cfs) to units of million gallons per day (mgd) as follows:

$$11.5\,\frac{ft^3}{\sec} \times 1{,}728\,\frac{in^3}{ft^3} \times 0.004329\,\frac{gal}{in^3} \times 86{,}400\,\frac{\sec}{day} \times 10^{-6} = 7.43\,mgd \qquad \text{(Eq. 1)}$$

It is important to remember that the TMDL itself is a value calculated at a defined critical condition, and is calculated as part of planning process designed to achieve water quality standards. Since flows vary throughout the year in these systems, the actual load at any given time will vary based on the changing flow.

7.3 Calculations

Target loads for stream bottom deposits (expressed as TSS) are calculated based on the critical flow, the water quality criterion, and a conversion factor (8.34) that is a used to convert milligram per liter (mg/L) units to pounds per day (lbs/day) (see Appendix B for Conversion Factor Derivation). The target loading capacity is calculated using **Equation 2**. The results are shown in Table 7.4.

Critical Flow (mgd) x Criterion (mg/L) x 8.34 = Target Loading Capacity (Eq. 2)

Table 7.4 Calculation of Target Loads for TSS (Sedimentation/Siltation surrogate)

Assessment Unit	Critical Flow (mgd)	TSS (mg/L)	Conversion Factor	Target Load Capacity (lbs/day)
Rito de las Palomas (Rio de las Vacas to headwaters)	7.43⁺	26.6*	8.34	1,648

Notes:

+ The flow value was calculated using the relationship established between flow and turbidity in Figure 7.3 (y = 0.5064x - 1.1369; R^2 = 0.9583) using the turbidity standard of 25 NTU for the X variable and converting units of cfs to mgd using Equation 1.

* The TSS value was calculated using the relationship established between turbidity and TSS in Figure 7.2 (y=1.0655x - 0.059, R^2 = 0.98) using the turbidity standard of 25 NTU for the X variable.

7.4 Waste Load Allocations and Load Allocations

7.4.1 Waste Load Allocation

There are no active point source contributions associated with this TMDL. There also are no Municipal Separate Storm Sewer System (MS4) storm water permits in this assessment unit. Sediment may be a component of some (primarily construction) storm water discharges so these discharges should be addressed.

In contrast to discharges from other industrial storm water and individual process wastewater permitted facilities, storm water discharges from construction activities are transient because they occur mainly during the construction itself, and then only during storm events. Coverage under the National Pollutant Discharge Elimination System (NPDES) construction general storm water permit (CGP) for construction sites greater than one acre requires preparation of a Storm Water Pollution Prevention Plan (SWPPP) that includes identification and control of all pollutants associated with the construction activities to minimize impacts to water quality. In addition, the current CGP also includes state specific requirements to implement Best Management Practices (BMPs) that are designed to prevent to the maximum extent practicable, an increase in sediment, or a parameter that addresses sediment (e.g., total suspended solids, turbidity, siltation, stream bottom deposits, etc.) and flow velocity during and after construction compared to pre-construction conditions. In this case, compliance with a SWPPP that meets the requirements of the CGP is generally assumed to be consistent with this TMDL.

Other industrial storm water facilities are generally covered under the current NPDES Multi-Sector General Storm Water Permit (MSGP). This permit also requires preparation of an SWPPP that includes identification and control of all pollutants associated with the industrial activities to minimize impacts to water quality. In addition, the current MSGP also includes specific requirements to further limit (or eliminate) pollutant loading to water quality impaired/water quality limited waters from facilities where there is a reasonable potential to contain pollutants for which the receiving water is impaired. In this case, compliance with a SWPPP that meets the requirements of the MSGP is generally assumed to be consistent with this TMDL.

Individual WLAs for the General Permits were not possible to calculate at this time in this watershed using available tools. Loads that are in compliance with the General Permits from facilities covered are therefore currently calculated as part of the watershed load allocation (LA).

7.4.2 Load Allocation

In order to calculate the LA, the WLA and MOS were subtracted from the target capacity TMDL following **Equation 3**:

$$WLA + LA + MOS = TMDL \qquad \text{(Eq. 3)}$$

The MOS is estimated to be 25% of the target load calculated in Table 7.5. Results are presented in Table 7.5. Additional details on the MOS chosen are presented in Section 7.7.

Table 7.5 Calculation of TMDL for TSS (Sedimentation/Siltation surrogate)

Assessment Unit	WLA (lbs/day)	LA (lbs/day)	MOS (25%) (lbs/day)	TMDL (lbs/day)
Rito de las Palomas (Rio de las Vacas to headwaters)	0	1,236	412	1,648

The extensive data collection and analyses necessary to determine background sediment loads for the Rito de las Palomas was beyond the resources available for this study. Therefore, it is assumed that a portion of the load allocation is made up of natural background loads.

7.5 Identification and Description of Pollutant Source(s)

Probable sources of sedimentation for this assessment unit will be evaluated, refined, and changed as necessary through the Watershed Restoration Action Strategy (WRAS) process. Probable sources that may contribute to the impaired reach are listed in Table 7.6.

Table 7.6 Pollutant source summary

Pollutant	Magnitude	Location	Probable Sources[(b)]
Point Source			
None	0%	---	0%
Nonpoint Source			
Sedimentation	24%[(a)]	Rito de las Palomas (Rio de las Vacas to headwaters)	100% Highway/road/bridge runoff (non-construction related), loss of riparian habitat, rangeland grazing, streambank modifications/destabilization

Notes:

(a) The magnitude is equal to the measured load expressed as percent fines. Fines are defined as particles less than 2 millimeters (mm) in diameter.

(b) From the 2008-2010 Integrated CWA §303(d)/§305(b) List. This list of probable sources is based on staff observation and known land use activities in the watershed. These sources are not confirmed or quantified at this time.

7.6 Linkage of Water Quality and Pollutant Sources

Clean stream bottom substrates are essential for optimum habitat for many fish and aquatic insect communities. The impact of fine sediment deposits is well documented in the literature. Impairment occurs when critical habitat components, such as spawning gravels and cobble surfaces, are physically covered by fines thereby decreasing intergravel oxygen and reducing or eliminating the quality and quantity of habitat for fish, macroinvertebrates, and algae (Chapman and McLeod 1987, Lisle 1989, Waters 1995). An increased sediment load is often the most important adverse effect of human 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. Excessive stream bottom deposits impact a stream's health by reducing the interstitial space and subsequently reducing intergravel dissolved oxygen, which adversely impact the macroinvertebrate population by reducing the stream's spawning and rearing potential. Minshall (1984) cited the importance of substratum size to aquatic insects and found that substratum is a primary factor influencing the abundance and distribution of insects. Aquatic detritivores also can be affected when their food supply either is buried under sediments or diluted by increased inorganic sediment load and by increasing search time for food (Relyea et al. 2000).

In addition, sediment loads that exceed a river's sediment transport capacity often trigger changes in stream morphology (Leopold et al. 1964). Increasing cobble embeddedness reduces channel roughness (Manning's "n"), thus reducing instream bed friction, which ultimately leads to further channel instability. Streams that become overwhelmed with sediment often go through a period of accelerated channel widening and streambank erosion before returning to a stable form (Schumm 1977, Knighton 1984). These morphological changes tend to accelerate erosion, thereby reducing habitat diversity and placing additional stress on designated aquatic life uses.

Total suspended solids (TSS) is the ultimate source of stream bottom deposit impairments because suspended solids settle to the bottom and can eventually blanket the river bed. Suspended solids can smother the eggs of fish and aquatic insects, and can suffocate newly-hatched insect larvae. Suspended solids can also harm fish directly by clogging and abrading gills, reducing growth rates, lowering resistance to disease, and preventing egg and larval development. Changes to the aquatic environment may result in diminished food sources and increased difficulties in finding food. Natural movements and migrations of aquatic populations may be disrupted. In addition, settling sediments can fill in spaces between rocks which could have been used by aquatic organisms for habitat.

High concentrations of suspended solids can cause many problems for stream health and aquatic life. Suspended solids absorb heat from sunlight, which increases water temperature and subsequently decreases levels of dissolved oxygen (warmer water holds less oxygen than cooler water). Photosynthesis also decreases, since less light penetrates the water. Reduced rates of photosynthesis causes less dissolved oxygen to be released into the water by plants. If light is completely blocked from bottom dwelling plants, the plants will stop producing oxygen and will die. As the plants are decomposed, bacteria will use up even more oxygen from the water. Some cold water species, such as trout, are especially sensitive to changes in dissolved oxygen and are consequently vulnerable to fish kills.

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.

Factors affecting total suspended solids in a waterway include:

1. Increases or decreases in flow rates
    - land clearing, constructing drainage ditches, and straightening natural water channels may strand fish upstream or dry out recently spawned eggs due to the subsequent low flows
    - fast running water can carry more particles and larger-sized sediment creating an obstacle to the upstream movement of fish

- heavy rains can pick up sand, silt, clay, and organic particles (such as leaves and soil) from the land and carry it to surface water destroying the aquatic habitat and harming and/or killing the aquatic life
- during low flow, the sediment that was carried by faster moving water will settle to the bottom of the streambed, which can have detrimental effects on the aquatic community by smothering eggs or suffocating newly hatched larvae and burying the homes of aquatic organisms

2. Soil erosion caused by disturbance of a land surface
    - increases suspended solids in the water
    - reduces transmission of sunlight needed for photosynthesis
    - interferes with animal behaviors dependent on sight (foraging, mating, and escape from predators)
    - impedes respiration (e.g., by gill abrasion in fish) and digestion
    - reduces oxygen in the water
    - covers bottom gravel and degrades spawning habitat
    - covers eggs, which may suffocate or develop abnormally; fry may be unable to emerge from the buried gravel bed

3. Clearing of trees and shrubs from streambanks
    - destabilizes banks and promotes erosion
    - increases sedimentation and turbidity
    - reduces shade and increases water temperature which could disrupt fish metabolism
    - causes channels to widen and become more shallow

Where data gaps exist or 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 probable sources of impairment (NMED/SWQB 1999). The completed *Pollutant Source(s) Summary Table* in **Appendix C** provides 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 probable sources of impairment in this watershed. Staff completing these forms identify and quantify probable sources of NPS 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 main sources of impairment along the Rito de las Palomas appear to be from highway/road/bridge runoff (non-construction related), loss of riparian habitat, rangeland grazing, and streambank modifications/destabilization.

7.7 Margin of Safety (MOS)

TMDLs should reflect a MOS based on the uncertainty or variability in the data, the point and nonpoint source load estimates, and the modeling analysis. The MOS is estimated to be **25%** of the TMDL. This MOS incorporates several factors:

•Errors in calculating source 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 which determines stream bottom impairment. There is also a potential to have errors in measurements due to equipment accuracy, time of sampling, etc. Accordingly, a conservative MOS for this element is **15%** of the TMDL.

•Errors in calculating flow

> Flow estimates were based on field measurements. Techniques used for measuring flow in water have a ±5 percent precision. In addition, there is a potential to have errors in measurements of flow due to equipment accuracy, time of sampling, etc. To be conservative, an additional MOS of **10%** will be included to account for accuracy of flow computations.

7.8 Consideration of Seasonal Variation

Data used in the calculation of this TMDL were collected during high and low flow seasons in order to ensure coverage of any potential seasonal variation in the system. Fall is a critical time in the life cycle stages of benthic macroinvertebrates in NM. Fall is also generally the low-flow period of the mean annual hydrograph in NM when bottom deposits are most likely to settle and cause impairment, after the summer monsoon season but before annual spring runoff. Thus, the critical condition used for calculating the TMDL was low flow. It is assumed that if critical conditions are met during this time, coverage of any potential seasonal variation will also be met.

7.9 Future Growth

Growth estimates by county are available from the New Mexico Bureau of Business and Economic Research. These estimates project growth to the year 2035. Growth estimates for Sandoval County project a 51% growth rate through 2035. However, Sandoval County includes major cities such as Bernalillo, Corrales, and Rio Rancho. As of 2009, Jemez Springs' population (the largest incorporated town in the study area) is 1,367 people. Since 2000, Jemez Springs has had a population growth of 9.37 percent, but is not expected to have much growth in the future because it is confined by valley walls and surrounded by National Forest.

Estimations of future growth are not anticipated to lead to a significant increase in sedimentation that cannot be controlled with BMP implementation in this watershed.

8.0 MONITORING PLAN

Pursuant to Section 106(e)(1) of the Federal CWA, the SWQB has established appropriate monitoring methods, systems and procedures in order to compile and analyze data on the quality of the surface waters of New Mexico. In accordance with the New Mexico Water Quality Act, the SWQB has developed and implemented a comprehensive water quality monitoring strategy for the surface waters of the State.

The monitoring strategy establishes the methods of identifying and prioritizing water quality data needs, specifies procedures for acquiring and managing water quality data, and describes how these data are used to progress toward three basic monitoring objectives: to develop water quality-based controls, to evaluate the effectiveness of such controls, and to conduct water quality assessments.

The SWQB utilizes a rotating basin system approach to water quality monitoring. In this system, a select number of watersheds are monitored each year with an established return frequency of approximately every eight years. Based on an 8-year rotation throughout the state, the next tentatively scheduled monitoring date for the Jemez River watershed is 2013. The SWQB maintains current quality assurance and quality control plans for the respective sample year to cover all monitoring activities. This document, called the QAPP, is updated and certified annually by USEPA Region 6 (NMED/SWQB 2005). In addition, the SWQB identifies the data quality objectives required to provide information of sufficient quality to meet the established goals of the program. Current priorities for monitoring in the SWQB are driven by the CWA Section 303(d) list of streams requiring TMDLs. Short-term efforts were directed toward those waters that are on the USEPA TMDL consent decree list (U.S. District Court for the District of New Mexico 1997), however NMED/SWQB completed the final remaining TMDL on the consent decree in December 2006 and USEPA approved this TMDL in August 2007. The U.S. District Court offically terminated New Mexico’s Consent Decree on April 21, 2009.

Once assessment monitoring is completed, those reaches showing impacts and requiring a TMDL will be targeted for more intensive monitoring. The methods of data acquisition include fixed-station monitoring, intensive surveys of priority assessment units (including biological assessments), and compliance monitoring of industrial, federal, and municipal dischargers, as specified in the SWQB Assessment Protocols (NMED/SWQB 2008a).

Long-term monitoring for assessments will be accomplished through the establishment of sampling sites that are representative of the waterbody and which can be revisited approximately every seven years. This information will provide time relevant information for use in CWA Section 303(d) listing and 305(b) report assessments and to support the need for developing TMDLs. The approach provides:

- a systematic, detailed review of water quality data which allows for a more efficient use of valuable monitoring resources;
- information at a scale where implementation of corrective activities is feasible;
- an established order of rotation and predictable sampling in each basin which allows for enhanced coordinated efforts with other programs; and

- program efficiency and improvements in the basis for management decisions.

SWQB routinely develops a 10-year monitoring strategy and submits it to USEPA. The strategy details both the extent of monitoring that can be accomplished with existing resources plus expanded monitoring strategies that could be implemented given additional resources. According to the proposed rotational cycle, which assumes the existing level of resources, the next time SWQB will sample the Jemez River watershed is during 2013.

It should be noted that a watershed would not be ignored during the years in between sampling. The rotating basin program will be supplemented with other data collection efforts such as the funding of long-term USGS water quality gaging stations for long-term trend data, and on-going studies being performed by USGS and USEPA. Data will be analyzed and field studies will be conducted to further characterize acknowledged problems and TMDLs will be developed and implemented accordingly. Both long-term monitoring and short-term water quality surveys can contribute to the State's Integrated CWA §303(d)/§305(b) listing process for waters requiring TMDLs.

9.0 IMPLEMENTATION OF TMDLS

9.1 NPDES Permitting

Arsenic and Boron

According to the data, a substantial source of arsenic and boron loading is from hot springs and other diffuse nonpoint sources. The Jemez Valley Public Schools WWTP contributes roughly 2% of the measured arsenic load and 1% of the measured boron load in the Jemez River, whereas the Village of Jemez Springs WWTP supplies approximately 7% of the measured arsenic and boron loads in the Jemez River. Moreover, current loading of arsenic and boron from the treatment plants is well within the limits set by their respective TMDLs (see Sections 3.0 and 4.0 for details). Therefore, SWQB recommends no effluent limits for arsenic and boron in the NPDES permits at this time. However, monitoring requirements for arsenic and boron should be outlined in the permits to ensure that current levels are not exceeded. Any variation from current levels that leads to excess arsenic and/or boron in the stream should result in numeric effluent limits when the NPDES permit is up for renewal.

