7-3-2008

Water resources assessment of the Sapello River

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June 2008

Preface

Water Resources 573, Field Methods, is a class taught each summer in the Water Resources program at the University of New Mexico (www.unm.edu/~wrp). The purpose of this class is to introduce students in the program to methods used in water resources investigations and includes field measurements of hydrologic parameters, field and laboratory analyses of water quality characteristics, and methods of collecting and interpreting information on water resources policies and management in a particular watershed.

The subject of the WR 573 class during the summer of 2008 was the Sapello River in San Miguel county of northern New Mexico. The class was taught by Bruce Thomson (Director, Water Resources Program) and Abdulmehdi Ali (Department of Earth and Planetary Sciences). Questions regarding this report should be directed to Bruce Thomson (bthomson@unm.edu).

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Acknowledgements

The students of the WR573 class express their appreciation to everyone who made this project possible. Each of the interviewees mentioned below provided invaluable historical and personal context. The generosity and hard work of Bruce Thomson, Dr. Abdul-Mehdi Ali, Dr. Enrique LaMadrid, Ken Smith, Amina Sena, David Blagg, and Grant Mitchell provided assistance and support that allowed the project to proceed smoothly and rapidly. Special thanks are due to Sterling Grogan, Anne Watkins, and the Biophilia Foundation for providing a place to stay and information about the Sapello River and its culture and history.

Introduction

The Sapello river originates in the Sangre de Cristo mountains in San Miguel County of northern New Mexico and flows east for 27.3 miles to Watrous, NM where it joins the Mora river. The Mora River is a tributary to the Canadian River. The Sapello River was the subject of an intensive three week study by the Water Resources 573, Field Methods class from the University of New Mexico in May and June, 2008. The main objective of the study was to conduct a stream assessment of the Sapello River that will serve as a baseline for future work.

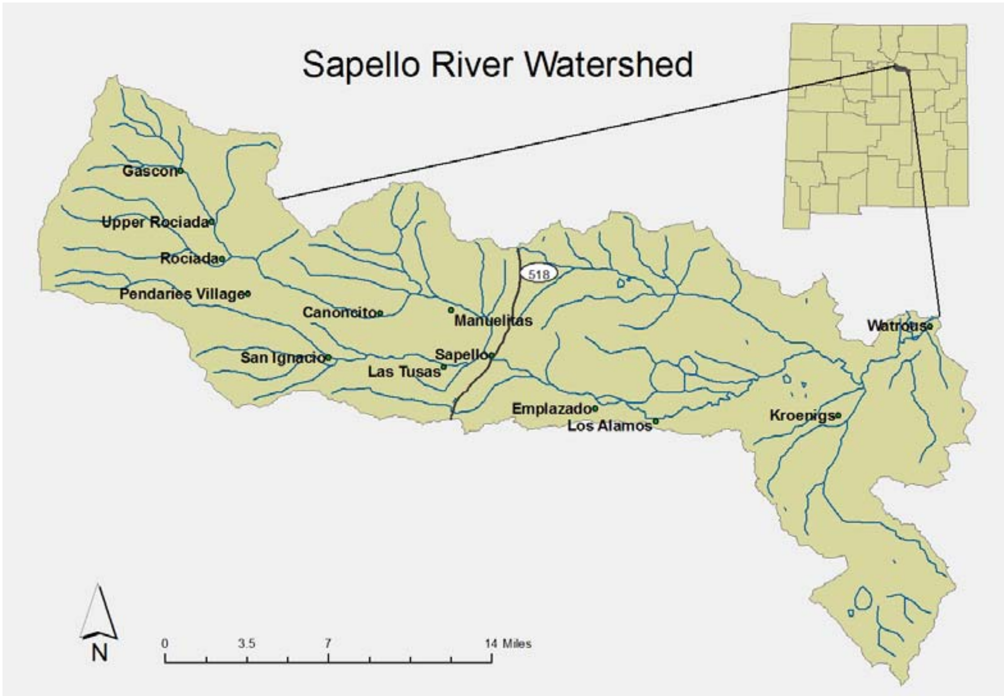

Figure 1. Map of the Sapello River watershed

Work on the river began with an evaluation of previous projects completed on the Sapello River. This work included assessments by the New Mexico Environment Department, Surface Water Quality Bureau (SWQB, 2007), the New Mexico Forest and Watershed Restoration Institution (NWFWRI), and a Master's Thesis recently completed by Sena (2008) at New Mexico Highlands University, Las Vegas, NM. A week of field research evaluating physical, hydrological and biological characteristics was conducted along the length of the river. Water samples were collected and analyzed for chemical parameters indicative of the quality of the river and ground water in the valley. All data was compiled and analyzed in order to assess the state of the river with respect to its environmental conditions and ability to meet the designated uses identified in the NM stream standard (SWQB, 2007). Future management and monitoring recommendations were then developed.

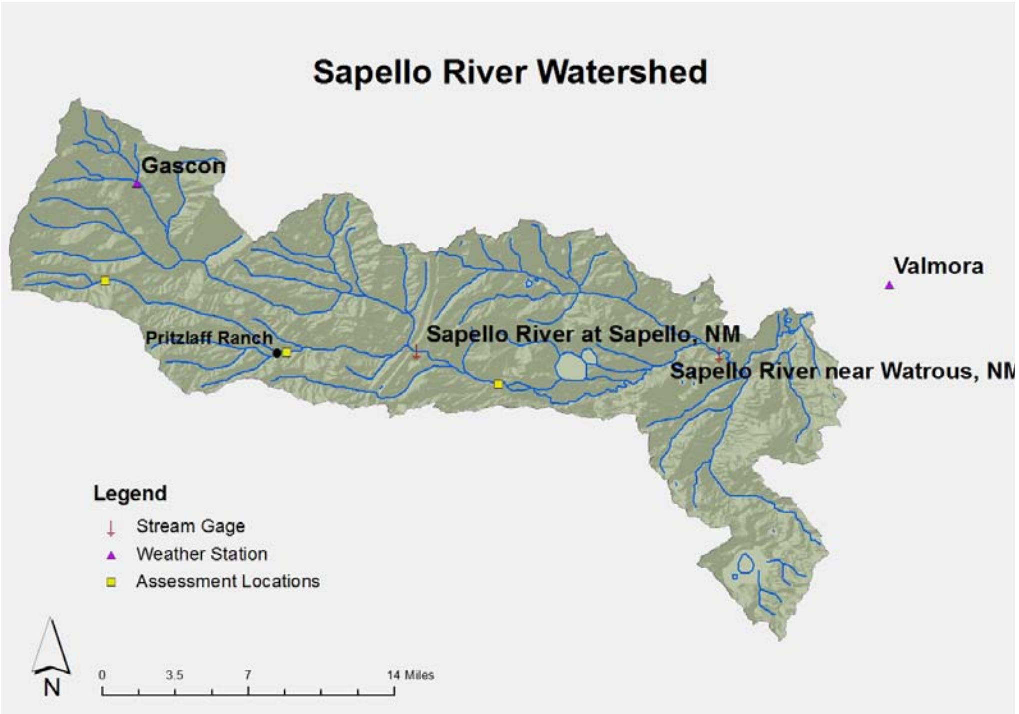

Figure 2. Location of stream assessment sites, weather stations, and historic stream gages.

Pritzlaff Ranch Background

The investigation was centered at the Pritzlaff Ranch, which was also the location of the field camp. The Pritzlaff Ranch consists of 3300 acres of meadows and forest land that is owned by the Biophilia Foundation, a private foundation that supports efforts to protect, restore, enhance and preserve wildlife habitat. Richard Pritzlaff purchased 2000 acres in 1934 to create the ranch and expanded the property to its current size through subsequent land acquisitions (Biophilia Foundation, 2004). In 1997, he donated the land to the Nature Conservancy which enacted a conservation easement upon it and subsequently sold it to the Biophilia Foundation in 2000 (Grogan, 2008). The ranch is currently being managed to develop and demonstrate forest, conservation and watershed management practices in Northern NM. The current ranch manager, Sterling Grogan, has extensive experience in range and watershed management in NM and elsewhere.

The Prizlaff Ranch has a rich heritage that evolved into an important role in the economy, culture, and watershed management in the Sapello valley for over 70 years. A significant aspect of the ranch's heritage was Richard Pritzlaff's use of the property to breed Arabian horses, and Pritzlaff Arabians are internationally recognized as an important bloodline of this breed. Through this activity he became one of the early land owners in the valley to recognize the beauty and value of the natural environment and the need to protect it for posterity." In addition to its function as a center for forest and watershed research, the ranch buildings also house a series of pueblo frescos by painter Ma Pe Wei (Grogan, 2008; Biophilia Foundation, 2004).

Watershed Issues

Sedimentation/Siltation

Under the Clean Water Act, each state must identify the designated uses of each reach of stream within its boundaries. The states must then develop numeric and descriptive criteria which are relevant to and protective of these uses. The New Mexico Water Quality Act delegates this responsibility to the NM Water Quality Control Commission. Different water bodies are assigned various designated uses which are dependent on their characteristics. Some factors that go into this determination are current use, historical use, and the climate of the area. The designated uses for the Sapello River are (20.6.4.307 NMAC): marginal coldwater aquatic life, warmwater aquatic life, secondary contact, irrigation, livestock watering and wildlife habitat.. This is defined as waters where "natural intermittent or low flows, or other natural habitat conditions severely limit maintenance of coldwater aquatic life populations or historical data indicate that the maximum temperature in the surface water of the state may exceeded 25°C (77° F)."

Descriptive criteria for these designated uses are (20.6.4.7 NMAC):

"Marginal coldwater" in reference to an aquatic life use means that natural intermittent or low flows, or other natural habitat conditions severely limit maintenance of a coldwater aquatic life population or historical data indicate that the maximum temperature in the surface water of the state may exceed 25°C (77°F).

"Warmwater" with reference to an aquatic life use means that water temperature and other characteristics are suitable for the support or propagation or both of warmwater aquatic life.

"Secondary contact" means any recreational or other water use in which human contact with the water may occur and in which the probability of ingesting appreciable quantities of water is minimal, such as fishing, wading, commercial and recreational boating and any limited seasonal contact.

"Wildlife habitat" means a surface water of the state used by plants and animals not considered as pathogens, vectors for pathogens or intermediate hosts for pathogens for humans or domesticated livestock and plants.

"Livestock watering" means the use of a surface water of the state as a supply of water for consumption by livestock.

The Surface Water Quality Bureau of the New Mexico Environment Department has surveyed the Mora River and its tributaries and determined that the major Sapello River water quality issue on the Sapello River is excessive sedimentation/siltation (SWQB, 2007). Under section 303d of the Clean Water Act, states are required to develop Total Daily Maximum Load (TDML) management plans for impaired water bodies (SWQB, 2007). "A TMDL documents the amount of a pollutant a water body can assimilate without violating a state's water quality standards. It also allocates the load capacity to known point sources and non-point sources at a given flow" (SQWB, 2007). The TDML is broken into Waste Level Allocations for point sources and Load Allocation (LA) for non-point sources, with an added Margin of Safety (MOS) to account for uncertainty (SWQB, 2007). As there are no permitted wastewater discharges to the Sapello River, the TDML establishes a LA of 60.6 lbs/day and a MOS of 20.2 lbs/day for a total TDML

of 80.8 lbs/day of sediment. The NMED has determined that the Sapello River exceeds this loading.

