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Watershed Health and Mechanical Fuel Reduction in the Walker Flats

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watershed: a term coined to refer to the higher ground – the line, ridge, or summit – that separates two drainage basins, watershed has since come to mean the region drained by such a divide, an area through which water is drained into a particular watercourse or body of water. Watershed also refers to a turning point, or dividing line, that precipitates significant change . . . In thinking about life in the watershed of the Kentucky River, Wendell Berry writes: "Pondering on the facts of gravity and the fluidity of water shows us that the golden rule speaks to a condition of absolute interdependency and obligation. People who live on rivers – or, in fact, anywhere in a watershed – might rephrase the rule in this way: do unto those downstream as you would have those upstream do to you."

-Donna Seaman, **Home Ground**

1 – Introduction

Walker Flats is a grazing allotment located in the Santa Fe National Forest above Cleveland, NM. This 608-acre section of thick, sub-alpine pines ranges in elevation from 8,800 feet to 9,600 feet and is part of the Rio la Casa Watershed. The Rio la Casa is a small, high mountain stream at the heart of the watershed. The stream is cold and clear as it runs over roots and cobbles, and if you step in the stream – instead of over it – you will send sand spiraling away from your footstep. This stream, with its clear water and mostly wild, mostly roadless watershed is showing the effects of human intervention. Until the arrival of European settlers nearly 200 years ago, forest fires played a vital and frequent role in the development of this forest and the species living in it. In the absence of regular fires and with the impacts of heavy grazing, the forest has become thick with spindly pines. These trees only thrive at the uppermost reach of the canopy, and for the most part their branches are rough, abandoned, and home to damaging dwarf mistletoe and bark beetles (LJEC, 2005). The forest floor is littered with the shrapnel of high winds through these branches. Sharp twigs lie partially buried in needles browned from exposure, and grasses peek infrequently out in tufts. The resulting landscape is highly susceptible to catastrophic forest fires, provides poor opportunities for recreation, and serves as mediocre to poor habitat for native animals. In order to remedy this situation, a prescription for mechanical fuel reduction – tree thinning – is being applied. If successful, this prescription will improve the usefulness of the area for wildlife habitat and recreation while returning the forest to a condition in which fire can interact in a manageable and sustainable way without significant risk to nearby residents.

Photo 1 - Close up of the forest floor.

The mechanical fuel reduction project being implemented in the Walker Flats area is the result of a collaborative effort on the part of La Jicarita Enterprise Community (LJEC)[1], the National Forest Service (USFS), the Santa Fe National Forest (SFNF), New Mexico State University (NMSU), the University of New Mexico (UNM), and numerous other Federal, state, local, non-profit, and educational agencies (LJEC, 2005). Each of these agencies is involved in several aspects of this project ranging from research, to developing the prescription, to monitoring the impacts and effectiveness of the project. The collective efforts of these agencies to develop and monitor this project are referred to as the Multi-Party Monitoring Team (MPMT), and this report is integral to the process. At the center of the project, LJEC is a community based Community Development Corporation (CDC) who will be administering the thinning prescription through the labor of trained, individual contractors. Next, the Forest Service is involved at both the national and forest levels. At the national level, The Forest Service is working under the Community Forest Restoration Act of 2000 to encourage local communities living near forests to work collaboratively to mechanically thin forests (USFS Southwestern Region Website). At the forest level, the SFNF is involved in the development of the prescription including preliminary research, ongoing monitoring, and educational outreach to impacted and interested communities (LJEC, 2005). There are four goals that the Forest Service hopes to accomplish from this prescription: reduce the risk of major wildfire, improve recreational opportunities, improve wildlife habitat, and create a mutually beneficial relationship between land managers at the Forest level with LJEC in which management objectives and economic benefits are realized by both parties.

NMSU is heavily involved in the development of the prescription and in-depth monitoring of the effectiveness of the process including vegetative recovery, changes in runoff patterns, and changes to infiltration patterns (LJEC, 2005). The

[1] Enterprise Community is a special designation given through the United States Department of Agriculture's (USDA) Rural Development program. This program is designed to give economically depressed areas access to resources which enable those communities to use community based practices to strive for self sustaining economies (USDA Rural Development website, accessed 2.9.2008)

prescription developed by NMSU specifies criteria for four aspects of the thinning operation: size of trees cut, density of remaining trees per acre, relative spacing of remaining trees, and instructions for dealing with the branches and small-diameter slash leftover after trees are removed (Fernald, 2006). Finally, UNM is working to monitor changes to watershed health, including riparian health and water quality, as well as to evaluate and monitor community impacts (Fleming, 2006). This report is the first component of a three-year commitment on the part of the Community and Regional Planning Department at UNM which will provide three consecutive years of student monitoring on the site including detailed reports at the conclusion of each student's tenure and the Center for Regional Studies, which is providing financial support for the students. The final outcome of this commitment will be a case study of the efforts of the MPMT, as well as an evaluation of the environmental and social impacts of mechanical tree thinning in a dense, northern New Mexico forest. This project will aid land managers, landowners, and rural communities interested in finding sustainable community approaches to natural resource management.

Mechanical fuel reduction is likely to improve the health of the Rio La Casa watershed by improving biodiversity, reducing the risk of fire, improving the quality of life of residents, the experience of visitors to the site, and evolving the planning paradigm practiced by the SFNF towards one in which local voices have a prominent role in management decisions. Primary impacts from this project will be most evident to visitors to the site, including contractors for LJEC, who will encounter more diverse wildlife, a healthier mosaic of shrubs and trees, more inviting recreational opportunities, and economic opportunities including free fuelwood as well as the possibility of value added products such as *latillas, vigas*, wood pellets, and other finished timber products. Secondary benefits will be experienced more broadly in the form of reduced risk of fire, improved water quality, and another step towards an ecologically conscious relationship between communities, planners, and natural resources. Water resource impacts are likely to be minimal during the application of the thinning prescription, and will benefit over

the long-term from a better functioning forest with less organic matter and more diverse biota.

2 – Forest Thinning in the Rio La Casa Watershed

This document is the first report on this thinning project and describes the baseline social and environmental conditions in the watershed. The purpose of establishing this baseline is to begin the evaluative process by identifying a methodology and establishing measurements and precedent for further study. Additional studies into this project will function cooperatively with the material in this paper and will be able to build upon this foundation.

There are four sections to this report: an overview of forest thinning in the Rio la Casa watershed, a Community Assessment, a Natural Resource Assessment, and Recommendations for improving the effectiveness of this study and the fuel reduction treatment. Background material for the report includes discussion of the importance of community considerations in natural resource planning, discussion of the benefits of mechanical fuel reduction, and detailed descriptions of the study area. The Community Assessment includes demographic information about Mora valley residents from the 2000 U.S. Census and discussion of defining community for this project. The Natural Resource Assessment presents results from a year of fieldwork including the methodology and results of the first year of inquiry.

2.1 - The Need for Community Consideration in Natural Resource Planning

Natural resource management in the Western United States is primarily the responsibility and mission of large management agencies at either the state or federal level such as the United States Forest Service (USFS), The Bureau of Land Management (BLM), the National Parks Service (NPS), the Fish and Wildlife Service (USFWS), the New Mexico State Parks Department, and the New Mexico

Department of Game and Fish (NMDG&F). Land management decisions made by these agencies are determined by a complex bureaucratic process beholden to a combination of historical development patterns, funding availability, and an ever-evolving interpretation of the mandate of each agency and the laws under which it operates. These interpretations are impacted by political cycles, social trends, and a complex legal landscape including the Endangered Species Act (ESA), National Environmental Protection Act (NEPA), the Clean Water Act, the Antiquities Act, and the Wilderness Act. Traditional management considerations are not oriented towards incorporating local interests, knowledge, labor, or skills. This omission has led to an adversarial relationship between management agencies and some rural communities, which works against the best interests of both parties and to the detriment of the environment. The inclusion of local voices, knowledge, and labor has the potential to improve the effectiveness of natural resource management as well as providing an opportunity for rural residents, scientists, and policy makers to learn from one another about the environment they live and work in (Chess, Hance, & Gibson, 2000). The incorporation of local knowledge is of particular value in the Walker Flats area, where it is recognized that local knowledge of these forests is extensive, as is the commitment to the land on the part of local stakeholders (Gallegos, Madrid, & Fernald, unpublished).

2.2 – Mechanical Fuel Reduction

The tree density of forested areas in the Southwestern United States has increased significantly over the past century as a result of the combination of extensive grazing, which has reduced the quantity of ground fuels that carry fires, and intensive fire suppression, which has been practiced by state and federal agencies for decades (Madrid, Fernald, & VanLeeuwen,

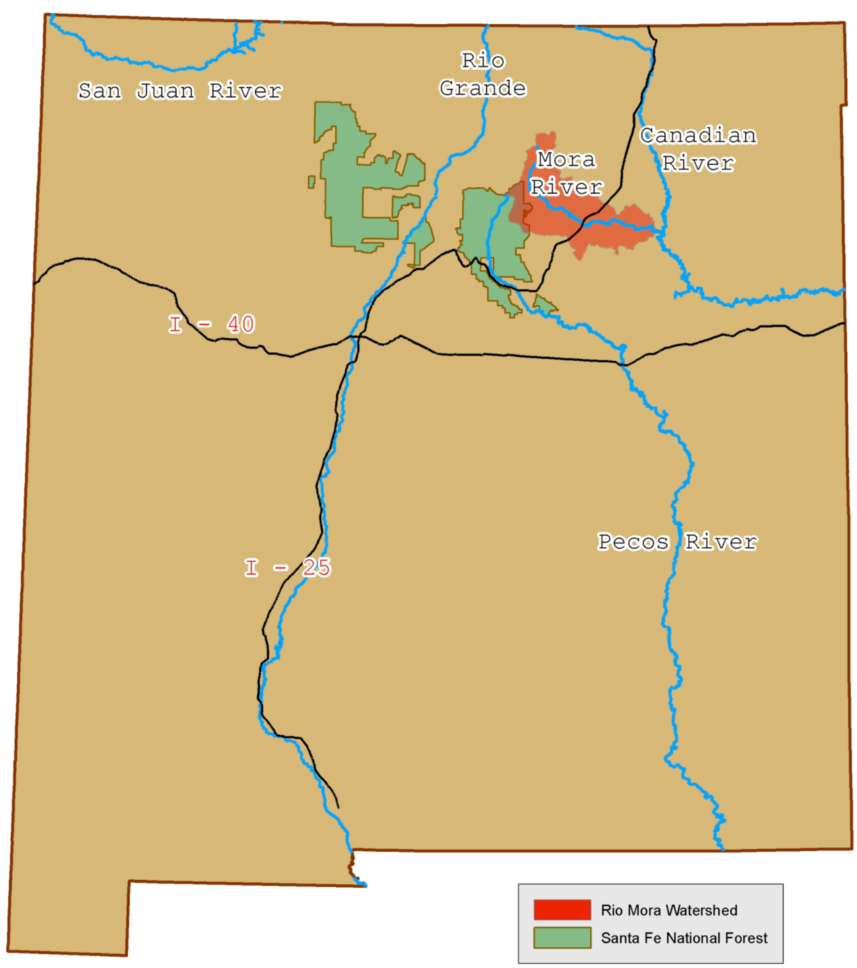
Photo 2 - Slash piles following mechanical fuel reduction

2006). Historically, fires served to thin forests naturally, creating an open landscape in which fires reoccurred at intervals between 2 and 30 years, depending on the forests predominant species (Madrid, Fernald, & VanLeeuwen, 2006). The dense forests created by these processes are characterized by low grass production, poor vegetative cover, high risk of catastrophic crown fires, reduced quality wildlife habitat, and poor access for recreational opportunities (Fernald, Gallegos, & Madrid, 2001). Mechanical fuel reduction, or tree thinning, is a management tool that can be used to restore an environment in which fire can begin to interact in a way that more closely reflects natural historic cycles. The goal of thinning is to establish a sustainable ecosystem in which forests can regain their capacity to control their own density while protecting biodiversity and improving the usefulness of the area for recreation (Covington, 2003). Mechanical tree thinning has been shown to be an effective fire management technique in both ponderosa and mixed conifer forests and has restored wildlife habitat without measured increases in either runoff or stream sedimentation (Fernald, Gallegos, & Madrid, 2001).