Nutrients (Phosphorus and Nitrogen)

Nutrient removal is one of the most pressing challenges facing wastewater treatment facilities. The Village of Jemez Springs WWTP contributes approximately 27% of the measured nitrogen load and 95% of the measured phosphorus load in the Jemez River. Current loading of nitrogen from the WWTP is well within the limits set by the TMDL. Conversely, current loading of phosphorus from the WWTP is above the target load set by the TMDL.

Several technologies for phosphorus removal exist. Phosphorus can be removed from wastewater via biological, chemical, or combined biological and chemical processes. There are theoretical limits for the lowest phosphorus that can be achieved with different removal mechanisms. The lowest effluent TP observed at biological wastewater treatment facilities ranges from 0.1 to 0.3 mg/L. The lowest phosphorus level that can be obtained through chemical removal is determined by the solubility of phosphorus, which depends on the dose ratio and the pH. At pH around 7, the lowest effluent TP observed is 0.01 to 0.02 mg/L for aluminum removal and 0.04 to 0.05 mg/L for iron removal. The choice of technology to be used depends on site-specific conditions and economic feasibility.

The Jemez Springs WWTP discharges to the Jemez River under authorization of an NPDES permit, but the facility is currently not designed to treat effluent for total phosphorus and total nitrogen. Federal regulations (40 CFR 130.12(a) and 40 CFR 122.44(d)(1)(vii)) clearly require that NPDES permits must be consistent with the wasteload allocation (WLA) of an adopted and approved TMDL. Because this facility is the sole point source discharger in this reach, it has been allocated the entire WLA of 0.626 lbs/day for total phosphorus and 2.97 lbs/day of total nitrogen as identified in Table 5.8 of the TMDL. The facility will need to develop and implement treatment to meet the new effluent requirements that will result from this TMDL. The New Mexico water quality standards (Subsection J of 20.6.4.12 NMAC) states that it is the policy of the WQCC to allow schedules of compliance in NPDES permits where facility modifications need to be made to meet new water quality based requirements.

9.2 WRAS and BMP Coordination

In this watershed, public awareness and involvement will be crucial to the successful implementation of these plans to improved water quality. Staff from SWQB have worked with stakeholders to develop a Watershed Restoration Action Strategy (WRAS) for the Jemez Watershed (Jemez Watershed Group 2005). The WRAS is a written plan intended to provide a long-range vision for various activities and management of resources in a watershed. It includes opportunities for stakeholders in reducing and preventing impacts to water quality. Stakeholders can include members of the general public, representatives of acequia associations, water users, private landowners, local government, environmental groups, state and federal agencies, tribal agencies, and any other interested party. This long-range strategy is instrumental in coordinating and achieving constituent levels consistent with New Mexico's WQS, and is used to prevent water quality impacts in the watershed. The WRAS is essentially the Implementation Plan, or Phase Two of the TMDL process. The completion of the TMDLs and WRAS leads directly to the development of on-the-ground projects to address surface water impairments in the watershed.

SWQB staff will continue to help with any technical assistance such as selection and application of BMPs needed to meet WRAS goals as well as trend monitoring to determine the effectiveness of those BMPs. Stakeholder public outreach and involvement in the implementation of this TMDL will be ongoing. Stakeholders in this process will include SWQB and members of the Jemez Watershed Group.

Implementation of Best Management Practices (BMPs) within the watershed to reduce pollutant loading from nonpoint sources will be encouraged. SWQB recognizes that the numerous hot springs in the Jemez River Watershed deliver a substantial amount of arsenic and boron into the surface waters, however the proportion of the total load coming from these hot springs is unknown at this time. BMP implementation to reduce arsenic and boron loads may not have an impact on hot spring contributions but could be helpful in reducing contributions from other sources. SWQB will communicate to designated federal land management agencies the intent of the TMDL and desire that BMPs be developed through the above coordination process.

9.3 Time Line

The Jemez Watershed Group was established in 2003 after the first set of Jemez Watershed TMDLs were prepared in 2002. As a result, the Jemez Watershed WRAS was developed and finalized before preparation of these TMDLs. The general implementation timeline is detailed below (Table 9.1).

Table 9.1 Proposed Implementation Timeline

Implementation Actions	Year 1	Year 2	Year 3	Year 4	Year 5
Public Outreach and Involvement	X	X	X	X	X
Form watershed groups	X	X			
WRAS Development		X	X	X	
Establish Performance Targets		X			
Secure Funding		X	X		
Implement Management Measures (BMPs)		X	X	X	
Monitor BMPs		X	X	X	
Determine BMP Effectiveness				X	X
Re-evaluate Performance Targets				X	X

9.4 Clean Water Act §319(h) Funding Opportunities

The Watershed Protection Section of the SWQB provides USEPA §319(h) funding to assist in implementation of BMPs to address water quality problems on reaches listed as category 4 or 5 waters on the Integrated CWA §303(d)/ §305(b) list. These monies are available to all private, for profit, and nonprofit organizations that are authenticated legal entities, or governmental jurisdictions including: cities, counties, tribal entities, Federal agencies, or agencies of the State. Proposals are submitted by applicants two times a year through a Request for Proposal (RFP) process and require a non-federal match of 40% of the total project cost consisting of funds and/or in-kind services. Funding is available for both watershed group formation (which includes WRAS development) and on-the-ground projects to improve surface water quality and associated habitat. Further information on funding from the CWA §319 (h) can be found at the SWQB website: http://www.nmenv.state.nm.us/swqb.

9.5 Other Funding Opportunities

Several other sources of funding existing to address impairments discussed in this TMDL document. NMED's Construction Programs Bureau assists communities in need of funding for WWTP upgrades and improvements to septic tank configurations (such as the design of cluster systems). They can also provide matching funds for appropriate CWA §319(h) projects using state revolving fund monies. The U.S. Department of Agriculture (USDA) Environmental Quality Incentive Program (EQIP) program can provide assistance to private land owners in the basin. The USDA Forest Service aligns their mission to protect lands they manage with the TMDL process, and are another source of assistance. The Bureau of Land Management (BLM) has several programs in place to provide assistance to improve unpaved roads and grazing allotments.

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10.0 ASSURANCES

New Mexico's Water Quality Act (Act) authorizes the WQCC to "promulgate and publish regulation to prevent or abate water pollution in the state" and to require permits. The Act authorizes a constituent agency to take enforcement action against any person who violates a water quality standard. (§74-6-10(A) NMSA 1978) Several statutory provisions on nuisance law could also be applied to nonpoint source water pollution. The Water Quality Act also states in §74-6-12(A):

> *The Water Quality Act (this article) does not grant to the commission or to any other entity the power to take away or modify the property rights in water, nor is it the intention of the Water Quality Act to take away or modify such rights.*

In addition, the State of New Mexico Surface Water Quality Standards (see Subsection C of 20.6.4.62) (NMAC 2007) state:

> *Pursuant to Subsection A of Section 74-6-12 NMSA 1978, this part does not grant to the water quality control commission or to any other entity the power to take away or modify property rights in water.*

New Mexico policies are in accordance with the federal Clean Water Act §101(g):

> *It is the policy of Congress that the authority of each State to allocate quantities of water within its jurisdiction shall not be superseded, abrogated or otherwise impaired by this Act. It is the further policy of Congress that nothing in this Act shall be construed to supersede or abrogate rights to quantities of water which have been established by any State. Federal agencies shall co-operate with State and local agencies to develop comprehensive solutions to prevent, reduce and eliminate pollution in concert with programs for managing water resources.*

New Mexico's 319 Program has been developed in a coordinated manner with the State's 303(d) process. All 319 watersheds that are targeted in the annual RFP process coincide with the State's biennial impaired waters list as approved by USEPA. The State has given a high priority for funding, assessment, and restoration activities to these watersheds.

As a constituent agency, NMED has the authority under Chapter 74, Article 6-10 NMSA 1978 to issue a compliance order or commence civil action in district court for appropriate relief if NMED determines that actions of a "person" (as defined in the Act) have resulted in a violation of a water quality standard including a violation caused by a nonpoint source. Proving causation by a nonpoint source of a violation of a water quality standard would be very difficult, and to date NMED has not brought an enforcement action on this basis. Instead, the NMED nonpoint source water quality management program has historically strived for and will continue to promote voluntary compliance to nonpoint source water pollution concerns by utilizing a voluntary, cooperative approach. NMED believes this is the best and most effective approach to addressing impairment of streams as a result of nonpoint source issues. The State provides technical support and grant monies for implementation of BMPs and other nonpoint source prevention mechanisms through §319 of the Clean Water Act. Since portions of this TMDL will be implemented through nonpoint source control mechanisms, the New Mexico Watershed Protection Program will target its efforts towards this and other watersheds with TMDLs.

In order to obtain reasonable assurances for implementation in watersheds with multiple landowners, including federal, State and private land, NMED has previously established Memoranda of Understanding (MOUs) with various federal agencies, in particular the USFS and the Bureau of Land Management. MOUs in the past have also been developed with other State agencies, such as the New Mexico State Highway and Transportation Department. These MOUs provided for coordination and consistency in dealing with nonpoint source issues.

The time required to attain standards for all reaches is estimated to be approximately 10-20 years. This estimate includes watershed projects that may not be starting immediately, and also contemplates response to earlier projects. This timeframe is intended to provide some measure of watershed response to projects but is not intended to be a fixed goal. Stakeholders in this process will include SWQB, and other stakeholders involved with the development and implementation of the WRAS. The cooperation of watershed stakeholders will be pivotal in the implementation of these TMDLs as well.

11.0 PUBLIC PARTICIPATION

Public participation was solicited in development of this TMDL (see **Appendix F**). The draft TMDL was made available for a 30-day public comment period beginning on June 8, 2009. Response to comments are attached as **Appendix G** of this document. The draft document notice of availability was extensively advertised via newsletters, email distribution lists, webpage postings (http://www.nmenv.state.nm.us/swqb), and press releases to the Albuquerque Journal, Santa Fe New Mexican, and Jemez Thunder. A public meeting in the Jemez Watershed was held on June 25, 3009 from 6-8 pm in Jemez Springs, New Mexico.

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12.0 REFERENCES

Barbour, Michael T., Jeroen Gerritsen, Blaine D. Snyder, and James B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish. Second Edition. EPA 841/B-99/002. Office of Water, Washington, DC.

Bartholow, J.M. 2002. *SSTEMP for Windows: The Stream Segment Temperature Model (Version 2.0)*. U.S. Geological Survey computer model and documentation. Available on the internet at http://www.fort.usgs.gov. Revised August 2002.

Behnke, R.J. and M. Zarn. 1976. *Biology and management of threatened and endangered western trouts*. USDA Forest Service, General Technical Report RM-28. Fort Collins, CO. 45 pp.

Chapman, D.W. and K.P. McLeod. 1987. Development of Criteria for Fine Sediment in Northern Rockies Ecoregion. United States Enviromental Protection Agency, Water Division, Report 910/9-87-162, Seattle, Washington, USA.

Chetelat, J., F.R. Pick, and A. Morin. 1999. Periphyton biomass and community composition in rivers of different nutrient status. Can. J. Fish Aquat. Sci. 56(4):560-569.

Chronic, Halka. 1987. *Roadside Geology of New Mexico*. Mountain Press Publishing Company, Missoula.

Constantz, J, C.L. Thomas, and G. Zellweger. 1994. Influence of diurnal variations in stream temperature on streamflow loss and groundwater recharge. Water Resources Research 30:3253-3264.

Dodds, W.K., V.H. Smith, and B. Zander. 1997. Developing nutrient targets to control benthic chlorophyll levels in streams: A case study of the Clark Fork River. Water Res. 31:1738-1750.

Jemez Watershed Group. 2005. *Jemez Watershed Restoration Action Strategy (WRAS)*. Developed by the Jemez Watershed Group under a 319 Grant administered by Meridian Institute. August.

Knighton, D.1984. Fluvial Forms and Processes. Edward Arnold of Hodder and Stoughton. London, England.

Leopold, L.B., M.G. Wolman, and J.P. Miller. 1964. *Fluvial Processes in Geomorphology*. Dover Publications, Inc., New York, NY.

Lisle, T. 1989. Sediment Transport and Resulting Deposition in Spawning Gravels, North Coast California. Wat. Resourc. Res. 25 (6):1303-1319.

McQuillan, D. 2004. *Ground-Water Quality Impacts from On-Site Septic Systems*. Proceedings, National Onsite Wastewater Recycling Association, 13th Annual Conference, Albuquerque, NM. November 7-10, 2004. 13 pp. Available online at http://www.nmenv.state.nm.us/fod/LiquidWaste/NOWRA.paper.pdf.

Minshall, G.W. 1984. Aquatic insect-substratum relationships. In The Ecology of Aquatic Insects, Resh and Rosenberg (eds.) Praeger Publishers, New York, NY.

Mount, D.I. 1969. *Developing thermal requirements for freshwater fishes*. *In* Biological Aspects of Thermal Pollution. Krenkel and Parker (eds.), Vanderbilit University Press, Nashville, TN.

Muldavin, E. and P. Tonne. 2003. A Vegetation Survey and Preliminary Ecological Assessment of Valles Caldera National Preserve, New Mexico. Albuquerque, NM.

Nebel, B. J. and R. T. Wright. 2000. Environmental Science: The Way the World Works. 7th ed. Prentice-Hall, Upper Saddle River, NJ.

New Mexico Administrative Code (NMAC). 2007. *State of New Mexico Standards for Interstate and Intrastate Streams.* 20.6.4. New Mexico Water Quality Control Commission. As amended through August 2007. (20.6.4 NMAC)

New Mexico Environment Department/Surface Water Quality Bureau (NMED/SWQB). 1999. *Draft pollutant source documentation protocol*. Available on the Internet at http://www.nmenv.state.nm.us/swqb/links.html.

———. 2004. *Standard Operating Prcedures for Data Collection*. Surface Water Quality Bureau. Santa Fe, NM.

———. 2005. *Quality Assurance Project Plan for Water Quality Management Programs*. Surface Water Quality Bureau. Santa Fe, NM.

———. 2006. *Final Approved Total Maximum Daily Load (TMDL) for the Jemez River Watershed – Valles Caldera National Preserve Boundaries to Headwaters*. October 11, 2006. Surface Water Quality Bureau. Santa Fe, NM. Available online at http://www.nmenv.state.nm.us/swqb/VallesCaldera.

———. 2008a. *State of New Mexico Procedures for Assessing Standards Attainment for the Integrated §303(d)/§305(b) Water Quality Monitoring and Assessment Report.* January. Available online at http://www.nmenv.state.nm.us/swqb/links.html.

———. 2008b. *State of New Mexico 2008-2010 Integrated Clean Water Act §303(d)/§305(b) List of Assessed Waters. August*. Santa Fe, NM.

———. 2009. Water Quality Survey Summary for the Jemez River Watershed, 2005. Santa Fe, NM.

Relyea, C.D., C. W. Marshall, and R.J. Danehy. 2000. *Stream insects as indicators of fine sediment.* Stream Ecology Center, Idaho State University, Pocatello, ID. Presented at WEF 2000 Watershed Management Conference.

Rosgen, D. 1996. *Applied River Morphology*. Wildland Hydrology, Pagosa Springs, CO.

Schumm, S.A. 1977. The Fluvial System. Wiley Interscience. New York, NY.

Thomas, Blakemore E., H.W. Hjalmarson, and S.D. Waltemeyer. 1997. *Methods for Estimating Magnitude and Frequency of Floods in the Southwestern United States*. USGS Water-Supply Paper 2433.

U.S. Department of Agriculture (USDA). 2005. *WinXSPRO 3.0 A Channel Cross Section Analyzer*. West Consultants Inc. San Diego, CA.