This problem was first determined in a 2002 survey of the entire Canadian Watershed by the NMED SWQB. In 2007, a final TDML for various water quality parameters was published. The survey sampled four locations on the Sapello: (1) a quarter-mile inside the Mosimann Ranch gates, (2) at San Ignacio, (3) at Highway 518, and (4) at Highway 161 (near Watrous). The Sedimentation/Siltation TDML was determined by numeric criteria or narrative standards that could be translated into specific standards and criteria as well as factors relating to the ability to monitor and quantify results of management strategies (SWQB, 2007). The narrative standard used was New Mexico Standard for Interstate and Intrastate Surface Waters for bottom deposits and suspended settled solids (20.6.4.13 NMAC). Further information about how the TDML was reached for New Mexico streams including for the Sapello River is available in Section 7 of the SWQB report (SWQB, 2007).

Clean stream bottoms are important for most cold water and many warm water aquatic organisms. High sediment loads degrade the aquatic habitat by leading to filling of ponds, accumulation of silt in bottom sand and gravel deposits, and reduced light penetration due to high turbidity. Sediment loads also contribute to changes in stream geomorphology. Human activities which contribute to high sediment loads include over grazing with subsequent soil erosion, construction activities in and near the stream, traffic on unpaved roads near the stream, and clearing of riparian vegetation by anthropogenic activities and by grazing animals. The 2007 SWQB report promulgating the final TDMLs concluded that non-point sedimentation and siltation was the main source of impairment of the Sapello River.

Social and Economic Characteristics

Primary water uses in the study area are cattle and horse ranching, irrigation, recreation, and domestic supply. The estimated irrigated agriculture for the Sapello River is 7810 ac-ft/yr (Stephens, 2007). A survey identified 146 residences visible from NM State Road 266 along the portion of the Sapello River between its head waters and Highway 518. A large portion of residences appear to be vacation or seasonal homes. Approximately 86% of the land in the watershed is privately owned with the remainder being federally owned and managed by the U.S. Forest Service (SWQB, 2007).

Because there are no community wastewater collection and treatment systems for communities in the watershed, all residential wastewater is treated and disposed of by on-site wastewater disposal systems. Poorly constructed or failing on-site wastewater disposal systems may cause contamination of surface and ground water resources. Other possible non-point sources of pollution may include recreation, erosion due to poor management practices, and road runoff.

The Sapello River is located within the Mora-San Miguel Water Planning Region. Some of the major issues identified by the regional water plan (NMOSE, 2005) that are relevant

to this study are (1) acequias and irrigation ditches account for 89 % of the region's water depletions (excluding riparian, stream, and reservoir evaporation) and play a major cultural role in the region, (2) uncertain water rights litigation because the watershed has not been adjudicated, (3) surface and ground water quality issues, especially associated with reliance upon on-site wastewater treatment and disposal systems, and (4) data gaps regarding water use, depletions and the extent of ground water resources.

The population of San Miguel County is expected to grow from 29,700 in 2000 to 43,900 (low growth scenario) and 53,900 (high growth scenario) by 2040. Population growth will impact water quality and quantity in the region. It should be noted that these growth scenarios do not include development of vacation and second homes and their consequent impact on the region's water resources (NMOSE, 2005).

Cultural Significance

Agricultural water supply in the region has historically been provided by irrigation ditches and acequias. Acequias are associations that govern members' water usage from community ditches, regulating the amount of water each member receives, maintaining water sharing customs and traditions that have lasted centuries in New Mexico. Historically, acequia associations played an important role in areas with limited access to water by allowing implementation of irrigated agriculture. Acequias in northern NM date to the Spanish colonization period of the 17th and 18th centuries.

Acequias are recognized under New Mexico law as a political subdivision of the state. Often these associations were the first form of local government in isolated communities and provided for the equitable distribution, conveyance, and use of water in the community. In addition to the recognized acequias, there are also several local irrigation ditches that have not sought acequia status. The acequias and community ditches registered with the Office of the State Engineer (OSE) are listed in Table 1.

Table 1. Acequias and community ditches registered with the Office of the State Engineer (Savedra, 1987).

Surface water	Ditch/acequia name	Irrigated acreage
Sapello Creek		
	Rackley Ditch	3
	San Ignacio Ditch	100
	Acequia de Las Tusas	400
	Acequia de Las Chimayosas	350
Sapello River		
	Acequia del Llano	300
	La Molina Ditch	150
Spring Sapello Creek		
	Acequia del Ojo	15
	Total irrigated acreage	1318

Several ditches and acequias that divert water from the Sapello River or its tributaries are no longer considered to be active (Table 2).

Table 2. Inactive acequias and ditches along the Sapello River (NMOSE, 2005).

Surface water	Ditch/acequia name
Manuelitas Creek	
	Le Tegua Ditch
Rociada Creek	
	Rociada Paniente Ditch
	Rociada Oriente Ditch
	Ramirez Creek
Rito Colorado (Deer) Creek	
	Rito Colorado Creek

There are also three ditches on the Sapello River for which declaration of water rights have been filed, but their existence or use had not been confirmed by the OSE (NMOSE, 2005):

- Lower Manuelitas Community Ditch
- Bookout Irrigation Ditch
- Pritzlaff Ditches – confirmed to be present on the Pritzlaff ranch by this study

Adjudication

The Sapello River watershed is currently not adjudicated, and there is not an estimated date for starting the adjudication process. Adjudication is the legal process that formally establishes ownership of water rights, the priority date, and the volume of water associated with each right. This situation leads to uncertainty regarding the current status of surface and ground water rights in the area. Without adjudication the amount of water owned by each water right holder is uncertain and when there are water shortages the impact on each holder is not known. A complicating factor is that much of the new development in the watershed are private residences that are served by private wells. Under current policy, private wells are entitled up to 3 acre-ft/yr of water for domestic use. Though this is a relatively small number, when multiplied by the predicted large growth in the region, domestic water use may become a significant contributor to over allocation of water resources in the valley (Richardson, 2008).

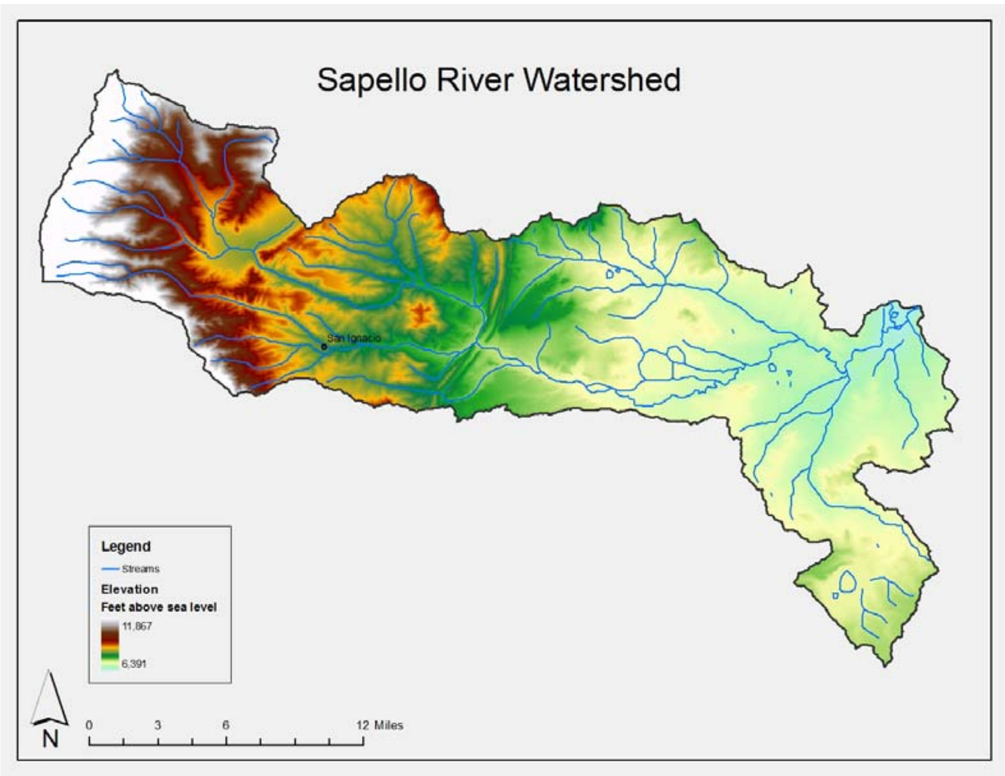

Figure 3. Elevation of Sapello watershed (USGS, 1999).

Physical Description

The Sapello watershed is a sub-basin of the Mora watershed which drains into the Canadian River in northeastern New Mexico. It ultimately drains into the Arkansas-White-Red River Basin, which drains in the Mississippi River. The Sapello watershed is located in San Miguel and Mora counties. The watershed has an area of 294 square miles, with elevation ranging from 6,390 to 11,870 feet above sea level (Figure 3). The watershed is bordered by the Santa Fe Mountains to the west, which includes Spring

Mountain, Lone Pine Mesa, and Hermits Peak. To the east, the topography flattens out and has minimal prominent features which define the watershed boundary. The upper most elevations are located in the west of the watershed as seen in Figure 3. Therefore, the Sapello River flows west to east.

Land cover is characterized by thick conifer forests in the west and rolling grasslands in the east. Land is used for raising cattle or horses, or orchards. The Land Use map shows that land remains undeveloped and is either forested land or grass land (represented as salt flats on the map) (Figure 4).

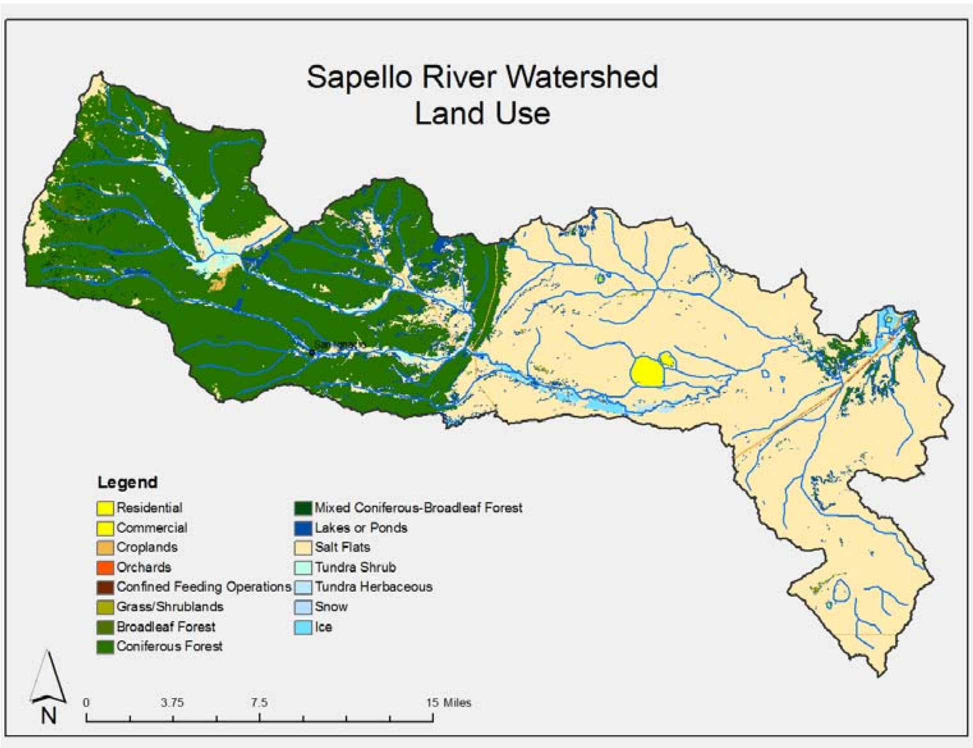

Figure 4. Land use of Sapello watershed (USGS, 2003).