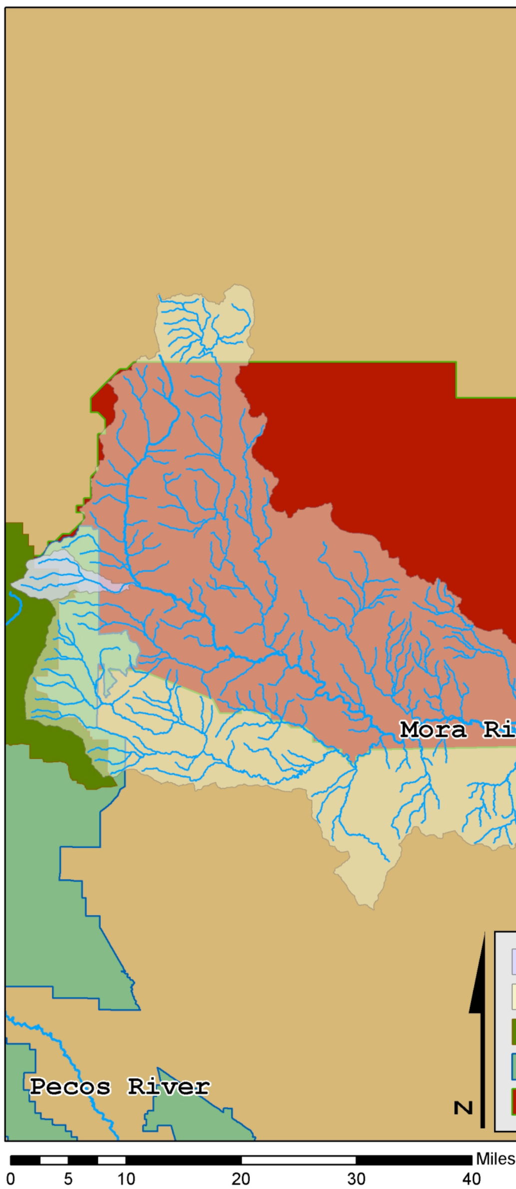
Mechanical fuel reduction has already begun in the Walker Flats following a prescription that restricts cutting to trees less than 12 inches in diameter at breast height with a goal of leaving 80 to 100 trees per acre (Fernald, Gallegos, & Madrid, 2001). Preferred species to leave in place are ranked: 1) Ponderosa Pine, 2) Limber Pine, 3) Aspen, and 4) Douglas Fir. Ideal spacing between trees is 20 feet, although the prescription specifies that clumps of trees should be left intact. Slash – woody debris less than four inches thick – will be piled in conical stacks (Gallegos, Madrid, & Fernald, unpublished). Timber removed from the area becomes property of the contractor and contractors working with LJEC are assured ample work. Should the thinning treatment be successful it may be applied more widely both in the National Forest and on private land in the Mora Valley.

2.3 – Site Location: The Mora Valley, the Rio la Casa Watershed, and Walker Flats

The SFNF is 1.6 million acres in the center of northern New Mexico. The forest is geographically divided in half. The western side of the forest centers on the Jemez River and is located between Albuquerque and Santa Fe on the west side of Interstate 40. The eastern half of the forest – where the Walker Flats site is located – is primarily centered on the Pecos River and lies to the north of Interstate 25 between Santa Fe and La Vegas, NM. The Pecos River has its headwaters high in



the Pecos Wilderness Area at the southern end of the Sangre de Cristo Mountains and flows north to south through the Forest. The river drains a watershed of approximately 38,300 square miles and runs for 926 miles before joining the Rio Grande (EPA Surf Your Watershed Website, 4.20.2007). The Santa Fe National Forest includes the uppermost 25 miles of the Pecos River, and extends north over

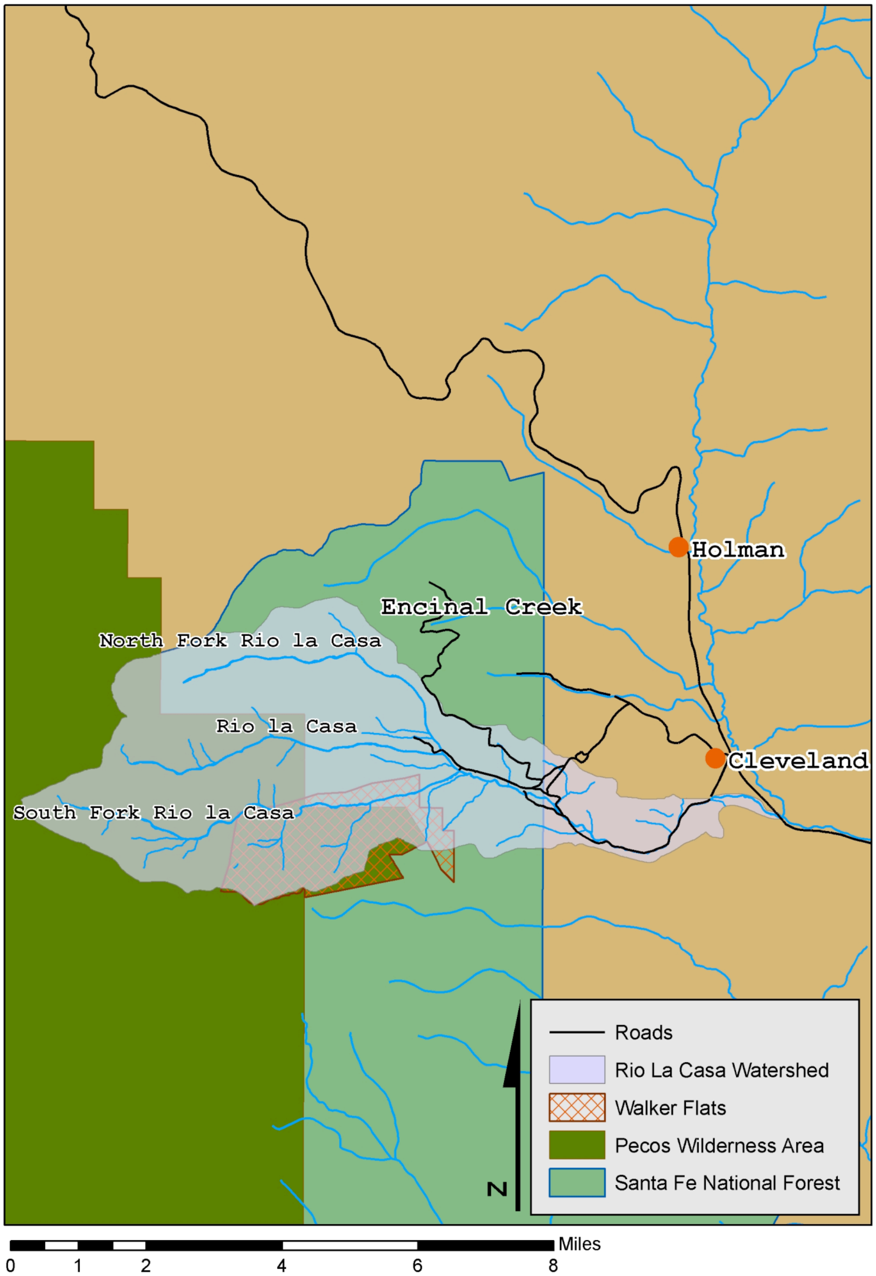


Truchas, Pyramid, and Chimayosos Peaks to include the upper extent of the range's north-east facing slope. This slope is the southern boundary of the Mora Valley.

The Mora River begins in the Sangre de Cristo Mountains in Taos County. The River flows south through the Mora Valley to Las Vegas, NM. The Mora Valley – from Chacon to Watrous – is one of the most iconic cultural landscapes in northern New Mexico. The valley retains many of the features of its historic settlement pattern, including *acequia* irrigation and a traditional roller mill powered by the river, which was at one time one of the two largest such mills in the southwestern United States (Cassidy, 2007).

The Mora Valley was first settled by new world immigrants in 1821 when Antonio Olguin led a group of families from the Picuris Pueblo area into the valley and settled the town of San Antonio (now Cleveland) (Rivera, 1998). In 1832, this group received permission from the Picuris Pueblo to divert water from their side of the mountain, which was the first transfer of water from the Rio Grande basin to the Canadian River Basin (notes from meeting of the Rio Grande Cutthroat Trout Task Force, 4.24.2007). In 1835, ownership of the land was assured by a Mexican community land grant (Ebright, 1994). The Mora River flows through this valley, and then continues south to join the Canadian River, which then flows east through northern Texas and Oklahoma and meets with the Arkansas River near the Oklahoma/Arkansas border. The Arkansas River flows east through the state and joins the Mississippi River, and then south, through Louisiana into the Gulf of Mexico.

The Walker Flats grazing allotment is located in the Rio la Casa watershed on a northeast facing slope. Access to the site is difficult and the site feels isolated from the Pecos half of the SFNF, although the area is continuous. This is because the Pecos Wilderness Area prevents roads from connecting the Walker Flats area with the more heavily used section of the Forest near Pecos, Cowles, and Panchuela. The Walker Flats trailhead is located in the site, and although it connects with the extensive wilderness trail system that runs along the ridges and drainages of the Pecos watershed, its isolated location likely means that it is less frequently used



than more popular access points such as Jack's Creek and Panchuela cabin. In order to reach Walker Flats, a one-hour off-pavement drive from Highway 518 takes visitors from the volunteer Fire Department in Cleveland past a few dozen clustered homes with remarkably large firewood piles, and up into the hills. For the first

several miles, the road winds through private in-holdings and crosses *acequia* diversions while passing pastures and homes. Upon reaching the Forest boundary, one still has to navigate a complex and unmapped series of dirt roads, many of which exist solely to provide large vehicle access to LJEC contractors. Many water sampling locations require additional hiking from the Flats, with the most distant site located approximately three miles by foot from the treatment area.

3 – Methods of Assessing Community and Environmental Impacts

The primary goals of this report are to establish replicable survey methodologies for fieldwork and to gather baseline information about existing environmental conditions and communities likely to be impacted by this project. This section describes the methodologies employed in this report to assess community and natural resource impacts of the Walker Flats mechanical fuel reduction project including evaluations of U.S census data, identification of sampling sites, riparian survey methodology, water quality testing, and the usefulness of the watershed as a unit for planning.

