# Springs of the Rio Grande Gorge, Taos County, New Mexico: Inventory, Data Report, and Preliminary Geochemistry

Final Technical Report

October 2007

Open-File Report 506

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New Mexico Bureau of Geology and Mineral Resources

AQUIFER MAPPING PROGRAM

Paul W. Bauer, Peggy S. Johnson, and Stacy Timmons

Big Arsenic spring

New Mexico Bureau of Geology and Mineral Resources

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# I. EXECUTIVE SUMMARY

Between August 2006 and April 2007, the New Mexico Bureau of Geology and Mineral Resources conducted a spring inventory and preliminary geochemical sampling as a first step in evaluating the hydrogeologic connections between the ground water and the Rio Grande in Taos County. The objective and principal task was to locate, inventory, describe, and selectively sample the springs of the Rio Grande gorge.

The springs in the Rio Grande gorge appear to naturally fall into zones or clusters that coincide with either a hydrologically important geologic feature, such as a fault or a volcano, or one of the perennial tributaries of the Rio Grande. Spring data are evaluated in the context of the regional geologic and hydrologic framework. Basic data are presented for springs surveyed in the following locations:

- the Sunshine Valley in the Ute Mountain reach,
- the Cerro Chiflo area, above the Cerro gaging station,
- the west side of the gorge near Bear Crossing,
- the Arroyo Hondo area,
- Taos Junction Bridge,
- Pilar, and
- The Racecourse reach of the Rio Grande, between the BLM quartzite site and the county line.

Water samples were collected from 31 springs and analyzed for general chemistry, trace metals, stable isotopes, and for several relative age-dating analyses, including tritium, chlorofluorocarbons (CFCs), and carbon-14. The report contains maps of the locations of inventoried springs, data tables that characterize the springs, the results of geochemical sampling and laboratory analysis of spring water chemistry and a variety of tracers, and a brief summary of the location and field parameters of each major cluster of springs.

# II. INTRODUCTION

### Background

It has long been known that the Taos County section of the Rio Grande is a gaining stream (Bliss and Osgood, 1928; Spiegel and Couse, 1969; Wilson and others, 1978; Coons and Kelly, 1984; Johnson, 1998). These and other workers have used a variety of techniques to quantify gains and losses along all or some of the 80 river miles between the Lobatos gage and the Embudo gage, including seepage measurements, gage data, and water balances. However, it appears that attempts to quantify the exact locations and magnitudes of the mainstem inflow have not been undertaken, even though they represent a major component of the net gain. Furthermore, no workers have integrated spring hydrogeochemistry with the detailed geology in an attempt to understand the hydrogeologic connections between the springs and the ground water systems.

Taos County is the northernmost county along the Rio Grande in New Mexico. As such, it plays an important role in the hydrologic health of the Rio Grande and a critical role in the administration of water within the Rio Grande ground water basin. The population of Taos County has increased steadily since 1960, with most of the rural homes pumping ground water for domestic use. Because most shallow ground water in the Taos region ultimately flows to the Rio Grande, consumption of ground water eventually results in depletions to the river. Recently, there has been some concern about the potential impacts of ground water pumping on the springs in the Rio Grande gorge and its tributaries.

This spring inventory and preliminary geochemical sampling effort is the first step in evaluating the hydrogeologic connections between the ground water and the river in Taos County. Future work will focus on the hydrogeologic setting of the springs and ground water/surface water interactions.

### Previous Work

Although a number of workers have published reports on some aspects of the springs in the Rio Grande gorge area of Taos County, there has been no comprehensive inventory of the springs with precise locations, and no methodical hydrogeochemical or hydrogeologic investigations. Summers (1976) reported on the thermal springs of New Mexico, including two springs located in the gorge. White and Kues (1992) published an inventory of springs in the state, although it only covered a small number of the springs in the gorge. Garrabrant (1993) produced a report on regional water resources of Taos County, including a compilation of some previously published spring data. Johnson (1998) presented a comprehensive surface water assessment of Taos County that included an inventory of all documented springs in the county. TetraTech (2003) located and estimated discharge for several springs in the Taos Box section. Benson (2004) summarized the ground water geology of Taos County, including new geochemistry on a few springs along the Rio Grande. The New Mexico Environment Department, DOE Oversight Bureau surveyed and sampled six springs in the gorge in 2004 (M. Dale, written communication, 2007).

## Purpose and Scope

The objective of this work was to locate, inventory, describe, and selectively sample the springs of the Rio Grande gorge in Taos County, New Mexico. The report contains maps of the locations of inventoried springs, data tables that characterize the springs, and the results of geochemical sampling and laboratory analysis of spring water chemistry. It also contains a brief summary of the location and field parameters of each major cluster of springs. An evaluation of the sources, ground water flow paths, and detailed geologic settings of the springs is beyond the scope of this project, but is planned as a future study.

## Description of Study Area

The Rio Grande gorge in Taos County extends from the Colorado border south to the Rio Arriba County Line downstream from the village of Pilar, a distance of 63.5 river miles (Fig. 1). Throughout that distance, the Rio Grande has excavated a steep-sided gorge that ranges from a small canyon at the state line, to a deep and narrow canyon in central Taos County, to a broad canyon south of the Rio Pueblo de Taos confluence. In Taos County, the Rio Grande is supplied by three major, perennial tributaries, the Red River, Rio Hondo, and Rio Pueblo de Taos, each of which has carved a steep-walled canyon that grades to the Rio Grande.

From the state line to the Rio Pueblo confluence, approach to the river is inhibited by the steep cliffs of basalt exposed in the gorge. The only road to the river is at the Rio Hondo, where the Dunn bridge links the east and west banks. Otherwise, a number of steep trails, which range from improved to primitive, provide the only reasonable access to the river. In general, hiking along the river on either bank is demanding, due to the preponderance of large basalt boulders and poison ivy. Below the Rio Pueblo confluence, access to the river corridor is much easier, as roads, trails, and bridges abound.

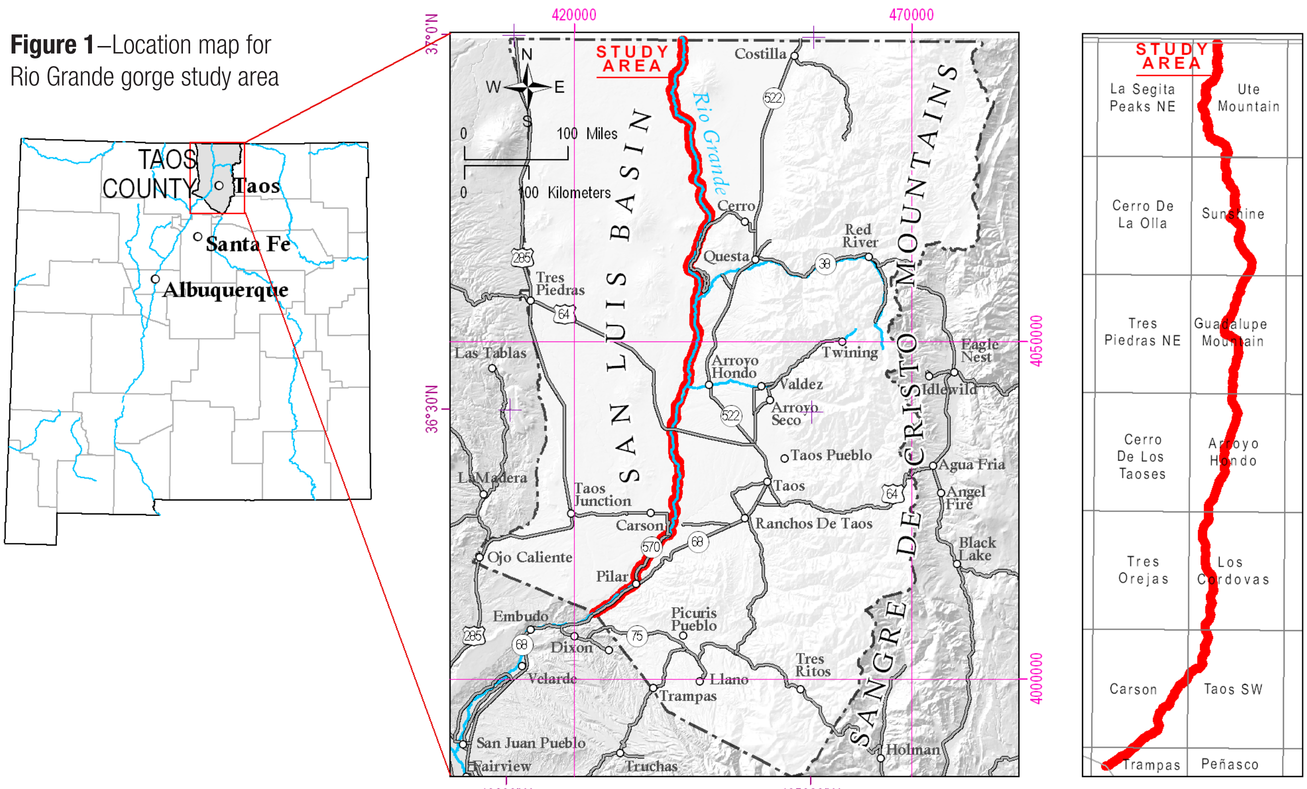


**Figure 1**–Location map for Rio Grande gorge study area

# III. METHODOLOGY

The principal task in this study was to locate, characterize, and sample springs in the Rio Grande gorge in Taos County. Prior to field work, a comprehensive search of published and unpublished spring-related literature was performed. We also interviewed land-management personnel and experienced naturalists in the Taos area for information on springs and access points into the gorge. Existing spring data were compiled on a spreadsheet. The lack of generally accepted names, and the poor quality of spring locations and descriptions, created uncertainty in the value of some of the existing data.

The major perennial tributaries of the Rio Grande in Taos County (Red River, Rio Hondo, Rio Pueblo de Taos) all contain noteworthy springs along their lower reaches. An inventory of these springs was beyond the scope of this project, although we did visit and sample a cluster of springs on the lower Rio Hondo.

Between August 2006 and September 2009, we conducted several field trips to the Rio Grande gorge, primarily targeting known spring locations. The springs were visited on foot by descending into the gorge from both the east and west canyon rims, and traversing either upstream or downstream to locate springs. In several cases, we crossed the river in an inflatable kayak in order to reach west-side springs. Two surveys were made downriver in inflatable kayaks – the 15-mile section from State Line to Lee Trail, and the 2-mile section from Dunn Bridge to Manby Hot Springs.

Springs were field-located with handheld GPS devices. Portable field meters (Orion 29A+Meter and YSI Multiprobe Model 85) were used to measure pH, temperature, dissolved oxygen, and specific conductivity. Where possible, spring discharges were measured with a bucket and stopwatch system. Where physical conditions prohibited direct measurement, spring (or spring zone) discharges were estimated. The springs were photographed and described according to their geographic setting, geologic setting, and physical parameters. All data were compiled onto an Excel spreadsheet. Elevations of all springs were calculated in ArcGIS using the 10-meter DEM coverage. A total of 167 springs and seeps were inventoried for this study. In addition, the inventory includes unpublished information on several springs that we did not visit, but were located and sampled by Michael Dale and colleagues from the NM Environment Department, DOE Oversight Bureau. Although these springs represent most of the important springs in the gorge, the scope of this project did not permit us to locate all of the springs in the gorge.

Thirty one of the springs were selected for sampling for some combination of general chemistry, trace element chemistry, stable isotopes of oxygen and hydrogen, tritium, CFCs, and carbon-14. Samples were collected according to generally accepted sampling protocols, and sent to analytical labs.

All of the above data were then compiled onto two spreadsheets. Table 1 presents information on locations, settings, discharge, field parameters. Table 2 presents the results of all geochemical analyses. Laboratory reports are included in Appendix A.

In early 2017, this report was updated to include springs that had been inventoried in 2008 and 2009. The results are included in revised Tables 1 and 2, but are not included in the chapter on spring chemistry or Plate 1.

# IV. GEOLOGIC AND HYDROLOGIC SETTING

**Regional Geology**

The study area lies within the southern San Luis Basin, the northernmost basin of the Rio Grande rift (Fig. 2). The 150-mile-long San Luis Basin is bordered by the Sangre de Cristo Mountains on the east and the Tusas and San Juan Mountains on the west. The basin is roughly divided into two physiographic and geologic provinces, the broad San Luis Valley of southern Colorado and the narrow Taos Plateau of northern New Mexico. The divide between the two consists of a prominent zone of volcanoes stretching west from Questa. At the southern end of the basin, near Taos, the rift is about 20 miles wide and filled with about a 3-mile-thick section of sediments and volcanic rocks.

Upon exiting the San Juan Mountains, the Rio Grande turns southward, transects the San Luis Basin, and continues its southward flow through successive rift basins towards the Gulf of Mexico. The river follows the topographically lowest part of the rift, carving several spectacular canyons along the way. Beginning in southern Colorado, the Rio Grande has cut a steep-walled canyon, known at the Rio Grande gorge, into the basalt cap rock. Near the Colorado state line, the gorge is relatively shallow, but deepens southward to a maximum of 850 feet at the Wild Rivers Recreation Area near Questa, and then gradually shallows as the Rio Grande flows out of the southern San Luis Basin.

Unlike the rift basins to the south, the San Luis Basin is relatively undissected. That is, the sedimentary material that fills the basin has not yet been extensively exposed by the action of rivers and streams. Instead, the Rio Grande and its major tributaries have cut deep, narrow canyons through the volcanic rocks that cap most of the Taos Plateau. The river canyons provide the only good exposures of the rocks in the basin, which in the study area consist of Tertiary volcanic rocks interlayered with poorly consolidated deposits of sand, gravel, and clay.

A single type of volcanic rock dominates the Taos Plateau landscape—the olivine tholeiite basalts of the Servilleta Formation. The gorge walls chiefly consist of thin, near-horizontal layers of this dark gray, pahoehoe (ropy), vesicular (with small air pockets) lava. Much of the basalt was erupted from a cluster of low-relief shield volcanoes near Tres Piedras, traveling as thin, molten sheets for tens of miles before solidifying. Over 600 feet of basalt were locally stacked up during about 2 million years of episodic eruptions, between about 4.8 and 2.8 million years ago. These rocks can be seen from any location along the gorge, but are especially well exposed near the Gorge high bridge.

In the gorge, the basalts have been subdivided into four major flow units (Peterson, 1981), from oldest to youngest they are the lower Servilleta basalt ($Tb_1$ and $Tb_2$), middle Servilleta basalt ($Tb_3$), and upper Servilleta basalt ($Tb_4$). All basalts are extensively fractured, especially by columnar joints that tend to vertically penetrate entire basalt flows (Fig. 3). Many of the columnar fractures are open. Such basalt fracturing formed as each lava flow cooled, thus we expect the buried basalt units to also be extensively fractured, and therefore highly permeable in the vertical dimension. In addition, the flow tops are typically characterized by highly vesicular ropey structures that create porous and permeable horizontal zones between flows. Interflow porosity and permeability is also enhanced by deposits of sand and gravel ranging upwards of tens of feet thick.

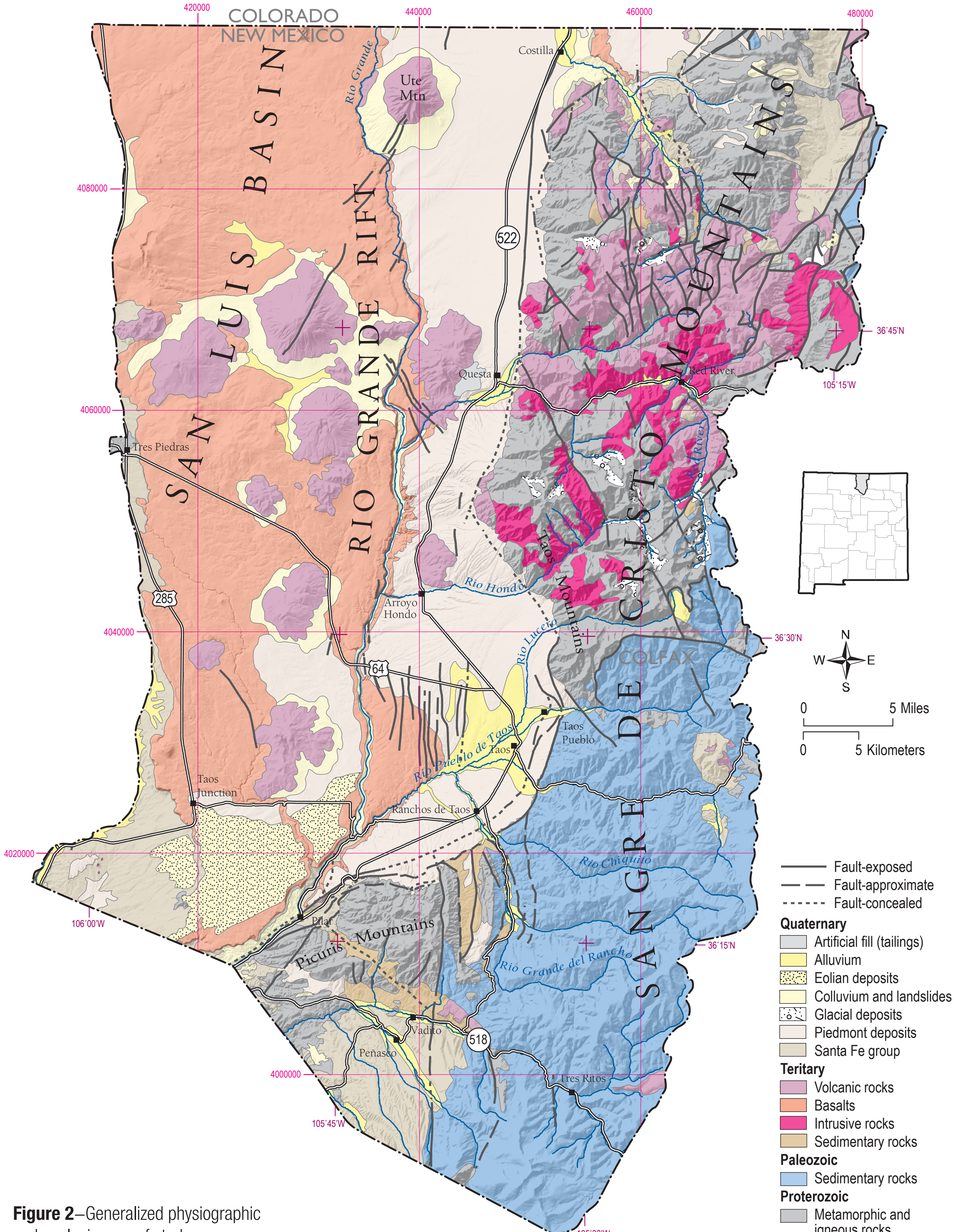


**Figure 2**—Generalized physiographic and geologic map of study area.

Other types of volcanic rock are seen in and adjacent to the gorge, including dacite lava domes formed by eruptions of sticky lava that could only flow short distances before solidifying. Such long, thin dacite flows are commonly seen in the walls of the gorge along some stretches of the river. Most of the large volcanoes on the Taos Plateau are lava domes. Other volcanic forms, such as cinder cones and rhyolite flows, have also been identified in the Taos Plateau volcanic field.

Each dacite dome is composed of many, perhaps thousands, of small lava flows, which have collectively built each volcanic edifice. The volcanoes contain multiple vents, and are therefore complex in three dimensions. Although each dacite flow is composed of relatively dense, fine-grained rock that generally lacks vesicles, they do contain large fracture systems, including columnar joints. In addition, the dacite flows are generally mantled by extremely fractured rubble zones that formed as the lava cooled. Accordingly, the hydrologic characteristics of these dacite domes (porosity and permeability) is highly variable, both in magnitude and spatial distribution, with values of hydraulic conductivity expected to vary over many orders of magnitude and locally reaching upwards to several hundreds of feet per day.

Although some of the sediment that fills the rift basin was deposited by the Rio Grande, most of the clay, silt, sand, gravel, and cobbles were eroded from the nearby mountains during the past 25 million years. The San Luis Basin is surrounded by alluvial fans that have slowly advanced from the mountains into the basin. This material forms an “apron” that radiates out from the point where the mountain stream enters the valley.

Over time, each alluvial fan is buried under successively younger alluvium as the basin slowly sinks. In the Rio Grande rift, these rift-fill deposits are called the Santa Fe Group. Over much of the basin, we can only see the youngest basin fill at the surface. However, glimpses of Santa Fe Group sediments exist in the gorge, commonly as red or tan layers sandwiched between basalts in the gorge walls. The youngest of these alluvial fans and ancestral Rio Grande river deposits supply the many sand and gravel quarries in the area. Over much of its length, the walls of the Rio Grande gorge are covered by landslide and talus deposits. In places, the landslides are enormous arc-shaped complexes of jumbled volcanic rock and gravels.

A number of known fault systems exist on the Taos Plateau, several of which intersect the gorge within the study area and are hydrologically significant (Fig. 4). The Red River fault system (Peterson, 1981; Dungan and others, 1984; Kelson and Bauer, 2006) consists of several steeply dipping, east-down normal, en echelon fault segments that offset Pleistocene gravels on the plateau. The faults strike northwesterly from near Lama to Cerro Chiflo. The faults are well exposed in the gorge where they form brittle fracture zones in the Servilleta basalts.

The Dunn fault (Peterson, 1981; Dungan and others, 1984; Kelson and Bauer, 2006) is an east-dipping, east-down rift fault that parallels the Rio Grande gorge near the confluence with the Rio Hondo. It exhibits about 115 feet of normal movement that appears to coincide in time with eruption of Servilleta Formation basalts and interlayered sediments (Dungan and others, 1984). Where exposed west of the Dunn bridge, the Dunn fault consists of a several-meter-wide brittle deformational zone that is characterized by brecciated basalt and fractured and altered sediments.

**Regional Hydrology**

The Taos region generates significant surface water resources through eleven perennial streams and rivers, and stores large quantities of ground water distributed in various local and regional-scale aquifers. These two regional sources, surface water and ground water, are intricately linked, and both discharge to the region’s principal hydrologic feature, the Rio Grande. The entire southern San Luis Basin is drained by the Rio Grande. The Rio Grande brings an annual

**Figure 3**–Photograph of the Rio Grande gorge showing persistent columnar jointing of basalt flows.

average of about 325,500 acre-feet across the state line from Colorado, and streams from the Sangre de Cristo Mountains in Taos County contribute, on average, an additional 276,200 acre-feet each year to the river (Shomaker and Johnson, 2005).