Vegetation Characteristics

The vegetation of the Sapello watershed is Mixed Conifer Forest and Woodland to the west and the Plains Shortgrass Prairie to east (NMGF, 2006). Mixed Conifer Forest and Woodland is a highly patchy mixed conifer forest occurs at elevations ranging from 3,900 feet to 10,800 feet. Douglas fir and white fir provide dominant canopy cover near the headwaters to the west. Spruces and ponderosa pines are dominant closer to San Ignacio. Also present were mixed conifer and aspen stands throughout the valley. The riparian areas in the watershed included trees species like cottonwoods, alders and willow species. Some cold-deciduous shrub and graminoid species include maple, gambel oak, Arizona fescue, etc. Herbaceous species in the watershed include bromes, sedges, and meadow-rue. About 8-10 miles east of San Ignacio is the Plains Shortgrass Prairie, which includes Graminoids of threeawn, grama species, needle and thread, sand dropseed, alkali sacaton,

Junegrass, and wheatgrass. Shrubs in the area include sagebrush, snakeweed, wolfberry and saltbrush (NMGF, 2006) (Figure 5).

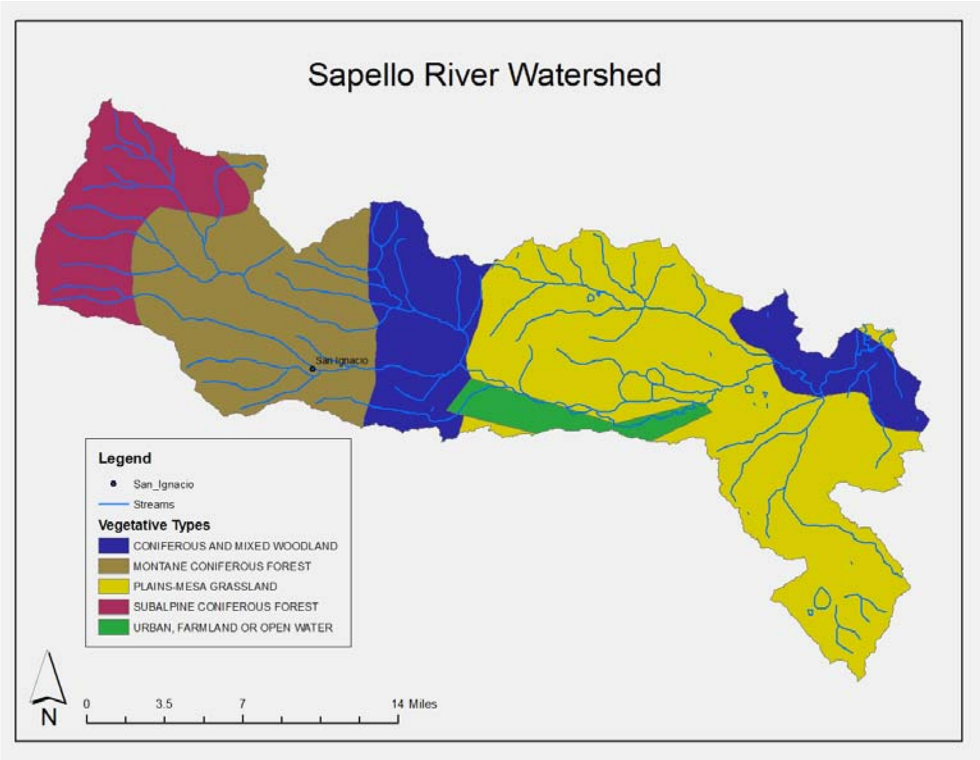

Figure 5. Vegetative types in the Sapello watershed (EDAC, 1991).

Soil Characteristics

Soil characteristics in the Sapello Watershed have about a 20-40 percent clay distribution over the entire watershed (Schwartz and Alexander, 1995). The headwaters have less clay content and more sandy and silty soils. The sandy soils have a composition formed from weathered rocks such as limestone, quartz, and shale. The rest of the watershed had more clay soils. Our watershed assessment did not include a soil analysis (Figure 6).

Hydrologic Characteristics

The hydrologic characteristics of the watershed are determined by the climatic variables of the area which in turn depend primarily on elevation. Changes between the upper and the lower elevations correlate to differences in temperature, precipitation, and evaporation. The Sapello watershed has a NOAA weather station located in the north-west corner of the watershed at an elevation of 8,250 feet above sea level, near the community of Gascon (WRCC, 2008). A second weather station is located approximately 5 miles outside of the eastern boundary of the basin near the community of Valmora (elevation: 6,310 ft.) with correspondingly higher temperatures throughout the year (Figure 7).

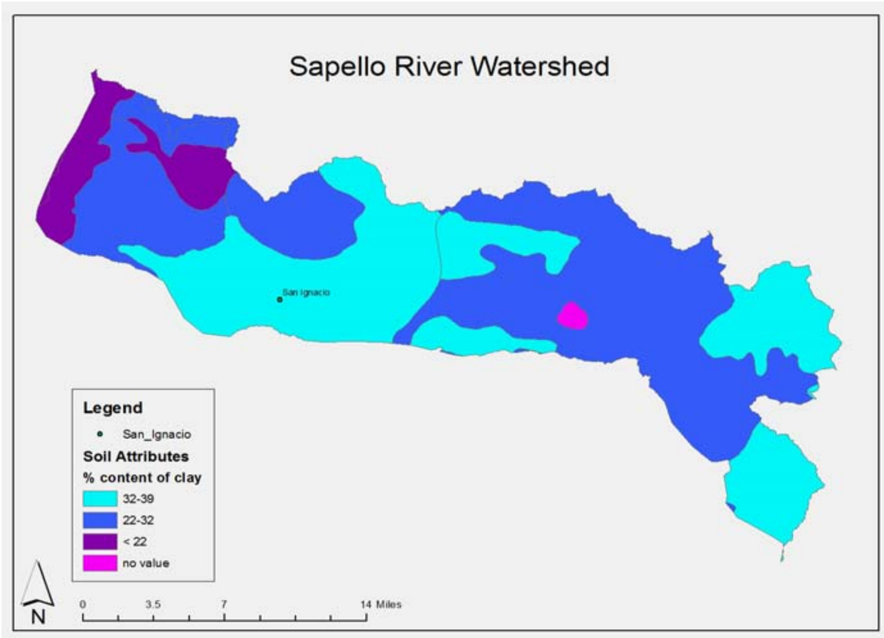

Figure 6. Clay content of watershed soil (Schwartz and Alexander, 1995).

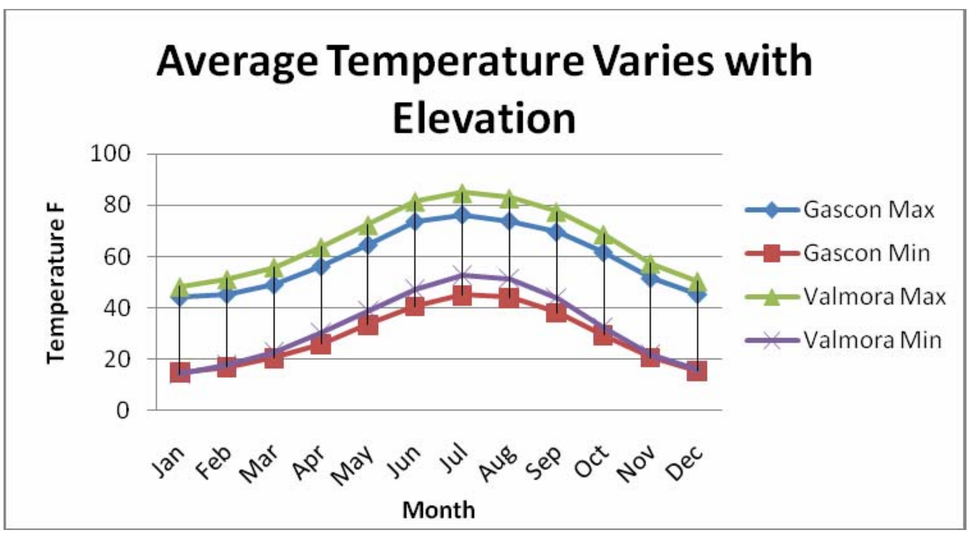

Figure 7. Average temperature range in and near Sapello watershed. (WRCC, 2008).

The annual precipitation in the basin, including snowmelt and rainfall, ranges from 17 to 43 inches per a year on average. Greater amounts of precipitation fall at higher elevations, while lower elevations receive less. Spring runoff is predominately due to snowmelt leading to high seasonal variability in stream flow. The average precipitation for the entire Sapello watershed is 19.66 inches per year. This average falls right between the two weather stations annual average total precipitation; Gascon receives 23.8 inches per a year while Valmora receives 16.7 inches per a year (WRCC, 2008) (Figure 8).

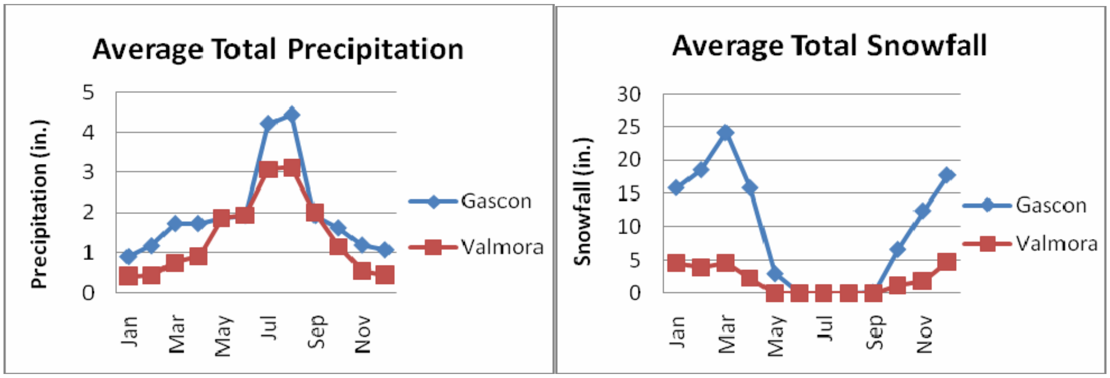

Figure 8. Average precipitation and snowfall in and near Sapello watershed. (WRCC, 2008).