3.1 – Methods for Assessing Community Impacts

The purpose of this assessment is to examine existing social conditions in the Mora Valley and to consider the social ramifications of cooperative mechanical fuel reduction. There are two parts to this assessment: an evaluation of data from the 2000 U.S. Census and consideration of specific groups likely to be impacted directly and indirectly by fuel reduction and the cooperative model this project establishes. Defining the community for a natural resource planning project is complicated. Demographic data used in this report is drawn from the 2000 US Census and represents the overall population of Mora County. Mora is a county with 4,033 residents and an area of 1,931 square miles (US Census Bureau, 2000). For this

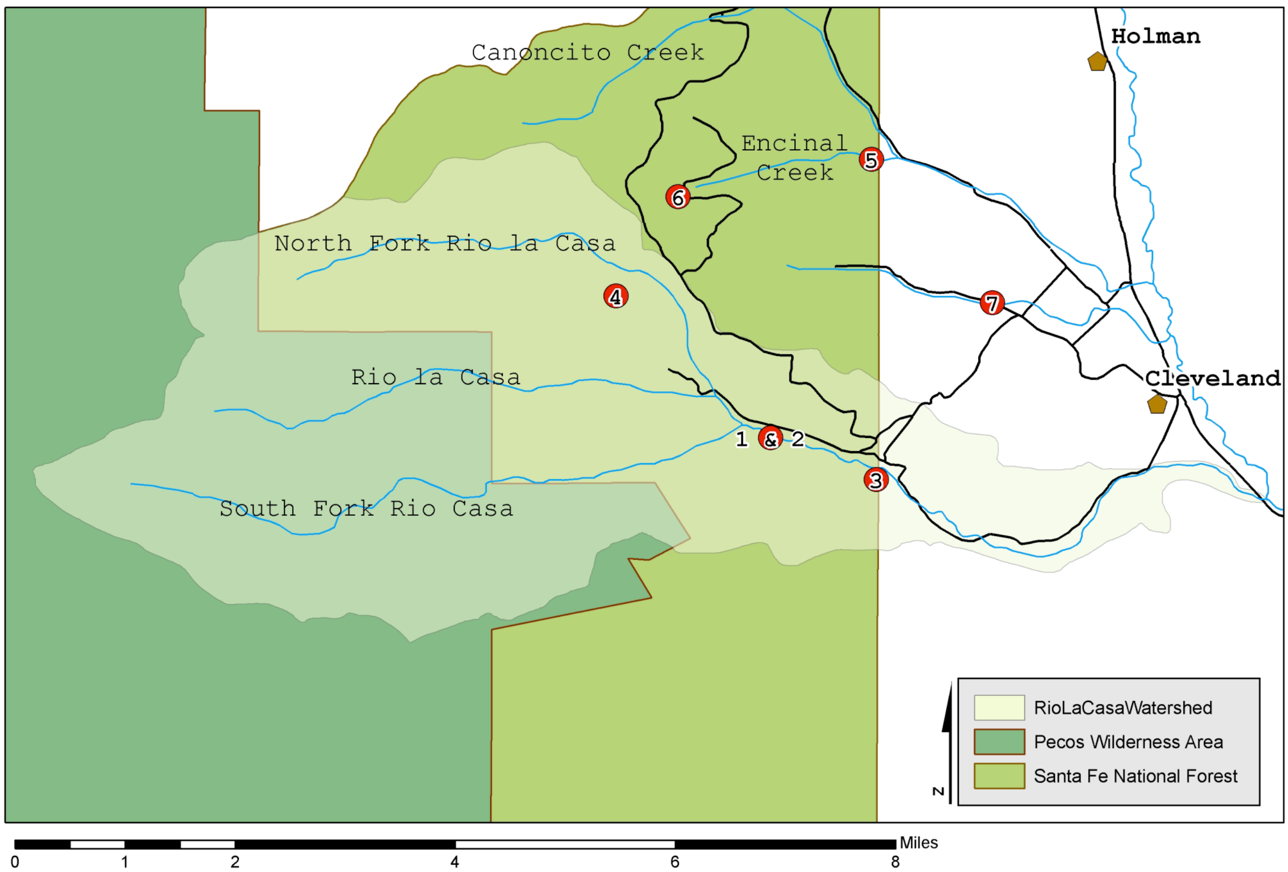
project, which is being conducted in an area without residents, defining the community requires subtler criteria than a project in an inhabited area. There are three groups of stakeholders who will experience the impacts of this project – Forest Users, Water Users, and Planning Interests – and each is addressed separately. While individuals may belong to more than one of these groups – such as a resident irrigator in Cleveland who also works as a contractor for LJEC or a downstream irrigation community using this model of community involvement to inform its own management practices – the relationship of each of these communities to the area is distinct.

3.2 – <u>Field Survey Methodology</u>

This study has two components to its fieldwork methodology: water sampling and riparian surveys. These two components are designed to give a picture of the chemical impacts of thinning as well as the physical condition of the riparian area. Field measurements were collected for this project three times between October 2006 and August 2007, and will continue to be collected by subsequent university students. The purpose of these measurements is to evaluate water quality and riparian health impacts caused by mechanical thinning. Water samples were analyzed using ion chromotography to measure anion levels – flouride, chloride, nitrite, bromide, nitrate, phosphate, and sulfate – as well as total phosphorous. A spectrophotometer was used in the field to evaluate sedimentation. Riparian health surveys were conducted at riparian sampling sites based on a methodology established by UNM Professor Bill Fleming and Richard Schrader for

Photo 3 - Collecting data on riparian conditions at sample site 1.

the New Mexico Watershed Watch program. These surveys measure the health of riparian areas by assessing the state of vegetation, flow, stream size and morphology, and the presence/absence of particular species of benthic macro-invertebrates.



3.2.1 – Site Selection[2]

Sites were selected to optimize the area from which flows were collected based on a combination of natural topography and property lines. Five of the seven sampling

[2] When entering the sample area, a number of private in-holdings within the forest boundary line the road. The site location map does not have sufficiently fine detail to show these properties. In reality, Sampling sites 1 & 2 are located at the boundary of the SFNF with these in-holdings, while site 3 is located beyond the forest boundary.

sites are located in the USFS Forest, which is preferential because it is difficult to account for the impacts of land use on private property. Prior to conducting the initial fieldwork, sampling locations were reviewed by professors William Fleming (UNM – Community & Regional Planning) and Alexander Fernald (NMSU – Animal and Range Sciences). Limitations on the accuracy of samples are related to the inclusion of property lines as a determining factor. Ideally, sampling sites would collect the total runoff from the Walker Flats. Unfortunately, most of the flow from these sites leaves the Forest before entering the stream. One result of this is that the levels reported in water quality sampling do not represent the runoff from the entire thinning site but rather include only portions of this area. This means that the focus in evaluating these samples should be on identifying patterns, such as gradual increases in nitrate levels, rather than on quantifying the precise impact of mechanical fuel reduction on a unit-per-acre basis.

3.2.2 – Water Sampling

Water samples were collected at each site in 16 oz. bottles filled with their mouths pointing downstream to reduce the amount of suspended sediment entering. Each bottle was filled once to rinse out the bottle and then dumped and submerged before collecting a second sample slightly upstream. Once collected, samples were refrigerated until testing. Turbidity testing was conducted on all samples in October 2007. In order to better emulate the natural condition of the stream, samples were vigorously shaken before testing. Samples had no visible sediment at the time of collection, but for future samples, testing turbidity in the field at the time of collection may yield more meaningful results.

3.2.3 – Riparian Surveys & Watershed Watch

Measuring riparian conditions is a helpful way to quickly learn about the health of a watershed. Riparian health is a good indicator of overall watershed health for two reasons: first, intact riparian areas are critical habitat and provide corridors for migrating animals (Fleming & Henkel, 2001). For wildlife – as for

livestock – access to water often comes with some negative impacts to the riparian area, namely trampling and selective grazing which can reduce biodiversity (Gifford, 1978). Habitat function is enhanced in healthy riparian areas, which "generally have a greater variety of types and sizes of vegetation and in greater abundance than in the adjacent uplands"(Fleming & Henkel, 2001). Second, riparian health is a barometer for the overall health of a watershed. The stream is the focal point of the watershed, and the health of the riparian area gives information about the condition of the watershed (Fleming & Henkel, 2001). For example, a sustainable watershed will have limited erosion, significant plant biodiversity, thorough and continuous bank cover, and should be (at least in New Mexico) well shaded with a regular mix of sun and shade. A stream that does not have these qualities, a stream with unstable banks, and poor vegetative and shade cover, reflects not only the poor health of the stream, but also the health of the land upstream (EPA, 2005).

Riparian surveys measure a variety of factors that can be interpreted to indicate the health of the watershed as well as the health of the critical riparian area itself. The methodology is easy to use – an advantage in terms of consistency and replicability – and calls for the measurement of several factors on a matrix in which each is scored based on stipulated criteria (see Table 1). Over the three years of this study, riparian health will be monitored by a succession of students. Rather than using an objective measure of riparian health, such as a reference stretch to compare with, this study uses the data in order to track changes over time. The data in this baseline report is valuable in that it provides a snapshot of the watershed as thinning begins. As future students continue to collect data, they will be able to compare that data with these baseline conditions to evaluate changes in watershed health following mechanical tree thinning.

Table 1 - Riparian survey parameters and methods

Parameter	Measurement Methodology
Riparian Vegetation Structural Diversity	Visual assessment designed to evaluate the presence/absence of forbs, grasses, shrubs, and trees, all of which should be present for a high score.
Bank Stability	Visual assessment based on the pitch of the stream's upper bank. The steeper the bank, the less the stability, and the lower the score.
Bank Cover	Rapid assessment of plant cover conducted by walking and noting whether plant matter or bare dirt is under one's feet. Scoring is based on the percentage of steps landing on plants.
Vegetation Buffer Width	Measured from the edge of the stream to the nearest disturbance – a farm, road, building, or golf course.
Vegetation Diversity	Visual count of how many different plant species are present – it is not necessary to identify the plants, simply to identify how many distinct species are present.
Embeddedness	A measurement of how much sediment has settled around cobbled substrate. The purpose is to evaluate the presence of benthic insect habitat, less sediment = better habitat, and to evaluate how much sediment has washed down the stream. Measured by lifting rocks from the streambed and visually assessing the percentage of the rock that was buried.
Flow	Estimated based on rough cross-sectional area multiplied by a flow-rate determined using Pooh-sticks.
Canopy Shading the Water	Visually assessed based on the nature of the canopy covering the stream. Highest points go to sites with a good mix of sun and shade, lowest points go to areas with extreme exposure.
Benthic Insects	In many streams, this can be difficult to survey because it requires being able to identify species of benthic macro-invertebrates. Insects are collected either through using a kick-net or by looking under rocks in the stream. So far in this watershed, all streams have had plentiful Stoneflies, which automatically qualify the habitat for the full points.
Width to Depth Ratio of Lower Bank	This is used to measure the adequacy of the channel to handle peak flows. Measurements are taken of the width of the lower stream banks, and the stream depth at that point. The lower the ratio, the higher the score.
Pools & Riffles	This measurement is based on the distance between pools, and varies with the gradient of the stream. Streams in this survey are small – less than 3' wide – and features are correspondingly small. Pools are the most desirable habitat for fish, and the more regular the pools, the higher the score and the better the aquatic habitat. Given that the streams in the Rio la Casa are not fish bearing, this field is less significant in this area than in fish-bearing streams.
Streambed Geology	Visual assessment of the streambed that identifies the relative mix of Boulders (basketball size+), Cobbles (tennis-ball size+), gravel, and logs. The greater the presence of the larger size classes (not gravel and sand), the higher the score.