As the perennial streams east of the Rio Grande gorge exit the high crystalline-bedrock valleys of the Sangre de Cristo Mountains and enter the lower alluvial valleys, a portion of their flow is lost to infiltration through the coarse sand and gravel of alluvial fans and slopes. This loss diminishes the stream's discharge, but in turn replenishes storage in the region's aquifers and, together with infiltration from acequia irrigation, sustains shallow water levels in the region's valleys. The complex hydrogeologic conditions adjacent to the mountain front give rise to complicated interactions between water flow in streams and water flow in aquifers. No perennial streams contribute surface flow from west of the Rio Grande gorge.

Recharge from the Sangre de Cristo Mountains moves westward away from the mountain front, flowing downward through young alluvial fan sediments close to the surface, then laterally through basalt flows and interbedded sediments of the Servilleta Formation before discharging into the Rio Grande. The large (500–900 feet) elevation difference between the areas of recharge adjacent to the mountain front and the Rio Grande, over a relatively short distance

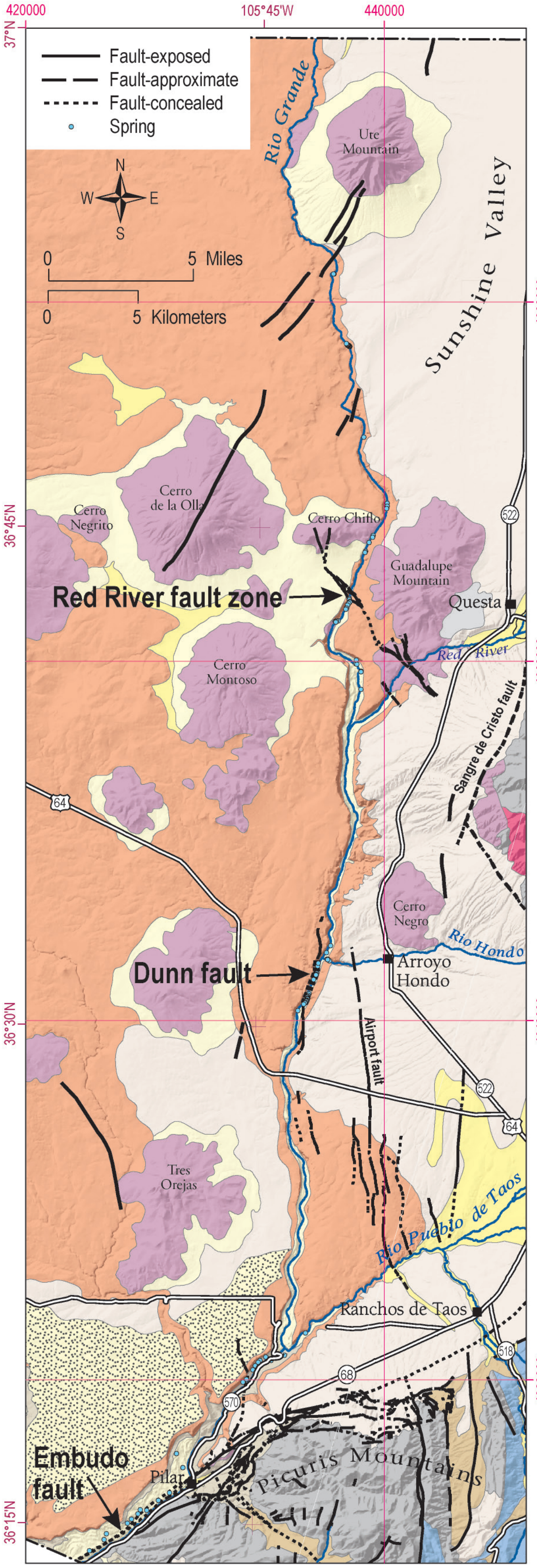


**Figure 4**–Faults on the Taos Plateau intersecting the Rio Grande gorge.

of 7–9 miles, leads to a strong downward component of ground water flow, and probably to perched ground water and unsaturated conditions below the water table in some places (Summers and Hargis, 1984; Winograd, 1984; Shomaker and Johnson, 2005). Ground water discharges into the Rio Grande gorge through springs emerging in the channel bottom and banks of the Rio Grande and from the canyon walls 100 feet or more above the river. Sources of recharge to aquifers west of the river are far removed from the gorge, residing primarily in the Tusas Mountains, San Antonio Mountain, and the southern San Juan Mountains. Ground water discharges from aquifers on the west side of the Rio Grande through springs along the west bank and canyon walls and probably also from springs emerging along the channel bottom.

# V. SPRINGS

The springs in the Rio Grande gorge appear to naturally fall into zones or clusters that coincide with either a hydrologically important geologic feature, such as a fault or a volcano, or one of the perennial tributaries of the Rio Grande. Figure 4 is a generalized map of the major zones and geologic features, and Plate 1 (in back pocket) displays all of the springs at a scale of 1:24,000. Table 1 presents a summary of data for all springs inventoried in the Rio Grande gorge. The following list summarizes the general characteristics and analytical results of these major spring zones. Spring locations are located by river miles south of the state line.

## Sunshine Valley Springs

Springs are rare along the Ute Mountain reach of the gorge, between the State Line and Lee Trail. The first known spring, named Cisneros spring, is located at river mile 10, on the west side, opposite the primitive Cisneros Trail (aka Cow Patty Trail). The small, cool (55°F) spring emerges just above the river from a talus slope of basalt and sandy sediment. Discharge was measured at 4 gpm.

Approximately 13 miles from the State Line is a nearly continuous, half mile-long zone of east-side springs and seeps named the Sunshine spring zone. These cool (55–56°F) springs emerge from beneath a basalt flow, at the base of the canyon wall. Cumulative discharge was estimated at about 20 gpm, with the largest single spring at 5 gpm.

Two of these springs were sampled for tritium in 2006. Results were -0.03 and 0.02 TU, respectively.

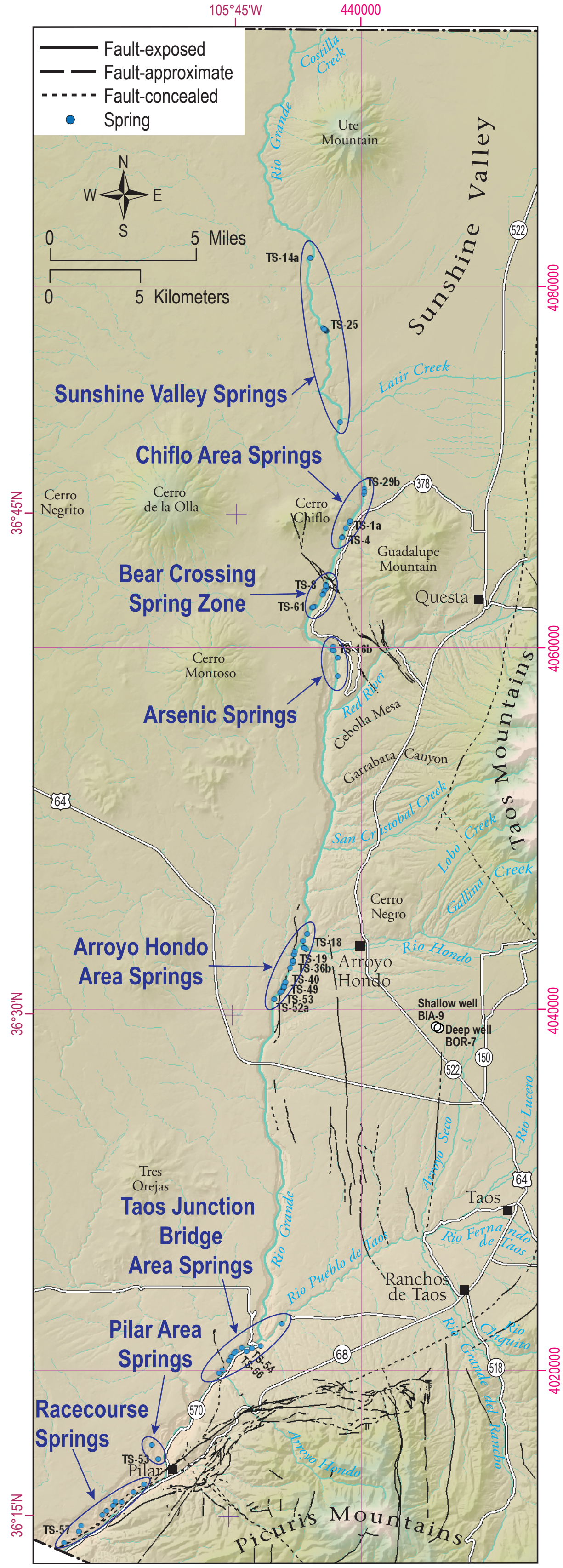

**Figure 5**–Index map of the Rio Grande gorge showing the major clusters of springs.

**Chiflo Area Springs**

A group of small, east-side springs is found near Cerro Chiflo, between the primitive Desagua Trail and the Cerro gaging station. These cool (53–60°F) springs are located near the base of basalt or dacite cliffs, just above river level. The cumulative discharge was estimated at about 30 gpm, with the largest single spring estimated at 5 gpm.

Two springs were sampled for tritium in 2006. Desagua Trail spring measured 4.5 TU. Gaging Station South spring measured 0.46 TU.

**Bear Crossing Spring Zone**

The most volumetrically significant spring zone in the gorge is located on the west side, just downstream from Bear Crossing Trail. The northernmost spring is located under the powerlines, and the springs emerge almost continuously for about 1.5 miles downstream. The upper line of springs is named Bear Crossing spring zone, and the lowermost cluster of three springs is named Felsenmeere. Due to logistical challenges, we were not able to survey the lower half of the Bear Crossing spring zone.

The Bear Crossing springs are invisible from the canyon rim, because they discharge on the canyon wall and flow beneath a huge basalt boulder field to the river. The springs orifices are nowhere visible, but appear to originate 50–100+ ft above the river in basalt talus. Distinctive zones of clear water along the western shore mark the locations of the largest spring inflows to the river. This spring zone is situated on the Red River fault zone which certainly provides fracture-enhanced permeability to the volcanic rocks and sedimentary deposits and probably behaves like a ground water drain, funneling ground water flow to the spring discharge zone in the canyon wall. Water temperatures are consistently 61–62°F along the zone. Nearly all of these springs were too large to measure directly, and oftentimes the flow of the springs were difficult to see beneath the boulders. Therefore, all estimates of discharge should be considered as minimum values, and it is possible that actual flows could be at least twice or more than our estimates. The largest spring was estimated at 1200 gpm, and the cumulative total for the zone was estimated at approximately 6400 gpm.

The Felsenmeere springs are visible from the eastern rim, as high-velocity, high-discharge columns of water that emerge from the basalt talus about 100 ft above the river. The southern two springs have single, discrete orifices below basalt blocks, whereas the northern spring consists of numerous medium-sized flows over an area of several hundred square meters. Spring waters are between 61–62°F. These springs are too large to measure directly, and therefore our estimates should be taken as minimums. Felsenmeere North zone was estimated at 4000 gpm. Felsenmeere Middle spring was estimated at 2500 gpm. Felsenmeere South spring was estimated at 3200 gpm.

A tritium sample taken in 2006 from a Bear Crossing spring measured 0.09 TU. A $^{14}C$ sample from Felsenmeere Middle spring returned an uncorrected apparent age of 4,400 +/- 40 yrs.

**Arsenic Springs**

The cluster of east-side Arsenic springs are well known due to their large size and easy access via the well-maintained Big Arsenic and Little Arsenic trails in the BLM Wild Rivers Area. Big Arsenic spring actually consists of several large northern springs and a single large southern spring. Little Arsenic spring consists of a single small spring. All of these springs appear to emanate well above the river, on or above the top of the landslide deposits. Some of the northern Big Arsenic spring water may actually emerge at the base of the eastern volcanic cliffs, but infiltrate into the landslide deposits, and later discharge from lower on the landslides. Temperatures range from about 60–63.5°F.

A minimum estimate of cumulative discharge from the Big Arsenic springs is about

5000 gpm, with the largest spring estimated at 3000 gpm. Little Arsenic spring was measured at 35 gpm.

Tritium samples from Big Arsenic and Little Arsenic taken in 2006 returned readings of 0.60 and 0.02 TU, respectively.

**Arroyo Hondo Area Springs**

Forty three of the surveyed springs are in the Arroyo Hondo area. Several sets of springs emerge from the eastern wall of the gorge, including cool springs upstream from the Dunn bridge, a nearly continuous line of springs downstream from the bridge, and Black Rock and Manby hot springs south of the bridge. A cluster of cool springs also emerges on the north slope of the Arroyo Hondo, just east of the confluence.

Nearly all of the cool springs emerge from near the base of the eastern gorge cliffs within about 50 vertical feet above the river. Where exposures of bedrock are sufficient, it appears that some of the springs emerge from just below basalt layers. These springs are generally small, and located in lines of distributed springs and seeps. The largest measured discharge is 144 gpm, although most flow is less than 15 gpm. The principal clusters of springs within the Arroyo Hondo area are summarized as follows:

a. North of the Rio Hondo confluence, the Dunn Bridge North spring zone consists of 20 springs and seeps that emerge from rock debris. The largest was measured at 144 gpm, with a cumulative estimate of about 240 gpm for the zone. The springs are cool (59°F), and yield a CFC age of 36 +/- 2 years. The southernmost spring in the zone, the Rael spring, yields a tritium value of 4 TU in 2006.

b. The Lower Arroyo Hondo spring zone is located near the mouth of the Rio Hondo, north of the stream, emerging from the base of the basalts along the cliff. The zone consists of a long zone of seeps plus two cool (58°F) springs with a total estimated discharge of 50 gpm.

c. The Dunn Bridge South spring is a small, cool (63°F) spring estimated at 1 gpm, located 500 meters south of the confluence.

d. The Godoi North spring zone is a cluster of many small springs and seeps that discharge from the base of the basalt, located about 1000 meters downstream of the confluence. The zone has an estimated cumulative discharge of 120 gpm, with the largest single spring at about 30 gpm. The springs are cool (63–67°F), and yield a CFC age of 53 +/- 2 yrs.

e. The Godoi South spring zone is a line of springs nearly 1000 meters long, just upstream from Manby Hot springs. The cumulative discharge was estimated at 112 gpm, with the largest spring at about 30 gpm. Temperatures range from cool (61°F) in the north to warm (74°F) near Manby Hot springs, and indicate a warming trend to the south. Tritium values from north and south samples were negligible in 2006. We suspect that this spring zone is at least partly fed by the deep aquifer, and is controlled by fracture permeability along the Dunn fault, allowing the cool spring water to partially mix with the geothermal water that feeds the nearby hot springs.

f. Black Rock Hot Spring is a small spring on the west side, with a measured discharge of 21 gpm in 2002. The maximum temperature of the pool is about 101°F. To the south, Manby Hot Springs (aka Stagecoach Hot Springs) discharges over 100 gpm of geothermal water (94°F). Both springs are located near the Dunn fault, which probably provides a vertical conduit for the ascent of deep geothermal water.

**Taos Junction Bridge Area Springs**

Several small, east-side springs are found near the Rio Pueblo de Taos confluence. Three of these springs are located near the Taos Junction bridge. Two (Dustbowl and Rio Grande/Klauer) are located in arroyos where they emerge from a section of sediments layered between basalt flows. They are cool (58°F and 60°F) and have discharges of 3 and 17 gpm, respectively. Rio Grande spring, which is piped for public use, yielded a $^{14}C$ uncorrected apparent age of 7,670 +/- 50 yrs. The third spring (Taos Junction South) emerges just above the road, is warmer (65.5°F), and yielded a $^{14}C$ uncorrected apparent age of 18,850 +/- 100 yrs.

Downstream from the bridge are a series of small west-side seeps that are perched 200–300 ft above the river on a 2-meter-thick layer of gray clay. This Orilla Verde seep zone is easily mapped by the vegetative zones that exist below the seeps.

**Pilar Area Springs**

The village of Pilar west-side acequia system (Acequia de los Ojos) is charged by a single spring (locally known as Big Spring) that emerges from the talus slope about 150 ft above the Rio Grande. The spring contains a single orifice that is located beneath a basalt boulder. Spring water is warm (72°F), and discharge was estimated at 450 gpm. A $^{14}C$ sample yields an uncorrected apparent age of 14,900 +/- 80 yrs.

A second spring, located about 0.5 mile to the north and 200 ft higher on the slope, feeds a line of large cottonwood trees that descend to the river.

**Racecourse Springs**

Between the BLM Quartzite Site and the County Line Site are approximately 20, west-side wetlands (cienegas) that are superimposed on massive landslide deposits of basalt and interlayered sediments. The wetlands are characterized by lush vegetation, waterlogged soils, springs that feed a network of drainage channels, and zones of active soil creep. All of the wetlands are nourished by small springs, whose water typically infiltrates before reaching the Rio Grande. We sampled several of these springs, including the largest spring in the largest wetland, located just to the north of Souse Hole rapid. The spring is cold (55°F) and has an estimated discharge of 5 gpm. A $^{14}C$ sample yields an uncorrected apparent age of 3400 +/- 40 yrs.

# VI. SPRING WATER CHEMISTRY

The quality of water describes both its potability for drinking and its specific chemical characteristics, which are governed by a combination of the original composition of precipitation, chemical conditions in the aquifer, and impacts of human development. Mapping the distribution of water quality and geochemical parameters in springs and aquifers is important to an overall understanding of the hydrologic systems and management of the water resources.

## Spring Sampling

During the fall and spring of 2006–2007, water samples were collected from 21 springs and analyzed for general chemistry, trace metals, and stable isotopes. Samples from some springs were also analyzed for several relative age-dating analyses, including tritium, chlorofluorocarbons (CFCs), and carbon-14. The sampled springs and analytical results are shown in Table 2. Interpretation of these data is beyond the scope of this study, but is planned for future work.

The following sections describe the analytical geochemical techniques that were performed on the spring samples, and the types of information that might be gleaned from such data.

## Hydrogeochemical Methods

The spatial distribution of certain hydrogeochemical parameters provides useful information about a ground water flow system, including general water quality and water type, recharge and discharge areas, recharge mechanisms, depth of ground water circulation, degree of hydraulic interconnection, length and continuity of ground water flow paths, and a relative sense of ground water residence time or age. The most useful chemical parameters for the characterization of springs in the Rio Grande gorge include total dissolved ions (TDI), ion chemistry, temperature, select trace elements, stable isotopes of oxygen ($^{18}O$) and hydrogen ($^{2}H$ or deuterium, D), radioisotopes of carbon ($^{14}C$) and hydrogen ($^{3}H$ or tritium, H) and other indicators of ground water age such as CFCs.

## Ion Chemistry

Ions are elements that carry a positive or negative charge, and are naturally found in ground water. As ground water moves along its flow path, changes in its ion chemistry occur as the water dissolves minerals in the rock. In general, shallow ground water near a recharge area is lower in TDI than water deep in the aquifer or water isolated from active recharge, and lower in TDI than shallow ground water in a discharge area. In addition, changes in anion (a negatively charged ion) and cation (a positively charged ion) chemistry occur along a ground water flow path, as water moves from shallow recharge areas into deeper or isolated portions of the aquifer where flow is attenuated and residence time is longer. The anion content generally increases and evolves progressively from bicarbonate-rich water toward higher concentrations of sulfate, and eventually chloride. The cation content generally increases from calcium-rich water toward higher concentrations of sodium and magnesium. A high potassium content is characteristic of geothermal waters. The temperature of ground water also increases as it follows a long or deep circulation pathway and increases in age or residence time. Two thermal types of ground water discharge in the gorge springs: cold ground water with a shallow circulation and hot or geothermal water with a history of deep circulation.  All of the sampled springs were analyzed for major and trace ion chemistry. Results are listed in Table 2, with complete laboratory data given in the appendix.