Surface Water Budget

The total surface water resources available in the Sapello watershed can be estimated by a mass balance. The relationship between precipitation, evapotranspiration (ET), infiltration, runoff, and diversions can be estimated using the following mass balance equation:

$$\text{Precipitation} = \text{ET} + \text{infiltration} + \text{runoff} + \text{diversions} \quad (1)$$

This equation represents a surface water hydrologic budget illustrating that precipitation is the main source of surface water recharge, whereas ET, infiltration, runoff and demand are surface water sinks.

Precipitation

Based on the climatic information, the Sapello watershed receives approximately 308,320 acre-feet per a year of precipitation. This amount was determined by multiplying the annual precipitation rate (ft/yr) for the watershed by its area (acres).

Evapotranspiration

Evapotranspiration (ET) varies across the watershed and is strongly correlated with elevation as well as vegetative type and cover. Higher evaporation rates occur in the lower elevations and lower evaporation rates occur at higher elevations. Woodhouse (2008) provided rough estimates of ET rates to expect in various vegetative types, including 11-19 inches/year of ET in ponderosa pine forests in northern New Mexico, and 2-16 inches/year of ET in mixed grass lands. Since precipitation is greater than the ET, the water budget calculation for the Sapello watershed incorporated the upper limits of ET provided by Woodhouse. A large amount of the precipitation will be lost to ET, therefore, approximately ten percent of the precipitation will be left to either infiltrate or runoff.

Infiltration

Infiltration is the amount of surface water that percolates through the soil to the underlying water table (Hornberger et al., 1998). Soil data acquired for the watershed provides relevant hydrologic group data which relates to the rate of infiltration. Hydrologic groups define the potential infiltration of particular soil map units provided by NRCS Soil Data Mart (2007). A hydrologic group defines the soil types that have similar infiltration and runoff characteristics under similar storm and cover conditions (USDA NRCS, 2007). These characteristics are described in Table 3. The majority of the soils in the Sapello watershed have moderate or slow infiltration rates. The water budget calculation done here assumed that approximately 40% of the precipitation remaining after ET will infiltrate.

Table 3. Descriptions of hydrologic soil groups (USDA, NRCS, 2007).

Hydrologic Group	Description of infiltration potential (USDA NRCS, 2007)
1	high infiltration even when thoroughly wetted, well drained to excessively drained sands and gravels
2	moderate infiltration rates, moderately well and well drained soils with moderately coarse textures
3	slow infiltration rates, soils with layers impeding downward movement of water, or soils with moderately fine or fine textures
4	very slow infiltration rates, soils are clayey, have a high water table, or are shallow to an impervious layer

Runoff

Runoff is the volume of surface water that flows over the land surface into streams and rivers (Hornberger et al., 1998). In the water budget calculation, runoff is the amount of precipitation that does not evaporate or infiltrate. In other words, the volume of runoff is the amount of precipitation that did not infiltrate, evaporate, or transpire.

The Mora-San Miguel-Guadalupe Regional Water Plan (NMOSE, 2005) estimated the Sapello River flow to be approximately 16,500 acre-feet per a year, which ultimately flows into the Mora River. The volume calculated in this study was estimated to be 18,910 acre-ft/year as shown by the following calculation.

	308,320 acre-feet/year	Precipitation
-	276,800 acre-feet/year	ET
-	12,610 acre-feet/year	Infiltration
	18,910 acre-feet/year	remaining for Runoff

The value estimated here is slightly greater than that in the Regional Water Plan (NMOSE, 2005). This difference may be due to diversions to the irrigation ditches and acequia systems throughout the Sapello watershed. This estimate of the total amount of surface water from the watershed is needed to support decisions regarding management of water resources in the basin. However, it is important to recognize that this decision is based on average precipitation and evapotransporation; no information is contained which describes the variability, particularly the limitations that might occur under drought conditions.

It is important to recognize that the figures reported here are based on average values for precipitation and estimated values for evapotranspiration and infiltration. Precipitation is highly variable both spatially (location in the basin) and temporally. The effects of drought or climate change have not been estimated for this watershed. Also note that evapotranspiration and infiltration rates are very difficult to quantify. When considering the numbers cited above, it can be seen that even a 10% difference in the estimated annual evapotranspiration rate will have a major impact on the calculated annual runoff.

Methods

The emphasis of the study described in this report was determination of flows together with assessment of the stream's geomorphic, biological and water quality conditions. This section describes the methods that were used to collect and analyze data in the watershed.

Sampling methods were based on those described in the Environmental Protection Agency (EPA) Field Operations Manual for Wadeable Streams (EPA, 2003). Data collection was based on the Environmental Monitoring and Assessment Program (EMAP) which provides protocols for collecting samples and measurement data (EPA, 2003). All river sample sites were classified as wadeable meaning "the stream can be sampled with wadeable stream protocols, continuous water flow and greater than 50% of the sample reach is wadeable" (EPA, 2003).

EMAP methods of assessment were used with the following modifications: Five transects were completed at each reach instead of the recommended 11 due to time constraints. Results were documented using assessment forms downloaded from the NMED SWQB website to assure consistency with previous and possibly future work by this agency. In order to get a representative picture of the area a sample reach of 400 feet was utilized at 100 foot intervals. Each transect was labeled A, B, C, D, E with A being downstream and E located in the upper reach of the sample area. (EPA, 2003). A smaller spacing of 20 ft between transects was used at the Surprise Valley Ranch near the head waters of the Sapello River because the stream was smaller and there was limited distance between fishing ponds and road culverts. The GPS coordinates were noted for each sampling location and photographs were taken of each location for future reference.

Hydrology and Geomorphology

The hydrology and geomorphology of the Sapello River varies by location, which impacts ecosystems and influences river characteristics. The stream flow and seasonal distribution, coupled with riparian vegetation shape the landscape and provide critical habitat for aquatic and riparian communities.

River discharge was measured using the velocity area procedure (EPA, 2003). The velocity and depth vary across a channel was collected at one foot or smaller increments. Velocity was measuring using a Marsh-McBirney Flo-Mate electromagnetic flow meter, while depth was measured using a surveyor's rod. The data was entered into a spreadsheet which calculated the volumetric flow through each increment of cross section and summed them to determine total flow. The criteria for each sample location included:

- Segment of river for each cross section is perpendicular to flow.
- Flow is generally uniform with no obstructions, backwater or excessive turbulence.
- The cross section is U shaped with a uniform streambed free of large debris.

The thalweg refers to the path of deepest water flow in the river. The depth of the thalweg was collected at each sampling reach at 10 foot increments between the upstream and downstream stations. The thalweg profile was collected using a surveyor's rod to locate the deepest path of the channel.

The geomorphology of each sample area was collected and recorded. Bank angle and undercut distances were determined at the left and right bank. Incised banks were recorded as 90 degree angles. Bankfull height of each channel was considered as a full channel during flood events which may occur every one to two years (EPA, 2003). The wetted width value refers to the present water level observed across each transect. The Sapello River appeared to be flowing under bank full conditions during this field study which is consistent with spring runoff following a winter with above average snow pack.

Stream bottom deposits or substrate size was determined due to the impacts these materials have on the habitat for benthic organisms and spawning fish. Each transect was analyzed at five points including left bank, middle left, middle, middle right, and right bank. This serves as a good indicator of habitat for fish and macrointervertebrates and can provide information about erosion or other anthropogenic influences. Estimates of the average percentage embeddedness of rocks were also recorded at the same five points to estimate the impact that fine sediment deposition had on stream bottom materials within each transect.

Riparian Vegetation Cover and Human Influence

Riparian vegetation plays an important role in river systems. Vegetation stabilizes banks through root system development, provides stream cover, which reduces water temperature, assists in sediment collection, and provides habitat for insects and wildlife. Vegetation was divided into three layers described as the canopy, understory, and ground cover. The canopy layer is considered to be vegetation greater than 5 meters high and is further classified as deciduous, coniferous, broadleaf evergreen, mixed or none. The understory layer refers to vegetation between 0.5 and 5 meters high. These are classified as the same manner as the canopy. The ground cover considers plants less than 0.5 meters high and is further classified into woody shrubs, seedlings, grasses and bare ground (EPA, 2003). Data was collected at each transect and averaged across the entire reach to determine the biological characteristic at each location. Averages were rounded up or down to arrive at a whole number which corresponds with the percentages given on the EMAP form. Zeros indicate an average of 0.4 or less as an average rating for that characteristic (Appendix I)

Benthic Macroinvertebrates

Benthic macrointervertebrates live in stream bottom substrates and serve as indicators of stream health. Habitat complexity and diversity correspond to the overall biological integrity of a stream. Monitoring provides useful indicators of stressors in the system. Samples were collected in the center of the channel at every transect using a kick net technique. A large net was stretched across the river while sediment and rocks were disturbed in order to dislodge organisms and wash them into the net. Samples were then transferred into a tray for further analysis and identified to Order at the sample site. The

organisms were classified, counted and recorded. Identification was completed with the assistance of Amina Sena, a graduate of New Mexico Highlands University whose Master's thesis focused on determining stream characteristics of the Sapello River near the Pritzlaff Ranch.

Water Chemistry

Water samples were analyzed for pH, electro-conductivity (EC), temperature, dissolved oxygen (DO), metals and anions by the field and laboratory methods identified in Table 4.

Table 4. Summary of field and laboratory methods used to measure water quality.

Parameter	Procedure	Field or Lab	EPA Method No.
Temperature	Temperature probe	Field	170.1
pH	Glass electrode & meter	Field	150.1
Dissolved oxygen	Membrane DO meter	Field	
Metals	ICP-AES spectroscopy	Lab	200.7
Anions	Ion Chromatography	Lab	300.0
Alkalinity	Titration	Lab	310.2

Water samples were collected in acid-washed bottles flushed with 18MΩ water. The samples were filtered with ashless Whatman #41 qualitative filter paper for the anion samples, and filtered and acidified with HNO_3 (pH less than 2) for the metals analyses. Samples for non-metals analysis were filtered and refrigerated; no preservative was added. All samples were refrigerated at 4ºC until analyzed. Alkalinity was measured by acid titration method using standardized H_2SO_4 (normality of 0.218). pH, temperature and EC were measured with a multi-meter probe that was calibrated daily with a buffer solution of pH 7. Dissolved oxygen (DO) was measured with a Yellow Springs Instruments DO meter that was calibrated by an air calibration technique that was adjusted for the elevation at each site.

All samples were filtered through 0.45 μm membrane filters to remove suspended material prior to laboratory analysis for metals and non-metals. All laboratory analyses were conducted in the geochemistry laboratory of the Department of Earth and Planetary Sciences at the University of New Mexico.

Results

Data was collected and analyzed from Surprise Valley Ranch (headwaters), the Pritzlaff Ranch (middle of watershed), and David Blagg's Ranch (near confluence with the Mora River) (Figure 2). Data, field and lab analyses include hydrology, geomorphology, riparian vegetation, fish cover, human influence, benthic macroinvertebrates, and water analysis.