Each criteria in the survey is scored from zero to four, and totals are tallied to provide a comprehensive score for the site. The Watershed Watch methodology is designed to favor fish-bearing streams, which are not present in the Rio La Casa watershed. In order to accommodate this, the weighting of factors can be modified (Fleming & Henkel, 2001). For this study, data is being considered in two ways: first, with the entire methodology and all parameters from the survey form, and second, modifying the survey methodology to exclude the aquatic habitat measurements of Flow and Pools & Riffles and to ignore Vegetation Buffer Width, which is more relevant in watersheds with greater levels of human disturbance. Complete reporting of all values is included in order to allow future surveyors access to all collected data.

3.3 – Watershed Scale Planning

The watershed is an excellent unit for planning because it is a ubiquitous, natural division that unites people based on their collective environmental impact and mutual dependency (Snyder, 1993). The usefulness of watershed-based planning has been acknowledged by planners and visionaries from John Wesley Powell to Gary Snyder and continues to gain prevalence among planning professionals in both community and natural resource planning (EPA, 2005). For planners, watershed boundaries provide unmoving and indisputable boundaries with a clear relationship between the macro- and micro-scales. Unlike unnatural boundaries – such as national, state, or county boundaries – which are based on artificial divisions such as lines of latitude and longitude, watersheds divide an area based on shared environmental circumstances. As Wendell Berry notes, "People who live on rivers – or, in fact, anywhere in a watershed – might rephrase the [golden] rule this way: do unto those downstream as you would have those upstream do unto you."(Berry, 2003) Here in New Mexico, the infrastructure that most closely follows watershed boundaries the boundaries of *acequia* irrigation communities and their corresponding dioceses (Rodriguez, 2007). The presence of

these divisions in the earliest holistic planning divisions of the state reflect the natural character of the watershed as a line of demarcation, and the longevity of these institutions may in part be due to the effectiveness of this planning model.

4 – Community Assessment

In the Rio la Casa watershed, there are very few residents with none living in the study area. Nonetheless, the nature of watershed planning is that communities of impact can be identified based on criteria both subtler and more elemental than location alone. For this community assessment, there are two parts: an analysis of U.S. Census data and a discussion of the potential impacts and communities of impact associated with the tree-thinning project. The Census data included is taken from the entire population of Mora county. Data was collected at this level to reflect the overall social conditions of the region, which is a uniquely intact area of traditional Hispanic settlement characterized by small communities, *acequia* oriented land divisions, and no significant population centers. The discussion of communities potentially impacted by this project is based on an evaluation of the role of this project in the context of land management, impacts to proximate populations, and users likely to visit Walker Flats.

4.1 – The Mora Valley: Demographics from the 2000 US Census

The population of Mora County is older, more predominantly Hispanic, lower income, and more likely to own their homes than residents statewide. Income levels are low – over 20% of households reporting a 1999 income of less than $10,000 – and this disparity is further pronounced in Hispanic households. Two of the most statistically significant differences between statewide and county statistics are income distribution and the age of homes.

Table 2 - Mora County Demographics From the 2000 U.S. Census

Census Category	Mora County	New Mexico
Total Population	4,033	1,819,046
Total Population: White Alone	58%	67%
Median Age	39.1	38.9
Median Age: Male	38.9	33.4
Median Age: Female	39.2	35.6
Hispanic or Latino	39.2	35.6
Median Age	39.1	38.9
Hispanic or Latino Median Age: Male	36.5	28.4
Hispanic or Latino Median Age: Female	36.5	27.6
Total # of Households	1,559	677,971
Average Household Size	2.59	2.63
Households with Hispanic or Latino Householder	84%	39%
Occupancy Rate	67%	87%
Owner Occupancy Rate	84%	70%
Median Household Income	$25,359	$34,133
% Claiming Public Income Assistance	8%	5%
Per Capita Income (1999)	$12,124	$17,261
Per Capita Income (White Alone)	$13,413	$20,307
Per Capita Income (Latino or Hispanic)	$10,777	$12,045
Median House Value	$82,500	$108,100

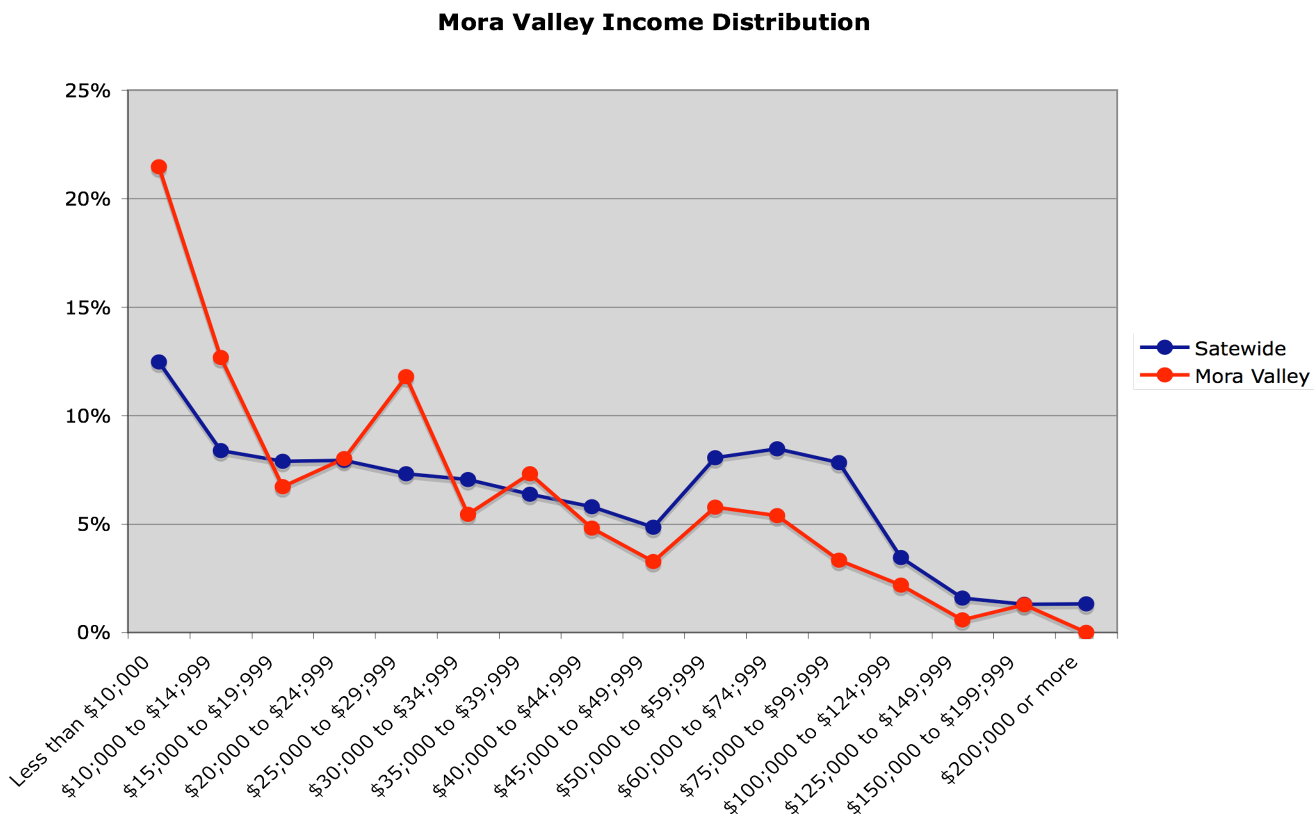


Figure 1 - Mora Valley income distribution

Income distribution in the Mora Valley is significantly different from statewide income distribution patterns because upper-middle class incomes ranging from $60,000 to $140,000 a year are less prevalent while low income levels – particularly incomes less than $10,000 annually – are far more common in Mora County.

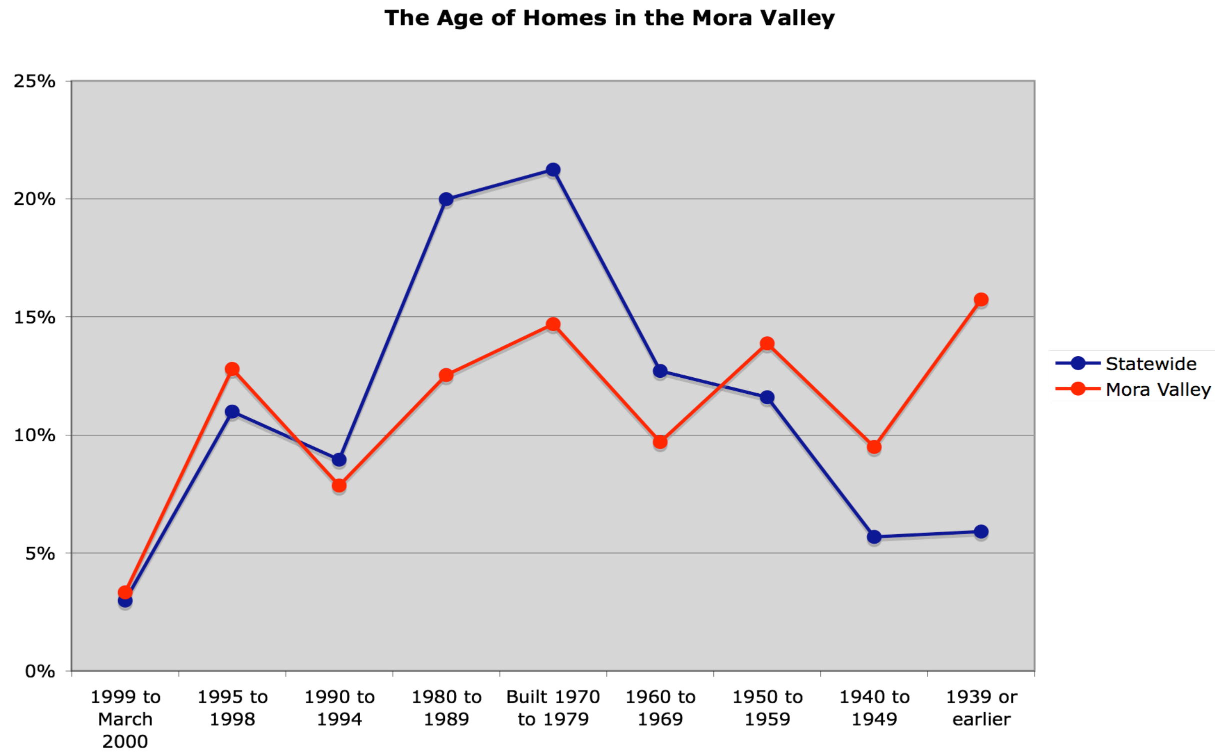


Figure 2 - Age of homes in the Mora Valley

Home construction is the second area in which the demographics of Mora County differ substantially from those of the entire state. In this graph, it is evident that home construction in the Valley has remained at a fairly steady rate since 1940 and that many residents live in older homes. This differs from statewide patterns in that home construction across the state boomed in the period between 1970 and 1990 and relatively few people live in older homes in the state as a whole. In the Mora Valley nearly three times as many of the homes were constructed before 1939, when compared to statewide data.

4.2 – Defining the Community

The Walker Flats fuel reduction project is likely to impact people in four ways. First, forest users will have firsthand experience with the changed face of the forest including lower tree density, increased wildlife habitat, more access to larger views, and the gradual recovery of the forest floor. Second, economic stakeholders

in the Mora Valley may experience changes in the scale and nature of their local economy based on the economic possibilities created by this project as both a source of new revenue and as a model for potential future economic growth. Third, water users may experience changes in water quality due to changes in the forest floor that may impact water quality. Finally, planning interests will benefit from the example of cooperative management established by the relationship of LJEC and the SFNF. Each of these communities of impact is discussed below.