### Stable Isotopes

The stable isotopes of hydrogen ($^2$H, commonly referred to as deuterium) and oxygen ($^{18}$O) are ideal, conservative hydrologic tracers as they are a part of the water molecule. The stable isotope content of ground water is expressed as ratios of $^2$H/H and $^{18}$O/$^{16}$O in units of parts per thousand (per mil or ‰). Stable isotope ratios in ground water are affected by meteorological processes that provide a characteristic fingerprint of the water's origin. Each step of the hydrologic cycle – evaporation from the oceans, condensation and rain, re-evaporation, snow accumulation and melting, and runoff – partitions the heavier isotopes of $^{18}$O and $^2$H amongst the different freshwater reservoirs. On a global scale, $\delta^2$H and $\delta^{18}$O in fresh waters correlate along a "global meteoric water line" (Figure 6), according to the equation $\delta^2\text{H} = 8\delta^{18}\text{O} + 10$. The meteoric water line ("MWL") is the key to interpretation of $^2$H and $^{18}$O data. Water with an isotopic composition falling close to the MWL generally originates as precipitation and is unaffected by other isotopic processes.  Various processes produce deviations from the MWL, but do so in unique ways. Figure 7 illustrates these processes and the resulting compositional trends away from the

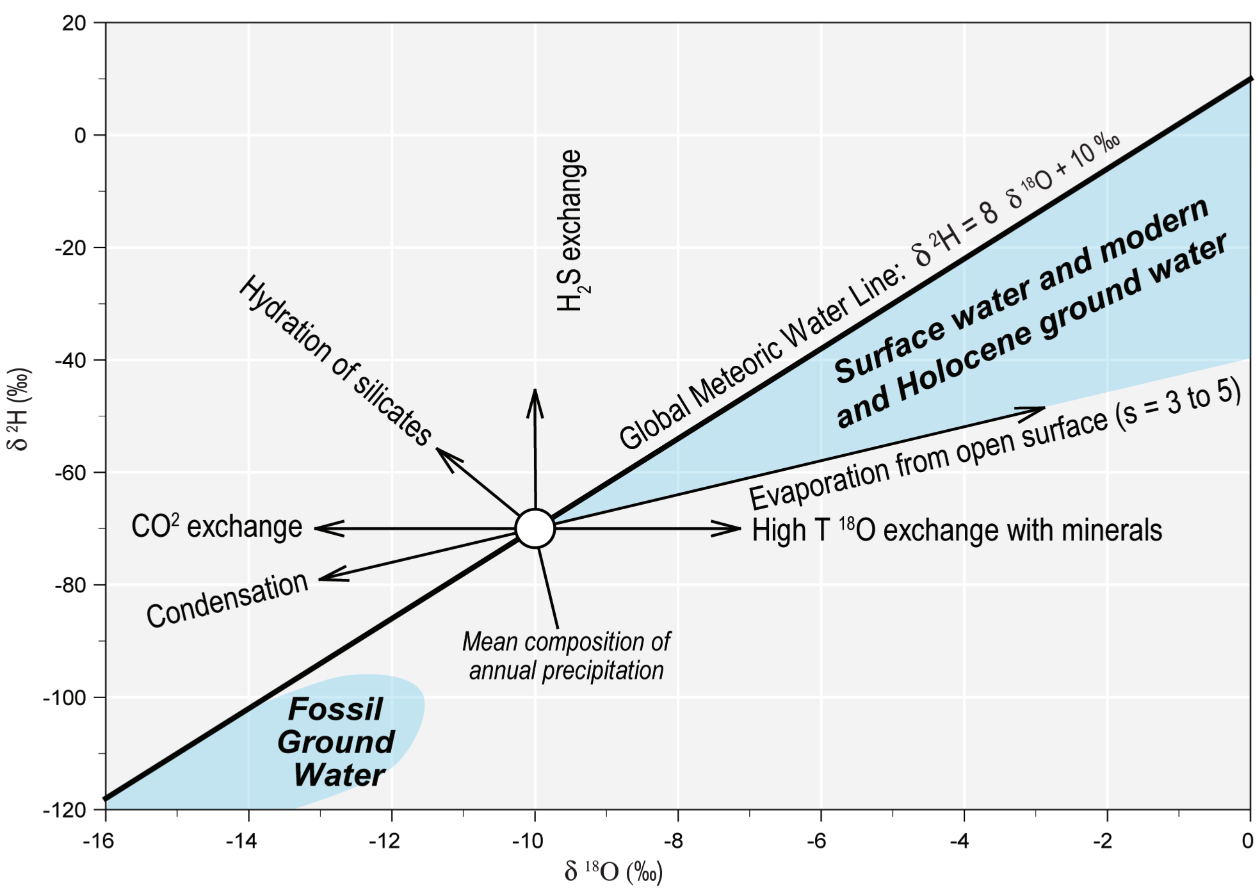


**Figure 6**–Deviations in isotopic composition away from the meteoric water line (Craig, 1961) as a result of various processes (modified from IAEA Report No. 288, 1983).

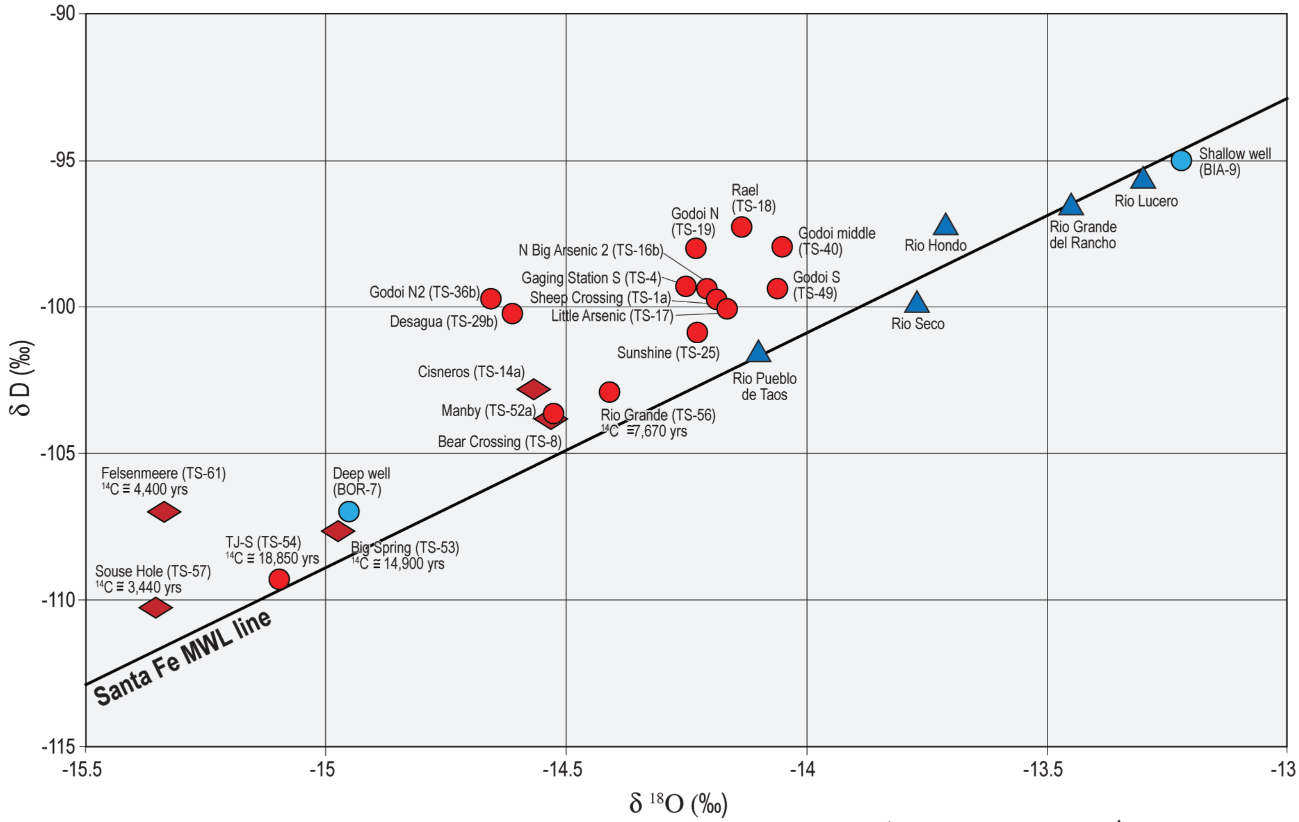


**Figure 7**–Graph of stable isotope data for 19 Rio Grande gorge spring samples.

MWL. The most important of these processes to this ground water provenance study are evaporation and paleoclimate effects. Fossil ground water recharged during late Pleistocene (more than 10,000 years ago) reflects the effect of a cooler, more humid climate. The temperature effect is expressed by depletion of fossil ground water with respect to modern water and a shift along the MWL towards more negative values. Pleistocene age ground water from the San Juan Basin, for example, reveals depletions of 25 ‰ in $^{2}H$ and 3 ‰ in $^{18}O$ (Phillips and others, 1986). Fossil ground water manifesting a paleoclimate shift (Figure 7) is not a part of an actively recharged flow system, and hence represents a very finite resource. Mixing of modern and fossil ground water produces an intermediate isotopic composition. Generally speaking, the stable isotope content of shallow ground water is not chemically altered once the water molecule is isolated from the atmosphere, and always reflects the isotopic content of the recharge water.

A preliminary plot of stable isotopes for 19 gorge samples is shown in Figure 7. In addition to our spring samples, the plot shows the results of surface water and well sampling reported by Drakos and others (2004) and a local MWL calculated for the Santa Fe area by Anderholm (1994), which in this case is similar to the global line. Results are listed in Table 2, with complete laboratory data given in the appendix.

## Age of Ground water

Ground water age or mean residence time refers to the amount of time that water derived from precipitation "resides" in an underground aquifer, and may be thought of as the age of the ground water. Ground water age is related to the amount of time taken for water to flow through an aquifer from the recharge area to points of discharge, such as springs or wells and thus is also related to ground water flow velocity. Where recharge mechanisms are complex and include multiple pathways, the "age" reflects integration of all the possible pathways, and thus indicates a "mean" residence time. The age determined is only an approximation of the mean residence time in a localized portion of the aquifer.A variety of naturally occurring and anthropogenic geochemical tracers are used to evaluate the residence time of ground water within an aquifer.

Determining the residence time and/or ground water age of spring waters is not a simple process. Our results so far are only the first step in evaluating the hydrogeologic system of northern Taos County.

***Tritium.*** Tritium is a short-lived isotope of hydrogen with a half-life of 12.32 years. Tritium (or $^3H$) is produced naturally in the stratosphere by cosmic radiation, and during the 1960s and early 1970s large concentrations were also associated with above-ground nuclear testing. Tritium enters the hydrologic cycle via rainfall, with the tritium atoms directly incorporated into the water molecule as $^3H_2O$. Radioactive decay of the tritium component of ground water allows us to estimate the age of ground water less than about fifty years old. Tritium concentrations are measured in Tritium Units (TU), where one TU indicates a tritium-to-hydrogen abundance ratio of $10^{-18}$. Present day tritium concentrations in rainfall in New Mexico are about 6.0 TU.

Qualitative assessments of the residence time of ground water are commonly made based on tritium concentrations in water samples. Water with a concentration of 5–15 TU is considered to be modern ground water, less than 5–10 years old. Tritium concentrations of 0.8–4 TU probably represent a mixture of submodern and recent recharge. Water samples with 3H concentrations less than 0.8 TU are assumed to be submodern, recharged prior to 1952. Exceptions can occur if ground water was recharged during the time of nuclear testing in the 1960s and early 1970s. Water samples from this time period would be expected to have much higher tritium levels than today's precipitation concentration. Generally, waters with lower tritium concentrations are older, whereas samples with higher tritium concentrations are younger.

We sampled 11 springs for tritium analysis. Results are listed in Table 2, with complete laboratory data given in the appendix.

***Chlorofluorocarbons (CFCs).*** Chlorofluorcarbons, or CFCs, are synthetic chemical compounds that were used in refrigeration systems and as aerosol propellants from the 1930s through the last decade of the 20th century. There are three varieties of chlorofluorocarbons, designated as CFC-11, CFC-12, and CFC-113. CFC-11 is the quickest to degrade, especially in the presence of organic material, so most ground water dates are based on abundance ratios of CFC-12 and CFC-113.

CFC compounds increased in the atmosphere in a quasi-exponential fashion from the 1950s through late 1980s, at which time their abundance began to decline because of international agreements to limit their production (CFC compounds were a principal cause of degradation of earth's ozone layer in the late 20th century). As with tritium, CFCs enter the hydrologic cycle via precipitation.

The advantages of CFCs as a tool for dating ground water relate to the fact that their atmospheric concentrations are very well-known, thus providing virtually year-to-year dating sensitivity (Fig. 8). Because CFC concentrations have leveled off and begun to decrease since the late 20th century, there is some degree of ambiguity in estimates of ground water age for water recharged since the early 1990s.

CFC results are presented in an approximate age (in years) of the water sample. The results are dependent upon an estimated recharge elevation and recharge temperature. The recharge temperature, in most cases, can be quite difficult to determine, creating uncertainty in the interpreted age. The age data are based on a temperature assumption that recharge was primarily related to snowmelt, which may overestimate CFC-derived ground water ages.

We sampled two springs for CFC analysis. Results are listed in Table 2, with complete laboratory data given in the appendix.

***Carbon-14.*** Carbon-14, or $^{14}C$, is a naturally occurring radioactive isotope of carbon, formed in the atmosphere by cosmic radiation. Carbon-14, like tritium, was increased in atmospheric concentration during the 1960s and early 1970s by above-ground nuclear testing. Carbon-14 has a half-life of 5,730 years and is widely used for radiometric dating of any material containing carbon compounds. Carbon-14 enters the hydrologic cycle during the recharge process, via precipitation and dissolved soil gases, and can be used to estimate the age of ground water. Radiocarbon measurements are usually reported as "percent modern carbon (pmc)". Significant ambiguity results when using $^{14}C$ to date ground water in limestone aquifers, because geochemical reactions of the groundwater with the calcium carbonate ($CaCO_3$) rock it flows through may contribute non-atmospheric "mineral carbon" to the ground water. The presence of mineral carbon in ground water samples will result in estimates of ground water age that are apparently much older than the water itself. Geochemical modeling is required to correct for the presence of mineral carbon in water samples collected from limestone aquifers. Assessment of the $^{14}C$ results from springs sampled so far may require geochemical corrections or modeling for the results to be useful.

We sampled 11 springs for $^{14}C$ analysis. Results are listed in Table 2, with complete laboratory data given in the appendix.

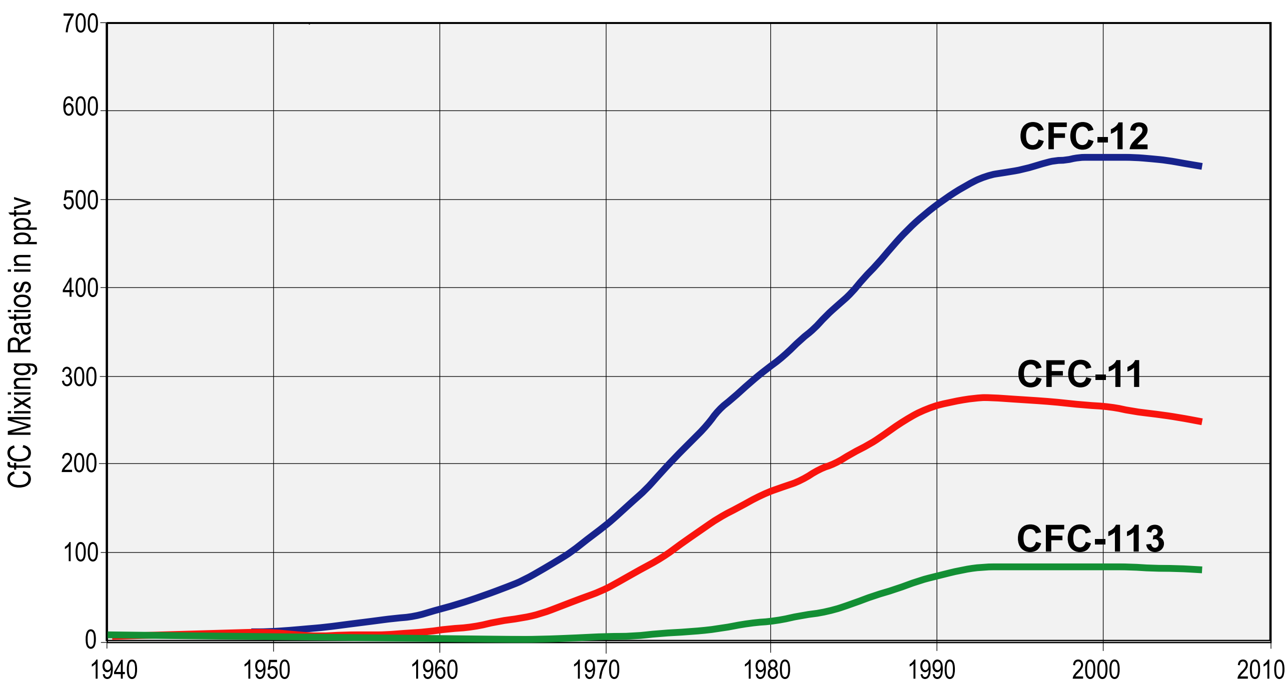


**Figure 8**–Atmospheric concentration of chlorofluorocarbons (CFCs).

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# TABLES

**Table 1-Summary data for all inventoried springs of the Rio Grande Gorge, Taos County, New Mexico (revised Jan 2017)**

| Name of Spring or Spring Zone | Spring ID | East or West or In the River | Description | 7.5-min Quad | UTM E NAD83 | UTM N NAD83 | Elev from DEM (ft) | Date visited | Measured discharge (gpm) | Estimated discharge of spring (gpm) | Estimated discharge of zone (gpm) | Measured discharge (cfs) | Estimated discharge (cfs) | Comments | Field pH | Field Specific Conductance (microS/cm) | Field Temp (C) | Field Temp (F) | Field Dissolved Oxygen (mg/L) | Chemistry Sample |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cow Patty E** | TS-74 | east | Spring 2 upstream of Cow Patty | Ute Mtn | 437367 | 4082068 | 7337 | 9/25/08 | | 0.5 | | | 0.001 | Small spring discharging from base of lowest exposed dacite flow, east side of RG w/ discharge ~ 0.5 gpm | 7.6 | 217 | 11.4 | 52.4 | 8.9 | |
| **Cow Patty E** | TS-75 | east | Spring pool upstream of Cow Patty | Ute Mtn | 437356 | 4081880 | 7337 | 9/25/08 | | 1.0 | | | 0.002 | Seep from base of intermediate grass-covered terrace, forms elevated pool on east side of RG ~ 2 ft above low river stage w/ discharge < 1 gpm to river | 7.8 | 248 | 8.2 | 46.8 | 4.4 | |
| **Cow Patty E** | TS-70 | east | Spring 2 upstream of Cow Patty | Ute Mtn | 437367 | 4082068 | 7337 | 9/25/08 | 0.5 | | | 0.001 | | Small spring discharging from base of lowest exposed dacite flow, east side of RG w/ discharge ~ 0.5 gpm | 7.6 | 217 | 11.4 | 52.4 | 8.9 | X |
| **Cow Patty W** | TS-14 | west | West bank, just downstream from Cisneros Trail (aka Cow PattyTrail). | Ute Mtn | 437167 | 4081556 | 7343 | 8/30/06 | | | | | | Dry, precipitate-encrusted, fractured basalt block that has previously had spring flow. | | | | | | |
| **Cow Patty W** | TS-14a | west | West bank, just downstream from Cisneros Trail (aka Cow PattyTrail). | Ute Mtn | 437135 | 4081577 | 7388 | 8/30/06 | 4.0 | | | 0.01 | | Small, cool spring from under fractured basalt block just above river. Good bucket and watch measurement, with quart bucket, at .5 qt per 2 sec. | 7.8 | 133 | 12.9 | 55.2 | 7.3 | X |
| **Cow Patty W** | TS-14a | west | West bank, just downstream from Cisneros Trail (aka Cow PattyTrail). | Ute Mtn | 437135 | 4081577 | 7388 | 9/25/08 | | | | | | Revisit to collect C14 sample. West-side spring, discharge >/= 4 gpm by bucket and watch. | 7.9 | 170 | 12.4 | 54.3 | 10.1 | X |
| **Cow Patty W** | TS-76 | west | Spring 2 at Cow Patty west | Ute Mtn | 437056 | 4081565 | 7337 | 9/25/08 | | 2.0 | | | 0.004 | West-side spring, discharge ~ 2 gpm at top of middle terrace and base of basalt rockfall, ~ 15 ft above river level, discrete discharge point w/ additional seeps up/down stream. | 7.9 | 177 | 12.6 | 54.7 | 9.2 | |
| **Cow Patty W** | TS-77 | west | Spring 3 at Cow Patty west | Ute Mtn | 437080 | 4081230 | 7318 | 9/25/08 | | 0.5 | | | 0.001 | Third west-side spring, discharge supports broad saturated river terrace and small (~ 0.5 gpm) channel flow. | | | | | | |
| **Ute Mtn W** | TS-78 | west | Small seep on west side | Ute Mtn | 437060 | 4081027 | 7298 | 9/25/08 | | 0.5 | | | 0.001 | Small seep on west side. | | | | | | |
| **Ute Mtn E** | TS-79 | east | Spring Set 1 below Cow Patty E side | Ute Mtn | 437068 | 4080973 | 7308 | 9/25/08 | | 13.0 | | | 0.03 | Three discrete east-side spring discharges from river terrace, ~35 m apart, at base of large dacite unit; Qtotal ~13 gpm. | 8.1 | 198 | 13.5 | 56.3 | 9.8 | |
| **Ute Mtn E** | TS-80 | east | Spring Set 2 below Cow Patty E side | Ute Mtn | 437051 | 4080812 | 7308 | 9/25/08 | | 8.0 | | | 0.02 | Three discrete east-side spring discharges from river terrace, ~30 m apart, at base of large dacite unit; Qtotal ~8 gpm. | | | | | | |
| **Sunshine** | TS-81 | east, west, river | Head of spring accretion zone. | Ute Mtn | 436996 | 4080595 | 7305 | 9/25/08 | | | 1000 | | 2.23 | Upstream head of spring accretion zone, large discharges from both sides of river and center of channel, many 100s of gpm; discharge pools at base of dacite unit, no good sample point. | | | | | | |
| **Sunshine** | TS-71 | west | TS-71, Sunshine west | Sunshine | 436962 | 4080507 | 7282 | 9/25/08 | | | 225 | | 0.50 | Very large spring zone discharging from river gravels beneath basalt boulders, zone is about 25 ft (8 m) long, Qest ~ 0.5 cfs (~225 gpm). | 8.2 | 202 | 14.9 | 58.7 | 9.3 | X |
| **Sunshine** | TS-82 | east | Sunshine east | Sunshine | 436975 | 4080433 | 7282 | 9/25/08 | | 1.0 | | | 0.002 | Continuous string of seeps/springs along east side, base of low terrace. | 8.1 | 210 | 14.6 | 58.2 | 9.6 | |
| **The Rio Grande** | TS-114 | | Rio Grande just above Lava Tube Spring. | Sunshine | 437000 | 4080300 | 7285 | 9/2/09 | | | | | | River discharge was 52.6 cfs, as measured with flow meter by M. Martinez and K. Kinzli. | 8.6 | 329 | 15.9 | 60.6 | 7.3 | |
| **Lava Tube** | TS-83 | in river | Large artesian spring in river. | Sunshine | 437003 | 4080326 | 7285 | 9/2/09 | 6005 | | | 13.38 | | Large, artesian spring discharge in channel bottom. May display a sand boil. This spring is the last discharge in the large Sunshine accretion zone (from base of lower dacite flow or dacite/Servilleta contact). Spring discharge from flow-meter discharge measurements of the river above and below the spring, by K. Kinzli and M. Martinez. | 8.0 | 214 | 15.2 | 59.3 | 7.3 | X |
| **Sunshine Trail** | TS-73 | east | TS-73, Sunshine Trail Spring 1 | Sunshine | 437865 | 4077691 | 7298 | 9/25/08 | 2.7 | | | 0.01 | | Small spring discharging from fractures in Servilleta Basalt. Q = 2.7 gpm (B&SW). 14C sample to supplement existing sample suite. This spring marks the top of the Sunshine Trail spring zone. | 7.7 | 204 | 13.7 | 56.6 | 7.8 | X |
| **Sunshine Trail** | TS-84 | east | Sunshine Trail Spring 2 | Sunshine | 438144 | 4077135 | 7285 | 9/25/08 | | 1.0 | | | 0.002 | Sunshine Trail reach, many small springs/seeps and dry outlets in lower terrace. Two small springs downstream of Sunshine trail w/ Qtot ~ 1 gpm. | | | | | | |
| **Sunshine Trail** | TS-85 | east | Sunshine Trail Spring 3 | Sunshine | 438197 | 4076893 | 7275 | 9/25/08 | | 2.0 | | | 0.004 | Sunshine trail reach, third set of small springs/seeps in lower terrace, east side, ~ 200 m in length, 8 total, each with Q ~ 1-2 gpm | | | | | | |
| **Sunshine Trail W** | TS-72 | west | TS-72, Sunshine Trail W Spring | Sunshine | 438133 | 4076798 | 7282 | 9/25/08 | | 0.5 | | | 0.001 | Small spring discharge from base of Servilleta basalt and top of river terrace, on west side; Qest ~ 0.5 gpm from discrete point ~40 ft above river level. | 7.9 | 183 | 12.5 | 54.5 | 9.3 | X |
| **Sunshine Trail** | TS-20a | east | East bank, just upstream from Sunshine Trail. | Sunshine | 438044 | 4077518 | 7293 | 8/30/06 | | 5.0 | | | 0.01 | Seep area along base of basalt, very slow flow. Too slow to measure, so dug hole which filled over 3 hours. Field parameters from dug pool in sun. T of 20.1C was too high, so not used. Water from under basalt layer. | 8.0 | 207 | | | 4.8 | |
| **Sunshine Trail** | TS-20b | east | East bank, just upstream from Sunshine Trail. | Sunshine | 438037 | 4077521 | 7293 | 8/30/06 | | | | | | Water from under basalt layer. | | | | | | |
| **Sunshine Trail** | TS-21a | east | East bank, just upstream from Sunshine Trail. | Sunshine | 438005 | 4077558 | 7290 | 8/30/06 | | 3 | | | 0.01 | Marshy area at slope break. Not enough water for field parameters. Water from under basalt layer. | | | | | | |