U.S. Environmental Protection Agency (USEPA). 1991. *Monitoring Guidelines to Evaluate Effects of Forestry Activities Activities on Streams in the Pacific Northwest and Alaska*. EPA 910/9-91/001. Seattle, WA.

———. 1999. *Draft Guidance for Water Quality-based Decisions: The TMDL Process (Second Edition)*. EPA 841-D-99-001. Office of Water, Washington, D.C. August.

———. 2006. DFLOW (Version 3.1). Hydrologic Analysis Software Support Program. Available on the internet at http://www.epa.gov/waterscience/models/dflow.

U.S. Geological Survey (USGS). 2000. Geothermal Hydrology of Valles Caldera and the Southwestern Jemez Mountains, New Mexico. WRIR 00-4067. 115 pp.

Van Nieuwenhuyse, E.E. and J.R. Jones. 1996. Phosphorus-chlorophyll relationship in temperate streams and its variation with stream catchment area. Can. J. Fish. Aquat. Sci 53: 99-105.

Waltemeyer, Scott D. 2002. *Analysis of the Magnitude and Frequency of the 4-Day Annual Low Flow and Regression Equations for Estimating the 4-Day, 3-Year Low-Flow Frequency at Ungaged Sites on Unregulated Streams in New Mexico*. USGS Water-Resources Investigations Report 01-4271. Albuquerque, New Mexico.

Waters, T. 1995. Sediment in Streams Sources, Biological Effects and Control. American Fisheries Society Monograph 7. Bethesda, Maryland.

Welch, E.B. 1992. Ecological Effects of Wastewater. Chapman and Hall, London.

Wohlman, M.G. 1954. A method of sampling coarse riverbed material. Transactions of American Geophysical Union. Vol. 35, pp. 951-956.

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APPENDIX A
GEOLOGY-BASED ANALYSIS OF ELEVATED ALUMINUM IN THE JEMEZ RIVER, NORTH-CENTRAL NEW MEXICO

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Geology-Based Analysis of Elevated Aluminum in the Jemez River, North-Central New Mexico

The occurrence of elevated concentrations total and dissolved aluminum in water quality samples from the majority of widely distributed sampling stations in the Jemez River watershed (NMED-SWQB, 1998) requires review in light of the element's exceedance of New Mexico State Standards. In general, increased metals in the water column can commonly be linked to sediment transport and accumulation, where the metals are a constituent part of the sediment. NMED's water sampling and sediment protocol does not identify a TSS exceedance or a sediment accumulation impact in the Jemez River, negating that relationship. High aluminum is especially characteristic of the spring snowmelt and runoff, and is not pronounced in other seasons' sampling runs which reflect baseflow, monsoon / flash flood regimes. In the absence of identifiable degraded uplands, poor streambank condition, or land use impact to explain the metals contribution, geochemical examination of the watershed area's bedrock and surface geology suggests a source of the increased aluminum values.

The Jemez volcanic field, including the Jemez and Pajarito Plateaus, is one of the most impressive and well studied volcano complexes on earth. It is composed of extremely thick accumulations of extrusive volcanic rocks, ranging in composition from tuffaceous ash to rhyolite, andesite, and basalts. Examination of the state's geologic map (1965) shows the Quaternary age Bandelier Tuff, dominantly composed of ashes, welded tuffs, and related rhyolite flows, are the most widespread units on the plateaus. To varying degrees the volcanic lithologies all share common constituent minerals from the feldspar/feldspathoid series of potassium-sodium-calcium *aluminum* silicates: **$(K,Na,Ca)AlSi_{(2,3)}O_{(6,8)}$.** For instance, the abundant rhyolite, a light-colored felsic lithology, is composed largely of quartz and alkaline feldspar (sanidine: $KAlSi_3O_8$). Rhyolite's average chemical composition is 71% SiO_2, and 14% aluminum oxide: Al_2O_3 (Travis, 1955). Andesite is an intermediate volcanic rock (52-66% SiO_2 and 17% Al_2O_3) with andesine as the feldspar mineral. Basalt is a mafic (sub-silicic, dominated by dark minerals) volcanic rock, composed of 16.8% Al_2O_3, derived from its plagioclase feldspar constituent ($CaAlSi_2O_8$). Geochemical studies of the full suite of Jemez volcanic rock types (Ellisor et.al.) indicate an average of 14.53% Al_2O_3, while more specific electron microprobe analysis of feldspar in the Bandelier Tuff was measured at an average of 23.6% Al_2O_3.

The above description serves to illustrate how abundantly available aluminum is in the bedrock stratigraphy of the Jemez River watershed. Mechanical and/or chemical processes must become active to free the metal and deliver it to streams where NMED's sampling program identifies it. Disintegration of the rocks and minerals, and delivery of detritus and metals in suspension or solution, is accomplished by: 1) **weathering** (in-place disintegration of bedrock and production of a regolith **-** loosely consolidated ground materials, including colluvium, alluvium or soils - via solution, freezing-thawing, pelting by rain, bioturbation, or vegetation and gravity effects); and 2) **erosion** (transportation and corrasion processes, chiefly accomplished by running water) (Gilbert, 1877). In the transport process, some materials, including soils (providing both dissolved and undissolved aluminum species) are quickly delivered overland into streams under slope runoff conditions, while a significant portion of the runoff may be absorbed into the earth. After underground circulation, that fraction reissues to charge the river, or is contributed by springs (chiefly introducing dissolved minerals). The overland delivery is credited as the larger and more frequent contributor of potential sediment, as well as total and dissolved minerals, although both of the processes are active in the Jemez watershed.

McDonald et. al. (1996) analyzed 175 soil profiles, distributed across the Pajarito Plateau, examining alluvial and colluvial settings. They reveal how aluminum and iron are the two most abundant metals in the Jemez soils (by full increased orders of magnitude). The aluminum is available for, and experiencing, redistribution or leaching from one soil horizon to the others. This study listed the element as highly bioavailable in its risk calculations. In addition, eolian dust is recognized as an important contributor to the soils of the Jemez region. In studies by Eberly et.al. (1996) aluminum is found to be enriched in all of the soil horizons examined in their study.

NMED's recent sampling results indicate the spring runoff period is the time when the largest aluminum standard exceedances occur. The Jemez climate plays a role here. Winter snow pack is, on the average, quite substantial. The slightly acidic condition of rain and snow accumulations act upon the disintegrating surface rocks, fragments, regolith and soils, providing the method and timing for peak transport of metals to occur during spring thaw. The "residence time factor", maximizing the frozen or melting snow's contact with the weathered fraction of the rock throughout the winter and early spring, develops into an effective spring pulse runoff, and is frequently observed to result in the highest concentrations of available metals from a given area. Other seasonal runoff events have more immediate instigation and completion, so the runoff, even if acidic, doesn't have as great an opportunity to take metals into solution and transport them to a receiving stream .

Since the watershed occupies a dormant volcanic field, there is a local abundance of active hot springs adding their contribution to the stream flow . The fractures and conduits the springs issue from may provide the opportunity for additional host rock alteration and mobilization of contained metals due to the action of slightly acidic, corrosive hot spring fluids. (The writer is unaware of any spring-specific water quality sampling to base further conclusions on.) Rocks with abundant feldspars, such as occur in the Jemez, are easily altered into secondary minerals and clays by the hot waters (example: formation of kaolinite, a hydrous aluminum silicate, $Al_2(Si_2O_5)(OH_4)$, from tuff and rhyolite parent materials). This alteration, combined with the springs' steady contribution to the streams, is another possible mode of introduction of excessive aluminum to the Jemez system.

In conclusion, it is recognized that the watershed draining the Jemez volcanic field has ample supply and opportunity to mobilize total and dissolved aluminum species. The active processes of local weathering and in-situ disintegration of the local rocks, eolian deposition and enrichment, winter/spring freeze-thaw runoff concentration, and diffuse delivery of aluminum to the network of local streams, are believed to be underway. Recognizing the metal contamination is apparently watershed wide, it is difficult-to-impossible to pinpoint a discrete source of contamination. The area-specific sampling results and the interpretation of causes presented here are limited to the Jemez watershed under consideration. These arguments are not intended to be applicable to every area of the state, absent of applicable geochemical and water quality studies, to explain the presence of metals, or to characterize New Mexico's large volcanic terrains in general.

REFERENCES CITED:

Dane, C.H. and G. Bachman, 1965, *Geologic Map of New Mexico:* U.S. Geological Survey, NM State Bureau of Mines, and University of New Mexico; 1: 500,000 scale.

Eberly, P., McFadden and Watt, 1996, *Eolian Dust as a Factor in Soil Development on the Pajarito Plateau, Los Alamos Area, Northern New Mexico:* in NM Geol. Soc. 47th Field Conf. Guidebook: Jemez Mountains Region; pp 383-389.

Ellisor, R., Wolff, and Gardner, 1996, *Outline of the Petrology and Geochemistry of the Keres Group Lavas and Tuffs:* in NM Geol. Soc. 47th Field Conf. Guidebook: Jemez Mountains Region; pp77,78.

Gilbert, G.K., 1877, *Geology of the Henry Mountains:* U.S. Geog. and Geol. Survey of the Rocky Mountains Region, U.S. Government Printing Office, Washington, D.C., 170 p.

McDonald, E., Longmire, Watt, Ryti, and Reneau, 1996, *Natural Major and Trace Element Background Geochemistry of Selected Soil Profiles, Los Alamos, New Mexico:* in NM Geol. Soc. 47th Field Conf. Guidebook: Jemez Mountains Region; pp 375-382.

Travis, Russel B., 1955, *Classification of Rocks:* Quarterly of the Colorado School of Mines, vol. 50, no. 1, 98p.

The above analysis was submitted to the USEPA Region 6 New Mexico Total Maximum Daily Load (TMDL) Team on 2/8/99 by: Michael W. Coleman, LRPG, Geoscientist/ Watershed Protection Team Lead, New Mexico Environment Department - Surface Water Quality Bureau.

Aluminum (see also www.atsdr.cdc.gov/tfacts22.html)

Acid can dissolve aluminum from rocks and soil into water sources. It is not a necessary substance for humans and too much may be harmful. It is not known to bioconcentrate up the food chain. Some studies have shown that people with Alzheimer's disease have higher aluminum levels than normal in their brains. It is uncertain if aluminum may lead to Alzheimer's or if the buildup is a result of the disease. Both adults and children who receive large doses of aluminum may develop bone diseases. Aluminum has not been classified as a carcinogen by the US Dept. of Health and Human Services, the International Agency for Research on Cancer, or by the USEPA.

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APPENDIX B
CONVERSION FACTOR DERIVATION

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Flow (as million gallons per day [MGD]) and concentration values (milligrams per liter [mg/L]) must be multiplied by a conversion factor in order to express the load in units "pounds per day." The following expressions detail how the conversion factor was determined:

TMDL Calculation:

$$Flow\,(MGD) \times Concentration\left(\frac{mg}{L}\right) \times CF\left(\frac{L-lb}{gal-mg}\right) = Load\left(\frac{lb}{day}\right)$$

Conversion Factor Derivation:

$$CF = 10^6 \times \frac{3.785\,L}{gal} \times \frac{1\,lb}{454{,}000\,mg} = 8.34\,\frac{L-lb}{gal-mg}$$

Flow (as million gallons per day [MGD]) and concentration values (micrograms per liter [ug/L]) must be multiplied by a conversion factor in order to express the load in units "pounds per day." The following expressions detail how the conversion factor was determined:

TMDL Calculation:

$$Flow\,(MGD) \times Concentration\left(\frac{ug}{L}\right) \times CF\left(\frac{L-lb}{gal-ug}\right) = Load\left(\frac{lb}{day}\right)$$

Conversion Factor Derivation:

$$CF = 10^6 \times \frac{3.785\,L}{gal} \times \frac{1\,lb}{454{,}000{,}000\,ug} = 0.00834\,\frac{L-lb}{gal-ug}$$

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APPENDIX C
SOURCE DOCUMENTATION SHEET AND SOURCES SUMMARY TABLE

Source Documentation Sheet (2005)

DES FOR USES NOT FULLY SUPPORTED

HQCWF =	HIGH QUALITY COLDWATER FISHERY	☐	DWS	=	DOMESTIC WATER SUPPLY	REACH NAME:
CWF =	COLDWATER FISHERY	☐	PC	=	PRIMARY CONTACT	
MCWF =	MARGINAL COLDWATER FISHERY	☐	IRR	=	IRRIGATION	SEGMENT NUMBER:
WWF =	WARMWATER FISHERY	☐	LW	=	LIVESTOCK WATERING	BASIN:
LWWF =	LIMITED WARMWATER FISHERY	☐	WH	=	WILDLIFE HABITAT	PARAMETER:

culture, secondary contact and municipal and industrial water supply and storage are also designated in particular stream reaches where these are actually being realized. However, no numeric standards apply uniquely to these uses.

STAFF MAKING ASSESSMENT:
DATE:

DES FOR SOURCES OF NONSUPPORT (CHECK ALL THAT APPLY)

	Code	Source
☐	0100	INDUSTRIAL POINT SOURCES
☐	0200	MUNICIPAL POINT SOURCES
☐	0201	DOMESTIC POINT SOURCES
☐	0400	COMBINED SEWER OVERFLOWS
☐	1000	AGRICULTURE
☐	1100	NONIRRIGATED CROP PRODUCTION
☐	1200	IRRIGATED CROP PRODUCTION
☐	1201	IRRIGATED RETURN FLOWS
☐	1300	SPECIALTY CROP PRODUCTION (e.g., truck farming and orchards)
☐	1400	PASTURELAND
☐	1500	RANGELAND
☐	1600	FEEDLOTS - ALL TYPES
☐	1700	AQUACULTURE
☐	1800	ANIMAL HOLDING/MANAGEMENT AREAS
☐	1900	MANURE LAGOONS
☐	2000	SILVICULTURE
☐	2100	HARVESTING, RESTORATION, RESIDUE MANAGEMENT
☐	2200	FOREST MANAGEMENT
☐	2300	ROAD CONSTRUCTION or MAINTENANCE
☐	3000	CONSTRUCTION
☐	3100	HIGHWAY/ROAD/BRIDGE
☐	3200	LAND DEVELOPMENT
☐	3201	RESORT DEVELOPMENT
☐	3300	HYDROELECTRIC
☐	4000	URBAN RUNOFF/STORM SEWERS
☐	5000	RESOURCES EXTRACTION
☐	5100	SURFACE MINING
☐	5200	SUBSURFACE MINING
☐	5300	PLACER MINING
☐	5400	DREDGE MINING
☐	5500	PETROLEUM ACTIVITIES
☐	5501	PIPELINES
☐	5600	MILL TAILINGS
☐	5700	MINE TAILINGS
☐	5800	ROAD CONSTRUCTION/MAINTENANCE 8400
☐	5900	SPILLS
☐	6000	LAND DISPOSAL
☐	6100	SLUDGE
☐	6200	WASTEWATER
☐	6300	LANDFILLS
☐	6400	INDUSTRIAL LAND TREATMENT
☐	6500	ONSITE WASTEWATER SYSTEMS (septic tanks, etc.)
☐	6600	HAZARDOUS WASTE
☐	6700	SEPTAGE DISPOSAL
☐	6800	UST LEAKS
☐	7000	HYDROMODIFICATION
☐	7100	CHANNELIZATION
☐	7200	DREDGING
☐	7300	DAM CONSTRUCTION/REPAIR
☐	7400	FLOW REGULATION/MODIFICATIO
☐	7500	BRIDGE CONSTRUCTION
☐	7600	REMOVAL OF RIPARIAN VEGETATI
☐	7700	STREAMBANK MODIFICATION DESTABILIZATION
☐	7800	DRAINING/FILLING OF WETLANDS
☐	8000	OTHER
☐	8010	VECTOR CONTROL ACTIVITIES
☐	8100	ATMOSPHERIC DEPOSITION
☐	8200	WASTE STORAGE/STORAGE TANK L
☐	8300	ROAD MAINTENANCE or RUNOFF
☐	8400	SPILLS
☐	8500	IN-PLACE CONTAMINANTS
☐	8600	NATURAL
☐	8700	RECREATIONAL ACTIVITIES
☐	8701	ROAD/PARKING LOT RUNOFF
☐	8702	OFF-ROAD VEHICLES
☐	8703	REFUSE DISPOSAL
☐	8704	WILDLIFE IMPACTS
☐	8705	SKI SLOPE RUNOFF
☐	8800	UPSTREAM IMPOUNDMENT
☐	8900	SALT STORAGE SITES
☐	9000	SOURCE UNKNOWN