4.2.1 - Forest Users

The people who will experience the greatest impact from mechanical fuel reduction in the Walker Flats are visitors to the site. These people are referred to as the Forest Users, and this group includes grazing permit holders, recreational users such as equestrians, hikers, and hunters, and monitoring groups entering the forest in order to measure its recovery and condition. These groups will see the visual impact of tree thinning, including first the preponderance of user-created access roads, piles of woody slash, and the thinned landscape of trees. As time passes, the gradual recovery of the area, including both the growth of under-story vegetation and the increased visible presence of wildlife, will become evident as well. The diverse range of motivations bringing people to the area reflects the utility and importance of forests as a place that has economic benefit, but also as a place that provides recreation and respite.

Grazing Permit Holders

Another user of the area impacted by tree thinning will be grazing permit holders. These individuals or corporations have limited use of those allotments due to the high risk of fire and scarcity of forage. If the thinning project has its intended impacts, both of these conditions will change, thereby dramatically increasing the usefulness of the area for grazing. These individuals will receive their benefits

gradually as the habitat recovers and an under-story of plants, grasses, and shrubs re-establishes itself. Increased utility of the region for grazing will also increase the amount of vehicular traffic in the area, as well as the density of livestock. Grazing and the presence of non-native, domesticated animals can have negative impacts to the aesthetic and environmental condition of wild places.

4.2.2 – Economic Stakeholders

One of the primary goals of LJEC is to create new economic opportunities for Mora valley residents. Many aspects of their proposal are designed to address this objective, including the procurement of a 15-acre site for a small business incubator for the production of wood products (LJEC, 2005). This site will serve as a place for contractors from the local community to work to create traditional products such as vigas and latillas, and also to develop modern goods such as charcoal, wood chips for biomass energy, and material to be used in the production of wood pellets in a facility located in Española (LJEC, 2005). Additional benefits will occur on a smaller scale as contractors are able to procure fuelwood at no cost, which offsets heating costs in the winter. The scale of all of these projects is limited by the size of the thinning application area, and the hope of the MPMT is that through educational outreach programs to regional landowners, the benefits of mechanical fuel reduction will be realized in a large scale that would facilitate significant growth in this industry and region.

Photo 4 - Fuel-Wood pile in Mora, NM.

Mechanical Fuel Reduction Contractors

Contractors working for LJEC will make investments of time and effort and will be the direct beneficiaries of income produced from the sale of timber and saved by the procurement of fuelwood. This corporation may find itself in a tenuous position as thinning nears completion. It is possible that surrounding landowners will choose to employ this organization to thin their own lands once they have completed the prescription in Walker Flats, but it is also possible that the group will have fulfilled its mandate with the completion of the Walker Flats thinning. Contractors working for the corporation face a decision of how much time and energy to invest in this project based on multiple possible outcomes. LJEC has chosen to invest in land for a small business incubator which would allow contractors to add value to the wood coming out of the forests by creating milled boards, carved vigas, and other products. Alternatively, contractors may also view this as short term work that provides temporary access to plentiful, free fuelwood which offsets the cost of heating their homes.

4.2.3 – Water Users

The predominant demands on water flowing out of the Rio la Casa are agricultural. The Rio la Casa watershed is a contributor to the continents largest basin in North America, the Mississippi River Basin. This basin is the subject of environmental and economic concern as the impacts of the vast amount of development and agriculture begin to be felt by residents at the bottom of the watershed. Recent flooding in New Orleans has brought many of these issues into sharper contrast. Loss of wetlands in the Mississippi Delta Region, the impact of agricultural pollution in the gulf of Mexico, and increased flood risks have brought the ecological concerns of this basin towards the forefront of American environmental politics. The Rio la Casa is a tiny contributor to this system, yet the nature of a watershed is such that effects are compounded and accumulate as one moves downstream. Remembering Wendell Berry's warning, "do unto those

downstream as you would have those upstream do to you," (Berry, 2003) it is the responsibility of ethical water users to return water to its natural systems as clean or cleaner than when the water reached them.

Acequia Irrigators

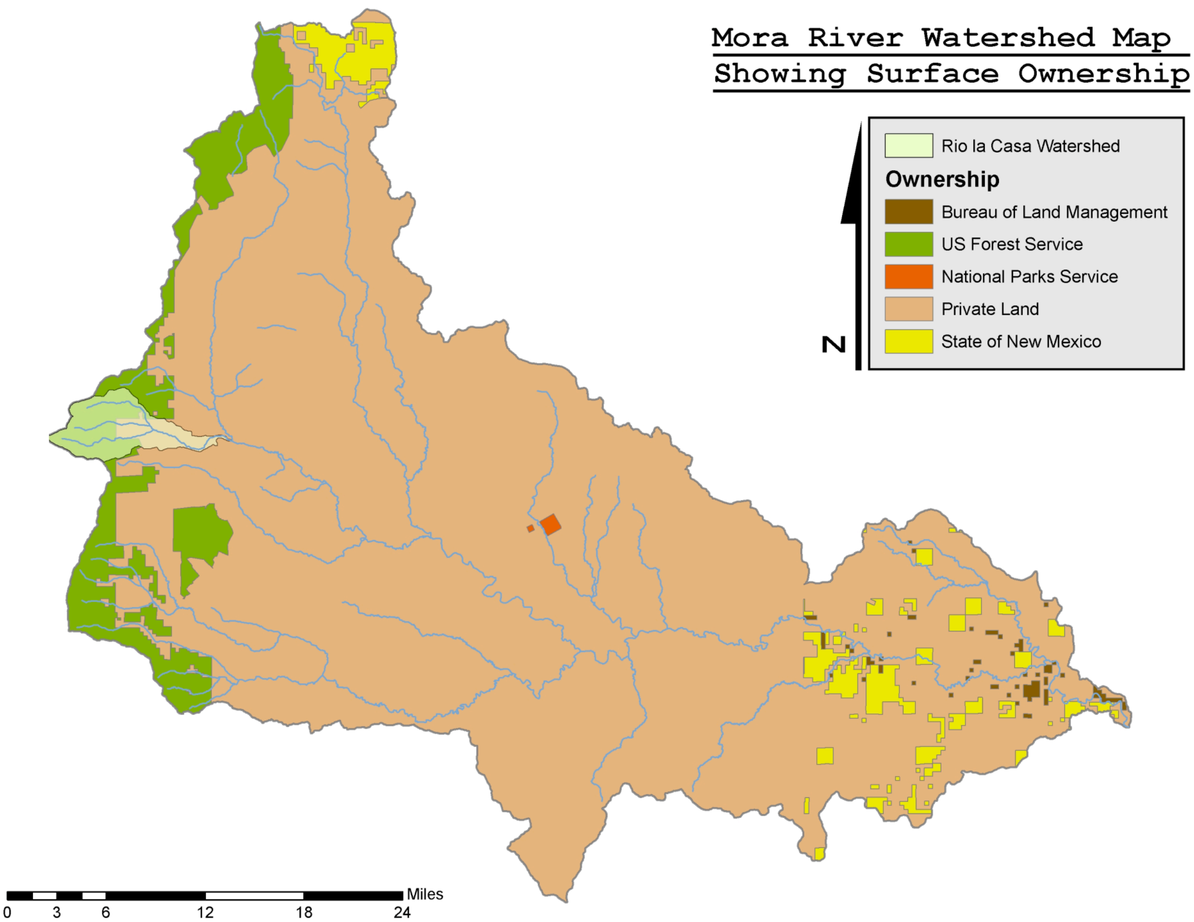
Directly below the Rio la Casa watershed is the town of Cleveland, NM. This town – the oldest settlement in the Mora Valley – relies on water flowing from the Rio la Casa to supply its *acequia*s. The water in these *acequia*s flows from directly from the SFNF, in some cases through diversions located in the forest itself. The quality of this water is unlikely to have significant impact on the productivity of farms which rely on this flow, and yet the importance of protecting water quality throughout the Canadian River basin relies on users receiving clean flows from upstream and returning clean flows for users located downstream. Were the project to diminish the water quality in this watershed, this would contribute to diminished water quality for the remaining hundreds of river miles in the Canadian, and eventually Mississippi River basins. This would impact aquatic life and all animals reliant on aquatic life, in addition to impacts on residents and farmers located along the course of these rivers.

4.2.4 – Planning Interests

This project – both the application of mechanical thinning and the example of citizen/Agency cooperation – will serve as a model for communities throughout the state. The two primary ways in which this project may inform management practices are as a model of citizen/agency cooperation and by contributing to knowledge about mechanical tree thinning. This model can be mutually beneficial to regional ecology, management agencies, and rural state residents. Northern New Mexico is full of small, rural, traditional communities living in close proximity to large parcels of land controlled by local, state, and federal agencies as well as

significant parcels held privately. Throughout the state the relationship between these communities ranges from symbiotic, to detached, to antagonistic. If this project proves to be effective for the members of LJEC, for the community of the Valley, and for land managers at the SFNF, this model could help other communities to organize and cooperate with other agencies.

Private Landowners In the Mora Valley



The majority of the land in the Mora valley is as densely forested as the Walker Flats area, but is privately owned. Depending on the success of the project, private may consider a similar treatment for their property. At the conclusion of the Walker Flats project, LJEC will no longer play a direct role in these thinning projects (Rivera, 2008). Nonetheless, the small business incubator and the model

project established by this group will be instrumental in future fuel reduction projects, and the thinning itself would alter the physical landscape of the valley while encouraging economic development and biodiversity and reducing the risk of major wildfire.

4.3 – Community Impacts

Mechanical tree thinning and the creation of LJEC are likely to benefit impacted communities. Reducing the risk of wildfire has benefits for all valley residents and contributes to reducing the statewide management costs of fighting, and being prepared to fight, forest fires. An additional benefit for the area comes in the form of environmental recovery in the Walker Flats as the area becomes healthier with more productive wildlife habitat. The potential for long-term protection of water quality in the Rio la Casa has benefits for local irrigators and to creating a more ethical water culture. Finally, the cooperative arrangement between LJEC and the National Forest may serve as a model to encourage management agencies to pursue cooperative arrangements with rural communities, and may also encourage rural communities to organize and look for opportunities to work for the mutual benefit of their environment, economy, and relationship with their local land managers.

5 – Natural Resource Assessment

Traveling to the watershed throughout the year provided an opportunity to observe changes. Stacks of fire-wood, located in the yards of nearly every home in the valley, grew from modest stacks to, in some cases, enormous piles which could easily conceal an elephant or Hummer, and which towered over the homes they would eventually heat. As the mechanical thinning operation expanded, weekends became noisy with chainsaws and roads became wider with deep ruts in places and littered with cans, cigarette packs, and lost pieces from the underbodies of trucks and trailers. Hikers and equestrians using the area to access the Pecos Wilderness via the Walker Flats trailhead – two of these groups were encountered while conducting fieldwork – would have seen and heard numerous chainsaws running throughout the days while people working in twos, threes, or fours, lopped down trees, sliced them into firewood, and loaded their trucks high with un-split rounds. Despite these disturbances in the Flats, sampling sites were isolated, quiet, and pristine, the only disturbance encountered while surveying was a mother black bear and her cubs who blocked access from one site and introduced an element of aerobic exercise.

Photo 5 - Fallen wood in the stream at sample site 4.