Hydrology and Geomorphology

The first site assessment was conducted at Surprise Valley Ranch near the confluence of John's Creek and the Sapello River. This site was at the highest elevation accessible by road and was considered to constitute the headwaters of the Sapello for the purposes of this study. Due to constraints associated with fish ponds and culverts the sampling profile consisted of five transects spaced 20 feet apart for a total of 100 ft. The average discharge for Surprise Valley Ranch was 5.54 cubic feet per second (cfs). The right bank slope averaged between 10 and 25 degrees except where an incision of 0.6 feet was reported. The left bank slope averaged between 10 and 50 degrees except where an incision of 0.9 feet was reported. The thalweg averaged 8.45 inches in depth throughout this reach. The stream bottom consists of small boulder and cobble sized substrates. Rock embeddedness varied from 20% to approximately 90 %.

The area chosen to represent the middle of the watershed was the Pritzlaff Ranch. The sample area consisted of 5 transects over a total distance of 400 feet. The average stream discharge for the Pritzlaff Ranch site was 5.14 cfs. River flow was less at this location than at the Surprise Valley Ranch site due to water use by upstream land owners as well as flow diverted into the two irrigation ditches on the Pritzlaff Ranch. The right bank slope averages between 5 and 30 degrees except where an incision of 0.5 feet was noted. The left bank slope ranged from 5 to 60 degrees where a change in sinuosity was present. A few areas had a bank undercut of 12 inches which provides critical fish habitat. The thalweg averages 15.2 inches in depth at this site. Boulder and cobbles dominate the upper reaches of the sample site, while silt and clay are more prevalent in the lower reaches. The stream bottom varies in sediment size due to areas with high vegetation capturing sediment loads. Rock embeddedness ranges from 50% to 100%.

The site chosen to represent the lower reaches of the watershed was a ranch owned by David Blagg, where significant restoration techniques have been conducted for the past 16 years. It is important to note that extensive grazing upstream from the Blagg ranch had removed nearly all riparian vegetation on the upstream property (Figure 9). This appears to have caused increased erosion and with subsequent accumulation of a fine grained sediments in beaver ponds and slack water at the Blagg ranch assessment site.

Figure 9. Photograph of the upstream boundary of the Blagg ranch showing the effects of protection of the riparian environment at this site.

The sample site at the Blagg ranch had recently contained a beaver dam that created a long pool of still water with depths as great as four feet. The dam had washed out a few weeks before the sampling trip. Sample transects were placed 100 feet apart for a total of 400 feet. The average discharge for the Blagg ranch site during the study was measured at 3.52 cfs. The right bank slope averaged between 5 and 30 degrees except where incision was noted at 0.9 feet. The left bank had much higher slopes averaging between 10 and 80 degrees. The thalweg averages 20.95 inches in depth throughout the property. The stream bottom consisted mainly of silt and clay with much of the rock embeddedness ranging from 30 % in the center to 100% along the banks. These findings are consistent with erosion protection provided by dense riparian vegetation and the presence of beaver dams at the site.

Riparian Vegetation Cover and Human Influence

The vegetation data for the three locations indicates that there is a lack of canopy trees (greater than 5 meters high) present at any of the three locations. The non-woody herbs, grasses and forbs were estimated at greater than 75% at the Surprise Valley location. The highest percentage of filamentous algae was found at the Blagg location, measuring between 10 and 40%, which accurately reflects the reduced stream velocity at this location.

Stream cover varied by location but showed fair to good shading of the waterway. It is important to note that riparian characteristics were measured subjectively, and measurements by different observers sometimes resulted in variability.

Human influences are considered to be any man made structures including buildings, walls, bridges, roads or other activities such as logging, mining or landfills/trash adjacent to the waterway. Surprise Valley ranch included pasture, pipes, buildings, pavement and dams. The Pritzlaff location appears to be the least impacted by human influence, where only pasture was noted. The Blagg ranch contained adjacent roads with signs of human trash in one section of the river.

Benthic MacroInvertebrates

The amount of diversity in benthic macroinvertebrates is an indicator of water quality in wadeable streams. A large number of taxa, or organism groups indicates low levels of ecological stress in the waterway since they denote the presence of a variety of food sources and habitats within the assessed area (EPA, 2007). The majority of the species included in the orders Ephemeroptera, Plecoptera and Trichoptera are intolerant of water pollution and require relatively high oxygen saturation (EPA, 2007). Therefore, greater numbers of organisms from these orders is an indicator of high water quality. Aquatic worms and blood midges are more tolerant of pollution and require less oxygen saturation (EMAP, 2003). Although water mites were not listed on the Pollution Tolerance Index Rating (PTIR) form, water mites are one of the best indicators of the quality of the stream environment since the diversity of the species decreases in disturbed or polluted waters. (Last and Whitman 1999). Their presence was documented at the Pritzlaff ranch sample site.

Benthic macroinvertebrate results were documented and interpreted using the Biological Monitoring Sheet available at the Hoosier Riverwatch website, sponsored by the Indiana Department of Resources, Division of Fish and Wildlife. The monitoring sheet facilitates calculation of the PTIR. The PTIR is a semi-quantitative rating in which higher values indicate larger proportions of insects which are intolerant of pollution A score of 23 or more is Excellent, 17 to 22 is Good, 11 to 16 is Fair, 10 or less is Poor (Figure 10).

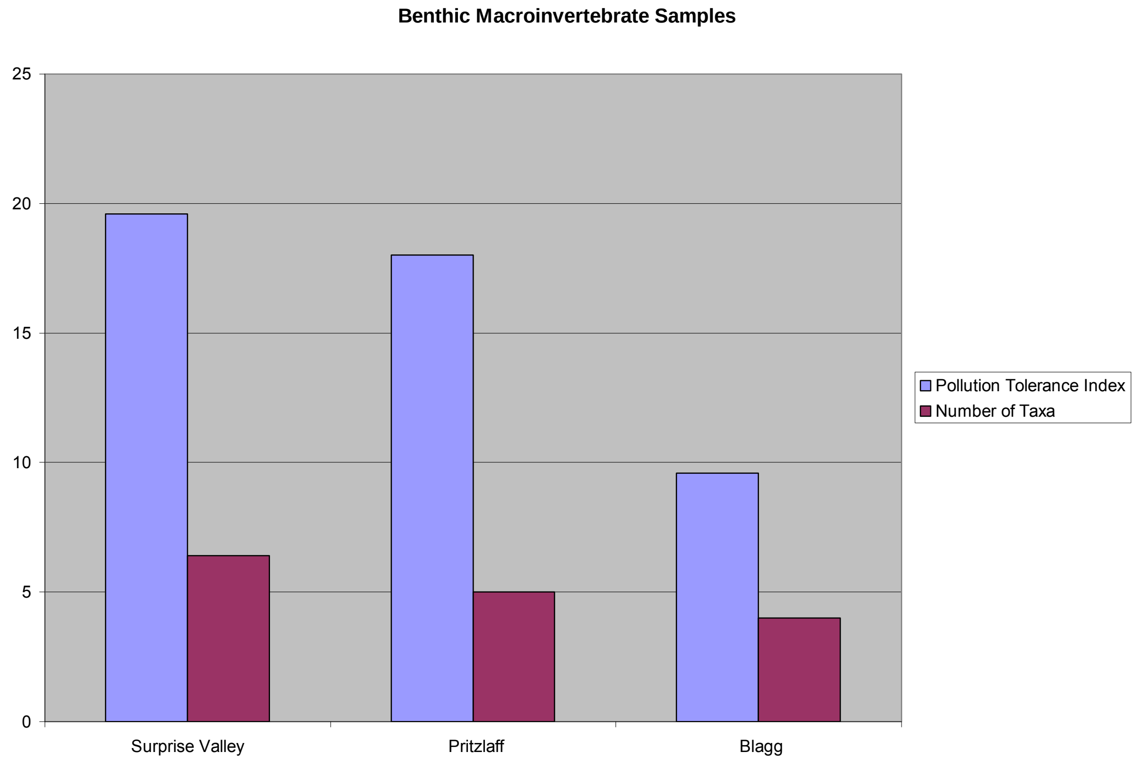

Figure 10. Summary of Pollution Tolerance Index Rating (PTIR) and number of taxa for benthic organisms at each of the three sites sampled in this study.

Based upon the PTIR and the number of taxa found, the benthic invertebrate samples reflect a decrease in water quality between the first two assessment locations and a greater measurable decrease at the final location (Table 5).

Table 5. Percentage of benthic organisms collected at each sampling site by kick net.

Order	Surprise Valley	Pritzlaff Ranch	Blagg Ranch
Caddis Fly larvae	21	6	3
May Fly larvae	14	58	35
Blood Midge	22	2	55
Mites	0	9	0
Worms	17	8	11

Water Chemistry

Between June 2 and June 6, 2008 ten surface water samples and six groundwater samples were collected for chemical analysis. Surface water samples were collected along various reaches of the Sapello River as well as at Manuelitas Creek, Deer Creek, Johns Canyon and Mora River. Johns Canyon, Manuelitas Creek and Deer Creek are all tributaries of the Sapello River, and the Sapello River is a tributary to the Mora River at

Watrous, NM. The water samples from the tributaries and Mora River were taken just upstream of the confluence with the Sapello River. Groundwater samples were taken at Pritzlaff Ranch and the Blagg ranch. Results for all field and laboratory chemical analyses are presented in Appendix I.

Groundwater and Surface water samples were analyzed for the following constituents: pH, electro conductivity (EC), temperature, dissolved oxygen, aluminum, arsenic, boron, barium, calcium, cadmium, cobalt, chromium, copper, iron, potassium, lithium, magnesium, manganese, sodium, nickel lead, selenium, silica, vanadium, zinc, fluoride, chloride, nitrate, nitrite, bromide, phosphate, sulfate and alkalinity. The following constituents were not detected in any of the samples: bromide, cadmium, cobalt, chromium, copper, nickel, lead, selenium, vanadium and zinc. Total dissolved solids (TDS) was estimated from EC measurements by the following equation:

$$TDS = \frac{640\ EC}{1000} \qquad (2)$$

where EC is the electrical conductivity measured in units of micro-Siemens (μS).

Surface Water

Analyses of the river water samples show that concentrations of the following constituents increase as one proceeds downstream: temperature, conductivity, alkalinity, TDS, aluminum (with the exception of the sample taken from the Mora River), calcium, iron, potassium, magnesium, sodium and silica.

Figure 11 is a temperature profile along the Sapello River between Surprise Valley Ranch and the Pritzlaff Ranch collected between 1500 and 1530 on the afternoon of June 3, 2008. Results from temperature measurements indicate temperature increases about 6 degrees from Surprise Valley Ranch to Pritzlaff Ranch. It is believed that the two contributing factors to this temperature rise are water retention in the numerous fish ponds over this seven mile reach of stream, and the exposure to direct sunlight caused by lack of riparian vegetation over much of the length of the stream.