Jemez Watershed TMDL Probable Sources Summary

Reach	Parameter(s)	Probable Sources (ADB v.2 terminology)
EAST FORK JEMEZ RIVER (SAN ANTONIO CREEK TO VALLES CALDERA NATIONAL PRESERVE BOUNDARY)	Arsenic Temperature	Highway/Road/Bridge Runoff Natural Sources Other Recreational Pollution Sources Rangeland Grazing Silviculture Harvesting Streambank Modifications/Destabilization
JEMEZ RIVER (ZIA PUEBLO BOUNDARY TO JEMEZ PUEBLO BOUNDARY)	Arsenic Boron	Natural Sources Source Unknown
JEMEZ RIVER (JEMEZ PUEBLO BOUNDARY TO RIO GUADALUPE)	Arsenic Boron	Flow Alterations from Water Diversions Highway/Road/Bridge Runoff (non-construction related) Inappropriate Waste Disposal Natural Sources Other Recreational Pollution Sources Rangeland Grazing Source Unknown
JEMEZ RIVER (RIO GUADALUPE TO SODA DAM NEAR JEMEZ SPRINGS)	Arsenic Boron Plant Nutrients Temperature	On-site Treatment Systems (septic systems and similar decentralized systems) Highway/Road/Bridge Runoff (non-construction related) Loss of Riparian Habitat Natural Sources Other Recreational Pollution Sources Rangeland Grazing Site Clearance (land development and redevelopment) Streambank Modifications/Destabilization
JEMEZ RIVER (SODA DAM NEAR JEMEZ SPRINGS TO EAST FORK)	Arsenic	Highway/Road/Bridge Runoff (non-construction related) Loss of Riparian Habitat Natural Sources Other Recreational Pollution Sources Rangeland Grazing Site Clearance (land development and redevelopment)

Reach	Parameter(s)	Probable Sources (ADB v.2 terminology)
		Streambank Modifications/Destabilization
RIO DE LAS VACAS (RIO CEBOLLA TO CLEAR CREEK)	Plant Nutrients	Loss of Riparian Habitat Rangeland Grazing Streambank Modifications/Destabilization
RIO GUADALUPE (JEMEZ RIVER TO CONFLUENCE WITH RIO CEBOLLA)	Temperature	Loss of Riparian Habitat Off-Road Vehicles Natural Sources Rangeland Grazing
RITO DE LAS PALOMAS (RIO DE LAS VACAS TO HEADWATERS)	Temperature Sedimentation/ Siltation	Highway/Road/Bridge Runoff (non-construction related) Loss of Riparian Habitat Rangeland Grazing Streambank Modifications/Destabilization
RITO PEÑAS NEGRAS (RIO DE LAS VACAS TO HEADWATERS)	Plant Nutrients	Highway/Road/Bridge Runoff (non-construction related) Loss of Riparian Habitat Rangeland Grazing Streambank Modifications/Destabilization
SAN ANTONIO CREEK (EAST FORK JEMEZ TO VCNP BND)	Arsenic	Forest Roads (road construction and use) Loss of Riparian Habitat Natural Sources Other Recreational Pollution Sources Rangeland Grazing Site Clearance (land development and redevelopment) Streambank Modifications/Destabilization

APPENDIX D
THERMOGRAPH SUMMARY DATA AND GRAPHICS

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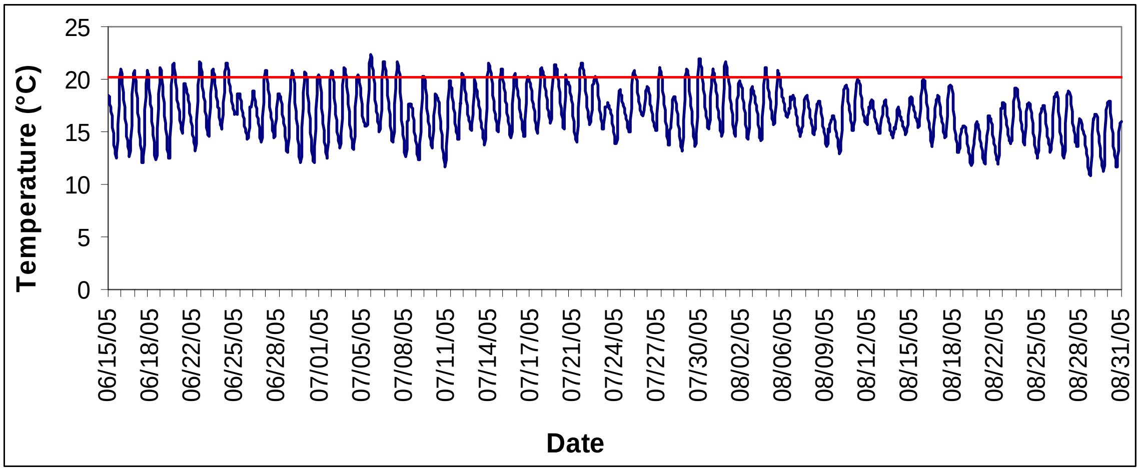
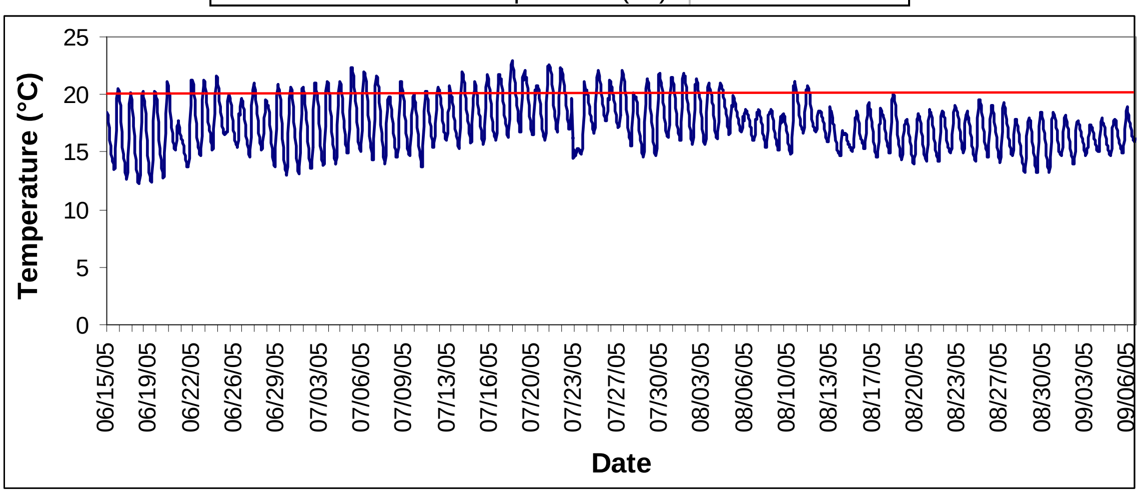
D1.0 East Fork Jemez (San Antonio Creek to Valles Caldera National Preserve bnd)

East Fork Jemez at Las Conchas Day Use Area June 15 (18:00) through August 31 (18:00)	
Number of Data Points:	1,849
Number of Measurements >20°C:	222
Percentage of Data Points >20°C:	12%
Minimum Temperature (°C):	10.81
Maximum Temperature (°C):	22.30

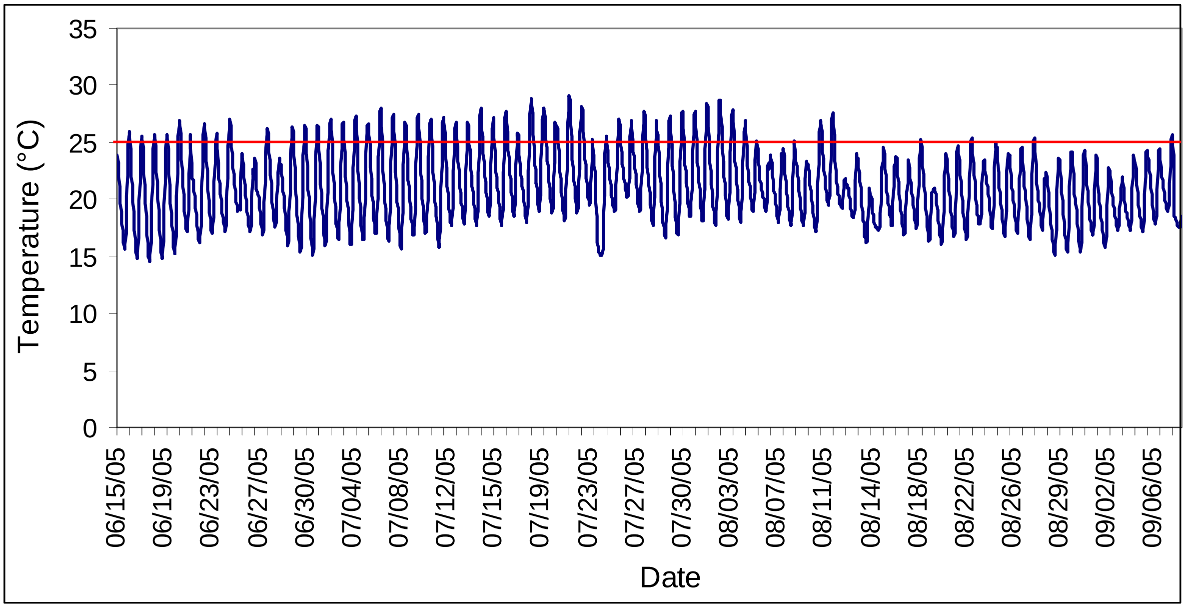


East Fork Jemez above San Antonio Creek June 15 (18:00) through Septemeber 7 (9:00)	
Number of Data Points:	2008
Number of Measurements >20°C:	314
Percentage of Data Points >20°C:	16%
Minimum Temperature (°C):	10.22
Maximum Temperature (°C):	22.99



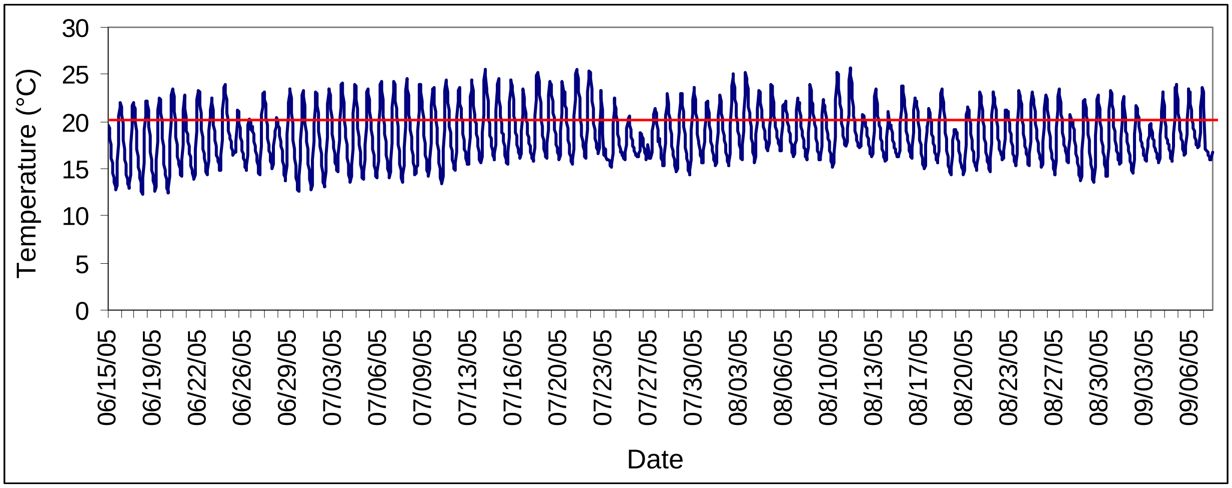
D2.0 Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs)

Jemez River above the Rio Guadalupe	
June 15 (18:00) through Septemeber 8 (10:00)	
Number of Data Points:	2033
Number of Measurements >25°C:	267
Percentage of Data Points >25°C:	13%
Minimum Temperature (°C):	11.20
Maximum Temperature (°C):	29.09

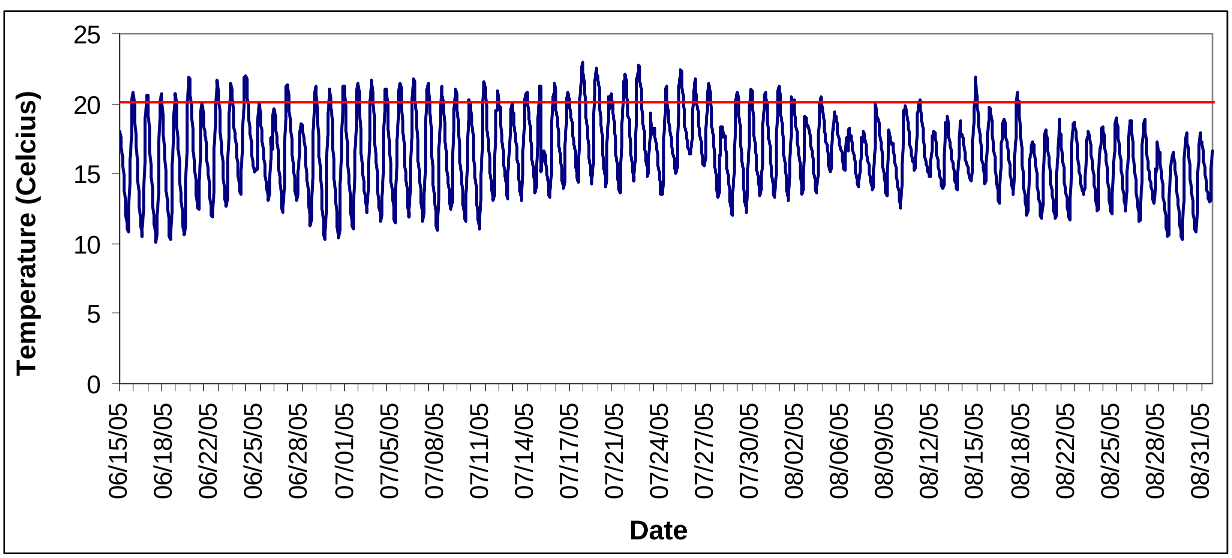


D3.0 Rio Guadalupe (Jemez River to confluence with Rio Cebolla)

Rio Guadalupe above the Jemez River June 15 (18:00) through Septemeber 8 (10:00)	
Number of Data Points:	2033
Number of Measurements >20°C:	656
Percentage of Data Points >20°C:	32%
Minimum Temperature (°C):	10.54
Maximum Temperature (°C):	25.67

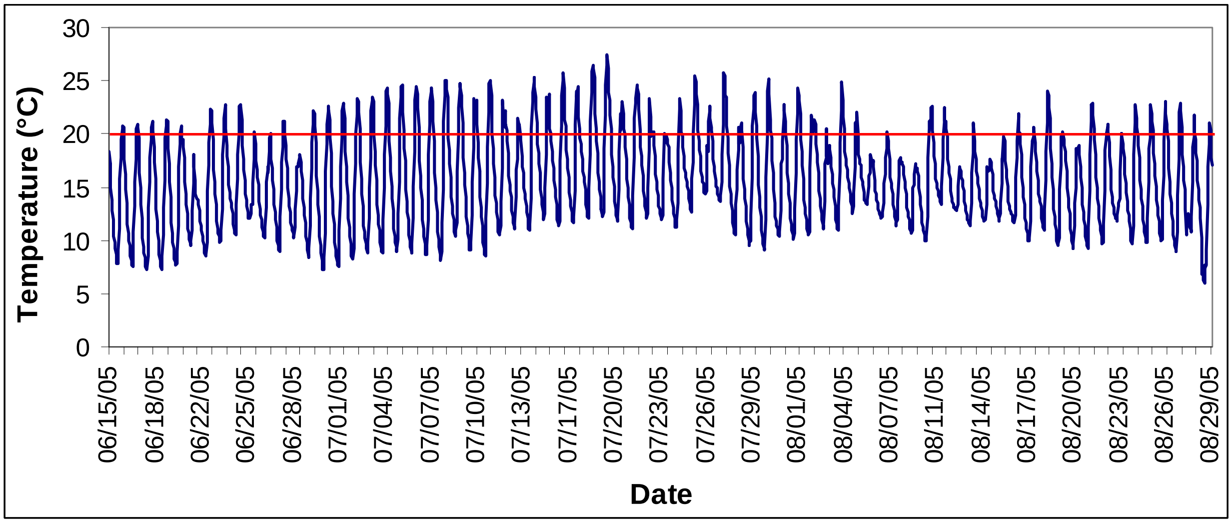


Rio Guadalupe at Porter Landing June 15 (18:00) through Septemeber 1 (12:00)	
Number of Data Points:	1867
Number of Measurements >20°C:	231
Percentage of Data Points >20°C:	12%
Minimum Temperature (°C):	10.08
Maximum Temperature (°C):	22.99