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| Name of Spring or Spring Zone | Spring ID | East or West or In the River | Description | 7.5-min Quad | UTM E NAD83 | UTM N NAD83 | Elev from DEM (ft) | Date visited | Measured discharge (gpm) | Estimated discharge of spring (gpm) | Estimated discharge of zone (gpm) | Measured discharge (cfs) | Estimated discharge (cfs) | Comments | Field pH | Field Specific Conductance (microS/cm) | Field Temp (C) | Field Temp (F) | Field Dissolved Oxygen (mg/L) | Chemistry Sample |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sunshine Trail** | TS-22a | east | East bank, just upstream from Sunshine Trail. | Sunshine | 437977 | 4077592 | 7310 | 8/30/06 | | 1.0 | | | 0.002 | Small seep from crack. Dug hole to collect water. Measured 2 hours later, water in sun, T was 21.2C, which is unreasonably high, so not used. Water from under basalt layer. | 7.9 | 191 | | | 3.2 | |
| **Sunshine Trail** | TS-22b | east | East bank, just upstream from Sunshine Trail. | Sunshine | 437963 | 4077604 | 7333 | 8/30/06 | | | | | | Water from under basalt layer. | | | | | | |
| **Sunshine Trail** | TS-23 | east | East bank, just upstream from Sunshine Trail. | Sunshine | 437949 | 4077604 | 7310 | 8/30/06 | | 2.0 | | | 0.004 | Small flow of water from sand. Dug hole to take field parameters. Water from under basalt layer. | 7.8 | 212 | 13.5 | 56.3 | 4.5 | |
| **Sunshine Trail** | TS-24 | east | East bank, just upstream from Sunshine Trail. | Sunshine | 437929 | 4077610 | 7287 | 8/30/06 | | 4.0 | | | 0.01 | Small overgrown spring. Water from under basalt layer. | | | | | | |
| **Sunshine Trail** | TS-25 | east | East bank, just upstream from Sunshine Trail. | Sunshine | 437933 | 4077640 | 7346 | 8/30/06 | 0.5 | | | 0.001 | | Seep visible at basalt-sand contact. Flowing in channel. Sampled from small pool <2" from outlet. Water from under basalt layer. | 8.4 | 210 | 12.5 | 54.5 | 5.6 | X |
| **Sunshine Trail** | TS-26 | east | East bank, just upstream from Sunshine Trail. | Sunshine | 437884 | 4077663 | 7287 | 8/30/06 | | 2.0 | | | 0.004 | Zone of seeps at base of basalt. Flow too low to take field parameters. Water from under basalt layer. | | | | | | |
| **Sunshine Trail** | TS-27 | east | East bank, just upstream from Sunshine Trail. | Sunshine | 437859 | 4077679 | 7297 | 8/30/06 | | 3.0 | | | 0.01 | Flow from basalt into 3-ft-wide channel. Water from under basalt layer. | 8.6 | 208 | 12.7 | 54.9 | 6.0 | |
| **Lone Tree Spring** | TS-30 | east | At base of Lone Tree trail. | Sunchine | 438820 | 4072483 | 7241 | 11/1/06 | | | | | | Spring is dry seepage face, about 30m long, covered with grass and phragmites. | | | | | | |
| **Desagua Trail** | TS-29a | east | Zone of springs and seeps below Desawaui Trail. North end of zone. | Sunshine | 440153 | 4068794 | 7146 | 11/1/06 | | 1 | | | 0.002 | | | | | | | |
| **Desagua Trail** | TS-29b | east | Largest spring in zone. | Sunshine | 440126 | 4068642 | 7136 | 11/1/06 | | | 20 | | 0.04 | Estimated flow of total zone is about 20 gpm. | 8.2 | 260 | 11.7 | 53.1 | 5.3 | X |
| **Desagua Trail** | TS-29c | east | South end of zone. | Sunshine | 440099 | 4068497 | 7136 | 11/1/06 | | 0.25 | | | 0.001 | Small trickle. | | | | | | |
| **S of Sheep** | TS-1 | east | East bank, downstream from Sheep Crossing. | Guad Mtn | 439353 | 4066997 | 7159 | 8/28/06 | | 1.0 | 3.0 | | 0.01 | Collective discharge of zone of springs from TS-1 to TS-1a is several GPM. | 6.8 | 263 | 13.4 | 56.1 | 2.6 | |
| **The Rio Grande** | TS-1b | river | Rio Grande river water parameters at TS-1. | Guad Mtn | 439350 | 4066997 | 7159 | 8/28/06 | | | | | | Rio Grande river parameters. | 8.3 | 184 | 19.0 | 66.2 | 7.4 | |
| **S of Sheep** | TS-1a | east | East bank, downstream from Sheep Crossing. | Guad Mtn | 439330 | 4066915 | 7142 | 8/28/06 | | 0.5 | | | 0.001 | Collective discharge of zone of springs from TS-1 to TS-1a is several GPM. | 7.8 | 245 | 15.2 | 59.4 | 6.1 | X |
| **Chiflo** | TS-2 | east | East bank, at Chiflo Trail. | Guad Mtn | 439140 | 4066604 | 7093 | 8/28/06 | | 5 | | | 0.01 | Large wetland. Parameters from northernmost channel. Probably very low estimate of total discharge in this zone. | 7.7 | 244 | 15.5 | 59.9 | 5.6 | |
| | | | | | | | | | **6013** | **58** | **1248** | **13.40** | **2.91** | | | | | | | |
| | | | **State Line to Cerro Gage: Cumulative Total Spring Discharge** | | | | | | **7318** | **gpm** | | **16.31** | **cfs** | | | | | | | |
| **Gaging Station N** | TS-3 | east | East bank, downstream from Chiflo Trail. | Guad Mtn | 438930 | 4066136 | 7106 | 8/28/06 | | | | | | Small discharge | 7.7 | 250 | 15.2 | 59.4 | 3.8 | |
| **Gaging Station S** | TS-4 | east | East bank, downstream from Chiflo Trail. Just downstream from TS-3. | Guad Mtn | 438906 | 4066080 | 7090 | 8/28/06 | | 1 | | | 0.001 | | 8.0 | 203 | 15.9 | 60.6 | 5.5 | X |
| **Bear Crossing spring zone** | TS-10 | west | Zone of large springs on west side that discharge into river beneath boulder fields. From Upper Powerline downstream. | Guad Mtn | 438033 | 4063504 | 7110 | 8/29/06 | | 50 | | | 0.11 | | | | | | | |
| **Bear Crossing spring zone** | TS-9 | west | Zone of large springs on west side that discharge into river beneath boulder fields. From Upper Powerline downstream. | Guad Mtn | 438022 | 4063486 | 7129 | 8/29/06 | | 100 | | | 0.22 | | 8.3 | 222 | 16.7 | 62.1 | 7.7 | |
| **Bear Crossing spring zone** | TS-8 | west | Zone of large springs on west side that discharge into river beneath boulder fields. From Upper Powerline downstream. | Guad Mtn | 438022 | 4063426 | 7136 | 8/29/06 | | 1200 | | | 2.68 | | 8.3 | 222 | 16.5 | 61.7 | 7.8 | X |
| **Bear Crossing spring zone** | TS-7 | west | Zone of large springs on west side that discharge into river beneath boulder fields. From Upper Powerline downstream. | Guad Mtn | 438044 | 4063330 | 7110 | 8/29/06 | | 150 | | | 0.33 | | 8.3 | 223 | 16.7 | 62.1 | 7.6 | |
| **Bear Crossing spring zone** | TS-6 | west | Zone of large springs on west side that discharge into river beneath boulder fields. From Upper Powerline downstream. | Guad Mtn | 438042 | 4063309 | 7096 | 8/29/06 | | 55 | | | 0.12 | | 8.3 | 220 | 16.5 | 61.7 | 7.6 | |
| **Bear Crossing spring zone** | TS-5 | west | Zone of large springs on west side that discharge into river beneath boulder fields. From Upper Powerline downstream. | Guad Mtn | 437992 | 4063217 | 7116 | 8/29/06 | | 30 | | | 0.07 | | 8.3 | 223 | 16.1 | 61.0 | 5.1 | |

| Name of Spring or Spring Zone | Spring ID | East or West or In the River | Description | 7.5-min Quad | UTM E NAD83 | UTM N NAD83 | Elev from DEM (ft) | Date visited | Measured discharge (gpm) | Estimated discharge of spring (gpm) | Estimated discharge of zone (gpm) | Measured discharge (cfs) | Estimated discharge (cfs) | Comments | Field pH | Field Specific Conductance (microS/cm) | Field Temp (C) | Field Temp (F) | Field Dissolved Oxygen (mg/L) | Chemistry Sample |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bear Crossing spring zone** | TS-11 | west | Zone of large springs on west side that discharge into river beneath boulder fields. From Upper Powerline downstream. | Guad Mtn | 437933 | 4063122 | 7100 | 8/29/06 | | 200 | | | 0.45 | | | | | | | |
| **Bear Crossing spring zone** | TS-12 | west | Zone of large springs on west side that discharge into river beneath boulder fields. From Upper Powerline downstream. | Guad Mtn | 437853 | 4062971 | 7087 | 8/29/06 | | 100 | | | 0.22 | | | | | | | |
| **Bear Crossing spring zone** | TS-13 | west | Zone of large springs on west side that discharge into river beneath boulder fields. From Upper Powerline downstream. | Guad Mtn | 437820 | 4062922 | 7087 | 8/29/06 | | 5 | | | 0.01 | | | | | | | |
| **Lower Bear Crossing spring zone** | TS-113 | west | The lower half of Bear Crossing spring zone not yet surveyed. Center point estimated using Google Earth. | Guad Mtn | 437667 | 4062681 | 7008 | | | | 4000 | | 8.92 | Zone of high-discharge springs along west side of river. Unable to survey these springs, but cumulative discharge is probably at least 4000 gpm. | | | | | | |
| **Felsenmeere North** | TS-60 | west | Zone of large springs on west side. | Guad Mtn | 437392 | 4062272 | 6978 | 5/9/07 | | | 4000 | | 8.92 | Continuous zone of springs that discharge into river beneath boulder fields. Several of the springs are very large. Cumulative estimate is 3000 to 5000 gpm. | | | | | | |
| **Felsenmeere Middle** | TS-61 | west | Large cascading spring on west canyon wall. | Guad Mtn | 437309 | 4062267 | 7057 | 5/9/07 | | 2500 | | | 5.58 | Very large spring with vegetation signature that emerges in a single 6-ft wide zone from under basalt boulders. | | | 16.8 | 62.2 | 6.6 | X |
| **Felsenmeere South** | TS-59 | west | Also known as Hemingway Spring. Located on west canyon wall, about 100 ft above the river. | Guad Mtn | 437250 | 4062227 | 7087 | 5/9/07 | | 3200 | | | 7.14 | Very large spring that emerges in a single 4-ft wide orifice below basalt boulder. Good vegetation signature. | | | 16.5 | 61.7 | 7.0 | |
| **Felsenmeere South** | TS-59 | west | Also known as Hemingway Spring. Located on west canyon wall, about 100 ft above the river. | Guad Mtn | 437250 | 4062227 | 7087 | 5/5/04 | | | | | | Very large spring that emerges in a single 4-ft wide orifice below basalt boulder. Sampled by the NMED in May 2004. | 7.7 | 196 | 16.3 | 61.3 | | X |
| **Felsenmeere South** | TS-59 | west | Also known as Hemingway Spring. Located on west canyon wall, about 100 ft above the river. | Guad Mtn | 437250 | 4062227 | 7087 | 9/27/04 | | | | | | Very large spring that emerges in a single 4-ft wide orifice below basalt boulder. Resampled by the NMED in September 2004. | 8.0 | 197 | 16.4 | 61.5 | | X |
| **Big Arsenic source** | TS-136 | east | Located at base of cliff in cottonwood grove that is NE of the river. Approximate center of spring zone was located using Google Earth. | Guad Mtn | 438420 | 4060083 | 7039 | 3/25/04 | | | | | | Spring sampled by NMED (Sample RG-1) in March 2004, and sampled by K. Robinson (Sample QU-532) in August 2014. Approximate location of the source of Big Arsenic Spring water. The springs and streams located between here and the river are probably sourced here. | 7.7 | 256 | 17.2 | 63.0 | | X |
| **North Big Arsenic** | TS-16 | east | North Big Arsenic Spring is actually a zone of large springs, some of which are shown as TS-16a, TS-16b, and TS-16c. Approximate center of spring zone was located using Google Earth. | Guad Mtn | 438412 | 4059882 | 6836 | 8/31/06 | | | 240 | | 0.54 | Collectively, Big Arsenic has about 5000 gpm discharge. TS-16a, b, c discharge estimates are for the large springs at those spots. Additional flows between those points are estimated at 240 gpm. | | | | | | |
| **North Big Arsenic 1** | TS-16a | east | Northernmost large spring zone in North Big Arsenic zone. | Guad Mtn | 438367 | 4059878 | 6837 | 8/31/06 | | 160 | | | 0.36 | Northernmost spring is relatively small (30 gpm) discharging from rock fall/ridge in bamboo by large east-leaning pine tree. Next spring is large (>100 gpm) with hidden discharge beneath basalt boulder with heavy vegetation on west side of trail south of ridge. The next spring is very large series of springs discharging beneath rocks of the trail. | | | | | | |
| **North Big Arsenic 2** | TS-16b | east | Largest spring zone in North Big Arsenic zone. | Guad Mtn | 438429 | 4059853 | 6818 | 8/31/06 | | 3000 | | | 6.69 | Large spring zone is 50 ft across with main flow zone confined to channel 30 ft wide by 1 ft deep. | 8.2 | 249 | 17.5 | 63.5 | | X |
| **North Big Arsenic 3** | TS-16c | east | Southernmost large spring in North Big Arsenic zone. | Guad Mtn | 438442 | 4059852 | 6824 | 8/31/06 | 160 | | | 0.36 | | Channel with flow concentrated into one stream.Discharge point is high on slope, about 25 ft above trail and TS-16b. Measured with bucket and timer. | 8.2 | 249 | 17.5 | 63.5 | 8.6 | |
| **South Big Arsenic** | TS-15 | east | Large, southern spring that cascades into the river upstream from shelter. | Guad Mtn | 438688 | 4059439 | 6778 | 8/31/06 | 1500 | | | 3.35 | | Estimate based on adding up flow of 7 major channels of the spring with buckets and timer. | 8.3 | 247 | 17.4 | 63.3 | 7.8 | |
| **South Big Arsenic** | TS-15 | east | Large, southern spring that cascades into the river upstream from shelter. | Guad Mtn | 438688 | 4059439 | 6778 | 1/1/04 | | | | | | Sampled by NMED in 2004. No discharge reported by NMED. | | | | | | X |
| **Little Arsenic** | TS-17 | east | Small spring near path. | Guad Mtn | 438678 | 4058447 | 6732 | 8/31/06 | 35 | | | 0.08 | | Small stream discharges from base of basalt boulder field at head of bamboo patch. Measured with gal bucket and timer. | 8.2 | 224 | 15.4 | 59.7 | 7.0 | X |
| | | | | | | | | | **1695** | **10,751** | **8240** | **3.78** | **42.35** | | | | | | | |
| | | | **Cerro Gage to Red River Confluence: Cumulative Total Spring Discharge** | | | | | | **20,686 gpm** | | | **46.13 cfs** | | | | | | | | |

| Name of Spring or Spring Zone | Spring ID | East or West or In the River | Description | 7.5-min Quad | UTM E NAD83 | UTM N NAD83 | Elev from DEM (ft) | Date visited | Measured discharge (gpm) | Estimated discharge of spring (gpm) | Estimated discharge of zone (gpm) | Measured discharge (cfs) | Estimated discharge (cfs) | Comments | Field pH | Field Specific Conductance (microS/cm) | Field Temp (C) | Field Temp (F) | Field Dissolved Oxygen (mg/L) | Chemistry Sample |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **The Rio Grande** | TS-88c | river | Rio Grande above confluence with Red River. | Guad Mtn | 437960 | 4056034 | 6567 | 9/1/09 | | | | | | | 8.5 | 280 | 17.3 | 63.1 | 8.0 | |
| **The Rio Grande** | TS-88a | river | Rio Grande below confluence with Red River. | Guad Mtn | 437974 | 4055939 | 6567 | 9/1/09 | | | | | | | 8.4 | 304 | 16.1 | 61.0 | 7.7 | |
| **The Red River** | TS-88b | river | Red River above confluence with Rio Grande. | Guad Mtn | 437997 | 4056042 | 6586 | 9/1/09 | | | | | | | 8.3 | 344 | 14.8 | 58.6 | 7.9 | |
| **La Junta East** | TS-91 | east | Just below launch site at base of Cebolla Trail. Emerges from under rocks and sand, 20 cm above river. | Guad Mtn | 437950 | 4055645 | 6570 | 9/1/09 | | 1 | | | 0.002 | Series of small springs/seeps. Some Fe staining. Dug out small pool. | 6.6 | 311 | 15.5 | 59.9 | 1.2 | |
| **La Junta West** | TS-90 | west | Just below launch site near base of Cebolla Trail. Emerges from under basalt boulders just above river level. | Guad Mtn | 437940 | 4055627 | 6576 | 9/1/09 | | 1 | | | 0.002 | Small spring/seep. Dug out small pool in sand/gravel for trickles to converge. | 6.9 | 196 | 17.5 | 63.5 | 5.4 | |
| **La Junta East** | TS-92 | east | One of many springs/seeps in a long, nearly continuous zone of small discharges that emerge from under basalt talus just above river. | Guad Mtn | 437958 | 4055587 | 6570 | 9/1/09 | | | 25 | | 0.06 | Rough estimate of cumulative discharge of more than mile-long spring zone that discharges from under basalt talus just above river. | 7.0 | 316 | 14.2 | 57.6 | 6.6 | |
| **La Junta East** | TS-92a | east | Another small spring in zone. | Guad Mtn | 437858 | 4054072 | 6576 | 9/1/09 | | 1 | | | 0.002 | | | | | | | |
| **La Junta West** | TS-93 | west | Cluster of springs is defined by stands of vegetation (Phragmites, salt cedar, etc.) about 1 meter above river. | Guad Mtn | 437782 | 4053511 | 6583 | 9/1/09 | | | | | | Due to thick vegetation, unable to get info on discharge. Good vegetation signature of Phragmites. | | | | | | |
| **San Cristobal Creek** | TS-94 | river | San Cristobal Creek just above confluence. | Arroyo Hondo | 437779 | 4048969 | 6534 | 9/1/09 | | | | | | Creek running at 1-2 cfs. | 8.3 | 328 | 18.8 | 65.8 | 7.6 | |
| **La Junta West** | TS-95 | west | Good spring emerges from under basalt boulders 30 cm above river. | Arroyo Hondo | 437302 | 4047513 | 6521 | 9/1/09 | | 2 | | | 0.004 | Samples collected from small pourover. Vegetative signature of horsetails and sedges. | 7.7 | 287 | 16.9 | 62.3 | 7.3 | X |
| **La Junta East** | TS-96 | east | Emerges from boulders and gravel just above river. | Arroyo Hondo | 437125 | 4045318 | 6511 | 9/1/09 | | 1 | | | 0.002 | Small spring. | | | | | | |
| **La Junta East** | TS-97 | east | Emerges from boulders and gravel just above river. | Arroyo Hondo | 436860 | 4044774 | 6498 | 9/1/09 | | 1 | | | 0.002 | Small spring. | | | | | | |
| **Dunn Bridge North** | TS-98 | east | Emerges from boulders about 40 ft above river. This is start of "Dunn Bridge North" spring zone, which is nearly continuous to bridge. | Arroyo Hondo | 436958 | 4044580 | 6557 | 9/1/09 | | 5 | | | 0.01 | This is start of long spring zone that continues down to Rio Hondo confluence on east side. | 7.3 | 218 | 17.4 | | 7.0 | |
| **Dunn Bridge North** | TS-99 | east | Zone of small to medium springs that emerge from 30-50 ft above river from under talus slope. | Arroyo Hondo | 436980 | 4044404 | 6544 | 9/1/09 | | 10 | | | 0.02 | One spring in a zone of small to medium springs that emerge from 30-50 ft above the river from under the talus slope. | | | | | | |
| **Dunn Bridge North** | TS-100 | east | Zone of small to medium springs that emerge from 30-50 ft above river from under talus slope. | Arroyo Hondo | 437002 | 4044339 | 6514 | 9/2/09 | | 10 | | | 0.02 | One spring in a zone of small to medium springs that emerge from 30-50 ft above the river from under the talus slope. | | | | | | |
| **Dunn Bridge North** | TS-101 | east | Zone of small to medium springs that emerge from 30-50 ft above river from under talus slope. | Arroyo Hondo | 436995 | 4044304 | 6517 | 9/3/09 | | 10 | | | 0.02 | One spring in a zone of small to medium springs that emerge from 30-50 ft above the river from under the talus slope. | | | | | | |
| **Dunn Bridge North** | TS-102 | east | Zone of small to medium springs that emerge from 30-50 ft above river from under talus slope. | Arroyo Hondo | 436984 | 4044265 | 6488 | 9/4/09 | | 10 | | | 0.02 | One spring in a zone of small to medium springs that emerge from 30-50 ft above the river from under the talus slope. | | | | | | |
| **Dunn Bridge North** | TS-103 | east | Zone of small to medium springs that emerge from 30-50 ft above river from under talus slope. | Arroyo Hondo | 436980 | 4044255 | 6485 | 9/5/09 | | 10 | | | 0.02 | One spring in a zone of small to medium springs that emerge from 30-50 ft above the river from under the talus slope. | | | | | | |
| **Dunn Bridge North** | TS-104 | east | Zone of small to medium springs that emerge from 30-50 ft above river from under talus slope. | Arroyo Hondo | 436972 | 4044239 | 6485 | 9/6/09 | | 10 | | | 0.02 | One spring in a zone of small to medium springs that emerge from 30-50 ft above the river from under the talus slope. | | | | | | |
| **Dunn Bridge North** | TS-105 | east | Zone of small to medium springs that emerge from 30-50 ft above river from under talus slope. | Arroyo Hondo | 436940 | 4044179 | 6491 | 9/7/09 | | 200 | | | 0.45 | One spring in a zone of small to medium springs that emerge from 30-50 ft above the river from under the talus slope. | | | | | | |
| **Dunn Bridge North** | TS-106 | east | Zone of small to medium springs that emerge from 30-50 ft above river from under talus slope. | Arroyo Hondo | 436934 | 4044169 | 6514 | 9/8/09 | | 200 | | | 0.45 | One spring in a zone of small to medium springs that emerge from 30-50 ft above the river from under the talus slope. | | | | | | |
| **Dunn Bridge North** | TS-107 | east | Zone of small to medium springs that emerge from 30-50 ft above river from under talus slope. | Arroyo Hondo | 436927 | 4044148 | 6488 | 9/9/09 | | 10 | | | 0.02 | One spring in a zone of small to medium springs that emerge from 30-50 ft above the river from under the talus slope. | | | | | | |