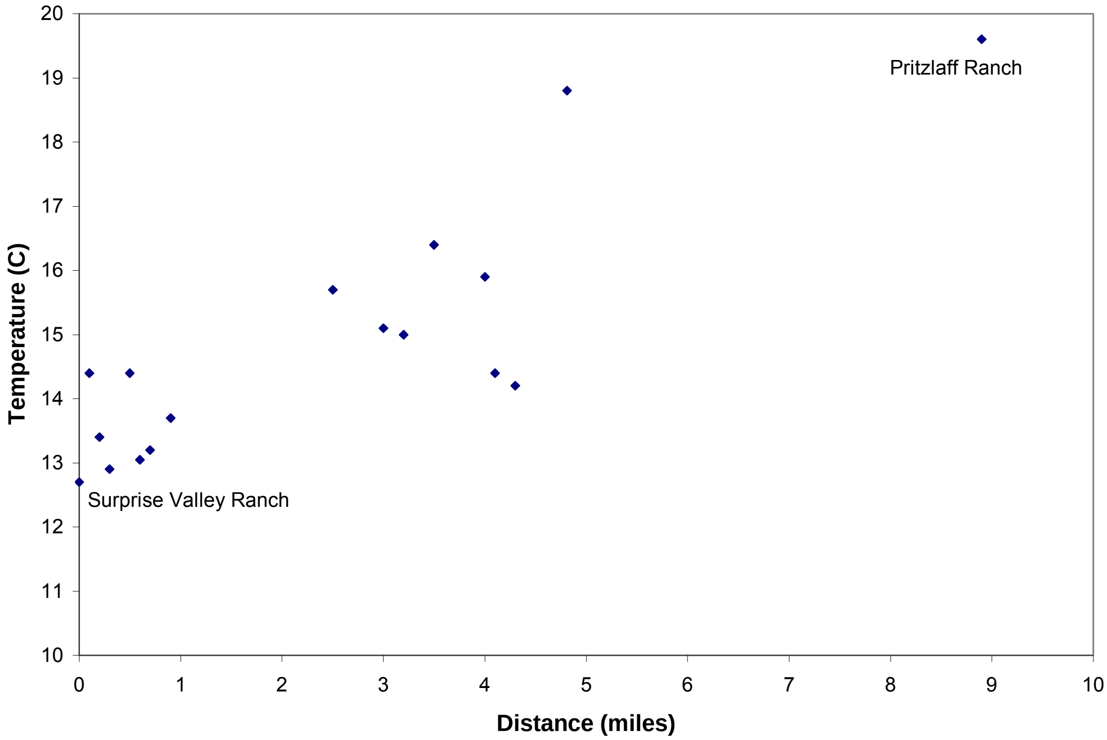

Figure 11. Temperature Profile between Surprise Valley Ranch and Pritzlaff Ranch for samples collected between 1500 and 1530 on June 3, 2008.

Figure 12 shows concentrations of dissolved aluminum versus distance along the Sapello River, its tributaries and the Mora River. All of the samples exceed surface water standards for aluminum for aquatic life (chronic and/or acute) except the sample collected from the Mora River. The high aluminum levels are likely associated with erosion of the clayey soils and subsequent elevated concentrations of suspended solids. Some clay particles are smaller than the 0.45 μm diameter used to filter the samples prior to analysis, thus these aluminum concentrations may reflect the presence of colloids in the water samples

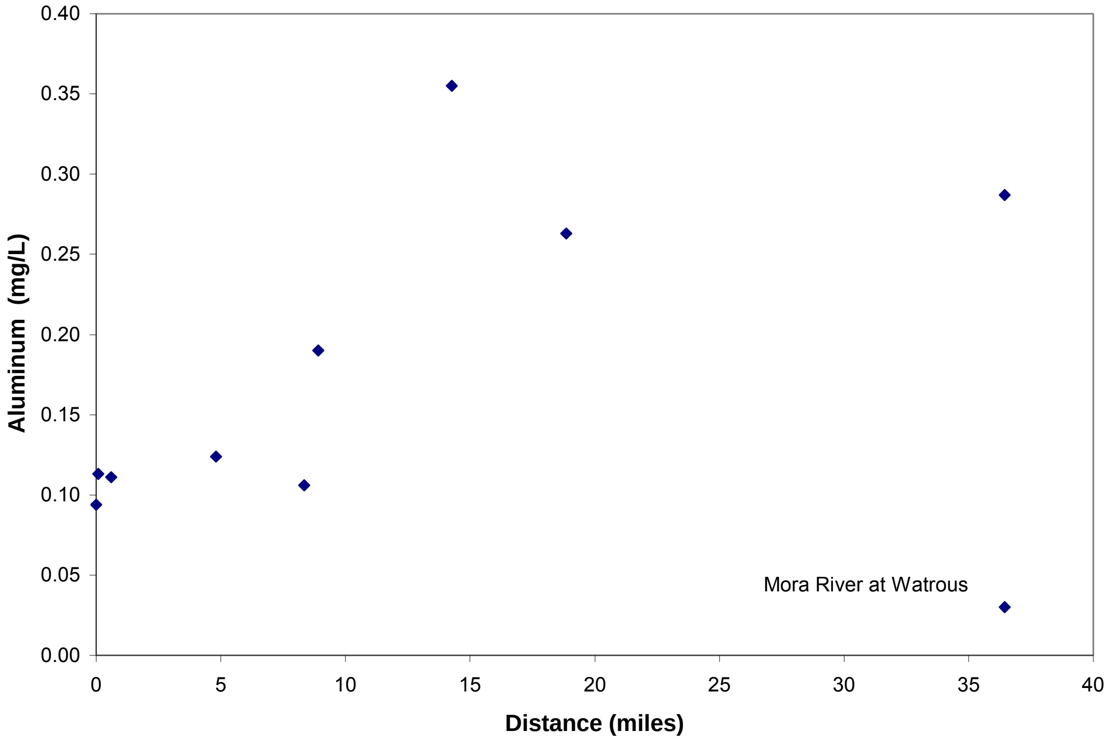

Figure 12. Aluminum concentrations versus distance for the Sapello River, its tributaries and the Mora River.

Figure 13 is a plot of the EC values along the Sapello River, its tributaries and the Mora River. The EC values increase from 180.4 µS at Sapello Canyon to 632 µS at Watrous. High EC values can be attributed to evaporation, presence of agricultural return flows, and to dissolution of soluble minerals associated with rocks and soils in the Sapello watershed.

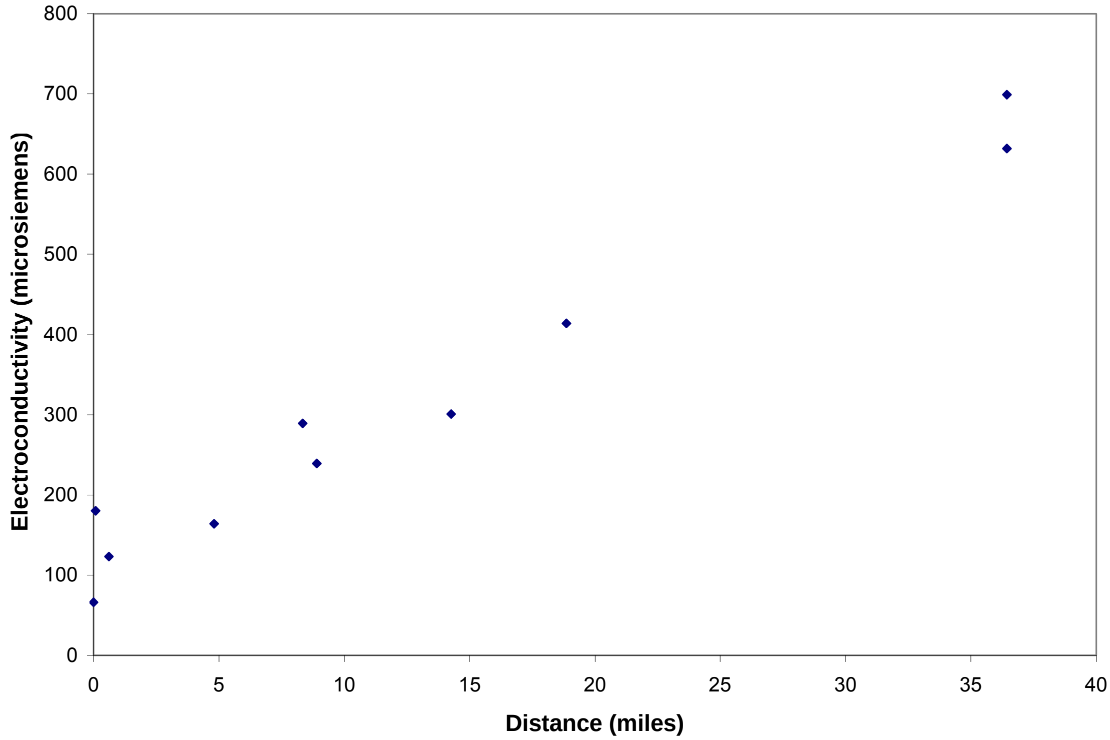

Figure 13. Electrical conductivity (µS) versus distance for the Sapello River, its tributaries and the Mora River.

Figure 14 shows the concentrations of nitrates along the Sapello River, its tributaries and the Mora River. Nitrate concentrations range from 0.32 mg/L at Sapello Canyon to 0.04 mg/L at Watrous. The upper portion of the watershed, west of NM 518, consists of a narrow and steep canyon with relatively thin soil horizons, and the presence of a large number of residences, all served by on-site wastewater disposal systems. Most of these disposal systems are less than 100 m from the river and are believed to be the cause of elevated nitrate levels. The community of San Ignacio is immediately upstream from the Pritzlaff ranch. It consists of several residences, all located close to the stream and leachate from their wastewater disposal systems is believed to be the source of the elevated nitrate concentration in the river at this site.

Downstream from NM 518 there is very low housing density along the river and this is believed to explain the low nitrate levels. The Mora River was sampled immediately downstream from the community of Watrous, thus it seems reasonable that runoff and wastewater leachate from this community are responsible for the elevated nitrate levels at this sample location.

Although there appears to be a correlation between nitrate and residential density, it should be noted that the nitrate concentrations throughout the Sapello River are well below the stream standard of 10 mg/L measured as N. This standard was established to protect human health, therefore, the water quality does not present a threat to humans.

However, nitrate is an important nutrient and will stimulate growth of algae and other aquatic plants. Moderate to dense algal growth was noted at some sampling sites. It is clear that nutrient concentrations should be monitored in future studies, as well as other indicators of eutrophic conditions in the river.