D4.0 Rito de las Palomas (Rio de las Vacas to headwaters)

Rito de las Palomas at NM 126	
June 15 (18:00) through August 29 (19:00)	
Number of Data Points:	1802
Number of Measurements >20°C:	349
Percentage of Data Points >20°C:	19%
Minimum Temperature (°C):	5.69
Maximum Temperature (°C):	27.43



APPENDIX E
HYDROLOGY, GEOMETRY, AND METEROLOGICAL INPUT DATA FOR SSTEMP

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LIST OF ACRONYMS

4Q3	Four-consecutive day discharge that has a recurrence interval of three years
cfs	Cubic Feet per Second
GIS	Geographic Information Systems
GPS	Global Positioning System
IOWDM	Input and Output for Watershed Data Management
mi^2	Square Miles
^oC	Degrees Celsius
SEE	Standard Error of Estimate
SSTEMP	Stream Segment Temperature
SWSTAT	Surface-Water Statistics
TMDL	Total Maximum Daily Load
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WinXSPRO	Windows-Based Stream Channel Cross-Section Analysis

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E 1.0 INTRODUCTION

This appendix provides site-specific hydrology, geometry, and meteorological data for input into the Stream Segment Temperature (SSTEMP) Model (Bartholow 2002). Hydrology variables include segment inflow, inflow temperature, segment outflow, and accretion temperature. Geometry variables are latitude, segment length, upstream and downstream elevation, Width's A-term, Width's B-term, and Manning's n. Meteorological inputs to SSTEMP Model include air temperature, relative humidity, windspeed, ground temperature, thermal gradient, possible sun, dust coefficient, ground reflectivity, and solar radiation. In the following sections, these parameters are discussed in detail for each assessment unit to be modeled using SSTEMP Model. The assessment units were modeled on the day of the maximum recorded thermograph measurement. The assessment units and modeled dates are defined as follows:

Table E.1 Assessment Units and Modeled Dates

Assessment Unit ID	Assessment Unit Description	Modeled Date
NM-2106.A_13	East Fork Jemez (San Antonio Creek to Valles Caldera National Preserve [VCNP] bnd)	7/18/2005
NM-2105.5_10	Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs)	7/21/2005
NM-2106.A_30	Rio Guadalupe (Jemez River to confluence with Rio Cebolla)	8/11/2005
NM-2106.A_43	Rito de las Palomas (Rio de las Vacas to headwaters)	7/19/2005

E 2.0 HYDROLOGY

E2.1 Segment Inflow

This parameter is the *mean daily* flow at the top of the stream segment. If the segment begins at an effective headwater, the flow is entered into SSTEMP Model as zero. Flow data from USGS gages were used when available. To be conservative, the lowest four-consecutive-day discharge that has a recurrence interval of three years but that does not necessarily occur every three years (4Q3) was used as the inflow instead of the mean daily flow. These critical low flows were used to decrease assimilative capacity of the stream to adsorb and disperse solar energy. The 4Q3 was estimated using the USGS A193 calculation for Log Pearson Type III distribution through DFLOW software, Version 3.1b (USEPA 2006). DFLOW 3.1b is a Windows-based tool developed to estimate user selected design stream flows for low flow analysis.

Discharges for ungaged sites on gaged streams were estimated based on methods published by Thomas *et al.* (1997). If the drainage area of the ungaged site is between 50 and 150 percent of the drainage area of the gaged site, the following equation is used:

$$Q_u = Q_g \left(\frac{A_u}{A_g} \right)^{0.566}$$

where,

Q_u = Area weighted 4Q3 at the ungaged site (cubic feet per second [cfs])
Q_g = 4Q3 at the gaged site (cfs)
A_u = Drainage area at the ungaged site (square miles [mi^2])
A_g = Drainage area at the gaged site (mi^2)

Drainage areas for assessment units to which this method was applied are summarized in the following table:

Table E.2 Drainage Areas for Estimating Flow by Drainage Area Ratios

Assessment Unit	USGS Gage	Drainage Area from Gage (mi^2)	Drainage Area from Top of AU (mi^2)	Drainage Area from Bottom of AU (mi^2)	Ratio of DA of Ungaged (upstream) to Gaged Site	Ratio of DA of Ungaged (downstream) to Gaged Site
NM-2106.A_13	08324000	470	43.7	67	9%[(b)]	14%[(b)]
NM-2105.5_10	08324000	470	179	200	38%[(b)]	43%[(b)]
NM-2106.A_30	08324000	470	187	265	40%[(b)]	56%
NM-2106.A_43	08324000	470	<0.3	12.2	—[(a)]	3%[(b)]

Notes:
[(a)] Assessment unit begins at headwaters.
[(b)] The method developed by Thomas et al. (1997) is not applicable because the drainage area of the ungaged site is less than 50 percent of the drainage area of the gaged site. Therefore, the method developed by Waltemeyer (2002) was used to estimate flows for this assessment unit.

mi^2 = Square miles
USGS = U.S. Geological Survey
AU = Assessment Unit

4Q3 derivations for ungaged streams were based on analysis methods described by Waltemeyer (2002). Two regression equations for estimating 4Q3 were developed based on physiographic regions of New Mexico (i.e., statewide and mountainous regions above 7,500 feet in elevation). The following statewide regression equation is based on data from 50 gaging stations with non-zero discharge (Waltemeyer 2002):

$$4Q3 = 1.2856 \times 10^{-4} \; DA^{0.42} \; P_w^{\;3.16}$$

where,

4Q3 = Four-day, three-year low-flow frequency (cfs)
DA = Drainage area (mi^2)
P_w = Average basin mean winter precipitation (inches)

The average standard error of estimate (SEE) and coefficient of determination are 126 and 48 percent, respectively, for this regression equation (Waltemeyer 2002). The following regression equation for mountainous regions above 7,500 feet in elevation is based on data from 40 gaging stations with non-zero discharge (Waltemeyer 2002):

$$4Q3 = 7.3287 \times 10^{-5}\ DA^{0.70}\ P_w^{\ 3.58}\ S^{1.35}$$

where,

4Q3 = Four-day, three-year low-flow frequency (cfs)
DA = Drainage area (mi^2)
P_w = Average basin mean winter precipitation (inches)
S = Average basin slope (percent)

The average SEE and coefficient of determination are 94 and 66 percent, respectively, for this regression equation (Waltemeyer 2002). The drainage areas, average basin mean winter precipitation, and average basin slope for assessment units where this regression method was used are presented in the following table:

Table E.3 Parameters for Estimating Flow using USGS Regression Model

Assessment Unit	Regression Model[(a)]	Average Elevation for Assessment Unit (feet)	Mean Basin Winter Precipitation (inches)	Average Basin Slope (unitless)
NM-2106.A_13	Mountainous	8,793	12.3	0.207
NM-2105.5_10	Mountainous	8,750	11.9	0.242
NM-2106.A_30	Mountainous	8,435	13.0	0.227
NM-2106.A_43	Mountainous	9,098	19.8	0.197

Notes:
mi^2 = Square miles
[(a)] Waltemeyer (2002)

Based on the methods described above, the following values were estimated for inflow:

Table E.4 Inflow

Assessment Unit	Ref.	4Q3 (cfs)	DAt (mi^2)	DAg (mi^2)	Pw (in)	S unitless	Inflow (cfs)
NM-2106.A_13	(a)	12.1[(1)]	43.7	470	12.6	0.181	0.892
NM-2105.5_10	(a)	12.1[(1)]	179	470	11.9	0.242	2.89
NM-2106.A_30	(a)	12.1[(1)]	187	470	15.2	0.224	6.44
NM-2106.A_43	N/A	12.1[(1)]	<0.3	470	19.8	0.197	0.00[(2)]

Notes:
N/A = Not applicable, assessment unit begins at headwaters.
Ref. = Reference
(a) Waltemeyer (2002), mountainous
(b) Thomas et al. (1997)

cfs = cubic feet per second
mi^2 = Square miles
in = Inches
Pw = Mean winter precipitation
DAt = Drainage area from top of segment
DAb = Drainage area from bottom of segment
DAg = Drainage area from USGS gage
S = Average basin slope
[(1)] Based on period of record for USGS Gage 08324000 – Jemez River near Jemez, NM
[(2)] Inflow is zero because assessment unit begins at headwaters.

E2.2 Inflow Temperature

This parameter represents the *mean daily* water temperature at the top of the segment. 2005 data from thermographs positioned at the top of the assessment unit were used when possible. If the segment began at a true headwater, the temperature entered was zero degrees Celsius (°C) (zero flow has zero heat). The following inflow temperatures for impaired assessment units were modeled in SSTEMP:

Table E.5 Mean Daily Water Temperature

Assessment Unit	Upstream Thermograph Location[1]	Inflow Temp. (°C)	Inflow Temp. (°F)
NM-2106.A_13	East Fork Jemez River below Las Conchas day use area	16.86	62.35
NM-2105.5_10	Jemez River above Soda Dam	21.18	70.12
NM-2106.A_30	Rio Guadalupe at Porter Landing	16.47	61.65
NM-2106.A_43	None (headwaters)	0	32.0

Notes:
°C = Degrees Celsius
°F = Degrees Fahrenheit
[1] uppermost thermograph in assessment unit

E2.3 Segment Outflow

Flow data from USGS gages were used when available. To be conservative, the 4Q3 was used as the segment outflow. These critical low flows were used to decrease assimilative capacity of the stream to adsorb and disperse solar energy. Outflow was estimated using the methods described in Section 2.1. The following table summarizes 4Q3s used in the SSTEMP Model:

Table E.6 Segment Outflow

Assessment Unit	Ref.	4Q3[(c)] (cfs)	DAb (mi^2)	DAg[(c)] (mi^2)	Pw (in)	S unitless	Outflow (cfs)
NM-2106.A_13	(a)	12.1	67	470	12.3	0.207	1.33
NM-2105.5_10	(a)	12.1	200	470	11.9	0.245	3.17
NM-2106.A_30	(b)	12.1	265	470	13.0	0.227	8.75
NM-2106.A_43	(a)	12.1	12.2	470	19.8	0.197	2.07

Notes:
Ref. = Reference
(a) Waltemeyer (2002), mountainous
(b) Thomas et al. (1997)

cfs = cubic feet per second
mi^2 = Square miles
in = Inches
Pw = Mean winter precipitation
DAb = Drainage area from bottom of segment
DAg = Drainage area from USGS gage
S = Average basin slope
[(c)] USGS Gage 08324000 – Jemez River near Jemez, NM

E2.4 Accretion Temperature

The temperature of the lateral inflow, barring tributaries, generally should be the same as groundwater temperature. In turn, groundwater temperature may be approximated by the mean annual air temperature. Mean annual air temperature for 2005 was used in the absence of measured data. The following table presents the mean annual air temperature for each assessment unit:

Table E.7 Mean Annual Air Temperature as an Estimate for Accretion Temperature

Assessment Unit	Ref.	Mean Annual Air Temperature (°C)	Mean Annual Air Temperature (°F)
NM-2106.A_13	(a)	10.98	51.77
NM-2105.5_10	(a)	10.98	51.77
NM-2106.A_30	(a)	10.98	51.77
NM-2106.A_43	(a)	10.98	51.77

Notes:
Ref. = References for Weather Station Data are as follows:
(a) Western Regional Climate Center (Jemez Springs, NM – Station #294369), ***1914-2006***
ºF = Degrees Fahrenheit
ºC = Degrees Celsius

E 3.0 GEOMETRY

E3.1 Latitude

Latitude refers to the position of the stream segment on the earth's surface. Latitude is generally determined in the field with a global positioning system (GPS) unit. Latitude for each assessment unit is summarized below:

Table E.8 Assessment Unit Latitude

Assessment Unit	Latitude (decimal degrees)
NM-2106.A_13	35.82
NM-2105.5_10	35.74
NM-2106.A_30	35.71
NM-2106.A_43	35.99

E3.2 Dam at Head of Segment

The following assessment units have a dam at the upstream end of the segment with a constant, or nearly constant diel release temperature:

Table E.9 Presence of Dam at Head of Segment

Assessment Unit	Dam?
NM-2106.A_13	No
NM-2105.5_10	No
NM-2106.A_30	No
NM-2106.A_43	No

E3.3 Segment Length

Segment length was determined with National Hydrographic Dataset Reach Indexing GIS tool. The segment lengths are as follows:

Table E.10 Segment Length

Assessment Unit	Length (miles)
NM-2106.A_13	10.39
NM-2105.5_10	9.67
NM-2106.A_30	12.65
NM-2106.A_43	5.61

E3.4 Upstream Elevation

The following upstream elevations were determined with National Hydrographic Dataset Reach Indexing GIS tool.

Table E.11 Upstream Elevations

Assessment Unit	Upstream Elevation (feet)
NM-2106.A_13	8,432
NM-2105.5_10	6,352
NM-2106.A_30	7,190
NM-2106.A_43	9,980

E3.5 Downstream Elevation

The following downstream elevations were determined with National Hydrographic Dataset Reach Indexing GIS tool.

Table E.12 Downstream Elevations

Assessment Unit	Downstream Elevation (feet)
NM-2106.A_13	6,785
NM-2105.5_10	5,669
NM-2106.A_30	5,669
NM-2106.A_43	8,110

E3.6 Width's A and Width's B Term

Width's B Term was calculated as the slope of the regression of the natural log of width and the natural log of flow. Width-versus-flow regression analyses were prepared by entering cross-section field data into a Windows-Based Stream Channel Cross-Section Analysis (WinXSPRO 3.0) Program (U.S. Department of Agriculture [USDA] 2005). Theoretically, the Width's A Term is the untransformed Y-intercept. However, because the width versus discharge relationship tends to break down at very low flows, the Width's B-Term was first calculated as the slope and Width's A-Term was estimated by solving for the following equation:

$$W = A \times Q^{B}$$

where,

W = Known width (feet)
A = Width's A-Term (seconds per square foot)
Q = Known discharge (cfs)
B = Width's B-Term (unitless)

The following table summarizes Width's A- and B-Terms for assessment units requiring temperature TMDLs:

Table E.13 Width's A and Width's B Terms

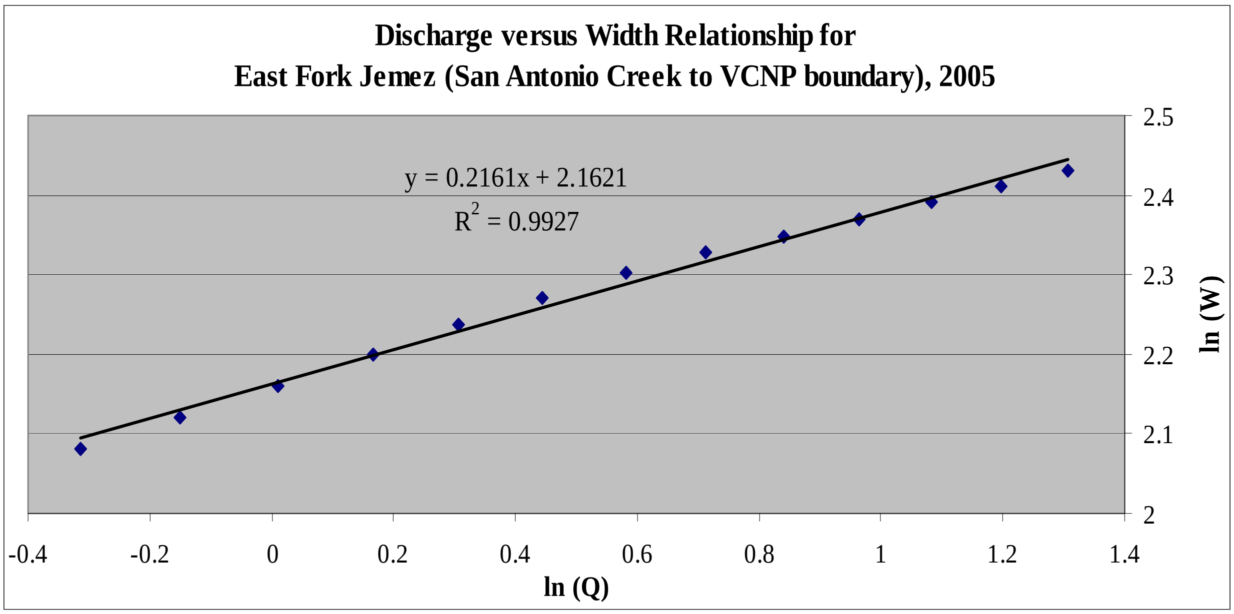
Assessment Unit	Width's B-Term	Width's A-Term [1]
NM-2106.A_13	0.216	8.69
NM-2105.5_10	0.096	18.4
NM-2106.A_30	0.145	13.5
NM-2106.A_43	0.358	2.34

[1] A=e^ constant from regression

Figures E.1 – E.4 present the detailed calculations for the Width's B-Term.