| Name of Spring or Spring Zone | Spring ID | East or West or In the River | Description | 7.5-min Quad | UTM E NAD83 | UTM N NAD83 | Elev from DEM (ft) | Date visited | Measured discharge (gpm) | Estimated discharge of spring (gpm) | Estimated discharge of zone (gpm) | Measured discharge (cfs) | Estimated discharge (cfs) | Comments | Field pH | Field Specific Conductance (microS/cm) | Field Temp (C) | Field Temp (F) | Field Dissolved Oxygen (mg/L) | Chemistry Sample |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Dunn Bridge North** | TS-108 | east | Zone of small to medium springs that emerge from 30-50 ft above river from under talus slope. | Arroyo Hondo | 436898 | 4044084 | 6488 | 9/10/09 | | 10 | | | 0.02 | One spring in a zone of small to medium springs that emerge from 30-50 ft above the river from under the talus slope. | | | | | | |
| **Dunn Bridge North** | TS-109 | east | Zone of small to medium springs that emerge from 30-50 ft above river from under talus slope. | Arroyo Hondo | 436840 | 4043987 | 6481 | 9/11/09 | | 10 | | | 0.02 | One spring in a zone of small to medium springs that emerge from 30-50 ft above the river from under the talus slope. | | | | | | |
| **Dunn Bridge North** | TS-110 | east | Zone of small to medium springs that emerge from 30-50 ft above river from under talus slope. | Arroyo Hondo | 436814 | 4043959 | 6452 | 9/12/09 | | 10 | | | 0.02 | One spring in a zone of small to medium springs that emerge from 30-50 ft above the river from under the talus slope. | | | | | | |
| **Dunn Bridge North** | TS-111 | east | Zone of small to medium springs that emerge from 30-50 ft above river from under talus slope. | Arroyo Hondo | 436783 | 4043865 | 6511 | 9/13/09 | | 10 | | | 0.02 | One spring in a zone of small to medium springs that emerge from 30-50 ft above the river from under the talus slope. | | | | | | |
| **Dunn Bridge North** | TS-112 | east | Zone of small to medium springs that emerge from 30-50 ft above river from under talus slope. | Arroyo Hondo | 436731 | 4043786 | 6455 | 9/14/09 | | 10 | | | 0.02 | One spring in a zone of small to medium springs that emerge from 30-50 ft above the river from under the talus slope. | | | | | | |
| **Dunn Bridge North** | TS-31a | east | Zone of springs and seeps north of Dunn Bridge, on East side. Northernmost spring, and largest discharge in zone. This is probably same as NMED Station DBN Spring. | Arroyo Hondo | 436991 | 4044179 | 6516 | 11/2/06 | 144 | | | 0.32 | | Measured largest flow of series of springs emerging from base of rock debris. | 8.3 | 230 | 15.0 | 59.0 | | |
| **Dunn Bridge North** | TS-31a | east | Zone of springs and seeps north of Dunn Bridge, on East side. Northernmost spring, and largest discharge in zone. This is probably same as NMED Station DBN Spring. | Arroyo Hondo | 436991 | 4044179 | 6516 | 1/1/04 | | | | | | Sampled by NMED in 2004. Measured largest flow of series of springs emerging from base of rock debris. No discharge reported by NMED. | | | | | | X |
| **Dunn Bridge North** | TS-31b | east | Zone of springs and seeps north of Dunn Bridge, on East side. Spring just south of TS-31a. | Arroyo Hondo | 436962 | 4044129 | 6583 | 11/2/06 | | 30 | | | 0.07 | | | | | | | |
| **Rael (aka Stark or Warmsley)** | TS-18 | east | Piped spring just upstream from Dunn Bridge on East side. | Arroyo Hondo | 436738 | 4043777 | 6460 | 9/1/06 | 8 | | | 0.02 | | Measured with quart bucket and time. | 8.0 | 247 | 14.5 | 58.1 | 7.4 | X |
| | | | | | | | | | **152** | **562** | **25** | **0.34** | **1.31** | | | | | | | |
| | | | **Red River Confluence to Rio Hondo Confluence: Cumulative Total Spring** | | | | | | **739** | **gpm** | | **1.65** | **cfs** | | | | | | | |
| **Lower Arroyo Hondo zone** | TS-32 | east | Spring along Rio Hondo, just upstream from small bridge, on north side. | Arroyo Hondo | 436794 | 4043419 | 6516 | 11/2/06 | | 3 | | | 0.01 | Good flow from base of basalt along cliff. | | | | | | |
| **Lower Arroyo Hondo zone** | TS-33 | east | Spring along Rio Hondo, just upstream from small bridge, on north side. Probably same site as NMED sample AH-0.2 spring. | Arroyo Hondo | 436809 | 4043400 | 6499 | 11/2/06 | | 10 | | | 0.02 | Thought to be the same as NMED Station AH-0.2 | 8.1 | 284 | 14.2 | 57.6 | 7.0 | |
| **Lower Arroyo Hondo zone** | TS-33 | east | Spring along Rio Hondo, just upstream from small bridge, on north side. Probably same site as NMED sample AH-0.2 spring. | Arroyo Hondo | 436809 | 4043400 | 6499 | 1/1/04 | | | | | | Thought to be the same as NMED Station AH-0.2. Sampled by NMED in 2004. No discharge reported by NMED. | | | | | | X |
| **Lower Arroyo Hondo zone** | TS-34a | east | West end of large seep zone along Rio Hondo. | Arroyo Hondo | 436838 | 4043387 | 6503 | 11/2/06 | | | 40 | | 0.09 | Estimated cumulative discharge for entire zone of TS-34a to TS-34b. | | | | | | |
| **Lower Arroyo Hondo zone** | TS-34b | east | East end of large seep zone along Rio Hondo. | Arroyo Hondo | 436925 | 4043330 | 6516 | 11/2/06 | | | | | | | | | | | | |
| **DBS-1** | TS-135 | west | Sampled by NMED. Located on west side, near river. Spring is only visible at low river levels. | Arroyo Hondo | 436285 | 4043206 | 6465 | 3/15/04 | | | | | | This spring was not visited by staff of NMBGMR. Discharge was not reported by NMED. | 7.8 | 353 | 15.9 | 60.6 | | X |
| **Black Rock Hot** | TS-28 | west | Small hot spring south of Dunn Bridge on west side. | Arroyo Hondo | 436247 | 4043051 | 6496 | 9/1/06 | | 10 | | | 0.02 | | 7.5 | 859 | 38.5 | 101.3 | 4.2 | X |
| **Taos Box N** | TS-35 | east | Small spring across from Black Rock Hot Spring. | Arroyo Hondo | 436274 | 4043027 | 6473 | 11/3/06 | | 1 | | | 0.001 | | | | | | | |
| **Taos Box North 1** | TS-19 | east | Small spring south of Dunn Bridge, on east side. Aka Dunn Bridge South. Probably included in the TS-36 series. | Arroyo Hondo | 436199 | 4042675 | 6447 | 9/1/06 | | 4 | | | 0.01 | | 8.3 | 189 | 17.4 | 63.3 | 7.4 | X |

| Name of Spring or Spring Zone | Spring ID | East or West or In the River | Description | 7.5-min Quad | UTM E NAD83 | UTM N NAD83 | Elev from DEM (ft) | Date visited | Measured discharge (gpm) | Estimated discharge of spring (gpm) | Estimated discharge of zone (gpm) | Measured discharge (cfs) | Estimated discharge (cfs) | Comments | Field pH | Field Specific Conductance (microS/cm) | Field Temp (C) | Field Temp (F) | Field Dissolved Oxygen (mg/L) | Chemistry Sample |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Taos Box N** | TS-36a | east | Northernmost spring from long spring and seep zone downstream from Dunn Bridge on East side. Possibly same spring as TS-19. | Arroyo Hondo | 436180 | 4042671 | 6473 | 11/3/06 | | 2 | | | 0.004 | Small seep on northern end of long spring/seep zone. | | | | | | |
| **Taos Box North 2** | TS-36b | east | Large spring. | Arroyo Hondo | 436194 | 4042669 | 6447 | 11/3/06 | | 15 | | | 0.03 | From base of basalt. | 8.3 | 166 | 17.3 | 63.1 | 6.9 | X |
| **Taos Box N** | TS-36c | east | Seep. | Arroyo Hondo | 436188 | 4042670 | 6463 | 11/3/06 | | 10 | | | 0.02 | Dug hole for water to take field parameters. | 8.2 | 179 | 18.1 | 64.6 | 7.4 | |
| **Taos Box N** | TS-36d | east | Good spring. | Arroyo Hondo | 436185 | 4042659 | 6497 | 11/3/06 | | 20 | | | 0.04 | | 8.2 | 185 | 17.5 | 63.5 | 6.5 | |
| **Taos Box N** | TS-36e | east | Small spring on east side. | Arroyo Hondo | 436181 | 4042643 | 6447 | 11/3/06 | | 7 | | | 0.02 | Bubbles out from below boulder field. | | | | | | |
| **Taos Box N** | TS-36f | east | Small spring on east side. | Arroyo Hondo | 436179 | 4042634 | 6488 | 11/3/06 | | 2 | | | 0.004 | | | | | | | |
| **Taos Box N** | TS-36g | east | Small spring on east side. | Arroyo Hondo | 436177 | 4042623 | 6491 | 11/3/06 | | 7 | | | 0.02 | | | | 18.0 | 64.4 | | |
| **Taos Box N** | TS-36h | east | Small spring on east side. | Arroyo Hondo | 436174 | 4042612 | 6483 | 11/3/06 | | 5 | | | 0.01 | | | | | | | |
| **Taos Box N** | TS-36i | east | Small spring on east side. | Arroyo Hondo | 436170 | 4042598 | 6447 | 11/3/06 | | 30 | | | 0.07 | | 8.3 | 170 | 19.4 | 66.9 | 8.2 | |
| **Taos Box N** | TS-36j | east | Small spring on east side. | Arroyo Hondo | 436166 | 4042588 | 6479 | 11/3/06 | | 10 | | | 0.02 | | | | | | | |
| **Taos Box N** | TS-36k | east | Small spring on east side. | Arroyo Hondo | 436161 | 4042578 | 6475 | 11/3/06 | | 5 | | | 0.01 | | | | | | | |
| **Taos Box N** | TS-36l | east | Small spring on east side. | Arroyo Hondo | 436157 | 4042569 | 6473 | 11/3/06 | | 2 | | | 0.004 | | 8.3 | | 18.6 | 65.5 | | |
| **Taos Box N** | TS-36 m | east | Small spring on east side. | Arroyo Hondo | 436153 | 4042557 | 6447 | 11/3/06 | | 3 | | | 0.01 | | | | | | | |
| **DBS-2** | TS-115 | west | Located on west side, near river. | Arroyo Hondo | 436022 | 4042296 | 6465 | 3/15/04 | | | | | | Sampled by NMED. No discharge reported. Spring is only visible at low river levels. Not visited by staff of the NMBGMR. | 7.7 | 474 | 14.3 | 57.7 | | X |
| **Taos Box S** | TS-52d | east | Spring zone on east side. | Arroyo Hondo | 435764 | 4041505 | 6463 | 11/3/06 | | 5 | | | 0.01 | Several seeps trickle down to river. | 7.4 | 151 | 17.2 | 63.0 | 7.4 | |
| **Taos Box S** | TS-37 | east | Spring zone on east side. | Arroyo Hondo | 435728 | 4041407 | 6447 | 11/3/06 | | 8 | | | 0.02 | Large seepage area. | 7.6 | 163 | 16.1 | 61.0 | 8.0 | |
| **Taos Box S** | TS-38 | east | Spring zone on east side. | Arroyo Hondo | 435697 | 4041345 | 6457 | 11/3/06 | | | | | | | | | | | | |
| **Taos Box S** | TS-39 | east | Small seep on east side. | Arroyo Hondo | 435691 | 4041303 | 6447 | 11/3/06 | | 3 | | | 0.01 | Small seep from area of tree root. | | | | | | |
| **Taos Box S** | TS-40 | east | Spring zone on east side. | Arroyo Hondo | 435700 | 4041249 | 6463 | 11/3/06 | | 10 | | | 0.02 | Springs from boulder pile. | 7.9 | 161 | 19.1 | 66.4 | 6.4 | X |
| **Taos Box S** | TS-41 | east | Small seep on east side. | Arroyo Hondo | 435676 | 4041241 | 6463 | 11/3/06 | | 1 | | | 0.001 | | | | | | | |
| **Taos Box S** | TS-42 | east | Small seep on east side. | Arroyo Hondo | 435675 | 4041224 | 6447 | 11/3/06 | | 1 | | | 0.002 | Right next to serious marsh zone, with deep mud. | | | | | | |
| **Taos Box S** | TS-43 | east | Spring with deep channel on east side. | Arroyo Hondo | 435660 | 4041171 | 6466 | 11/3/06 | | 8 | | | 0.02 | Deep channel. | 7.7 | 165 | 19.8 | 67.6 | 6.3 | |
| **Taos Box S** | TS-44 | east | Marsh zone on east side. | Arroyo Hondo | 435648 | 4041158 | 6447 | 11/3/06 | | 2 | | | 0.004 | Marshy area with flow reaching river. | | | | | | |
| **Taos Box S** | TS-45 | east | Tiny trickle on east side. | Arroyo Hondo | 435641 | 4041134 | 6457 | 11/3/06 | | 1 | | | 0.002 | | | | | | | |
| **Taos Box S** | TS-46 | east | Small spring on east side. | Arroyo Hondo | 435615 | 4041091 | 6447 | 11/3/06 | | 1 | | | 0.002 | | | | | | | |
| **Taos Box S** | TS-47 | east | Marsh and seeps on east side. | Arroyo Hondo | 435555 | 4041014 | 6447 | 11/3/06 | | 7 | | | 0.02 | Marshy area and small rivulet seeps from toeslope of boulder field. | 7.5 | | 18.9 | 66.0 | | |
| **Taos Box S** | TS-48 | east | Two small rivulets on east side. | Arroyo Hondo | 435566 | 4041009 | 6457 | 11/3/06 | | 8 | | | 0.02 | Two small rivulets. | | | | | | |
| **Taos Box S** | TS-49 | east | Spring on east side. | Arroyo Hondo | 435544 | 4040995 | 6447 | 11/3/06 | | 15 | | | 0.03 | Flows from toeslope of boulder pile. | 7.8 | 163 | 23.1 | 73.6 | 5.9 | X |
| **Taos Box S** | TS-50 | east | Spring on east side. | Arroyo Hondo | 435539 | 4040977 | 6447 | 11/3/06 | | 12 | | | 0.03 | | | | | | | |
| **Taos Box S** | TS-51 | east | Small spring on east side. | Arroyo Hondo | 435496 | 4040926 | 6467 | 11/3/06 | | 30 | | | 0.07 | | 7.1 | 183 | 22.3 | 72.1 | 5.6 | |

| Name of Spring or Spring Zone | Spring ID | East or West or In the River | Description | 7.5-min Quad | UTM E NAD83 | UTM N NAD83 | Elev from DEM (ft) | Date visited | Measured discharge (gpm) | Estimated discharge of spring (gpm) | Estimated discharge of zone (gpm) | Measured discharge (cfs) | Estimated discharge (cfs) | Comments | Field pH | Field Specific Conductance (microS/cm) | Field Temp (C) | Field Temp (F) | Field Dissolved Oxygen (mg/L) | Chemistry Sample |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Manby Hot Spring S pool** | TS-52a | east | South pool. | Arroyo Hondo | 435150 | 4040574 | 6460 | 11/3/06 | 38 | | | 0.08 | | Discharge measurement from BOR/BIA (2002) seepage study with bucket and watch. Measured and sampled at east side vent. Clear water, no gas bubbles. | 6.8 | 516 | 32.8 | 91.0 | 5.3 | X |
| **Manby Hot Spring N pool** | TS-52b | east | North pool. | Arroyo Hondo | 435150 | 4040574 | 6460 | 11/3/06 | 10 | | | 0.02 | | Discharge measurement from BOR/BIA (2002) seepage study with bucket and watch. Some river water getting into pool, but metered near vent. Clear water, no gas bubbles. | 6.9 | 788 | 38.0 | 100.4 | 3.8 | |
| **Manby Hot Spring building** | TS-52c | east | Old stone biulding. | Arroyo Hondo | 435150 | 4040574 | 6460 | 11/3/06 | 16 | | | 0.04 | | Discharge measurement from BOR/BIA (2002) seepage study with bucket and watch. From crack between rocks in floor. Some gas bubbles from source area. | 7.0 | 780 | 36.7 | 98.1 | 2.5 | |
| **Lower Rio Pueblo de Taos** | TS-116 | east | Zone of small springs on east side of Rio Grande, just north of Rio Pueblo de Taos confluence. | Taos SW | 434459 | 4021833 | 6101 | | | | | | | Not visited by NMBGMR staff. Approximate location from Google Earth. Land owned by Taos Pueblo. Vegetative signatures suggest small spring zone in this area. | | | | | | |
| | | | | | | | | | **64** | **244** | **0** | **0.14** | **0.54** | | | | | | | |
| | | | **Rio Hondo Confluence to Rio Pueblo de Taos Confluence: Cumulative Tot** | | | | | | **308 gpm** | | | **0.69 cfs** | | | | | | | | |
| **Old NM-570 road** | TS-55 | east | Along old NM-570 road in Rio Pueblo de Taos gorge, up-road from landslide that closed road. | Taos SW | 435573 | 4022633 | 6473 | 4/24/07 | | | | | | Very small spring seepage at base of sediment layer on basalt. Much less than 1 gpm discharge. Too small to sample. | 8.3 | 337 | 9.9 | 49.8 | 5.4 | |
| **Dustbowl** | TS-58 | east | Spring that originates on east canyon wall, above Dustbowl camping area, and enters river just below TJ Bridge. | Taos SW | 434401 | 4021378 | 6150 | 5/7/07 | | 3 | | | 0.01 | Hydrogeologic setting of this spring is very similar to the nearby Rio Grande spring (TS-56). | 8.2 | | 14.6 | 58.3 | 6.0 | |
| **Taos Junction South** | TS-54 | east | Spring along road, just upstream from Rio Grande Spring, east side. Runs under culvert to river. Also known as TJ-1. | Taos SW | 433924 | 4021264 | 6060 | 4/23/07 | 15 | | | 0.03 | | Measured with bucket and watch, at pourover from culvert under road, at 2g/8sec. | 7.8 | 448 | 18.6 | 65.5 | 5.2 | X |
| **Taos Junction South** | TS-54 | east | Spring along road, just upstream from Rio Grande Spring, east side. Runs under culvert to river. Also known has TJ-1. | Taos SW | 433924 | 4021264 | 6060 | 6/11/09 | 17 | | | 0.04 | | Revisit and resample on June 11, 2009. Samples from small pool with orifice under rocks. Measured with bucket and watch, at pour over from culvert under road, at 2gal/7sec. | 7.7 | 457 | 19.0 | 66.1 | 7.1 | X |
| **Rio Grande (aka Klauer)** | TS-56 | east | South of TJ Bridge, on east side. Piped at road. Source is in arroyo about 100 ft above road. | Taos SW | 433641 | 4021102 | 6115 | 4/24/07 | 17 | | | 0.04 | | Spring runs down arroyo and is then diverted into pipe near road. Measured with bucket and watch at small waterfall located above pipe at 2g/7sec. | 7.5 | 383 | 15.7 | 60.3 | 5.5 | X |
| **Orilla Verde seep** | TS-63 | west | One of a series of small seeps with vegetative signatures that are located on west gorge wall between TJ Campground and the gaging station, a distance of one mile. | Taos SW | 433372 | 4021279 | 6201 | | | | | | | Small discharges of spring water that is perched on a 2-meter-thick, gray clay layer between elevations of about 6200' and 6400'. | | | | | | |
| **Orilla Verde seep** | TS-64 | west | One of a series of small seeps with vegetative signatures that are located on west gorge wall between TJ Campground and the gaging station, a distance of one mile. | Taos SW | 433044 | 4021101 | 6227 | | | | | | | Small discharges of spring water that is perched on a 2-meter-thick, gray clay layer between elevations of about 6200' and 6400'. | | | | | | |
| **Orilla Verde seep** | TS-65 | west | One of a series of small seeps with vegetative signatures that are located on west gorge wall between TJ Campground and the gaging station, a distance of one mile. | Taos SW | 432944 | 4020988 | 6218 | | | | | | | Small discharges of spring water that is perched on a 2-meter-thick, gray clay layer between elevations of about 6200' and 6400'. | | | | | | |
| **Orilla Verde seep** | TS-66 | west | One of a series of small seeps with vegetative signatures that are located on west gorge wall between TJ Campground and the gaging station, a distance of one mile. | Taos SW | 432769 | 4020810 | 6291 | | | | | | | Small discharges of spring water that is perched on a 2-meter-thick, gray clay layer between elevations of about 6200' and 6400'. | | | | | | |
| **Orilla Verde seep** | TS-67 | west | One of a series of small seeps with vegetative signatures that are located on west gorge wall between TJ Campground and the gaging station, a distance of one mile. | Taos SW | 432640 | 4020569 | 6286 | | | | | | | Small discharges of spring water that is perched on a 2-meter-thick, gray clay layer between elevations of about 6200' and 6400'. | | | | | | |