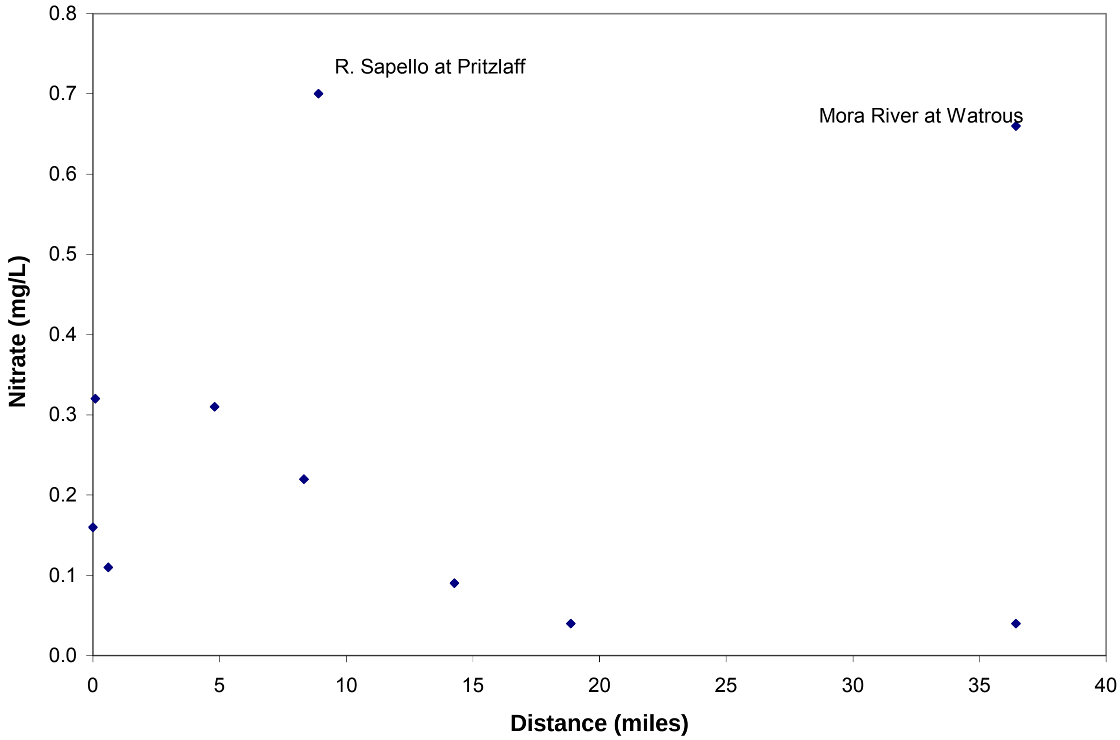

Figure 14. Nitrate concentrations versus distance for the Sapello River, its tributaries and the Mora River.

Groundwater Samples

As with the surface water, generally the ground water sampled in the valley was found to be of excellent quality. There were, however, a couple of exceedences of State standards for arsenic, barium, iron, manganese. The concentrations of barium, iron and manganese just slightly NM groundwater standards. A sample taken from the Pritzlaff Ranch horse pasture spigot had an arsenic concentration of 0.223 mg/L. This concentration is is 22 times greater than the federal Safe Drinking Water Act standard for arsenic (0.010 mg/L) and, if real, could present a health hazard to humans or livestock who might use the water for drinking. A repeated analysis of this sample gave the same concentration. However, because it was the only sample that contained detectable arsenic there is a question as to whether the sample was truly representative of water from this spigot, or whether the sample might have been contaminated. Arsenic has been used as a dietary supplement for horses, and it is possible that the shallow well which supplies this spigot may in fact be contaminated by this material. Regardless, the spigot and well should be resampled to provide assurance that this water is safe to use.

Trilinear Diagrams

Figure 15 is a trilinear diagram of all surface water and groundwater samples analyzed. This type of diagram is used to summarize the major ion chemistry of a collection of water samples to quickly identify their similarities and differences. Because they are tightly grouped, the results of this plot show a remarkable consistency in the surface water samples. The water is dominated by high concentrations of calcium (Ca^{2+}) and bicarbonate-carbonate (HCO_3^- - CO_3^{2-}). This is consistent with the presence of large amounts of limestone ($CaCO_3$) throughout the valley. There is more variability in the ground water chemistry, although all of the samples but one have 50% or greater as the dominant cation. It is likely that the three ground water samples that plot with the surface water samples are hydraulically well-connected to the Sapello River. The other ground water samples appear to be influenced by other factors, most likely the geochemistry of the formation in which they were completed.

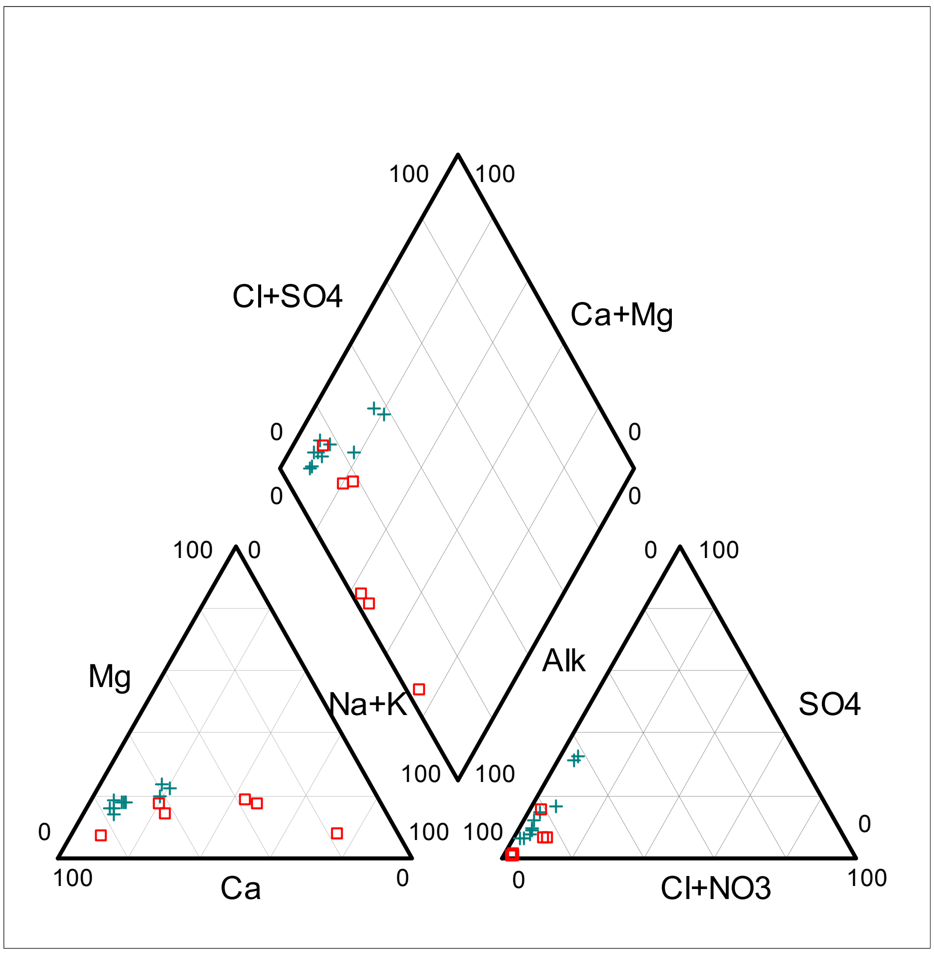

Figure 15. Trilinear Plot of surface water (+) and groundwater samples (□)

Information Gaps/Future Data Needs

One of the objectives of this project was to establish a base line of knowledge regarding the water resources and stream characteristics in the Sapello River. At the same time, analysis of data collected during this study can be used to identify additional information needed to facilitate equitable and rationale management of the watershed and its water resources. This section briefly identifies information that is needed to support water resources management and provides recommendations for programs to collect this information.

One of the most critical information needs to support management of water resources in the Sapello watershed is quantitative data on flows in the river, surface water diversions for agricultural use, and ground water pumping for domestic and agricultural applications. The highest priority should be given to replacing stream gauge(s) on the river. Historically there were two gauges in the Sapello River, one near Watrous, NM and the other at Sapello, NM. However, measurements were discontinued in 1965 and 1975 respectively, so that there is little information available to show impacts of changing land use, water use or climatic conditions on water resources. Placing stream gages on the Sapello would provide data on flows within the watershed and discharges to the Mora River.

While most USGS stream gages are now automated, their readings transmitted to a central site by telemetry, and the results available on the web within minutes of the measurement, it is suggested that this level of monitoring is not needed for small watersheds such as this. Instead it is suggested that a simple solid state water level detector linked to an inexpensive data logger would be sufficient for the Sapello. This type of system is relatively inexpensive, it could be installed quickly, it would be secure, and would require servicing perhaps once every 3 to 6 months to change batteries and download the data. However, to be meaningful, the organization in charge would have to make a commitment to maintain the system for many years or decades to generate sufficient data to quantify the variability of the hydrologic system.

This study showed that diversions into irrigation ditches and acequias withdraw a large fraction of water from the Sapello River. It is believed that none of these diversions are metered. As with flow in the river, this information is needed to allow development of a quantitative assessment of water resources in the watershed. While it is likely not feasible to install flow monitoring on each ditch, their capacity should be determined and ditch masters should be required to keep records of how many hours per year each is operated. Staff gages could be located at each ditch's head works which, coupled with an appropriate weir equation, would provide semi-quantitative information on flow.

A survey of OSE records needs to be done to identify all wells in the watershed their capacity, and for non-domestic wells, their annual pumping rates. While this information is generally available in files and records by the OSE, to our knowledge it has not been compiled or analyzed to quantify the impact of ground water development on the water resources of the Sapello watershed.

Water quality and biological characteristics of the stream should continue to be monitored to determine whether quality in the Sapello River remains consistent with its designated use, and more importantly, whether the impacts of changing land uses and drought affect the water quality of the stream. In particular, measurements of water quality and biological characteristics similar to those reported in this study should be conducted during periods of low flow. Because of above-normal winter precipitation the stream was flowing under bank-full conditions which provides large dilution of anthropogenic contaminants, and has high velocities that limit temperature gains and increase stream aeration. Measurements under low flow conditions are also needed to determine whether problems might occur that were not detected by this study.

Conclusions

The objective of this assessment of the Sapello River was to collect information on the hydrology of the watershed, conduct a baseline assessment of the chemical and biological characteristics of the stream, and identify any impairment that might exist. Overall, this study found that the characteristics of the hydrology, geomorphology, and biological characteristics are consistent with those expected for a healthy river in its upper reaches (west of NM 518), and the river appears to be slightly impaired in its lower reaches.

The upper portion of the river has excellent water quality, minimal sedimentation, incision, and erosion, and good over-bank protection. Additionally, the population of the benthic organisms present in the river are intolerant to pollutants and decreased dissolved oxygen, which indicates a healthy stream with high quality water. Water samples in the upper reaches found slightly elevated nitrate levels which are believed to be the result of residential development near the river with homes that utilize on-site wastewater treatment and disposal systems. Elevated aluminum concentrations were detected at levels exceeding New Mexico Surface Water Quality Standards for protection of aquatic life.

The lower portion of the Sapello River (east of NM 518) appears to be slightly impacted by agricultural activities. In this reach the river had generally less vegetative cover, slower velocities with a deeper thalweg, a greater incidence of bank failure, and increased amounts of sediment in the river bottom. These observations are consistent with a lower energy stream flowing through a region that is intensively grazed. These characteristics have resulted in less diversity of benthic organisms and a higher frequency of organisms with increased tolerance of diminished water quality, coupled with increased concentrations of total dissolved solids and dissolved aluminum. Decreased riparian vegetation and canopy cover and slower water velocities contribute to increased water temperatures.

As the river flows from its headwaters to its confluence with the Mora River, concentrations of the following changes in water chemistry were noted:

- Increase in Total Dissolved Solids (TDS) concentrations (determined from measurements of electrical conductivity)
- Increase in alkalinity
- Increase in dissolved aluminum, calcium, iron, potassium, magnesium, sodium and silica
- Decrease in nitrate concentrations

Results found during this field assessment confirmed issues previously documented by the NMED SWQB. In addition, elevated nitrate concentrations suggest that residential development and associated wastewater discharge to onsite treatment and disposal systems is beginning to stimulate algal growth that may lead to eutrophication problems in the future.