Measurements were collected at one site within these assessment units. The regression of natural log of width and natural log of flow for each location is as follows:

Figure E.1 Wetted Width versus Flow for Assessment Unit NM-2106.A_13



SUMMARY OUTPUT

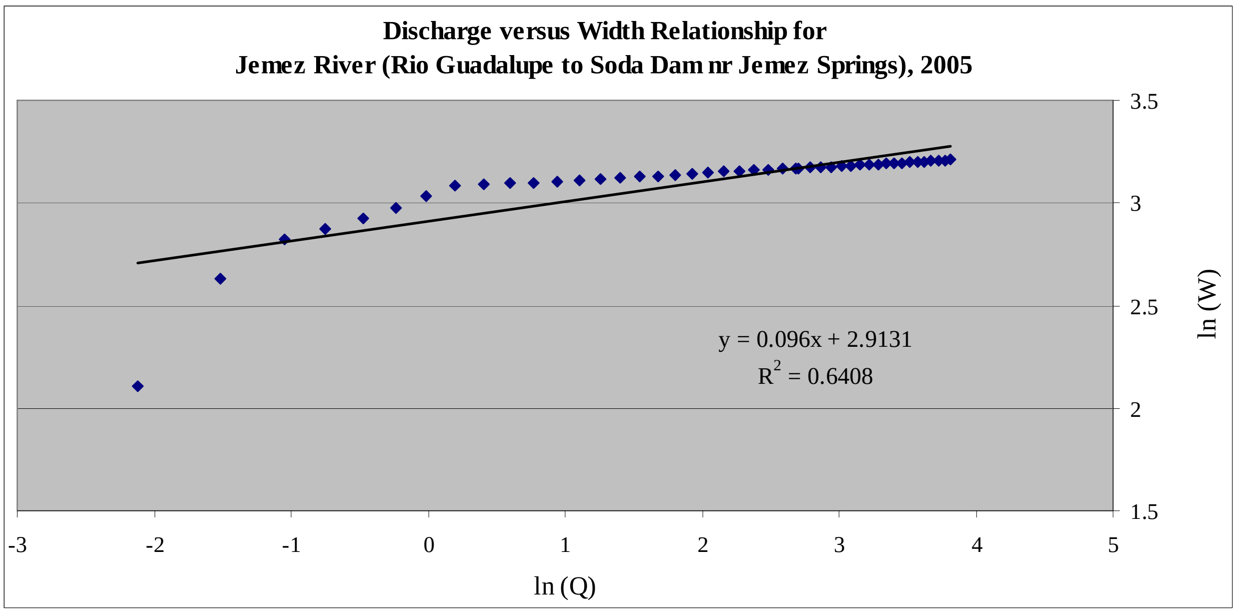
Regression Statistics	
Multiple R	0.996035628
R Square	0.992086972
Adjusted R Square	0.99129567
Standard Error	0.009417003
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.111181497	0.111181	1253.739	7.66039E-12
Residual	10	0.0008868	8.87E-05		
Total	11	0.112068296			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.166291681	0.004597139	471.226	4.56E-23	2.156048616	2.176534746	2.156048616	2.176534746
-0.314710745	0.211122106	0.005962525	35.40817	7.66E-12	0.197836773	0.224407438	0.197836773	0.224407438

Figure E.2 Wetted Width versus Flow for Assessment Unit NM-2105.5_10



SUMMARY OUTPUT

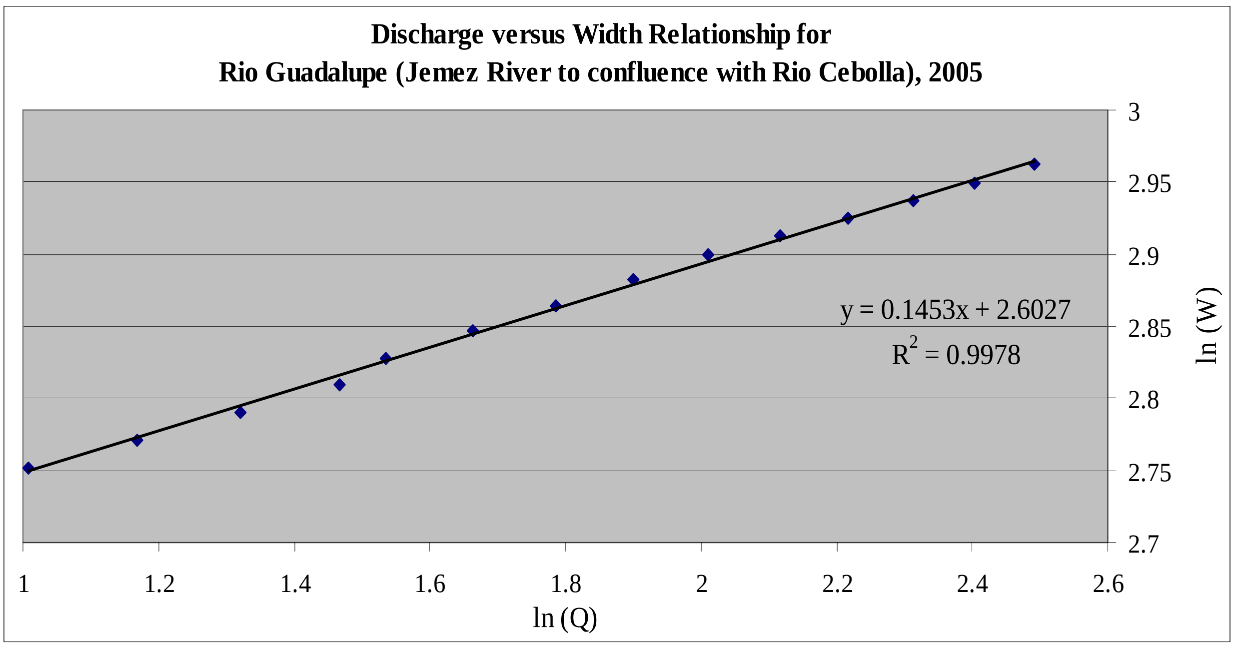
Regression Statistics	
Multiple R	0.88213115
R Square	0.778155366
Adjusted R Square	0.772873351
Standard Error	0.054914989
Observations	44

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.444271522	0.444272	147.3217	2.54949E-15
Residual	42	0.126657551	0.003016		
Total	43	0.570929073			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.981411324	0.014196096	210.0163	4.29E-65	2.952762443	3.01006021	2.95276244	3.01006021
-2.120263536	0.069059515	0.005689711	12.13761	2.55E-15	0.057577214	0.08054182	0.05757721	0.08054182

Figure E.3 Wetted Width versus Flow for Assessment Unit NM-2106.A_30



SUMMARY OUTPUT

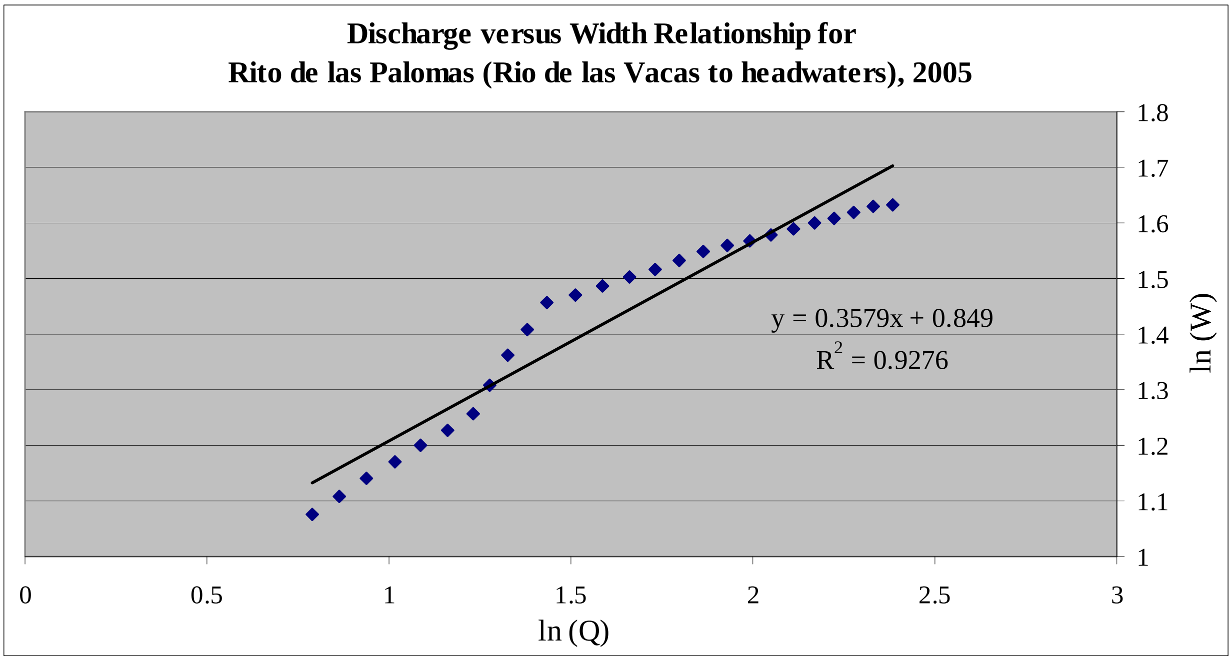
Regression Statistics	
Multiple R	0.99868569
R Square	0.99737311
Adjusted R Square	0.9971343
Standard Error	0.00334713
Observations	13

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.046790028	0.04679	4176.455	1.5094E-15
Residual	11	0.000123236	1.12E-05		
Total	12	0.046913264			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.60057855	0.004350252	597.7996	3.6E-26	2.591003706	2.6101534	2.59100371	2.61015338
1.00795792	0.14635396	0.002264647	64.6255	1.51E-15	0.141369504	0.1513384	0.1413695	0.15133841

Figure E.4 Wetted Width versus Flow for Assessment Unit NM-2106.A_43



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.958864219
R Square	0.91942059
Adjusted R Square	0.915917137
Standard Error	0.049448076
Observations	25

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.641677432	0.641677	262.4327	4.51509E-14
Residual	23	0.05623758	0.002445		
Total	24	0.697915013			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.866461701	0.036936968	23.45785	1.46E-17	0.790051762	0.9428716	0.79005176	0.94287164
0.78845736	0.348677588	0.021523607	16.19978	4.52E-14	0.304152615	0.3932026	0.30415262	0.39320256

E3.7 Manning's n or Travel Time

Site-specific values were calculated using Strickler's equation to estimate Manning's roughness based on prevailing sediment sizes in the streambed:

$$n = \frac{(d_{50})^{1/6}}{21.0}$$

where d_{50} is the median sediment size in meters.

The following table summarizes the Manning’s n input values for each assessment unit:

Table E.14 Manning’s n Values

Assessment Unit	d_{50} (in meters)	Manning’s n
NM-2106.A_13	0.1138 [(a)]	0.033
NM-2105.5_10	0.0766 [(b)]	0.031
NM-2106.A_30	0.0337 [(c)]	0.027
NM-2106.A_43	0.0160 [(d)]	0.024

[a] data from site above San Antonio Creek at Battleship Rock
[b] data from site above the Rio Guadalupe
[c] data from site above the Jemez River
[d] data from site at NM State Route 126

E 4.0 METEOROLOGICAL PARAMETERS

E4.1 Air Temperature

This parameter is the mean daily air temperature for the assessment unit (or average daily temperature at the mean elevation of the assessment unit). Air temperature will usually be the single most important factor in determining mean daily water temperature. Air temperatures are usually measured directly (in the shade) using air thermographs and adjusted to what the temperature would be at the mean elevation of the assessment unit. The following table summarizes mean daily air temperatures for each assessment unit (for its modeled date) requiring a temperature Total Maximum Daily Load (TMDL):

Table E.15 Mean Daily Air Temperature

Assessment Unit	Elevation at Air Thermograph Location[1] (meters)	Measured Mean Daily Air Temperature (°C)	Mean Elevation for Assessment Unit (meters)	Adjusted Mean Daily Air Temperature (°C)	Adjusted Mean Daily Air Temperature (°F)
NM-2106.A_13	2,510	20.03	2,680	18.91	66.04
NM-2105.5_10	2,510	18.53	2,667	17.50	63.50
NM-2106.A_30	2,510	15.36	2,571	14.96	58.93
NM-2106.A_43	2,510	19.80	2,773	18.07	64.53

Notes:

[1] Air thermograph location was *Rio de las Vacas at NM State Route 126 (31RVacas023.7)*

°F = Degrees Fahrenheit

°C = Degrees Celsius

The adiabatic lapse rate was used to correct for elevational differences from the met station:

$$T_a = T_o + C_t \times (Z - Z_o)$$

where,

T_a = air temperature at elevation E (°C)
T_o = air temperature at elevation E_o (°C)
Z = mean elevation of segment (meters)
Z_o = elevation of station (meters)
C_t = moist-air adiabatic lapse rate (-0.00656 °C/meter)

E4.2 Maximum Air Temperature

Unlike the other variables, the maximum daily air temperature overrides only if the check box is checked. If the box is not checked, the SSTEMP Model estimates the maximum daily air temperature from a set of empirical coefficients (Theurer et al., 1984 as cited in Bartholow 2002) and will print the result in the grayed data entry box. A value cannot be entered unless the box is checked.