## Table 1-Summary data for all inventoried springs of the Rio Grande Gorge, Taos County, New Mexico (revised Jan 2017)



| Name of Spring or Spring Zone | Spring ID | East or West or In the River | Description | 7.5-min Quad | UTM E NAD83 | UTM N NAD83 | Elev from DEM (ft) | Date visited | Measured discharge (gpm) | Estimated discharge of spring (gpm) | Estimated discharge of zone (gpm) | Measured discharge (cfs) | Estimated discharge (cfs) | Comments | Field pH | Field Specific Conductance (microS/cm) | Field Temp (C) | Field Temp (F) | Field Dissolved Oxygen (mg/L) | Chemistry Sample |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Orilla Verde seep** | TS-68 | west | One of a series of small seeps with vegetative signatures that are located on west gorge wall between TJ Campground and the gaging station, a distance of one mile. | Taos SW | 432296 | 4020034 | 6340 | | | | | | | Small discharges of spring water that is perched on a 2-meter-thick, gray clay layer between elevations of about 6200' and 6400'. | | | | | | |
| **Orilla Verde seep** | TS-69 | west | One of a series of small seeps with vegetative signatures that are located on west gorge wall between TJ Campground and the gaging station, a distance of one mile. | Taos SW | 432090 | 4019900 | 6397 | | | | | | | Small discharges of spring water that is perched on a 2-meter-thick, gray clay layer between elevations of about 6200' and 6400'. | | | | | | |
| **Little Spring cienega** | TS-86 | west | Spring zone located half way up gorge wall, with cottonwoods and large wetland at northern edge of Pilar. Zone of seeps wets large cienega. Similar to Racecourse cienegas. | Taos SW | 428390 | 4015777 | 6370 | 6/11/09 | | | 30 | | 0.07 | Spring zone lies at slope break between dry slopes and cienega. Seeps coalesce into several small streams in arroyos. Line of cottonwoods from springs to river. Estimated total flow is 30 gpm. | 7.6 | 266 | 15.7 | 60.3 | 5.0 | X |
| **Big Spring** | TS-53 | west | North of Pilar, on west side. Spring feeds the Los Acequias de los Ojos of the village of Pilar. Feeds the Pilar Community Ditch. | Carson | 428734 | 4015141 | 6152 | 4/23/07 | | 450 | | | 1.00 | Large spring discharges under basalt boulders. Used bucket and watch to measure a portion of the flow and thus estimate total flow. | 7.1 | 277 | 22.3 | 72.1 | 6.4 | X |
| **Big Spring** | TS-53 | west | North of Pilar, on west side. Spring feeds the Los Acequias de los Ojos of the village of Pilar. Feeds the Pilar Community Ditch. | Carson | 428734 | 4015141 | 6152 | 5/29/04 | | | | | | Large spring discharges under basalt boulders. Sampled by NMED in May 2004. No discharge reported by NMED. | 7.0 | 284 | 22.5 | 72.5 | | X |
| **Big Spring** | TS-53 | west | North of Pilar, on west side. Spring feeds the Los Acequias de los Ojos of the village of Pilar. Feeds the Pilar Community Ditch. | Carson | 428734 | 4015141 | 6152 | 9/28/04 | | | | | | Large spring discharges under basalt boulders. Resampled by NMED in September 2004 No discharge reported. Stable isotope analysis from LANL lab. | | | | | | X |
| **Racecourse cienegas** | TS-117 | west | Series of spring-fed cienegas on west gorge wall between Pilar and Souse Hole rapid. | Carson | 427467 | 4013198 | 6148 | | | | | | | Not visited by NMBGMR staff. Located from Google Earth. Strong vegetation signature. Springs and seeps that are perched on a 2-meter-thick gray clay layer. Discharge unknown. | | | | | | |
| **Racecourse cienegas** | TS-118 | west | Series of spring-fed cienegas on west gorge wall between Pilar and Souse Hole rapid. | Carson | 427423 | 4013176 | 6159 | | | | | | | Not visited by NMBGMR staff. Located from Google Earth. Strong vegetation signature. Springs and seeps that are perched on a 2-meter-thick gray clay layer. Discharge unknown. | | | | | | |
| **Racecourse cienegas** | TS-119 | west | Series of spring-fed cienegas on west gorge wall between Pilar and Souse Hole rapid. | Carson | 427099 | 4013037 | 6201 | | | | | | | Not visited by NMBGMR staff. Located from Google Earth. Strong vegetation signature. Springs and seeps that are perched on a 2-meter-thick gray clay layer. Discharge unknown. | | | | | | |
| **Racecourse cienegas** | TS-120 | west | Series of spring-fed cienegas on west gorge wall between Pilar and Souse Hole rapid. | Carson | 427093 | 4012893 | 6129 | | | | | | | Not visited by NMBGMR staff. Located from Google Earth. Strong vegetation signature. Springs and seeps that are perched on a 2-meter-thick gray clay layer. Discharge unknown. | | | | | | |
| **Racecourse cienegas** | TS-121 | west | Series of spring-fed cienegas on west gorge wall between Pilar and Souse Hole rapid. | Carson | 426758 | 4012753 | 6200 | | | | | | | Not visited by NMBGMR staff. Located from Google Earth. Strong vegetation signature. Springs and seeps that are perched on a 2-meter-thick gray clay layer. Discharge unknown. | | | | | | |
| **Racecourse cienegas** | TS-122 | west | Series of spring-fed cienegas on west gorge wall between Pilar and Souse Hole rapid. | Carson | 426359 | 4012735 | 6219 | | | | | | | Not visited by NMBGMR staff. Located from Google Earth. Strong vegetation signature. Springs and seeps that are perched on a 2-meter-thick gray clay layer. Discharge unknown. | | | | | | |
| **Racecourse cienegas** | TS-123 | west | Series of spring-fed cienegas on west gorge wall between Pilar and Souse Hole rapid. | Carson | 426346 | 4012548 | 6128 | | | | | | | Not visited by NMBGMR staff. Located from Google Earth. Strong vegetation signature. Springs and seeps that are perched on a 2-meter-thick gray clay layer. Discharge unknown. | | | | | | |
| **Racecourse cienegas** | TS-124 | west | Series of spring-fed cienegas on west gorge wall between Pilar and Souse Hole rapid. | Carson | 426276 | 4012533 | 6158 | | | | | | | Not visited by NMBGMR staff. Located from Google Earth. Strong vegetation signature. Springs and seeps that are perched on a 2-meter-thick gray clay layer. Discharge unknown. | | | | | | |

| Name of Spring or Spring Zone | Spring ID | East or West or In the River | Description | 7.5-min Quad | UTM E NAD83 | UTM N NAD83 | Elev from DEM (ft) | Date visited | Measured discharge (gpm) | Estimated discharge of spring (gpm) | Estimated discharge of zone (gpm) | Measured discharge (cfs) | Estimated discharge (cfs) | Comments | Field pH | Field Specific Conductance (microS/cm) | Field Temp (C) | Field Temp (F) | Field Dissolved Oxygen (mg/L) | Chemistry Sample |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Racecourse cienegas** | TS-125 | west | Series of spring-fed cienegas on west gorge wall between Pilar and Souse Hole rapid. | Carson | 426219 | 4012481 | 6179 | | | | | | | Not visited by NMBGMR staff. Located from Google Earth. Strong vegetation signature. Springs and seeps that are perched on a 2-meter-thick gray clay layer. Discharge unknown. | | | | | | |
| **Racecourse cienegas** | TS-126 | west | Series of spring-fed cienegas on west gorge wall between Pilar and Souse Hole rapid. | Carson | 425991 | 4012306 | 6147 | | | | | | | Not visited by NMBGMR staff. Located from Google Earth. Strong vegetation signature. Springs and seeps that are perched on a 2-meter-thick gray clay layer. Discharge unknown. | | | | | | |
| **Racecourse cienegas** | TS-127 | west | Series of spring-fed cienegas on west gorge wall between Pilar and Souse Hole rapid. | Carson | 425865 | 4012253 | 6145 | | | | | | | Not visited by NMBGMR staff. Located from Google Earth. Strong vegetation signature. Springs and seeps that are perched on a 2-meter-thick gray clay layer. Discharge unknown. | | | | | | |
| **Glenwoody E cienega** | TS-87a | west | Large cienega on north side of Glenwoody Bridge consists of multiple terraced fens on complex landslide blocks with distributed flow on gray clay layer. | Carson | 425840 | 4012169 | 6091 | 6/12/09 | | 1 | | | 0.001 | Zone along top of cienega is a continuous seep zone, without any discreet orifices for measurements. Seeps feed the fens, and water coalesces downhill into many small streams which flow and infiltrate in complex manner. Gray clay underlies fens. Tested small pool near head of fen. | 8.1 | 334 | 17.7 | 63.9 | 8.3 | |
| **Glenwoody W cienega** | TS-87b | west | Large cienega on north side of Glenwoody Bridge. Westernmost drainage. | Carson | 425697 | 4011943 | 6071 | 6/12/09 | | 10 | | | 0.02 | Western fens coalesce into good stream, which is tapped for irrigation with pipe and drum. Sampled from steel pipe under road that fills steel barrel in arroyo. Sample is not primary spring water, but only source in area. | 8.5 | 405 | 23.1 | 73.5 | 7.3 | X |
| **Racecourse cienegas** | TS-128 | west | Series of spring-fed cienegas on west gorge wall between Pilar and Souse Hole rapid. | Carson | 425639 | 4012046 | 6140 | | | | | | | Not visited by NMBGMR staff. Located from Google Earth. Strong vegetation signature. Springs and seeps that are perched on a 2-meter-thick gray clay layer. Discharge unknown. | | | | | | |
| **Racecourse cienegas** | TS-129 | west | Series of spring-fed cienegas on west gorge wall between Pilar and Souse Hole rapid. | Trampas | 425614 | 4011951 | 6141 | | | | | | | Not visited by NMBGMR staff. Located from Google Earth. Strong vegetation signature. Springs and seeps that are perched on a 2-meter-thick gray clay layer. Discharge unknown. | | | | | | |
| **Racecourse cienegas** | TS-130 | west | Series of spring-fed cienegas on west gorge wall between Pilar and Souse Hole rapid. | Trampas | 424880 | 4011433 | 6231 | | | | | | | Not visited by NMBGMR staff. Located from Google Earth. Strong vegetation signature. Springs and seeps that are perched on a 2-meter-thick gray clay layer. Discharge unknown. | | | | | | |
| **Souse Hole cienega** | TS-57 | west | Large wetland on north side of river, just above Souse Hole rapid. | Trampas | 424335 | 4011126 | 6224 | 5/6/07 | | 5 | | | 0.01 | Spring is at north end of large, green, grassy meadow, and emerges as clear stream under basalt boulders. | 8.9 | 242 | 12.9 | 55.2 | | X |
| **Racecourse cienegas** | TS-131 | west | Series of spring-fed cienegas on west gorge wall near Souse Hole. | Trampas | 424297 | 4011114 | 6219 | | | | | | | Not visited by NMBGMR staff. Located from Google Earth. Strong vegetation signature. Springs and seeps that are perched on a 2-meter-thick gray clay layer. Discharge unknown. | | | | | | |
| **Racecourse cienegas** | TS-132 | west | Series of spring-fed cienegas on west gorge wall near Souse Hole. | Trampas | 423544 | 4010492 | 6192 | | | | | | | Not visited by NMBGMR staff. Located from Google Earth. Strong vegetation signature. Springs and seeps that are perched on a 2-meter-thick gray clay layer. Discharge unknown. | | | | | | |
| **Racecourse cienegas** | TS-133 | west | Series of spring-fed cienegas on west gorge wall near Rinconada. | Velarde | 419882 | 4008797 | 6017 | | | | | | | Not visited by NMBGMR staff. Located from Google Earth. Strong vegetation signature. Springs and seeps that are perched on a 2-meter-thick gray clay layer. Discharge unknown. | | | | | | |
| **Racecourse cienegas** | TS-134 | west | Series of spring-fed cienegas on west gorge wall near Rinconada. | Velarde | 419882 | 4008797 | 6017 | | | | | | | Not visited by NMBGMR staff. Located from Google Earth. Strong vegetation signature. Springs and seeps that are perched on a 2-meter-thick gray clay layer. Discharge unknown. | | | | | | |
| | | | | | | | | | **49** | **469** | **30** | **0.11** | **1.11** | | | | | | | |
| | | | **Rio Pueblo de Taos to County Line: Cumulative Total Spring Discharge** | | | | | | **548** | **gpm** | | **1.22** | **cfs** | | | | | | | |
| | | | | | | | | | **7972** | **12,083** | **9543** | **17.77** | **48.23** | | | | | | | |
| | | | **Total spring discharge measured plus estimated in Rio Grande Gorg** | | | | | | **29,598** | **gpm** | | **65.99** | **cfs** | | | | | | | |

New Mexico Environment Dept. (NMED) chemistry sample

## Table 2-Rio Grande Gorge Springs Chemistry, Taos County, New Mexico (revised Jan 2017)



| Sample Information | | | | Isotopes and Age Dating | | | | | Physical Parameters | | | Ion Chemistry | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Name of Spring or Spring Zone | Spring ID | East or West or In the River | Date sampled | Del O (‰) | Del D (‰) | Tritium (TU) | CFC Recharge Age (yrs) | 14C Apparent Age (yrs) | Field Temp (C) | pH | Conductivity (microS/cm) | TDS calc (ppm) | Bicarbonate HCO3- (ppm) | Chloride Cl- (ppm) | Nitrite NO2- (ppm) | Nitrate NO3- (ppm) | Phosphate PO43- (ppm) | Sulfate SO42- (ppm) | Calcium (ppm) | Magnesium (ppm) | Potassium (ppm) | Sodium (ppm) | Total meq/L Cations | Total_ meq L Anions | % Difference |
| Cow Patty E | **TS-70** | east | 9/25/08 | -14.1 | -97.6 | -0.01 | | | 11.4 | | | | | | | | | | | | | | | | |
| Cow Patty W | **TS-14a** | west | 8/30/06 | -14.5 | -102.8 | -0.03 | | | 12.9 | 7.9 | 170 | 130 | 93 | 3.1 | <0.1 | 1.6 | <0.5 | 9.9 | 17 | 6.5 | 2.4 | 10 | 1.88 | 1.86 | 0.39 |
| Cow Patty W | **TS-14a** | west | 9/25/08 | -14.3 | -96.9 | | | 1640 +/- 40 | 12.4 | | | | | | | | | | | | | | | | |
| Sunshine | **TS-71** | west | 9/25/08 | -14.2 | -97.6 | 0.08 | ~30 | 2910 +/- 40 | 14.9 | | | | | | | | | | | | | | | | |
| The Rio Grande | **TS-114** | | 9/2/09 | -12.0 | -89.7 | | | | 15.9 | | | | | | | | | | | | | | | | |
| Lava Tube | **TS-83** | in river | 9/2/09 | -14.5 | -101.0 | 0.10 | ~41 | 3840 +/- 40 | 15.2 | | | | | | | | | | | | | | | | |
| Sunshine Trail | **TS-73** | east | 9/25/08 | | | | | 2370 +/- 40 | 13.7 | | | | | | | | | | | | | | | | |
| Sunshine Trail W | **TS-72** | west | 9/25/08 | -14.4 | -96.4 | 0.02 | | 2540 +/- 40 | 12.5 | | | | | | | | | | | | | | | | |
| Sunshine Trail | **TS-25** | east | 8/30/06 | -14.2 | -100.9 | 0.02 | | | 12.5 | 8.1 | 190 | 147 | 100 | 4.8 | <0.1 | 3.1 | <0.5 | 15 | 18 | 7.3 | 2.4 | 14 | 2.16 | 2.16 | 0.05 |
| Desagua Trail | **TS-29b** | east | 11/1/06 | -14.6 | -100.2 | 4.51 | | | 11.7 | 7.9 | 240 | 176 | 115 | 6.4 | <0.1 | 5.4 | <0.5 | 24 | 28 | 8.9 | 1.9 | 12 | 2.69 | 2.68 | 0.35 |
| S of Sheep | **TS-1a** | east | 8/28/06 | -14.2 | -99.8 | 0.44 | | | 15.2 | 8.0 | 230 | 177 | 105 | 7.2 | <0.1 | 3.3 | <0.5 | 23 | 20 | 6.5 | 3.1 | 21 | 2.52 | 2.52 | -0.05 |
| Gaging Station S | **TS-4** | east | 8/28/06 | -14.3 | -99.3 | 0.46 | | | 15.9 | 8.0 | 230 | 177 | 105 | 7.3 | <0.1 | 3.8 | 0.59 | 24 | 20 | 6.6 | 2.9 | 20 | 2.48 | 2.57 | -1.77 |
| Bear Crossing spring zone | **TS-8** | west | 8/29/06 | -14.5 | -103.8 | 0.09 | | | 16.5 | 8.3 | 210 | 173 | 110 | 8.0 | <0.1 | 2.6 | <0.5 | 11 | 17 | 6.3 | 3.1 | 21 | 2.35 | 2.34 | 0.31 |
| Felsenmeere Middle | **TS-61** | west | 5/9/07 | -15.3 | -107.0 | | | 4400 +/- 40 | 16.8 | 8.3 | 190 | 149 | 100 | 3.1 | <0.1 | 2.7 | <0.5 | 8.2 | 18 | 6.5 | 2.9 | 13 | 2.05 | 1.96 | 2.20 |
| Felsenmeere South | **TS-59** | west | 5/5/04 | -14.6 | -99.8 | 0.12 | | | 16.3 | 7.9 | | 202 | 104 | 2.4 | | | | 8.5 | | | | | | | |
| Felsenmeere South | **TS-59** | west | 9/27/04 | -14.3 | -105.5 | | | | 16.4 | 7.8 | | 204 | 105 | 2.4 | | | | 8.4 | | | | | | | |
| Big Arsenic source | **TS-135** | east | 3/25/04 | -14.1 | -95.0 | 0.77 | | | 17.2 | | | | | | | | | | | | | | | | |
| North Big Arsenic 2 | **TS-16b** | east | 8/31/06 | -14.2 | -99.4 | 0.60 | | | 17.5 | 8.2 | 235 | 175 | 105 | 7.9 | <0.1 | 4.1 | <0.5 | 25 | 21 | 6.9 | 2.4 | 20 | 2.54 | 2.59 | -0.94 |
| South Big Arsenic | **TS-15** | east | 1/1/04 | -13.6 | -94.4 | 0.53 | | | | 8.3 | | 179 | 89 | 7.4 | | | 0.02 | 25.5 | 20.8 | 5.8 | 2.5 | 22 | | | |
| Little Arsenic | **TS-17** | east | 8/31/06 | -14.2 | -100.1 | 0.02 | | | 15.4 | 8.2 | 210 | 159 | 100 | 6.6 | <0.1 | 2.7 | <0.5 | 18 | 17 | 6 | 2.5 | 19 | 2.23 | 2.31 | -1.83 |
| La Junta West | **TS-93** | west | 9/1/09 | | | | | | | 8.0 | 305 | 225 | 180 | 2.5 | <0.1 | 3 | <0.5 | 5 | 28 | 10 | 4.2 | 18 | 3.16 | 3.2 | -0.58 |
| San Cristobal Creek | **TS-94** | river | 9/1/09 | | | | | | 18.8 | 8.3 | 225 | 162 | 110 | 4.2 | <.1 | 3 | <.5 | 13 | 19 | 7 | 2.6 | 14 | 2.24 | 2.26 | -0.59 |
| La Junta West | **TS-95** | west | 9/1/09 | -14.6 | -103.0 | -0.08 | | 12,630 +/- 60 | 16.9 | 8.7 | 345 | 212 | 130 | 9.9 | <.1 | 1 | <.5 | 36 | 23 | 7 | 4.6 | 33 | 3.34 | 3.31 | 0.51 |
| Dunn Bridge N | **TS-31a** | east | 11/2/06 | | | | ~36 | | 15.0 | | | | | | | | | | | | | | | | |
| Dunn Bridge N | **TS-31a** | east | 1/1/04 | -14.0 | -94.8 | 4.54 | | | | 8.2 | | 166 | 98 | 2.4 | | | <0.01 | 23.5 | 25.8 | 6.6 | 3.1 | 10.4 | | | |
| Rael (aka Stark or Warmsley) | **TS-18** | east | 9/1/06 | -14.1 | -97.3 | 4.03 | | | 14.5 | 8.1 | 230 | 170 | 120 | 3.4 | <0.1 | 2.2 | <0.5 | 23 | 28 | 8.5 | 3 | 11 | 2.64 | 2.59 | 1.01 |
| Lower Arroyo Hondo zone | **TS-33** | east | 1/1/04 | -13.7 | -95.8 | 6.01 | | | | 8.1 | | 198 | 120 | 3.3 | | | | 30.4 | 33.0 | 8.4 | 3.3 | 12.8 | | | |
| DBS-1 | **TS-135** | west | 3/15/04 | -14.3 | -100.0 | 0.16 | | | 15.9 | | | | | | | | | | | | | | | | |
| Black Rock Hot | **TS-28** | west | 9/1/06 | | | | | | 38.5 | 7.7 | 820 | 470 | 185 | 61.0 | <0.1 | 1.5 | <0.5 | 135 | 21 | 5.5 | 11 | 140 | 7.78 | 7.73 | 0.94 |
| Taos Box N 1 | **TS-19** | east | 9/1/06 | -14.2 | -98.0 | 0.60 | | | 17.4 | 8.3 | 175 | 138 | 93 | 2.4 | <0.1 | 1.9 | 0.82 | 18 | 19 | 5.9 | 2.5 | 11 | 1.97 | 2.04 | -1.73 |
| Taos Box N 2 | **TS-36b** | east | 11/3/06 | -14.7 | -99.7 | | 52-55 | | 17.3 | 8.2 | 180 | 139 | 92 | 2.4 | <0.1 | 1.9 | <0.5 | 19 | 19 | 5.7 | 2.4 | 11 | 1.95 | 2.02 | -1.63 |
| DBS-2 | **TS-115** | west | 3/15/04 | -14.2 | -104.7 | 0.16 | | | 14.3 | | | | | | | | | | | | | | | | |
| Taos Box S | **TS-40** | east | 11/3/06 | -14.0 | -98.0 | 0.02 | | | 19.1 | 7.9 | 155 | 123 | 83 | 2.0 | <0.1 | 1.5 | <0.5 | 14 | 14 | 4.8 | 2.3 | 12 | 1.67 | 1.75 | -2.3 |
| Taos Box S | **TS-49** | east | 11/3/06 | -14.1 | -99.4 | -0.02 | | | 23.1 | 7.9 | 165 | 140 | 92 | 3.3 | <0.1 | 2.1 | <0.5 | 18 | 16 | 4.7 | 2.3 | 16 | 1.94 | 2.03 | -2.27 |
| Manby Hot Spring S pool | **TS-52a** | east | 11/3/06 | -14.5 | -103.7 | | | | 32.8 | 7.3 | 510 | 358 | 185 | 25.0 | <0.1 | 2.2 | <0.5 | 63 | 28 | 6.2 | 6.3 | 67 | 4.98 | 5.18 | -1.89 |
| Taos Junction South | **TS-54** | east | 4/23/07 | -15.1 | -109.3 | | | 18,850 +/- 100 | 18.6 | 8.2 | 440 | 303 | 270 | 2.2 | <0.1 | 3.1 | <0.5 | 20 | 13 | 1.4 | 3.5 | 89 | 4.75 | 5.02 | -2.82 |
| Taos Junction S | **TS-54** | east | 6/11/09 | -15.0 | -104.5 | 0.08 | 35-41 | 17,630 +/- 90 | 19.0 | 8.1 | 480 | 297 | 270 | 2.7 | <.1 | 2.9 | <.5 | 21 | 13 | 1.4 | 3.4 | 89 | 4.72 | 5.04 | -3.27 |
| Rio Grande (aka Klauer) | **TS-56** | east | 4/24/07 | -14.4 | -102.9 | -0.03 | | 7670 +/- 50 | 15.7 | 7.9 | 375 | 258 | 140 | 4.2 | <0.1 | 1.6 | <0.5 | 71 | 36 | 6.2 | 3.2 | 33 | 3.81 | 3.94 | -1.59 |
| Little Spring cienega | **TS-86** | west | 6/11/09 | -13.9 | -97.4 | 0.04 | | 8910 +/- 50 | 15.7 | 7.8 | 290 | 165 | 155 | 2.3 | <.1 | 3.8 | <.5 | 10 | 29 | 3.5 | 3.8 | 19 | 2.66 | 2.91 | -4.4 |
| Big Spring | **TS-53** | west | 4/23/07 | -15.0 | -107.7 | 0.08 | | 14,900 +/- 80 | 22.3 | 7.9 | 295 | 194 | 160 | 1.7 | <0.1 | 3.5 | <0.5 | 11 | 28 | 1.7 | 4.4 | 27 | 2.82 | 2.98 | -2.88 |
| Big Spring | **TS-53** | west | 5/29/04 | -14.6 | -103.9 | -0.02 | | | 22.5 | | | | | | | | | | | | | | | | |
| Big Spring | **TS-53** | west | 9/28/04 | -14.4 | -105.3 | | | | | | | | | | | | | | | | | | | | |
| Glenwoody W cienega | **TS-87b** | west | 6/12/09 | -15.8 | -110.6 | | | | 23.1 | 8.5 | 425 | 252 | 235 | 1.7 | <.1 | 2.5 | <.5 | 12 | 3.6 | 0.037 | 0.85 | 89 | 4.09 | 4.3 | -2.54 |
| Souse Hole cienega | **TS-57** | west | 5/6/07 | -15.4 | -110.3 | 0.26 | | 3,440 +/- 40 | 12.9 | 8.0 | 455 | 322 | 265 | 2.8 | <0.1 | 2.5 | <0.5 | 26 | 38 | 12 | 21 | 38 | 5.03 | 5.02 | 0.05 |