Impairment of the watershed by activities such as residential development, overgrazing and development of paved and unpaved roads may be difficult to limit as populations increase and economic pressures continue. It is clear that ensuring the overall health of the Sapello River will require cooperation among all landowners in the watershed as well as support from visitors who use the land for recreational activities..

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Appendix I – Water Chemistry Data

Table 6. Chemical analyses of ground water samples.

Sample ID	EPA Method 200.7 Aluminum (mg/L)	Arsenic (mg/L)	Boron (mg/L)	Barium (mg/L)	Calcium (mg/L)	Iron (mg/L)	Potassium (mg/L)	Lithium (mg/L)	Magnesium (mg/L)	Manganese (mg/L)	Sodium (mg/L)	Silica (mg/L)
Pritzlaff Garden In	0.125	ND	0.374	**1.109**	41.73	0.359	4.121	0.078	12.70	ND	63.52	3.709
Pritzlaff Garden Out	0.181	ND	0.473	**1.064**	46.54	**1.206**	4.672	0.074	13.75	ND	58.63	3.715
Pasture Spigot	0.228	**0.229**	0.401	0.210	227.80	ND	2.403	0.067	11.86	**0.214**	26.90	3.015
Guest House Tap	0.145	ND	0.368	0.122	66.99	ND	2.247	0.054	11.10	ND	24.06	3.116
Blagg's Well	0.182	ND	0.456	0.023	75.54	ND	1.392	0.057	10.420	ND	31.69	4.231
Blagg's Pond Well	0.156	ND	0.480	0.077	15.80	0.546	3.496	0.066	4.241	0.036	77.24	0.766
Groundwater Stnd.		0.1		1.0		1.0				0.2		

Red and Bold indicated the sample has exceeded a surface water standard.

Sample ID	EPA Method 300.0 Chloride (mg/L)	Fluoride (mg/L)	Nitrate (mg/L)	Phosphate (mg/L)	Sulfate (mg/L)	Alkalinity (mg CaCO3/L)
Pritzlaff Garden In	6.01	0.67	0.27	0.09	1.48	278
Pritzlaff Garden Out	5.14	0.56	0.08	ND	2.21	287
Pasture Spigot	17.49	0.30	0.13	ND	15.77	218
Guest House Tap	17.27	0.3	ND	ND	15.82	228
Blagg's Well	5.94	0.38	0.82	ND	48.43	265
Blagg's Pond Well	3.98	0.55	0.06	ND	3.42	223
Groundwater Stnd.	250.0	1.6	10.0		600.0	

Table 7. Chemical analyses of surface water samples

Location	Distance (feet)	Distance (miles)	Aluminum (mg/L)	Boron (mg/L)	Calcium (mg/L)	Iron (mg/L)	Potassium (mg/L)	Lithium (mg/L)	Magnesium (mg/L)	Manganese (mg/L)
Sapello Canyon	0	0.00	**0.094**	0.376	6.116	0	0.809	0.042	1.185	0
Johns Canyon	468	0.09	**0.113**	0.345	22.900	0	0.890	0.042	3.428	0
Surprise Valley Ranch	3198	0.61	**0.111**	0.376	14.730	0	0.891	0.420	2.169	0
Culvert	25390	4.81	**0.124**	0.349	21.960	0.064	0.908	0.042	2.788	0
Deer Creek	44031	8.34	**0.106**	0.354	44.860	0	0.959	0.045	4.934	0
Sapello @ Pritzlaff	47016	8.90	**0.190**	0.358	36.470	0.201	1.185	0.043	4.603	0
Manuelitas Creek	75355	14.27	**0.355**	0.401	45.690	0.223	1.194	0.045	6.769	0
Sapello @ Blagg's Ranch	99593	18.86	**0.263**	0.384	60.620	0.080	1.316	0.047	9.128	0
Sapello @ Watrous	192396	36.44	**0.287**	0.409	75.050	0.201	1.698	0.055	18.130	0.073
Mora @ Watrous	192396	36.44	0.030	0.298	88.140	0	1.938	0.059	21.220	0

Location	Sodium (mg/L)	Silica (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Phosphate (mg/L)	Sulfate (mg/L)	Elec. Cond. uSiemens
Sapello Canyon	1.672	2.865	0.94	0.08	0.16	0.00	0.47	4.63	65.9
Johns Canyon	1.928	2.810	1.09	0.09	0.32	0.00	0.00	8.97	180.4
Surprise Valley Ranch	1.849	2.783	1.05	0.09	0.11	0.00	0.00	4.93	123.2
Culvert	2.164	2.769	1.34	0.11	0.31	0.02	0.00	6.12	164
Deer Creek	5.211	4.019	1.77	0.23	0.22	0.00	0.00	9.86	289
Sapello @ Pritzlaff	3.140	2.988	1.94	0.21	0.70	0.00	0.00	8.83	239
Manuelitas Creek	5.842	3.061	2.76	0.23	0.09	0.00	0.00	9.06	301
Sapello @ Blagg's Ranch	9.459	3.300	4.88	0.25	0.04	0.00	0.00	28.34	414
Sapello @ Watrous	30.240	3.045	11.80	0.36	0.04	0.00	0.00	106.39	632
Mora @ Watrous	28.820	4.093	11.72	0.36	0.66	0.00	0.00	111.91	699

Table 8. Field measurements of surface water flow and chemical parameters.

Location	Date	Time	Discharge CFS	EPA Method 360.1	EPA Method 170.1		EPA Method 150.1	EPA Method 120.1	EPA Method 310.2	
				DO mg/L	Air Temp °C	Water Temp °C	pH	Electro conductivity (EC) µS	Alkalinity as $CaCO_3$ mg/L	Total Dissolved Solids (TDS) mg/L
Johns Creek (Canyon)	6/3/2008	9:40	4.63	12.8	19.3	6.7	7.7	65.9	22	42.176
Sapello Canyon	6/3/2008	10:15	1.33	12.3	19.9	8.3	8.15	180.4	66	115.456
Surprise Valley Ranch	6/3/2008	11:05	5.54	12.1	20.6	10.9	8.14	123.2	45	78.848
Culvert 01	6/2/2008	16:00	3.53	11.2	31	18.8	7.92	164	60	104.96
Deer Creek @ Pritzlaff	6/5/2008	14:30	0.17	6	19.3	18.3	7.41	289	146	184.96
Sapello @ Pritzlaff	6/5/2008	8:05	5.14	7.5	7.2	11.3	7.97	239	104	152.96
Manuelitas Creek	6/6/2008	10:50	1.03	9.3	16.1	13.1	7.99	301	134	192.64
Sapello @ Blaggs	6/4/2008	9:25	3.52	12	21.5	14.5	8.04	414	164	264.96
Sapello @ Watrous	6/4/2008	14:25	1.53	16.4	25.5	20.8	7.94	632	210	404.48
Mora River @ Watrous	6/4/2008	14:00	3.91	13	25.9	18.7	8	699	238	447.36

TDS calculated from EC by the following equation: TDS=(EC/1000)*640

Table 9. Field measurements of ground water chemical parameters.

Sample ID	Date	Time	Discharge CFS	EPA Method 360.1	EPA Method 170.1		EPA Method 150.1	EPA Method 120.1	EPA Method 310.2	
				DO	Air Temp	Water Temp	pH	Electro conductivity (EC)	Alkalinity as $CaCO_3$	TDS
				mg/L	°C	°C		µS	PPM (mg/L)	mg/L
Guest House Tap	6/2/2008	20:35	Not Analyzed	NM	NM	NM	NM	510	228	326.4
Pasture Spigot	6/2/2008	20:38	Not Analyzed	NM	NM	NM	NM	512	218	327.68
Pritzlaff Garden Inlet	6/5/2008	17:30	Not Analyzed	NM	NM	NM	NM	494.7	278	316.608
Pritzlaff Garden Outlet	6/5/2008	17:30	Not Analyzed	NM	NM	NM	NM	479	287	306.56
Blagg's House Well	6/4/2008	9:00	Not Analyzed	NM	NM	NM	NM	517	265	330.88
Blagg's Pond Well	6/4/2008	10:30	Not Analyzed	NM	NM	NM	NM	376.9	223	241.216

TDS calculated from EC by the following equation: TDS=(EC/1000)*640

Appendix II – Summary of Measurements of Benthic Organisms

Sapello watershed: Surprise Valley

Summary of 5 Transects (20 ft spacing)

Riparian Vegetation Cover	% Present
Canopy (>5m high):	none
Understory (0.5-5m high):	
Vegetation type	
Woody shrubs and saplings	O
Non-woody herbs, grasses, forbs	<10
Ground Cover(<0.5m high):	
Woody shrubs and saplings	O
Non-woody herbs, grasses, forbs	>75
Barren, bare dirt, duff	10 to 40
Human Influence	**Proximity to site**
Pasture/Range/Hayfield	On bank or greater than 10 meters
Pipes	Within 10 meters
Buildings	Greater than 10 meters
Pavement	Greater than 10 meters
Wall/Dike/Riprap/Dam	Greater than 10 meters

Fish Cover	% Present
Filamentous algae	O
Macrophytes	<10
Woody debris >0.3m	<10
Brush/woody debris <0.3m	O
Live trees or roots	O
Overhanging vegetation	<10

Sapello watershed: Pritzlaff

Summary of 5 Transects (100 ft spacing)

Riparian Vegetation Cover	% Present
Canopy (>5m high):	
Small tree (Trunk<0.3 m DBH)	O
Understory (0.5-5m high):	
Vegetation type	Deciduous
Woody shrubs and saplings	<10
Non-woody herbs, grasses, forbs	<10
Ground Cover(<0.5m high):	
Woody shrubs and saplings	<10
Non-woody herbs, grasses, forbs	10 to 40

Fish Cover	% Present
Filamentous algae	<10
Macrophytes	<10
Woody debris >0.3m	<10
Brush/woody debris <0.3m	<10
Live trees or roots	<10
Overhanging vegetation	<10

Barren, bare dirt, duff	O
Human Influence	**Proximity to site**
Pasture/Range/Hayfield	On bank

Sapello watershed: Blagg Ranch Summary of 5 Transects(100 ft spacing)

Riparian Vegetation Cover	**% Present**
Canopy (>5m high):	none
Understory (0.5-5m high):	
Vegetation type	Deciduous
Woody shrubs and saplings	<10 to 40
Non-woody herbs, grasses, forbs	<10 to 40
Ground Cover(<0.5m high):	
Woody shrubs and saplings	<10
Non-woody herbs, grasses, forbs	10 to 40
Barren, bare dirt, duff	<10 to 40
Human Influence	**Proximity to site**
Pasture/Range/Hayfield	On bank or within 10 meters
Wall/Dike/Riprap/Dam	Within 10 meters
Road	> 10 meters
Landfill/Trash	Within 10 meters

Fish Cover	**% Present**
Filamentous algae	10 to 40
Macrophytes	10 to 40
Woody debris >0.3m	O
Brush/woody debris <0.3m	<10
Live trees or roots	O
Overhanging vegetation	O