E4.3 Relative Humidity

Relative humidity data were obtained from the New Mexico State University Climate Network (http://weather.nmsu.edu/data/data.htm). The data were corrected for elevation and temperature using the following equation:

$$R_h = R_o \times \left(1.0640^{(To-Ta)}\right) \times \left(\frac{T_a + 273.16}{T_o + 273.16}\right)$$

where,

R_h = relative humidity for temperature T_a (decimal)
R_o = relative humidity at station (decimal)
T_a = air temperature at segment (°C)
T_o = air temperature at station (°C)

The following table presents the adjusted mean daily relative humidity for each assessment unit:

Table E.16 Mean Daily Relative Humidity

Assessment Unit	Ref.	Date	Mean Daily Air Temp. at Weather Station (°C)	Mean Daily Air Temperature at AU (°C)	Mean Daily Relative Humidity at Weather Station (percent)	Mean Daily Relative Humidity for AU (percent)
NM-2106.A_13	(a)	7/18/2005	21.29	20.03	38.875	41.86
NM-2105.5_10	(a)	7/21/2005	21.64	18.53	35.75	42.90
NM-2106.A_30	(a)	8/11/2005	17.36	15.36	66.542	74.81
NM-2106.A_43	(a)	7/19/2005	21.71	19.80	24.102	26.96

Notes:
Ref. = References for Weather Station Data are as follows:
(a) *New Mexico State University Climate Network (Jemez RAWS, Elevation 2,438 meters; Latitude 35° 50' 28" N, Longitude 106° 37' 8" W)*
AU = Assessment Unit
°C = Degrees Celsius

E4.4 Wind Speed

Average daily wind speed data were obtained from the New Mexico State University Climate Network (http://weather.nmsu.edu/data/data.htm). The following table presents the mean daily wind speed for each assessment unit:

Table E.17 Mean Daily Wind Speed

Assessment Unit	Ref.	Mean Daily Wind Speed (miles per hour)	Date
NM-2106.A_13	(a)	4.333	7/18/2005
NM-2105.5_10	(a)	4.375	7/21/2005
NM-2106.A_30	(a)	4.458	8/11/2005
NM-2106.A_43	(a)	4.000	7/19/2005

Notes:
Ref. = References for Weather Station Data are as follows:
(a) *New Mexico State University Climate Network (Jemez RAWS, Elevation 2,438 meters; Latitude 35° 50' 28" N , Longitude 106° 37' 8" W)*

E4.5 Ground Temperature

Mean annual air temperature data for 2005 were used in the absence of measured data. The following table presents the mean annual air temperature for each assessment unit:

Table E.18 Mean Annual Air Temperature as an Estimate for Ground Temperature

Assessment Unit	Ref.	Mean Annual Air Temperature (°C)	Mean Annual Air Temperature (°F)
NM-2106.A_13	(a)	10.98	51.77
NM-2105.5_10	(a)	10.98	51.77
NM-2106.A_30	(a)	10.98	51.77
NM-2106.A_43	(a)	10.98	51.77

Ref. = References for Weather Station Data are as follows:

(a) Western Regional Climate Center (Jemez Springs, NM – Station #294369), ***1914-2006***

°F = Degrees Fahrenheit

°C = Degrees Celsius

E4.6 Thermal Gradient

The default value of 1.65 was used in the absence of measured data.

E4.7 Possible Sun

Percent possible sun for Albuquerque is found at the Western Regional Climate Center web site http://www.wrcc.dri.edu/htmlfiles/westcomp.sun.html#NEW%20MEXICO. The percent possible sun is 76% for July and 75% for August in Albuquerque. There were no data for Jemez Springs or the Jemez watershed, specifically.

E4.8 Dust Coefficient

If a value is entered for solar radiation, SSTEMP Model will ignore the dust coefficient and ground reflectivity and "override' the internal calculation of solar radiation. Solar radiation data are available from the New Mexico State University Climate Network (see Section 4.10).

E4.9 Ground Reflectivity

If a value is entered for solar radiation, SSTEMP Model will ignore the dust coefficient and ground reflectivity and "override' the internal calculation of solar radiation. Solar radiation data are available from the New Mexico State University Climate Network (see Section 4.10).

E4.10 Solar Radiation

Because solar radiation data were obtained from an external source of ground level radiation, it was assumed that about 90% of the ground-level solar radiation actually enters the water. Thus, the recorded solar measurements were multiplied by 0.90 to get the number to be entered into the SSTEMP Model. The following table presents the measured solar radiation at the Jemez RAWS climate station for 2005:

Table E.19 Mean Daily Solar Radiation

Assessment Unit	Ref.	Date	Mean Solar Radiation (L/day)	Mean Solar Radiation x 0.90 (L/day)
NM-2106.A_13	(a)	7/18/2005	740.928	666.84
NM-2105.5_10	(a)	7/21/2005	620.976	558.88
NM-2106.A_30	(a)	8/11/2005	464.904	418.41
NM-2106.A_43	(a)	7/19/2005	648.600	583.74

Ref. = References for Weather Station Data are as follows:

(a) *New Mexico State University Climate Network (Jemez RAWS, Elevation 2,438 meters; Latitude 35° 50' 28" N , Longitude 106° 37' 8" W)*

E 5.0 SHADE

Percent shade was estimated for the assessment units using field estimations per geomorphological survey field notes from 2005. The measurements may have also been averaged along with visual estimates using USGS digital orthophoto quarter quadrangles downloaded from New Mexico Resource Geographic Information System Program (RGIS), online at http://rgis.unm.edu/. This parameter refers to how much of the segment is shaded by vegetation, cliffs, etc. The following table summarizes percent shade for each assessment unit:

In a 2005 study, Optional Shading Parameters and concurrent densiometer readings were measured at seventeen stations in order to compare modeling results from the use of these more extensive data sets to modeling results using densiometer readings as an estimate of Total Shade. The estimated value for Total Shade was within 15% of the calculated value in all cases. Estimated values for Maximum Temperatures differed by less than 0.5% in all cases. The Optional Shading Parameters are dependent on the exact vegetation at each cross section, thus requiring multiple cross sections to determine an accurate estimate for vegetation at a reach scale. Densiometer readings are less variable and less inclined to measurement error in the field. Aerial photos are examined and considered whenever available.

Table E.20 Percent Shade

Assessment Unit	Percent Shade
NM-2106.A_13	65% [a]
NM-2105.5_10	22% [b]
NM-2106.A_30	35% [c]
NM-2106.A_43	19% [d]

[a] data from site above San Antonio Creek at Battleship Rock
[b] data from site above the Rio Guadalupe
[c] data from site above the Jemez River
[d] data from site at NM State Route 126

E 6.0 REFERENCES

Bartholow, J.M. 2002. SSTEMP for Windows: The Stream Segment Temperature Model (Version 2.0). U.S. Geological Survey computer model and documentation. Available on the internet at http://www.fort.usgs.gov. Revised August 2002.

U.S. Department of Agriculture (USDA). 2005. WinXSPRO 3.0. A Channel Cross Section Analyzer. WEST Consultants Inc. San Diego, CA & Utah State University.

U.S. Geological Survey (USGS). 2002a. Input and Output to a Watershed Data Management File (Version 4.1). Hydrologic Analysis Software Support Program. Available on the internet at http://water.usgs.gov/software/surface_water.html.

U.S. Geological Survey (USGS). 2002b. Surface-Water Statistics (Version 4.1). Hydrologic Analysis Software Support Program. Available on the internet at http://water.usgs.gov/software/surface_water.html.

Theurer, Fred D., Kenneth A. Voos, and William J. Miller. 1984. Instream Water Temperature Model. Instream Flow Inf. Pap. 16 Coop. Instream Flow and Aquatic System Group. U.S. Fish & Wildlife Service, Fort Collins, CO.

Thomas, Blakemore E., H.W. Hjalmarson, and S.D. Waltemeyer. 1997. Methods for Estimating Magnitude and Frequency of Floods in the Southwestern United States. USGS Water-Supply Paper 2433.

Viger, R.J., S.L. Markstrom, G.H. Leavesley and D.W. Stewart. 2000. The GIS Weasel: An Interface for the Development of Spatial Parameters for Physical Process Modeling. Lakewood, CO. Available on the internet at http://wwwbrr.cr.usgs.gov/weasel/.

Waltemeyer, Scott D. 2002. Analysis of the Magnitude and Frequency of the 4-Day Annual Low Flow and Regression Equations for Estimating the 4-Day, 3-Year Low-Flow Frequency at Ungaged Sites on Unregulated Streams in New Mexico. USGS Water-Resources Investigations Report 01-4271. Albuquerque, New Mexico.

APPENDIX F
PUBLIC PARTICIPATION FLOWCHART

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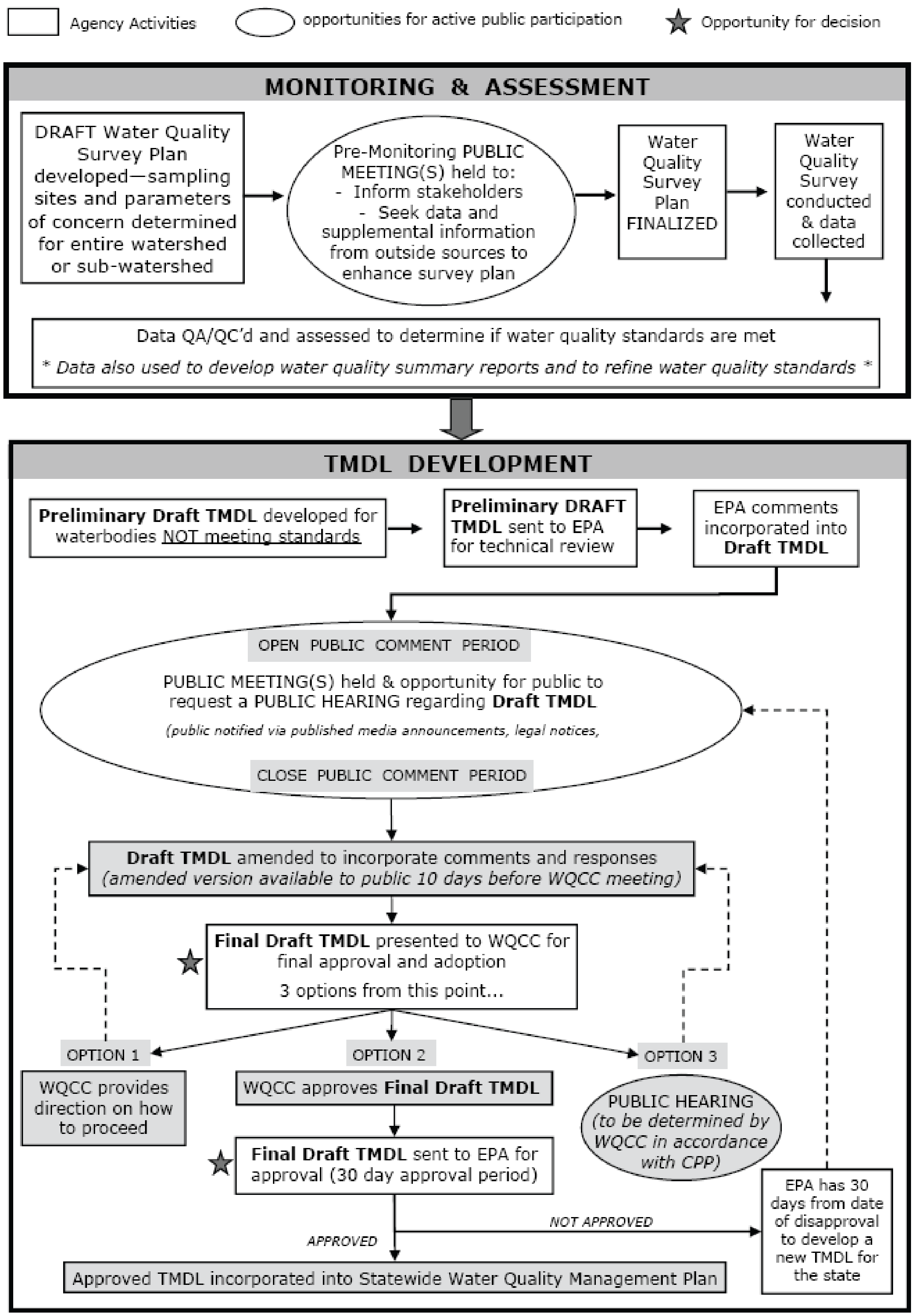
Monitoring, Assessment, & TMDL Development Process



New Mexico Environment Department

Protecting Our Environment, Preserving The Enchantment

Surface Water Quality Bureau

1190 St. Francis Dr, Santa Fe, NM 87106 / 505-827-0187 / www.nmenv.state.nm.us/swqb

The NMED Surface Water Quality Bureau invites you to attend a:

COMMUNITY MEETING

Thursday, June 25, 2009
6:00 - 8:00 PM
Jemez Springs Village Offices
46 Jemez Springs Plaza
Jemez Springs, New Mexico

Jemez Watershed

♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦

TMDL Document Presentation

DISCUSSION TOPICS

Total Maximum Daily Load (TMDL) development for the Jemez Watershed

•

Discussion of water quality survey results from 2005 and previous TMDLs

•

Current and future water quality restoration projects in watershed.

For more information contact:
Shelly Drinkard at 505-827-2814 shelly.drinkard@state.nm.us

The State of Our Environment is up to You

APPENDIX G
RESPONSE TO COMMENTS

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Changes made during public comment period based on staff and USEPA review:

1. **Executive Summary, p. 6 –** Based on a clerical oversight, the wasteload allocation (WLA) and load allocation (LA) for total phosphorus in the Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs) were changed to match the WLA and LA from Table 5.8 in the TMDL document.

2. **Table 3.7, p. 29 –** Based on a recalculation, the load reduction for dissolved arsenic in the Jemez River (Jemez Pueblo bnd to Rio Guadalupe) was changed from 94% to 88% and in the Jemez River (Rio Guadalupe to Soda Dam nr Jemez Springs) the percent reduction was changed from 92% to 91%.

3. **Section 7.1, p. 77 –** Fourth sentence of the last paragraph now states, "The purpose of the [sedimentation/siltation assessment] protocol is to *provide an assessment of the narrative criterion for stream bottom deposits*."
   italics added to emphasize addition

4. **Section 9.1, p. 91 –**
   a. Discussion on the dilution capacity as well as examination of effluent limits for total phosphorus and total nitrogen were removed.
   b. The last paragraph in the Nutrients (Phosphorus and Nitrogen) Discussion was changed to:
   "The Jemez Springs WWTP discharges to the Jemez River under authorization of an NPDES permit, but the facility is currently not designed to treat effluent for total phosphorus and total nitrogen. Federal regulations (40 CFR 130.12(a) and 40 CFR 122.44(d)(1)(vii)) clearly require that NPDES permits must be consistent with the wasteload allocation (WLA) of an adopted and approved TMDL. Because this facility is the sole point source discharger in this reach, it has been allocated the entire WLA of 0.626 lbs/day for total phosphorus and 2.97 lbs/day of total nitrogen as identified in Table 5.8 of the TMDL. The facility will need to develop and implement treatment to meet the new effluent requirements that will result from this TMDL. The New Mexico water quality standards (Subsection J of 20.6.4.12 NMAC) states that it is the policy of the WQCC to allow schedules of compliance in NPDES permits where facility modifications need to be made to meet new water quality based requirements."

Comment Set A:

From: Vernon Hershberger [mailto:hershber@unm.edu]
Sent: Wednesday, June 10, 2009 9:50 AM
To: Henderson, Heidi, NMENV
Subject: Re: Draft Jemez TMDL and Public Meeting

Ms. Henderson,

The NMED's proposal to set TMDLs for naturally occurring contaminants makes me curious. The hot springs and other natural sources of water that feed the Jemez area rivers have relatively high levels of arsenic, warm temperatures, etc. Is one of the purposes of setting such TMDLs to continue to allow the contaminated water sources to continue to feed into the rivers? If the new TMDLs were set low, would the Forest Service, VCNP or other land management entity have to treat hot spring water to reduce arsenic, temperature. etc.?

Thanks,
Vern Hershberger

SWQB Response: *Thank you for your written comments. Several reasons prompted the development of the arsenic and boron TMDLs. First, both constituents violate established and approved water quality standards (i.e. the waterbodies are impaired for arsenic and boron). Second, arsenic is a public health concern and localized sources of boron not only include the weathering of rocks, but also include municipal wastewater treatment plant discharges as well as boron-containing fertilizers and cleaning products. Finally, the list of probable sources includes "natural sources" such as hot springs, but also details other sources such as "highway/road/bridge runoff, other recreational pollution sources, streambank modification/destabilization, site clearance, and inappropriate waste disposal", all of which could contribute arsenic and boron through erosion. Therefore, the SWQB felt that these TDMLs were warranted and justified.*

How a TMDL will be implemented is generally outlined in the Watershed Restoration Action Strategy (WRAS). The WRAS is a written plan intended to provide a long-range vision for various activities and management of resources in a watershed in order to improve water quality and quality of life. It is up to the local stakeholders, with guidance from SWQB, to develop and revise the WRAS based on local interests and concerns.