New Mexico Environment Dept. (NMED) chemistry sample

| | Trace Element Chemistry | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spring ID | Aluminum (ppm) | Antimony (ppm) | Arsenic (ppm) | Barium (ppm) | Beryllium (ppm) | Boron (ppm) | Bromide (ppm) | Cadmium (ppm) | Chromium (ppm) | Cobalt (ppm) | Copper (ppm) | Fluoride F- (ppm) | Iron (ppm) | Lead (ppm) | Lithium (ppm) | Manganese (ppm) | Molybdenum (ppm) | Nickel (ppm) | Selenium (ppm) | Strontium (ppm) | Silica SiO2 (ppm) | Silicon (ppm) | Silver (ppm) | Thalium (ppm) | Thorium (ppm) | Tin (ppm) | Titanium (ppm) | Uranium (ppm) | Vanadium (ppm) | Zinc (ppm) |
| **TS-70** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **TS-14a** | 0.035 | <0.001 | 0.001 | 0.026 | <0.001 | 0.019 | <0.1 | <0.001 | 0.003 | <0.001 | <0.001 | 0.39 | 1.20 | <0.001 | 0.004 | 0.002 | 0.001 | <0.001 | <0.001 | 0.14 | 32 | 15 | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | 0.002 | 0.007 | <0.001 |
| **TS-14a** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **TS-71** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **TS-114** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **TS-83** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **TS-73** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **TS-72** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **TS-25** | 0.002 | <0.001 | 0.001 | 0.023 | <0.001 | 0.021 | <0.1 | <0.001 | 0.003 | <0.001 | 0.001 | 0.47 | <0.01 | <0.001 | 0.005 | <0.001 | 0.001 | <0.001 | 0.001 | 0.15 | 32 | 15 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | 0.002 | 0.008 | <0.001 |
| **TS-29b** | 0.001 | <0.001 | 0.001 | 0.034 | <0.001 | 0.014 | 0.11 | <0.001 | 0.002 | <0.001 | 0.019 | 0.42 | <0.01 | <0.001 | 0.007 | <0.001 | 0.001 | 0.001 | 0.001 | 0.23 | 31 | 14 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | 0.003 | 0.004 | 0.001 |
| **TS-1a** | 0.013 | <0.001 | 0.001 | 0.016 | <0.001 | 0.024 | <0.1 | <0.001 | 0.002 | <0.001 | 0.001 | 1.3 | 0.11 | <0.001 | 0.020 | 0.001 | 0.004 | <0.001 | 0.001 | 0.17 | 39 | 18 | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | 0.003 | 0.007 | 0.001 |
| **TS-4** | 0.007 | <0.001 | 0.001 | 0.027 | <0.001 | 0.023 | <0.1 | <0.001 | 0.002 | <0.001 | 0.001 | 1.2 | 0.05 | <0.001 | 0.019 | <0.001 | 0.004 | <0.001 | 0.001 | 0.17 | 37 | 17 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | 0.003 | 0.008 | 0.001 |
| **TS-8** | 0.003 | <0.001 | 0.004 | 0.016 | <0.001 | 0.047 | <0.1 | <0.001 | 0.003 | <0.001 | 0.001 | 0.77 | <0.01 | <0.001 | 0.029 | <0.001 | 0.002 | <0.001 | <0.001 | 0.16 | 48 | 22 | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | 0.002 | 0.013 | <0.001 |
| **TS-61** | 0.001 | <0.001 | 0.003 | 0.018 | <0.001 | 0.027 | 0.04 | <0.001 | 0.002 | <0.001 | 0.001 | 0.4 | <0.01 | <0.00 | 0.010 | <0.001 | 0.001 | <0.001 | <0.001 | 0.16 | 21 | 21 | 0.159 | <0.001 | <0.001 | <0.001 | 0.003 | 0.002 | 0.011 | <0.00 |
| **TS-59** | | | | | | | 0.02 | | | | | 0.34 | | | | | | | | | | | | | | | | | | |
| **TS-59** | | | | | | | 0.01 | | | | | 0.33 | | | | | | | | | | | | | | | | | | |
| **TS-135** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **TS-16b** | 0.005 | <0.001 | 0.001 | 0.023 | <0.001 | 0.023 | <0.1 | <0.001 | 0.002 | <0.001 | 0.001 | 1.1 | 0.04 | <0.001 | 0.021 | <0.001 | 0.003 | <0.001 | 0.001 | 0.18 | 34 | 16 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | 0.003 | 0.006 | <0.001 |
| **TS-15** | | | | | | | 0.07 | | | | | 1.18 | | | | | | | | | | | | | | | | | | |
| **TS-17** | 0.012 | <0.001 | 0.002 | 0.025 | <0.001 | 0.029 | <0.1 | <0.001 | 0.003 | <0.001 | 0.001 | 1.3 | <0.01 | <0.001 | 0.021 | <0.001 | 0.005 | <0.001 | 0.001 | 0.15 | 36 | 17 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | 0.002 | 0.008 | <0.001 |
| **TS-93** | 0.001 | <.005 | 0.007 | 0.098 | <.001 | 0.04 | 0.033 | <.001 | 0.005 | <.001 | 0.019 | 0.5 | <.05 | <.001 | 0.029 | <.005 | 0.002 | <.001 | <.005 | 0.22 | 62 | 24 | <.001 | <.001 | <.001 | <.001 | 0.003 | 0.004 | 0.020 | 0.019 |
| **TS-94** | 0.004 | <.005 | 0.002 | 0.079 | <.001 | 0.033 | 0.055 | <.001 | 0.003 | <.001 | 0.006 | 0.48 | <.05 | <.001 | 0.008 | <.005 | 0.002 | <.001 | <.005 | 0.18 | 43 | 17 | <.001 | <.001 | <.001 | <.001 | 0.002 | 0.002 | 0.009 | 0.015 |
| **TS-95** | 0.023 | <.005 | 0.003 | 0.079 | <.001 | 0.069 | 0.089 | <.001 | 0.001 | <.001 | 0.006 | 0.56 | <.05 | <.001 | 0.008 | 0.008 | 0.004 | <.001 | <.005 | 0.23 | 28 | 11 | <.001 | <.001 | <.001 | <.001 | 0.002 | 0.002 | 0.007 | 0.01 |
| **TS-31a** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **TS-31a** | | | | | | | 0.03 | | | | | 0.24 | | | | | | | | | | | | | | | | | | |
| **TS-18** | 0.002 | <0.001 | <0.001 | 0.020 | <0.001 | 0.008 | <0.1 | <0.001 | 0.002 | <0.001 | <0.001 | 0.23 | <0.01 | <0.001 | 0.003 | <0.001 | 0.005 | <0.001 | 0.001 | 0.22 | 30 | 14 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | 0.004 | 0.005 | 0.002 |
| **TS-33** | | | | | | | 0.04 | | | | | 0.21 | | | | | | | | | | | | | | | | | | |
| **TS-135** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **TS-28** | 0.018 | <0.001 | 0.014 | 0.039 | <0.001 | 0.25 | 0.29 | <0.001 | 0.002 | <0.001 | 0.012 | 2.6 | 0.01 | <0.001 | 0.32 | 0.005 | 0.020 | <0.001 | 0.001 | 0.38 | 67 | 32 | <0.001 | <0.001 | <0.001 | <0.001 | 0.003 | 0.002 | 0.036 | 0.002 |
| **TS-19** | 0.002 | <0.001 | <0.001 | 0.007 | <0.001 | 0.009 | <0.1 | <0.001 | 0.003 | <0.001 | 0.001 | 0.29 | 0.14 | <0.001 | 0.003 | <0.001 | 0.005 | <0.001 | 0.001 | 0.14 | 30 | 14 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | 0.002 | 0.006 | <0.001 |
| **TS-36b** | 0.002 | <0.001 | <0.001 | 0.007 | <0.001 | 0.008 | <0.1 | <0.001 | 0.003 | <0.001 | 0.026 | 0.29 | 0.04 | <0.001 | 0.003 | <0.001 | 0.005 | <0.001 | 0.001 | 0.14 | 31 | 15 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | 0.002 | 0.006 | <0.001 |
| **TS-115** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **TS-40** | 0.001 | <0.001 | 0.001 | 0.009 | <0.001 | 0.009 | <0.1 | <0.001 | 0.005 | <0.001 | 0.025 | 0.33 | 0.01 | <0.001 | 0.003 | <0.001 | 0.005 | <0.001 | 0.001 | 0.10 | 30 | 14 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | 0.001 | 0.010 | <0.001 |
| **TS-49** | 0.001 | <0.001 | 0.001 | 0.013 | <0.001 | 0.011 | <0.1 | <0.001 | 0.006 | <0.001 | 0.021 | 0.32 | <0.01 | <0.001 | 0.005 | <0.001 | 0.005 | <0.001 | 0.001 | 0.12 | 31 | 15 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | 0.001 | 0.009 | <0.001 |
| **TS-52a** | 0.001 | 0.000 | 0.014 | 0.097 | <0.001 | 0.179 | 0.13 | <0.001 | 0.002 | <0.001 | 0.025 | 1.70 | 0.24 | <0.001 | 0.16 | <0.001 | 0.010 | 0.001 | 0.001 | 0.50 | 65 | 30 | <0.001 | <0.001 | <0.001 | <0.001 | 0.003 | 0.003 | 0.019 | 0.001 |
| **TS-54** | 0.002 | <0.001 | 0.005 | 0.010 | <0.001 | 0.143 | 0.04 | <0.001 | 0.007 | <0.001 | 0.008 | 1.30 | 0.08 | <0.00 | 0.11 | <0.001 | 0.002 | <0.001 | 0.001 | 0.23 | 15.87 | <0.001 | 0.23 | <0.001 | <0.001 | <0.001 | 0.001 | 0.004 | 0.029 | <0.00 |
| **TS-54** | 0.006 | <.005 | 0.005 | 0.083 | <.001 | 0.140 | 0.04 | <.001 | 0.008 | <.001 | 0.002 | 1.00 | <.05 | <.001 | 0.10 | <.005 | 0.002 | <.001 | <.005 | 0.23 | nr | 15 | <.001 | <.001 | <.001 | <.001 | 0.002 | 0.004 | 0.028 | 0.02 |
| **TS-56** | 0.001 | <0.001 | 0.002 | 0.024 | <0.001 | 0.047 | 0.05 | <0.001 | 0.004 | <0.001 | 0.005 | 0.35 | 0.23 | <0.00 | 0.09 | <0.001 | 0.001 | 0.001 | 0.001 | 0.34 | 14.64 | <0.001 | 0.34 | <0.001 | <0.001 | <0.001 | 0.00 | 0.00 | 0.01 | 0.00 |
| **TS-86** | 0.019 | <.005 | 0.002 | 0.11 | <.001 | 0.04 | 0.04 | <.001 | 0.003 | <.001 | 0.001 | 0.43 | <.05 | <.001 | 0.043 | <.005 | 0.002 | 0.001 | <.005 | 0.56 | nr | 16 | <.001 | <.001 | <.001 | <.001 | 0.002 | 0.003 | 0.007 | 0.024 |
| **TS-53** | 0.002 | <0.001 | 0.003 | 0.12 | <0.001 | 0.045 | 0.03 | <0.001 | 0.004 | <0.001 | 0.004 | 0.52 | <0.010 | <0.001 | 0.066 | <0.001 | 0.002 | 0.000 | 0.001 | 0.70 | 16 | <0.001 | 0.70 | <0.001 | <0.001 | <0.001 | 0.001 | 0.002 | 0.015 | <0.001 |
| **TS-53** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **TS-53** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **TS-87b** | 0.066 | <.005 | 0.01 | 0.073 | <.001 | 0.16 | 0.03 | <.001 | 0.009 | <.001 | 0.002 | 0.89 | <.05 | <.001 | 0.18 | <.005 | 0.004 | <.001 | <.005 | 0.01 | nr | 12 | <.001 | <.001 | <.001 | <.001 | 0.004 | 0.006 | 0.017 | 0.013 |
| **TS-57** | <0.001 | <0.001 | 0.019 | 0.117 | <0.001 | 0.09 | 0.04 | <0.001 | 0.004 | <0.001 | 0.004 | 0.39 | <0.01 | <0.00 | 0.065 | <0.001 | 0.003 | 0.002 | 0.001 | 0.57 | 23 | <0.001 | 0.570 | <0.001 | <0.001 | <0.001 | 0.003 | 0.008 | 0.054 | <0.00 |

# APPENDIX A

**Geochemical data sheets for Rio Grande gorge spring analyses** **14 pages**

BETA

**BETA ANALYTIC INC.**

DR. M.A. TAMERS and MR. D.G. HOOD

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# REPORT OF RADIOCARBON DATING ANALYSES

Dr. Stacy Timmons — Report Date: 7/26/2007

New Mexico Bureau of Geology — Material Received: 6/26/2007

| Sample Data | Apparent C14 Age (fraction modern) | C13/C12 Ratio |
|---|---|---|
| Beta - 232037 | 14900 +/- 80 BP (Fmdn 0.1564 +/- 0.0016) | -9.6 o/oo |

SAMPLE : TS-53
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (water DIC): carbonate precipitation

| Sample Data | Apparent C14 Age (fraction modern) | C13/C12 Ratio |
|---|---|---|
| Beta - 232038 | 18850 +/- 100 BP (Fmdn 0.0957 +/- 0.0012) | -8.4 o/oo |

SAMPLE : TS-54
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (water DIC): carbonate precipitation

| Sample Data | Apparent C14 Age (fraction modern) | C13/C12 Ratio |
|---|---|---|
| Beta - 232039 | 3440 +/- 40 BP (Fmdn 0.6514 +/- 0.0032) | -12.6 o/oo |

SAMPLE : TS-57
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (water DIC): carbonate precipitation

| Sample Data | Apparent C14 Age (fraction modern) | C13/C12 Ratio |
|---|---|---|
| Beta - 232040 | 7670 +/- 50 BP (Fmdn 0.3847 +/- 0.0024) | -11.4 o/oo |

SAMPLE : TS-56
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (water DIC): carbonate precipitation

Dates are reported as RCYBP (radiocarbon years before present, "present" = 1950A.D.). By International convention, the modern reference standard was 95% of the C14 content of the National Bureau of Standards' Oxalic Acid & calculated using the Libby C14 half life (5568 years). Quoted errors represent 1 standard deviation statistics (68% probability) & are based on combined measurements of the sample, background, and modern reference standards.

Measured C13/C12 ratios were calculated relative to the PDB-1 international standard and the RCYBP ages were normalized to -25 per mil. If the ratio and age are accompanied by an (*), then the C13/C12 value was estimated, based on values typical of the material type. The quoted results are NOT calibrated to calendar years. Calibration to calendar years should be calculated using the Conventional C14 age.

BETA

**BETA ANALYTIC INC.**

DR. M.A. TAMERS and MR. D.G. HOOD

UNIVERSITY BRANCH
4985 S.W. 74 COURT
MIAMI, FLORIDA, USA 33155
PH: 305/667-5167 FAX: 305/663-0964
E-MAIL: beta@radiocarbon.com

# REPORT OF RADIOCARBON DATING ANALYSES

Dr. Stacy Timmons

Report Date: 6/21/2007

New Mexico Bureau of Geology

Material Received: 5/21/2007

| Sample Data | Apparent C14 Age (fraction modern) | C13/C12 Ratio |
|---|---|---|
| Beta - 230815 | 4400 +/- 40 BP (Fmdn 0.5790 +/- 0.0030) | -10.6 o/oo |

SAMPLE : TS-61 FELSENMEERE
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (water DIC): carbonate precipitation

Dates are reported as RCYBP (radiocarbon years before present, "present" = 1950A.D.). By International convention, the modern reference standard was 95% of the C14 content of the National Bureau of Standards' Oxalic Acid & calculated using the Libby C14 half life (5568 years). Quoted errors represent 1 standard deviation statistics (68% probability) & are based on combined measurements of the sample, background, and modern reference standards.

Measured C13/C12 ratios were calculated relative to the PDB-1 international standard and the RCYBP ages were normalized to -25 per mil. If the ratio and age are accompanied by an (*), then the C13/C12 value was estimated, based on values typical of the material type. The quoted results are NOT calibrated to calendar years. Calibration to calendar years should be calculated using the Conventional C14 age.

UNIVERSITY OF
Miami
THE ROSENSTIEL SCHOOL

June 28, 2007

TRITIUM LABORATORY

Data Release #07-074
Job # 2341

NEW MEXICO BUREAU OF GEOLOGY AND MINERAL RESOURCES
TRITIUM SAMPLES

for James D. Happell / 

Dr. James D. Happell
Associate Research Professor

Distribution:
Stacy Timmons
NM Bureau of Geology at NM Tech
801 Leroy Place
Socorro, NM 87801

Rosenstiel School of Marine and Atmospheric Science
Tritium Laboratory
4600 Rickenbacker Causeway • Miami, Florida 33149-1098
Phone: 305-421-4100 • Fax: 305- 421-4112
E-mail: tritium@rsmas.miami.edu
www.rsmas.miami.edu/groups/tritium/

Revised 1 January 2002

## GENERAL COMMENTS ON TRITIUM RESULTS

### Tritium Scale New Half-life

Tritium concentrations are expressed in TU, where 1 TU indicates a T/H abundance ratio of $10^{-18}$. The values refer to the tritium scale recommended by U.S. National Institute of Science and Technology (NIST, formerly NBS), and International Atomic Energy Agency (IAEA). The TU-numbers are based on the NIST tritium water standard #4926E. Age corrections and conversions are made using the recommended half-life of **12.32 years**, i.e., a decay rate of $\lambda$ = 5.626% year$^{-1}$. In this scale, 1 TU is equivalent to 7.151 dpm/kg $H_2O$, or 3.222 pCi/kg $H_2O$, or 0.1192 Bq/kg $H_2O$ (Bq = disint/sec).