5.1 – Expectations

This report provides baseline watershed health information that will become part of a larger, multi-year project to evaluate the impacts of mechanical tree thinning to watershed health. This document is a starting point and will become more valuable as data continues to be collected and compared. The hypotheses expressed in this report address the expected condition of the watershed and to a limited extent, the impact of this project. However, because this report includes only data about the first year of this study, expectations regarding the long-term impacts of tree thinning are not yet tested.

Photo 6 - Site 2, *acequia* diversion in the Forest near site 1.

Despite decades of fire suppression, water quality following the thinning prescription was expected be of high quality with low levels of nitrate and phosphorous. Water quality is expected to be un-impacted because, whatever increases there may be in organic matter and sediment leaving the treatment area, these will be filtered by vegetation and distance before those flows enter watercourses. Moreover, because sampling was conducted seasonally, rather than following peak events, significant portions of streamflow will be base-flows from high-mountain springs unlikely to be influenced by surface conditions.

5.2 – Results: Nutrients & Turbidity[3]

Table 3 - Nutrient levels in water samples by site and collection round.

Site	Survey Round		IC Results (mg/L)					
		Total Phosphorous	Flouride (Fl)	Chloride	Nitrite	Bromide	Nitrate	Sulfate
1	Fall	< .05	< .05	< .05	< .05	< .05	0.59	13.63
1	Spring	< .05	< .05	0.05	0.13	0.06	< .05	16.31
1	Summer	< .05	0.1	< .05	< .05	< .05	< .05	18.22
2	Fall	< .05	< .05	< .05	0.12	0.16	0.06	13.62
2	Spring	< .05	< .05	< .05	0.05	< .05	< .05	16.44
2	Summer	< .05	0.05	< .05	0.05	0.07	0.08	18.32
3	Fall	< .05	< .05	< .05	0.06	0.08	< .05	13.55
3	Spring	< .05	0.15	< .05	0.06	0.05	< .05	161.37
3	Summer	< .05	< .05	0.05	< .05	0.06	< .05	16.17
4	Fall	< .05	0.07	< .05	0.06	< .05	0.06	20.08
4	Spring	< .05	< .05	< .05	< .05	< .05	< .05	31.7
4	Summer	< .05	0.06	< .05	0.1	0.06	< .05	33.32
5	Fall	< .05	0.06	< .05	< .05	0.08	< .05	74.19
5	Spring	< .05	0.07	< .05	< .05	< .05	< .05	35.04
5	Summer	< .05	0.11	< .05	< .05	< .05	< .05	50.27
6	Fall	< .05	0.12	0.07	0.06	0.05	0.05	155.48
6	Summer	< .05	0.05	< .05	< .05	0.06	0.18	23.93
7	Fall	< .05	< .05	< .05	0.06	0.05	< .05	17.09
7	Summer	< .05	< .05	< .05	< .05	< .05	< .05	18.14

[3] Manu values presented in this table fall within the margin of error for the equipment used to measure them. While these errors may have less significance with higher nutrient and phosphorous levels, with levels approaching zero it creates measurements below zero. For values reported at extremely low concentrations, the levels can be read as essentially zero.

Data collected from water samples was consistent with the expectations of the survey. Total phosphorous measurements, intended to quantify the amount of dissolved orthophosphate and decomposing debris (organic phosphate) in the water were less than 0.05 mg/L in all samples and at all seasons. Nitrate levels were also low, less than 0.1 mg/L, with one exception. This exception, from the first sample collected on the project, showed nitrate levels of 0.59 mg/L, more than 20 times higher than the next sample. This may be related to poor sampling, the sample having been collected in a water bottle that had formerly held drinking water. Turbidity testing was conducted on all samples with negligible results. However, this value may be unreliable as testing was completed after the samples had sat for some time, and because samples were collected in such a way as to minimize the inflow of sediment into the sampling bottles. The parameter that showed the greatest variation was sulfate, which varied from 13 to 19 mg/L, with two spikes at 155 and 162 mg/L. This may point to the fact that the water sampled originated in springs which had a high sulfate content, although sampling directly from a spring did not produce remarkably high or consistent levels of sulfate.

Photo 7 – Sample site 5.

5.2.2 – Results – Riparian Health

Table 4 - Riparian survey results by location and sampling date

Site #	Survey Date	Riparian Vegetation/ Structural Diversity	Bank Stability	Bank Cover	Vegetation Diversity	Embeddedness	Streambed Geology	Canopy Shading the Water	Benthic Insects	Width to depth ratio of lower bank	Pools & Riffles	Flow m3/sec	Vegetation Buffer Width	% of Total Parameters	% of Modified Parameters
1	Fall	4	3	3	3	4	4	4	4	3	4	4	4	92%	89%
1	Spring	4	3	3	2	4	4	4	4	3	4	4	4	90%	86%
1	Summer	4	3	4	3	4	4	4	4	3	4	4	4	94%	92%
5	Fall	3	4	4	2	2.5	4	4	4	3	4	4	4	89%	85%
5	Spring	3	3	2	2.75	3	3	4	3	3	3	4	4	79%	74%
5	Summer	3	3	3	2	3	3	4	3	3	3	4	4	79%	75%
6	Fall	3	4	2	2	3	3	4	4	2	2	2	4	73%	75%
6	Summer	4	4	4	3	3.5	4	4	3	4	3	1	4	86%	93%
7	Fall	4	4	4	3	2.75	4	4	4	3	4	4	4	93%	91%
7	Summer	4	4	4	2	2	4	4	4	3	4	4	4	90%	86%

Riparian data supported expectations that this watershed, despite decades of fire suppression, maintains fairly healthy riparian corridors. Sites scored well, and lowest in the spring samples. Sites were scored in two ways: first with the complete set of criteria, and second with a modified set of criteria excluding the categories of pools & riffles and flow because these are non-fish bearing streams, and Vegetation Buffer Width because the Rio la Casa watershed is generally roadless. For most sites, scores went down using the modified criteria. This was not the case for site #6, which has low scores in both flow and pools & riffles. Excluding these categories increased the scores of this site.

Flow estimates were made for each site based on cross-sectional area and flow. These estimates were plugged into the Watershed Watch matrix and categorized based on expectations for well functioning coldwater streams. Nearly all survey sites, the single exception being site 6, were categorized as having flow rates of 2 cfs or greater. The exception to this was at site 6, which is located high in the watershed and whose flow was between 0.5-1.0 cfs in the fall, and less than 0.5 cfs in the summer.

6 - Recommendations

As the first component of a three year study, one function of this report is to identify ways in which the study, survey methodology and thinning treatment could be improved. These recommendations are provided in order to inform and improve the usefulness of this report for subsequent student work as well as to improve the effectiveness of this three-year project in meeting the needs of LJEC and other interested parties. Recommendations are also made regarding ways to ensure the continued monitoring of water quality on this site.

6.1 – Study Recommendations

In the process of researching and creating this project, a number of possibilities for improving the study have arisen. First, in terms of evaluating the social implications of thinning, census data could be evaluated at a more local level to address the block group or tracts most proximate to the thinning area or by working to identify census groups that relate to the communities of impact. This data could be further improved by incorporating interviews and personal accounts from irrigators and contractors working for LJEC.

Field methodology could also be improved. One way that this could be accomplished is by testing conditions more frequently and by making a particular effort to check turbidity and stream quality during peak runoff events. This is

difficult to do because of issues with site access, and might be facilitated through the use of remote sensing equipment or the inclusion of local involvement in the monitoring process. In field turbidity testing would also improve the meaningfulness of the results. This could be accomplished using available equipment, but may necessitate a change in sample collection so that samples better represented the average turbidity of the streamflow.

6.2 – Mechanical Fuel Reduction Recommendations

Additional considerations could improve the effectiveness of the thinning procedure and the recovery of watershed health. These include a long-term prohibition on grazing in the Walker Flats in order to allow the grasses and sedges time to re-establish, and the incorporation of mechanical disturbance into the thinning prescription. Incorporating mechanical disturbance would mean that the areas that have been thinned would then be dug, plowed, and turned over to some extent to encourage the establishment of new plants (Fleming & Henkel, 2001). One area in which this process could be helpful is in removing the user-access roads that have sprung up to allow contractors access to thinning areas. Prohibiting grazing would, similarly, protect the watershed in order that it might re-establish under-story plants and begin the process of reclaiming stumps and the detritus of thinning.

Photo 8 - Tracks from LJEC contractors removing felled trees.

An additional incentive to limit grazing would be to improve the area for recreation. At present, the Walker Flats area – though connected by trails to the

popular Pecos Wilderness Area – is underused by recreational hikers and visitors to the National Forest. In part, this is due to the difficulty of access, it is a three-hour drive from the town of Pecos to the Walker Flats trailhead, but this is also due to the area being underdeveloped for recreation. Hiking and nature trails could be enhanced in order to allow multi-day hikers from the Pecos area to drop down from the ridges and explore, which would broaden the interest in the area as well as awareness of mechanical fuel reduction as a management tool.

6.3 – Recommendations for Continued Monitoring

Long term monitoring of water quality on this site would be advantageous to all parties involved in this process and could increase the role of the local community in the management of natural resources in the Mora valley. One way in which this could be accomplished would be to incorporate a program like Watershed Watch into the local school curriculum. As with any project implemented through a school system, this would have to be catered to the mutual benefit of a variety of interests, in this case valley residents, students, and the environment. Monitoring could be expanded to include the main-stem of the Mora as well as other contributors, and could include some education on geography and environmental studies by teaching students about the role of the watershed and the role that their community plays in the larger watershed scale including the Canadian and Mississippi River Basins. Moreover, data collected by students in such a project could be coordinated with the State's Universities – UNM, New Mexico Highlands University, and NMSU – as well as with state and federal management agencies such as the Office of the State Engineer, NMED, USFS, BLM, NMDG&F, and the US Fish & Wildlife Service. In this way, students could learn about their home watershed, gain valuable skills, focus on local environmental education, and contribute to the body of data that informs environmental management decisions.

7 – Conclusions

The cooperative mechanical fuel reduction project being carried out by LJEC in the Walker Flats grazing allotment of the Santa Fe National Forest has three primary goals: improving wildlife habitat and vegetative productivity on the site, improving recreational opportunities, and reducing the risk of uncontrollable wildfires so that smaller fires can again play a role in the natural cycles of the place. These goals are well conceived, and the thinning prescription being applied is likely to facilitate their accomplishment.

Census research of Mora County reveals a population that is older, lower income, and more predominantly Hispanic than the overall population of the state of New Mexico. This community will likely benefit from the project economically as contractors from LJEC are able to turn their labor into value-added lumber products which they can either sell, or use to offset costs they would otherwise incur. This community will also benefit from the reduced risk of catastrophic wildfire in this site. No residents live in the Walker Flats area, and very few in the Rio la Casa watershed. Instead, this report identified communities of impact likely to be affected by this thinning treatment. These communities are divided into four groups based on the ways in which they will experience the impact of the project. The first of these three groups are forest users, including grazing permit holders in this region of the Santa Fe National Forest, and recreational visitors to the site. Members of this community will benefit from the improvements to the site in terms of the areas ability to sustain productive wildlife habitat, increased vegetative productivity, and improved aesthetic and recreational opportunities. The second community impacted by this project is economic stakeholders, including thinning contractors. These individuals will profit directly from the sale of timber products removed from the thinning area, from savings derived from the procurement of free fuelwood from the site, and may in the long-term benefit from the small business incubator being established through the efforts of LJEC. The third community impacted by this project is water users. The most immediate members of this

community are the *acequia* irrigators in the town of Cleveland, which diverts its irrigation water directly from this watershed. Additional water user groups include the population of the Canadian and Mississippi River basins, of which the Rio la Casa is a part, who will benefit from the example of ethical water stewardship provided by a conscientious watershed partner. Finally, the fourth community of impact is planning interests who can benefit from the cooperative model of agency cooperation with a local CDC and from the increased understanding of the impacts of tree thinning generated from conscientious monitoring and analysis of this project.