Implementation of Best Management Practices (BMPs) within the watershed to reduce pollutant loading from nonpoint sources will be encouraged. SWQB recognizes that the numerous hot springs in the Jemez River Watershed deliver a substantial amount of arsenic and boron into the surface waters, however the proportion of the total load coming from these hot springs is unknown at this time. BMP implementation to reduce arsenic and boron loads may not have an impact on hot spring contributions but could be helpful in reducing contributions from other sources. SWQB will communicate to designated federal land management agencies the intent of the TMDL and desire that BMPs be developed through the above coordination process.

Comment Set B:

From: Michael Dechter [mikedechter@hotmail.com]
Sent: Monday, June 29, 2009 12:41 PM
To: Drinkard, Shelly, NMENV
Subject: Comments on Jemez TMDL

Shelly,

Thank you for coming to the Jemez to present on the Jemez TMDL last week. Below are my comments on the document:

- Arsenic - the TMDL says that the data shows "...the overwhelming source of arsenic is from hot springs and other diffuse nonpoint sources." Also, on page 26, the report states, "Management of the load to improve stream water quality should be a goal to be obtained." These statements give the idea that there is a large amount of arsenic coming from non-point sources and if these non-point sources were managed better the arsenic standard would be obtained. I believe this is strongly misleading given the evidence cited on page 32 which shows high arsenic levels as naturally occurring in the watershed as a result of the hot springs. Also, I didn't see any data that clearly demonstrated elevated arsenic levels as a result of non-point sources. I think it should state somewhere in this section of the TMDL that the known sources of the elevated aresenic levels at this time are from the hot springs and that non-point source management may not have any impact or an impact not enough to meet the stated TMDL goals.

- I'd say the same thing for Boron. This way, we are not using scarce resources to manage for something for which we may have little or no control.

SWQB Response: *Thank you for your written comments and attendance at the public meeting on June 25, 2009 in Jemez Springs, NM..*

To address your comments regarding elevated arsenic and boron levels from hot springs and non-point source management, the final paragraph in Section 9.2 (WRAS and BMP Coordination) now reads:

> *"Implementation of Best Management Practices (BMPs) within the watershed to reduce pollutant loading from nonpoint sources will be encouraged. SWQB recognizes that the numerous hot springs in the Jemez River Watershed deliver a substantial amount of arsenic and boron into the surface waters, however the proportion of the total load coming from these hot springs is unknown at this time. BMP implementation to reduce arsenic and boron loads may not have an impact on hot spring contributions but could be helpful in reducing contributions from other sources. SWQB will communicate to designated federal land management agencies the intent of the TMDL and desire that BMPs be developed…"*

- for plant nutrients, I think septic tanks need to be mentioned as a major source. Pg 58 lists a number of potential sources, but gives little or no indication of the magnitude of the impact of these sources. In the Jemez, where homemade septic structures are commonplace, it seems likely that addressing these would be one of the most effective efforts to reduce N and P.

SWQB Response: *SWQB agrees that septic tanks should have been listed as a probable source of impairment, therefore "On-site Treatment Systems (Septic Systems and Similar Decentralized Systems)" will be added to the upcoming 2010-2012 Integrated List as a probable source for the Jemez River. This change has also been noted in the "Identification and Description of Pollutant Sources" section of the TMDL document (Tables 5.10 and 5.11), the Executive Summary, and the Probable Sources Summary (Appendix C). The list of probable sources is based on staff observation and known land use activities in the watershed. Unfortunately, these sources are not confirmed nor quantified at this time. Typically it is during the implementation stage of the TMDL that sources may be confirmed and their contributions (i.e. magnitude) quantified.*

- Temperature - One of the pollutant sources idenitified is "other recreational pollution sources". It would be helpful and more accurate to be more specific here. Much of the Jemez and East Fork Jemez River are off-limits to motorized vehicles. For example, the East Fork is a Wild and Scenic river, which means off-road vehicular use is not allowed. However, it is one of the most heavily used camping areas on the Jemez Ranger District and as a result some long stretches adjacent to the stream completely lack riparian vegetation. The Jemez River has very limited vehicular access as well and little or no grazing, but includes development, trails leading to the water's edge that reduce riparian cover, and several old 'stream improvements' that have widened the channel and reduced riparian cover as well. The Rio Guadalupe has really high camping and is generally open to OHV use at this point, both of which likely contribute to lack of riparian vegetaion and high water temperatures. This specificity may be helpful for those hoping to manage for temperature. The Santa Fe National Forest inventory reports document some of this information. These reports can be found online here:
http://www.fs.fed.us/r3/sfe/fish/reports/stream_inventory_reports/index.html

SWQB Response: *The Assessment Database (ADB) is a relational database application for tracking water quality assessment data, including use attainment, and any pollutants and non-pollutants causing impairments and their probable sources. For New Mexico, the probable sources of impairment are documented using a pre-defined list of 172 probable sources from ADB. Terms to describe probable sources of pollution in ADB match the source categories in EPA's Section 319 Nonpoint Source Grants Reporting and Tracking System (GRTS).*

According to ADB, "other recreational pollution sources" include pollution from recreational-related activities not covered under resorts or public bathing areas. This could include pollution from human activities on hiking trails. There is not a probable source on this list that is specific to the impacts from camping.

Based on your suggestion, "off road vehicles" will be added to the upcoming 2010-2012 Integrated List as a probable source for the Rio Guadalupe. This change has also been noted in the "Identification and Description of Pollutant Sources" section of the TMDL document (Table

6.8), the Executive Summary, and the Probable Sources Summary (Appendix C). SWQB definitely appreciates local stakeholder input regarding the list of probable sources.

- Temperature - On pg. 74 the elevated temperatures are attributed to several factors including reduced summertime base flows. One likely cause of this is the high density of vegetation in the surrounding landscape. There is a plethora of studies showing that the Jemez has a higher density of trees in its ponderosa pine and mixed conifer habitats than ever before. There is also much research showing that this high density of trees effects base flows and makes the watershed more susceptible to high-intensity wildfires that can substantially alter stream flows and riparian cover. I think this well-documented trend should be mentioned.

SWQB Response: *SWQB would prefer to review said research prior to incorporating this information into the TMDL document and will look into this issue more thoroughly in the future. If you have specific papers and/or reports you would like SWQB to review, please forward them to Shelly Drinkard (shelly.drinkard@state.nm.us). Thank you.*

Thanks for the opportunity to comment.

Mike Dechter
mikedechter@hotmail.com

Comment Set C:

* sent via USPSCMR
7007 2560 0000 8583 5996
mailed-out 6-29-09,
all 3 pages

Page 1 of 3
(copy retained)

JUN 30 2009

June 25, 2009

135 Rincon Valverde
Ponderosa, NM
87044-9500

Shelly Drinkard
TMDL Writer
New Mexico Environment Department
Surface Water Quality Bureau
Harold Runnels Building, N2050
1190 South St Francis Drive (87505)
P.O. Box 5469
Santa Fe, NM
87502-0160

TMDL Writer Drinkard,

Concerning Public Comment Draft Total Maximum Daily Load for the Jemez River (from San Ysidro to headwaters excluding waters of the Valles Caldera National Preserve), if there are any changes to:

June 25, 2009

- its cover,
- Pages 1-13,
- Page 15,
- Page 16, and/or
- Page 20,

then I would like for this communication to serve as my directive that I be placed on the Water Quality Control Commission meeting agenda wherein this aforementioned TMDL document is presented by NMEDSWQB for approval so that I might contest said changes. Let this serve as my notice of intent to appear at same.

I appreciated your surface-mailing me hardcopy of said public comment draft TMDL and outreach meeting flyer concerning same,

(copy retained)
June 25, 2009

Thank you for your June 11, 2009 communication and the comment period announcement.

Please, if no changes as I have specified are made and it is not necessary for me to appear before WQCC, surface-mail me hardcopy of the WQCC-approved final TMDL related to this public comment draft.

Enclosed is a copy of the communication regarding this living document process that I sent to New Mexico Environment Department Secretary Ron Curry.

Respectfully,

Rebecca G. Perry-Piper

Rebecca G. Perry-Piper
135 Rincon Valverde
Ponderosa, NM 87044-9500

SWQB Response: *Thank you for your written comments. SWQB appreciates your local knowledge of and commitment to the Jemez River Watershed.*

Here is a list of changes that have occurred:

> *Title Page*
> *"Public Comment Draft" has been changed to "Final Draft" and the date has been changed from June 8, 2009 to July 31, 2009.*
>
> *Page 6*
> *Based on a clerical oversight, the wasteload allocation (WLA) and load allocation (LA) for total phosphorus in the Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs) were changed to match the WLA and LA from Table 5.8 in the TMDL document.*
>
> *Based on several comments and concern at the public meeting regarding septic tanks, the category "On-site Treatment Systems (Septic Systems and Similar Decencentralized Systems)" has been added as a probable source of impairment of the Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs).*
>
> *Page 9*
> *Based on several comments and concern at the public meeting regarding off-road vehicles, the category "Off-road Vehicles" has been added as a probable source of impairment of the Rio Guadalupe (Jemez River to confluence with Rio Cebolla).*

No other changes have been made to the cover page, pages 1-13, pages 15-16, and/or page 20.

If you would like to contest said changes on the title page, page 6, or page 9 of the Final Draft TMDL please contact Joyce Medina at (505) 827-2425 to be placed on the Water Quality Control Commission meeting agenda for their regularly scheduled meeting on August 11, 2009.

Comment Set D:

VILLAGE OF JEMEZ SPRINGS

P.O. Box 269 **Jemez Springs, NM 87025**
(575) 829-3540 **Fax: (575) 829-3339**
website: www.JemezSprings.org **email: vclerk@JemezSprings.org**

John H. Garcia, Mayor

June 30, 2009

Shelly Drinkard
NMED SWQB
P.O. Box 5469
Santa Fe, NM 87502

Dear Ms. Drinkard,

The Village of Jemez Springs is in receipt of the Public Comment Draft document outlining proposed “Total Maximum Daily Load (TMLD) for the Jemez River Watershed”. We have the following questions and comments about the waste load allocation of the Jemez River as it relates to the Village of Jemez Springs WWTP permit NM0028011.

- In the TMDL draft document for the Jemez River watershed the waste load allocation for the Jemez Springs WWTP has the flow 0.75 MGD [sic][1] based on the design capacity of the WWTP.
    - Prior to 2003, flow data generated by the Jemez wastewater treatment plant was incorrect due to poor installation of the staff gauge used to record effluent flow.
    - Since the new wastewater treatment plant went on line in 2003, flow data has been consistently between 20-35,000 gpd with a few brief peaks around 40,000 gpd.
    - Why were the TMDLs for this portion of the river based on speculative data rather than actual recorded data?

SWQB Response: *Thank you for your written comments and attendance at the public meeting on June 25, 2009 in Jemez Springs, NM.*

Please see the discussion below regarding water quality based effluent limit calculations.

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[1] SWQB believes this is a typographical error and the correct design flow is 0.075 MGD as documented in the Village’s NPDES permit application received July 24, 2006.

- How much time will be allowed for engineering and construction that might be needed to meet the target concentration for total phosphorus and total nitrogen?

SWQB Response: *The New Mexico water quality standards at 20.6.4.12.J NMAC provide an allowance for compliance schedules. The USEPA as the permitting agency often allows schedules of compliance so long as their implementation is consistent with both state and federal requirements. USEPA will make the final decision regarding a schedule of compliance in the permit. While SWQB cannot respond on behalf of USEPA, in other NPDES permits USEPA has typically allowed a 3-year compliance schedule to meet new water quality based effluent limits. However this is variable and dependent on, among other things, the specifics and complexity of the engineering project to be completed.*

- The Jemez Springs WWTP is a sequencing batch reactor (SBR) system that discharges 4-5,000 gpd, 5 times per day at 15 minute intervals. How does this affect the dilution capacity of the receiving stream to dilute and disperse effluent?

SWQB Response: *It is the daily discharge that matters in a Total Maximum Daily Load, not how it is discharged over the day. However, if all the waste load was discharged to the receiving stream during one 15-minute stretch the river would have less ability to dilute and disperse the effluent during that period of time (i.e. it's dilution capacity would decrease).*

The Village of Jemez Springs management proposes the following steps in anticipation of meeting the proposed waste load allocations:

- The Village is investigating what is involved in setting up a moratorium on phosphate soaps.
  - After a moratorium is put in place, periodic influent sampling will be performed to evaluate the total phosphate loading
- The Village has contracted with Robert Gott of Gott Consulting to work with plant operator, Karen Nalezney to fine tune the SBR cycles in an effort to reduce the total nitrogen in the effluent.
- A review of the Jemez Springs WWTP effluent data documents the following:
  - Average Total Nitrogen – 4.32 mg/l
  - Average Total Phosphorus – 2.37 mg/l
- The target concentrations as stated in the Draft TMDL document are as follows:
  - Total Nitrogen – 4.75 mg/l
  - Total Phosphorus – 1.0 mg/l

The Village of Jemez Springs management would like to request a variable Total Phosphorus concentration based on the following flows. The target concentrations were calculated using the waste load allocation of 0.626 lb/day.

Flows	Conversion	Target Concentration
.020 MGD	$.020\ MGD\ x\ 8.34 = \frac{0.626}{0.166} = 3.77\frac{mg}{l}\ Total\ Phosphorus$	3.77 mg/l TP
.025 MGD	$.025\ MGD\ x\ 8.34 = \frac{0.626}{0.208} = 3.0\frac{mg}{l}\ Total\ Phosphorus$	3.0 mg/l TP
.030 MGD	$.030\ MGD\ x\ 8.34 = \frac{0.626}{0.250} = 2.5\frac{mg}{l}\ Total\ Phosphorus$	2.5 mg/l TP
.035 MGD	$.035\ MGD\ x\ 8.34 = \frac{0.626}{0.291} = 2.15\frac{mg}{l}\ Total\ Phosphorus$	2.15 mg/l TP
.040 MGD	$.040\ MGD\ x\ 8.34 = \frac{0.626}{0.333} = 1.87\frac{mg}{l}\ Total\ Phosphorus$	1.87 mg/l TP

Additional phosphate sampling is being performed so that we can target sources of phosphorus into the waste stream. If additional information is required please contact us soon so that we are able to respond before the deadline of July 10, 2009, or is a deadline extension possible.

The aforementioned moratorium on phosphate soaps and fine tuning of the SBR cycles have great potential for bringing the Village closer to being in compliance with the proposed target concentrations. We anticipate your response to our questions regarding the waste load allocations and the measures we have proposed for meeting the TMDL target concentrations.

Sincerely,

Johnny H Garcia, Mayor

SWQB Response: *SWQB appreciates your local knowledge of and commitment to the Jemez River Watershed as demonstrated by the proposed moratorium on phosphate-laden soaps, intent to perform some additional water quality sampling, and desire to improve the efficiency and effectiveness of your treatment process to reduce nutrient concentrations in the effluent.*

The phosphorus proposal suggested above is an interesting and innovative approach that would theoretically meet the wasteload allocation assigned to your facility. However, NPDES permits are written and issued by the USEPA. For this reason, SWQB consulted with the USEPA regarding the Village's suggested five-tiered approach. USEPA raised concern that the multiple tiers proposed by the Village would lead to an overly complex permit that would present *compliance and enforcement problems for not only the Agency but also the permittee and discouraged such a complex approach.*

Nevertheless, this facility has a wasteload allocation (WLA) of 0.626 lbs/day for total phosphorus and 2.97 lbs/day of total nitrogen. Federal regulations (40 CFR 130.12(a) and 40 CFR 122.44(d)(1)(vii)) clearly require that NPDES permits must be consistent with the wasteload allocation (WLA) of an adopted and approved TMDL. How the WLA is incorporated in the NPDES permit (i.e. effluent concentration limits versus discharge volume) is a discussion that should occur during the NPDES permit renewal process rather than in this TMDL document. Current USEPA Region 6 permit guidance states that the design flow should be used to calculate concentrations for effluent limits. NMED supports efforts by the Village and USEPA Region 6 to develop and implement innovative solutions, such as those proposed by the Village, provided that they are consistent with Federal Regulation and EPA guidance.