TU values are calculated for date of sample collection, REFDATE in the table, as provided by the submitter. If no such date is available, date of sample arrival at our laboratory is used.

The stated errors, eTU, are one standard deviation (1 sigma) including all conceivable contributions. In the table, QUANT is quantity of sample received, and ELYS is the amount of water taken for electrolytic enrichment. DIR means direct run (no enrichment).

Remark: From 1 Jan 1994 through 31 Dec 2001 we used the previously recommended value for the half-life, 12.43 years. The use of the new number, 12.32 years will in practice increase the reported TU-values by 0.9 %. This is insignificant since our reported values carry 1 sigma uncertainties of 3 % or more.

It is interesting to note that before 1994 we used the older, then recommended value of 12.26 years.

### Very low tritium values

In some cases, negative TU values are listed. Such numbers can occur because the net tritium count rate is, in principle the difference between the count rate of the sample and that of a tritium-free sample (background count or blank sample). Given a set of "unknown" samples with no tritium, the distribution of net results should become symmetrical around 0 TU. The negative values are reported as such for the benefit of allowing the user unbiased statistical treatment of sets of the data. For other applications, 0 TU should be used.

### Additional information

Refer to Services Rendered (Tritium), Section II.8, in the "Tritium Laboratory Price Schedule; Procedures and Standards; Advice on Sampling", and our Web-site www.rsmas.edu/groups/tritium.

Tritium efficiencies and background values are somewhat different in each of the nine counters and values are corrected for cosmic intensity, gas pressure and other parameters. For tritium, the efficiency is typically 1.00 cpm per 100 TU (direct counting). At 50× enrichment, the efficiency is equivalent to 1.00 cpm per 2.4 TU. The background is typically 0.3 cpm, known to about ± 0.02 cpm. Our reported results include not only the Poisson statistics, but also other experimental uncertainties such as enrichment error, etc.

End

Purchase Order: DP044454

Client: NM BUREAU GEOLOGY, NM TECH
Recvd : 07/05/17
Job# : 2341
Final : 07/06/26

Contact: S. Timmons, 505/835-6951
801 Leroy Place
Socorro, NM 87801

| Cust | LABEL INFO | JOB.SX | REFDATE | QUANT | ELYS | TU | eTU |
|---|---|---|---|---|---|---|---|
| NM - | TS-29b | 2341.01 | 061102 | 1000 | 175 | 4.51 | 0.18 |
| NM - | TS-4 | 2341.02 | 060828 | 1000 | 275 | 0.46 | 0.09 |
| NM - | TS-16b | 2341.03 | 060831 | 1000 | 275 | 0.60 | 0.09 |
| NM - | TS-17 | 2341.04 | 060831 | 1000 | 275 | 0.02 | 0.09 |
| NM - | TS-18 | 2341.05 | 060901 | 1000 | 275 | 4.03 | 0.13 |
| NM - | TS-19 | 2341.06 | 060901 | 1000 | 275 | 0.60 | 0.09 |
| NM - | TS-49 | 2341.07 | 061103 | 1000 | 275 | -0.02 | 0.09 |
| NM - | TS-40 | 2341.08 | 061103 | 1000 | 275 | 0.02 | 0.09 |

UNIVERSITY OF
# Miami
THE ROSENSTIEL SCHOOL

April 2, 2007

TRITIUM LABORATORY

Data Release #07-029
Job # 2300

NEW MEXICO BUREAU OF GEOLOGY AND MINERAL RESOURCES
TRITIUM SAMPLES

Dr. James D. Happell
Associate Research Professor

Distribution:
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NM Bureau of Geology at NM Tech
801 Leroy Place
Socorro, NM 87801

Rosenstiel School of Marine and Atmospheric Science
Tritium Laboratory
4600 Rickenbacker Causeway • Miami, Florida 33149-1098
Phone: 305-421-4100 • Fax: 305- 421-4112
E-mail: tritium@rsmas.miami.edu
www.rsmas.miami.edu/groups/tritium/

Revised 1 January 2002

## GENERAL COMMENTS ON TRITIUM RESULTS

### Tritium Scale New Half-life

Tritium concentrations are expressed in TU, where 1 TU indicates a T/H abundance ratio of $10^{-18}$. The values refer to the tritium scale recommended by U.S. National Institute of Science and Technology (NIST, formerly NBS), and International Atomic Energy Agency (IAEA). The TU-numbers are based on the NIST tritium water standard #4926E. Age corrections and conversions are made using the recommended half-life of **12.32 years**, i.e., a decay rate of $\lambda = 5.626\%$ $year^{-1}$. In this scale, 1 TU is equivalent to 7.151 dpm/kg $H_2O$, or 3.222 pCi/kg $H_2O$, or 0.1192 Bq/kg $H_2O$ (Bq = disint/sec).

TU values are calculated for date of sample collection, REFDATE in the table, as provided by the submitter. If no such date is available, date of sample arrival at our laboratory is used.

The stated errors, eTU, are one standard deviation (1 sigma) including all conceivable contributions. In the table, QUANT is quantity of sample received, and ELYS is the amount of water taken for electrolytic enrichment. DIR means direct run (no enrichment).

Remark: From 1 Jan 1994 through 31 Dec 2001 we used the previously recommended value for the half-life, 12.43 years. The use of the new number, 12.32 years will in practice increase the reported TU-values by 0.9 %. This is insignificant since our reported values carry 1 sigma uncertainties of 3 % or more.

It is interesting to note that before 1994 we used the older, then recommended value of 12.26 years.

### Very low tritium values

In some cases, negative TU values are listed. Such numbers can occur because the net tritium count rate is, in principle the difference between the count rate of the sample and that of a tritium-free sample (background count or blank sample). Given a set of "unknown" samples with no tritium, the distribution of net results should become symmetrical around 0 TU. The negative values are reported as such for the benefit of allowing the user unbiased statistical treatment of sets of the data. For other applications, 0 TU should be used.

### Additional information

Refer to Services Rendered (Tritium), Section II.8, in the "Tritium Laboratory Price Schedule; Procedures and Standards; Advice on Sampling", and our Web-site www.rsmas.edu/groups/tritium.

Tritium efficiencies and background values are somewhat different in each of the nine counters and values are corrected for cosmic intensity, gas pressure and other parameters. For tritium, the efficiency is typically 1.00 cpm per 100 TU (direct counting). At 50x enrichment, the efficiency is equivalent to 1.00 cpm per 2.4 TU. The background is typically 0.3 cpm, known to about ± 0.02 cpm. Our reported results include not only the Poisson statistics, but also other experimental uncertainties such as enrichment error, etc.

End

Client: NM BUREAU GEOLOGY, NM TECH
Recvd : 06/12/08
Job# : 2300
Final : 07/03/29

Purchase Order: DP035458
Contact: S. Timmons, 505/835-6951
801 Leroy Place
Socorro, NM 87801

| Cust LABEL INFO | | JOB.SX | REFDATE | QUANT | ELYS | TU | eTU |
|---|---|---|---|---|---|---|---|
| NM BUREAU GEOLOGY - | TS-8 | 2300.01 | 060829 | 1000 | 275 | 0.09 | 0.09 |
| NM BUREAU GEOLOGY - | TS-25 | 2300.02 | 060830 | 1000 | 275 | 0.02 | 0.09 |
| NM BUREAU GEOLOGY - | TS-14A | 2300.03 | 060830 | 1000 | 275 | -0.03 | 0.09 |

UNIVERSITY OF MIAMI
THE ROSENSTIEL SCHOOL

June 21, 2007

TRITIUM LABORATORY

Data Release #CFC07-03

NEW MEXICO BUREAU OF GEOLOGY AND MINERAL RESOURCES
CFC-039

Dr. James D. Happell
Associate Research Professor

Distribution:
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NM Bureau of Geology at NM Tech
801 Leroy Place
Socorro, NM 87801

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E-mail: tritium@rsmas.miami.edu
www.rsmas.miami.edu/groups/tritium/

## General Comments on CFC Results

All CFC concentrations are reported on the SIO1998 absolute calibration scale (Prinn et al., 2000). The atmospheric histories of the CFCs were obtained from Prinn et al. (2000). The temperature, salinity, pressure dependent CFC solubilities were obtained from Warner and Weiss (1985) and Bu and Warner (1995).

In general, CFC-12 derived recharge ages are the best age estimates to use. Both CFC-11 and CFC-113 atmospheric concentrations have leveled off or started to decrease since the early to mid 1990s, making more than one derived recharge age possible. CFC-12 atmospheric concentrations continued to increase until 2003, but are now slowly decreasing. CFC-11 is known to be degraded in water under sub-oxic and anoxic conditions, frequently leading to older CFC-11 derived recharge ages when compared to CFC-12 derived recharge ages.

The equivalent atmospheric concentration given in the enclosed data release is the calculated atmospheric concentration that the water sample would be in equilibrium with at the given recharge temperature and recharge elevation (i.e. atmospheric pressure). The atmospheric pressure at the given recharge elevation was estimated with the following expression:

$$\ln P = -H/8300$$

where P is the pressure in atmospheres and H is the elevation in meters. Also included in the data release is the present average atmospheric concentration of the 3 CFCs. Local variations in the atmospheric concentration of the CFCs can occur, especially if the sampling location is close to industrial or urban areas.

When the CFC peak area in an unknown sample is greater than the largest CFC peak area used in the calibration curve the water concentration will be listed as > the maximum quantifiable value and the words "out of range" will appear in the equivalent atmospheric concentration and CFC-derived recharge age columns.

When the calculated equivalent atmospheric concentration is above present day atmospheric concentration of a given CFC the word supersaturated will appear in the CFC-derived recharge age column. Ages cannot be derived when the CFC's are supersaturated, because this means that the atmosphere is not the sole source of CFC's to the aquifer. Please remember that the greatest expected CFC concentrations, if equilibrium with the atmosphere is the only source of CFC's to the aquifer, is on the order of 10,000 times less than the current drinking water standards for the CFC's. Even though a volatile organic drinking water analysis may have shown undetectable amounts of the CFC's, it is still possible that CFC contamination may be present and the CFC's will be supersaturated with respect to equilibrium with the atmosphere. Out of range values also indicate the CFC's are supersaturated.

References

Bu, X., and M.J. Warner, Solubility of chlorofluorocarbon 113 in water and seawater, Deep-Sea Res. I, 42, 1151-1161, 1995.

Prinn R.G., et al., A history of chemically and radiatively important gases in air deduced from ALE/GAGE/AGAGE, J. Geophys. Res., 105(D14) 17751-17792, 2000.

Warner, M.J. and R.F. Weiss, Solubilities of chlorofluorocarbons 11 and 12 in water and seawater, Deep-Sea Res., 32, 1485-1497, 1985.

**Data Release CFC07-03, Job # CFC0039**

New Mexico Bureau of Geology and Mineral Resources
801 Leroy Place
Socorron, NM 87801

Atten: Stacy Timmons
505-835-6951
stacy@gis.nmt.edu

| Lab ID# | Bottle | Well | Samp. Date | Arrive Date | Anal. Date | Recharge Elev. (m) | Recharge Temp oC | Water Concentration Corrected for Stripping Efficiency CFC12 pmol/Kg | error pmol/Kg | CFC11 pmol/Kg | error pmol/Kg | CFC113 pmol/Kg | error pmol/Kg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0039.01 | 1 | TS-36 | 11/3/06 | 5/17/07 | 6/8/07 | 2195 | 4.40 | 0.102 | 0.010 | 0.276 | 0.006 | 0.006 | 0.010 |
| 0039.01D | 2 | TS-36 | 11/3/06 | 5/17/07 | 6/8/07 | 2195 | 4.40 | 0.071 | 0.010 | 0.196 | 0.005 | 0.002 | 0.010 |
| 0039.01D2 | 3 | TS-36 | 11/3/06 | 5/17/07 | 6/8/07 | 2195 | 4.40 | 0.053 | 0.010 | 0.128 | 0.005 | 0.001 | 0.010 |

D in column one indicates duplicate sample,
there is no charge for this analysis.

Detection limit for CFC-12 and CFC-113 is 0.010 pmol/Kg
Detection limit for CFC-11 is 0.005 pmol/Kg

| Lab ID# | Bottle | Well | Samp. Date | Arrive Date | Anal. Date | Recharge Elev. (m) | Recharge Temp oC | Equivalent Atmospheric Concentration CFC12 pmol/mol | error pmol/mol | CFC11 pmol/mol | error pmol/mol | CFC113 pmol/mol | error pmol/mol |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0039.01 | 1 | TS-36 | 11/3/06 | 5/17/07 | 6/8/07 | 2195 | 4.40 | 18.3 | 1.8 | 12.4 | 0.2 | Below Detection Limit | |
| 0039.01D | 2 | TS-36 | 11/3/06 | 5/17/07 | 6/8/07 | 2195 | 4.40 | 12.7 | 1.8 | 8.8 | 0.2 | Below Detection Limit | |
| 0039.01D2 | 3 | TS-36 | 11/3/06 | 5/17/07 | 6/8/07 | 2195 | 4.40 | 9.4 | 1.8 | 5.8 | 0.2 | Below Detection Limit | |

D in column one indicates duplicate sample,
there is no charge for this analysis.

current atmospheric value for CFC-12 is ~ 544 pmol/mol
max. atmospheric value for CFC-12 was ~ 546 pmol/mol in 2003
current atmospheric value for CFC-11 is ~ 250 pmol/mol
max. atmospheric value for CFC-11 was ~ 272 pmol/mol in 1994
current atmospheric value for CFC-113 is ~ 79 pmol/mol
max. atmospheric value for CFC-113 was ~ 85 pmol/mol in 1994

| Lab ID# | Bottle | Well | Samp. Date | Arrive Date | Anal. Date | Recharge Elev. (m) | Recharge Temp oC | CFC-Derived Recharge Age In years before sampling date CFC12 years | error years | CFC11 years | error years | CFC113 years | error years |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0039.01 | 1 | TS-36 | 11/3/06 | 5/17/07 | 6/8/07 | 2195 | 4.40 | 52 | 2 | 47 | 2 | Below Detection Limit | |
| 0039.01D | 2 | TS-36 | 11/3/06 | 5/17/07 | 6/8/07 | 2195 | 4.40 | 54 | 2 | 49 | 2 | Below Detection Limit | |
| 0039.01D2 | 3 | TS-36 | 11/3/06 | 5/17/07 | 6/8/07 | 2195 | 4.40 | 55 | 2 | 51 | 2 | Below Detection Limit | |

D in column one indicates duplicate sample,
there is no charge for this analysis.

UNIVERSITY OF MIAMI
THE ROSENSTIEL SCHOOL

December 28, 2006

TRITIUM LABORATORY

Data Release #CFC06-09

NEW MEXICO BUREAU OF GEOLOGY AND MINERAL RESOURCES
CFC0035

James D. Happell

Dr. James D. Happell
Associate Research Professor

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www.rsmas.miami.edu/groups/tritium/

## General Comments on CFC Results

All CFC concentrations are reported on the SIO1998 absolute calibration scale (Prinn et al., 2000). The atmospheric histories of the CFCs were obtained from Prinn et al. (2000). The temperature, salinity, pressure dependent CFC solubilities were obtained from Warner and Weiss (1985) and Bu and Warner (1995).

In general, CFC-12 derived recharge ages are the best age estimates to use. Both CFC-11 and CFC-113 atmospheric concentrations have leveled off or started to decrease since the early to mid 1990s, making more than one derived recharge age possible. CFC-12 atmospheric concentrations continued to increase until 2003, but are now slowly decreasing. CFC-11 is known to be degraded in water under sub-oxic and anoxic conditions, frequently leading to older CFC-11 derived recharge ages when compared to CFC-12 derived recharge ages.

The equivalent atmospheric concentration given in the enclosed data release is the calculated atmospheric concentration that the water sample would be in equilibrium with at the given recharge temperature and recharge elevation (i.e. atmospheric pressure). The atmospheric pressure at the given recharge elevation was estimated with the following expression:

$$\ln P = -H/8300$$

where P is the pressure in atmospheres and H is the elevation in meters. Also included in the data release is the present average atmospheric concentration of the 3 CFCs. Local variations in the atmospheric concentration of the CFCs can occur, especially if the sampling location is close to industrial or urban areas.

When the CFC peak area in an unknown sample is greater than the largest CFC peak area used in the calibration curve the water concentration will be listed as > the maximum quantifiable value and the words "out of range" will appear in the equivalent atmospheric concentration and CFC-derived recharge age columns.

When the calculated equivalent atmospheric concentration is above present day atmospheric concentration of a given CFC the word supersaturated will appear in the CFC-derived recharge age column. Ages cannot be derived when the CFC's are supersaturated, because this means that the atmosphere is not the sole source of CFC's to the aquifer. Please remember that the greatest expected CFC concentrations, if equilibrium with the atmosphere is the only source of CFC's to the aquifer, is on the order of 10,000 times less than the current drinking water standards for the CFC's. Even though a volatile organic drinking water analysis may have shown undetectable amounts of the CFC's, it is still possible that CFC contamination may be present and the CFC's will be supersaturated with respect to equilibrium with the atmosphere. Out of range values also indicate the CFC's are supersaturated.

References

Bu, X., and M.J. Warner, Solubility of chlorofluorocarbon 113 in water and seawater, Deep-Sea Res. I, 42, 1151-1161, 1995.

Prinn R.G., et al., A history of chemically and radiatively important gases in air deduced from ALE/GAGE/AGAGE, J. Geophys. Res., 105(D14) 17751-17792, 2000.

Warner, M.J. and R.F. Weiss, Solubilities of chlorofluorocarbons 11 and 12 in water and seawater, Deep-Sea Res., 32, 1485-1497, 1985.

**Data Release CFC06-09, Job # CFC0035**

New Mexico Bureau of Geology and Mineral Resources
801 Leroy Place
Socorron, NM 87801

Atten: Stacy Timmons
505-835-6951
stacy@gis.nmt.edu

| Lab ID# | Bottle | Well | Samp. Date | Arrive Date | Anal. Date | Recharge Elev. (m) | Recharge Temp oC | Water Concentration Corrected for Stripping Efficiency CFC12 pmol/Kg | error pmol/Kg | CFC11 pmol/Kg | error pmol/Kg | CFC113 pmol/Kg | error pmol/Kg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0035.01 | 1 | TS-31A | 11/2/06 | 12/7/06 | 12/11/06 | 3048.00 | 5.60 | 0.652 | 0.013 | 1.116 | 0.022 | 0.055 | 0.010 |
| 0035.01D | 2 | TS-31A | 11/2/06 | 12/7/06 | 12/11/06 | 3048.00 | 5.60 | 0.698 | 0.014 | 1.100 | 0.022 | 0.050 | 0.010 |
| 0035.01D2 | 3 | TS-31A | 11/2/06 | 12/7/06 | 12/11/06 | 3048.00 | 5.60 | 0.657 | 0.013 | 1.078 | 0.022 | 0.051 | 0.010 |

D in column one indicates duplicate sample,
there is no charge for this analysis.

Detection limit for CFC-12 and CFC-113 is 0.010 pmol/Kg
Detection limit for CFC-11 is 0.005 pmol/Kg

| Lab ID# | Bottle | Well | Samp. Date | Arrive Date | Anal. Date | Recharge Elev. (m) | Recharge Temp oC | Equivalent Atmospheric Concentration CFC12 pmol/mol | error pmol/mol | CFC11 pmol/mol | error pmol/mol | CFC113 pmol/mol | error pmol/mol |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0035.01 | 1 | TS-31A | 11/2/06 | 12/7/06 | 12/11/06 | 3048.00 | 5.60 | 138.2 | 2.8 | 59.8 | 1.2 | 9.3 | 1.7 |
| 0035.01D | 2 | TS-31A | 11/2/06 | 12/7/06 | 12/11/06 | 3048.00 | 5.60 | 148.1 | 3.0 | 59.0 | 1.2 | 8.4 | 1.7 |
| 0035.01D2 | 3 | TS-31A | 11/2/06 | 12/7/06 | 12/11/06 | 3048.00 | 5.60 | 139.3 | 2.8 | 57.8 | 1.2 | 8.6 | 1.7 |

D in column one indicates duplicate sample,
there is no charge for this analysis.

current atmospheric value for CFC-12 is ~ 544 pmol/mol
max. atmospheric value for CFC-12 was ~ 546 pmol/mol in 2003
current atmospheric value for CFC-11 is ~ 250 pmol/mol
max. atmospheric value for CFC-11 was ~ 272 pmol/mol in 1994
current atmospheric value for CFC-113 is ~ 79 pmol/mol
max. atmospheric value for CFC-113 was ~ 85 pmol/mol in 1994

| Lab ID# | Bottle | Well | Samp. Date | Arrive Date | Anal. Date | Recharge Elev. (m) | Recharge Temp oC | CFC-Derived Recharge Age In years before sampling date CFC12 years | error years | CFC11 years | error years | CFC113 years | error years |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0035.01 | 1 | TS-31A | 11/2/06 | 12/7/06 | 12/11/06 | 3048.00 | 5.60 | 36 | 2 | 37 | 2 | 33 | 2 |
| 0035.01D | 2 | TS-31A | 11/2/06 | 12/7/06 | 12/11/06 | 3048.00 | 5.60 | 36 | 2 | 37 | 2 | 34 | 2 |
| 0035.01D2 | 3 | TS-31A | 11/2/06 | 12/7/06 | 12/11/06 | 3048.00 | 5.60 | 36 | 2 | 37 | 2 | 33 | 2 |

D in column one indicates duplicate sample,
there is no charge for this analysis.

New Mexico Bureau of Geology and Mineral Resources

A Division of New Mexico Institute of Mining and Technology

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