There are two components to the natural resource assessment of the watershed implications of the Walker Flats thinning: water quality and riparian health. Data were collected at three times between October 2006 and August 2007. Water quality testing revealed clean water with low levels of all tested nutrients. One anomaly appeared in this testing in that two samples were found to have substantially greater levels of sulfates than all others. The cause and importance of this anomaly are unclear, but may become more apparent as further samples are collected and tested in subsequent years. Riparian health surveys revealed a moderately healthy ecosystem with healthy levels of macroinvertebrate presence and bank stability, but lower scores in terms of vegetative and structural diversity.

Overall, the goals of this project are consistent with the needs of the environment and community in which it is being conducted. Tree thinning is likely to benefit the forest by creating more productive and diverse wildlife habitat, improved aesthetics and access to the site to facilitate recreational opportunities, and reducing the risk of unmanageable wildfire which will enable smaller fires to again play a regular role in the natural cycles of the place. The environmental impacts of this project are likely to be minimal in the short term, and positive over the long term. The community impacts of this project are also likely to be positive in terms of providing economic benefits to individual residents and families, improving the relationship of the community with the Santa Fe National Forest,

and leading to the creation of a well organized and intentioned Community Development Corporation in La Jicarita Community Enterprises.

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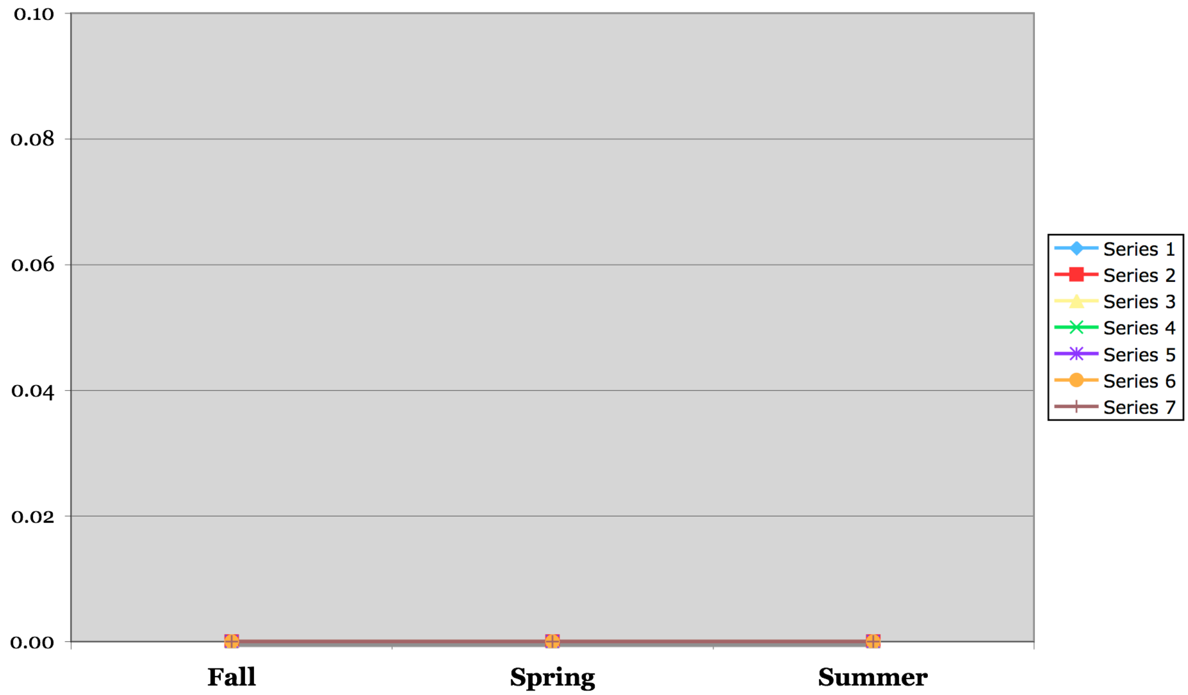
Appendix A:

Detailed Tables and Charts for Water Quality Samples[4]

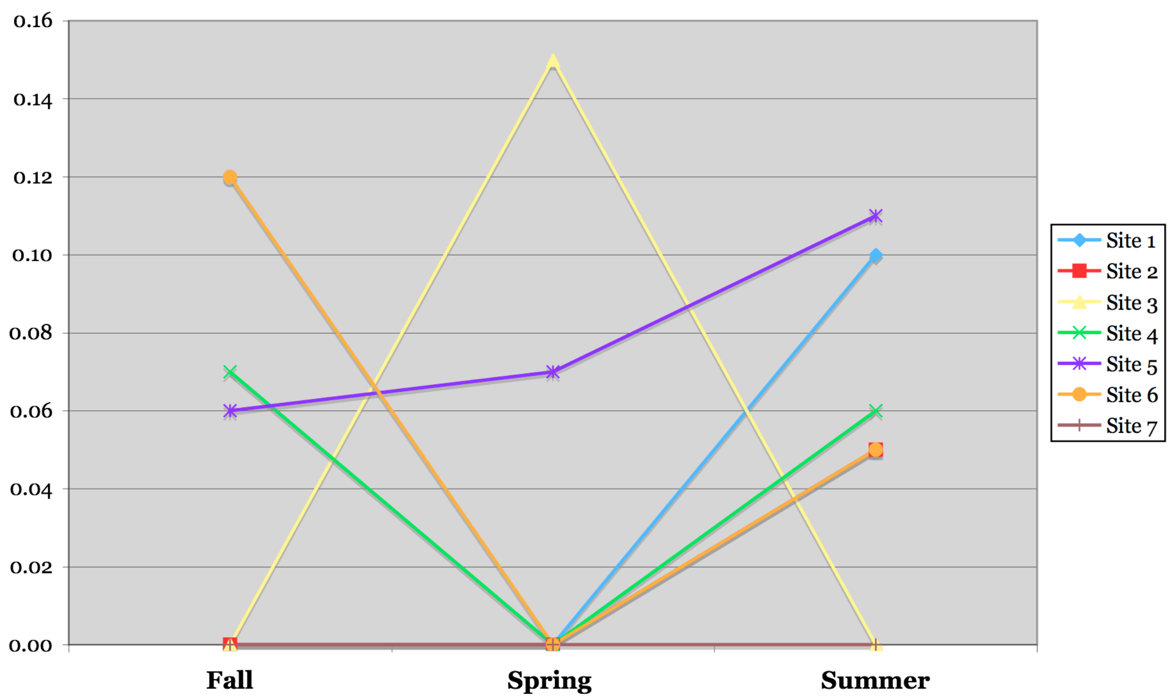
Site	Survey Round		IC Results (mg/L)					
		Total Phosphorous	Flouride (Fl)	Chloride	Nitrite	Bromide	Nitrate	Sulfate
1	Fall	< .05	< .05	< .05	< .05	< .05	0.59	13.63
1	Spring	< .05	< .05	0.05	0.13	0.06	< .05	16.31
1	Summer	< .05	0.1	< .05	< .05	< .05	< .05	18.22
2	Fall	< .05	< .05	< .05	0.12	0.16	0.06	13.62
2	Spring	< .05	< .05	< .05	0.05	< .05	< .05	16.44
2	Summer	< .05	0.05	< .05	0.05	0.07	0.08	18.32
3	Fall	< .05	< .05	< .05	0.06	0.08	< .05	13.55
3	Spring	< .05	0.15	< .05	0.06	0.05	< .05	161.37
3	Summer	< .05	< .05	0.05	< .05	0.06	< .05	16.17
4	Fall	< .05	0.07	< .05	0.06	< .05	0.06	20.08
4	Spring	< .05	< .05	< .05	< .05	< .05	< .05	31.7
4	Summer	< .05	0.06	< .05	0.1	0.06	< .05	33.32
5	Fall	< .05	0.06	< .05	< .05	0.08	< .05	74.19
5	Spring	< .05	0.07	< .05	< .05	< .05	< .05	35.04
5	Summer	< .05	0.11	< .05	< .05	< .05	< .05	50.27
6	Fall	< .05	0.12	0.07	0.06	0.05	0.05	155.48
6	Summer	< .05	0.05	< .05	< .05	0.06	0.18	23.93
7	Fall	< .05	< .05	< .05	0.06	0.05	< .05	17.09
7	Summer	< .05	< .05	< .05	< .05	< .05	< .05	18.14

[4] Values in this table reflect measured levels. However, values below .05 mg/L are smaller than the sensitivity of the measurement process is able to detect. In the text of this paper, these values are uniformly described as <.05 mg/L.

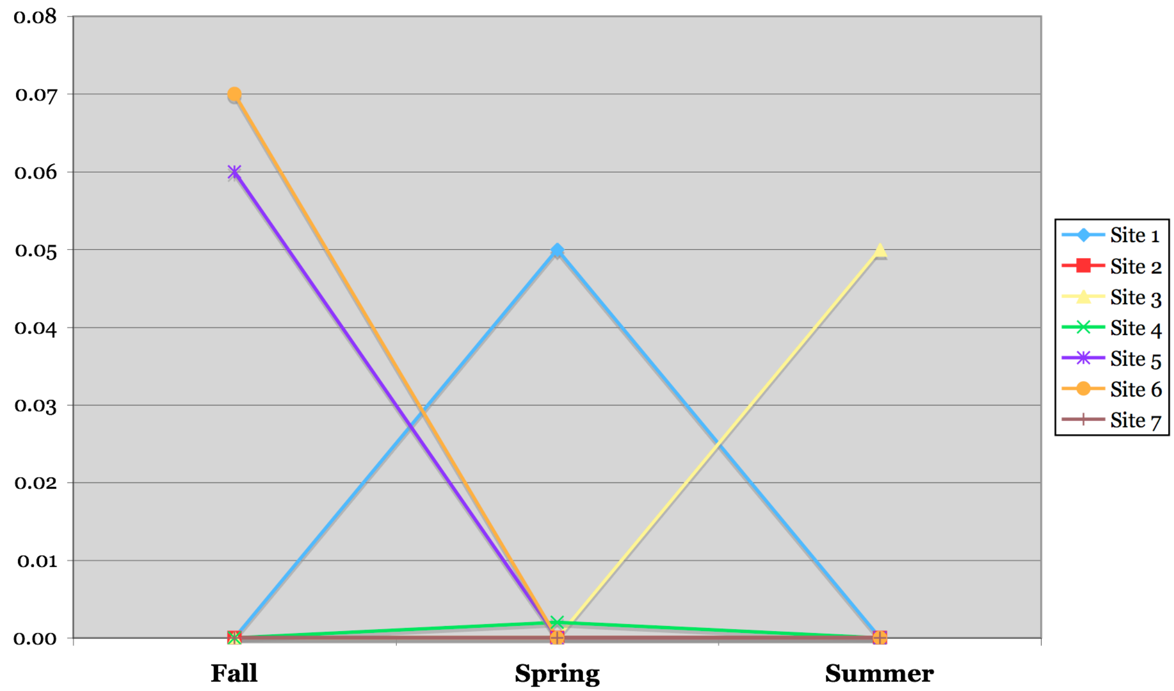
Total Phosphorous (mg/L)



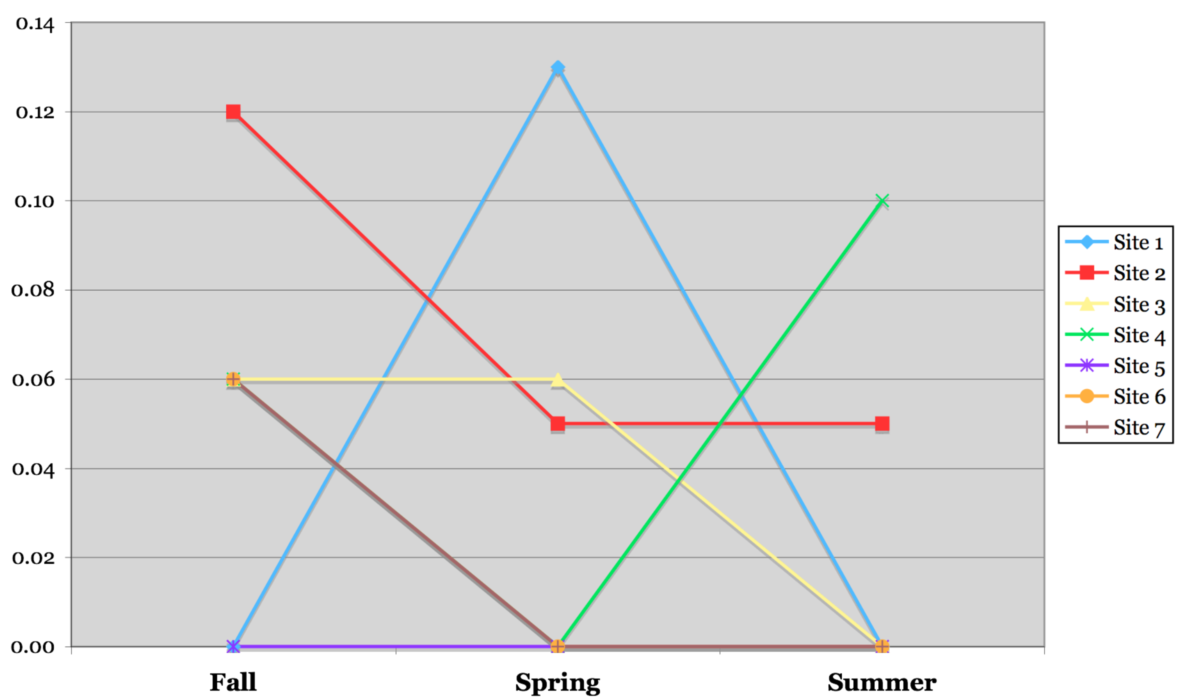
Flouride (mg/L)



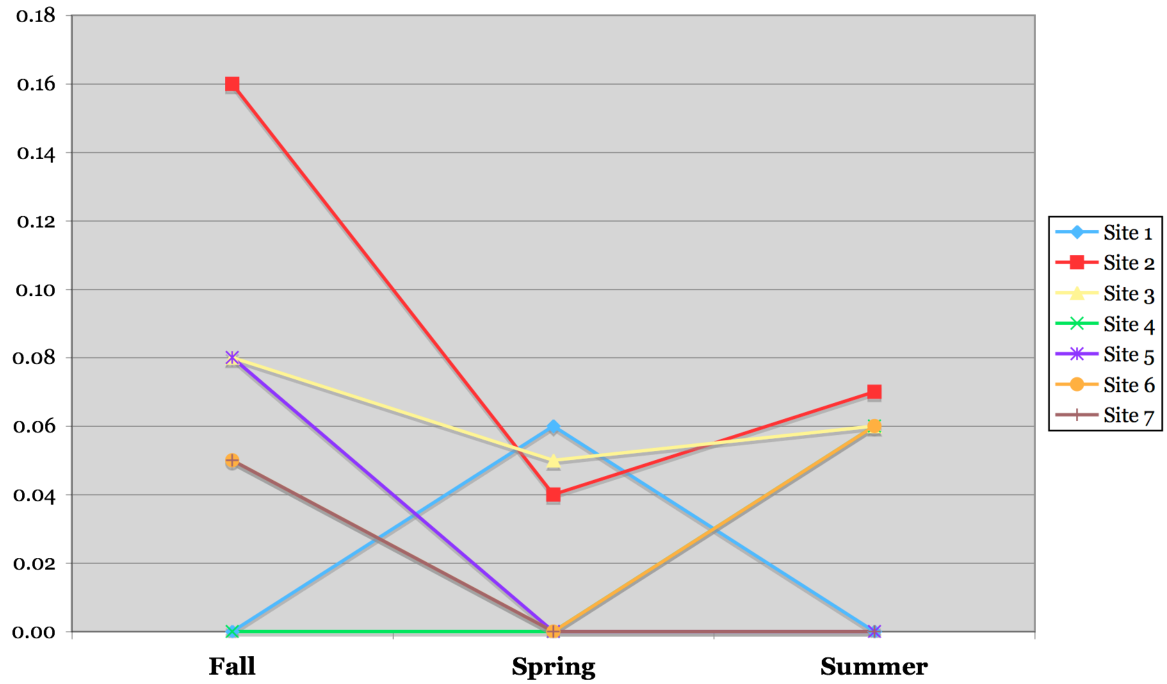
Chloride (mg/L)



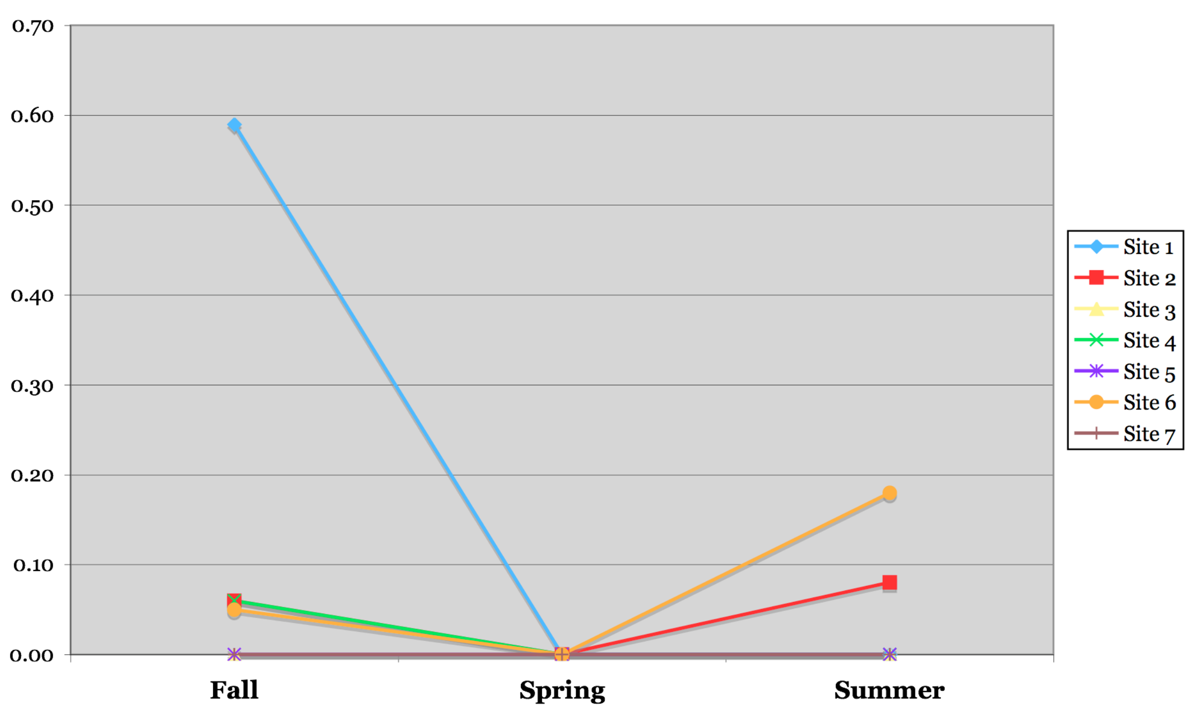
Nitrite (mg/L)

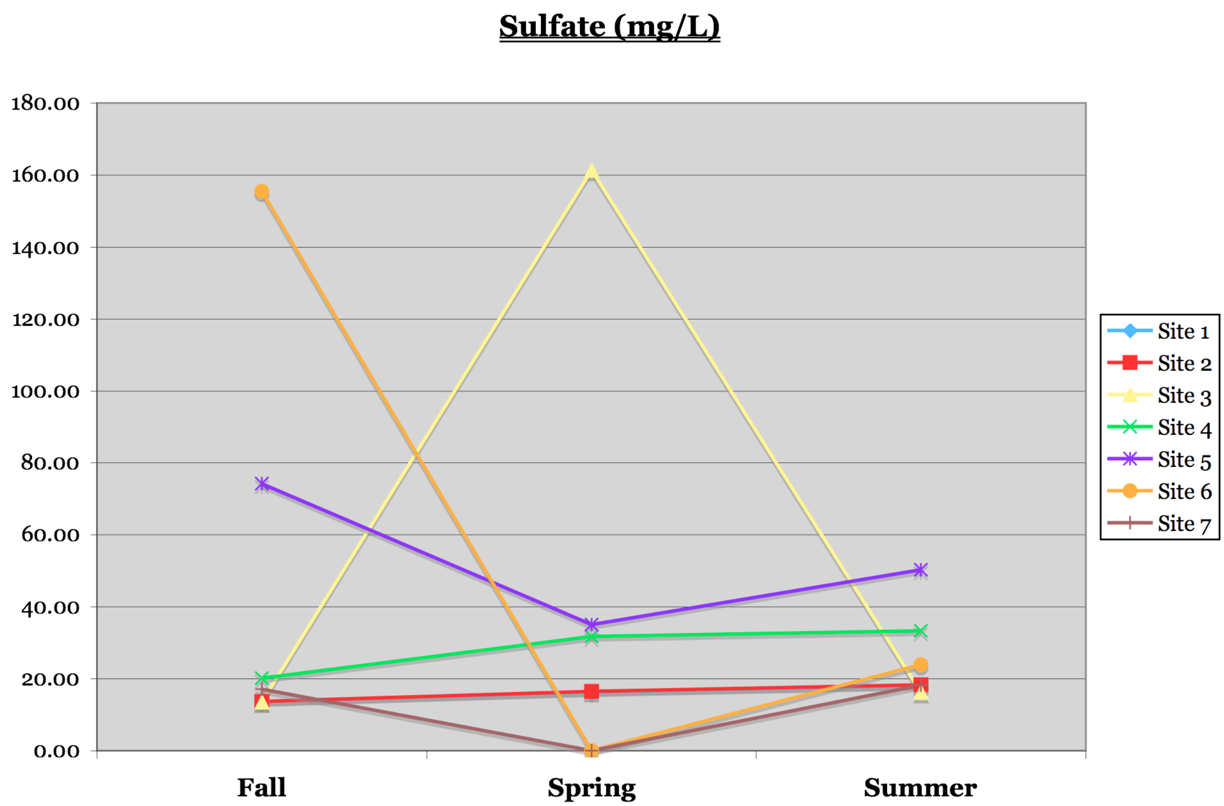


Bromide (mg/L)



Nitrate (mg/L)




Sulfate (mg/L)
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Fall
Spring
Summer
Site 1
Site 2
Site 3
Site 4
Site 5
Site 6
Site 7